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IN THIS ISSUE:

- Field test of GSHP in a low-energy house
- NZEB in the Nordic countries
- Market report - Switzerland
- Strategic outlook - Japan

IEA HEAT PUMP CENTRE

NEWSLETTER
VOL. 30
NO. 3/2012

Heat Pumps - A key technology for the future

The role of heat pumps in NZEB

IEA **Heat Pump** CENTRE
NEWSLETTER

Volume 30 - No. 3/2012

In this issue

Heat Pump Centre Newsletter, 3/2012
The topic of this issue is *The role of heat pumps in NZEB*. Heat pumps are especially suited for NZEB, since they have the ability to provide both heating and cooling, and to tap renewable energy.

The first article describes the work done in the HPP Annexes 32, and the work planned in Annex 40, both dealing with heat pumps in low energy/ NZEB buildings. Further, views are provided from cold (European Nordic countries; Canada) and hot, humid (Japan) horizons. A Roadmap to reach the EU carbon emission reductions is also presented.

Also in this issue you will find a Market overview for Switzerland, and a Strategic outlook from Japan.

Enjoy your reading!

Johan Berg, Editor

Heat pump news

Regulars

Topical articles

COLOPHON

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The Role of Heat Pumps in Net-Zero Energy Buildings

Sophie Hosatte,
Natural Resources Canada

Van Baxter,
Oak Ridge National Laboratory, USA

Many countries in the world have adopted the concept of Net Zero Energy Buildings (NZEB) as a driving force for significant reductions of energy consumption and greenhouse gas emissions in the building sector. The building sector is an important area where significant energy and environmental reductions may be achieved. According to IEA, buildings account for almost one third of final energy consumption globally and are an equally important source of CO_2 emissions. However, the challenge is high when we consider the discrepancies in the building types over the world, the climatic conditions which they are designed and operated for, and the available local renewable and fossil energy resources. In addition, we know that in OECD and Economies in Transition (EIT) countries, major activities in this sector will be dedicated to building retrofits while, in developing countries, new buildings will be the focus, with anticipated growing demands for air-conditioning, reinforced by increasing living standards and climate change.

The most commonly accepted definition for NZEB is "A building that, on an annual basis, produces as much energy as it uses when measured at the site". Even though this definition seems to emphasize site energy production aspects, major improvements are initially required in the design, construction, and optimization of buildings to maximize their energy efficiency before local production needs are considered. Achieving a building design with minimized energy needs (maximum efficiency) requires an integrated, multi-step approach: use of high performance envelopes and windows and hot water distribution systems to minimize energy loads; use of maximum efficiency equipment/systems to meet the loads with minimum energy use and; use of system operation strategies employing fault detection and diagnostics, advanced control, and continuous optimization to maintain its operation at design efficiency during the entire service life. Such efficient building and system designs can minimize the size (and therefore costs) of any on-site renewable energy production technologies needed to reach the NZEB performance level.

For heating (space and domestic hot water) and cooling, heat pump systems are essential to meet the NZEB challenge, because of their capability to deliver more energy than they consume. They may be combined with renewable energy systems (e.g. thermal or photovoltaic solar systems, geothermal heat source/sink systems, etc.) and storage, to provide a wide range of technical solutions to efficiently meet building loads adapted to various climatic conditions and building requirements. Articles in this issue discuss particular issues and needs related to heat pump centered NZEBs in both cold and hot, humid climates.

The adoption of heat pumps has been strong in a few areas but limited in many until now for several reasons such as high initial costs, low performance in cold climates, and lack of awareness about the technology benefits. The IEA Heat Pump Programme is strongly engaged to address these barriers in order to get the technology widely deployed, through active international collaborations in R&D, demonstration, and deployment. Among these are newly approved Annexes 40 (Heat Pump Applications for NZEBs – described further in the article in this issue by Wemhoener) and 41 (Cold Climate Heat Pumps).

Column

Secure our future: towards a European energy strategy

Günther H. Oettinger,
European Commissioner for Energy

Energy is the lifeblood of our society: never before has the world needed so much energy. If this trend continues, it will be difficult to avoid a major energy crisis. In the EU, our economic prosperity depends on a reliable energy supply at affordable prices. Further concerns are global warming and imports from third countries. These challenges require strong action, and large investment. If this is done wisely, we can develop new energy sources, expand supply networks, boost renewable energy use and cut energy consumption. But this requires bold decisions now.

The European Commission is therefore proposing an ambitious strategy to support the single European energy market. National policies are no longer sufficient: we need a common energy policy serving the policy objectives of competitiveness, sustainability and security of supply. For this, I see five pillars for action.

There is a vast amount of untapped potential to save energy. We need to reduce emissions and increase energy efficiency by 20 % by 2020. The Commission recently proposed a new Energy Efficiency Action Plan, and the Energy Savings Directive to clarify the energy savings objective and identify innovative solutions, notably in buildings and transport.

The energy single market must be fully integrated. A European market has the right scale to assure access to resources and justify the huge investments needed. Also, it is time that energy is given a pan-European infrastructure. We must therefore concentrate on our goals: solidarity, an inter-connected market, new power capacities, an "intelligent grid", and large-scale production of renewables. The EU must ensure that these investments take place.

These efforts must focus on the impact on citizens. Consumers should benefit from wider choice. Energy policies must be consumer-friendly. All tools must be improved and applied more widely. EU energy policy also aims for more transparency, more information, better retail markets, development of infrastructure and safety nets for consumers.

In energy technology, we need to develop a European framework in which Member States can accelerate market uptake of technologies. Beyond the implementation of the SET Plan, we have already launched some large-scale projects: smart electricity grids and the 'smart cities' innovation partnership.

The EU has the world's largest regional energy market. Every time the EU has spoken with one voice it has led to results. Europe needs a mechanism to coordinate its efforts and send coherent messages to our main partners. A common European policy will strengthen our position in difficult negotiations and secure our international position.

The global energy system is entering a phase of rapid transition. The time for action is now. Our five-pillar strategy paves the way for success. I will continue to present a number of new European energy initiatives, and the Energy Roadmap 2050, during 2012. The winners will be our citizens. Our generation must make a reality of our strategic vision.

IEA Heat Pump Programme News

Successful HPP Symposium!

The Heat Pump Programme held a well visited symposium during the Chillventa Congressing Day (Nürnberg, October 8). About 70 persons visited the HPP Symposium and listened to presentations about the work and visions of ongoing and planned HPP Annexes. There were also invited speakers, with presentations on hot subjects, such as the ETP 2012 (by a representative from the IEA), heat pumps in smart cities, heat pumps and energy storage, heat pump research in the US and Japan, and others.

All presentations can be downloaded from http://www.heatpumpcentre.org

IEA Heat Pump Conference 2014 – A brief update from the IOC

Dear future conference participant,
On behalf of the International Organizing Committee (IOC), I have the pleasure of welcoming you to the 11th IEA Heat Pump Conference in Montréal, Canada on May 13-15, 2014. It is the 11th in a series of triennial conferences on heat pumping technologies staged by IEA's Heat Pump Programme (HPP). Previous conferences were held in Graz, Austria (1984), Orlando, Florida, USA (1987), Tokyo, Japan (1990), Maastricht, Netherlands (1993), Toronto, Canada (1996), Berlin, Germany (1999), Beijing, China (2002), Las Vegas, Nevada, USA (2005), Zürich, Switzerland (2008) and Tokyo, Japan (2011).

The National Organizing Committee (NOC) is working diligently to prepare for this upcoming conference, the latest information can be found at http://www.iea-hpc2014.org . The IOC is pleased with the work that has already has been accomplished and looks forward to helping the NOC in making the 11th IEA Heat Pump Conference in Montréal, Canada a successful conference.
Your participation and attendance is requested for this conference as we all work towards making heat pumps a technology of choice for heating, cooling and refrigeration. This IEA conference presents a unique opportunity to provide a global perspective of the markets, applications, and technology development for heat pumping technologies.

Antonio M. Bouza
Chairman, International Organizing Committee
11th IEA Heat Pump Conference – Montréal 2014

11TH IEA HEAT PUMP CONFERENCE 2014 MONTRÉAL

General

Chillventa ends on a record

Chillventa, in the beginning of October, had a record 915 exhibitors. Visitor figures were again around 29 000, of which 55% were from overseas, according to close of exhibition reports by the organiser. The next Chillventa will take place in Nuremberg from 14-16 October 2014.

Source: http://www.acr-news.com

Asian Development Bank and IEA workshops: low-carbon energy

The International Energy Agency (IEA) and the Asian Development Bank (ADB) held their first joint workshop this autumn at the ADB headquarters in Manila. Together, they gathered more than 50 participants to explore the potential and best practices for smart grids (high-tech systems that monitor and manage electricity flow and usage to better balance supply and demand), wind energy and other technological innovations in power generation.

Source: https://www.iea.org

Frozen food produces less CO_2 emissions than chilled

Contrary to popular belief, new research suggests that frozen food is responsible for less CO2 emissions than chilled food. A new scientific report by Bristol-based Refrigeration Developments and Testing Ltd, calculated the carbon dioxide equivalent for a typical UK Sunday roast meal for four people. Researchers found that a frozen meal for a family of four produced just over 3 % less CO2 than its identical chilled counterpart. Lead researcher on the study Judith Evans said: "This report goes some way to debunking the commonly held assumption that producing, storing and consuming frozen food is more energy intensive than chilled products."

Source: http://www.acr-news.com

Cryogenics may play a role in renewable energy storage

Refrigeration could provide a solution to large-scale storage of renewable energy. This is an absolute necessity for the future success of the low carbon grid. While batteries are viable for small scale energy balancing, pumped hydro has been employed as the solution for large-scale storage. However, this technology is limited by geographical constraints. UK company Highview Power Storage has developed a pilot plant using liquefied air or liquid nitrogen as the storage medium. This approach extracts carbon dioxide and water vapour out of the air and super-chills it using wind, solar or other renewable power, to its liquid state. As with a traditional steam engine, a cryogenic engine relies on phase-change (liquid to gas) and expansion within an engine cylinder or turbine.

Source: http://www.acr-news.com

Food store waste heat heats apartments

An apartment building in central Stockholm, Sweden, will implement an extensive waste heat recovery system. The total floor area of the building is 10 000 m^2, and it includes 98 apartments, a bank office and a food store. Waste heat from effluent water, exhaust air, and the foodstore cooling system will be fed to closely controlled heat pumps that will provide space and water heating. The system, which is designed to be able to include geothermal energy in the future, is expected to generate large savings compared to more traditional heating.

Source (in Swedish): http://www.kyla-varme.se

Renewable cooling may provide nearly 100% of cooling demand

A new report suggests that with the right commitment, renewable cooling could provide close to 100% of cooling demand in Europe by 2050. However, without guidelines and political objectives from the EU, member states lack the necessary incentive instruments to promote renewable cooling. The study is produced by the German Öko-Institute on behalf of the Netherlands Agency for Energy and Climate. Renewable cooling only plays a minor role in the discussions and policies on climate change, and data on the use of renewable heat technologies are not even included in the statistics. As a result, the numbers will not count towards the goals defined in the Renewable Energy Directive of the EU.

Source: http://www.acr-news.com

It's official: Refrigeration is the greatest invention

We already knew it and now it's official - refrigeration is the greatest invention in the history of food and drink. So says the Royal Society, the UK's pre-eminent national academy of science, together with experts in the food and drink industry who judged each innovation on four criteria: accessibility, productivity, aesthetics, and health. The final decision saw refrigeration out on top, beating such vital items as the plough, the fishing net and the knife.

Source: http://www.acr-news.com

Policy

EU: final step in adopting Energy Efficiency Directive

EU ministers in October placed the last piece of the 20-20-20 climate puzzle, agreed in 2007, by supporting the EU's Energy Efficiency Directive. The main changes the directive brings to existing legislation are:

a) Energy companies are requested to reduce their energy sales to industrial and household clients by at least 1.5% each year;

b) A 3% renovation rate for public buildings which are "central government-owned and occupied";

c) An obligation on each EU member state to draw up a roadmap to make the entire buildings sector more energy efficient by 2050 (commercial, public and private households included).

Source: http://www.euractiv.com

EPEE/EHPA: single energy label for heaters

The current proposal for an energy label for heaters is a result of the inter service consultation in the European Commission, taking into account all aspects of the heating technologies on the market today. It suggests setting up one single energy label scheme for all heat generators placed on the EU market.

EPEE and EHPA believe such a single energy label to be the way to go if the EU wants to achieve its energy savings targets. "The single energy label will … create an incentive mechanism for the uptake of the most energy efficient heating systems, including renewable energy technologies, and will enable a clear differentiation between products on the EU market." – says jointly Thomas Nowak, Secretary general of EHPA and Andrea Voigt, EPEE's Director General.

Source: http://www.ehpa.org

EUROSTAT has updated website for RES calculation

The Directive 2009/28/EC on the promotion of the use of energy from renewable sources obliges Eurostat to calculate not only the RES share in electricity production (19.57 % in 2010) but also the average efficiency of energy to electricity conversion. This data is now published and freely available.

Source: http://www.ehpa.org

EHPA: Future cities are heat pump cities!

In the framework of the 10th European Week of Regions and Cities, the European Heat Pump Association united European and regional politicians, renewable energy experts, planners and relevant EU-based decision makers to ease the way to the realization of more and more heat pump cities through real examples of existing technologies, financial schemes and projects. The event "European cities and regions fit for the future: Integrating heat pumps in local infrastructure" took place on the 11th October. By taking success stories from the Netherlands, Estonia, Hungary and Denmark, different cities/regions already active in supporting heat pumps, the participants could directly experience how they went about deciding, planning and executing their ambitious heat pump plans.

Source: http://www.ehpa.org

Working fluids

EC proposes significant reduction in emissions of F gases

On November 7, the European Commission took an important step today towards long-term climate objectives by presenting a proposal to significantly reduce emissions of fluorinated gases (F-gases). Emissions of F-gases, have risen by 60% since 1990, while all other greenhouse gases have been reduced. The proposed Regulation aims to reduce F-gas emissions by two-thirds of today's levels by 2030. It also bans the use of F-gases in some new equipment, such as household fridges, where viable more climate-friendly alternatives are readily available.

Source: http://europa.eu/rapid/press-release_IP-12-1180_en.htm

The following news item includes comments to early drafts of the F Gas Regulation; see the date of publication of the Source.

EU F-GAS DEBATE: Initial reactions on draft Regulation

Several associations such as the European Partnership for Energy and the Environment (EPEE) and the Air Conditioning and Refrigeration European Association (AREA) as well as NGO Environmental Investigation Agency (EIA) have given their first feedback to the early draft of the EU F-Gas Regulation.

The leaked F-Gas proposal seen by many has brought about some discussions and first reactions to some of its provisions. The proposal is still in hands of the European Commission and by the time it is officially presented within few weeks, it is expected that certain parts of it will have changed.

Brussels-based trade association EPEE has welcomed the phase-down principle, which will set a cap on

annual consumption of HFCs: "The big advantage of a phase down is that you can spread the cost and not suddenly be faced with the massive costs linked to a ban," said Andrea Voigt, EPEE director. "We don't see the necessity of adding any bans on top of a phase-down," stressed Andrea Voigt.
On the other hand, NGOs like EIA have repeatedly reminded that bans are not "sudden" in nature in the sense that they do not apply as of tomorrow, but rather set clear timelines that give industry certainty for their investments.
"The Commission's own analysis shows that most sectors can ban HFCs in new equipment by 2020 or earlier and there is therefore no reason not to propose bans in all these sectors. There are many more low-hanging fruits to be picked", said EIA Senior Campaigner Clare Perry.
"We welcome the draft proposal as a step in the right direction but it clearly doesn't go far enough and could easily be seriously diluted if the lobbyists currently working behind the scenes for the HFC industry get their way".
Source (October 8): http://www.r744.com

R1234yf: the car industry seeks further tests

Following Daimler's test findings of flammability for vehicles involved in head-on collisions, SAE International, the standards-setting association representing automotive engineers, says it is working with an international group of car manufacturers to investigate the formation of a new Cooperative Research Program to investigate the safety of R1234yf.
Source: http://www.acr-news.com

Klima-Therm installs first HFO chiller with Turbocors

Eighteen months on from announcing that it was to be the first company to use HFO1234ze with the oil-less Turbocor compressor on one of its chillers, UK company Klima-Therm has achieved its wish with an installation at a department store.
They broke new ground last year with the installation of two reciprocating chillers running on HFO1234ze at a store in South Bromley, near London. It was the first application of the new fourth generation low global warming refrigerants in a working supermarket.
Source: http://www.acr-news.com

Europe sees fall in HFC usage

Usage of HFCs in refrigeration and air conditioning equipment in Europe fell by 23% last year compared to 2010, according to a study of F-gas production, import and exports from the European Environment Agency (EEA).
The figures show that 53,571 tonnes of HFCs were sold in Europe last year for ACR applications, compared to 69,404 tonnes in 2010. In terms of CO_2-equivalents, this represented a fall of 25%.
Refrigeration and air conditioning still represents around 77% of total European F-gas sales, an increase on 2010 figures when it was just over 70%. Much of this is accounted for by steep falls in the use of F-gases as aerosol propellants and in the foam industry.
Source: http://www.acr-news.com
http://www.hydrocarbons21.com

World: Increasing demand for HFCs to 2016

Increasing worldwide demand for HFC refrigerants is expected to be a significant factor in a predicted 3.9% year-on-year increase in the fluorochemical market to 2016. The forecast, in the latest report from Freedonia, sees increasing production of refrigeration and cooling equipment worldwide being a key factor in pushing the global market for fluorine-containing chemicals to 3.5 million tonnes by 2016. However, the report recognises that restrictions on the supply of raw materials and a move towards lower GWP alternatives in Western Europe are challenges to this growth. .
Source: http://www.acr-news.com

Fake refrigerants: we should be very concerned

The world should be very concerned about the dangers of counterfeit refrigerants. This is the overriding message to come out of a roundtable discussion during the 32nd Open-ended Working Group Meeting of the Parties to the Montreal Protocol in Bangkok in July. Under the topic of "Fake Refrigerant: Should We Worry?" experts from around the world discussed the proliferation of counterfeit refrigerants, in particular the dangerous presence of methyl chloride (R40) in some of these cocktails. While the four explosions and three deaths in reefer explosions attributed to fake R134a last year have been well publicised, discussions revealed that there had been a fifth explosion in south China in December and unconfirmed reports of a recent air conditioning explosion in Brazil resulting in two further deaths.
Source: http://www.acr-news.com

US laboratory identifies 1200 potential new refrigerants

Researchers at the National Institute of Standards and Technology (NIST) have developed a new computational method for identifying potential low GWP refrigerants. The new method was used to identify about 1,200 promising, low-GWP chemicals for further study among some 56,000 that were considered. Only about 60 of these are found to have boiling points low enough to be suitable for common refrigeration equipment, an indication of how difficult it is to identify usable fluids. The ongoing NIST project is a response to US industry interest in a new generation of alternative refrigerants that already are required for use in the European Union.
Source: http://www.acr-news.com

Technology

Cryogenics solution for renewable energy storage

A large scale means of storing renewable energy is an absolute necessity for the future success of the low carbon grid. While batteries are viable for small scale energy balancing, pumped water has been employed for large-scale storage. However, this technology is limited by geographical constraints and its needs for water. Highview Power Storage (UK) has developed a pilot plant using liquefied air or liquid nitrogen as the storage medium. They extract carbon dioxide and water vapour out of the air and then super-chills it to its liquid state (-196º C), using renewable power. Liquefied air has a high expansion ratio between its liquid and gaseous state, about 700. As with a traditional steam engine, a cryogenic engine relies on phase-change (liquid to gas) and expansion within a confined space, e.g. engine cylinder or turbine.

Source: http://www.acr-news.com

Wind-up refrigerator for drug storage

A novel wind-up vaccine refrigerator addresses the challenge of storing drugs and vaccines in developing countries where power is unavailable or, at best, unreliable. Vaccine distribution workers typically use ice boxes and are faced with two problems as a result. First, they must race against the melting of the ice. Second, accidentally packing too high an ice-to-vaccine ratio would freeze the vaccines and destroy them. The novel vaccine refrigerator is operated by using a hand crank for about 5 minutes to power the device. It can then run for about 15 minutes before needing to crank it again. The crank powers a small DC generator that charges a 9V rechargeable Li-ion battery. In turn, the battery powers Peltier units which carry out thermoelectric cooling.

Source: http://www.acr-news.com

Refrigeration-free cold drink dispenser unveiled

The first dispenser in Europe of a refrigeration-free drinks can has been unveiled at the University of Surrey. The ChillCan can chill a drink by about 15ºC at the push of a button on the base of the can. This releases pressurised carbon dioxide adsorbed onto activated carbon contained in an inner can.

The carbon dioxide is said to come from waste gases and the activated carbon from waste coconut shells.

Source:http://www.acr-news.com

Markets

Asian Conference on Refrigeration and Air Conditioning in Xi'an

Organized by the Chinese Association of Refrigeration (CAR), the 6th Asian Conference on Refrigeration and Air Conditioning was held at the Jianguo Hotel Xi'an from August 26 to 28. More than 220 engineers, researchers, and employees in the field of refrigeration and relevant disciplines joined this event, and about 100 of them were overseas representatives from Japan, Korea, the United States, and Singapore. The topic of this conference was 'Toward the sustainable development.'

Source: http://www.ejarn.com

Zero-energy Buildings and Smart Homes in Focus

Zero-energy buildings (ZEB) and smart homes have become a hot topic. In November 2009, the Japanese Ministry of Economy, Trade and Industry (METI) issued a report summarizing a new vision and plan, including related issues and ways to resolve them, regarding the creation of zero-energy buildings, with the aim of advancing energy savings in commercial buildings down to zero net-energy consumption.

Source: http://www.ejarn.com

World Heat Pump Market Review from BSRIA

BSRIA have recently published the world heat pumps study based on 16 key countries around the world. The report highlights that despite the continued downturn in the world economy, the heat pump market is increasing compared to other products. The market increased by 31% from last year and is forecast to increase by 33% in 2013. However this increase is due largely to Asia as the biggest market is in China.

Source: http://www.ejarn.com

The Swiss Heat Pump Market

Stephan Peterhans, Switzerland

The nuclear catastrophe of Fukushima that occurred in the wake of the earthquakes in Japan in March 2011 deeply affected the Swiss energy market. On May 25th 2011, the federal government decided to phase out nuclear electricity production in the period to 2034. Based on this decision no new nuclear power plants will be built. Existing units will go off grid once they have reached the end of their planned operating period (i.e., during 2019 – 2034). In 2011, 40.57 % of the electricity consumed in Switzerland was accounted for by nuclear power plants and 49.82 % by hydroelectric power plants [1]. Power supply shortfalls and exploding electricity prices were rumoured to be the results of the nuclear phase out. Yet the grid operator Swissgrid declared at the end of 2011 that electricity prices were expected to fall by 2 % on average during 2012, a forecast that was supported by several electricity producers.

In consequence the overall evolution of energy prices is positive for heat pumps. Fuel oil and natural gas prices show a clear tendency to increase whereas the electricity prices remain rather stable.

The Swiss Heat Pump Market in 2011

The fiscal year 2011 was the third successive year that saw a decrease in heat pump sales, see Figure 1. 18 905 units were sold in 2011, compared with 20 044 in 2010 and 20 595 in 2009 [2]. Without the backing by an economic stimulus program that triggered 1 110 additional heat pump sales, the market drop would have been even more pronounced. The government's goal to have a total of 400 000 heat pumps installed by 2020 remains in place, thus, by then about 30 % of all houses would have a heat pump installed as their primary heating system.

Heat pumps by energy source

The sales of heat pumps in 2011 (space & water heating combined) were split in the following way.

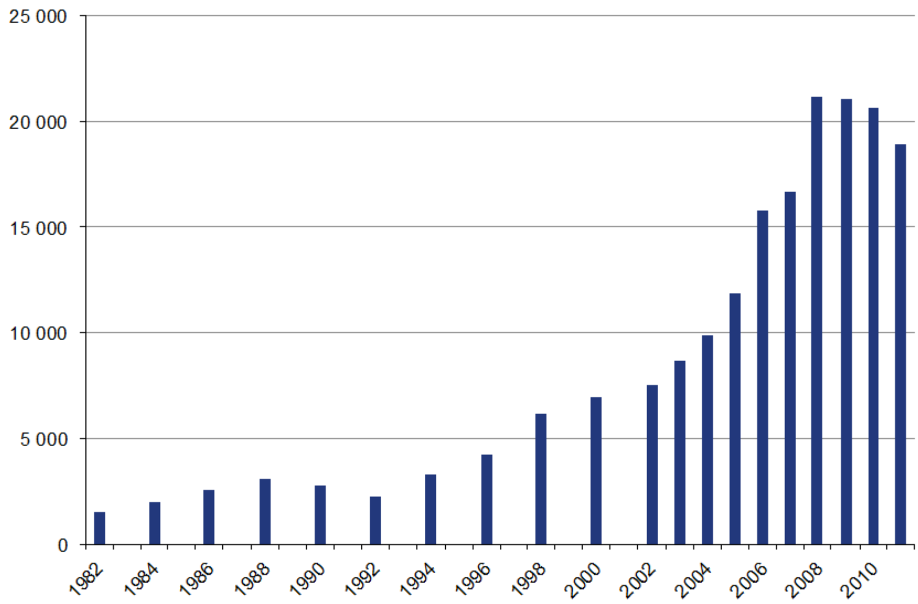

Figure 1: Swiss heat pump market (space heating) development 1982-2011

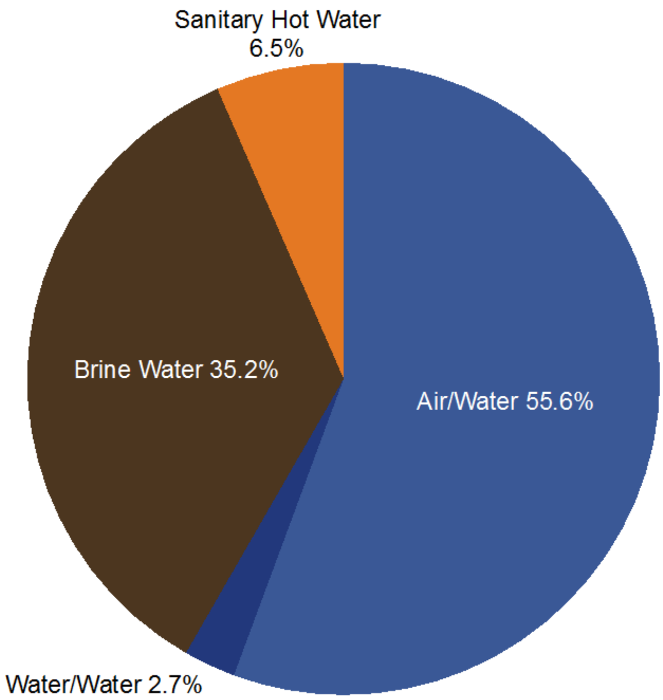

Figure 2: Swiss heat pump market in 2011 by type of heat pump

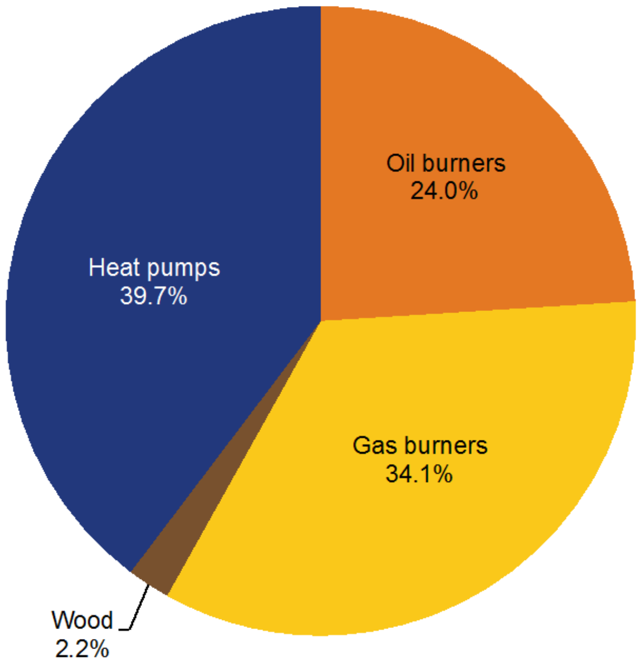

Figure 3: Swiss space heating market by technology

65.6 % of the air/water units were indoor units, 34.5 % outdoor units. Split-units accounted for 50 % of the latter type. Sales of air/water-units for smaller multi-family dwellings were marked by a significant increase. Sales of brine/water units decreased by 3.5 %. As the market demonstrated a slight tendency towards large to very large installations, the sale of borehole heat exchangers remained constant.

Sanitary Hot Water Heat Pumps

The sales of sanitary hot water units almost doubled in 2011. With sales totalling approximately 1300 units the market still remains small, but shows high growth potential, as the political environment in Switzerland is calling for ever higher energy efficiency, which may potentially lead to a ban on direct electric boilers in the future.

Oil and gas burners

Taken individually, more heat pumps than oil or gas burners are sold in the Swiss market. Wood stoves only account for a very modest 2.2 % of total sales. Yet the fossil fuel alternatives still account for almost 60 % of all heating systems sold. It is remarkable that more than 90 % of the fossil fuel heating boilers are condensing boilers. Oil and gas condensing boilers reach seasonal performance factors of 0.7 – 0.85, heat pumps in comparison reach seasonal performance factors from 2 to 4 and above.

Trends

There have been many changes with regard to heating technology in the last number of years. The introduction of condensing boiler technology required the design of new heat distribution systems with lower return temperatures. Inverter based heat pumps are now becoming more prevalent designed as split systems or supplying sanitary hot water. The use of solar thermal energy is also increasingly being integrated in heat generation systems. Why the market share of wood stoves remains so low cannot be easily explained. The key question however is how long the exclusive use of fossil fuels for space heating will still be possible.

When it comes to heat production systems and heat pumps, objective advice is much sought after. Hence the Swiss Heat Pump Association is active in running information offices in three locations in the country. Significant ongoing efforts will have to be made in the area of the initial and ongoing training of professionals in heat pump application and system technology, integration of solar thermal systems, dimensioning of borehole heat exchangers as well as acoustics (particularly regarding air/water units).

A well-functioning quality assurance system is a key factor in the success of heat pumps. The quality label for heat pumps ensures minimum levels of energy efficiency and quality standards. The equivalent quality label for drilling companies ensures that the energy sources for the heat pump have been dimensioned and constructed correctly. This provides the owner of the installation with the guarantee that the borehole heat exchangers will provide reliable energy for several decades.

Regarding the refrigerants there is now intense pressure from the government to use natural refrigerants. Laws are currently in preparation that aim at banning environmentally damaging refrigerants. The industry, however, is objecting to these measures, as heat pumps with natural refrigerants are not yet ready for a large-scale market deployment.

Subsidy programs for heat pumps are disappearing gradually as authorities and funding agencies have come to the conclusion that the heat pump technology can now successfully compete without them.

References

[1] Source: Bundesamt für Energie – Gesamte Erzeugung und Abgabe elektrischer Energie in der Schweiz 2011.
http://www.bfe.admin.ch
The ratio of hydroelectric power production given refers to net power production (i.e. total hydroelectric power production – pumped storage)

[2] These numbers do not take in account the sales of SHW-Units

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Japanese regulatory and support measures to disseminate highly energy-efficient equipment

Takeshi Hikawa, Japan

This report describes government support for developing EcoCute, a heat pump water heater with CO_2 refrigerant, as well as government support for its promotion. It also describes the Top Runner program, to show how Japan has applied political methods to assist deployment of energy-efficient equipment in the commercial and residential sectors, together with regulatory & support measures by the government to assist R&D of energy conservation technologies and to promote energy-saving consciousness nationwide.

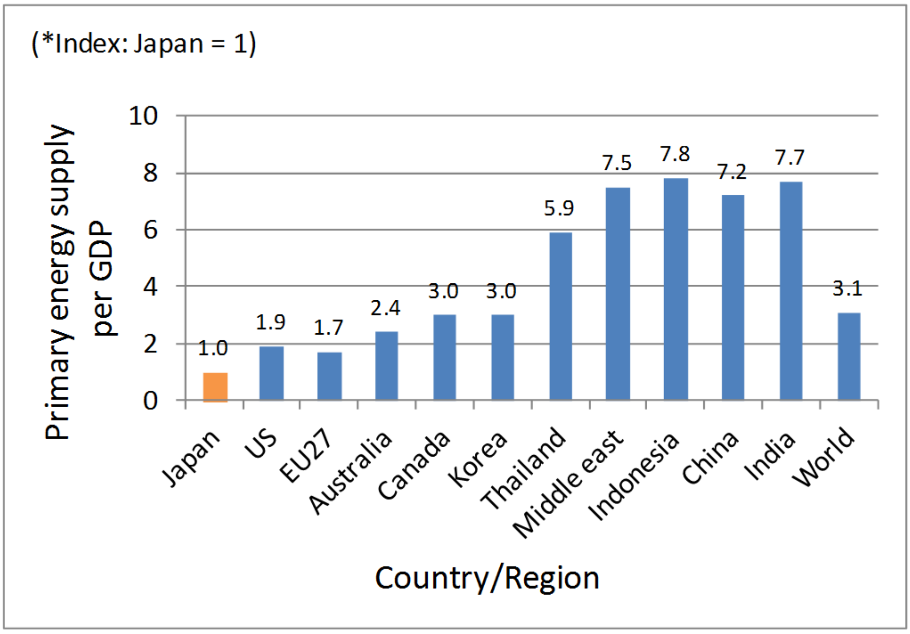

Fig1 Primary energy consumption per GDP in major countries [1]

*Total consumption of primary energy (tons in crude oil equivalent) / real GDP (U.S. dollars) is calculated with Japan = 1.

Introduction

Japan's self-sufficiency ratio in energy supply is one of the lowest in major developed nations, and we have made tremendous collaborative efforts for saving energy in the public and private sectors, particularly after the oil crises of the 1970s , which resulted in approx. 33 % improvement in energy efficiency between 1979 and 2009.

On the other hand, as far as energy efficiency is concerned, the results of various energy conservation measures saw Japan achieving the highest energy efficiency in the world in terms of primary energy supply per unit of GDP in 2009, as shown in Figure 1.

In Japan, citizens are required to make a further effort for energy saving in response to the Fukushima nuclear power plant accident. The Japanese government has been re-examining the country's energy policy, but has been unable to guarantee a stable energy supply ever since the accident.

Japan urgently needs a support policy for energy-saving equipment and its further take-up.

This report describes government support for developing EcoCute, a heat pump water heater with CO_2 refrigerant whose energy efficiency is excellent, together with government support for its promotion. It also describes the Top Runner program, to show how political measures have been used to spread deployment of energy-efficient equipment in the commercial and residential sectors, assisted by regulatory & support measures by the government to support R&D of energy-conserving technologies and to promote energy-saving consciousness nationwide.

EcoCute

End user energy consumption in the residential sector has been growing in Japan: over 50 % of it is used for water and space heating. Heat supply for these two purposes has been dominated by combustion equipment, and so substantial CO_2 reductions could be expected by replacing conventional combustion equipment with energy-efficient heat pumps.

EcoCute, a heat pump for hot water supply, has been developed for this application. It consists of a heat pump unit and a thermal storage tank. Heat is stored in the tank at night and provides hot water for the day, so that users can take advantage of less expensive night-time power tariffs.

A highly efficient compressor and a counter-flow heat exchanger for CO_2 refrigerant enhance the performance. With a COP of approximately 5, it significantly reduces primary energy consumption.

However, it has not been easy to launch EcoCute onto the market. Difficulties had to be overcome, of which the first was that of costs. A vast amount of funding was needed in order to invest in production equipment and to develop refrigeration cycle devices, compressors and heat exchangers suitable for CO_2 refrigerant, as every piece of pressurised equipment had to be designed from scratch. CO_2 requires a higher design pressure compared to that of conventional refrigerants such as R410A. Collaboration was therefore started between the public and the private sectors.

R&D projects, mainly focusing on downsizing equipment and on cold climate operation, were led by the New Energy and Industrial Technology Development Organization, NEDO. Given the high-density dwelling environment of Japan, the size of the outdoor unit and the storage tank was considered as a main obstacle to take-up. In addition, we had a potential market in cold regions of the country where combustion-type water heating equipment was dominant.
A total of over USD 13 million was provided by NEDO for the R&D projects. (1 USD = JPY 80).

Grants were available for EcoCute buyers, so it can be clearly seen that both these subsidies and the R&D project funding from NEDO contributed to development and take-up of EcoCute.

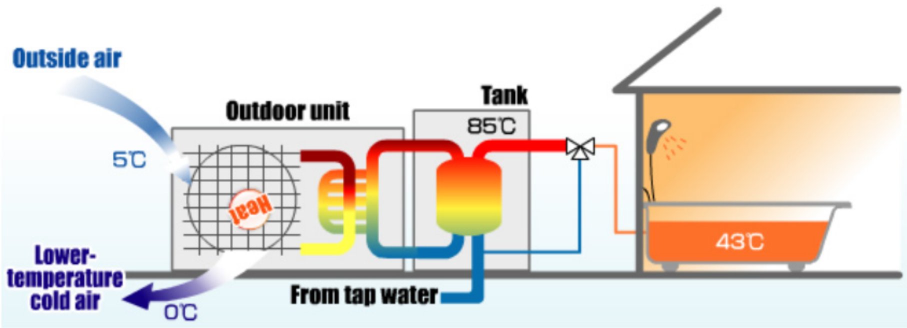

Fig2 Description of Eco Cute mechanism

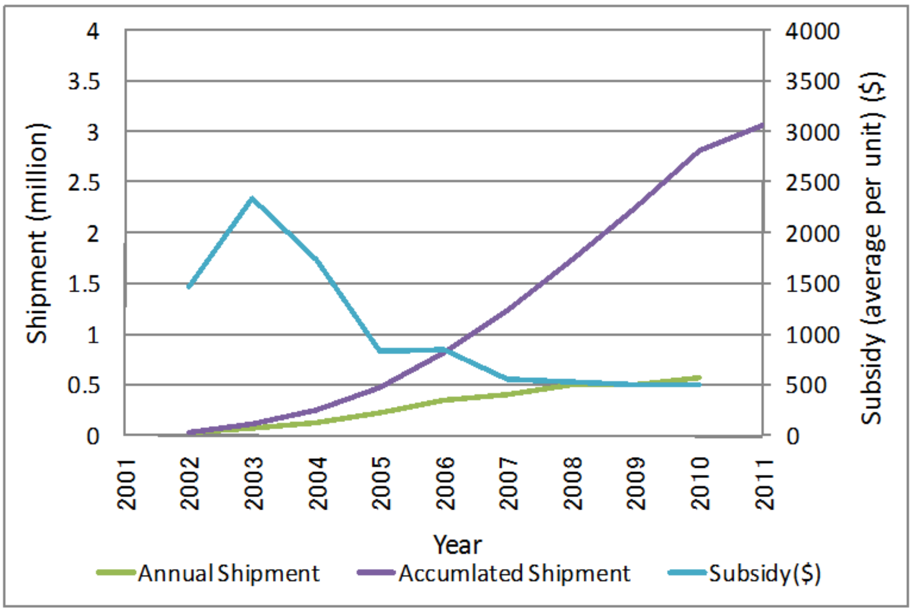

Fig3 Eco Cute shipment and average amount of subsidy per unit

Figure 3 shows the relationship between production numbers and subsidy values. We have been able to increase sales steadily thanks to the subsidies in the first couple of years and price reduction due to mass production in the following years. In 2003, the average subsidy per unit was over USD 2000, which shows how seriously the take-up of these units was taken by the Japanese government. Total shipment numbers of the EcoCute have now exceeded 3 million units, with annual shipment numbers passing 0.5 million in 2008.

APF (Annual Performance Factor)

The APF shows the cooling/heating capacity (kW) per 1 kW of power consumption. It takes into account not only power consumption at rated conditions, but also load conditions, outside air temperature and other parameters where air conditioners are used. Since September 2006, the Japanese energy conservation law has used APF instead of COP as a standard factor to show annual energy savings levels.

The Top Runner programme

Energy conservation regulations in Japan prescribe energy efficiency standards for appliances and vehicles in accordance with the Top Runner method. Standards are prescribed for 23 items, including passenger vehicles, air conditioners, TV sets, fluorescent lamps and refrigerators. The concept of the Top Runner program is that standards are set higher than the best performance value of each product type currently on sale in the market. The manufacturers calculate weighted average values for each product category and are required to meet the standard within a specified time, which is set for each category.

Let's take an example of air conditioners. The standard was set in 1999, and the manufacturers were required to exceed the weighted average performance and clear the Top Runner level by 2004. As a result, energy efficiency performance of air conditioners was improved by over 60 % from 1997 to 2004, as is shown in Figure 4, followed by approximately 20 % improvement between 2005 and 2010. The former improvement is based on COP, while the latter is based on APF, in accordance with Japanese energy conservation regulations. In other words, the Top Runner program has pushed manufacturers towards high energy-efficient equipment production, which has accelerated the take-up of energy-saving equipment throughout Japan.

As for EcoCute, it has also adopted the APF labelling system, and some units have achieved APF values of 3.3. In addition, EcoCute was brought within the Top Runner program in 2009, with a performance target to be reached in 2017.

The Top Runner program has obviously improved the energy efficiency of whole systems, and improved the competitiveness of Japanese products on international markets.

Fig 5 shows the effect of the Top Runner program. The annual energy consumption of 2.8 kW wall mounting air conditioners has continuously decreased, falling to nearly half between 1995 and 2009.

Energy conservation policy & measures in Japan

In addition to subsidies for eco-friendly products such as EcoCute, and policy programs such as the Top Runner program to promote eco-friendly products, other energy conservation policies & measures are targeted at specific sectors or across a range of sectors, as shown in Table 1. The labelling system is one of the regulatory measures promoting environmental awareness nationwide. Some targeted items under the Top Runner program are required to be labelled to show their energy efficiency. Consequently, Japan compares well with other countries when comparing COPs of the most efficient model on the market in each country or region (Figure 6) This shows that Japanese consumers tend to choose higher performing products developed under the Top Runner program. The product labelling enables consumers easily to compare the efficiency of each product.

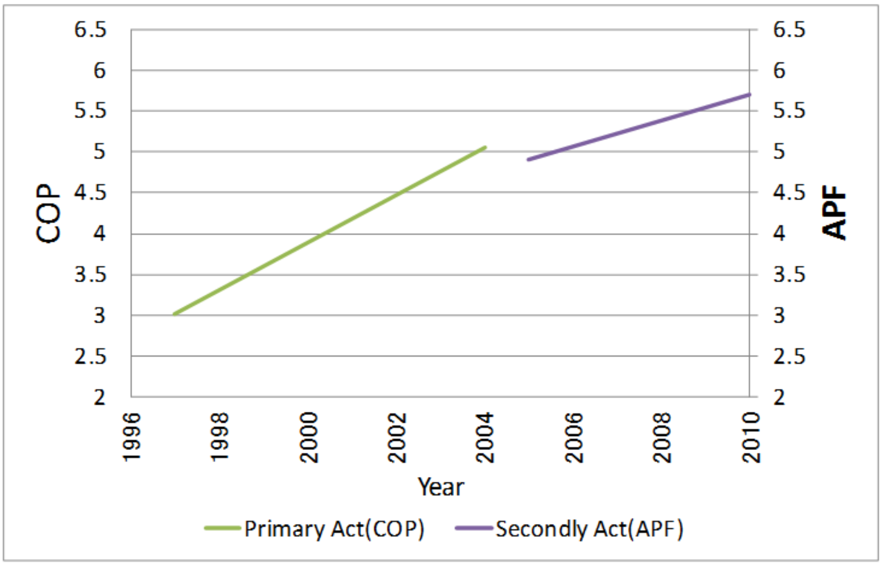

Fig4 Performance improvement by the top runner program [2]

Table1 Regulatory & Support measures

	Industrial sector	Commercial sector	Residential sector	Transportation sector
Regulatory measures (ruled by Act on the Rational Use of Energy)	Periodical report on energy saving measures to accomplish reduction of energy use by 1% per year.			Reporting System on Energy by Cargo owners and carriers
	Submission of document to show if meeting the energy saving standard when constructing the building			
		Top runner program to electric appliances		
		Labeling system to show an energy-efficient category		
Support measures (e.g. Subsidies, tax reduction)	**Subsidies for introduction of energy saving equipment**		Eco-point program for residences	Subsidies for implementation of Clean Energy cars
	Tax system for introduction of energy saving equipment and low energy building		Tax reduction for renovation of residences	Tax reduction for Eco Car
	Grants for R & D of energy conservation technologies e.g. high efficient HPs, high efficient insulators			
	Disseminate information to encourage energy consciousness nationwide			

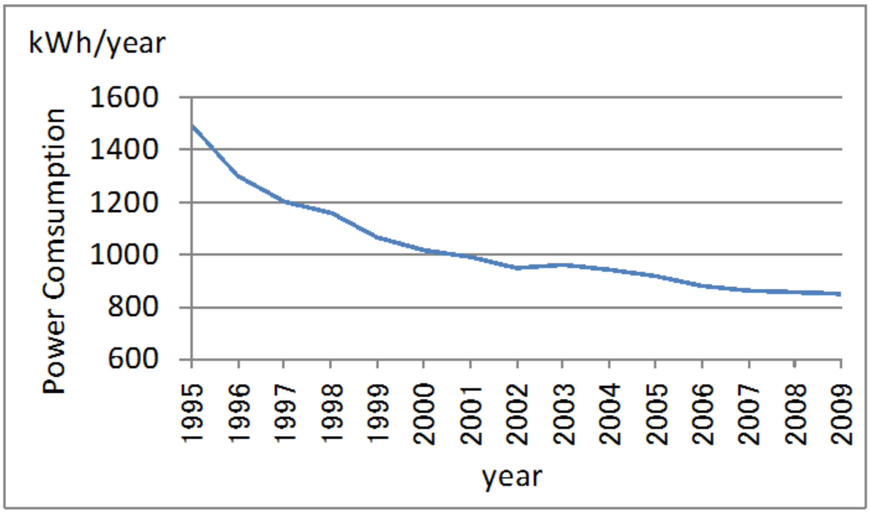

Fig5 Annual electricity consumption on wall mount type of 2.8kW
(*Based on an average of wall mounted, typical energy conserving type air conditioners with 2.8 kW) [2]

Conclusions

The energy conservation counter-measures have borne fruit, as described above.

EcoCute, a breakthrough product in terms of energy conservation and reduction of CO_2 emissions, has expanded its market share through subsidies for buyers and grants for R&D for the development of heat pumps using natural refrigerant CO_2.

The Top Runner program has encouraged the development of high-efficiency heat pumps, while the labelling system promoted environmental awareness, together contributing to a substantial reduction in primary energy consumption.

Regulatory & support measures have successfully assisted R&D, helping to develop energy-saving technologies and promoting wider awareness of the importance of energy saving.

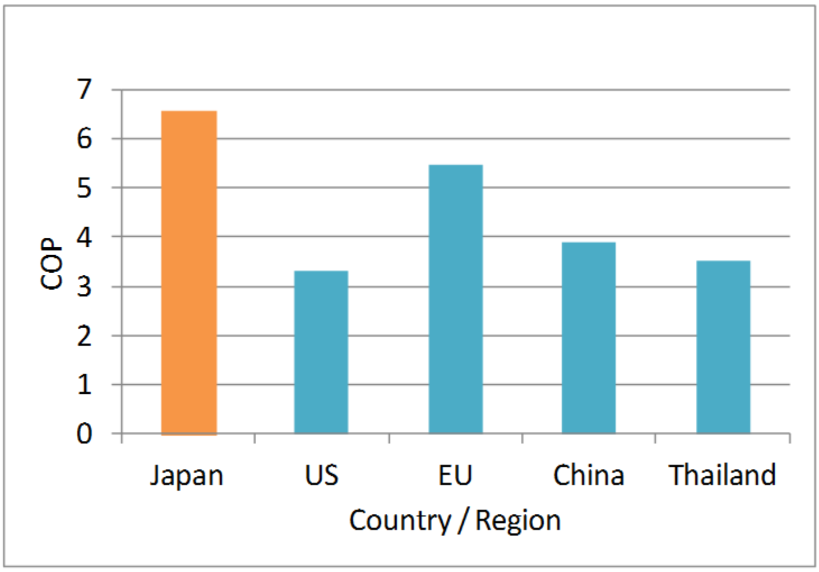

Fig6 Energy efficiency based on the top efficient model of each country
(*Based on air conditioners with cooling capacity of 2.5 kW) [2]

Reference

[1] IEA statistics
[2] "Saving energy of Japan" Agency for Natural Sources and Energy, November 2011

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Annexes, ongoing

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

The work of Annex 35 / 13, a joint venture of the IEA Implementing Agreements "Industrial Energy-Related Technologies and Systems" (IETS) and "Heat Pump Programme" (HPP), is still concentrated on Task 2 "Modeling calculation and economic models", as the most important contribution to energy efficiency and reduction of greenhouse gas emissions in industrial processes.

IZW e.V., as Annex coordinator, has analyzed Task 2 in detail. Four IZW notes were provided:

- 01/2011 Analysis of the Annex 21 IHP Screening Program
- 02/2011 Upgrade of the Annex 21 Screening program
- 11/2012 Some thoughts regarding Annex 35 /13 Task 2 report
- 12/2012 Integration of heat pumps into chemical processes: An outline of theoretical methods

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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 to be undertaken by each participating country is given in the table below.

The Annex is scheduled to run through November 2013. The participants concluded a working meeting (at the National Institute of Standards & Technology; Gaithersburg, MD, USA) on 25 September; included was a tour of two heat pump installations as well as presentations by industry spokespersons on market forces and trends. A future working meeting is planned for the fall 2013 (in France) with tel-conferences in the interim.

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

The aim of the project is to demonstrate and disseminate the economic, environmental and energy saving potential of heat pumping technology. The focus will be on modern technology, and results from meas-

Annex 36 Participants	Focus Area	Work to be Undertaken
France	Space heating and water heating applications.	Field: Customer feedback survey on heat pump system installations, maintenance, and after-sales service. Lab: Water heating performance tests on sensitivity parameters and analysis.
Sweden	Large heat pumps for multi-family and commercial buildings Geothermal heat pumps	Field: Literature review of operation and maintenance for larger heat pumps. Investigations and statistical analysis of 22000 heat pump failures. Modeling/Lab: Determination of failure modes and analysis of found failures and failure statistics.
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.

urements on good examples will be used to calculate energy savings and CO_2 reductions. The results will be presented on the HPC website.

The project partners are Sweden, Switzerland, the United Kingdom and the newest partner Norway. Austria is participating in the annex as an observer. The operating agent at SP (Sweden) has been changed in the project: Pia Tiljander has been replaced by Marcus Olsson.

In the project, a template has been produced of what should be reported for each heat pump. Moreover, the limit criterium for a good heat pump have been decided: for GSHPs, the SPF should be at least 3.8 and for ASHPs at least 3.0. The criteria for good quality of field measurements have been determined, as well as important parameters for assured quality. Calculations of energy savings and CO_2 reduction are on-going. The calculations of CO_2 reductions are based on comparisons with the heat source that was replaced by the heat pump or the probable alternative to the heat pump in new productions.

The number of heat pumps included from each country will be 15 in Switzerland, 3 from Sweden and 2-4 from the UK. The number of heat pumps from Norway remains to be decided.

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IEA HPP Annex 38 Solar and heat pump systems

The objective of Annex 38 of the Heat Pump Programme (which, as Task 44, is a joint effort with the Solar Heating and Cooling Programme) is assessment of the performances and relevance of combined systems using solar thermal heating and heat pumps. The work is also intended to develop a common definition of Figure of Merit for such systems, to develop new simulations tools, and to contribute to successful market penetration of these new systems.
The annex started in January 2010, and will run until December 2013.
In a 2011 HPC Newsletter we described Sub-tasks A and B: in this issue we focus on sub-tasks C and D.

Sub-task C: Performance assessment
Leader: Michel Haller, SPF, Switzerland
The objective of this sub-task is to provide the Annex with simulation models for all components and to simulate the different configurations of systems to derive optimization paths.

The four working groups - solar collectors, ground heat exchangers, heat pumps and heat storage - have delivered their contributions to the Annex in a report named “Models of Subcomponents and Validation”. It has been an excellent shared effort. The report describes available models world-wide, and their features. Some new components need special models, such as ice storage, heat pumps with desuperheaters, uncovered collectors that can freeze on both sides, PVT collectors, etc. Development of such models is the work of Sub-task A, by the teams who need them to simulate the system they monitor.

System model validations have been started with monitored projects in Sub-task A.

Sub-task D: Dissemination
Leader: Wolfram Sparber, Eurac, Italy
The objective of this sub-task is to publicise the results.
A second Newsletter was issued at the end of June 2012, and is available on our web site.

An industry workshop was organized in Povoa de Varzim before Meeting 5, attended by 40 delegates from Portugal.

A Wikipedia page has been set up under: http://en.wikipedia.org/wiki/Solar_and_heat_pump_systems

Annex 38 is progressing with many basic elements for delivery in 2013, together with more system results and an overall comparison, as defined as the ultimate goal of the annex.

http://www.iea-shc.org/task44

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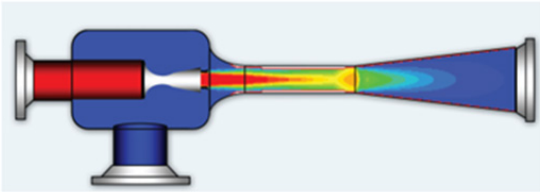
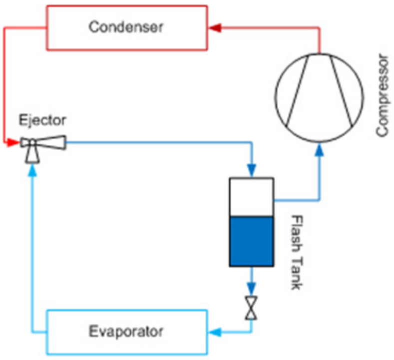
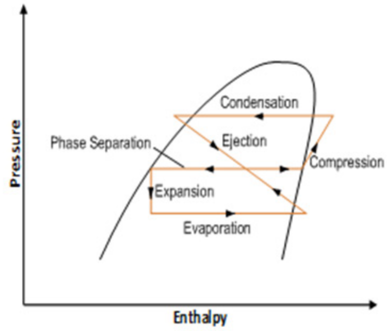
IEA HPP Annex 41 Cold Climate Heat Pumps

Approved by ExCo
In May 2012, the HPP ExCo approved the new IEA HPP Annex 41 with a starting date of July 2012. Heat pump technology provides a significant potential for CO_2 emissions reduction. This annex will 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-to-air or air-to-water air-source heat pumps (ASHP), with air or hydronic heating systems, since these products suffer severe loss of heating capacity and efficiency at lower outdoor temperatures. Thermally activated (engine-driven, absorption, etc.) ASHPs and ground-source heat pumps (GSHP) may also be included in individual country contributions if desired. The main technical objective is to identify solutions leading to ASHPs with heating SPF ≥ 2.63 W/W, recognized as a renewable technology in the EU. 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. Currently Japan and the US (OA) are officially participating in this Annex and Canada plans to join pending receipt of funding for their national project. The Annex is open to new members so other HPP member countries are encouraged to join.

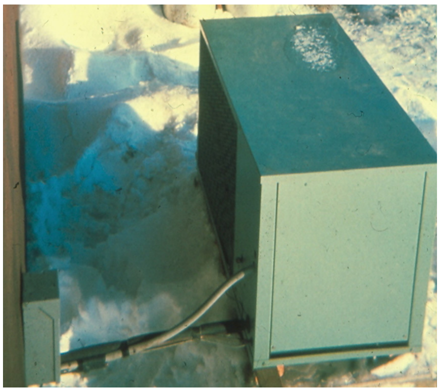
An initial organizing meeting was held on June 23, 2012 in San Antonio, TX, USA with representatives from Canada, Japan, and the US. The Annex work is divided into four tasks. Task 1 is dedicated to a thorough review of prior RD&D activities related to heat pump applications in cold climates to identify potential equipment and system options for detailed evaluation. In Task 2, detailed analyses of promising component/system concepts are performed, considering the system performance and cost implications as well as design and control issues. Laboratory prototype and field prototype testing may be included in this task as well. Task 3 will involve seasonal/annual performance simulations based on the prototypes developed in Task 2 to estimate energy and emissions savings potential. Task 4 is dedicated to development of a final report comparing CCHP design options on a common format.







Contact: Van Baxter, baxtervd@ornl.gov



Ongoing Annexes

Bold text indicates Operating Agent. ** Participant of IEA IETS or IEA SHC

Annex 34 Thermally Driven Heat Pumps for Heating and Cooling	34	AT, CA, CH, **DE**, FR, IT, NO, UK 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
Annex 36 Quality Installation/Quality Maintenance Sensitivity Studies	36	FR, SE, UK, **US**
Annex 37 Demonstration of field measurements of heat pump systems in buildings – Good examples with modern technology	37	CH, NO, **SE**, UK
Annex 38 Solar and Heat Pump Systems	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, KR, NL, **SE**, US
Annex 40 Heat pump concepts for Nearly Zero Energy Buildings	40	CA, **CH**, FR, NL, NO, JP
Annex 41 Cold climate heat pumps	41	CA, JP, **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.

From low energy to nearly zero energy - heat pumps for high performance buildings in HPP Annex 32 and 40

Carsten Wemhoener, Switzerland

High-performance buildings are a key strategy for climate protection targets. The HPP Annex 32, concluded in 2011, stressed the suitability of multifunctional heat pumps for application in low-energy buildings. The new HPP Annex 40 catches up with the political targets of Nearly Zero Energy Buildings (NZEB), which will set the standard for new buildings from 2020 on. Annex 40 has just started, and is to develop heat pump technology and system concepts for the requirements of NZEB.

Introduction

High-performance buildings have growing market shares, in particular in the central European countries. For example, the Swiss MINERGIE® standard for low-energy buildings has reached a market share of 25 % in the new-building sector within about one decade. Further, the most recent revision of the building directives made low-energy buildings the standard in many countries. While much research has been performed on the building envelope, system technology for low-energy buildings has not been developed to the same extent. Since heat pumps have several advantages, including possible CO_2-free operation when supplied with renewable electricity, Annex 32 was started in order further to develop heat pumps for low-energy houses.

Outline of HPP Annex 32

The work of Annex 32 has therefore been concentrated on multifunctional heat pump systems for application in low-energy buildings, which typically have a dedicated ventilation sys-tem and often have some demand for comfort cooling. The ten countries - AT, CA, CH, DE, FR, JP, NL, NO, SE and US – have contributed both to the development of new prototypes of integrated heat pumps in the low-capacity range, and to field tests of the prototypes and systems on the market, including an extensive field trial of more than 100 heat pumps for space heating and DHW installed in low-energy houses in Germany, while integration of cooling options in common heat pump system configurations has been investigated in Switzerland. Results from the simulation work and field tests were used for heat pumps which are now on the market.

Prototype developments

Different prototype heat pump systems have been developed by the participating countries.

A focus has been on the application of natural refrigerants and the integration of additional functions such as space cooling or dehumidification: both being features which were not available on the market when Annex 32 was started in 2006.

As an example of the work, IWT of TU Graz in Austria has built a 5 kW CO_2-B/W heat pump prototype as shown in Figure 1, which was based on system layout comparisons and refrigerant cycle analysis performed in the beginning of the project. . The prototype has been lab-tested, and the results used to develop simulation models.

System simulations for space heating, DHW, passive and active cooling operation in a typical low-energy house yielded an overall system performance of 3.2, based on the energy supplied to the floor heating and DHW heat exchanger. With higher cooling loads in extreme summers, the performance increases due to high performance of the passive cooling operation. Scope for possible system improvements lies in improved components, e.g. improving the compressor efficiency for low capacities, as well as in system integration of the buffer storage and control.

In Norway, a CO_2 heat pump for space heating and DHW has been compared to the best HFC B/W heat pump on the market. It was found that, with a DHW share of 55 %, the CO_2 heat pump outperforms the best system on the market. With improved components, the break-even domestic hot water share falls to 45 %, which is typical for passive houses.

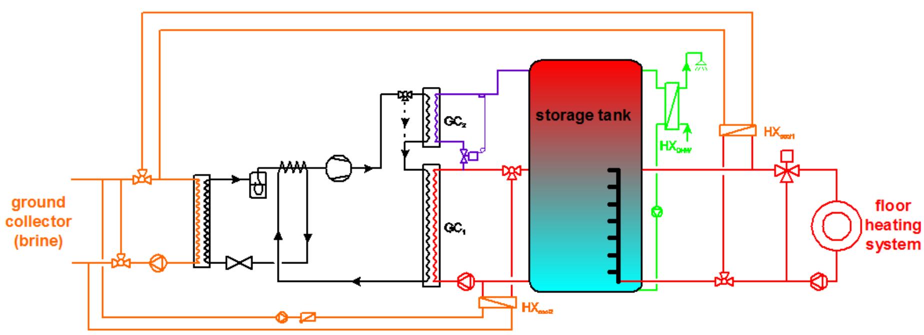
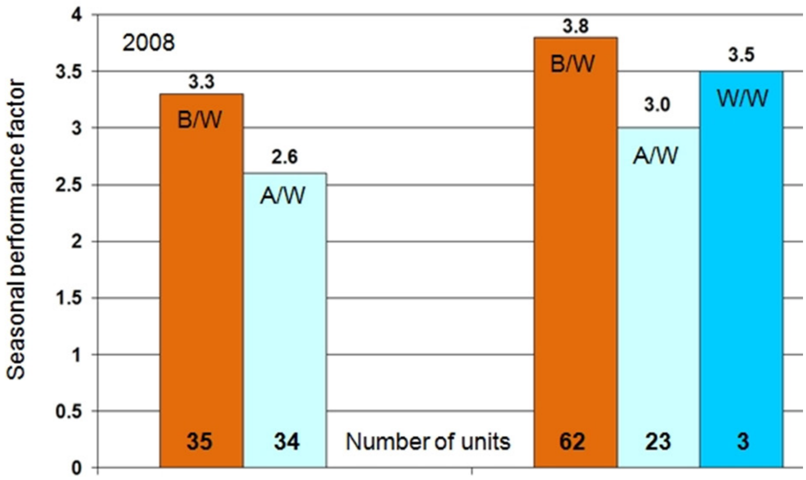


Fig. 1: System layout of the Austrian prototype system (Heinz and Rieberer [2])

Field test results

Field tests have been performed of newly developed prototype heat pumps, and are partly still ongoing.
A new design of a propane W/W-heat pump, including a desuperheater for DHW production, was installed in a passive house in southern Norway and field-monitored for two years. The overall seasonal performance for space heating and domestic hot water production, with a DHW share higher than 40 %, reached 3.7 for the heat pump alone, or 3.1 including all auxiliaries.
Extensive field tests of over 100 heat pumps installed in low-energy houses in the 5-10 kW range have been performed by Fraunhofer ISE in Germany, in collaboration with seven manufacturers and two utilities. A further ten systems have been tested by AIT in Austria.
Results confirm that on average, the performance of heat pumps outperforms fossil fuel systems significantly, since ground-coupled systems reach an SPF in the range of 4, with air-source heat pumps delivering an SPF in the range of 3, for combined space heating and DHW production. In Germany, a field test has been performed in existing buildings with heat pumps as replacement for boilers. About 70 heat pumps in the capacity range of up to 20 kW were monitored. Measured seasonal performance factors are about 0.5 lower than those in low-energy houses. Fig. 2 shows details of the results of the two German field tests.
Despite the good perform-ance, areas of potential improvement have been identified; e.g. concerning the installation, design and integration of heat storage. Systems with heat stores often failed to perform as well as they could do, in particular in the case of combination stores.



Project	HP existing buildings			HP Efficiency	
DHW-share	14%	12%	22%	28%	18%
Back-up heating	2%	1%	2%	2%	2%
Auxiliary energy	5%	3%	6%	7%	15%

Fig. 2: Comparison of the SPF for heat pumps installed in new and existing buildings in the German field tests of the year 2008 (based on data of Miara [3])

Results of HPP Annex 32

Results of the research work have been published at workshops and conferences during the progress of the work, and concluded in four final reports on the different subtasks.
An umbrella report presents an introduction to low-energy houses, an overview of the participating organisations, and the main results. Part 1 contains a market overview of the different state-of-the-art systems applied in low energy buildings.
Part 2 contains details of the developed prototypes, while Part 3 summarises and compares the results of the extensive field tests of more than 150 heat pump systems. In addition, 17 single well-performing systems have been documented in more detail in a four-page fact sheet.
All results are publicly available and can be downloaded from the Annex 32 project website at http://www.annex32.net
or from the Heat Pump Centre website. The website also includes information on the participating institutions and projects as well as related national and international links.

New challenge: NZEB

Political targets focus on Nearly or Net Zero Energy Buildings (NZEB). While such buildings have been prioritised in the US and Canada since the middle of the first decade of the new millennium, the revised European Building Performance Directive (EPBD:2010) sets the target for "Nearly Zero Energy Building" for all new buildings in EU member states as 2020. NZEB put the emphasis on the quality of the building envelope and on renewable generation on site. Figure 3 shows the basic concept of NZEB concerning the balance between aspects. An NZEB is often defined as a grid-connected building which, on an annual basis, produces as much en-

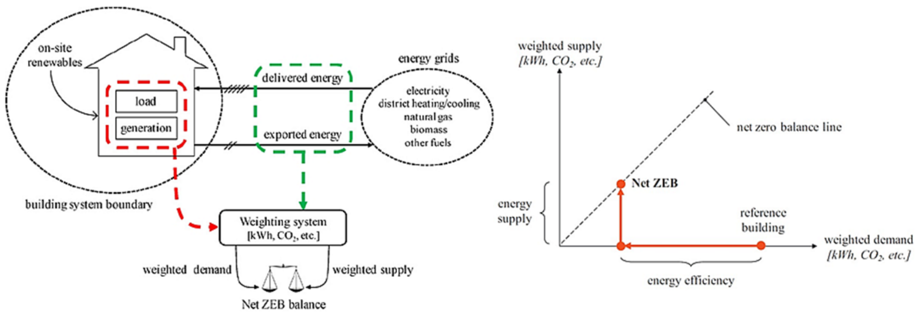


Fig. 3: Principle of the balancing for Net Zero Energy buildings (source: Sartori et al.[1])

ergy from renewable sources on site as it consumes. Although the concept of an annual balance of consumption and generation sounds straightforward, it is difficult in terms of determining and defining the details of system boundaries, weighting factors between imported and exported energy, and load matching and grid interaction issues. A joint IEA ECBCS Annex 52/SHC Task 40 has recently published a consistent framework of criteria to be applied for an NZEB definition [1].

The work of the new Annex 40 will be built upon this ongoing work in the joint ECBCS/SHC activity.

As far as the system technologies of heat pumps for NZEB are concerned , different developments in the US and Canada have already started in Annex 32. In the US, Oak Ridge National Laboratory (ORNL) has developed an integrated heat pump intended for NZEB application by supplying all building services, including dehumidification was developed. The system has been laboratory-tested, simulated and is currently on field test at the test site at ORNL. Fig. 4 shows the layout of the ground-source prototype of the integrated heat pump (IHP).

In Canada, different field test projects of building-integrated PV/T and heat pump systems have been tested as part of the work of the Canadian EquilibriumTM house initiative.

In fact, a large share of the currently built NZEBs comprise PV systems for the generation on site, so that the combination of PV and heat pumps is a very common system configuration in NZEB. In addition to system integration and design, topics to be addressed in the new Annex 40 include storage options and control issues to improve load matching by optimised self-consumption at building level, thus reducing grid interaction. Work has currently started with a state-of-the-art analysis of installed systems in existing NZEBs, and outlining the definition to be used in the Annex 40.

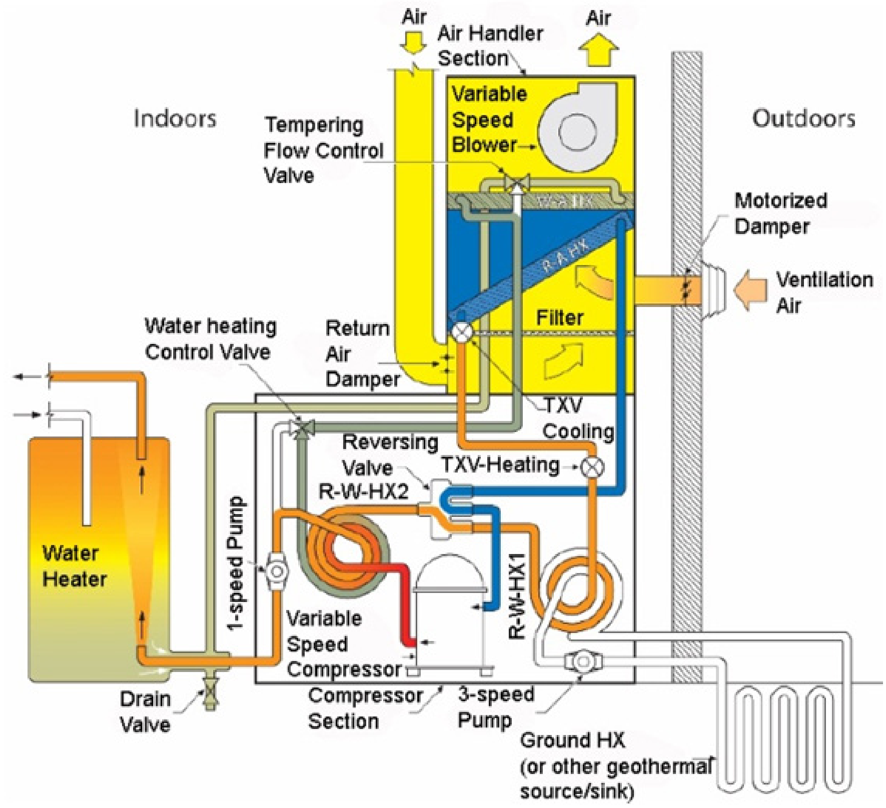


Fig. 4: Ground-source IHP in dedicated dehumidification and water heating mode (Murphy et al. [4])

Conclusions

Results from IEA HPP Annex 32 simulations and field tests have confirmed that multifunctional heat pumps are well suited for low energy houses, since internal heat recovery can improve their performance, and integrated systems can reduce installation costs and space requirements. However, political targets are now prioritising “Nearly or Net Zero Energy buildings”, which currently are in the pilot and demonstration phases, with about 400 NZEBs worldwide. Heat pumps can play an important role in these buildings, but this should be supported by further development.

The new Annex 40 has been started to contribute to advanced heat pump technology for application in nearly zero energy buildings. Five countries - CH, JP, NL, NO and SE - have already declared their participation, while further countries are interested in joining the Annex. Work started with a Kick-off meeting in July 2012, and further participants are welcome to join the co-operative research. Further information on the new HPP Annex 40 will be published on the Annex’s website http://www.annex40.net soon.

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Source: A-hus/Derome Group

Nearly Zero-Energy Buildings in the Nordic Countries

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In less than ten years, all new buildings in EU shall be ´nearly zero-energy buildings´. What that means is to be defined by each member state based its unique prerequisites. The term ´nearly zero-energy buildings´ is also somewhat confusing, as the actual use of energy can only be minimised but never reduced to zero level or even to near-zero level. In addition, as member states will not be required to set minimum energy performance requirements that are not cost-effective over the estimated economic life cycle of the building, the actual energy use may be far from zero. Even though the Nordic countries have similar climatic conditions, they seem to define ´nearly zero-energy buildings´ in quite different ways, as a result of historically different building regulations and different national energy supply systems. Even during the coldest winter periods, heat pumps are a viable way of supplying buildings with a significant amount of on-site produced renewable energy.

Nearly zero energy buildings and the EPBD recast 2010/31/EU

The concept of ´nearly zero-energy buildings´ (nZEB) is introduced as a very fundamental part of the Energy Performance of Buildings Directive recast 2010/31/EU (EPBD2) [1]. It is stated in EPBD2 Article 9 that member states shall ensure that:

(a) by 31 December 2020, all new buildings are nearly zero- energy buildings; and

(b) after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings.

However, the required energy performance of nZEBs should be calculated on the basis of a methodology, which may be differentiated at national and regional level. This means that the definition of an nZEB may be quite different from member state to member state. This also means that the definition may also be different between countries with somewhat similar climatic conditions.

Nearly zero energy buildings are not net zero energy buildings

In EPBD2, nZEB is defined as buildings that have a very high energy performance. The nearly zero or very low amount of energy required should, to a very significant extent, be covered by energy from renewable sources, including energy from renewable sources produced on-site or nearby.

´Including´, as used here, means that when calculating the extent of renewable energy we must not forget to include the renewable energy produced on-site or nearby, e.g. by thermal solar, PV solar panels or geothermal energy extracted by heat pumps. On the other hand, according to the definition above, it is not necessary that any of the renewable energy supplied to the nZEB is actually produced on-site or nearby. It might just as well be produced anywhere else, as long as it is renewable. There already exist market mechanisms for buying renewable energy produced off-site by wind turbines etc.

Net zero energy buildings (NZEB) are of course one way to achieve nZEB, but it is not necessary to go so far. From an energy system point of view, requiring every single building to be an NZEB might even lead to sub-optimisation. However, it seems that many researchers and others involved in implementation of EPBD2 believe that nZEB is the same as NZEB. This is a misunderstanding that needs to be pointed out.

The term ´nearly zero-energy buildings´ is actually rather confusing, as the actual use of energy can only be minimised but never reduced to zero level or even to near-zero level, especially if household and operational energy is also to be included. The definition given for the ´nearly zero-energy buildings´ implies that a better term would have been ´nearly zero-emission buildings´.

Different national regulations and roadmaps to nZEB

EPBD2 Article 9 also states that member states shall draw up national plans for increasing the number of nearly zero-energy buildings. Although all the Nordic countries have started this work, it is still not finished. There might also be considerable differences between definitions of nZEB that different organisations are suggesting and what is actually decided at national level. As an example, in Sweden's Energy Agency has proposed that nZEB means almost a halving of the energy requirements as specified in existing building regulations. The National Board of Building and Planning, which is responsible for the national building regulations in Sweden, on the other hand is arguing that the existing regulations already meet the requirements of EPBD2. The Swedish government has decided that there is still not enough knowledge to define nZEB in Sweden, but has stated that the energy requirements for nZEB in Sweden will probably be stricter than the existing regulations, at least for most building categories. Denmark has agreed on a very ambitious national framework with energy targets down to 20 kWh/year and m^2 of heated floor area. But the weighting factors for different energy sources, used to calculate the energy use, may still be changed. Norway has an unofficial roadmap, drawn up by SINTEF and others, for 2017 (low-energy buildings), 2022 (passive houses) and 2027 (net zero energy houses). The building regulations in Norway are based on national standards developed by Standards Norway. However, a recent study from the Norwegian Energy Agency ENOVA, performed by Ramböll and Xrgia, shows that there are substantial barriers to the realisation of passive houses, and even more so for net zero-energy houses in the national building regulations in Norway. In the summer of 2012, the Norwegian government appointed the Directorate for Building Quality to investigate how nZEB should be defined in Norway. It has been suggested that a Norwegian nZEB is a passive house with a heat pump and thermal solar collectors for on-site production of renewable energy.

Finland has its ERA17 roadmap to meet the requirements of EPBD2 by 2017. ERA17 is divided into five categories; planning, decentralised energy production, building regulations, classifications/incentives and competence. A total of 31 different measures have been identified. The energy requirement in the Finish building regulations has recently been strengthened and will be even stricter by 2017. But exactly how strict is still not decided.

Even if all details are not yet decided, it might be supposed that future building regulations, and hence the definition of nZEB, will to a great extent be based on the existing building regulations in each country. The following table is an attempt to give a qualitative comparison between the building regulations for expected nZEB definitions in Sweden, Norway, Denmark and Finland.

The table shows that there are many differences between the national regulations and approaches to nZEB. For instance, only Finland and Denmark have official weighting factors for different energy sources. But we cannot directly compare even these weighting factors, as Denmark excludes household/operational energy and Finland includes it. It is evident from the table above that there has been very little cooperation in developing the national regulations and the approaches to nZEB. Even though the climatic conditions are quite similar, there are also differences between the countries that can explain the different approaches. The national energy supply systems are, for example, quite different. However, they are all countries with fairly

	Sweden	Norway	Denmark	Finland
National definition of nZEB	No	No	Yes	No
National regulations include household/operational energy/electricity	No	Yes	No	Yes
Weighting factors for different energy sources	No	No	Yes	Yes
Correction factor for smaller buildings	No	Yes	Yes	Yes
National calculation method	No	Yes	Yes	Yes
Requires measured energy performance	Yes	No	No	No
Reduction for on-site production of renewable energy	Yes	No	Yes	Yes
Requires ventilation heat recovery	No	Yes	No	Yes
Different requirements depending on type of building	Yes (2)	Yes (12)	Yes (2)	Yes (9)

small populations. From a building manufacturing point of view, it would therefore be an advantage if the building regulations and nZEB definition were more similar in the Nordic countries.

Cost optimality versus nZEB

Article 4 of EPBD2, setting minimum energy performance requirements, states that member states shall take the necessary steps to ensure that minimum energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels. The energy performance shall be calculated in accordance with the comparative methodology framework referred to in Article 5. On 19th April 2012, the European Commission published guidelines on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements [3]. The cost-optimal framework methodology is based on the net present value (global costs) methodology. The calculation of global cost considers the initial investment, the sum of annual costs for every year and the final value, as well as disposal costs. The cost-optimal level of requirements is reached when the global cost is minimal. Some common values for calculation of net present value are

- a calculation period of 30 years.
- a discount rate of 4 %.

The discount rate used in the macroeconomic and financial calculations is to be established by the member state after performing a sensitivity analysis on at least two rates for each calculation. Depending on different financing environments and mortgage conditions, the discount rate used to establish the cost-optimal energy requirements may therefore be different from one member state to another member state. The abovementioned report from Enova [2] indicates that there might be quite a large discrepancy between what is technically possible and what is economically feasible. A member state shall not be required to set minimum energy performance requirements which are not cost-effective over the estimated economic life cycle. The definition of nZEB according to EPBD2 Article 4 may therefore lead to an amount of energy use that is quite some way from zero. But also, vice versa, if the minimum energy performance requirements allow higher energy use than the cost-optimal level they should be tightened up. A difference of up to 15 % between the cost-optimal level and the minimum energy performance requirements is acceptable under EPBD2. Higher differences must be justified to the European Commission. All the Nordic countries are now working on calculation of cost-optimal levels. When this has been done, the minimum energy performance requirements can be set or changed.

Accounting for heat pumping technology in nZEB

Even though all renewable energy can be supplied by off-site production, on-site production is to be preferred as there can be no doubt about the origin of the energy supply. Using a heat pump with a seasonal performance factor (SPF) of 3 or higher will always lead to a significant amount of renewable energy, regardless of how the electricity input is produced. Using the ground as the heat source in a Nordic climate also means that the performance factor is quite high even when the heat demand is at its peak. Depending on the weighting factors for different energy sources, the benefit of using heat pumps may be quite different in different national building regulations and definitions of nZEB. The existing Norwegian regulations and first approaches to nZEB are very much focused on the building envelope and ventilation heat recovery, and therefore little focus on heat pumps. The Swedish regulations, on the other hand, are quite favourable for heat pumps, less so for district heating and biomass, while the Danish regulations seem to favour district heating and on-site electricity production. The Finnish regulations seem to be a mix of the other national regulations, meaning that both heat pumps and district heating may be a viable alternative. In Finland, the choice between heat pumps and district heating is based more on economic conditions than on the building regulations. The different national approaches probably to a great extent reflect the national energy systems.

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Feasibility study for nZEB in hot and humid climates

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Over the last few years, the importance of net Zero-Energy Building (nZEB) has been increasingly recognised, but this recognition has not been accompanied by sufficient demonstration projects. In particular, hot and humid regions require considerable quantities of energy for cooling and dehumidification, and so it is vital to develop detailed case studies under realistic conditions. The objective of this paper is to investigate the feasibility of nZEB as an office building in a hot and humid region.

Introduction

Tackling global warming is now urgent: against this background, the need for net Zero-Energy Buildings (nZEB) is very clear. For non-residential buildings, near-zero-energy operation may be theoretically practicable with current technology if they are provided with photovoltaic devices. Nevertheless, PV panels require a large surface area and involve high installation costs, which restrict practical use. The feasibility of nZEB should be discussed under realistic conditions. One working area to be considered is that of developing suitable heat pump technology to reduce energy consumption for cooling. This is essential in Japan, where summers are hot and humid. This article describes how nZEB can be developed for an assumed building using practicable technology.

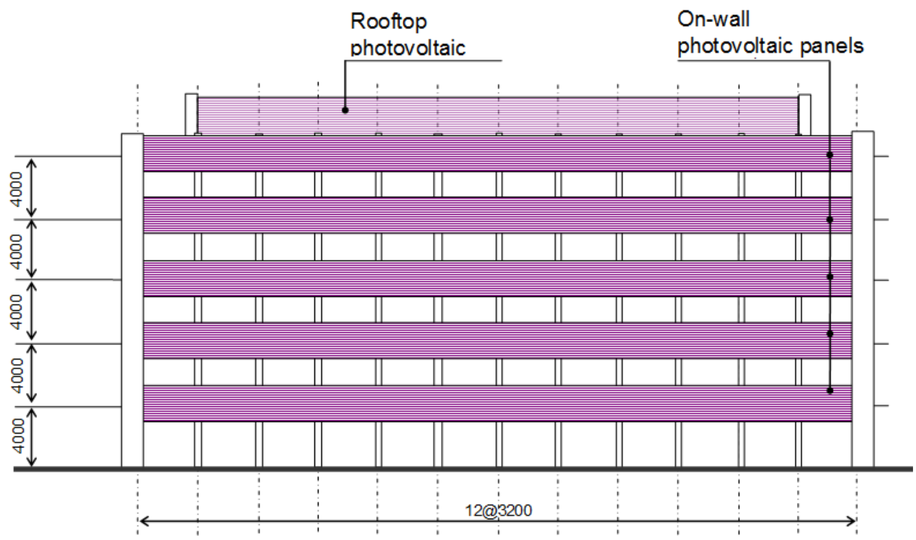


Fig. 1 Modeled building: Elevation

Modeled building

Figures 1-3 show the model building, which is assumed to be a five-story reinforced concrete office building in Tokyo. Its services systems and operation conditions are assumed to be standard ones. The air-conditioning system is of conventional current decentralised design, using heat pumps. The blocks in Figure 2 correspond to the air-conditioning zones.

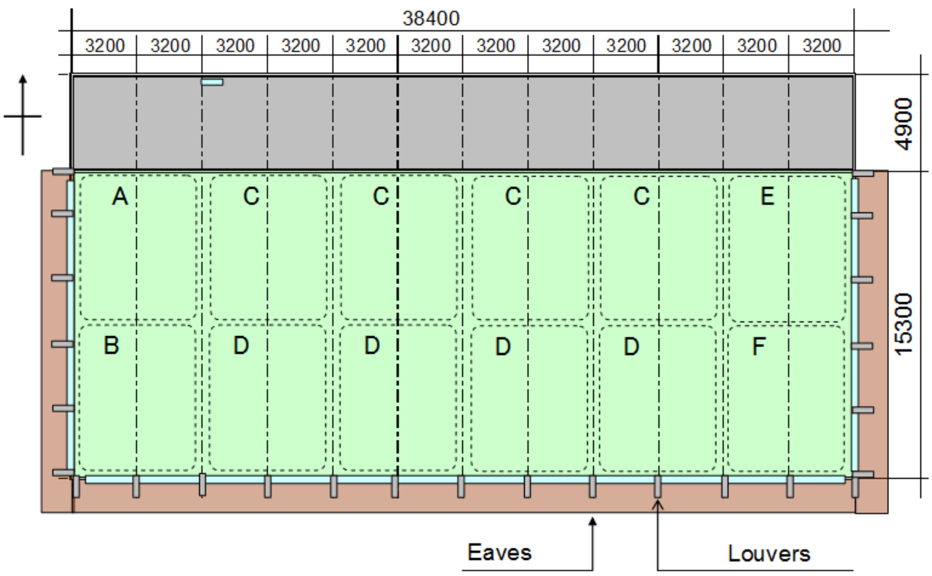


Fig. 2 Modeled building: Plan

Use of renewable energy is vital

Renewable energy is essential for the nZEB. In this case, photovoltaic panels are assumed to be mounted on the rooftop and walls (except for windows), as shown in Figures 1- 3.

For the study, three cases have been assumed: 1) a reference building, 2) a high-performance building, and 3) ZEB-orientated building, all of energy-saving type. The reference building is a low-energy building of common standard type; the high-performance building is built with the most advanced technology; and the ZEB-orientated building is assumed to be a next-generation-type low-energy building as expected to be the result of future technology development. Table 1 shows the calculation conditions for each case. Comparison shows how the cases differ in terms of heat insulating performance, indoor heat generation rates, natural ventilation and outdoor air intake volumes. In addition, prospective technology development is assumed for lighting (LED etc.) for the ZEB-orientated building. Table 2 lists the setting conditions of the assumed individual decentralised air-conditioning systems. In the three cases, corresponding items of equipment differ in their performance (such as rated performance, partial load performance), control methods, etc.

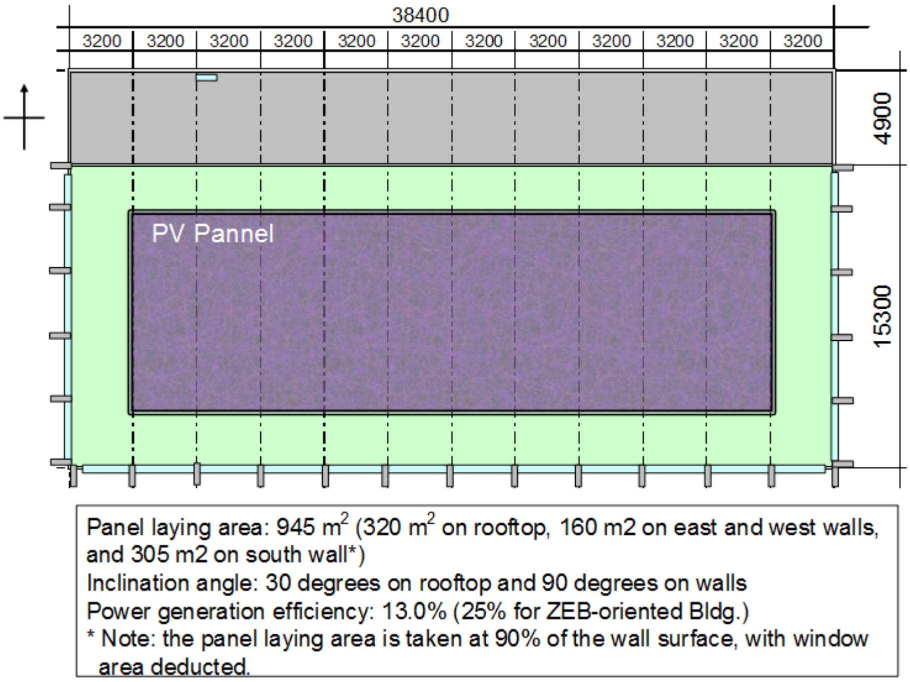


Fig. 3 Modeled building: Rooftop plan

Method of study

Life-Cycle Energy Management (LCEM) tools (available for public use from the Ministry of Land, Infrastructure, Transport and Tourism) have been used for simulation of air conditioning. HASP, which is the most commonly used heat load calculator in Japan, has been used for the heat load calculation. The same values of constants have been used for the energy consumption of transport and sanitary systems.

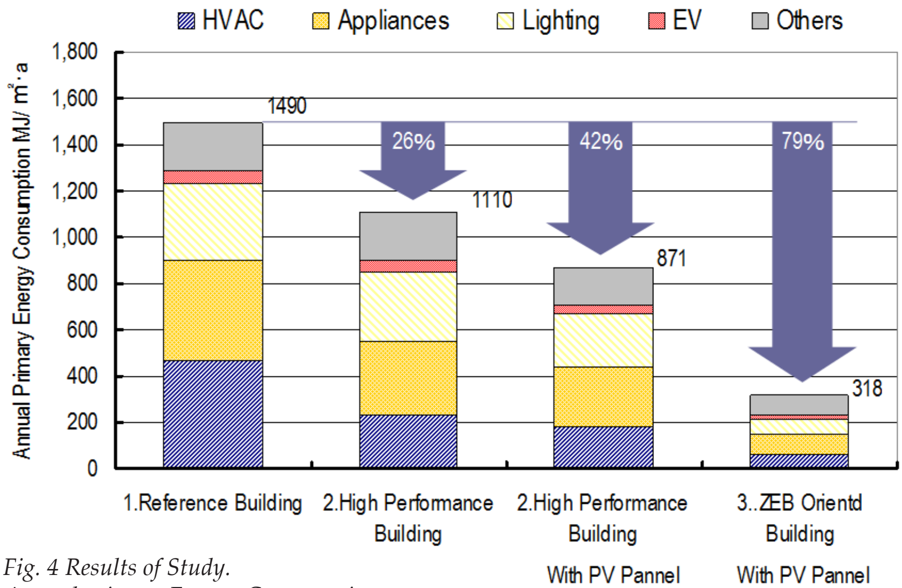


Fig. 4 Results of Study.
Annual primary Energy Consumption

Results of study

Figure 4 shows the primary energy consumption per
air-conditioning area as derived from 1) the reference building, 2) the high-performance building and (modified 2) the same high-performance building but having photovoltaics for power generation, and 3) the ZEB-orientated building with photovoltaics. The power generated by the photovoltaic system has been deducted from the total power consumption, assuming that the power is all used for battery charging or reverse power flow to the public supply. Looking at the calculation results, as compared with the reference building, the high-performance building's energy consumption has been reduced by 24 % by the photovoltaics. For the ZEB-orientated building of the next-generation type, use of expected future technology has given a 79 % reduction,
but could not deliver a zero-energy building.
It can be seen that realising the nZEB is very difficult, but that there is a realistic prospect for doing so using prospective future technological development.

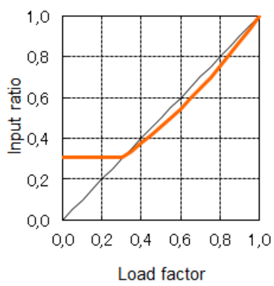
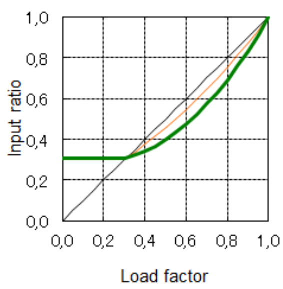
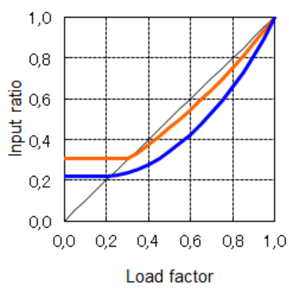
Conclusions

This study has calculated the primary energy consumption of the model buildings on a trial basis in order to verify the feasibility of an nZEB in a hot and humid climate. The results show that current technology levels can give a 42 % reduction in energy use, and that prospective future technological development should be able to produce a saving of about 80 %.

Tab. 1 Calculation conditions for each case

Case		1.Reference Building	2.High Performance Building	3．ZEB oriented Building
Location		Tokyo		
Usage		Office		
Scale		Five stories above ground; 3,878 m^2 in total floor area; 2,938 m^2 in air-conditioned floor space		
Indoor temperature and humidity		Summer (Jun to Sep) at 26°C/50%; Winter (Dec to Feb) at 22°C/40%; Intermediate seasons (others) at 24°C/50%		
Air-conditioner operation time		8:00 to 20:00 hours (Sunday, Saturday and legal holidays at halt)		
Outer skin	Outer walls	Concrete 150 mm thick Air layer Foamed styrene 25 mm thick Plaster board 12 mm thick	Sheet metal 1.2 mm + air layer Concrete 150 mm Foamed styrene 50 mm + air layer Plaster board 9+12 mm	Sheet metal 1.2 mm + air layer Foamed styrene 50 mm Concrete 150 mm Foamed styrene 50 mm + air layer Plaster board 9+12 mm
		Inner heat shielding K=1.03 W/m2•K	Inner heat shielding K=1.06 W/m2•K	Inner and outer heat shielding K=0.37 W/m2•K
	Window	Window ratio at 47% (window height 1.8 m)	Window ratio at 53% (window height 2.0 m)	Window ratio at 53% (window height 2.0 m)
		Single pane glass 6 mm K=4.8 W/m2•K Shade factor: 0.66 when rolling blind closed and 1.0 when open	Low-e glass K=2.6 W/m2•K Shade factor: 0.34 when rolling blind closed and 0.51 when open	AF+Low-e glass K=1.0 W/m2•K Shade factor: 0.12 when rolling blind closed and 0.3 when open
	Eaves	None	1.2m	1.8m
	Louvers	None	None	1.0 m (pitched at 1.6 m)
Indoor heat release	Lighting	13W/m2 750lx（HF）	9.5W/m2 500lx(HF）	6.5W/m2 350lx（LED+TAL+Dimer)
	Equip. heat	20W/m2 (Load factor 50% in daytime, 12.5% in night waiting)	15W/m2 (Load factor 50% in daytime, 12.5% in night waiting)	10W/m2 (Load factor 50% in daytime, 12.5% in night waiting)
	Personnel density	10 m^2/person, sensible heat 65W/person, latent heat 55 W/person		
Natural Ventilation		None	None	Effective

Tab. 2 Setting conditions of air-conditioning systems

Case			1.Reference Building	2.High Performance Building	3.ZEB oriented Building
Outdoor air-conditioner	Rated operations Outdoor equip.'s performance coefficient	Cooling	**3,0**	**5,0**	**7,0**
		Heating	**3,5**	**5,5**	**7,5**
	Input rate characteristic against load factor during partial loading operation (in cooling)				
Outdoor air-conditioner	Refrigerant control		Constant evaporation temp.	Constant evaporation temp.	Variable evaporation temp.
	Fan control		Not existing	Same as left	Same as left Fan at halt when thermostat is off
	Fan consumption power ratio		**1,0**	**0,8**	**0,6**
Outdoor air treatment	System		Total heat exchanger	Same as left	Total heat exchanger + Outdoor air treatment air-conditioner
	heat exchanger efficiency		**60%**	**70%**	**80%**

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Multi-year thermal behaviour of a vertical ground heat exchanger for a low-energy house

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This article focuses on the thermal behaviour, over five consecutive winters, of a vertical closed-loop ground-coupled heat exchanger installed for a Canadian low-energy house. The house's HVAC system integrates a reversible brine-to-air geothermal heat pump as a main heating and cooling system, electricity and heat generation from building-integrated photovoltaic & solar thermal panels, concrete wall and floors as passive and active solar energy storage systems, and several heat recovery devices. The results obtained show that the ground-source heat pump has run with relatively high heating coefficients of performance, while the ground thermal capacity has been well balanced and fully recovered between one heating-dominated season and the next. In addition, the annual electrical energy consumption of the occupied low-energy house has been reduced by 56.8 % compared to the average consumption of Québec's conventional electrically heated houses.

Introduction

In 2008, the Canadian total end use demand amounted to approximately 11 000 PJ, of which the residential sector, with more than eight million detached residential houses, represents 13.75 % [1]. Heating accounted for over 50 % of this residential annual energy consumption. In the province of Québec (Eastern Canada), more than 75 % of new houses use electric skirting boards as heating systems. Each of these houses consumes on average 26 700 kWh per year [2]. Because residential energy consumption for heating still constitutes a significant component of the total energy demand, reducing it presents a major challenge.

Canadian initiative

The 2006 Equilibrium Initiative lead by Canada Mortgage and Housing Corporation and the Canadian Solar Building Network brought together the private and public sectors to develop homes producing as much energy as they consume on an annual basis, by integrating solar and geothermal energies and commercially available HVAC systems [3].

Eco Terra low-energy house

Eco Terra house is a 234 m² (including a 90 m² basement), two-story home located in Québec (Eastern Canada) [4, 5]. The site's daily average winter (December to March) and summer (June to September) temperatures are -8.6 °C and 15.6 °C respectively [6]. A 2.86 kW (electrical), 57.2 m² roof-integrated photovoltaic/thermal (BIPV/T) system converts light directly into electricity (Figure 1). The outdoor air is heated by absorbing a portion of the solar energy that falls on the arrays. During the day, some of this energy is used to dry clothes, preheat domestic hot water via an air-to-water heat exchanger and heat the mass of a ventilated concrete slab. The preheated water is stored in a domestic hot water (DHW) tank, where it is further

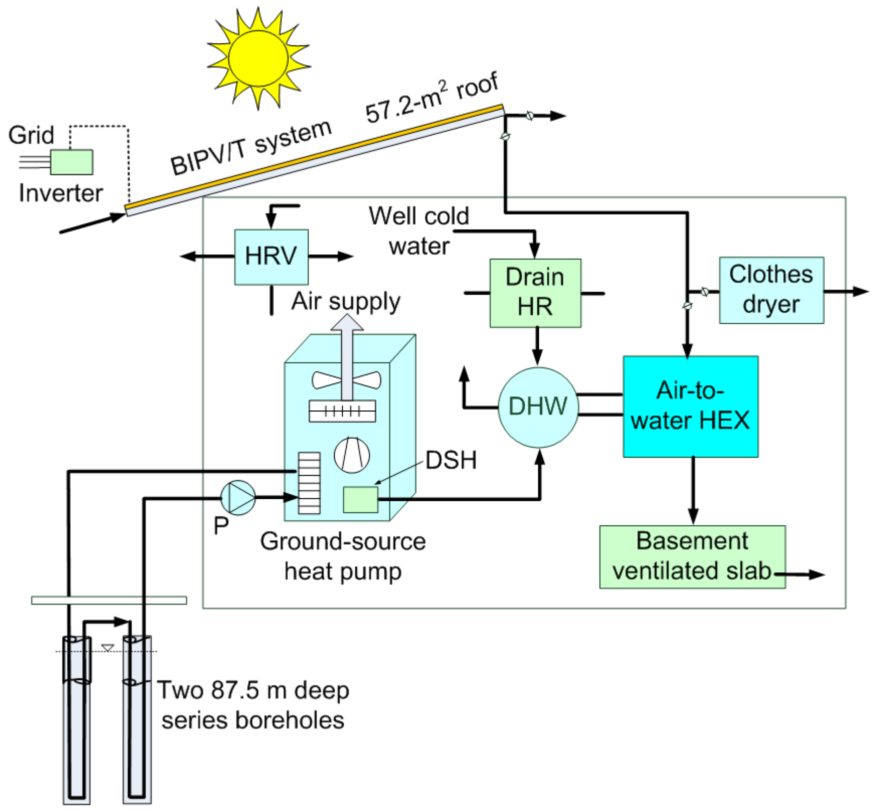


Figure 1 – Schematic of the Eco Terra house HVAC system. BIPV/T: building-integrated photovoltaic/thermal; P: brine circulating pump; HR: heat recovery; DHW: domestic hot water; DSH: desuperheater; HRV: heat recovery ventilator [8, 9]

heated by the heat pump's desuperheater. A second DHW tank with an electric immersion heater raises the hot water temperature to 60 °C for supply to the consumers. Cold water coming from a well is first heated by a drain water heat recovery heat exchanger, prior to entering the preheating DHW storage tank. A heat exchanger in the ventilation system (HRV) recovers heat from ventilation exhaust air and uses it to preheat the outdoor air [4, 5, 7].

Ground-coupled heat exchanger

At the Eco Terra home site, the depth of overburden is 14.4m, underlain by bedrock, and the average static level of the groundwater table is at 1.8 m depth. The required length of vertical U-tubes has been determined by software. The ground heat exchanger consists of a high-density polyethylene pipe containing a water/methanol mixture (brine, 25 % by weight) that circulates in two vertical series-connected U-tubes (Figure 1). They are inserted into two 87.5 m deep, 114.3 mm diameter boreholes [8, 9].

Ground thermal balance issue

During the heating-dominated seasons, the ground provides heat to the heat exchanger and the ground temperature around the boreholes decreases. If, overall, the soil temperature falls from one heating season to the next, the energy performance of the geothermal heat pump will deteriorate year by year. This study therefore focuses on the multi-year behaviour of the vertical ground heat exchanger installed in the Eco Terra low-energy house in order determine if the ground thermal capacity been recovered from one heating season to another or not.

Brine-to-air heat pump

The brine-to-air geothermal heat pump provides the main air-conditioning function (i.e., both heating and cooling) of the house. The brine-to-air heat pump includes a two-stage 3-tonne (10.5 kW nominal cooling capacity) reciprocating compressor using R-410A as refrigerant, a four-way reversible valve, an evaporator, a condenser, a desuperheater and a fan, as well as standard controls (Figure 1).

Results

Between 2007 and 2012, the ground-source heat pump has operated in both heating (winter) and cooling (summer) modes. The house was unoccupied until September 2009, and then occupied by a family of three to four people. The lowest outdoor dry bulb temperature (-35.1 °C) was recorded on January 16th, 2009, during winter #2 (Table 1) [10]. This section focuses on operation of the ground-source heat pump in the heating mode during five consecutive winters, i.e. between November 1st and February 26th of each year.

Heat pump parameters

The ground-source heat pump has run intermittently during the winter heating mode, depending on the house indoor thermostat setting, i.e. 16 °C during the night and 20 °C during the day. When the house has been occupied, the brine entered the heat pump at constant flow rate (0.536 kg/s) and temperatures between 4.6 and 5.4 °C (Table 2). It can be seen that the refrigerant (R-410A) evaporating temperatures have never dropped below –2 °C in winter (see Table 2 and Figure 2a), while the average coefficient of performance, defined as the thermal power supplied to the house divided by the total electrical power input (compressor and fan), was as high as 5, with temperature rises of 35.6 K.

Table 1 – Outdoor weather conditions during five consecutive winters

Winter (house status)	Dry bulb temperature			Relative humidity		
-	Min.	Av.	Max.	Min.	Av.	Max.
-	°C	°C	°C	%	%	%
#1 (2007-2008) (unoccupied)	-32.0	-5.8	14.2	26.6	76.3	100
#2 (2008-2009) (unoccupied)	-35.1	-6.9	19.7	34.0	74.6	100
#3 (2009-2010) (occupied)	-28.0	-4.3	18.0	13.0	83.4	100
#4 (2010-2011) (occupied)	-31.0	-6.0	15.0	20.0	83.6	100
#5 (2011-2012) (occupied)	-26.0	-3.3	20.0	21.0	79.3	100

Table 2 – Average operating parameters of the ground-source heat pump

Winter	Brine entering the evaporator		Refrigerant saturated parameters			
-	Temperature	Flow rate	Evaporating		Condensing	
-	°C	kg/s	MPa (abs)	°C	MPa (abs)	°C
#3	5.0	0.536	0.770	-1.76	314	37.4
#4	4.6	0.536	0.756	-1.56	309	37.1
#5	5.4	0.536	0.770	-1.76	308	37.0

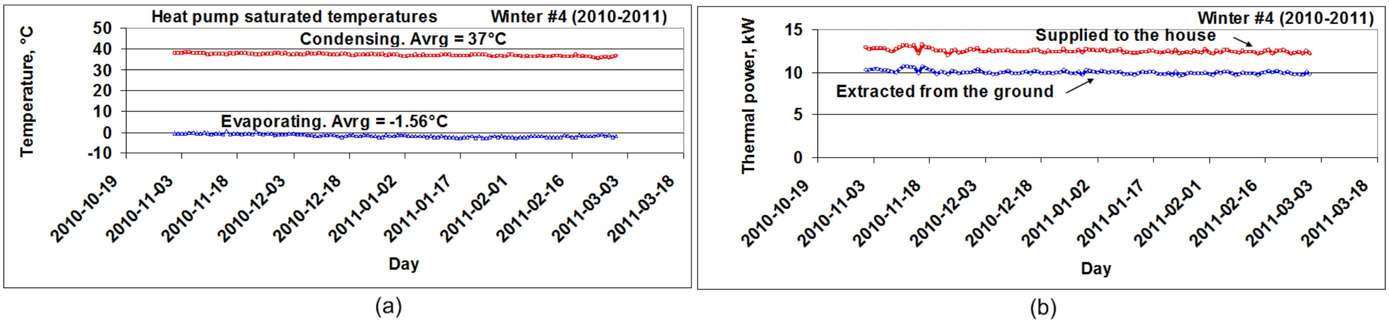


Figure 2 – Heat pump operating parameters in heating mode during winter #4; (a) Average saturated temperatures; (b) Thermal powers extracted from the ground and supplied to the house

Table 3 – Electrical energy consumptions during three consecutive winters

Winter	House		Heat pump	Heat pump as function of house energy use
-	kWh	kWh/m²	kWh	%
#3	6398	27.8	2055	32.1
#4	5963	25.9	1856	31.1
#5	4948	21.5	1612	32.5

Winter energy consumption

Table 3 shows the electrical energy consumptions of the house and the heat pump (compressor and fan) respectively, during the last three winters when the house was occupied. Both the house and the heat pump energy consumptions have fallen during these last three winters as a result of more efficient indoor climate control by the owners (among other factors [weather, etc.]). It can also be seen that, in winter heating-dominated modes, the heat pump consumed between 31.1 and 32.5 % of the total house electrical energy consumption. Based on the house total surface (234 m^2), the specific electrical energy consumption of the occupied house during the winter varied between 27.8 kWh/m^2 (winter #3) and 21.5 kWh/m^2 (winter #5) (Table 4). Other electrical energy consumers during these winters were the back-up domestic hot water tank (between 6.5 and 9.2 %), and the heat recovery ventilator (around 3.2 %).

Ground thermal behaviour

The geothermal system provided heating in the winter and cooling in the summer. The thermal energy transferred to the ground in the summer was stored and was partially available to be extracted in the winter. Figure 3 shows that during the years when the house has been unoccupied (2008), partially occupied (2009) or fully occupied (2010 and 2011), the heat pump has each year extracted from the ground 14 to 20 times more heat in the heating modes than it has rejected in the cooling modes.

On the other hand, the efficiency of the heat transfer from the ground to the geothermal fluid can be characterised in a simple way by the brine temperature entering the heat pump evaporator during the first and the last heating cycle of each year. First,

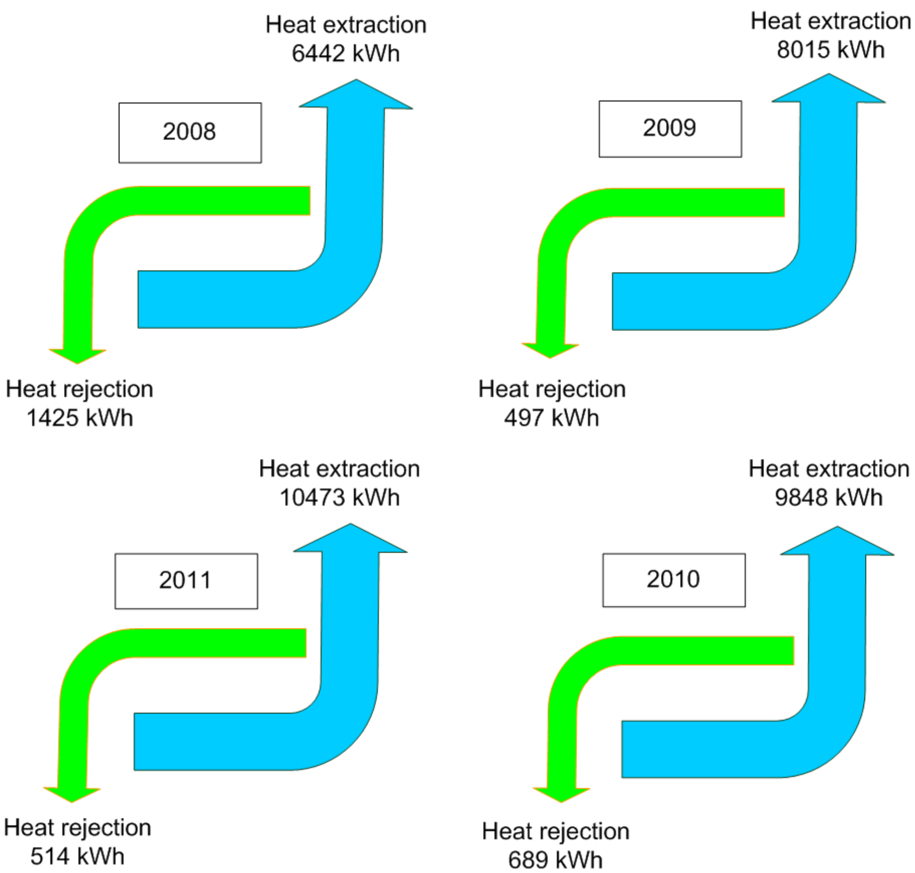


Figure 3 –Annual heat rejection and heat extraction by the heat pump during four consecutive years

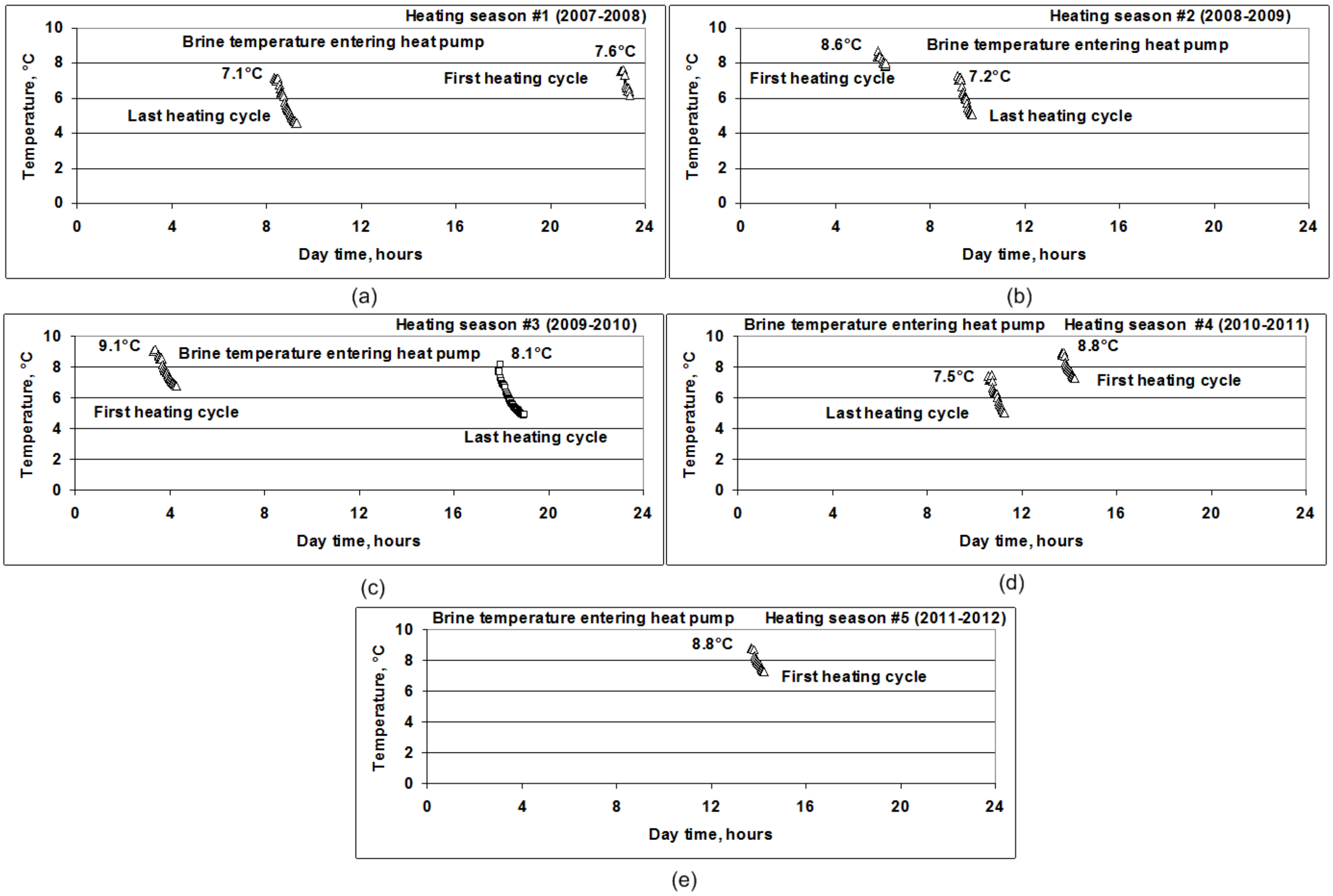


Figure 4 – Brine temperatures entering the heat pump during the first and the last cycles of each heating dominated season

it can be seen that, at the beginning of the last heating cycle of each heating season, the brine entered the heat pump evaporator at temperatures of only 2 K lower than the brine temperatures entering the heat pump at the beginning of each first heating cycle. Second, during each summer cooling-dominated season, the ground completely recovers its thermal capacity because at the beginning of next heating season, the brine entered the heat pump is at practically at the same temperature, i.e. around 8.4 °C (see Figures 4a-e and Figure 5).

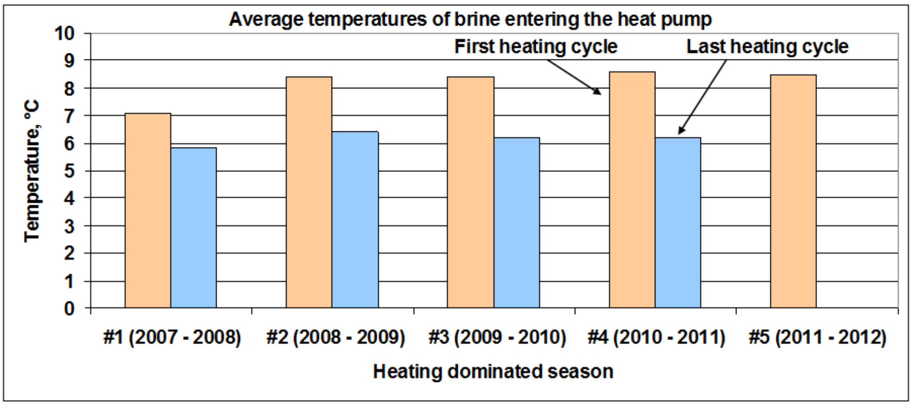


Figure 5 – Summary of brine average temperatures entering the heat pump during the first and last heating-dominated cycles of five consecutive winters (see also Figure 4)

Looking over the entire five-year period, it can be seen that at the beginning of the first heating cycle, the brine entered the heat pump at 7.5 °C, and, approximately four years later, it entered the heat pump at a slightly higher temperature (i.e., about 8.8 °C) (Figure 6). On the other hand, at the end of the last heating cycle of winter #1, the brine entered the heat pump at 4.5 °C, while at the end of the last heating cycle of winter #4, i.e. approximately three years later, it entered the heat pump at 5 °C (Figure 7).

These experimental results prove that the ground has completely recovered its initial thermal capacity after three and four years of operation respectively. During these periods of time, the ground was not excessively cooled and so no freezing phenomena occurred. This performance can be explained by the correct design of the vertical closed-loop heat exchanger that, among many other factors, accounted for summer ground thermal storage, ground thermal conductivity and groundwater movement.

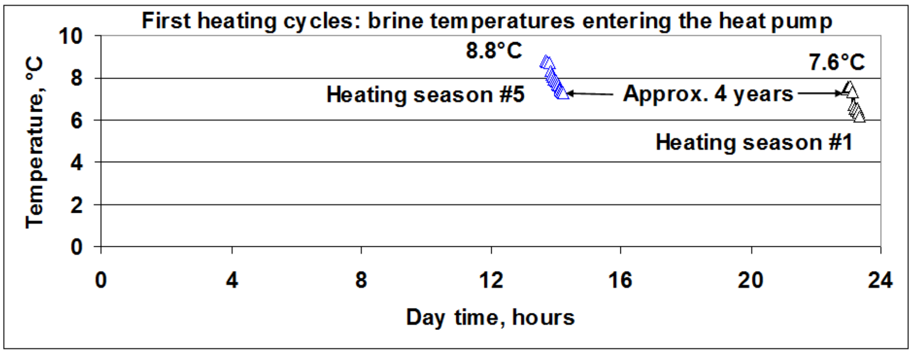


Figure 6 – Brine temperatures entering the heat pump during the first heating cycles of winter #1 and winter #5 respectively

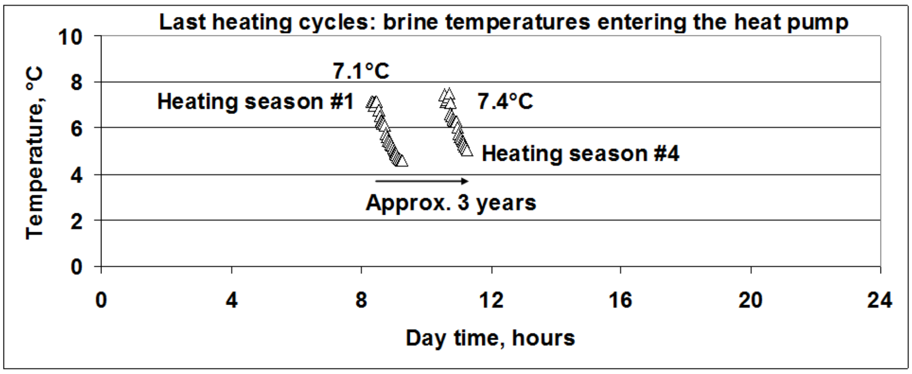


Figure 7 – Brine temperatures entering the heat pump during the last heating cycles of winter #1 and winter #4 respectively

Example: very cold winter days

The thermal behaviour of the ground can also be analysed for two very cold winter days, i.e. January 23rd and January 24th, 2011. During these two days, the lowest outdoor dry bulb temperature was –32 °C and the highest, -20 °C (Figure 8a). It can be seen that, at the beginning of the first heating cycle, the brine entered the heat pump at 7 °C, and, at the end of the same cycle, at 2.8 °C (Figure 8b). After about five hours of the heat pump long OFF cycle, the brine entered the evaporator at the same temperature, i.e. 7 °C. This means that the ground had recovered its full thermal capacity from one heating cycle to the next. When shorter heat pump ON/OFF cycles occurred during the night of the second day, the brine inlet temperature was lower, i.e. around 5 °C, but this temperature has been generally recovered from one heating cycle to another (Figure 8b). It can be concluded that, even the heat pump OFF cycles were shorter (about two hours), the ground was able to recover its initial thermal capacity and supply brine at approximately the same temperatures as at the beginning of each ON heating cycle. Consequently, during two of the coldest winter days, the soil did not freeze around the vertical boreholes.

Outline on house annual energy consumptions

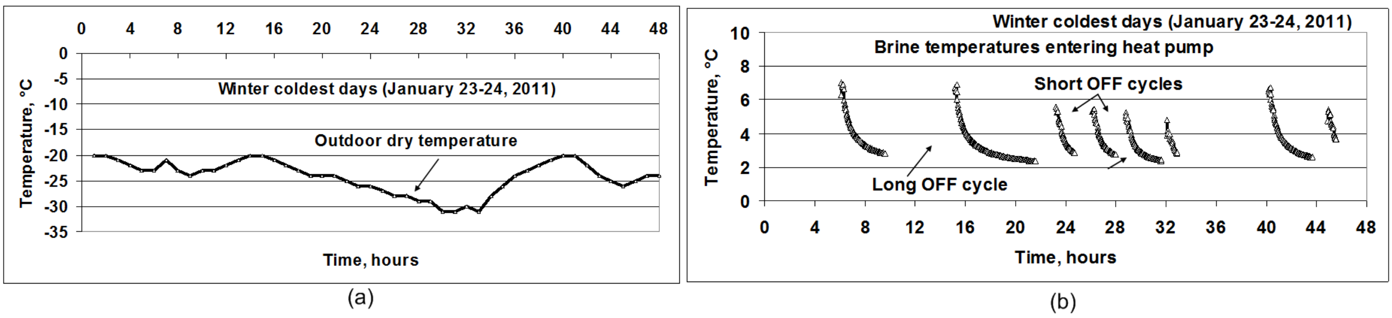
As can be seen in Table 4, the annual electrical energy consumption of the occupied low-energy house (11 077 kWh in 2010 and 11 993 kWh in 2011) was, on average, 56.8 % lower than the average consumption of conventional houses which, in the Eastern Canada, ranges around 26 700 kWh/year [2]. This energy use does not include the electrical energy generated by the BIPV/T system, of which about 58 % was estimated to be supplied to the grid each year.

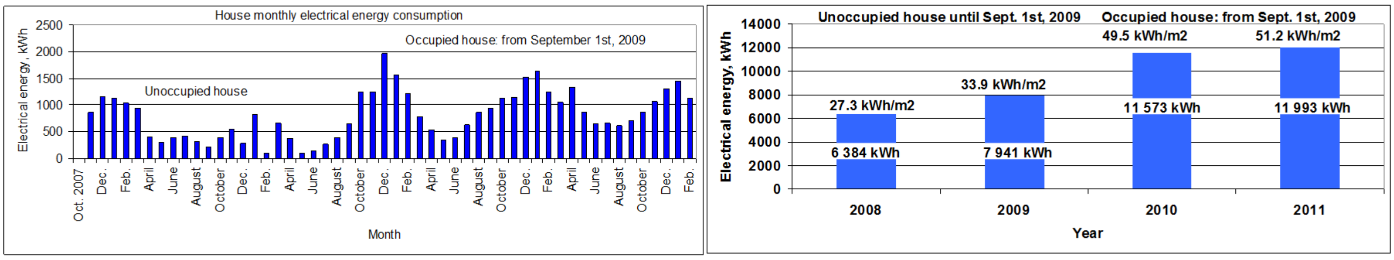
Table 4 – House annual electrical energy consumption

Year	House	Total electrical energy consumption
-	-	kWh/year
2010	Occupied	11 077
2011	Occupied	11 993

Figure 9a shows the profile of monthly energy consumptions of the unoccupied and occupied low-energy house, while Figure 9b shows the annual total and specific energy consumptions. It can be seen that the annual specific electrical energy consumption (versus the total area) varied between 27.3 kWh/m² in 2008 (with the house unoccupied) to 51.2 kWh/m² in 2011 (with the house occupied). The heat pump (i.e., compressor, fan and brine circulating pump), which was the main heating and cooling device), consumed 8.2 kWh/m² in 2008, 8.8 kWh/m² in 2009, 10.8 kWh/m² in 2010, and 9.9 kWh/m² in 2011. These last two performance metrics are significantly lower than the annual energy consumption target for air-conditioning (i.e., both heating and cooling) of the occupied house, which was 15 kWh/m².

Figure 8 – Two of the coldest winter days; (a) Outdoor dry bulb temperatures; (b) Brine temperatures entering the heat pump





(a) (b)

Figure 9 – Electrical energy consumption of the house; (a) Monthly; (b) Annual total and specific (i.e. per m2 of total surface area

Conclusions

This article has described the thermal behaviour of a vertical ground-coupled heat exchanger / heat pump system installed in a Canadian low-energy house over five consecutive winters. Firstly, the measurements show that, although the heat pump has extracted 14 to 20 times more heat from the ground in the heating-dominated seasons than it has returned to the ground in the cooling season each year, the ground entirely recovered its thermal capacity from one year to the next. Second, as the main air-conditioning device, the heat pump consumed about 10 kWh/m2/year for heating and cooling the occupied house. Third, this study showed that the annual electricity consumption of the Eco Terra low-energy house was 56.8 % less than that of conventional houses with 10 % electric heating in Québec (Eastern Canada).

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A European Innovation Development Strategy towards Energy-efficient Buildings

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The key objective of the Energy-Efficient Buildings Association (E2BA), representing a large group of stakeholders from the construction sector and associated technology sectors, is to promote the creation of an active industry for the production, supply/distribution of advanced systems, solutions and added-value services with a view to satisfying the need for energy efficiency in the built environment. The paper concentrates on presentation of the new Roadmap recently prepared by the Association in cooperation with the EC, setting out the major RDI challenges faced by the sector by 2020 to meet the EU carbon emission reduction targets.

Introduction

The key objective of the Energy-Efficient Buildings Association (E2BA), representing a large group of stakeholders from the construction sector and associated technology sectors, is to promote the creation of an active industry for the production, supply/distribution of advanced systems, solutions and added-value services with a view to satisfying the need for energy efficiency in the built environment.

Since 2009, the Association has been engaged in a Public-Private Partnership (EeB PPP) with the European Commission (EC) to develop and deploy a full Research, Development and Innovation (RDI) program at EU level. As a matter of fact, buildings provide a large untapped cost-effective potential for energy savings, but in order to speed up the deployment of key technologies for least cost, it is crucial to increase innovation in the fields of energy-efficient construction processes, products and services.

This paper concentrates on presentation of the new Roadmap recently prepared by the Association in conjunction with the EC, setting out the major RDI challenges faced by the sector by 2020 to meet EU carbon emission reduction targets.

Context

Worth at least 1.3 trillion Euros of annual turnover (2010), the European building sector and its extended value chain (material and equipment manufacturers, construction and service companies) is on the critical path to decarbonise the European economy by 2050. This requires a reduction of CO_2 emissions by 90 %, and a reduction of energy consumption by as much as 50 %. This is a unique opportunity for sustainable business growth, provided that products (new or refurbished buildings) and related services are affordable and of durable quality, in line with several past or future European directives. Yet, together with the 2050 deadlines, such directives are putting more constraints onto a sector which is directly affected by the ongoing financial and economic crisis (less purchasing power, but also potentially higher building costs due to more stringent requirements in terms of reducing building energy requirements). The time frame left to develop innovative technology and business models in line with the 2050 ambitions is reducing, to the effect that it is now less than ten years.

The current EeB PPP

The EeB PPP was launched as part of the economic recovery plan in 2008. The EeB PPP uses existing FP7 mechanisms whilst providing a midterm approach to R&D activities. It brings together various Directorates-General (DGs): DG Research and Innovation (Nano, Materials & Processes, and Environment priorities), DG Energy, and DG Communications Networks, Content and Technology, in close dialogue with industry. In this framework, a roadmap was constructed on the following pillars, namely: 1) a systemic approach; 2) exploitation of the potential at district level; 3) geo-clusters, conceived as virtual trans-national areas/markets where strong similarities are found (for example) in terms of climate, culture and behaviour, construction typologies, economy and energy/resources price policies, Gross Domestic Product, as well as types of technological solutions (because of local demand-supply aspects) or building materials used etc.

These pillars are clearly identified in a new Research and Innovation Roadmap, which is strongly based on the long-term programme defined in 2009 [1] around a "wave action". In this "wave action" plan, continuous, on-going research feeds successive waves of projects, as shown in Figure 1. The knowledge gained in the first "wave" feeds into the second at the design stage, giving a continuous implementation process.

As a result of this "wave action", industry expects to deliver results in a stepped approach, namely:

- Step 1: Reducing the energy use of buildings and its negative impact on the environment through integration of existing technologies (the main focus of the current EeB PPP);
- Step 2: Buildings meet their own energy needs;
- Step 3: Transformation of buildings into energy providers, preferably at district level.

The long-term programme set by industry also tackles the develop-

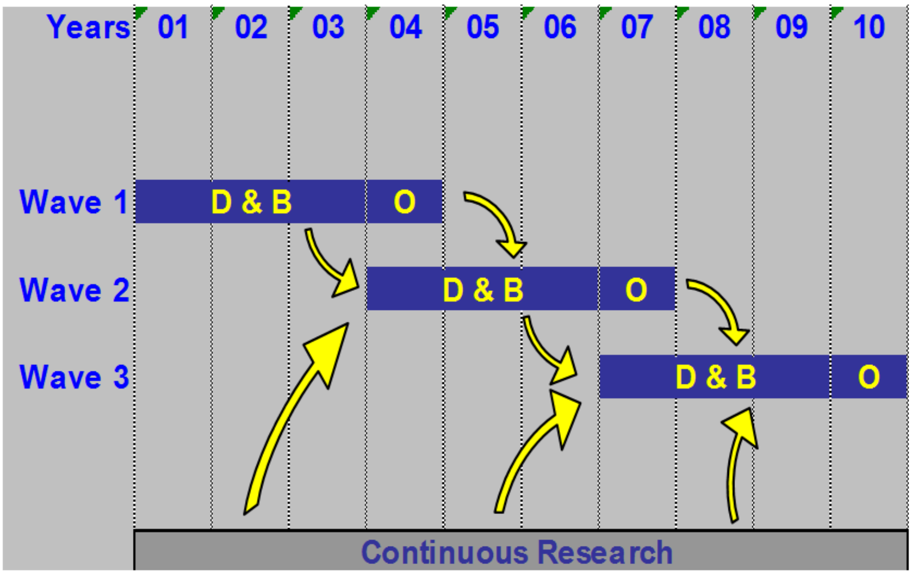

Figure 1 - Wave action along the roadmap (D&B: Design & Building; O: Operation)

ment of knowledge and technologies which are essential in achieving these targets, launching the necessary fundamental and applied research actions. This long-term approach has heavily engaged industry, with over 50 % participation in calls and SME involvement over 30 %, figures which are well above usual business levels such as in collaborative research projects under the framework programme.

A review of the different running projects [2, 3] has highlighted some of the innovations under development, such as:

- Nanotechnology coatings
- Integrated Air Quality Sensors
- Tools to improve Indoor Environment
- Operational guidance for performing life cycle assessment studies
- Sustainable, innovative and energy-efficient concrete
- High-performance bio-composites for buildings
- Component and systems for buildings, such as multi-functional façade panels
- Components and systems for districts, such as energy storage solutions
- Standardised building and user-friendly models
- Energy control hardware
- Building energy management systems (BEMS)
- Heating, ventilation and air conditioning (HVAC) control systems
- Energy performance simulation
- Virtual building models
- Integration of multi-functional energy modules
- Business models

Overall vision till 2030 and strategic objectives

The E2BA ambition is to drive the creation of an innovative high-tech energy efficiency industry, extending the scope of the current EeB PPP beyond 2013. Connecting construction industry to other built environment system suppliers will be the decisive step for Europe to reach its economic, social and environmental goals, contributing to the objectives of the Innovation Union. By creating and fostering this paradigm shift, EU companies will become competitive on a global level in the design, construction and operation of the built environment while sustaining local economies across EU-27 through job creation and skills enhancement, driven by the vast number of SMEs active in the value chain.

If the ambitious 2050 targets are to be achieved, it will be necessary by 2030 for the entire value chain to be producing advanced systems, solutions and high-value services for intelligent and sustainable buildings and districts. The long-term strategic objectives [4] include:

- Most buildings and districts become energy-neutral, with zero CO_2 emissions. A significant number of buildings would then be energy-positive, thus becoming real power plants, integrating renewable energy sources, clean distributed generation technologies and smart grids at district level.
- Industry will employ highly skilled individuals capable of efficiently, safely and quickly carrying through construction processes. This means an extended value chain and collaborative "assembly-line" methods delivering adaptive and multi-functional energy and resource-efficient buildings and district solutions.
- Unemployment will be reduced, as skilled local jobs will be created through effective and dynamic matching of demand and supply. Public Private Partner-ships will indeed cover the entire innovation chain, fostering performance-based contracting and innovation-friendly procurement practices. This will be achieved through sustainable financial incentive schemes on the demand side. On the supply side, system-technical solutions optimised on European scale will be integrated locally.
- Urban planning and smart cities implementation leverage on these novel solutions on building and district scale, creating the basis for intelligent connections between buildings and districts and all urban resources.
- Such globally competitive energy-efficiency industry will be able to deliver new business opportunities, jobs and solutions. In terms of environmental impacts, greenhouse gas emissions will be reduced to 80-95 % below 1990 levels, as required by the Energy Roadmap 2050 (COM(2011) 885/2). In addition, the use of renewable energy and efficiency technologies is extended as required by the Strategic Energy Technology Plan, the Energy Efficiency Plan and the update of the Energy Performance of Buildings Directive (EPBD).

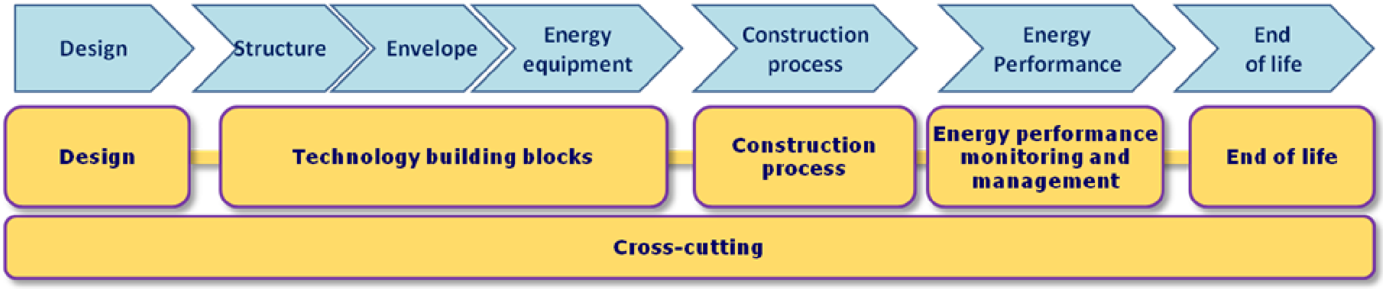

Figure 2: representation of the segmentation of the value chain

Research and innovation strategy

The innovation rationale proposed by industry is to extend the aim of running EeB PPP beyond 2013 in line with the 2030 vision to develop and to validate a set of innovative integrated novel tools, technology and process components covering the whole value chain. They will then be integrated to meet future market conditions, as follows:

- transforming barriers and regulatory constraints into innovation opportunities,
- fostering the creation of innovative supply chains, that become more user-centric to cope with the difficulty of implementing refurbishment strategies,
- reorganising and stimulating innovative procurement of buildings and ordering of technology/ services.

Today's fragmented nature of the construction chain gives little freedom for innovations that are indispensable to shape a more sustainable built environment. Yet, collaborative project management in the construction sector is prerequisite for developing built environment that is technically and economically optimised: this goes against centuries of working habits. In addition, the focus must be on creating value (not only in terms of economics, but also in terms of comfort, health, environment, etc.) for all the users involved. This requires new skills together with a major behavioural shift across the entire construction sector. Coalitions must be formed, dedicated to collaboration between players from different disciplines to contribute to the realisation of buildings with energy-ambitious goals.

The whole value chain (see Figure 2) will be involved in this continuous optimisation process, which follows three major steps:

Step 1: From design to commissioning of new or refurbished buildings, optimisation consists of picking, amongst a portfolio of material and energy equipment solutions, the ones which meet both a cost of ownership target and have minimum potential GHG emissions over the foreseen life cycle.

Step 2: During this life cycle, robust user-centric energy management systems ensure that the initial GHG emission targets are continuously met, thanks to adaptive energy management tools able to correct for or modify the behaviours of users. Only natural ageing of technology can affect the initial energy performance at commissioning.

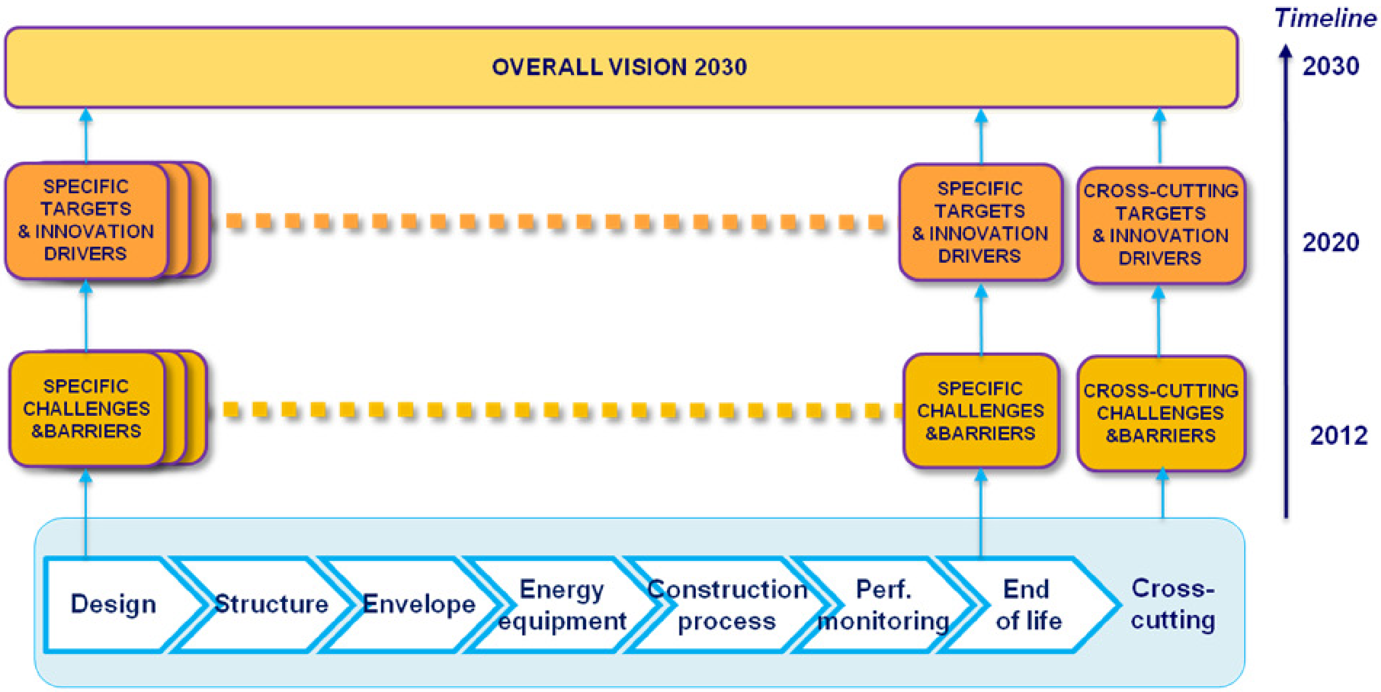

Figure 3: Road mapping process

Step 3: The next refurbishment involves another optimisation approach where the investment for refurbishment can be recovered through further savings on the cost of ownership.

This approach will reinforce the value chain optimisation approach initiated in the EeB PPP, which will require more dedicated R&D and innovation activities covering each of the following components of the value chain:

- design and commissioning with novel approaches to narrow down the gaps existing between performance by design and performance when built,
- structural parts where material processing innovations will allow further reduction of the CO_2 footprint of the structural components over the life cycle of new buildings,
- building envelopes, which protect the building from external mechanisms while reducing space heating/cooling demands by smart use of renewable energy with the help of thermal storage,
- energy equipment (heating, cooling, lighting, ventilation) and their control systems which have to be downsized since energy demand is reduced, but must also be user-centric to optimise energy supply and demand in real time,
- construction processes where combining pre-manufacture of critical components and self-inspection/automation of construction tasks increases quality and productivity of construction workers,
- building energy management systems able to optimise supply and demand according to price signals sent to consumers, coupled with energy cooperation between buildings at district level,
- end-of-life optimisation in view of recycling/reusing demolition wastes.

Conclusion

This Research and Innovation Roadmap sets out dedicated R&D trajectories for each element of the value chain of the building sector (see Figure 3): progressive market availability of technologies and processes will come from large-scale demonstrations. They will show irrefutably that the best technical and cost performances can be reached on time for the market demand, thanks to integration processes taking care of the global optimisation at building or even district level, and data sharing to help minimising the interface risks inherent in any such complex system optimisation process.

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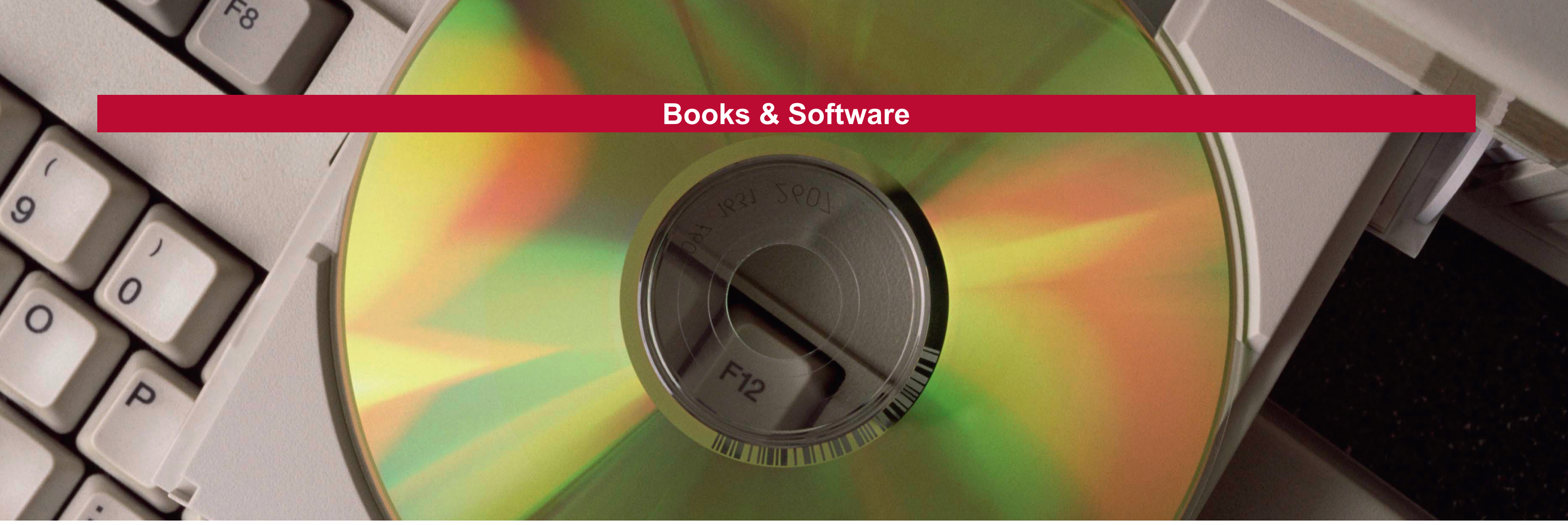

World Energy Outlook 2012

The 2012 edition of the World Energy Outlook was released on 12 November and presents authoritative projections of energy trends through to 2035 and insights into what they mean for energy security, environmental sustainability and economic development. Oil, coal, natural gas, renewables and nuclear power are all covered, together with an update on climate change issues. Global energy demand, production, trade, investment and carbon dioxide emissions are broken down by region or country, by fuel and by sector.

WEO-2012 presents in-depth analysis of several topical issues, such as: the benefits that could be achieved if known best technologies and practices to improve energy efficiency were systematically adopted; the dependence of energy on water, including the particular vulnerabilities faced by the energy sector in a more water-constrained future; how the surge in unconventional oil and gas production in the United States is set to have implications well beyond North America; and a detailed country focus on Iraq, examining both its importance in satisfying the country's own needs and its crucial role in meeting global oil and gas demand.

Furthermore, it analyses the implications of energy trends on climate change, quantifies the cost of subsidies to fossil fuels and renewables, which are both coming under closer scrutiny in this age of austerity, and presents measures of progress towards providing universal access to modern energy services.

Source: http://www.worldenergyoutlook.org

Events

This section lists exhibitions, workshops, conferences etc. related to heat pumping technologies.

2012

3-7 December
Ecobuild America
Washington DC, USA
http://www.aececobuild.com/conference-schedule

2013

26-30 January
ASHRAE Winter Conference
Dallas, Texas, USA
http://www.ashrae.org/membership--conferences/conferences/dallas-conference

5-7 February
Chillventa Rossija
Moscow, Russia
http://www.chillventa-rossija.com/en/

28 February – 1 March
GeoTHERM
Offenburg, Germay
http://www.geotherm-offenburg.de/en/geothermal_expo_congress

7-9 March
ACREX India 2013
Mumbai, India
http://www.acrex.in/

17-20 March
2013 IIAR Industrial Refrigeration Conference & Exhibition
Colorado Springs, Colorado, USA
https://www.iiar.org//index.cfm?

8-10 April
China Refrigeration 2013
Shanghai, China
http://www.cr-expo.com/EN/Index.asp

12-16 April
ISH 2013
Frankfurt, Germany
http://ish.messefrankfurt.com

2-4 April
2nd IIR International Conference on Sustainability and the Cold Chain
Paris, France
http://www.iccc2013.com

9-11 May
5th International Conference Ammonia Refrigeration Technology
Ohrid, Republic of Macedonia
http://www.mf.ukim.edu.mk/web_ohrid2013/ohrid-2013.html

14-15 May
EHPA General Assembly and Conference 2013
Brussels, Belgium
http://bit.ly/VlgJNr

3-7 June
European Geothermal Congress 2013
Pisa, Italy
http://www.geothermalcongress2013.eu/

7-8 June
15th European Conference - Italy
Refrigeration and Air Conditioning
Milano, Italy
http://www.centrogalileo.it/milano/congressodimilano2013english.html

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

22-26 June
ASHRAE Annual Conference
Denver, Colorado, USA
http://ashraem.confex.com/ashraem/s13/cfp.cgi

9-10 September
International Conference on Compressors and their Systems
London, UK
http://www.city.ac.uk/compressorsconference

25-27 September
5th International Conference Solar Air-Conditioning
Kurhaus Bad Krotzingen, Germany
http://www.otti.eu/event/id/5th-international-conference-solar-air-conditioning.html

3-4 October
7th CLIMAMED Mediterranean Congress of Climatization
Istanbul, Turkey
http://www.climamed.org/

2014

18-22 January
ASHRAE Winter Conference
New York, USA
http://www.ashrae.org/membership--conferences/conferences/ashrae-conferences

31 March – 3 April
2014 International Sorption Heat Pump Conference
College Park, Maryland, USA
http://www.ceee.umd.edu/events/ISHPC2014

12-16 May
11th International Energy Agency Heat Pump Conference
Montreal, Canada
http://www.iea-hpc2014.org/

In the next Issue

ETP 2012

Volume 30 - No. 4/2012

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.

The IEA Heat Pump Centre is operated by

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