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IN THIS ISSUE:



# IEA HEAT PUMP CENTRE


NEWSLETTER
VOL. 31
NO. 1/2013


## Thermal energy storage

**A new member of the Heat Pump Programme: We welcome Denmark!**

IEA **Heat Pump** CENTRE
NEWSLETTER

Volume 31 - No. 1/2013

# In this issue

**Heat Pump Centre Newsletter, 1/2013**
We are happy to welcome Denmark as a new member country of the HPP! In this issue you will find both an interview with the Danish HPP delegate and a market overview from Denmark.

Thermal Energy Storage (TES) and heat pumps may be viewed as the perfect couple, with TES extending the opportunities and possibilities of heat pumps.
With TES as the topic of this issue, an overview is provided, as well as examples from Japan and Spain, of sensible and latent TES, respectively.
Also, you will find a brief account of a meeting regarding the IEA Roadmap for Energy Storage.

Further in this issue you will find a Strategic Outlook from Finland.

Enjoy your reading!

Johan Berg
Editor

## Heat pump news



## Topical articles



## Regulars



COLOPHON



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# Thermal energy storage taps into nature for a more sustainable future

*Halime Paksoy*
*IEA Energy Storage Through Energy Conservation, Chair*
*Çukurova University Center for Environmental Research, Adana, Turkey*

Nature provides us with a tremendous supply of thermal energy in earth or rocks, in air, in the ground, in surface waters, and in the oceans. The question now should be how to tap and exploit these natural and abundant sources of energy.

Most thermal energy sources suffer from a mismatch in terms of time, space or temperature – that is, they may be delivered away from where they are wanted, or delivered or available at a time when they are not wanted, or be at a wrong temperature. The key to utilize this incredible potential of natural energy lies in thermal energy storage (TES) systems. Thermal energy can be stored as sensible or latent heat or cold, and as physical or chemical reactions.

Over the last 35 years, the IEA Energy Conservation Through Energy Storage (ECES) Programme has been developing and implementing TES technologies for a wide variety of applications, in order to achieve sustainable solutions to our imminent global energy shortages.

Heat pumps increase the quality of thermal energy and make it better available to users. Many current applications use TES in combination with heat pumps; the most common being Aquifer Thermal Energy Storage (ATES) and Borehole Thermal Energy Storage (BTES). The capacity of BTES systems are generally in the range of 50 to 500 kW, with COPs of 4 to 5. ATES is a better solution for higher capacity systems of 0.5 to 6 MW, with COP values of 5-7 when used with heat pumps, and 20-40 without heat pumps.

The market for thermally driven heat pumps that use solar energy and industrial waste heat is now growing significantly. By providing a constant temperature heat source and a continuous supply of heat to a thermally driven heat pump, thermal energy storage systems play an important part in such applications.

In climates where a high cooling demand exists, a different thermal energy storage / heat pump concept is used. Ice produced by chillers consuming low-cost night-time electricity is used for peak shaving of energy demand curves.

Energy systems will need to become more decentralised in the near future. Hybrid systems that can combine electrical and thermal requirements with an overall system approach will gain importance. Solar-assisted heating and cooling systems, heat pump or micro combined heat and power production in combination with thermal energy storage will be very attractive solutions.

IEA ECES is starting a new Annex, "Integration of Renewables by Distributed Energy Storage Systems (DES)", that will study such future decentralised energy systems. Heat pumps are one such technology that will be investigated in this annex.

Heat pumps and thermal energy storage are key technologies for our future. Using heat pumps with thermal energy storage increases the systems' flexibility and provides a variety of sustainable solutions for heating and cooling demands.

Recent climate disasters show again and again that we are not yet ready for the catastrophic effects of climate change. By tapping into nature's bountiful thermal energy with storage and heat pump applications, the disastrous effects can be reduced.

We must make sacrifices in order to achieve long-term benefits that may become effective only in decades. No simple answers exist. One simple question every human being should now ask is: Can we afford not to use better heat pump and thermal energy storage systems?

Column

# A Smart Grid test-bed in Korea

*Dr Seong-Ryong Park*
*Korea Institute of Energy Research*
*South Korea*

Energy is vital to the very existence of mankind. However, increasing dependency on limited energy resources, and rapidly rising energy consumption, is causing extremely serious environmental problems, such as global warming. Such destruction of the Earth's environment threatens the survival of mankind by its effects on the social economy and on the ecosystem. Our future can be bright only when all of us recognize the importance of energy.

Next-generation energy efficiency optimisation is essential, by incorporating smart grid technology into current electric grid systems and exchanging real-time power information between suppliers and consumers. The seven key features of such a grid are:

1. consumer participation
2. expansion of distributed power supply (renewable energy), and advancement of storage technology
3. creation of new power markets
4. delivery of reliable, high-quality power services
5. asset optimisation
6. operational efficiency maximisation
7. establishment of an electric vehicle infrastructure.

Smart grids represent an energy revolution for countries, businesses and individuals, and is the best solution for overcoming future energy crises.

For this reason, the world's largest, cutting-edge smart grid test-bed was established on Jeju island, South Korea, in 2009. It is intended to lay the foundations for the early commercialisation and creation of globally competitive export opportunities for smart grid technologies through demonstrations of smart grid technology as the key infrastructure element of green growth. The test bed includes about 6000 homes on the north-eastern part of the island. A total of $230 million will be invested in the first step (Dec. 2009 ~ May 2013), i.e., $70 million from the government and $160 million from the private sector, in five areas: smart consumers, smart transportation, smart renewables, smart power grid, and smart electricity services. These areas are running separately during the first stage, and will be combined in May 2013.

The first five-year master plan came into force in 2011, in the form of the 'Special Act on Smart Grids'. The plan sets strategic goals to develop smart grid base cities for each of the country's seven metropolitan regions. By 2016, $3.3 billion will be invested in policy improvement, market creation, technology development and infrastructure development. The economic impact of smart power metering, electric vehicle charging infrastructure, energy storage systems, and demand-responsive systems, is expected to amount to $9 billion.

According to the plans, a consumer-centered 'metropolitan area smart grid' will be established during the second step (2013~2020), and the world's first-ever smart grid at national level will be constructed by 2030. It is estimated that a total investment of $25 billion will be required to establish the smart grid successfully by 2030.

This project is being carried out by the Korean government, the Korea Smart Grid Institute (KSGI), Korea Electric Power Corporation (KEPCO), the Jeju Special Autonomous Province, companies joining the complex, the Korea Smart Grid Association, research institutes, and academia.

*Source: http://www.smartgrid.or.kr*

# IEA Heat Pump Programme News

## Interview with Svend Pedersen, representing Denmark in the IEA HPP

Dear Mr. Pedersen, welcome to the IEA Heat Pump Program (HPP).
Our readers are interested in knowing more about Denmark, and are also interested in knowing more about your expectations for HPP.

### The heat pump market in Denmark

**1. Could you briefly describe Denmark's heat pump scene today? Which industries are sited in Denmark, and what products are manufactured?**

The number of heat pumps on the Danish market has increased over the past four years, and the list of heat pump models approved by the Danish Energy Agency now includes 553 heat pumps from 33 manufacturers. In comparison, only 107 heat pumps from 18 manufacturers were on this list in 2008. Denmark has a long tradition of manufacturing heat pumps, with the main manufacturers with production facilities in Denmark being Nilan, DVI and Dantherm. Nilan and Dantherm are the two largest companies, with their main products being heat pumps in ventilation units and exhaust air heat pumps. DVI's production is aimed at the residential market, and their main products are ground-source and air-to-water heat pumps. The main manufacturers of industrial heat pumps are Johnson Controls and Advansor.
Heat pump sales numbers are increasing, and will continue to increase in the future as one of the country's political aims is to phase out oil-fired boilers before 2030. Until now, there has not been official collection of sales statistics for the different heat pump types.

**2. Are there any subsidy schemes, soft loans or other measures in Denmark to stimulate market growth?**

Currently, there are no special subsidy schemes for heat pumps in Denmark. However, if you change to a more energy-efficient heating solution, it is possible to sell your energy savings to an energy company. In addition, house-owners who use electricity power as their primary energy source are eligible for a tax reduction on the energy price, which reduces the running costs of heat pumps.

### Acceptance of heat pumps in Denmark

**3. What is the general opinion about heat pumps? Are they well-known to the public?**

The public, and especially house owners and holiday home owners, is very aware of heat pumps. One reason for this is that the fossil fuel phase-out has been at the centre of political debate this past year, with the debate concerning the phase-out of oil-fired boilers being followed with interest by house owners. It is expected that 80 000 households will change their heat source from oil-fired boilers to district heating or gas boilers. In addition, it is expected that 180 000 households will change their heat source to either heat pumps or boilers burning biofuels such as wood pellets, straw or wood.

**4. Are heat pumps considered as renewable energy in Denmark?**

Yes they are, if the annual efficiency is higher than 2.5. When a new heating supply is to be chosen for a new or an existing building, the reduction in the use of primary energy is a driving force behind the choice of heat pumps as energy source. The energy labelling of a building and the running costs for heating influence the sales price of a building when being sold, and that is a fact of which house owners are aware.

### Research in Denmark

**5. What research is being carried out in Denmark related to heat pumps? Any specific area of research that is "hot" at the moment?**

For many years, Denmark has aimed at reducing the use of ozone-depleting and greenhouse-warming refrigerants, which has resulted in many research and development projects on natural refrigerants. This means that today we have heat pumps using hydrocarbons, $CO_2$, ammonia and water as refrigerants.

At the moment there are many research projects on the implementation of heat pumps in a smart grid, in addition to projects on how to make best use of heat pumps in conjunction with the electricity grid. As far as large-scale heat pumps are concerned, the focus is mainly on their implementation in district heating systems. It is particularly valuable for the Danish heat pump industry to participate in the international projects of the IEA Heat Pump Program.

Mr. Pedersen, thank you for taking your time to answer these questions, and once again, welcome to the IEA HPP.

Fact sheet: Svend Pedersen
Name: Svend Pedersen
Affiliation: Senior Consultant at Danish Technological Institute.
Lives in (city): Aarhus
Interests (apart from heat pumps): Running and tour kayaking.

## Call for papers to 11th IEA HP Conference - Extended Deadline to June 30, 2013

Due to requests from authors wishing to amend their abstracts and many who missed the initial abstract deadline, we are pleased to announce that the International Organizing Committee has agreed to **extend the deadline for abstracts to June 30, 2013**. Please visit the conference website at http://www.iea-hpc2014.org/ to submit an abstract.

This will be the final call.

11TH IEA
HEAT PUMP
CONFERENCE
2014
MONTRÉAL

The Conference will be an excellent opportunity for heat pump stakeholders from all over the world to meet and discuss the current state of the heat pump industry. Research and development activities, policies, environmental issues are commons themes which will also lead to many discussions about the industry's future. More than 200 addresses, keynote presentations and papers are usually presented during the IEA Heat Pump Conferences, with participants from over 25 countries.

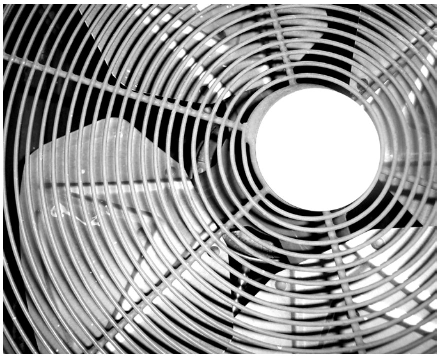
The CGC, Canadian GeoExchange Coalition, is the host organization for the International Energy Agency Heat Pump Conference 2014 which will be held downtown Montréal (Québec, Canada) on May 13-15, 2014 at the Fairmont Hotel - The Queen Elizabeth.

# General

## AC decreases heat-related deaths

Air conditioning has been responsible for a dramatic decline in heat-related deaths in the USA over the last 50 years, according to a new report from the Massachusetts Institute of Technology (MIT). Based on a comprehensive set of data files on mortality and its determinants over the course of the 20th century, the report reveals that on days with a mean temperature exceeding 32 °C, mortality rates have declined by about 80 % over the course of the 20th century in the USA, with almost the entire decline occurring after 1960. The report points to the installation of air conditioning in domestic properties as the main cause of this dramatic reduction.

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



## Data centres are likely overcooled

The UK is currently overcooling its data centres, according to a leading industry expert. Speaking at a seminar focused on energy use in data centres, Dr. Ian Bitterlin of Ark Continuity explained that many of the current guidelines on temperature and humidity are outdated, as they reflect the past use of punch cards and other early computer technology, and it is now possible to raise the acceptable limits.

*Source: JARN, March 25, 2013*

## Efficiency drives home heating and cooling use down

Residents across the USA are using less of their electricity budget on heating and cooling, a new residential use survey found. According to the Energy Information Administration (EIA), the percentage of Americans' energy budget spent on heating and cooling in 2009 dropped below half for the first time in decades. Heating accounted for just 42 % of household energy use in 2009, down from 53 % in 1993.

"The lower energy consumption is attributable in part to more efficient heating and cooling equipment, building practices that resulted in better insulation and more efficient windows, and population shifts to areas with warmer climates," the EIA consumption advisory stated.

*Source: http://www.statejournal.com*

# Policy

## Heat pumps benefit from new energy label

The adoption of the energy label for heaters in Europe from 2015 is expected to foster the uptake of renewable heating solutions and, in particular, heat pumps. As of 2015, consumers will be able to choose the most efficient heater, based on a single energy label.

Welcoming the move, a joint statement by the European Heat Pump Association (EHPA) and European Partnership for Energy and the Environment (EPEE) said: "With the adoption of the energy label for heaters, the European Commission is sending a very positive and strong signal to citizens and industry in Europe, setting a major milestone towards the achievement of its EU 2020 targets, in particular improving energy efficiency and the use of renewables."

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

## China soon to announce new inverter AC standard

A Chinese national energy efficiency standard for inverter air conditioners is expected to be announced soon, and enforced in August or September this year. In this new national standard, the efficiency rating, minimum allowable value, and evaluation indicator in the current standard will be revised. This standard is established based on EU standard.

*Source: JARN, April 25, 2013*

## US government withdraws new furnace efficiency standards

The federal US government has agreed to withdraw new rules that would require consumers in 30 northern states to purchase high-efficiency furnaces. The decision is the result of a legal settlement between the Department of Energy and the American Public Gas Association (APGA), which argued the new regulations would prove too costly for certain consumers and ultimately steer some of them to heat their homes with other, less-efficient fuels.

The furnace standards would have required new units installed after May 1 to have efficiency ratings of at least 90 %. Current standards require at least 80 % efficiency.

The APGA and utilities applauded the decision, which they said could have been burdensome for some consumers. Energy efficiency advocates said the government's retreat is a huge setback for efforts to pare energy use and reduce greenhouse gas emissions.

*Source: http://www.stltoday.com*

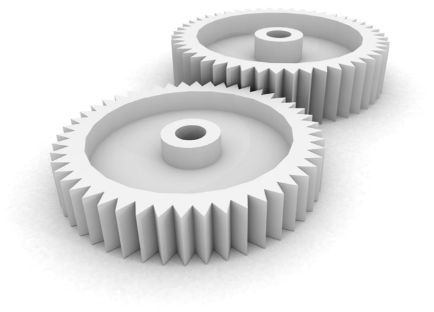
## ASHRAE and UNEP Strengthen Global Cooperation

ASHRAE and the United Nations Environment Programme (UNEP) have launched their third biennial Work Plan for 2013-2014, based on a global cooperation agreement signed in 2007, at ASHRAE's 2013 Winter Conference.

The ASHRAE-UNEP cooperation agreement was developed to achieve several international goals, including the sustainable phase-out of Ozone Depleting Substances (ODS) in refrigeration and air-conditioning applications, maximizing the climate benefits of using zero ODS alternatives including aspects of energy saving in buildings, as well as facilitating the transfer and adoption of suitable technologies in developing countries.

The new work plan covers the

2013-2014 timeframe with an objective of increasing cooperation between ASHRAE and UNEP by transferring relevant technologies amongst different regions and continents. The plan is prepared based on success achieved and lessons learned from the implementation of two previous work plans.
*Source: https://www.ashrae.org*



# Working fluids

## SAE states R1234yf is "safe and effective"

The team formed by SAE International to perform an updated engineering safety analysis of R1234yf in car air conditioning systems has found the refrigerant is "safe and effective" for use.
The SAE Cooperative Research Project (CRP) team included car manufacturers Chrysler/Fiat, Ford, General Motors, Honda, Hyundai, Jaguar Land Rover, Mazda, PSA, Renault and Toyota. The team has said it believes that R1234yf refrigerant is safe and effective to use in automotive applications.
The latest research was prompted by Daimler's announcement that it had developed a new test method that demonstrated an additional risk of post-collision fires in vehicles using R1234yf.
"The Daimler testing did not include any actual vehicle collisions or the mitigating factors that occur in an actual collision," says the CRP team.
*Source: http://www.acr-news.com*

## Australian Institute issues draft code for handling flammables

Faced with the rising popularity of flammable refrigerants, the Australian Institute of Refrigeration Air-conditioning and Heating (AIRAH) has issued a draft code of practice for handling these gases.
The Code specifically applies to all stationary refrigerating systems of all sizes - including air conditioners and heat pumps - which are to be charged with flammable refrigerants that have a refrigerant classification of A2, A2L or A3, or any other refrigerant that meets the criteria to be classified as A2, A2L or A3 refrigerant.
*Source: http://www.acr-news.com*

## Midea receives European certification for R32 and R290 products

With increasing interest amongst air conditioning manufacturers in the "mildly flammable" refrigerant R32, Chinese manufacturer Midea has received TUV approval for both R32 and R290 (propane) products. The approval from the German certification body covers the EC Low Voltage Directive (LVD) and Electromagnetic Compatibility (EMC) Directive.
As Europe awaits revisions to safety standards that will ease the application of flammable refrigerants to air conditioning systems, Far Eastern manufacturers continue to line-up products to run on the hydrocarbon R290 and the HFC R32.
*Source: http://www.acr-news.com*

## Honeywell releases new HFO blend replacement for 410A

Honeywell has announced the availability of its new Solstice L-41 low GWP refrigerant alternative to R410A in residential and light commercial air conditioning and heat pump applications.
The new blend is said to offer a 75 % reduction in GWP compared to R410A's GWP of 2088. In addition, it is claimed to offer excellent energy efficiency, to be cost effective and possible to use in existing equipment designs with minimal changes.
While the exact GWP has not been released, early development work claims a GWP of less than 500 and a classification of A2L (mildly flammable).
*Source: http://www.acr-news.com*

## Chemical companies consider HFO/$CO_2$ blends

The search for low GWP refrigerants has revealed the intriguing possibility of the development of blends containing both "natural" and man-made components. However implausible this combination might seem, Honeywell has patents for refrigerants containing these components as has fellow refrigerant manufacturer Mexichem.

However, blend developments are still only at the research stage so imminent introductions to the market are not likely.

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

## China agrees to phase out HCFCs

China has agreed to accept $385 million from the Multilateral Fund for the Implementation of the Montreal Protocol (MLF) to eliminate industrial production of HCFCs by 2030. China is the world's largest producer of HCFCs, accounting for 92 % of the total HCFC production of developing countries. Developed nations contribute to the MLF to pay "incremental costs" for developing countries to transition from HCFCs to environment-friendly substitutes. According to a statement by the government of China, the phase-out will prevent the emission of more than 4.3 million metric tonnes of HCFCs.

*Source: The HVAC&R Industry for May 9, 2013*

*Further link: http://www.multilateral-fund.org*

*22 April 2013*

## DuPont and EOS partner on CFC buy-back program

DuPont Refrigerants and EOS Climate have developed a program to reduce impact to the environment by stimulating the return of recovered chlorofluorocarbon (CFC) refrigerants. The CFC BuyBack Program is intended to give contractors and business owners a streamlined process to dispose R-11, R-12, R-113, R-114, R-115 and R-500.

*Source: The HVAC&R Industry for May 9, 2013*

*Further link: http://www2.dupont.com*

## AHRI reports on dangerous refrigerant contamination

Contamination of refrigerants may be far wider reaching than previously reported. A new white paper from the American Air Conditioning, Heating and Refrigeration Institute (AHRI) suggests that the R40 contamination is not restricted to R134a and has also been found in some counterfeit brand products. The AHRI, which represents 300 US manufacturers including leading refrigerant producers Arkema, DuPont and Honeywell, says it has published the white paper to assist contractors and others in the industry in identifying and avoiding counterfeit refrigerants.

"Members of the chemicals and refrigerant reclaimers and mobile refrigeration product sections of AHRI are taking these claims very seriously," said AHRI president and CEO Stephen Yurek. "Refrigerants contaminated with R40 pose the risk of explosion, so we must make every effort to detect its presence and ensure that its concentration is below the maximum level recommended by AHRI Standard 700."

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

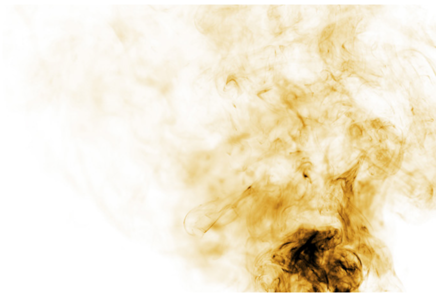
# Technology

## Leak detection gas pinpoints the smallest leaks

UK: Contractor WR Refrigeration is rolling out a refrigerant leak detection system which is said to be able to pinpoint tiny leaks that are almost impossible to detect using traditional methods.

Trace-A-Gas, by refrigerant specialist A-Gas, is oxygen-free nitrogen (OFN) with 5 % hydrogen. Due to its exceptionally small molecular size, hydrogen penetrates the smallest fractures in pipe work, joints and components, making it an excellent leak indicator. Used in conjunction with an electronic detector, it enables engineers to quickly find leaks as low as 5 g a year.

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



## "Wet" server could cut cooling costs

A computer server completely immersed in liquid could drastically cut the energy requirement of internet servers and data centres, according to scientists at the University of Leeds. Its designers calculate that the server cuts energy consumption for cooling by between 80 and 97 %.

The non-flammable coolant, a zero-ODP, GWP of 1 liquid called 3M Novec, can be in direct contact with electronics because it does not conduct electricity. A fluoroketone, the liquid's unusual properties have found ready acceptance in fire suppression systems.

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

## How to treat heat like light

An MIT researcher has developed a technique that provides a new way of manipulating heat, allowing it to be controlled much as light waves can be manipulated by lenses and mirrors. The approach relies on engineered materials consisting of nanostructured semiconductor alloy crystals.

Potential applications include thermal diodes: materials in which heat can pass in one direction, but not in the reverse direction. Such a one-way heat flow could be useful in energy-efficient buildings in hot and cold climates.

*Source: http://www.sciencedaily.com*

# Markets

## Can Eco Cute market switch to recovery mode?

Together with the market for all-electric homes, the market for Eco Cute heat pump water heaters using $CO_2$ refrigerant has been adversely affected by shortages of electricity and growing interest in electricity savings following the Great East Japan Earthquake.

Some, however, predict that the Eco Cute market will switch to a recovery track reflecting the tendency of houses to become more efficient, as exemplified by the spread of smart homes, as well as the expanding trend of low-carbon technologies and lifestyle.

Since the advent of Eco Cute products in 2001 as innovative heat pump technology capable of reducing the energy needed to heat water, the Eco Cute market has continued to expand rapidly. In 2011, the cumulative number of units installed topped 3 million, and the product has steadily increased its penetration in the housing market. To enhance the energy-saving performance, manufacturers are introducing new technologies such as a vacuum heat insulator for the hot water storage tank, development of a high-efficiency compressor, and improvement of water-refrigerant heat exchanger efficiency.

*Source: JARN, April 25, 2013*

## Government incentives to boost heat pump sales

Further growth in the UK domestic heat pump market is expected this year, according to Daikin UK.

Installation figures have increased noticeably since the onset of various Government incentive schemes and are set to rise further in 2013.

"Government schemes, such as the Renewable Heat Premium Payment (RHPP) and Carbon Emissions Reduction Target, have already been very successful in encouraging wider uptake of air-to-water heat pump technology," says the company in a press statement. "They are likely to pave the way for even more widespread heat pump installations, with further incentive schemes such as the domestic Renewable Heat Incentive Scheme, Green Deal and Energy Company Obligation (Affordable Warmth) schemes being introduced in 2013."

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

**Correction**

In the news item "Turnaround of GSHP market in Japan" in the previous issue of the HPC Newsletter, (issue 4/2012, p. 7, directly under the "Markets "heading), it was incorrectly referred to ground-source heat pumps. However, it should have referred to gas-engine driven heat pumps. The editor regrets this mistake. The correct version of this news item is provided below.

## Turnaround of market for gas-engine driven heat pumps in Japan

After having declined steadily between 2006 and 2010, Japan's market for gas-engine driven heat pumps showed 26 % growth in 2011, compared with 2010. Japan has experienced electricity shortages since the earthquake, tsunami and nuclear crisis last year, and this has sparked new interest in gas-fired systems, including air-conditioning systems, which consume less electricity than electrically driven systems.

*Source: JARN, August 25, 2012*

# Heat Pumps in Denmark - an overview

*Svend Vinther Pedersen, Denmark*

*Danish energy policy aims at making the best possible use of energy sources from within its own borders. There is therefore a political focus on reducing the use and production of energy from fossil fuels in the form of North Sea gas and oil to renewable energy sources such as wind, solar energy and biofuels. The political incentives and rising energy prices have resulted in rapid growth in the heat pump market. Industry is increasingly concentrating on efficient energy use, and the incentives from the energy utility companies help as drivers for the industrial heat pump market.*

## Introduction

Denmark's energy policy of basing the country's power and heating energy supply on 100 % renewable energy production by 2035 has attracted much interest in heat pumps as a heating solution for the future. A ban on the installation of oil-fired boilers in many households means that heat pumps have become an alternative heating solution to be considered by domestic property-owners.

## A growing market

The last few years have seen a public debate on how to meet the aim of providing a large part of the country's energy demand from renewable energy. The Danish government has set a target of supplying 50 % of the country's electricity from wind turbines in 2020, with coal and oil being phased out by 2030. By 2035, 100 % of electricity and heat production must be met by renewable energy. To achieve these targets, installation of oil-fired boilers and gas boilers in new buildings has been banned from 2013, extending to a ban on the installation of oil-fired boilers in any buildings in areas where gas or district heating are available from 2016. The target is that buildings must be supplied with energy from either electricity, gas or district heating. The introduction of smart electrical grids, coupled with the use of more electricity and biomass in the transport sector, are of vital importance if the targets are to be achieved.

Today, there are 260 000 buildings with oil-fired boilers, and it is expected that 80 000 of them will be connected to a gas grid or to district heating. The owners of the remaining 180 000 buildings will have a choice of keeping their oil-fired boilers or changing to renewable energy sources such as heat pumps and biomass-fired boilers.

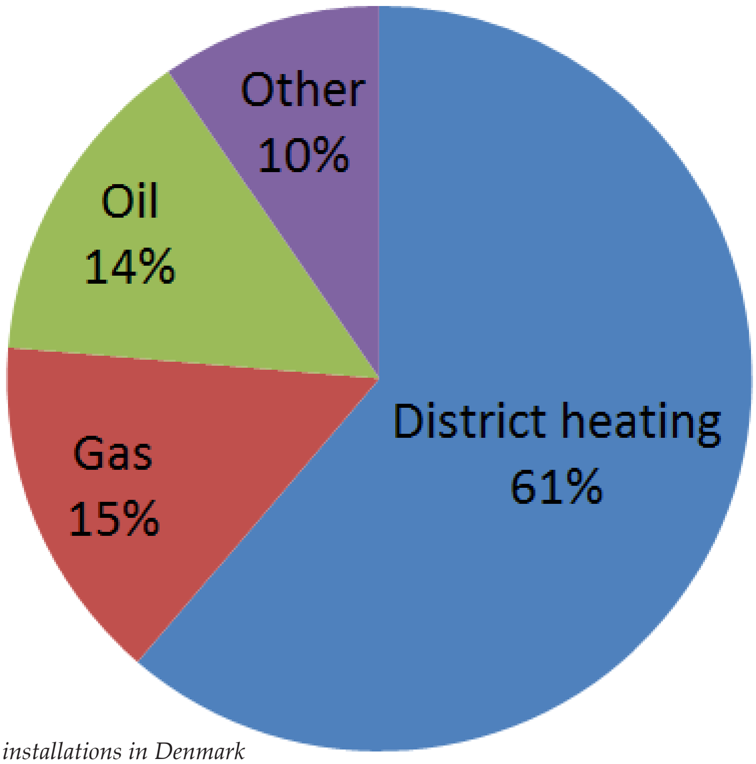
The intense debate in the mass media, property-owners' increased interest in heating costs, and the requirement for energy labelling of buildings when being sold, have resulted in heat pumps becoming a potential heating solution to be considered by house owners.

To support electricity as a primary heating source in buildings, the Danish government has reduced the tax on electricity for buildings which use electricity as their primary energy source. This reduces the cost of electricity from about 0.35 USD/kWh to about 0.25 USD/kWh for energy consumption above 4000 kWh/year.

## Installation and market data

There are 2.6 million households in Denmark, of which 1.5 million are in the form of single-family houses, two-family houses, or farmhouses. Additionally, there are 200 000 holiday homes. In the country as a whole, 2.75 million heating installations are registered. Their heating supply is shown in the figure.

There are no official sales statistics on the number of heat pumps in use in Denmark, or the number sold. In the register of the 205 000 energy-labelled buildings, 27 000 buildings are shown as heated by heat pumps, of which 18 000 are ground-source heat pumps and 9000 are air-to-water heat pumps. The Danish Energy Agency estimates that approximately 100 000 heat pumps are in use in




*Heating installations in Denmark*

Denmark, with about 5000 being sold each year. The majority of heat pumps sold are ground-source heat pumps with vertical ground source heat exchangers. However, in cases where boilers must be replaced, the sale of air-to-water heat pumps is increasing due to low installation costs.

The number of air-to-air heat pumps sold is unknown, but this type of heat pump is usually sold for use in holiday homes, houses with electrical heating, and houses without a hydronic heating system.

Exhaust air heat pumps are usually sold for use in low-energy buildings, as these buildings have a need for ventilation. The sale of heat pumps for ventilation and heat recovery is increasing, as the requirements for ventilation increase due to the increased demands for airtight buildings.

At the moment, the Danish Heat Pump Manufacturers' Association and the Danish Energy Agency are working on improved registration of heat pump sales in the future.

## Market trends

In the market for heating systems in residential buildings with a high heating demand, ground-source heat pumps will often be the right solution, while heat pump systems with lower installation costs are likely to be chosen for buildings with a low heating demand. This means that air-to-water heat pumps will be an attractive solution in areas with single- family houses and also in areas with a gas grid.

As the energy utilities are obliged by the government to deliver a certain amount of energy reductions every year, it is possible for house owners to sell their first-year energy reduction to the energy utilities. The energy savings follows a plan, which lists the different energy improvements for the house. This means that house owners are motivated to improve the energy efficiency of their houses and to change to a more efficient heating supply. Many specialists have been taking courses in energy efficiency improvement and on how to advise house owners about the possibilities. This will lead to an increased sale of heat pumps.

District heating is installed in 61 % of the country's buildings, with district heating systems in all larger cities. As the European Energy Efficiency Directive requires that the energy utilities improve the energy efficiency in their systems, large-scale heat pumps are a technology which is of interest to the district heating utilities to improve the system efficiency. More projects on the implementation of heat pumps in district heating are currently being carried out.

## Conclusion

The political aims and directions for energy use and production in Denmark are clearly set out by the government. Political targets for changing from oil as a heating source, to electric heating or district heating, are assisted by economic incentives to the house-owners. This means that heat pump as a heat source are of considerable interest at the moment, particularly for house-owners having oil boilers. The focus on energy efficiency in industry means that the market and interest for industrial heat pumps is growing. District heating utilities, too, are running various projects with heat pumps. All this means that the future for heat pumps in Denmark is bright. However, one of the challenges for the future is to combine different energy sources such as wind turbines, solar cells and other renewable energy sources in a smart way with the help of the different energy grids such as the gas, electricity and district-heating-grids.

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***Author contact information***
*Svend Vinther Pedersen, Senior Consultant, Danish Technological Institute, Denmark*
svp@teknologisk.dk

# Strategic outlook for heat pumps in Finland

*Jussi Hirvonen, Finland*

*This article presents the strategic outlook for heat pumps in Finland. The Finnish heat pump market has developed very strongly over the last ten years, and the reasons for this are described in this article. Special features of the Finnish energy market, as well as the role of heat pumps in helping Finland to achieve its EU renewable energy sources (RES) targets for 2020, are also presented.*

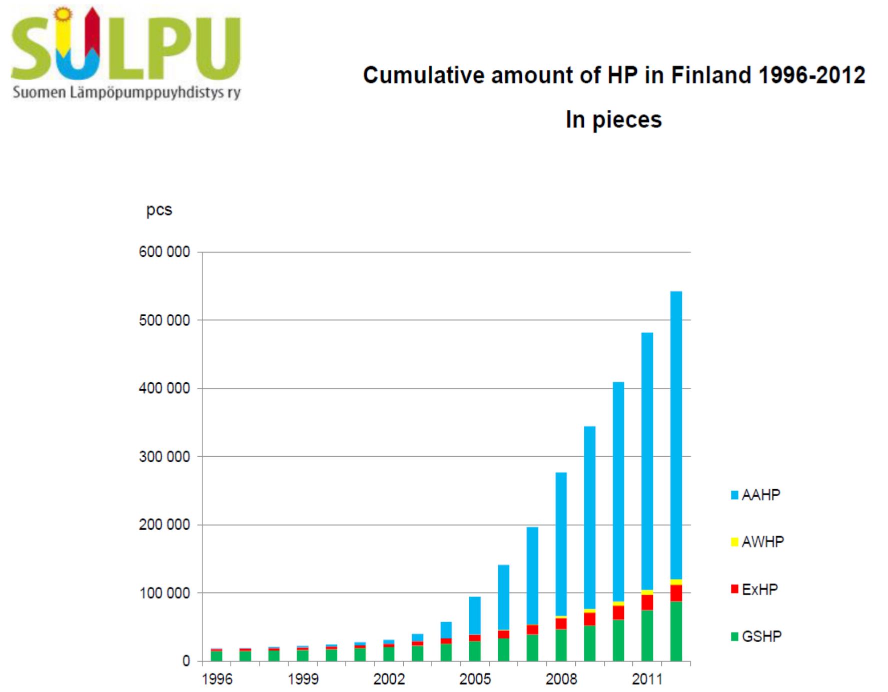



*Figure 1. The number of heat pumps in Finland reached half a million in 2012, supplying 4 TWh per year of local renewable energy from the ground, rock or outdoor air.*

## Introduction

One of the key issues in energy discussions in Finland is the share of final consumption met from renewable energy sources (RES). Finland's binding target from the EU is to increase this share by about 10 percentage points (from 28.5 % to 38 %), which represents an increase in the amount of energy supplied from renewable energy sources of approximately 38 TWh per year. Today, with over 500 000 heat pumps in use (Figure 1), a total of 4 TWh per year of renewable energy is produced for heating buildings.

Taking into account the rapid growth of the Finnish heat pump market, good climate conditions, advanced house technology and expected environment policy trends, the one million heat pumps that are forecast for 2020 will provide 15–20 % of the increase of the renewable energy target for Finland.

It is clear that Finland has a strong heat pump market, with considerable potential. Different types of heat pumps suit different market segments. Passive and low-energy buildings present their own challenges for heat pump solutions in Finnish cold-climate conditions. One million existing houses have electricity or oil heating, presenting a replacement market with a major potential for ground-coupled, air-to-water, exhaust air and air-to-air heat pumps.

Finland's subsidy policy and punishing tax policy applicable to $CO_2$-releasing fuels will also play a part and help heat pumps to meet the challenging 2020 target for RES in Finland.

## The canvas for the rapid development of the heat pump branch in Finland

The Finnish heat pump market has developed very strongly over the last ten years, for a wide range of reasons. Sales figures have grown by 20-30 % per year over the last twenty years, so that in 60 000 heat pumps were sold in 2012. The total number of heat pumps in use has reached half a million (Figure 1), so it is realistic to predict that the millionth heat pump will be installed before 2020. Lobbying, incentive schemes, system quality, product and installer certification, training as well as national IEA HPP annex forums from universities, institutes of technology, research institutes and financiers for creating national projects have played and will play important parts in the success story of heat pumps in Finland.

## Lobbying

Too often, the importance of lobbying is forgotten as an essential part of creating favourable conditions for the introduction of a new branch. The heat pump sector is a challenger, a change-maker, an alternative to traditional and conventional heating systems. In the early stages, it is seen as a threat and a surprising competitor. SULPU, the Finnish Heat Pump Association and its active participation in the European Heat Pump Association, EHPA, has helped to establish heat pumps on the heating market. Lobbying decision-makers and opinion leaders, information dissemination, participation in preparing rules and regulations, incentive schemes, directives and education campaigns have been at the forefront of the Associations' strategy.

## Subsidies and incentive schemes

Subsidy policies play a part in the establishment of heat pumps. Although some subsidy programmes have given good results, such schemes have also caused considerable fluctuation and uncertainty in the market, to the extent that their influence in the long term can even be seen as questionable. The best results have been from the tax reduction scheme that applies to renovation and extension works in private households. Under the scheme, up to 45-60 % of the labour costs for renovation and extension may be set against tax for the owner of a private property, with a maximum permitted deduction of EUR 2 000 - 3 000. Another incentive programme has provided a grant of up to a maximum of 20 % for replacing oil or electric heating systems by a heat pump, biomass firing or connection to a district heating system. This programme was concluded in 2012.

## EUCERT certified heat pump installers, EHPA Quality Labelling scheme, education schemes

Finland joined the EUCERT certified heat pump installer scheme and the EHPA Quality Labelling scheme in 2009. The system quality of heat pumps and their installations are a key element when considering the success factors of a new market entrant. Training under the European Certified Heat Pump Installer scheme has been offered by three training institutes to over 300 heat pump installers since 2009. The introduction of EUCERT training has also started other heat pump training schemes in further education and similar institutes. Until now, the main importance of the EHPA Quality Label has been in the export activities of Finnish manufacturers, but in future the label will be essential part of product quality indication and a requirement of (for example) incentive and grant schemes.

| Renewable | More RES 2020 | In practice |
|---|---|---|
| Bio | 18 TWh/a | A lot of heat and power plants from fossile fuels to wood chips and pellets |
| Wind | 6 TWh/a | 1000 windmills 3 MW each |
| Heat Pumps | 6 TWh/a | Heat pumps 300.000 ->1.000.000 pcs (2 TWh/a => 8 TWh/a) |
| Others | 2 TWh/a | Additional hydropower, usage of wood chips and pellets in small houses, solar, bio gas |
| Traffic | 6 TWh/a | Adding ethanol and biodiesel in traffic fuels upto 20% |
| **Total** | **38 TWh/a** | RES from 28,5% to 38 %. Corresponds annual energy production of 10 Loviisa nuclear power plant units (470 MW) |

*Table 1. Renewable Energy Source (RES) targets in 2020 (Ministry of Employment and the Economy)*

## IEA HPP and its annex work

Finland joined the IEA HP Program in 2009, opening the way to international forums, information and (especially) to annexes and the national work associated with them. Since joining the Program, we have witnessed unparalleled forums from universities, institutes of technology, research institutes and financiers for creating national projects for participation in IEA HPP. Finland participates already in Annex 38 "Systems Using Solar Thermal Energy in Combination with Heat Pumps" and in Annex 39 "A Common Method for Testing and Rating of Residential HP and AC Annual/Seasonal Performance". Initial work for participation in national projects for Annex 40 "Heat Pump Concepts for Near Zero-Energy Buildings" and Annex 42 "Heat Pumps in Smart Grids" is in progress.

## Finnish target for renewable energy in 2020 in EU RES Directive

The RES Directive sets out country-specific goals for renewable energy use by 2020. For Finland, the Directive stipulates an increase in energy use from renewable sources of 28.5 % to 38 %, i.e. 38 TWh. This means that, in 2020, there will have to be an increase of 38 TWh per year in the energy generated from renewable energy sources. In other words, eight years from now, an amount of energy equivalent to the present output of ten Loviisa nuclear power plants must be provided from renewable sources. Table 1 shows the 2010 plan of the Ministry of Employment and the Economy for achieving this challenging target.

The major part of RES, 18 TWh/year, is planned to be supplied by increasing the use of wood chips as a fuel for electricity and heat production in power plants. 6 TWh/year will be delivered by adding biodiesel and ethanol to motor fuels. Wind power is making an increasing contribution, with 150 wind turbines in operation today, delivering 250 MW. A further 800 new wind turbines are planned, with a total output of 3000 MW, producing approximately 6 TWh/year of renewable energy by 2020. Heat pumps have the same target. The remaining 2 TWh/year RES contribution would be provided by other means, such as the use of biogas, pellets and solar energy.

## The role of heat pumps in Finland

Over 500 000 heat pumps have been installed in Finland, supplying 4 TWh/year of renewable energy. The market, which is worth EUR 400 million per year, has been achieved without special subsidies or political pressure. Heat pumps are already making an important contribution to space heating, even in a cold coun-

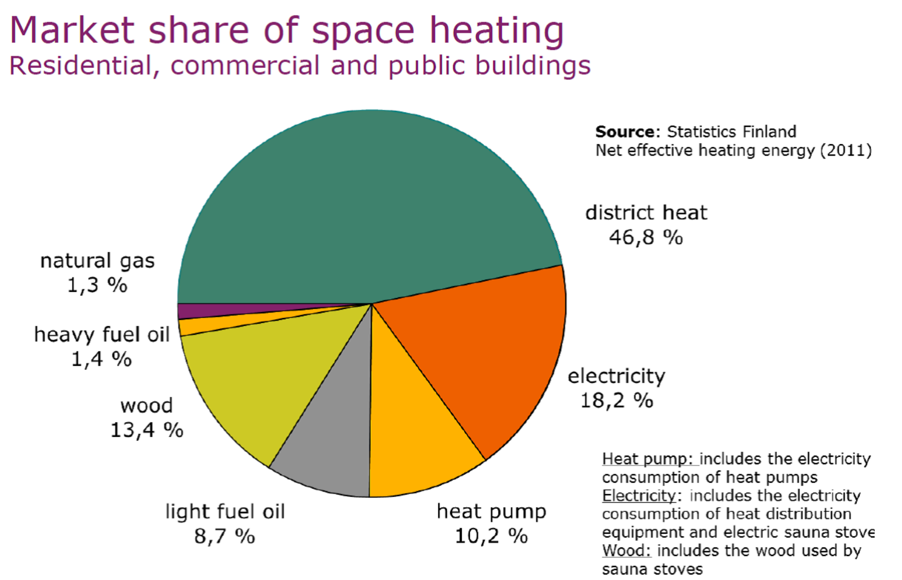



*Figure 2. Over 10 % of space heating in Finnish residential, commercial and public buildings was produced by heat pumps in 2011.*

try like Finland. Over 10 % of space heating was supplied by heat pumps in 2011 (Figure 2).

## Conclusion

The heat pump sector has expanded substantially in Finland: conditions for them in Finland are excellent. The country's cold climate requires a lot of energy for heating. But, as a large country with a small population (5 million inhabitants), a country-wide gas distribution network would not be profitable. Factors favouring heat pumps include the absence of gas as a potential competitor, relatively cheap electricity and good drilling conditions. However, the part played by active lobbying, incentive schemes, system quality, product and installer certification, training, and the contribution from IEA HPP annex forums from universities, institutes of technology, research institutes and financiers for creating national projects must not be forgotten in the success story of the heat pumps in Finland.

The Finnish heat pump market is already worth EUR 400 million per year (Figure 3). An important reason for this is that the return on investment usually exceeds 10 % per year. The effect of the associated fuel savings on the Finnish trade balance is already in the region of EUR 100 million. In addition, the reduction in $CO_2$ emissions is in the region of 1 megaton, since as many as half a million heat pumps are extracting local energy from the ground, rock or outside air.

The outlook for the heat-pump industry is promising. This decade will be the decade of renewable energy and energy saving. More than half of all new single-family house builders end up choosing a heat pump in one form or another. Nevertheless, there still remain 220 000 oil-fired boilers, half a million directly electrically heated houses, and over 100 000 water-based electric heating systems in Finnish houses and properties, regardless of the high heat-pump sales figures. Replacing these with renewable-energy solutions is crucial for Finland in order to achieve its commitments under the EU Renewable Energy Directive. Heat pumps will play a significant role in this work.

In 2020, we expect to see an installed base of one million heat pumps, producing over 8 TWh/year of renewable energy - the equivalent of 15 % of the EU requirements for renewable energy for Finland. This will further be reflected in the reduction in the amount of electricity used for heating. The use of oil for heating will, by then, already be very uncommon.

***Author contact information***
*Jussi Hirvonen, Executive Director,*
*The Finnish Heat Pump Association*
*SULPU ry, Finland*
*jussi.hirvonen@sulpu.fi*

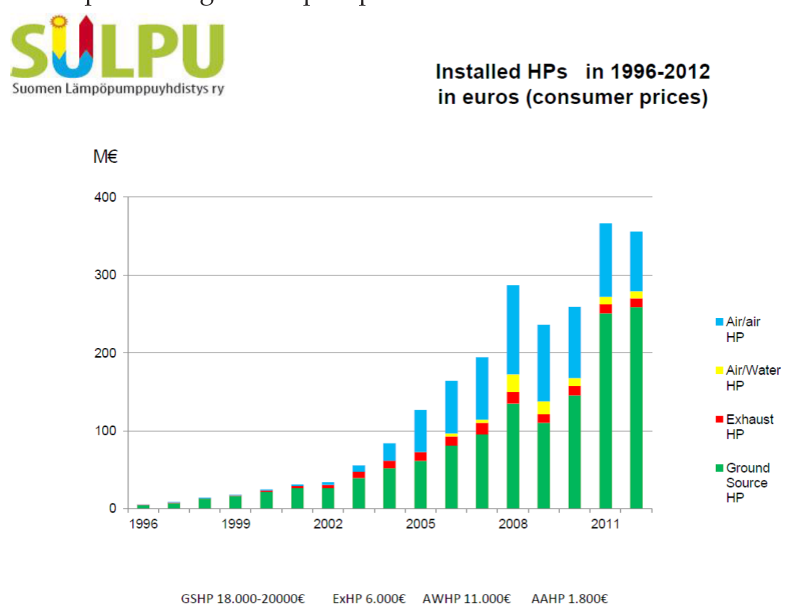



*Figure 3. The Finnish heat pump market is already worth EUR 400 million per year. A particular reason for this is the fact that the return on investment is usually more than 10 % per year.*
*[**Installation cost**: GSHP (Ground Source Heat Pump): 18 000-20 000 €. ExHP (Exhaust Air Heat Pump): 6 000 €. AWHP (Air-Water Heat Pump): 11 000 €. AAHP (Air-Air Heat Pump: 1 800 €]*

# Annexes, ongoing

## IEA HPP Annex 34 Thermally Driven Heat Pumps for Heating and Cooling

Annex 34 has now been completed, and the final report has been submitted to the IEA Executive Committee for approval. The purpose of Annex 34 was to reduce the environmental impact of heating and cooling by the use of thermally driven heat pumps. During its more than four years of operation, partners from 18 institutions and ten countries have contributed the latest developments in this field of technology. Some of the results are:

- Country reports on the framework requirements, opportunities and challenges for the market of thermally driven heat pumps
- A set of universally valid performance figures for heating and cooling, including different boundary conditions and level of detail from apparatus level to system level
- Input to normative bodies for performance evaluation and testing
- Benchmarking and comparison of characterization methods for sorption materials and sorption heat exchangers
- A graphical easy-to-understand method for representation of complex hydraulic systems (generic systems)

### Introduction

Thermally driven heat pumps (TDHPs) are heat pumps driven by waste heat, solar heat, district heating or similar. The temperature level of the driving heat should at least be about 70 °C and above. TDHP can be used for heating, cooling and simultaneous heating and cooling applications. The best known technologies for this application are absorption and adsorption heat pumps.

### Task A

Thermally driven heat pumps may be economically viable when the installation investment cost and the costs for the driving heat are lower than the equivalent costs for electric heat pumps. However, the total costs depend on many parameters and boundary conditions. Task A of Annex 34 involved a market overview for thermally driven heat pumps. A list of available products and technologies with the current state of the art is given in the final report. Additionally, for the member countries, specific investigations looked at the political and legislative frameworks, as well as the availability of heating and gas distribution systems. The results from these investigations indicated the strengths and weaknesses, opportunities and threads for thermally driven heat pumps in the respective countries. The country reports are available on the internal part of the Annex 34 web page.

### Task B

At the same time, the very flexibility of thermally driven heat pumps is both an advantage and a disadvantage. Although these systems can be adapted to so many existing hydraulic systems, and can score with customer-specific solutions, this flexibility makes standardization difficult. Task B therefore defined a set of performance figures and performance boundaries. The set of performance figures covers different levels of detail. There are performance figures which describe the entire system, whereas other performance figures apply specifically to only one component within the system. The performance figures also stress the importance of power measurements and energy measurement, and the relationship between laboratory measurements and in-situ measurements. The performance figures are given in the final report. The next step will be to develop these performance figures into national and international standards, in order to develop an accepted and valid benchmarking system as orientation for customers.

### Task C

The need for standardization is not only an issue at system level but also at apparatus level. When designing the heat exchangers and the refrigerant for thermally driven heat pumps, the characteristics of the heat exchangers - and in particular those of the adsorption and evaporation heat exchangers - need to be known.
Working on the international level, the measurement procedures used by different research institutes for characterization of heat exchangers and adsorption materials were collected and compared. From this material, a database of adsorption materials (available in the internal section of the Annex 34 web page), and a proposal for measurement standards (available in the final report) were developed.

### Task D

In addition to the definition of performance figures in Task D, methods were developed to represent the variety of system options in a simple way. A generic system was developed which allows representation of the hydraulic architecture. Further representation systems show the energy flow between components. The advantage for planners is the easy access to what may actually be a complex system. The working principles of the generic systems can be looked up in the final report.

### Results

In ten general meetings with an average attendance of 78 % of the member states, and many uncounted individual meetings, it was possible to harmonize the working load of the 18 participating institutions. The outcome will hopefully soon be available for the public, when the final report is approved by the Executive Committee of the IEA.

### Acknowledgement

After co-ordinating Annex 34 for more than four years I would like to thank all partners involved in the work of the Annex. Without the personal dedication and passion from each participant it would not have been possible to achieve these results. My thanks to all participants.

Contact: Peter Schossig, Fraunhofer ISE,
peter.schossig@ise.fraunhofer.de

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

Annex 35 / 13, a joint venture of the IEA "Industrial Energy-related Technologies and Systems" (IETS) and "Heat Pump Programme" (HPP) Implementing Agreements, officially concludes on 30 April 2013.

At the last Annex meeting in October 2012, held in conjunction with Chillventa 2012 in Nuremberg, Germany, it was stated that the status of the Annex at that time (and in particular Task 2-5), had not fulfilled the objectives of the Annex to contribute to a reduction in energy demand and emissions of greenhouse gases through increased use of heat pumps in industry. It was therefore proposed to extend the Annex for at least one year until 30 April 2014. This extension has been approved by all participating organisations, with the following activities/tasks:

**Task 1**
Report finished, although new results may require a definitive update.

**Task 2**
To concentrate all existing resources in Annex 35/13 on updating and modernising a data base of industrial heat pumps. Such a data base is missing in existing software tools, whether based on pinch analysis or on more complex optimisations. However, it is intended that work during the extended Annex 35/13 duration will be limited to development of an online industrial-based heat pump data base of present-day knowledge for users. It is not planned to develop an interface to process integration software tools. Details need to be evaluated

**Task 3** (R&D results) and **Task 4** (Case studies)
Should be completed for the final reports of both tasks.

**Task 5**
The main focus of this task should be on arranging the information on heat pumping technologies for industry for policymakers, industrial planners and designers, stakeholders and heat pump manufacturers in such a way as to lead to a better understanding of the opportunities for, and correct use of, reduction of primary energy consumption, $CO_2$ emissions and energy costs of industrial processes.

The first Annex meeting of 2013 is planned in connection with the International Process Integration Jubilee Conference 2013, March 18-20, 2013 in Gothenburg, Sweden.

Contact: Hans-Jürgen Laue
Information Centre on Heat Pumps and Refrigeration, IZW. e.V
laue.izw@t-online.de

# 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.

Two working meetings have been completed – in Sweden (June 2011) and in the USA (September 2012) – and a final working meeting is planned for the Fall 2013 (France); tel-conferences in the interim.

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

| 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.<br>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.<br>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<br>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.<br>Lab: Cooling and heating tests with imposed faults to correlate performance to the modeling results. |

*Participating countries in Annex 36*

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

The active project partners are Sweden, Switzerland and the United Kingdom. Norway and Austria are participating in the annex as observers.

In the project, a template has been produced of what should be reported for each heat pump. Moreover, the SPF limits 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 being finalized. 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 project will be finished during the spring of 2013.

The number of heat pumps included from each country will be 5 in Switzerland, 3 from Sweden and 4 from the United Kingdom.

Contact: Marcus Olsson,
marcus.olsson@sp.se

# IEA HPP Annex 38 - Solar and heat pump systems

The objective of Annex 38 of the Heat Pump Programme, which is also Task 44 of the Solar Heating and Cooling Programme of the IEA, is the assessment of the performances and the relevance of combined systems using solar thermal and heat pumps.

Participants come from research institutions, engineering firms, and HVAC and solar industry. Participating countries are Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Portugal, Spain, Sweden, Switzerland and USA.

A welcome advancement is combined solar thermal technology and heat pumps to heat houses and produce domestic hot water. And the market for these S+HP systems is booming in countries like Switzerland, Austria and Germany where favourable conditions such as $CO_2$ reduction promotion programs and minimum 30 % renewable obligations for domestic hot water production, high electricity peak cost and incentives exist. However, to ensure this technology's long-term commercial success, standards and norms are required.

During 2012, more than 100 systems in countries participating in the Annex were surveyed and experts classified the systems in four new categories: parallel, serial, regenerative, and complex concept. A special tool called the "square view" was developed to describe the systems in a consistent way.

The survey results showed that 70 % of the systems were parallel systems, 7 % serial system, 21 % complex, and very few were regenerative systems. Air and ground heat sources were comparable in numbers and some systems used only a solar collector as the heat source for the evaporator while many systems used "multi sources". A report presenting the survey results will be available in early 2013.

About 20 different systems monitored in real conditions will be reported on during 2013. The monitoring results from the field tests show varying results, some with very attractive seasonal performance factors and some with disappointing values that can be explained by several factors.

### Performance Indicators Defined

A set of performance indicators were agreed upon, which proved to be more difficult than anticipated. To compare systems, performance indicators include system and component efficiency, primary energy, and $CO_2$ emissions or savings.

One important question when dealing with hybrid systems such as S+HP systems is how to calculate the benefit of the combination "solar and heat pump". Table 1 is what this Annex is working with

Annex meeting is planned to be held in Japan in August 2015 in conjunction with the next IIR International Congress of Refrigeration.

Contact: Jean-Christophe Hadorn,
jchadorn@baseconsultants.com

# IEA HPP Annex 39 - A Common Method for Testing and Rating of Residential HP and AC Annual /Seasonal Performance

The outcome from Annex 39 will be proposals for a common transparent SPF calculation method for domestic heat pumps, including heating, cooling and domestic hot water production, as well as proposals for global harmonization of test points, to minimize testing efforts. The idea is to conduct pre-normative research, which later can be incorporated in standardization (ISO, CEN etc.) in the same way as HPP Annex 28, on the results of which Annex 39 will partly build.

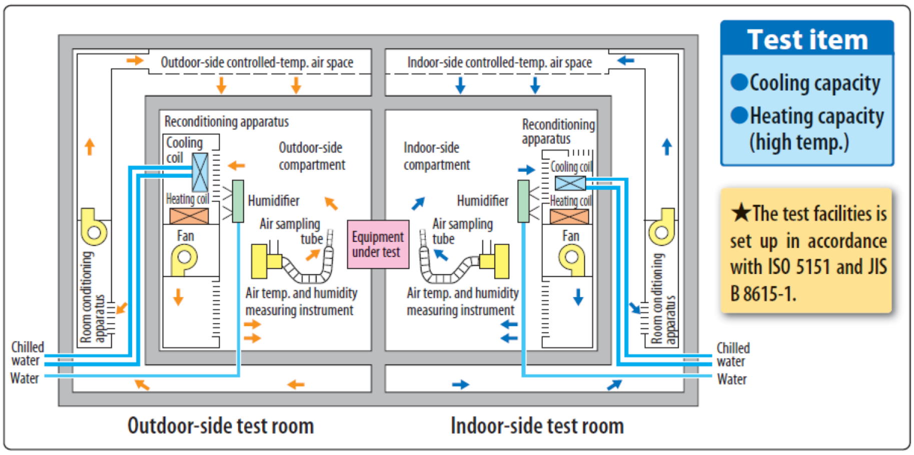
The following task-sharing activities have been planned and initiated:

- **Task 1**: Review and evaluation of existing test and calculation methods for SPF - In task 1, a template for reporting has been developed, and the national methods are currently summarized.
- **Task 2:** Development of a matrix defining needs for testing and calculation methods
- **Task 3:** New calculation methods for SPF/commonly accepted definitions on how SPF is calculated
- **Task 4:** Identification of improvements to existing test procedures
- **Task 5:** Validation of SPF method
- **Task 6:** Development of an alternative method to evaluate heat pump performance
- **Task 7:** Communication to stakeholders.

Two meetings were held in 2012, one in Chicago during the ASHRAE winter meeting, and one in Nurnberg during the Chillventa. Information on national and international standards has been collected, analyzed and a SWOT analysis of current standards has been made. In addition, Japan has compiled information on test laboratory accuracy which can serve as a benchmark for minimum requirements in testing. What is extra interesting is the detailed schematics of the set-up of the test equipment.

The Netherlands and Japan have joined the Annex in 2012. The project website (link to website) has been set up and contains material from the first meetings and the open workshop that was organised in conjunction with the Heat Pump Summit in Nurnberg 2011.

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




*Balanced ambient room-type calorimeter*

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

IEA HPP Annex 40 is to investigate and optimize the integration of heat pumps in HVAC system concepts of Nearly or Net Zero Energy buildings (NZEB). The Annex 40 was started with a Kick-off meeting in Rapperswil, Switzerland, in July 2012. The working time of the Annex 40 is scheduled for three years from 2012 -2015.

The countries CH (Operating Agent), NL, NO, JP, SE and the USA declared their participation in the Annex 40. The countries BE, CA, DE and FI have strong interest to join the Annex 40 soon. The participating countries have started the work on Task 1, which is dedicated to a state-of-the-art survey of the political framework and current definitions of NZEB, realised NZEB and installed building technologies in the different countries and existing field experience of NZEB in operation.

The next IEA HPP Annex 40 meeting is planned for spring 2013, where results of the state-of-the-art analysis will be compiled and discussed. Moreover, the further tasks will be prepared. In Task 2, analysis and optimisation of promising system concepts with heat pump are to be performed by system simulations, regarding both performance and cost. Options are seen in system and building integration as well as in control of systems. In parallel, work on Task 3 shall start, which is dedicated to a further development of HVAC technology with a heat pump as core component and the field monitoring of marketable and prototype NZEB technologies.

Task 4 will conclude the Annex work by evaluating technology requirements for the integration of NZEB into the energy system, which will become important with a broad introduction of NZEB. These technical requirements may refer to local stor-

*IEA HPP Annex 40 Kick-off meeting in July 2012 at HSR Rapperswil, Switzerland*

age options for electricity and heat, load match and interaction with energy grids as well as options for "smart" operation by enhanced IC-Technologies. Notably, control issues are important in this context, as well.

Contact: Carsten Wemhöner,
carsten.wemhoener@hsr.ch

# IEA HPP Annex 41 Cold Climate Heat Pumps

Heat pump technology provides a significant potential for $CO_2$ emissions reduction. Annex 41 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. 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.

Organizing meetings was held on June 23 and October 10, 2012 with representatives from Canada, Japan, and the US attending. 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.

The Annex officially began in July 2012 and is expected to run through September 2015. A 1st working meeting is planned to be held in the US in mid-2013 at Purdue University with a 2nd meeting and open workshop planned for May 2014 at the 11th IEA Heat Pump conference in Montreal. The final Annex meeting is planned to be held in Japan in August 2015 in conjunction with the next IIR International Congress of Refrigeration. Currently Japan and the US (OA) are the only official participants in this Annex, but Austria, Canada, and Italy have all expressed interest in joining. The Annex remains open to new members at least through mid-2013 so other HPP member countries are strongly encouraged to join.

Contact: Van D. Baxter,
baxtervd@ornl.gov

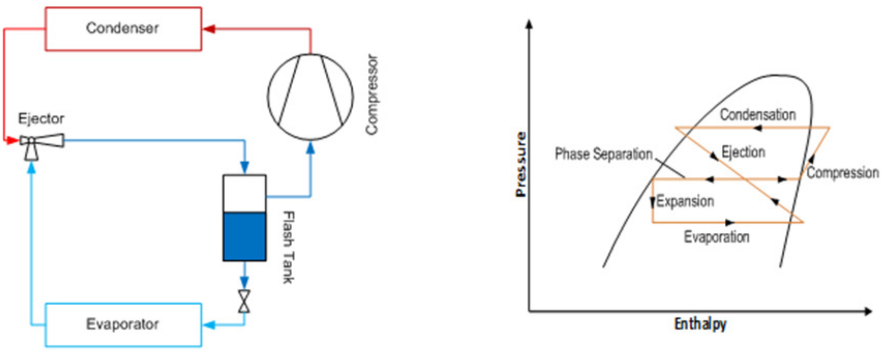



*Diagram of ejector-assisted heat pump cycle – Diagram courtesy of Omar Abdelaziz, ORNL, USA*

# IEA HPP Annex 42 Heat Pumps in Smart Grids

After discussing this item as a potential subject for an Annex in fall 2011, the Legal Text was further developed in close cooperation between the IEA Heat Pump Centre in Sweden and the undersigned during summer 2012. Initial presentations at the HPP Symposium in Nurnberg in October 2012 about, at that time, the 'Proposed Annex' were received very well by delegates of the member states within the HPP.

During the National Teams' meeting, the member states gave their input for further detailing and elaboration of the Legal Text. The conclusion at the end of this meeting was that more or less 'a full house' of member states intended to join and support the Annex. At the ExCo meeting in November in London, a final presentation and brief discussion of the proposed Annex led to a clear positive vote by the ExCo delegates. Commitment to the Annex 42 was expressed by, amongst others, Sweden, USA, Korea, Finland, Germany, The Netherlands, and Austria. Several other member states consider participating in this Annex 42 in due course as well.

Due to the upcoming new year, with the new budgets, this might take somewhat more time.

**Status of activities:**

- Template notification letters have been sent to the member states in which they can officially confirm their participation to the IEA office in Paris, HPP and the Operating Agent.
- The first version of a planning scheme is being drafted.
- An online project management tool in ActiveCollab is equipped to enable all participants from all over the world to cooperate within one single online project management environment.
- The first meeting of the Annex 42 project group is foreseen in May 2013 (Parallel to EHPA General Assembly in Brussels).

Contact:
Peter Wagener, Business Development Holland,
wagener@bdho.nl

# IEA HPP Annex 43 Fuel-driven sorption heat pumps Proposal for a new annex

In parallel with the work on Annex 34, "Thermally Driven Heat Pumps for Heating and Cooling", it became apparent that there was increasing interest in the field of fuel-driven sorption heat pumps, with a growing number of products approaching market release. The work of Annex 34 showed that the fields of solar thermal cooling and fuel-driven heat pumping need to be treated separately for wider market penetration, with the result that a common understanding to continue this work in two different annexes or tasks emerged. The work of Annex 34 concerning solar thermal cooling will therefore be continued as part of the IEA-SHC Task 48 "Quality Assurance and Support Measures for Solar Cooling", while a new annex, "Fuel-driven Sorption Heat Pumps", was proposed to the ExCo in March 2012 for continuation of the work on fuel-driven heat pumps. After an annex definition meeting, a legal text was compiled and accepted by the ExCo in draft form, so a start in May 2013 is planned.

The scope of the work of this Annex will cover the use of fuel-driven sorption heat pumps in domestic and small commercial or industrial buildings applications. If appropriate, the additional possibility of supplying cooling will also be considered.

The planned structure is as follows:

**Task A Generic Systems and System Classification**

- Available sources and heating systems
- Existing market and regulatory boundary conditions
- Control strategies
- Evaluate different fuels (oil, gas, wood -> no hot water)

**Task B Technology Transfer**

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

**Task C Field test and performance evaluation**

- Measurement/monitoring procedures standardisation (e.g. how to cope with different fuel qualities, system boundaries, auxiliary energy etc.)
- Continue work from Annex 34 and Task 44, and extend standards to seasonal performance factors at system level
- Develop quality insurance procedures in cooperation with IEA-SHC Task 48

**Task D Market potential study and technology roadmap**

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

**Task E Policy measures and recommendations, information**

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

So far, several countries have expressed interest in joining, but of course more participants are welcomed.

A kick-off meeting is planned in May 2013, and a duration of four years is expected.

Contact: Peter Schossig, Fraunhofer ISE,
peter.schossig@ise.fraunhofer.de

# 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, **DE**, DK, FR, JP, KR, NL, 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, **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 | **CH**, FR, JP, NL, NO, US |
| **Annex 41** Cold Climate Heat Pumps (Improving Low Ambient Temperature Performance of Air-Source Heat Pumps) | 41 | JP, **US** |
| **Annex 42** Heat Pump in Smart Grids | 42 | DE, FI, KR, **NL**, US |
| **Annex 43** Fuel Driven Sorption Heat Pumps | 43 | **DE**, UK |

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

# Thermal Energy Storage and Heat Pumps: A Hot Combination

*Marc A. Rosen, Canada*

*Thermal energy storage can offset the mismatch between thermal energy demand and supply, as occurs when some intermittent sources of thermal energy such as solar are exploited. The two main types of TES, sensible and latent, can be advantageously used with heat pumps for heating and/or cooling applications, yielding such benefits as enhanced efficiency, technical performance and economics, as well as reduced environmental impact. The design of a TES in conjunction with heat pumps depends on many factors, but can with care often be attractive in many applications.*

## Introduction

The heat pump is a key component of many energy efficiency and conservation approaches. Thermal energy storage (TES) can be used beneficially in conjunction with heat pumps, for heating and/or cooling applications. These benefits can range from efficiency and technical performance through economics and on to environmental factors. This article describes why thermal energy storage and heat pumps can make a hot combination, drawing extensively on prior publications by the author [1,2].

## Thermal Energy Storage

TES is the storage of thermal energy (heat or cold) to offset the mismatch between thermal energy demand and supply.

Examples of TES uses (Figure 1) are the storage of solar energy for overnight heating, of summer heat for winter use, of winter ice for space cooling in summer, and of the heat or cool generated electrically during off peak hours for use during subsequent peak demand hours. District heating and cooling systems often also incorporate TES advantageously. For instance, the Drake Landing Solar Community in Okotoks, Alberta, Canada has successfully integrated TES with solar energy and district heating, allowing almost 90 % of the space heating requirement of a 52-home community to be solar.
TES can allow thermal equipment to operate more effectively, flexibly and economically, increasing TES applications in many locations. Specific benefits of TES include:

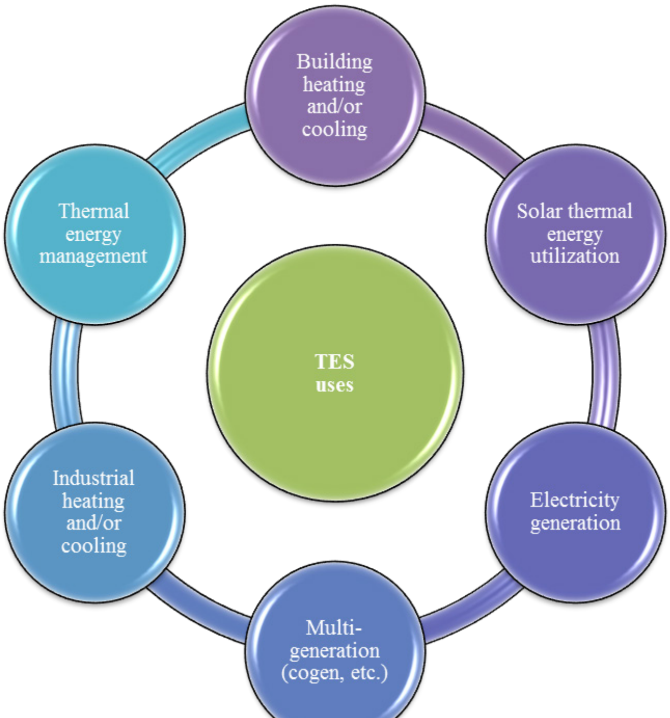



*Figure 1. Uses of TES*

- Facilitation of use of intermittent energy sources, including include renewables like solar thermal energy as well as waste heat, by allowing intermittent energy sources to meet a greater fraction of the loads for which they are used.
- Increased generation capacity: When demands for heating, cooling or electricity vary temporally, the excess generation capacity available during low-demand periods can be used to charge a TES, increasing the effective generation capacity during high-demand periods.
- Increased efficiency and reduced environmental impact: By storing heat or cold, with temperature enhancement where necessary via heat pumps, heating and cooling efficiencies can be increased and environmental impacts reduced.
- Shifting of energy use to low-cost periods: TES allows energy consumers subject to time-of-day pricing to shift energy purchases from high- to low-cost periods, yielding financial benefits.

Thermal energy may be stored mainly by changing a substance's sensible heat (i.e. temperature) and/or latent heat (i.e. phase). Consequently, there exist two primary TES categories:

- Sensible: Common types of sensible TES include: tanks containing a storage medium, earth beds and boreholes that exploit underground soil and rock, aquifers that utilize groundwater reservoirs, rock caverns that can be filled with a storage medium, and salinity gradient solar ponds that provide an integrated collection and storage device of solar energy. Desired characteristics of a sensible TES medium are low cost, high specific heat capacity, long term stability under charging/discharging cycles, and compatibility with containment.
- Latent: Latent storage materials often involve solid-liquid phase changes and are often called phase change materials (PCMs). Latent TES storage media often include water, salt hydrates, inorganic materials, organic materials, large fatty acids, and aromatics. Eutectic salts, salt hydrates and Glauber's salt absorb much thermal energy on melting, while paraffin waxes exhibit high-stability and little degradation over repeated storage cycles. The PCM be contained in a single large vessel or small modules.

Some sensible and latent TESs are compared in Table 1. Latent TES typically has a higher energy storage density than sensible units, allowing for a more compact storage. A third category of TES, thermochemical storage, is also being investigated, especially since it offers the potential for even more compact TES, but such systems are not yet commercially available.

The selection or design of a TES system mainly depends on such factors as the application, required storage period, economics, operating conditions, etc. Various factors affect the performance and economics of TES systems (Figure 2).

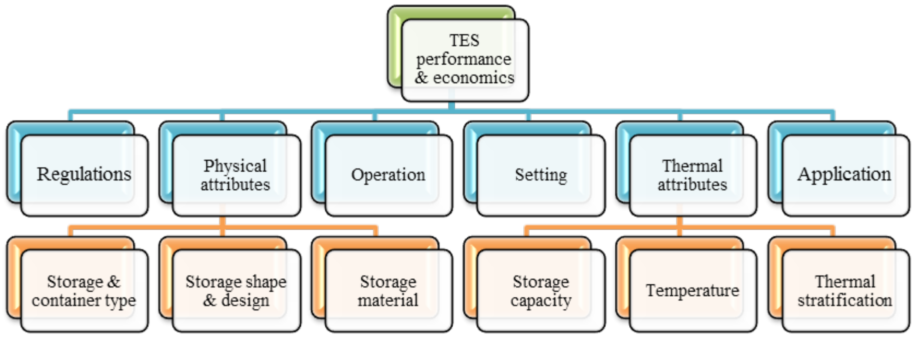



*Figure 2. Factors affecting TES performance and economics.*

## Use of TES with Heat Pumps

A particularly beneficial use of TES is in tandem with heat pumps, especially for heating and/or cooling applications.
In heating applications, integrating TES with heat pumps can provide numerous benefits, ranging from more effective use of renewable thermal resources to more effective HVAC. Two examples follow:

- A heat pump was integrated with latent TES by surrounding a rotary compressor in a building air-conditioner/heat pump with a polyethylene glycol PCM. Compressor heat is transferred to the TES, and recovered for use during start-up (halving the time to reach a 45 °C discharge air temperature and improving heat capacity by about 10 % and coefficient of performance by 5 %).
- Solar thermal energy can be used as a heat source for a heat pump, allowing the solar-collector outlet temperatures to be lower than with direct heating, increasing heat pump coefficient of performance and reducing solar collector cost. Such a solar-augmented heat-pump system requires two TESs: one to store solar energy and one to store the heat-pump output for space heating. The solar collector improves heat-pump efficiency mainly during sunny periods with a small TES and provides a warm storage for heat-pump operation during cloudy periods and nights with a larger TES.

For cooling, heat pumps can be beneficially integrated with sensible or latent TES to improve economics and level electrical loads. For instance, heat pumps for air cooling operate during the day when cooling demands exist, increasing daytime electricity demand. Cooling demand can account for over 30 % of peak electrical demand, and half of the daily cooling load can met by night operation of heat pumps using typical water-based cold TES. This reduces costs for customers subject to time-of-day electricity rates. Other benefits of integrating cold TES with heat pumps include efficiency, because heat pumps combined with cold TES can operate independently of the cooling and heating loads of buildings and thus run at the most efficient operating condition, and capacity, since the longer operating hours of a heat pump integrated with cold TES allow for a smaller capacity heat pump and corresponding operating cost savings, since for a fixed air conditioning load.

For combined heating and cooling operations, heat pumps can be advantageously integrated with TES, particularly for multi-season applications. For example, a heat pump and an aquifer TES allows cold water to be extracted from a cold well during summer and warmed by cooling a building, and then returned to a warm well in the aquifer. The warmed water increases the temperature of the aquifer near the warm well. The operation is reversed during winter, with warm water extracted from the warm well and boosted in temperature by the heat pump if necessary. After some time, the ground temperature may be too high for direct cooling, but the system then can be operated as a conventional heat pump until the next heating season.

## Example: System at University of Ontario Institute of Technology

A borehole TES system is utilized in conjunction with heat pumps at the north campus of the University of Ontario Institute of Technology (UOIT) in Oshawa, Ontario, Canada (Figure 3). UOIT opened in 2003 and has about 8500 students. The north campus includes over 10 buildings, most of which are designed to be heated and cooled using ground-source heat pumps in conjunction with the borehole TES, which began operation in 2004.

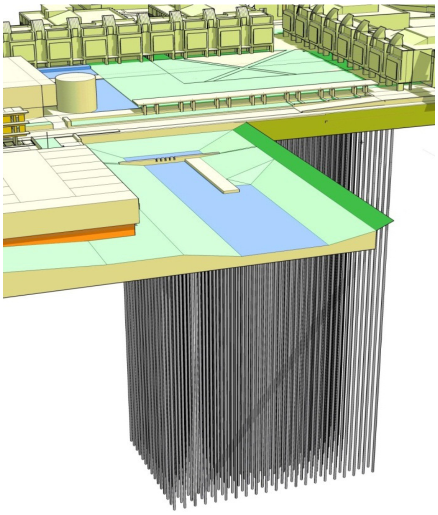


*Figure 3. Borehole TES system at UOIT. Left: Present appearance, showing boreholes below university buildings. Right: View during construction, showing grid of borehole headers and interconnecting piping.*

Energy from the ground is upgraded by ground-source heat pumps for heating. Alternatively the ground can absorb energy rejected by heat pumps in operating in cooling mode. The UOIT facility integrates the borehole TES (including ground-based heat exchangers), heat pumps, HVAC and distribution equipment and related devices. The borehole thermal energy storage provides for both heating and cooling on a seasonal basis. The total cooling load of the campus buildings is about 7000 kW. The borehole TES field is divided into four quadrants in order to optimize seasonal energy storage. The system has 384 boreholes each 213 metres deep, through which a glycol solution circulates within 150 km of polyethylene tubing. The circulation pumps and their motors have continuously variable and controllable flow rates. The boreholes are located on a 4.5 m square grid. Water-filled rather than grouted borehole heat exchangers are utilized to improve the efficiency of U-tube installation and extend the borehole life.

Central ground-source heat pumps are key to the system. Two chillers, each having seven 90-ton [320 kW] modules, transfer energy from the buildings to the borehole TES, and two sets of heat pumps, each with seven 50-ton [180 kW] modules, assist in cooling. The field retains the condensing heat for use in the winter (when the heat pumps reverse) and provide low temperature hot water for the campus. All but a few services use this low-temperature (53 °C) hydronic heat. Each building is hydronically isolated with a heat exchanger, and has an internal distribution system. Supplemental heating is also provided by condensing boilers.

The borehole TES field approximately has a total area of about 7000 m$^2$ and volume of 1.4 million m$^3$. The hydrogeologic setting includes over 40 m of unconsolidated overburden deposits overlying bedrock, and groundwater resources in the Oshawa area are limited to isolated, thin sand deposits. Two sedimentary bedrock formations were present: shale (14 m) and limestone (55 m to 200 m below grade), which is almost impermeable. Steel casing is used in the upper 58 m of each borehole to seal out groundwater. The background temperature is 10 °C.

Annual energy use is reduced using the TES system by 40 % for heating and 16 % for cooling (with corresponding emissions reductions), while reductions were achieved in potable water use (23 million liters annually) and treatment chemicals. The simple payback period for the geothermal well field was 7.5 years when the system was designed, and for the high-efficiency HVAC equipment incorporated was about 4 years.

## Conclusions

By offset the mismatch that often occurs between thermal energy demand and supply, such as when solar thermal energy is used to heat and/or cool buildings, TES can be advantageously employed. The advantages are particularly notable when TES is integrated with heat pumps for heating and/or cooling, with the ensuing benefits potentially including efficiency and performance enhancements and cost and environmental impact reductions. Existing systems, such as the one at University of Ontario Institute of Technology in Canada, bear this out and suggest that, with the continual advances extending from research and development of the technologies, TES and heat pump technology will prove to be an even hotter combination in the future.

### References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2. Rosen, M.A. and Kumar, R., 2012. Thermal energy storage. In Rosen, M.A., Ed., Energy Storage, Nova Science Publishers, Hauppauge, NY, pp. 337-354.



***Author contact information***

*Marc A. Rosen, Faculty of Engineering and Applied Science, University of Ontario Institute of Technology, Ontario, Canada*

*marc.rosen@uoit.ca*

# A practical application of continuous optimisation of a district heating and cooling plant in Japan

**- Effectiveness of heat pumps with thermal energy storage in water -**

*M. Momota; T. Ibamoto; T. Inoue; R. Yanagihara; A. Okagaki, Japan*

*The importance of plant commissioning, or Testing, Adjusting and Balancing, is well known to Japanese engineers, but there are as yet few examples of their application, especially of continuous optimisation as an ongoing extension of commissioning. Against this background, this article presents an analysis of ten years' operational results of a district heating and cooling (DHC) plant. The plant is one of the most efficient DHC plants in the country, with the largest thermal energy storage capacity in the country (a total water volume of 19 060 m³). The plant has been in operation since March, 2001. With over ten year's operational data therefore available, it is possible to see the results of continuous optimisation and of the use of high-capacity thermal energy storage.*

## Introduction

Increasing public awareness of energy conservation has led to growing interest in efficient energy management strategies, such as the use of heat pumps and thermal energy storage. However, problems are likely to be encountered if the heat pump and thermal energy storage facility are installed without ongoing continuous optimisation to ensure that the system operates as intended.

The whole system consists of numerous machines, and so the plant requires continuous optimisation or at least "Testing, Adjusting and Balancing". The importance of this is well known to Japanese engineers, but there are as yet few examples (especially long-term) of its application.

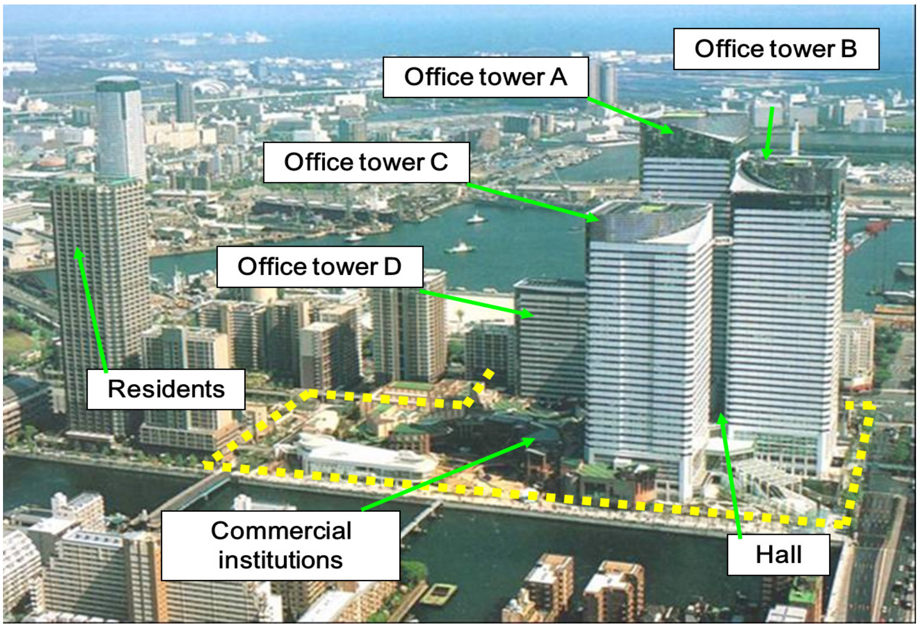


*Figure 1. Buildings in the DHC area*

## Subject of study

This report describes practical application of continuous optimisation of the Harumi DHC, which has the largest thermal energy storage tanks (19 060 m³) in Japan. The plant, in Tokyo, was completed in March 2001 (Figure 1): Table 1 shows user data. Located near the Tokyo waterfront, the plant provides chilled and hot water to three office skyscrapers (over 150 m), one tall office building, a commercial institution, and a hall. A redevelopment plan for the area was announced in 1988, and the guidelines for the plan and specific requirements were determined by a committee consisting of academic experts, owners, power companies and designers. This was an innovative approach at the time. The committee decided the following, for both energy conservation and economic reasons.

| | | Office tower A | Hall | Office tower B | Office tower C | Office tower D | Common part |
|---|---|---|---|---|---|---|---|
| Use | | Office / Shop | Hall | Office | Office | Office | Grand Lobby / Shop |
| Stories | Above ground | 19 | 6 | 45 | 40 | 34 | 6 |
| | Below ground | 1 | | 4 | 4 | 4 | 4 |
| Total floor area | | 31,610m² | 4,871m² | 131,197m² | 119,506m² | 103,781m² | 71,444m² |
| Air conditioning area | | 24,000m² | 3,400m² | 83,400m² | 77,900m² | 63,400m² | 30,260m² |

*Table 1. Details of customers*

1. To install the main plant in the centre of this area
2. To adopt a temperature difference of 10 °C
3. To install large thermal energy storage tanks
4. To run the system using only electric power

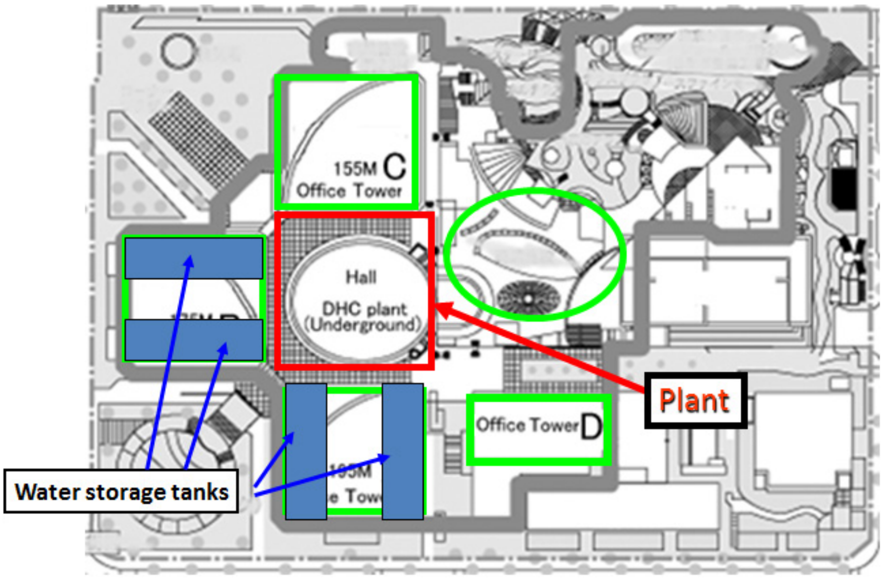


*Figure 2. Area plan of the plant*

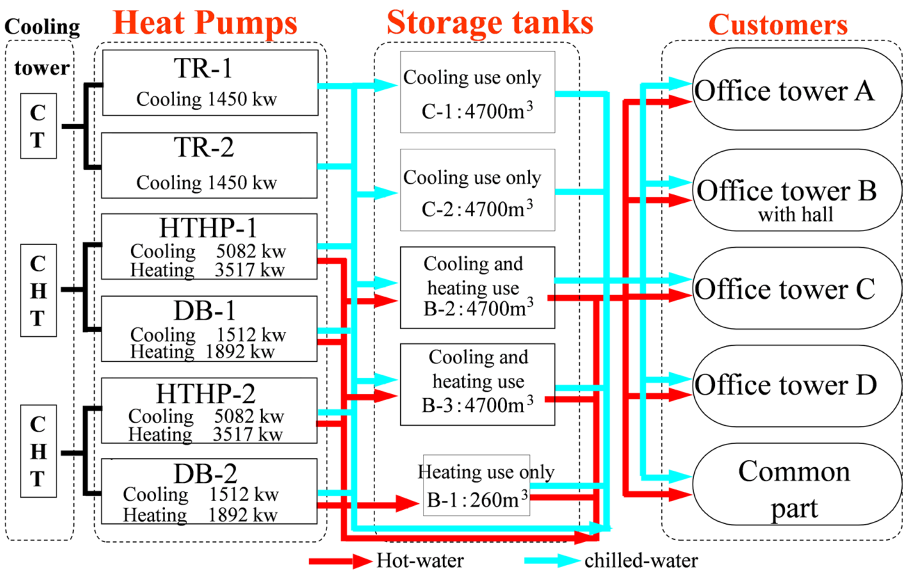


*Figure 3. Facility outline*

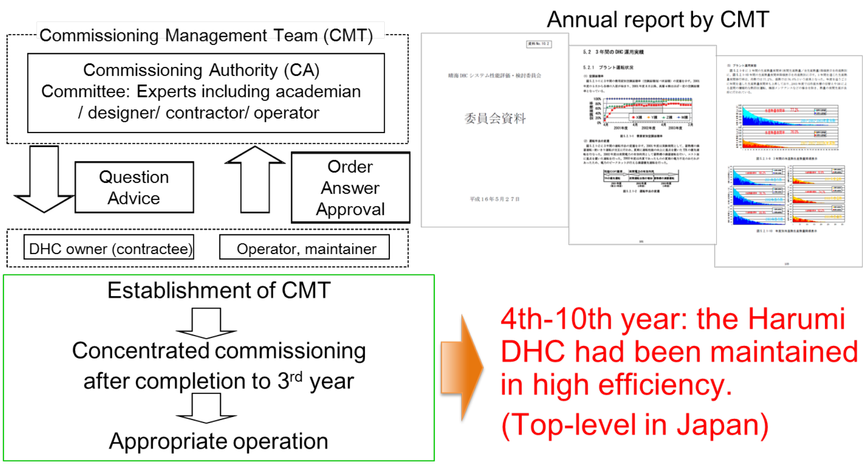


*Figure 4. Maintaining the high efficiency by continuous optimisation (Administrative operation framework)*

## Outline of facilities

Figure 2 shows a plan of the area, and Figure 3 is a schematic diagram of the plant.

Five large water storage tanks can supply half of the peak daytime load in summer. Installed under office towers B and C, they have a total capacity of 19 060 m$^3$. Two tanks are used exclusively for cooling, one tank for heating, and the remaining two tanks are used for cooling and heating as required by seasonal changes. All are temperature-stratified-type.

The capacity of the heat pumps are 16 088 kW for cooling and 10 818 kW for heating. They consist of two electric turbo heat pumps (TRs; only for cooling, and connected to the cooling tower), two heating tower heat pumps (HTHPs; can supply either cold or hot water, and are connected to the heating/cooling tower), and two double-bundle heat-recovery turbo heat pumps (DBs; connected to the cooling tower). The source for the heat pumps is air. Chilled water data is 6 ˚C (supply) and 16 ˚C (return), while hot water design data is 47 ˚C (supply) and 37 ˚C (return). Pump power and pipeline diameters were reduced by using large temperature differences. It also appears feasible to improve the performance of the water tanks.

All the customers' secondary systems employ closed circuits with heat exchangers. Secondary pumps are controlled by Variable Water Volume (VWV) operation, with inverter-controlled pumps, and contribute to maintaining the temperature differences and reducing pumping power. In addition, fan-coil units and air-handling units installed in customers' areas are designed to maintain a temperature difference of 10 ˚C.

## Framework for high-efficiency operation

Figure 4 shows the commissioning and ongoing commissioning framework. In 2000, shortly before completion of the plant, a Commissioning

Management Team (CMT) was set up, starting the concentrated three-year post-commissioning (or continuous optimisation) stage. Over these three years, the CMT and the plant owner established a good working relationship, which still continues. An annual report is also published.

After the three-year phase, the operator and maintainer concentrated on their respective working areas. As a result, the plant has been maintained at high efficiency for over ten years.

Figure 5 is a flow diagram for high-efficiency operation by means of optimisation of thermal energy storage. Generally, maintaining the temperature difference between supply and return water is not the responsibility of the plant operator.

However, as Figure 5 shows, as the temperature difference indirectly affects the efficiency of the plant, the commissioning management team was also concerned with the HVAC systems in customers' buildings in order to avoid adverse effects on operation of the plant.

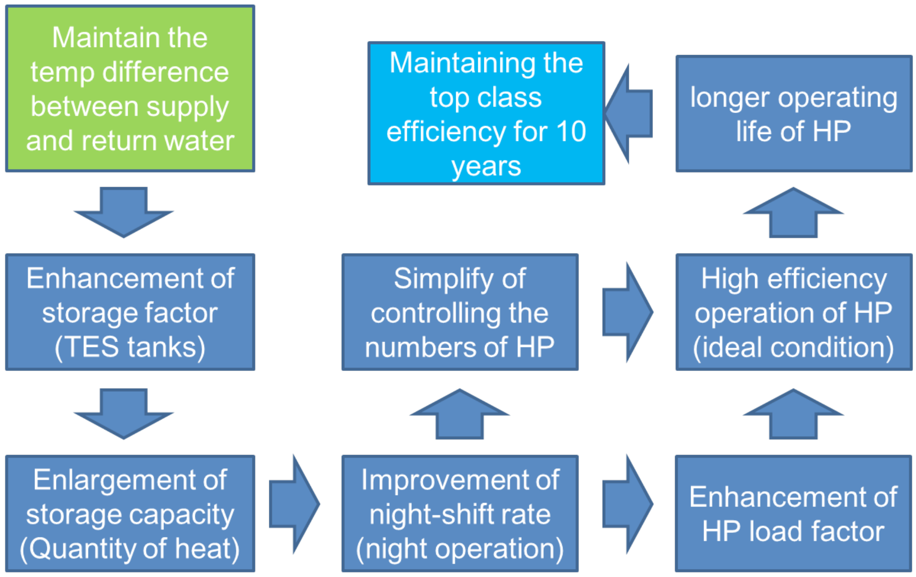


*Figure 5. Flow diagram for high-efficiency operation by optimisation of thermal energy storage*

## Harumi DHC operation results

### Evaluation of whole DHC plant operation

Figure 6 shows the (primary energy conversion) COP (including all pumps and cooling/ heating towers) of the plant from 2001 until 2010. In 2008 and 2009, the summer COP exceeded 1.4. This reflects the effectiveness of base operation of TR heat pumps (COP: 5.3) in generating cold energy. On the other hand, the plant COP in winter falls to below 1.0, due to base load operation of HT heat pumps (heating mode COP: 3.2). The original design assumed greater cooling demand in winter than was actually the case. For this reason, the DB heat recovery mode could not generate enough cold and hot energy. The COP for primary energy conversion has fluctuated slightly from year to year, with the highest value (1.25) occurring in 2009: the average value over ten years is 1.25. This result shows that this plant is one of the most efficient district heating and cooling plants in Japan.

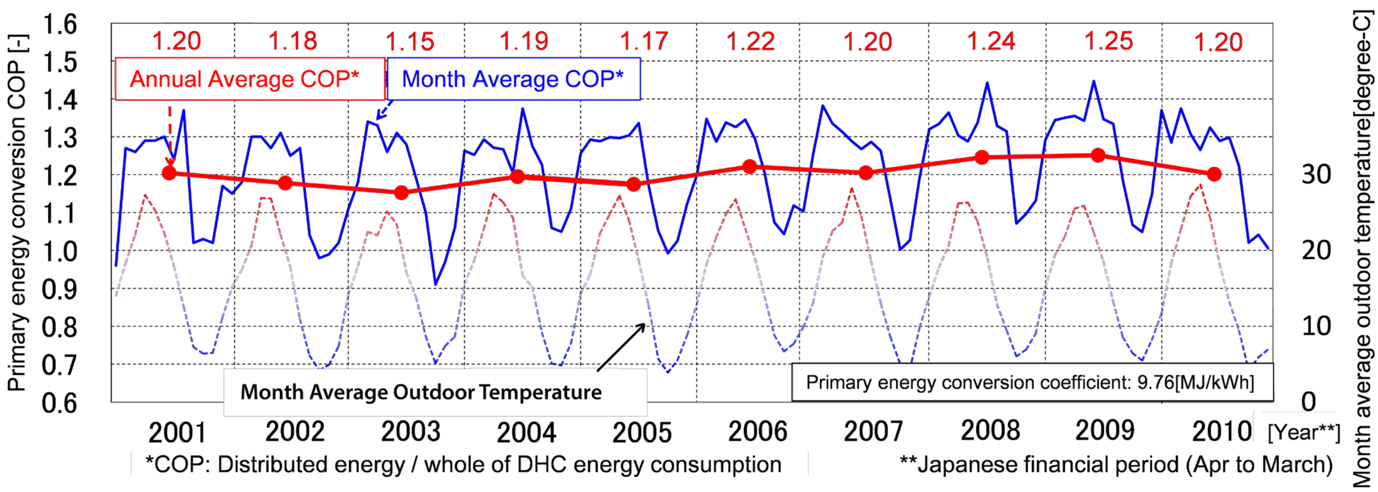


*Figure 6. Primary energy conversion COP, 2001 – 2010 (electric power generation coefficient in Japan is 9.76 MJ/kWh), and average temperature (2001-2010)*

The diagram also shows that the system has been operated at a high COP, without any deterioration due to the effects of ageing. The primary energy conversion COP and $CO_2$ emission per unit of energy are shown in Figure 7.

This figure also includes other district heating and cooling plants (of which there are approximately 140 in Japan). The Harumi plant is the third most efficient in the country. The Harumi plant design is a typical high-efficiency system in Japan.

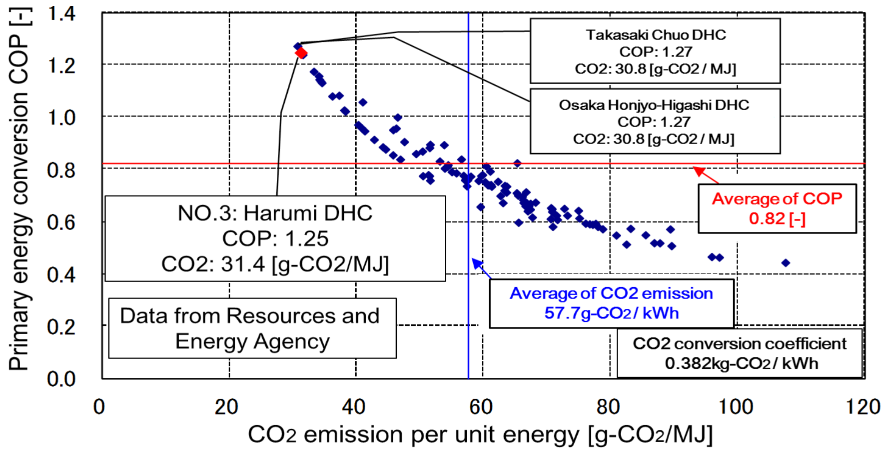


*Figure 7. Primary energy conversion COP and $CO_2$ emission per unit of energy [All Japan DHC: approx 140 sites]*

## Optimisation of thermal energy storage

### Maintaining the temperature difference

The temperature difference of this district heating and cooling plant was designed high, at 10 °C. However, it was not easy to maintain such a high temperature difference, especially at lower flow volumes, such as during the night.

Figure 8 shows the temperature difference between supply and return water in 2009. Low flows were seen for most of the operating time. We therefore had to adjust the system to prevent the pumps wasting electric power and to guard against loss of temperature stratification in the storage tanks.

The annual average temperature difference is shown in Fig 9. Except in 2001 and 2002, both chilled water and hot water daytime temperature differences came close to almost 10 °C. Even at night, both temperature differences were maintained at over 7 °C. When it is borne in mind

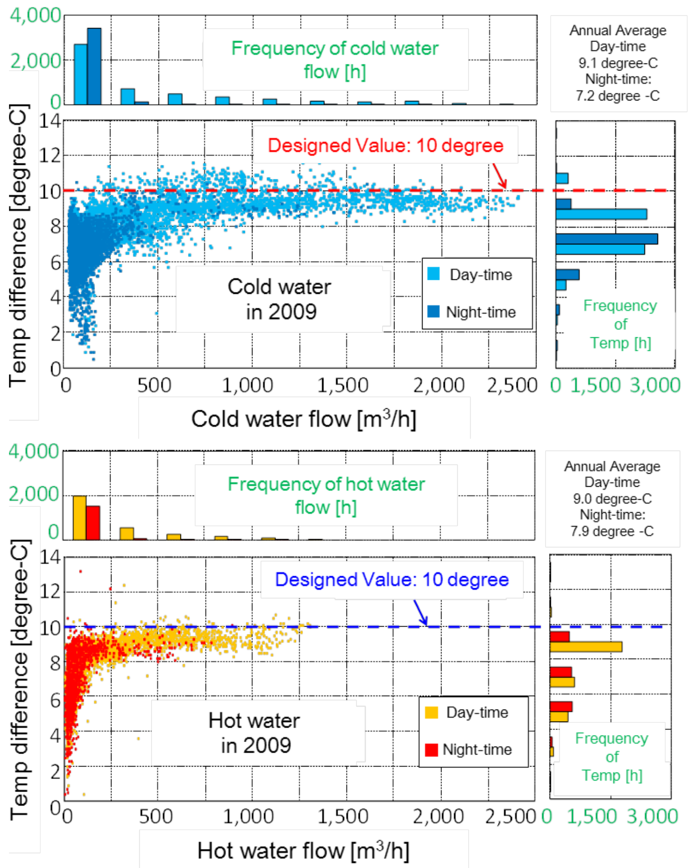


*Figure 8. Supply and return water temperature difference, 2009. [Upper graph: Cold water, Lower graph: Hot water]*

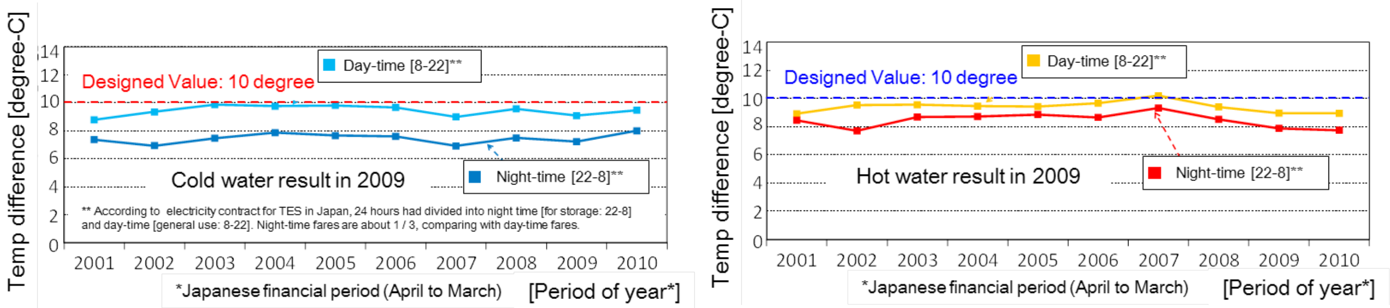


*Figure 9. Annual average temperature difference between supplied water and returned water, 2001-2009*
*[Left graph: Cold water, Right graph: Hot water]*

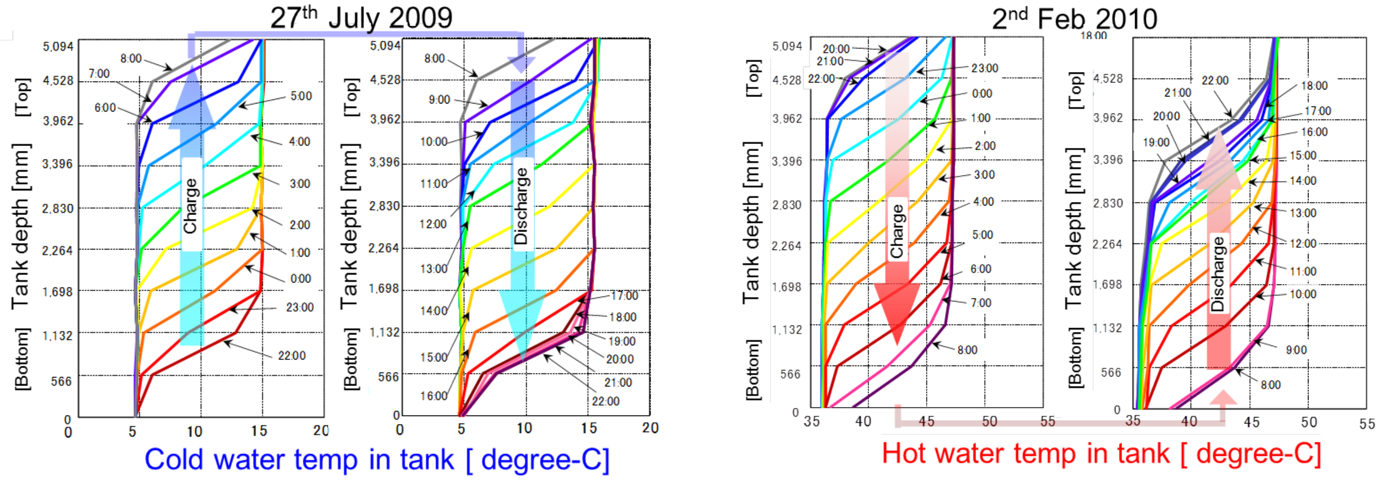


*Figure 10. Temperature profile of stratified tanks.*
*[Left graph: Cold water: Cold water charging, cold water discharging, Right graph: Hot water: hot water charging, hot water discharging]*

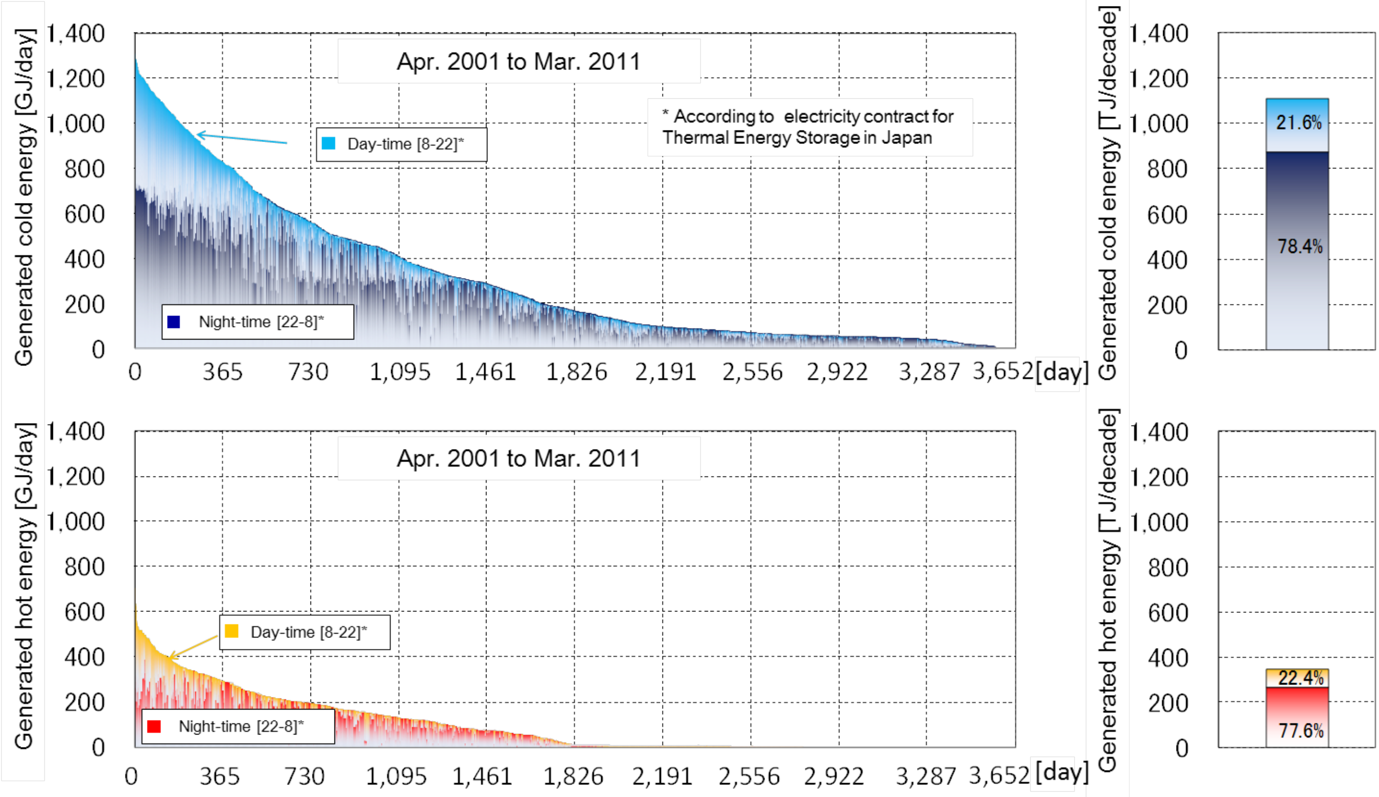


*Figure 11. Load duration diagrams for cold/heat energy supplied. Overall period: Ten years, 3652 days' data*

that other DHC system values are generally half of these, we believe that these results are among the best results in Japan.

## Enlargement of the storage capacity

The temperature profile of a typical day is shown in Fig. 10. These temperature profiles show that the heat storage tanks were being operated correctly.

## Utilisation of the thermal energy storage for DHC

Power companies have an electric load-levelling agenda. In Japan, where/when possible, thermal and hydro power are not used for night-time power generation: nuclear power generation is the chief type of power generation used. This means that $CO_2$ emissions are low for night-time electric power. Electricity charges during the night are about 20 % of those during the day. Therefore, greater use of night-time rates is very important, not only for power companies but also for end users. Figure 11 shows load duration diagrams: in addition to showing the overall supply of cold and of heat, they also show the breakdown between daytime and night-time demand. It can be seen that the proportion of energy supplied during the night was about 78 % of the total day/night supply over the ten-year period. This favourable result was brought about by increasing the effective amount of thermal energy storage.

### Optimisation of heat pump operation

Figure 12 shows the heat pump COP and load factor. The points shown in the graph are annual averages of the aggregated performances of peer heat pumps in each operating mode. The heat pump load factors have been maintained at a very high level, and so the COP was also maintained at a constant value around the rated design value. This ideal state was due to the use of very large thermal storage tanks, showing that installing sufficient tank capacity leads to a high heat pump load factor.

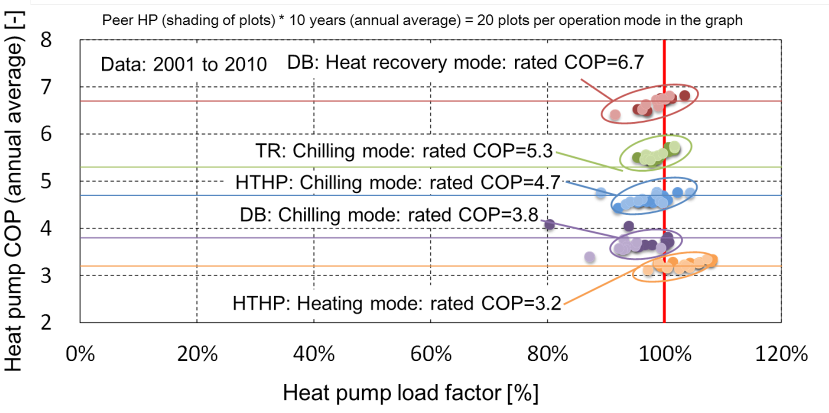


*Figure 12. Heat pump COPs and load factors, for indicated operation modes. Annual average over ten years*

Figure 13 shows the operating results of heat pumps and thermal storage tanks, in cooling mode operation in 2009. The left-hand graph shows the summer peak, the middle graph shows the autumn performance, and the right-hand graph shows the winter performance. The actual amount of cooling energy supplied varies from day to day, and is also affected by time-shifting and seasonal changes. The heat pumps, on the other hand, which are supplying the fixed thermal energy storage tank loads, operate in basic Stop/Start mode. The resulting simplified operation with thermal energy storage contributes to steady and efficient improvement of system capability.

Figure 14 shows the total operating time of the heat pumps, amounting to 87 648 hours over ten years. On the other hand, the two turbo heat pumps, which are the main machines, have operated for only 21 000 hours. The heat pumps operate with almost 100 % load factor, and so the total operating time was reduced by the simplified operating regime. This

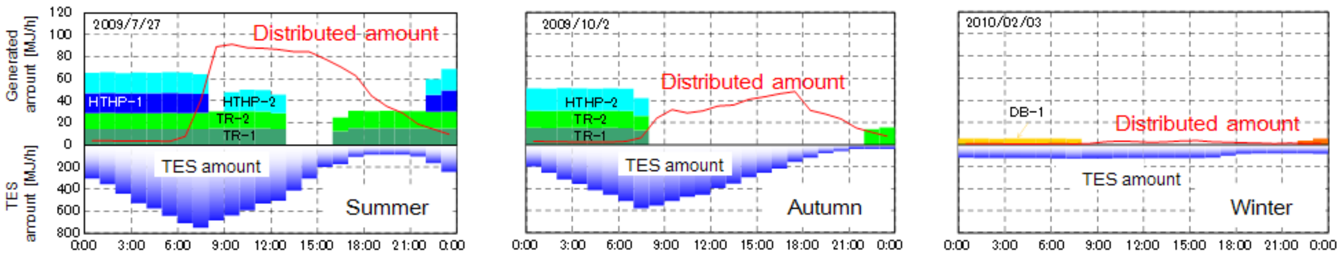


*Figure 13. Heat pump operation with thermal energy storage, 2009 cooling operation.*
*[Left to Right graphs: Summer, Autumn, and Winter]*

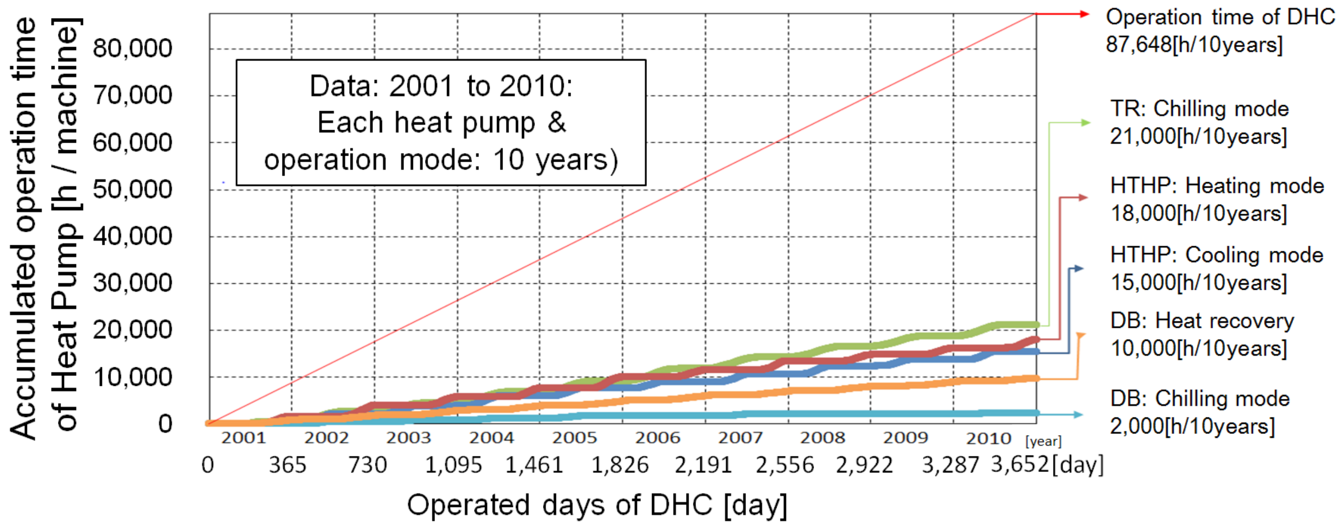


*Figure 14. Accumulated operation time of heat pumps (each heat pump & operation mode: ten years)*

high efficiency also contributes to long life of the heat pumps.

## Conclusion

Ten years' long-term measurement and performance analysis of Harumi DHC has shown the benefits of continuous optimisation.

The following results were found during the Operation and Maintenance Stage:

1. It was shown that Harumi DHC has operated at a high primary energy conversion COP, which has not been affected by performance deterioration due to ageing.
2. Maintaining the temperature difference is the basic factor for optimum operation.
3. Maintaining the temperature difference of the water in large thermal energy storage tanks enabled most of the energy consumption to be shifted to the night-time, permitting the heat pumps to be operated with a high load factor.
4. Thermal energy storage provides a particularly favourable system for heat pumps.

These results are one of the first case examples in Japan of a practical study of continuous optimisation of a plant during its operation and maintenance stage. Considering that the importance of energy management will increase, not only in district heating and cooling plants but also in individual buildings, we hope that our study will be of value for energy conservation.

## Nomenclature

**COP [-]** = energy production / electric power consumption

**Night-shift rate (electricity) [-]** = electric power consumption during the daytime [kWh] / electric power consumption (24 hour total) [kWh]

**Night-shift rate (quantity of heat) [-]** = quantity of heat production at night [MJ] / quantity of heat production (24 hour total) [MJ]

**Primary energy conversion value** = 9.97 [MJ/kWh] *

**Primary energy conversion COP[-]** = quantity of heat production (24 hour total) [MJ]/ electric power consumption (24 hour total) [kWh] * 9.97[MJ/kWh]

* electricity generation efficiency: mean value of all (ten) electricity companies in Japan.

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***Author contact information***
*Masashi Momota, School of Science and Technology for Future Life, Department of architecture, Tokyo Denki University, Japan*
*momota@cck.dendai.ac.jp*

# PCM thermal energy storage system coupled to a heat pump

*P. Moreno[1], C. Solé[1], A. Castell[1], L. F. Cabeza[1], M. Kaju[2], R. Jung[2], A. Aguirre Gonzalez[1], Z. Ure[3]*
*[1]Spain; [2]Estonia; [3]UK*

*The University of Lleida (Spain) has an experimental set-up consisting of a thermal energy storage (TES) system coupled to a heat pump. Phase-change materials (PCM) are used in the TES system as latent heat storage material. The system operates with a load-shifting strategy, so the two TES units installed supply the entire cooling or heating demand while shifting the electricity demand of the HVAC system to off-peak hours. The system prototype has been tested under summer conditions in Spain and is being tested for winter conditions in Estonia. This article describes the system and the first results of the trials*

## Introduction

Thermal energy can be mainly stored in two different ways: as sensible heat or as latent heat.

Water is the most used sensible heat storage material because it is well known and is cheap compared to other storage materials. However, the major disadvantage of using water is the volume needed. For instance, for the same amount of thermal capacity, a water TES system requires approximately three times as much volume as using ice.

Latent heat TES systems take advantage of the higher storage density when a substance changes from one phase to another over a constant temperature range [1]. The higher storage capacity of these materials allows the use of smaller TES tanks compared to sensible heat storage.

There are many materials that are similar to ice in this respect, i.e. which change phase at a specific temperature, and may be used for latent TES. These substances are called 'phase change materials' (PCM). The choice of material depends on the application temperature range. Thus, for cooling applications, materials with a melting/solidification temperature of 8 °C are typically used because standard cooling equipment supplies thermal energy at this temperature range [2].

This article describes the use of PCM tanks when coupled to a heat pump system for space cooling application. The tanks are filled with commercial macro-encapsulated PCMs in order to accumulate thermal energy at night for use through the day.

## Description of the system

The University of Lleida (Spain) has been working on an EU Seventh Framework project, named HESTOR, to design and construct a TES system coupled to a heat pump for load shifting. The objective of the system is to shift the entire peak load, either heating or cooling, to off-peak hours, when the electricity tariff is lower.

The system was designed to store heat and cold using commercial PCMs in two different TES tanks. As part of the project, the system prototype was intended to be tested under summer conditions in Spain, and under winter conditions in Estonia. The summer testing was carried out in summer 2012, from which the first

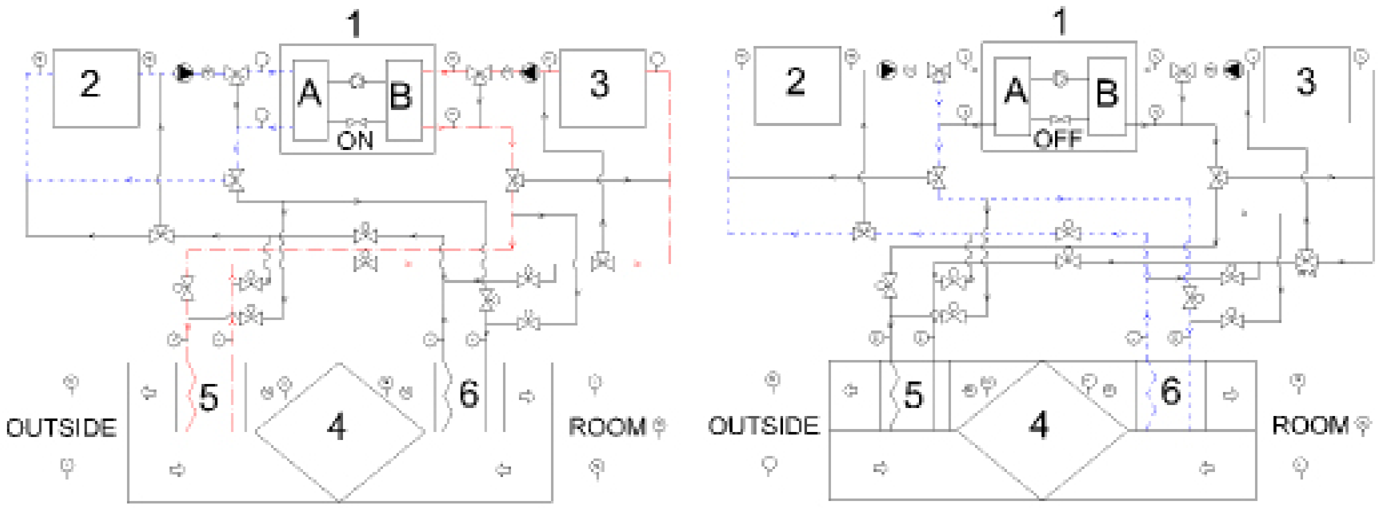


*Figure 1. System schematic diagram. Charging mode (left) and discharging mode (right). 1. Heat pump (A. Evaporator, B. Condenser), 2. Cold tank, 3. Hot tank, 4. AHU, 5. Outlet coil heat exchanger, 6. Inlet coil heat exchanger.*

results have been analysed. The winter tests are being performed in winter 2013. In addition, further experiments are expected to be performed during this next year in Lleida.

Figure 1 shows how two different 104-litre tanks ([2] and [3] in the diagram) are connected to a water-to-water heat pump (4.2 kW cooling and 5.2 kW heating) and an air handling unit (AHU). One tank is connected to the evaporator to store cold, and the other takes heat from the condenser of the heat pump.
The system can therefore be used for either heating or cooling. The temperature levels of the system (about 58 °C from the condenser and 2 °C from the evaporator) have been chosen to ensure solidification of the cold PCM during night. As can be seen in Figure 1, when the hot tank is fully charged (i.e. the PCM is completely melted) the heat transfer fluid (HTF) dissipates the excess heat to the environment through the outlet coil heat exchanger [5].

## Experimental set-up

The system was tested in the experimental set-up that the University of Lleida has in Puigverd de Lleida (Spain) (Figure 2). Here, 21 small house-like cubicles (2.4 m x 2.4 m x 2.4 m internally) were built with different construction systems to test their thermal behaviour. Some include PCMs on their walls and roofs, where the serve as passive TES systems [3].
Up to now, test of the heat pump system have been carried out under summer conditions to cool one of the cubicles (Figure 3), using PCM as an active TES system.
In order to take advantage of the low electricity tariff, the system is intended to solidify the PCM at night, using the heat pump, and melt it during the day in order to supply cool air to the room.
The PCMs used are salt hydrates enclosed in commercial plastic flat slab encapsulation (500 mm x 250 mm x 32 mm). According to the manufacturer's specifications, phase change temperatures are 10 °C for the cold store material and 46 °C for the hot store material. As can be seen in Figure 4, the PCM packages are stacked inside the tanks, creating narrow channels for the heat transfer fluid flow.
The system is fully instrumented with NTC 10k temperature sensors, and controlled by Carel programmable controllers. Five temperature sensors register the HTF temperature inside the tank, and another measures the PCM temperature inside one of the flat slab packages.

## Methodology

Two types of tests have been carried out. The first one consisted of charging the TES tank at night and discharging it constantly during the day. This allows the energy stored and supplied by the tank to be determined. In the second test type, the indoor temperature of the cubicle is controlled by the system to a specific set point. This means that the HVAC system provides cooling when required, using the PCM tank. Here, the objective is to record the time during which the temperature of the cubicle is kept within the set point range. Future work will investigate the effect of the PCM on the energy supply time by comparing the use of the PCM tank and a water tank.

## Results and discussion

The first results show the capacity of the PCM tank and the temperature/time values of both the HTF and the PCM.
At night, thermal energy is stored

*Figure 2. General view of the University of Lleida experimental set-up*

*Figure 3. System connected to the cubicle*

when the PCM solidifies, so that 1.82 kWh are supplied during the day.

Figure 5 shows the melting process in the tank: inlet and outlet HTF temperatures, temperatures at different positions in the tank (TE18 - TE20), and the PCM temperature. The PCM temperature remains lower than the other temperatures throughout the process, so that the PCM cools down the HTF.

A slight change of the PCM temperature slope indicates the presence of latent heat between 8 °C and 18 °C approximately. After the melting process, the PCM temperature remains closer to the HTF temperatures.

Since the tank supplies cold HTF to cool the room, the outlet HTF temperature is a key parameter for evaluation. As shown in Figure 5, it takes 240 minutes for this temperature to reach 18 °C and 300 minutes to reach 20 °C. During this time, the energy from the TES is enough to refrigerate the cubicle.

## Conclusions

Thermal energy storage is a technology which can be used for load shifting. The capacity of these systems can be improved by using phase-change materials (PCMs) due to their higher energy storage density.

This article has described a system using PCM tanks in a heat pump system and the first results of its use in space cooling tests.

The PCM melting temperature range has been observed in tests carried out under summer conditions.

A comparison between the performance of a PCM tank and that of a water tank is being analysed and the results will be presented in due course. When comparing these tanks it is expected that the PCM tank will deliver better performance, resulting in (i) higher stored/supplied energy, and (ii) an increase in the cooling time.

*Author contact information*
*Luisa F. Cabeza, GREA Innovació Concurrent, Universitat de Lleida,Spain*
*lcabeza@diei.udl.cat*


*Figure 4. PCM thermal energy storage tanks*

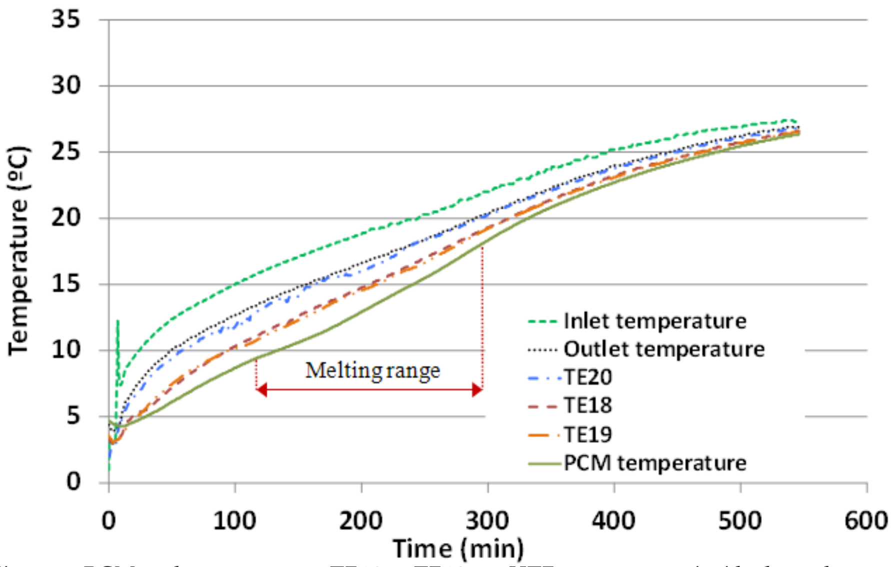


*Figure 5 PCM tank temperatures. TE18 to TE19 are HTF temperatures inside the tank.*

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# IEA stakeholder engagement workshop on the new Energy Storage Technology Roadmap

On 13-14 February, 2013, the IEA held a workshop on the development of a new roadmap on energy storage technology. The workshop gathered over 60 participants from academia, associations, governments and industry engaged in discussions on the new IEA Roadmap for Energy Storage Technology. The Heat Pump Programme was represented by Åsa Jardeby from the Heat Pump Centre.

The presentations and discussions started with the role of and key considerations for energy storage. This was followed by two breakout sessions on thermal storage systems and electricity storage systems, which both discussed current state of the market, incentives and barriers and innovative technologies that could significantly change the future outlook in each technology respectively.

The two-day workshop concluded by exploring the links between electricity and thermal storage in the energy system, and discussions of the scope for the roadmap, including which metrics, milestones, goals, and actions that should be further investigated and considered.

This roadmap will be one in the series of energy technology roadmaps produced by the IEA. The overall aim of the roadmaps is to advance global development and uptake of key technologies to reach a 50 % reduction in energy-related $CO_2$ emissions by 2050. The roadmaps identify priority actions for governments, industry, financial partners and civil society that will advance technology development and uptake to achieve international climate change goals.

The vision for each of the IEA's roadmaps is based on the Energy Technology Perspective's (ETP) scenario of a temperature increase of 2 °C (2DS). This scenario describes how technologies across all energy sectors may be transformed by 2050 to give an 80 % probability of limiting average global temperature increase to 2 °C. The 2DS sets the target of cutting energy-related $CO_2$ emissions by more than half by 2050 (compared to 2009), and ensuring that they continue to fall thereafter.

Each roadmap represents international consensus on milestones for technology development, legal/regulatory needs, investment requirements, public engagement/outreach and international collaboration.

Prior roadmaps published can be downloaded from the IEA website: http://www.iea.org/roadmaps/

## World Green Building Trends: SmartMarket Report

As sustainability and energy efficiency initiatives take hold around the world, firms are finding business opportunities from green building, according to McGraw-Hill Construction's latest SmartMarket Report, 'World green building trends - Business benefits driving new and retrofit market opportunities in over 60 countries,' released on Feb 28, 2013. The report is based on a study of global green building trends and aims to discern drivers of the green building marketplace.

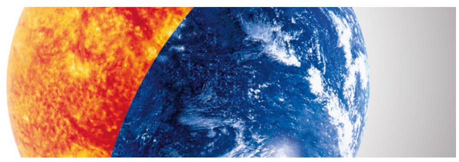
According to the study, firms are shifting their business toward green building, with 51 % of respondents planning more than 60 % of their work to be green by 2015. This is a significant increase from the 28 % that said the same for their work in 2013, and double the 13 % in 2008.

This growth is not a trend localized to one country or region. From 2012 to 2015, the number of firms anticipating that more than 60 % of their work will be green will more than triple in South Africa; more than double in Germany, Norway and Brazil, and will grow between 33 and 68 % in the United States, the United Kingdom, Singapore, the United Arab Emirates and Australia.

The key driver to going green is that green building is now a business imperative around the world. In the 2008 report, McGraw-Hill Construction found that the top driver for green building was 'doing the right thing.' However, in 2012, business drivers such as client and market demand are the key factors influencing the market.

*Source: JARN, March 25, 2013*





# Events

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

## 2013

**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/

**17-19 June**
**4th Conference on Thermophysical Properties and Transfer Processes of Refrigerants**
Delft, The Netherlands
http://www.tptpr2013.nl/

**18-19 June**
**ATMOsphere**
Washington DC, USA
http://www.atmo.org/events.details.php?eventid=12

**19-20 June**
**ASHP ASIA 2013**
Wuxi, China
http://www.ashpasia.com/overview.html

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

**2-4 September**
**Compressors 2013 - 8th International Conference on Compressors and Coolants**
Castá Papiernicka, Slovakia
http://www.szchkt.org/a/conf/event_dates/6?locale=en_GB

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

**16-18 September**
**Big 5 Kuwait**
Kuwait City, Kuwait
http://www.big5kuwait.com/page.cfm/link=105

**25-27 September**
**ISH Shanghai & CIHE 2013**
Shanghai, China
http://www.eco-business.com/events/ish-shanghai-cihe-2013/

**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/

**15-16 October**
**Heat Pump Summit 2013**
Nürnberg, Germany
http://www.hp-summit.de/en/symposium/

**15-18 October**
**IAQ 2013 - Environmental Health in Low Energy Buildings**
Vancouver, British Columbia, Canada
http://www.ashrae.org/

**19-21 October**
**ISHVAC (International Symposium on Heating, Ventilation and Air Conditioning)**
Xi'an, China
http://www.ishvac2013.org/v2/index.php

## 2014

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

**28-31 January**
**HVAC&R Japan**
Tokyo, Japan
http://www.hvacr.jp/eng/index.html

**26-28 February**
**49th AiCARR International Conference**
Rome, Italy
http://www.aicarr.org/Pages/Convegni/Roma_2014/Home_English.aspx

**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/

**28 June – 2 July**
**ASHRAE Annual Conference**
Seattle, USA
http://www.ashrae.org/membership--conferences/conferences/ashrae-conferences

**31 August – 2 September**
**11th IIR-Gustav Lorentzen Conference on Natural Refrigerants - GL2014**
Hangzhou, China
http://www.iifiir.org/medias/medias.aspx?INSTANCE=exploitation&PORTAL_ID=general_portal.xml&SETLANGUAGE=EN

**14-16 October**
**Chillventa**
Nuremberg, Germany
http://www.chillventa.de/en/

## 2015

**31 August - 6 September**
**ICR 2015**
**The 24th International Congress of Refrigeration**
Yokohama, Japan
http://www.icr2015.org/index

**In the next Issue**

Heat pump performance monitoring and evaluation

Volume 31 - No. 2/2013

## 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

SP Technical Research Institute of Sweden

IEA Heat Pump Centre
SP Technical Research
Institute of Sweden
P.O. Box 857
SE-501 15 Borås
Sweden
Tel: +46 10 516 55 12
E-mail: hpc@heatpumpcentre.org
Internet: http://www.heatpumpcentre.org

IEA OECD heat pump centre

# National team contacts

**AUSTRIA**
Prof. Hermann Halozan
Consultant
Waltendorfer Höhe 20
A-8010 Graz
Tel: +43 316 422 242
hermann.halozan@chello.at

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

**DENMARK**
Mr. Svend Pedersen
Danish Technological Institute
Refrigeration and Heat Pump Technology
Kongsvang Alle 29
DK-800 AArhus C
Tel: +45 72 20 12 71
svp@teknologisk.dk

**FINLAND**
Mr. Jussi Hirvonen
Finnish Heat Pump Association
SULPU ry
Lustetie 9
FI-01300 Vantaa
Tel: +35 8 50 500 2751
jussi.hirvonen@sulpu.fi

**FRANCE**
Mr. David Canal
ADEME
Service des Réseaux et des
Energies Renouvelables
500 route des Lucioles
FR-06560 Valbonne
Tel: +33 4 93 95 79 19
david.canal@ademe.fr

**GERMANY**
Prof. Dr.-Ing. Dr. h.c. Horst Kruse
Informationszentrum Wärmepumpen
und Kältetechnik - IZW e.V
c/o FKW GmbH
DE-30167 Hannover
Tel. +49 511 167 47 50
email@izw-online.de

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

**JAPAN**
Mr. Takeshi Hikawa
Heat Pump and Thermal Storage
Technology Center of Japan (HPTCJ)
1-28-5 Nihonbashi Kakigaracho
Chuo-ku, Tokyo 103-0014
Tel +81 3 5643 2404
hikawa.takeshi@hptcj.or.jp

**NETHERLANDS**
Mr. Onno Kleefkens
Agentschap NL
Divisie NL Energie en Klimaat
P.O. Box 8242
Croeselaan 15
3503 REUtrecht
Tel: +31 88 620 2449
onno.kleefkens@agentschapnl.nl

**NORWAY**
Mr. Bård Baardsen
NOVAP
P.O. Box 5377 Majorstua
N-0304 Oslo
Tel. +47 22 80 50 30
baard@novap.no

**SOUTH KOREA**
Mr. Hyun-choon Cho
KETEP
Union Building, Tehyeranro 114-11
Department of Renewable Energy
Gangnam-gu, Seoul
Republic of Korea 135-280
Tel: +82 2 3469 8302
energy@ketep.re.kr

**SWEDEN**
Ms. Emina Pasic (Team leader)
Swedish Energy Agency
Energy Technology Department
Bioenergy and Energy Efficiency Unit
Kungsgatan 43
P.O. Box 310
SE-631 04 Eskilstuna
Tel: +46 16 544 2189
emina.pasic@energimyndigheten.se

**SWITZERLAND**
Mr. Martin Pulfer
Swiss Federal Office of Energy
CH-3003 Bern
Tel: +41 31 322 49 06
martin.pulfer@bfeadmin.ch

**UNITED KINGDOM**
Ms. Penny Dunbabin
Department of Energy & Climate
Change (DECC)
Area 6D, 3-8 Whitehall Place
London SW1A 2HH
Tel: +44 300 068 5575
penny.dunbabin@decc.gsi.gov.uk

**THE UNITED STATES**
Mr. Van Baxter - Team Leader
Residential Building and Equipment Research
Engineering Science and Technology Division
Oak Ridge National Laboratory
P.O. Box 2008, Building 3147
Oak Ridge, TN 37831-6070
Tel: +1 865 574 2104
baxtervd@ornl.gov

Ms. Melissa Voss Lapsa - Team Coordinator
Oak Ridge National Laboratory
Engineering Science and Technology Division
Bethel Valley Road
P.O. Box 2008
Oak Ridge, TN 37831-6054
Tel: +1 865 576 8620
lapsamv@ornl.gov