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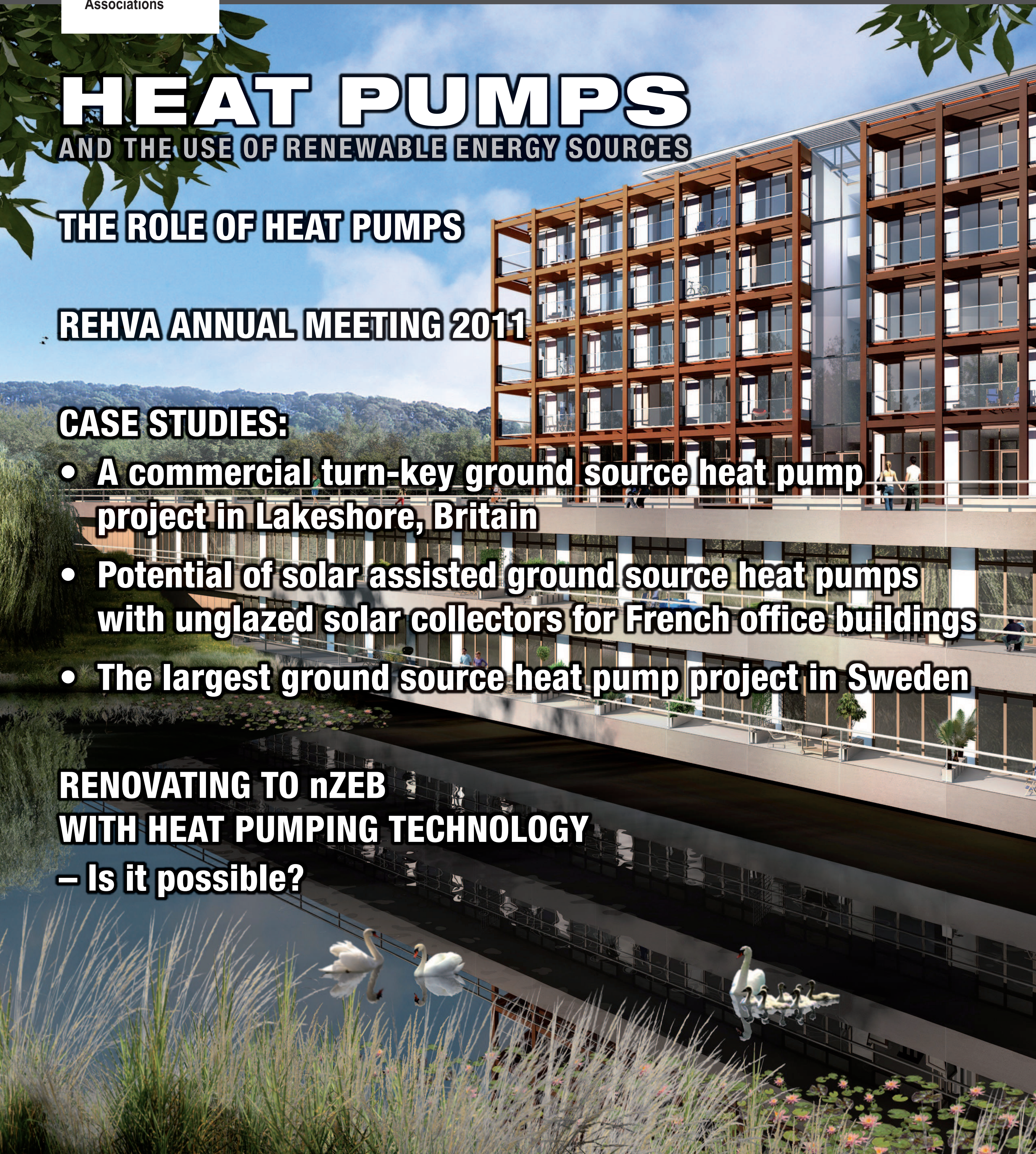

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AND THE USE OF RENEWABLE ENERGY SOURCES

THE ROLE OF HEAT PUMPS

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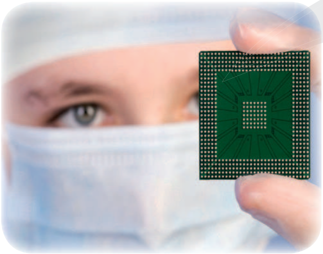

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Theme: A/C systems & EU regulations for HVAC products
Articles due: 15.9.2011. **The Guest Editor:** Mr Jacques Benoist from AICVF (France).
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Heat pumps
- a key to sustainability

The world does not lack energy. But energy is seldom available at a suitable temperature exactly where and when it is needed. The challenge for HVAC engineers is then to find the right energy sources and use them in the most effective way. Heat pumps enable us to collect otherwise useless thermal energy in air, water and ground, and refine it into highly useful thermal energy, with a comparatively small amount of driving energy. Heat pumps enable us to build a sustainable society based on the use of renewable energy. They make seasonal energy storage possible. Heat pumps help us move energy through time and space.

In the EU Directives EPBD, RES and ErP, heat pumps are a key enabling technology to reach the EU target of a reliable, affordable and sustainable energy supply. The EU RES target of 20% renewables in 2020 hinted at the right energy sources to use, but a clear definition of "renewable" was needed. European Commission eventually defined renewable energy sources to include thermal energy captured from air, ground and water by heat pumps. This means that heat pump technology has a great potential for reaching the RES target in the short term at low cost as the technology is already available. Industry sales statistics from European Heat Pump Association data give a total of 2.64 million heat pumps sold between 2005 and 2010. The market growth of heat pumps has been on average 30% per year since 2003.

The IEA road map for heat pumps envisions a dramatic increase of heat pump market share for space and water heating, with total worldwide installed units for heating and cooling reaching almost 3.5 billion by 2050. Today's 800 million installed heat pumps must then grow four-fold. The total installed capacity of heat pumps for space and water heating must grow to 6.6 times today's level, but more R&D is needed to further improve heat pump efficiency. The roadmap sets goals of 20% improvement in COP by 2020 and 50% by 2030.

The recast EPBD demands "nearly zero-energy" as a requirement for all new buildings by January 2021. Furthermore EU member states must stimulate the transformation of existing buildings undergoing renovation into nearly zero-energy buildings. Conversion to heating and cooling systems based on ground source heat pumps and air-to-water heat pumps is a well-proven measure to approach nZEB requirements. Also installation of exhaust air heat pumps can help meet nZEB requirements during major renovations, although the latter solution has a considerably greater electricity usage.

At the REHVA World Congress Clima 2010 in Antalya the growing awareness of heat pumps as a means to reach energy efficiency in buildings became apparent. More sessions and presentations were focused on heat pumping technology than at any previous Clima conference. This growing interest reminds us that both heat pumps and HVAC engineers are essential for building the future sustainable society to which we aspire.

Is it possible to achieve zero energy demand while rebuilding multi-dwelling buildings?

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Introduction

In the newly recast directive on the energy performance of buildings (2010/31/EU), there is a demand that "nearly zero-energy buildings" are to be a requirement for the construction of new public buildings from 1 January 2019 and for all new buildings from 1 January 2021. In addition, the member states are to undertake the measures needed to ensure that when buildings undergo a major renovation, the energy performance of the building, or the renovated part of the building, is improved so that it meets the minimum requirements regarding energy performance to the extent that this is technically, functionally and economically feasible. The requirement is to be applied to the renovated building, or the renovated unit, as a whole. The member states are to stimulate the transformation of buildings that are being renovated into nearly zero-energy buildings.

In order to achieve such a change, a number of measures that promote this aim are needed, as well as a stricter set of guidelines for construction and rebuilding. The Swedish Energy Agency has developed a strategy for the implementation of the recast energy directive that was submitted on 18 October 2010 to the Ministry of Enterprise, Energy and Communications. In the strategy, target levels are proposed for the promotion of nZEB (nearly zero-energy buildings) for major renovations of buildings in accordance with **Table 1**. The levels refer to the highest permitted energy use.

Electrically-heated buildings are buildings in which the installed electric power for heating is greater than 10 W/m². Installed power is the total electric power that can be received by the electrical heating appliances that are needed to maintain the intended indoor climate, domestic hot water production and ventilation when the maximum power needs of the building prevail, that is, during the design outdoor winter temperature.

Table 1. Proposed levels for the highest permitted energy performance in renovated flats, the so-called nZEB requirements (kWh/m^2, year).

Building	Annual energy use for heating, comfort cooling, domestic hot water provision and other shared services in the building (kWh/m^2) Climate zone		
	I	II	III
Flats that have a heating system other than electric heating	105	90	75
Flats with electric heating	70	55	40

At the same time, the National Board of Housing, Building and Planning has produced new building regulations that are to apply when changes are made to buildings. These regulations are currently under consideration. Demands are made in part at the component level and in part for the entire building during major renovations.

Rapid change is needed in the renovation concept

Taken together, the above entails a large and rapid change for the construction and real estate sector, together with its suppliers of components and energy. In order for the sector to be able to prepare effective renovation concepts with relevant energy-efficiency measures in combination with effective heating techniques, a thorough impact analysis is needed of some representative existing multi-dwelling buildings. Based on the results of such an impact analysis, different renovation concepts can be developed for the building types that represent substantial parts of the existing stock. The impact analyses is financial supported by The Swedish Energy Agency's R&D program for resource effective cooling- and heating systems, called EFFSYS+.

Many of the modernist, multi-dwelling buildings built in the boom years between the end of the Second World War and the start of the oil crisis require and are awaiting substantial renovation work. The next opportunity after this for profitable rebuilding may not be available for another 40 years. To motivate complete renovation concepts in place of separate component measures, new renovation concepts need to be developed that manage a renovation down to the nZEB level.

If new renovation concepts down to nZEB are used during all rebuilding works involving multi-dwelling buildings until 2020, there is an energy-saving potential of 1–2 TWh annually. The technical potential, that is, the potential with an increased pace of rebuilding, is considerably higher.

Multi-dwelling buildings in Sweden

About half of the population of Sweden lives in multi-dwelling buildings. These contain approximately 2.4 million flats, with a total of about 180 million square metres. In 2009, the multi-dwelling sector used about 26 TWh for heating and domestic hot water provision. Heating was dominated by district heating, which represented 84% of the total heated area. Of the total energy use for heating and domestic hot water provision, 91% is from district heating, 5% is from electricity, less than 2% is from oil and the remainder is from natural gas and biofuel.

Just over half of the multi-dwelling buildings were built between 1950 and 1975. Most of these are today, or will soon be, in need of renovation. Multi-dwelling buildings can differ greatly regarding size, shape, materials, building technique, etc. The most common types are low-rise apartment buildings, high-rise blocks of flats and tower blocks.

Figure 1. Example of low-rise apartment building.

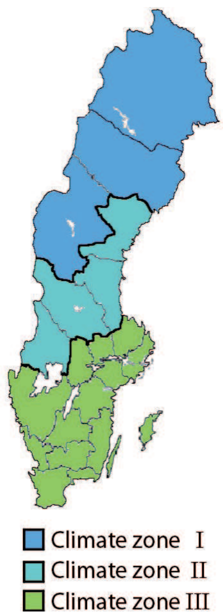
Figure 2. Examples of high-rise blocks.

Low-rise apartment buildings have been the dominant building type from the 1930s and onwards. They are often 3 to 4 stories high and are built as long, detached structures. Each story can be reached by several stairwells, often without an elevator. During the 1960s and 1970s, high-rise blocks of flats became very common as a part of the industrialized construction of the million homes programme. These high-rise blocks of flats are multi-story buildings, with an elongated form, usually 8–9 stories high, built on a rectangular ground plan and equipped with elevators. Tower blocks are free-standing buildings with a stairwell located in the core of the building. Tower blocks began to be used in the 1930s and were four to five stories high, but they became common first in the 1940s. Since the 1950s, the height of the buildings has increased, and often includes eight to ten stories.

Impact analysis

An impact analysis has been carried out of the energy-efficiency measures that are needed in combination with different heating systems to meet the new demands during major renovations. The impact analysis has been conducted by different types of buildings being combined with different packages of energy-efficiency measures and different heating systems. The energy performance of each combination has been calculated and compared with the proposed nZEB demands during major renovations.

Four building types were investigated: low-rise apartment buildings, high-rise blocks of flats, tower blocks and a small multi-dwelling building containing 6 flats. The building types were located in Sweden's three different climate zones, and three building ages were investigated. There were thus thirty-six different combinations considered. U-values (heat transfer coefficients) varied depending on the age of the building and its geographical location. The estimated



heating requirements in these different types of buildings were compared with the national statistics for measured values.

In order to investigate how the energy performance of the buildings can be improved, the following energy-efficiency measures were examined: measures addressing electricity use for shared services in the building, measures addressing domestic hot water provision, loft insulation, window replacement, facade renovation and the installation of a heat recovery system between the exhaust air and the supply air. The measures were investigated in twelve different packages of measures, and an analysis was then made of which heating systems could meet the remaining energy needs. Four different heating systems were examined. These were retaining district heating, complementing district heating with an exhaust air heat pump, converting to a ground-source heat pump or an air-to-water heat pump.

The target levels are different for the different heating alternatives. For the exhaust air heat pump, a size was chosen with an installed power of less than 10 W/m², which entails target levels of 105, 90 and 75 kWh/m² in the respective climate zones, that is, the same target levels as apply for district heating. For ground-source heat pumps or air-to-water heat pumps, the target levels for electrically heated buildings apply, that is 70, 55 and 40 kWh/m² in the respective climate zones.

Measures addressing electricity use for shared services in the building include a package of efficiency measures for lighting, electricity for countering ice formation in gutters, etc. Measures addressing domestic hot water provision contain a package of measures to improve efficiency by having better fittings, individual gauges or solar heating.

Heat pumping technologies can be the solution

The results show that heat pumping technologies will be important in the renovation of multi-dwelling buildings. The larger multi-dwelling buildings, low-rise apartment buildings, high-rise blocks of flats and tower blocks, give largely the same results. The type of building has little importance in determining which package of measures in combination with which heating system will meet the nZEB requirements during a major renovation. The building age also has little effect. However, the climate zone does have considerable importance in determining which package of measures in combination with which heating system will meet the nZEB requirements during a major renovation.

Heat pumping technologies become more and more advantageous the further north the building is located. This is a direct consequence of the difference being constant between the nZEB requirements during major renovations for flats that are electrically heated and for flats that have another heating system than electric heating.

Largely the same measures in low-rise apartment buildings, high-rise blocks of flats and tower blocks

Retaining district heating in large multi-dwelling buildings such as low-rise apartment buildings, high-rise blocks of flats and tower blocks, requires a substantial package of measures in order to meet nZEB requirements. For buildings that were constructed in the period 1950–1975, all the considered measures must be carried out, that is, measures addressing electricity use for shared services in the building, measures addressing domestic hot water provision, loft insulation, window replacement, facade renovation and the installation of heat recovery. For buildings constructed after 1976, nZEB requirements can be reached during major renovations without the need for facade renovation.

Ground-source heat pumps are most advantageous in climate zone I, where installing ground-source heat as a single measure is enough to meet nZEB requirements during major renovations. The exception to this are low-rise apartment buildings built in the period 1950–1960, which also require measures addressing electricity use for shared services in the building and measures addressing domestic hot water provision. In climate zone II, it is sufficient to install ground-source heat as a single measure for buildings constructed after 1976. For older buildings, ground-source heat pumps must be combined with the installation of heat recovery. In climate zone III, measures addressing electricity use for shared services in the building must be carried out, together with the installation of ground-source heat pumps and heat recovery. Low-rise apartment buildings and tower blocks built in the period 1950-1960 also require measures addressing domestic hot water provision and loft insulation.

Air-to-water heat pumps in climate zone I must be combined with the installation of heat recovery in order to meet nZEB requirements during major renovations. For low-rise apartment buildings and tower blocks built during the period 1950–1960, measures addressing electricity use for shared services in the building and measures addressing domestic hot water provision must also be carried out. In climate zone II, air-to-water heat pumps must be combined with the installation of heat recovery, measures addressing electricity use for shared services in the building, measures

Table 2. Possible packages of measures for buildings of the following types: low-rise apartment buildings, tower blocks and high-rise blocks of flats. (x = always needed, (x) = needed depending on the age or type of building)

Climate zone		Measures addressing electricity use for shared services in the building	Measures addressing domestic hot water provision	Loft insulation	Window replacement	Facade renovation	Heat recovery
I	District heating	x	X	X	X	(x)	X
	Exhaust air heat pump	(x)					
	Ground-source heat pumps	(x)	(x)				
	Air-to-water heat pumps	(x)	(x)				X
II	District heating	x	X	X	X	(x)	X
	Exhaust air heat pump						
	Ground-source heat pumps: alternative 1						X
	Ground-source heat pumps: alternative 2	(x)	(x)	(x)	(x)		
	Air-to-water heat pumps	(x)	(x)	(x)			X
III	District heating	x	x	X	x	(x)	X
	Exhaust air heat pump						
	Ground-source heat pumps: alternative 1	x	(x)	(x)			X
	Ground-source heat pumps: alternative 2	x	x	X	x	(x)	
	Air-to-water heat pumps	(x)	(x)	(x)	(x)	(x)	X

addressing domestic hot water provision and loft insulation. Low-rise apartments buildings constructed during the period 1950–1960 also require window replacement. In climate zone III, the installation of air-to-water heat pumps and heat recovery in combination with measures addressing electricity use for shared services in the building, measures addressing domestic hot water provision, loft insulation and window replacement are needed. Low-rise apartment buildings also require facade renovation.

In **Table 2**, the different packages of measures are summarised that are needed in this impact analysis to meet nZEB requirements during major renovations of low-rise apartment buildings, tower blocks and high-rise blocks of flats.

Exhaust air heat pumps can be the winner

Exhaust air heat pumps are a relatively simple measure that may become advantageous during major renovations of multi-purpose dwellings. By installing an exhaust air heat pump that is less than 10 W/m² and retaining district heating for peak load, nZEB requirements can be achieved during major renovations of flats that have another heating system than electric heating, that is, 105, 90 and 75 kWh/m² in the respective climate zones.

The installation of exhaust air heat pumps meets nZEB requirements during major renovations as a single energy efficiency measure for in principle all of the considered large multi-dwelling buildings: low-rise apartment buildings, high-rise blocks of flats and tower blocks. The alternative however has a considerably greater electricity usage than the package of measures with ground-source heat pumps or air-to-water heat pumps.

Difficult for small multi-purpose dwellings to meet nZEB requirements

It is more difficult for small multi-purpose dwellings to meet nZEB requirements during major renovations. In short, some form of heat-pumping technology or the installation of solar electricity is needed to meet the standards adopted in this impact analysis. The proposed collected package of measures, that is, measures addressing electricity use for shared services in the building, measures addressing domestic hot water provision, loft insulation, window replacement, facade renovation and the installation of heat recovery, in combination with retaining district heating, is not sufficient to meet nZEB requirements during major renovations. Retaining district heating requires a renewable energy source of some type, such as solar cells being installed, in addition to the extensive package of measures. Another alternative is to install exhaust air

Table 3. Possible packages of measures for buildings of the type: small multi-dwelling building (x = always needed, (x) = needed depending on the age of the building).

Climate zone		Measures addressing electricity use for shared services in the building	Measures addressing domestic hot water provision	Loft insulation	Window replacement	Facade renovation	Heat recovery
	Exhaust air heat pump	x	x	(x)	(x)	(x)	
	Ground-source heat pumps	x	x				
	Air-to-water heat pumps	x	x	x	x	(x)	x
	Exhaust air heat pump	x	(x)	(x)	(x)		
	Ground-source heat pumps: alternative 1	(x)	(x)	(x)	(x)		x
	Ground-source heat pumps: alternative 2	x	x	x	(x)		
	Air-to-water heat pumps	x	x	x	x	(x)	x
	Exhaust air heat pump	x	(x)	(x)	(x)		
	Ground-source heat pumps	x	x	x	x	(x)	x
	Air-to-water heat pumps	x	x	x	x	x	x

heat pumps and retain district heating for periods of peak demand. However, even in this case, a package of measures is required, which would need to include the implementation of measures addressing electricity use for shared services in the building, measures addressing domestic hot water provision, loft insulation and window replacement. Small multi-dwelling buildings constructed after 1976 can however satisfy nZEB requirements during major renovations by the use of exhaust air heat pumps, measures addressing electricity use for shared services in the building and measures addressing domestic hot water provision. Air-to-water heat pumps also require an extensive package of measures, including measures addressing electricity use for shared services in the building, measures addressing domestic hot water provision, loft insulation, window replacement, facade renovation and the installation of heat recovery. With a ground-source heat pump and a package of measures including measures addressing electricity use for shared services in the building, measures addressing domestic hot water provision, loft insulation and window replacement, requirements can be met in most cases in climate zones I and II. In climate zone III, the installation of heat recovery is also needed.

Table 3 summaries the different packages of measures that need to be taken to meet nZEB requirements during major renovations of small multi-dwelling buildings of the type considered in this impact analysis.

Life cycle costs can be decisive

The quantitative estimates made in this study provide an indication of the possible packages of measures that could be relevant during major renovations of multi-dwelling buildings. The study uses buildings of different types in order to analyse which solutions can be of interest, which provides results that can differ greatly in particular cases. Technical difficulties have not been taken into consideration, such as that it can be difficult to install heat recovery in tower blocks, or that the flow of exhaust air to an exhaust air heat pump can be difficult to collect in long low-rise apartment buildings.

The studies reported in this article only include the technically possible packages of measures. In order to obtain a complete supporting documentation for decision making, an economic analysis also needs to be made, which takes into consideration the life cycle costs for the different packages of measures. One of the alternatives that was not discussed here is to combine heat pumping technologies with solar cells in the production of electricity. Electricity produced by solar cells placed on or in connection to the building is not included in nZEB requirements.

Heat pumps – a renewable energy technology?

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"Are heat pumps using renewable energy?" was one of the questions most vigorously debated during the consultation on and preparation of the Directive on the promotion of the use of renewable energy sources (2009/28/EC). Positions, especially in the European Commission did only change very slowly towards acknowledging the full renewable potential from air, water and ground. Eventually, agreement was found between the negotiating parties to augment the definition of renewable sources by "aerothermal" and "hydrothermal" sources – to be used by heat pump technology. Article 2 states: 'energy from renewable sources' means energy from renewable non-fossil sources, namely wind, solar, **aerothermal**, **geothermal**, **hydrothermal** and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases. 'Aerothermal energy' means energy stored in the form of heat in the ambient air; 'geothermal energy' means energy stored in the form of heat beneath the surface of solid earth (geothermal energy was already part of existing renewables definition which included energy sources usable for the generation of electricity); 'hydrothermal energy' means energy stored in the form of heat in surface water.

This change in wording must be seen as a huge success of those lobbying for it and as a tremendous change in many decision-makers positions in the European Commission, the European Parliament and the Member States. It has also considerable consequences on the treatment of heat pump technology in European and national legislation. While sometimes it is still debated whether or not heat pumps use renewable energy, a reference to the RES Directive solves most disputes. Thus heat pumps will eventually find their way into all legislation related to the use of (renewable) energy, energy efficiency and GHG emission reduction.

Counting of renewables from heat pumps in statistics

The renewable share of heat pumps is determined based on final energy. **Figure 1** illustrates the ratio of auxiliary to renewable energy for an electric heat pump.

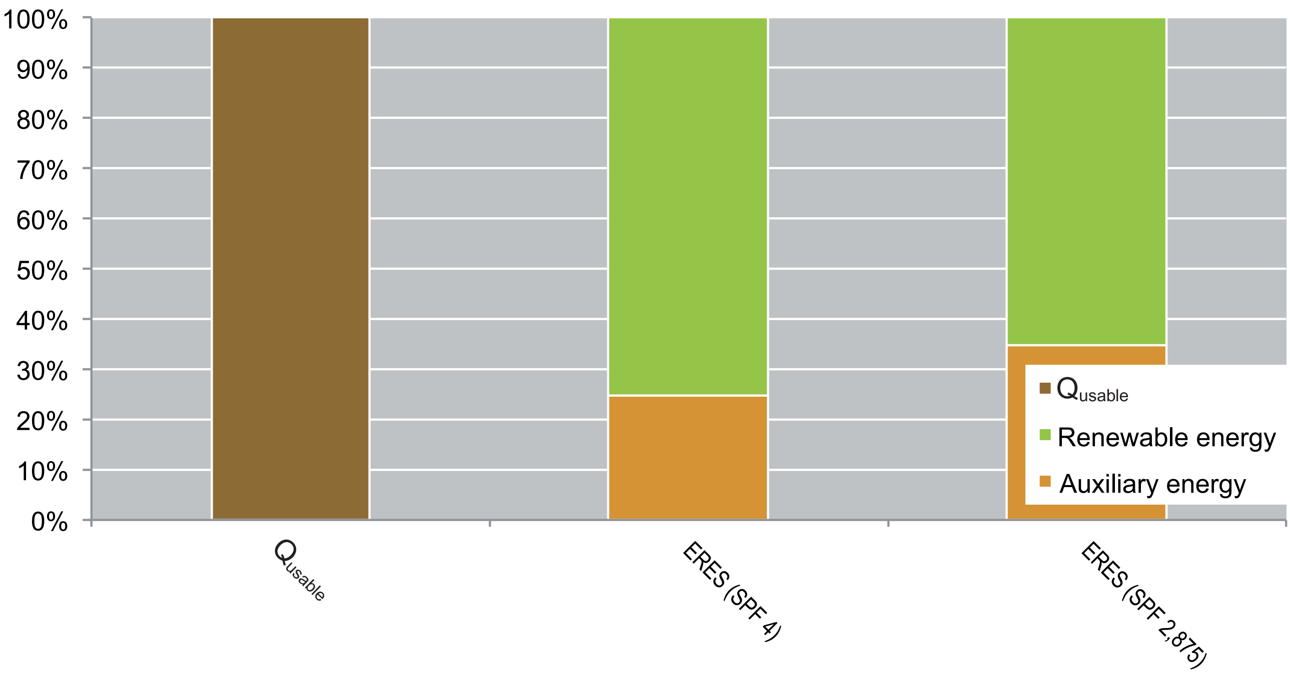

Figure 1. Renewable and auxiliary energy shares of heat pumps based on eta = 0,4. (Source: own)

Its calculation is described in Annex VII of the RES-Directive:

(1) $E_{RES}=Q_{usable} * (1-1/SPF)$
with Q_{usable} being the total usable heat delivered by the heat pump.

Q_{usable} is only counted for those heat pumps, which achieve 115% efficiency based on primary energy use.

(2) SPF > 1.15 * 1/eta
with eta being the ratio between total gross production of electricity and the primary energy consumption for electricity production.
Eta shall be determined by EUROSTAT as an **average value for Europe**.

Column 2 of **Figure 1** shows the renewable final energy contribution for a standard heat pump with an average SPF of 4 based on eta = 0,4. According to (1) heat pumps with an SPF of 4 provide 75% of renewable energy. Based on (2) heat pumps need to achieve a minimum SPF of 2,875 for their RES contribution to be counted. A heat pump with this SPF provides 64% of final renewable energy (see column 3). In terms of primary energy, this implies still 28% of renewable energy.

A greening electricity mix will effect the minimum SPF by an improvement of eta. The EUROSTAT calculation for 2007 data results in eta_{2007} = 43.8%. Electric heat pumps need to achieve a minimum seasonal efficiency (SPF) of 2,63 or better. According to preliminary discussion, the equivalent requirement for thermally driven heat pumps will be $\mathbf{eta_{thermal} = 1}$.

In addition to the calculation of eta, the European Commission needs to provide guidelines on how to estimate values for Q_{usable} and SPF values for different heat pump technologies and applications by the end of 2011 – the deadline was originally set for 1.1.2013 but was moved forward as these values are essential for calculating RES from heat pumps.

The described calculation will be used in EU energy statistics to determine each Member State's achieved share of renewable energy (via their National Renewable Energy Action Plan – NREAP) and the achievement of the 20% renewable target on the aggregated EU level.

RES contribution from heat pump sales – status quo and target

Member States are obliged to set trajectories on how to achieve their mandatory RES targets for 2020. This is done via their NREAPs. The evaluation of all plans shows a target contribution from heat pumps towards the 2020 use of final energy of 1 298 TWh (111 587 ktoe). Ambition among Member States is however not evenly spread. While the UK aims to cover 36% of its RES target by contributions from heat pumps, others like Portugal, Bulgaria, Estonia, Malta and Romania have not (yet) included the technology into their plans (see **Figure 2**).

The technologies proven yet unused potential may however turn into an advantage in the future if some of the foreseen measures to achieve the national renewables targets (as set in the NREAPs) fail. In this case, heat pump technology would be an easy alternative for Member States to still achieve their targets: it is available, reliable, efficient and cost per kWh_{th-RES} is comparatively low.

Today's contribution of the heat pump stock can be determined from industry sales statistics. Based on EHPA data, a total of 2,64 mio. heat pumps were sold from 2005 to 2010 (the actual stock is higher, as significant heat pump markets existed before 2005 in at least Austria, France, Germany, Italy, Sweden and Switzerland).[1] The European Heat Pump Industry – represented by different associations – has worked with EUROSTAT on defining a feasible approach to include their RES contribution from heat pumps in EU energy statistics.

Using average values for SPF and Q_{usable} the total annual contribution of the heat pump stock is 27,37 TWh, saving 6,83 Mt of GHG emission annually [2]

When comparing both the contribution from the stock and the Member States' targets, an average approximate growth rate of 15% per year is necessary to achieve the cumulated target of the NREAPs. This pretty much reflects the growth rate observed over the past five years and can thus be understood as a business as usual scenario. Real growth can be expected to exceed 15% as markets are developing and this development will further be fuelled by heat pump recognition in institutional

1 Nowak, T.; Murphy, P.; Forsén, M. 2011: Outlook 2011 (data preview, final version forthcoming). Brussels

2 Nowak, T. 2011: Heat pumps in Europe – a "smart" future? IEA heat pump conference 2011. https://www.hpc2011web.org/.

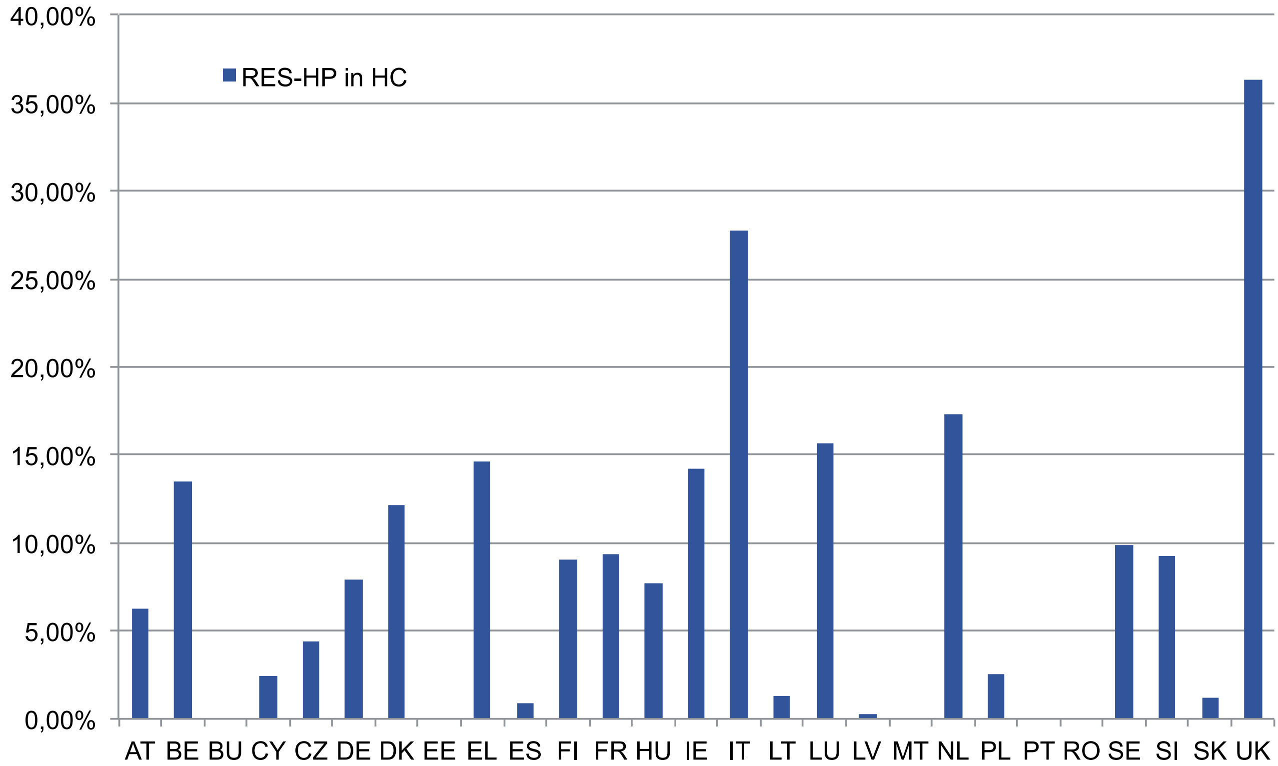

Figure 2. Contribution from heat pumps to achieve the designated RES share in heating and cooling. (Source: own, based on NREAPs and EREC 2011). EREC 2011: Mapping renewable energy pathways towards 2020, Brussels, download (6.5.2011) at http://www.repap2020.eu/fileadmin/user_upload/Roadmaps/ERECroadmap-V4_final.pdf

and financial support schemes as well by greater technology visibility in statistics.

In addition, the growing share of intermittent renewable sources from solar and wind requires peak shaving and storage options to better integrate them. Heat pumps are well equipped to provide demand side potential, thus helping indirectly to further increase the share of renewable sources in the energy mix. Smart grids and improved in-house controls will play an important role in balancing supply and demand towards a more sustainable energy supply.

Multiplier effects

A positive leverage effect exists between the amount of renewables used by heat pumps and its determining values – SPF and eta. The more efficient heat pumps become, the larger their RES contribution and their possible field of application. The more efficient the average EU power mix is, the better the efficiency of heat pumps primary energy use. As well, a better eta enlarges the number of heat pumps included in statistics, as the threshold value decreases. Both effects increase the amount of RES used by heat pumps.

A promising outlook

The basis for strong market growth is prepared. Heat pumps are reliable, efficient and affordable, and can add to comfort and building quality by providing heating, cooling and sanitary hot water. The industry is ready to deliver on these promises. Foreseeable developments in technology will result in even better technology and opening additional application fields for the technology, namely in the renovation sector, hybrid systems and large applications.

Government recognition of heat pump technology based on the minimum efficiency threshold as well as the upcoming energy label related to the implementing measures of the Ecodesign Directive will provide transparency and channel demand towards more efficient systems. From the RES perspective this means that the full amount of renewable energy used by heat pumps will be countable as contribution towards Member States' and the European Union's 2020 renewable energy targets.

Investment in heat pumps pays off over time – for individuals and governments alike. Now is the time to switch to higher gear to reap the benefits of these technologies.

The International Energy Agency's Roadmap for Energy Efficient Heating and Cooling Systems in Buildings:

The role of heat pumps

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Summary

The International Energy Agency's (IEAs) *Energy Efficient Buildings: Heating and Cooling Systems* roadmap lays out the "big picture" vision for stakeholders in the buildings sector of the goals for heating and cooling equipment if the world is to achieve a 50% reduction in energy related CO_2 emissions by 2050. It provides concrete advice on how to achieve the savings in the BLUE Map scenario, highlights the key technology options, the barriers they face and the policy options to address these barriers. Heat pumps are a particularly important abatement option and are a key part of the solution for buildings in this roadmap.

Energy Technology Roadmaps at the IEA

We are facing challenging economic times, with a range of events yet again highlighting the vulnerability of the global economy to high energy prices. At the same time, all nations share a responsibility to ensure their energy sectors become more sustainable and more secure to manage the risks and impacts of climate change.

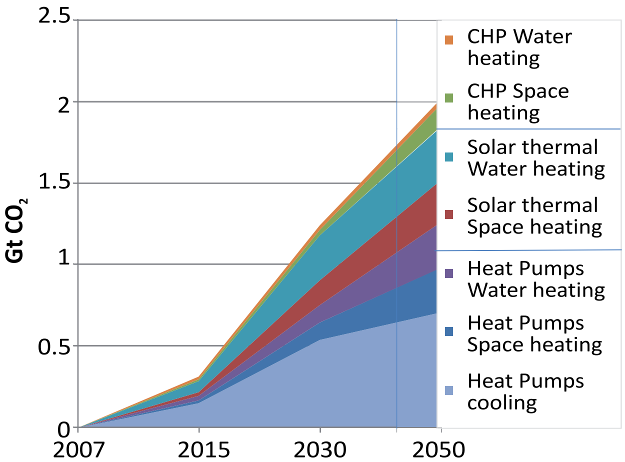
The need for action is urgent, but drastically changing energy infrastructure and end-use equipment on a national scale is a complex and expensive undertaking. Careful planning is required to ensure that limited resources are devoted to the highest-priority, highest-impact actions in the near term while laying the groundwork for longer-term improvements.

The International Energy Agency's (IEAs) energy efficient and low-carbon technology roadmaps are strategic plans that help to outline activities, policies and organisation to transform the market for a given technology or grouping of technologies. The roadmaps are designed to identify, and provide solutions to overcome, all of the technical, market, R&D, regulatory, consumer acceptance, legal, etc. barriers to the uptake of these technologies as well as lay out specific goals and outcomes for technology R&D, development, costs and performance and deployment.

The Buildings Sector in Context: The IEAs Energy Technology Perspectives Scenarios

In the Baseline scenario, carbon dioxide (CO_2) emissions from the buildings sector, including those associated with electricity use, nearly double from 8.1 gigatonnes (Gt) of CO_2 to 15.2 Gt CO_2 until 2050. In the BLUE Map scenario CO_2 emissions are reduced by 12.6 Gt CO_2 from the Baseline scenario level in 2050, with 6.8 Gt CO_2 of this reduction being attributable to the decarbonisation of the electricity and heat sectors. This reduces the direct and indirect CO_2 emissions attributable to the buildings sector to 2.6 Gt CO_2 in 2050, one-third of the 2007 level.

The heating and cooling technology solutions that will allow the building sector to shift to a more sustainable energy and environmental future contribute 2 Gt CO_2 of the total savings. The increased deployment of heat pumps for space and water heating, as well as the deployment of more efficient heat pumps for cooling account for 63% of the heating and cooling technology savings.



CO_2 emissions reductions in buildings from heating and cooling systems in the BLUE Map scenario (reduction below the Baseline). Key point: Heat pumps play a critical role in reducing CO_2 emissions from heating and cooling equipment in the buildings sector.

The Heating and Cooling Systems for Buildings Roadmap

The roadmap establishes a "big picture" vision for stakeholders in the buildings sector[1] of the goals for heating and cooling equipment, and provides concrete advice on how to achieve the savings in the BLUE Map scenario. It highlights the key technology options, the barriers they face and the policy options to address these barriers.

The roadmap lays out a well structured and comprehensive vision of the appropriate and feasible long-term goals for the sector, as well as identifying specific milestones and packages of policies to achieve these goals. An integral part of the roadmap is the identification of the role and contribution of different stakeholders in this process and how they will need work together to reach the common objectives outlined in the BLUE Map scenario. The key areas addressed in this roadmap are:

- The status, costs and future developments in selected heating and cooling technologies;
- The areas where specific R&D needs have been identified, as well as future technology development goals and milestones
- Specific deployment goals for heating and cooling technologies in the buildings sector
- Policy recommendations, to overcome existing and future barriers to heating and cooling technologies, and their timing to ensure achievement of the BLUE Map scenario results.

The key technology options for heating and cooling in buildings have been narrowed down to those with the greatest long-term potential for CO2 emissions reductions, or facilitating them. This roadmap covers the following technologies for space and water heating, heat storage, cooling and dehumidification:

- Active solar thermal
- Combined heat and power (CHP)
- Heat pumps for cooling and space and water heating
- Thermal storage

The increased deployment of heat pumps for space and water heating, as well as the deployment of more efficient heat pumps for cooling account for 23% of the savings. Solar thermal systems for space and water heating account for around 12% of the savings. CHP plays a small but important role in reducing CO_2 emissions, as well as assisting in the balancing of the renewables-dominated electricity system in the BLUE Map scenario.

Heat Pumps in Buildings in the BLUE Map Scenario

The potential energy and CO_2 savings from the wider use of heat pumps are substantial, given their high efficiency and relatively low market penetration for space and water heating. The efficiency of today's BAT for air-conditioners is considerably higher than average installed efficiencies, offering further scope for CO_2 emission savings. When combined with thermal storage, to enable load to be shifted out of peak periods, heat pumps could also help reduce the costs in the BLUE Map scenario of integrating a high share of intermittent renewables into the grid.

The BLUE Map scenario will require nothing short of a complete transformation of the way space and water heating is provided, while the global average efficiency of cooling systems will have to more than double by 2050. Highlights for space and water heating include:

- The share of useful space and water heating demand met by fossil fuels will drop to between 5-15% (depending on region) from today's position of dominance.
- Installed solar thermal capacity will increase by more than 25 times today's level to reach 3 743 GWth by 2050.
- The installed capacity of distributed CHP in buildings will be 50 times greater than today's level, reaching 489 GWe in 2050.
- Heat pumps will dramatically increase their share of space and water heating, with total installed units for heating and cooling reaching almost 3.5 billion by 2050.
- Thermal energy storage will be associated with half of all space and water heating systems by 2050.

The deployment of today's heat pump systems will give way in the BLUE Map scenarios over time to integrated systems providing space heating, water heating and cooling, and hybrid heat pumps systems (i.e. combined with solar thermal systems) for improved efficiency. Although heat pumps are often competitive today, the large-scale global deployment of heat pumps for heating and higher efficiency air-conditioning devices will require additional R&D, demonstration programmes and support policies to help transform the market for heating and cooling.

1 The "Buildings sector" is defined as the buildings of the residential and service sectors. The service sector includes activities related to trade, finance, real estate, public administration, health, food and lodging, education and commercial services (ISIC codes 50-55 and 65-93). This is sometimes also referred to as the commercial and public services sector. The energy savings potential in industrial buildings is not covered in this roadmap, although the technologies described in this roadmap are those also found in these buildings.

Worldwide, around 800 million heat pumps are estimated to be installed in the residential sector in 2010 and this will grow to 3 500 million in the BLUE Map scenario.[2] Three-quarters of today's heat pumps are small air conditioning or reversible units with an average capacity of 2.5 kW. Their contribution to space and water heating at a global level is modest. The estimated total installed capacity of heat pumps for space and water heating needs to grow to 6.6 times today's level, critically, with installed capacity for water heating going from virtually nothing today to 1 300 GWth by 2050.

The roadmap sets goals for a 20% improvement in COPs by 2020 and 50% by 2030, at the same time as reducing costs by 15% in 2020 and by 25% in 2030. Further R&D, as well as wider deployment will help to achieve these goals, while at the same time heat pump systems capable of providing simultaneous space and water heating, and cooling for all market segments need to be developed, as well as hybrid systems (*e.g.* heat pump/active solar thermal systems) to achieve very high efficiencies and CO_2 emissions reductions.

To achieve the level of deployment envisaged in the roadmap, and hence the energy and CO_2 emissions reductions, will require strong, consistent, stable and balanced policy support. The roadmap recommends the policy focus should be in the following four main areas:

– Increased technology R&D, significant demonstration programmes and the development of beyond BAT technologies.
– Improved information for consumers and agreed, robust metrics for analysing the energy and CO2 savings of heating and cooling technologies, as well as their life-cycle financial benefits.
– Market transformation (deployment) policies, which are ideally technology neutral, to overcome the current low-uptake of the many energy efficient and low/zero carbon heating and cooling technologies.
– International collaboration to foster greater collaboration in R&D, best-practice policy packages and deployment programmes to maximise the benefits of policy intervention, as well as the transfer of technical knowledge between countries and regions.

2 This is based on a mixture of actual installed capacity data (predominantly in the OECD); and sales data married with assumptions about product lifetimes. Although some confidence can be had in the order of magnitude of the total, better publically available data is still required. This figure is thought to be accurate to within 50 million units.

The market transformation policies need to focus on addressing current and future market barriers (lack of prioritisation of energy efficiency, capital market barriers, absence of external costs) and address market failures (lack of adequate number of market participants, lack of perfect information, principal-agent problems, transactions costs and delays, inadequate financial mechanisms etc). The roadmap recommends specific policies to:

– Improve information availability and relevance for decision makers.
– Improve heating and cooling system actors (architects, engineers, installers, etc) knowledge and competence with energy efficient and low-carbon heating and cooling technologies
– Implement deployment policies to accelerate uptake and reduce costs through economies of scale.
– Expand quality assurance schemes to encompass the entire sector and provide consumers with the confidence to invest.
– Remove regulatory, policy, fiscal and other barriers.

Achieving complete market transformation in the building sector is an extremely challenging policy goal, due to the large number of individual decision-makers and the fact that the buildings sector is large, diverse and fragmented. A clear message from the roadmap is that policies need to be "broad", to tackle the range of barriers, and "deep" to ensure the barriers faced by all those in the decision-making chain are addressed. Another clear message is the important role heat pumps play in achieving CO_2 emissions reductions in the buildings sector, in the OECD for space and water heating and in non-OECD countries for water heating and cooling. 3ε

Sources:
Energy Efficient Buildings: Heating and Cooling Systems 2011 (c) OECD/IEA, 2011
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Potential of solar assisted ground source heat pumps with unglazed solar collectors for French office buildings

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Abstract

This paper presents a system configuration for a Solar Assisted Ground-Source Heat Pump (SA-GSHP) system that was developed and implemented in an experimental test platform at EDF R&D. The proposed configuration uses low-cost unglazed solar collectors and is intended to deliver a significant reduction in capital costs, which represent the main barrier to a wider adoption of GSHP systems, particularly in France.

Experimental results are used to validate component models in the TRNSYS simulation program. The model is then used to assess the potential of the proposed SA-GSHP configuration in French office buildings. Simulation results obtained for a heating-only application show that this configuration can lead to a 30% reduction of ground heat exchanger length and a 20% reduction of capital costs.

Introduction

In spite of proven benefits in terms of energy performance and integration of renewable energy at the building level, Ground-Source Heat Pump (GSHP) systems have a limited market penetration in France. The main barrier to a wider deployment of this mature technology resides in higher capital costs compared to competing technologies. These capital costs are mainly due to the cost of the ground heat exchanger (GHE), which represents about 50% of the total costs in typical systems.

The required GHE size – hence the associated capital costs – depends on the ground heat load, i.e. the amount of heat that is extracted from or rejected to the ground by the heat pump. The peak ground load is a major factor in the required GHE length, but the highest monthly value and the yearly average value (thermal annual imbalance) also play a role.

In a heating-dominated (or heating-only) building, the heat extracted from the ground will show a large yearly imbalance. Bernier (2007) has shown that in typical cases, the peak ground load is responsible for about 65% of the GHE required length, the maximum monthly load accounts for 20 to 25%, and the annual imbalance accounts for 10 to 15% of the sizing.

Studies have shown that hybrid systems that include a secondary heat source (or heat sink in the case of a cooling-dominated system) to supplement the ground can lead to a significant reduction of the required borehole length. The secondary heat source can be a conventional gas boiler but solar collectors provide an opportunity to use renewable energy for that purpose. Some studies have shown a good potential in some applications (e.g. Chiasson and Yavuzturk, 2003) but Rad et al. (2009) and Cauret et al. (2008) have shown that systems including glazed collectors present some challenges to achieve significant capital cost savings. The cost of solar collectors is not negligible compared to the GHE cost, and solar heat is mainly provided in summer – which can only influence the yearly imbalance but not the other factors that have an impact on the required borehole length.

The present study investigates a configuration of SA-GSHP equipped with unglazed solar collectors. These low-cost collectors have a lower thermal efficiency at high fluid temperature, but they present the advantage of being capable of operating as a water to air heat exchanger even when the solar radiation is very low or zero. In relatively mild climates such as in France, the air temperature is often higher than the ground return temperature even in winter, allowing some heat recovery. An adequate coupling of these collectors with the GHE could deliver a reduction of the yearly imbalance but also the maximum monthly load, with a very favourable cost ratio compared to the avoided GHE length.

The paper first presents the results of an experimental study of a full-scale SA-GSHP system. These experiments were performed by EDF R&D to assess the relevance of the proposed system configuration. Then, simulation results obtained with a TRNSYS model of the SA-GSHP system for a typical French office building are presented and used to discuss the potential interest of this technology in similar applications.

Ground-source heat pump coupled with unglazed solar collectors

The proposed configuration for the SA-GSHP system uses unglazed solar collectors as a supplemental heat source for the brine-to-water heat pump. The solar array is connected in series with the GHE loop, and it can be used either to complement the ground when the heat pump is operating or to recharge the ground when the heat pump is off.

The selected solar collectors are flexible elastomer modules connected to plastic manifolds and laid out on a flat roof. The advantages of these collectors for our application are their low cost (8 times cheaper than typical glazed collectors), light weight (5 kg/m² empty), ease of installation, and their ability to operate as water to air heat exchanger at low temperatures and low solar radiation levels.

The solar collectors are connected to the source-side loop of the heat pump through a three-way valve, as shown in **Figure 1**. This valve is controlled by two temperature measurements, at the GHE outlet (T_{ghe_out}) and at the solar collector outlet (T_{ung_out}). In heating mode, the valve opening is controlled as follows:

If $T_{ghe\_out} > T_{ung\_out}$: the unglazed collectors cannot provide useful heat. The solar collector branch is closed and the brine goes directly to the heat pump.

If $T_{ghe\_out} < T_{ung\_out}$: the unglazed collectors are able to provide useful heat. The solar bypass branch is closed and the brine circulates through the collectors. If the heat pump (HP) is operating the solar collectors act as a supplemental heat source to increase the HP inlet temperature, and the fluid is moved by the HP circulating pump. If the heat pump is off, the fluid is moved by a dedicated pump in the solar loop and used to recharge the ground.

Experimental study

Description of the experimental installation

The experimental set-up was installed on a field-test platform at EDF R&D centre. This platform is designed to test GSHP systems in a natural climate for periods up to several years. It consists of a 3 000 m² area dedicated to the installation of ground heat exchangers and a control room equipped with heat pumps (see **Figure 2**). The operation of each heat pump is driven by a control loop which mimics the operation of a real building (house) according to real-time weather. Thus, whenever heating is required the heat pump is activated to heat a 500 litre tank which acts as the heat distribution system of the house. The heat load produced by the heat pump is rejected outside using an air cooler loop.

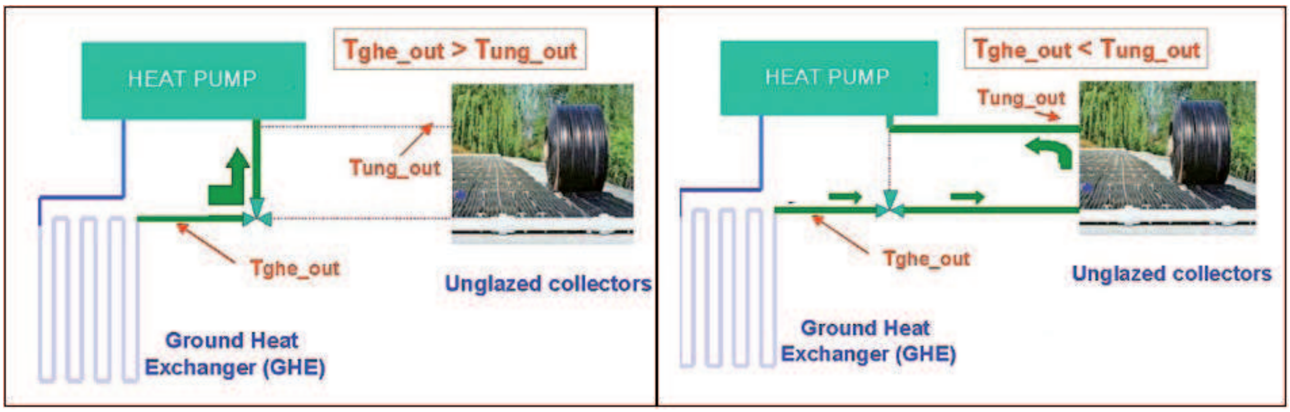

Figure 1. Hybrid heat source principle (photo: HELIOPAC)

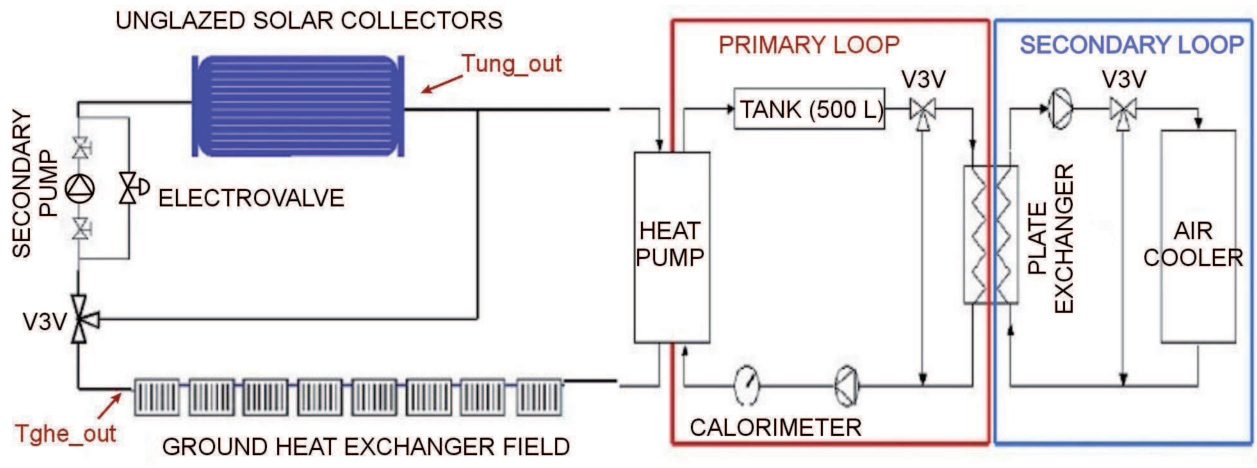

Figure 2. Experimental set-up at EDF R&D field test platform.

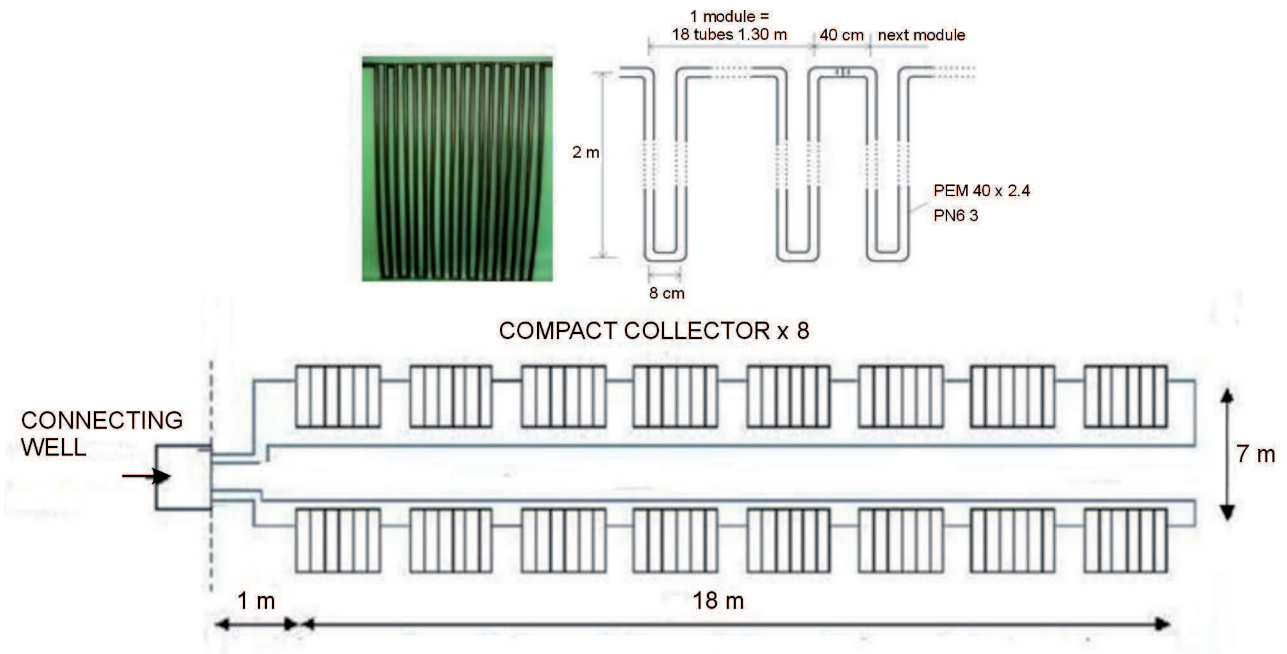

Figure 3. Experimental compact collectors field. (Figure: IVT Industrier AB)

The setup tested in the present study is shown in Figure 2. It consists of a 9 kW brine-to-water heat pump connected to a ground collector field and optionally in series with a 20 m² area of unglazed solar collectors. The GHE field consists of compact collectors provided by IVT Industrier AB. These collectors are in the shape of modules of 1 500 x 2 000 mm (width x height), installed vertically in narrow 3 meters deep trenches. Up to ten modules can be connected in series. These modules and the constituted field are shown in **Figure 3**. The performance of these modules was previously assessed at the EDF R&D center and is reported in (Cauret and Bernier, 2009). The unglazed collectors – so-called "helio-atmospheric" collectors – were manufactured and installed by Heliopac (CSTB, 2008).

The GHE sizing was intentionally reduced by 50% compared to the heat pump manufacturer recommendation to validate the assumption that the installed area of unglazed solar collectors would compensate for that reduction.

Instrumentation and control

The platform is equipped to measure, with a time step of one minute, key parameters of the heat pump operation, ground loop and solar loop behaviour. The main parameters recorded during the experimental study were as follows: ambient temperature and humidity, global horizontal solar radiation, water (load side) and brine (source side) flow rates, water temperatures at condenser inlet and outlet, brine temperature at evaporator inlet and outlet, brine temperature at unglazed collectors inlet and outlet, and ground temperatures (within a few cm of the GHE, and in an undisturbed location).

As seen previously, a motorized three-way valve controls the coupling of ground and unglazed collectors, based on two temperature measurements. The control criteria are based on the difference between these two temperatures. The opening threshold for the solar branch has been fixed at 0.5°C to avoid instability issues whereas the closing threshold was chosen as 0.3°C.

Results and system operation

This SA-GSHP system worked in heating mode, from November 15th, 2007 to May 16th, 2008. These tests demonstrated a very predictable operation of the unglazed collectors during the winter. Heat injection by the unglazed collectors generally occurred a few hours after heat extraction by the heat pump.

Monthly results are shown in **Figure 4**. The Figure shows the heat that is directly provided by the GHE to the heat pump evaporator when it is operating (Heat from the GHE to the HP) and the heat that is directly added by solar collectors when the HP operates (Direct solar heat to HP). The unglazed collectors also provide heat to the GHE loop when the heat pump is off, which is represented by the third bar series in the Figure (Solar heat to the ground). The resulting balance on the ground is the difference between the heat

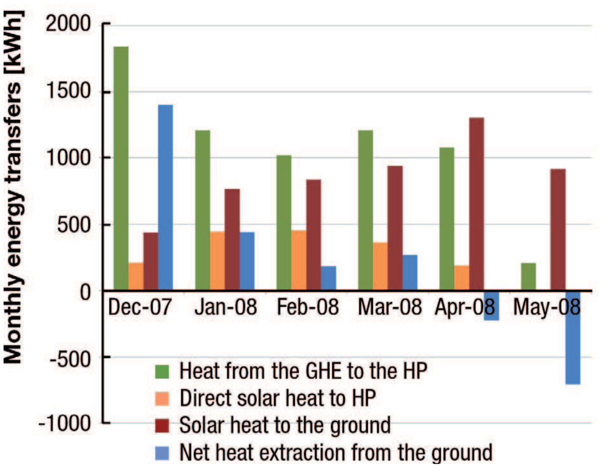

Figure 4. Monthly heat transfers in the SA-GSHP system.

extracted (provided to the HP) and the heat added by the solar collectors. That quantity is also shown in the Figure (Net heat extraction from the ground). At the end of the heating season, the solar collectors provide more heat to the ground than what is extracted by the heat pump, which leads to a negative net extraction (i.e. heat addition).

Over the heating season, the heat pump provided 15500 kWh to the load side, corresponding to the heating load of a standard 150 m² house. The total energy collected at the heat pump source side (evaporator) is 11 300 kWh. This energy was mostly provided by the GHE (85%, or 9 600 kWh) with some direct contribution by the solar collectors when they were operating in series with the GHE (15%, or 1 700 kWh). In addition to this direct contribution, the unglazed collectors also injected 5 650 kWh into the ground when the heat pump was off, leading to a significant reduction of the seasonal imbalance. If the heat pump was operating in a conventional GSHP system, the net heat extracted from the ground over the heating season would be 11 300 kWh. In the SA-GSHP system, the net heat extracted from the ground is (9 600 – 5 650) = 3 950 kWh, i.e. only 35% of the heat extraction in a conventional GSHP system.

The regular operation of the unglazed collectors permitted to maintain a higher evaporator inlet temperature, although somewhat less stable than in a classical GSHP system. The resulting seasonal coefficient of performance (COP) is 3.7, which compares favourably with classical designs.

SA-GSHP potential in a French office building

The experimental study presented above demonstrated the feasibility of a SA-GSHP based on unglazed collectors. A simulation study was carried out to assess the potential of this system configuration in a typical French office building. The simulation was performed with the TRNSYS program (Klein et al., 2010) using component models that were validated against the experimental results presented above. The performance and cost of the proposed SA-GSHP configuration are compared to those of a conventional GSHP system in a heating-only application. Details are provided in a paper to be presented at the upcoming Building Simulation conference (Helpin & al., 2011).

The simulation case study uses a vertical borehole heat exchanger. The TRNSYS model includes the whole SA-GSHP system and a building model. The selected building is based on (Filfli, 2006). It is a well-insulated

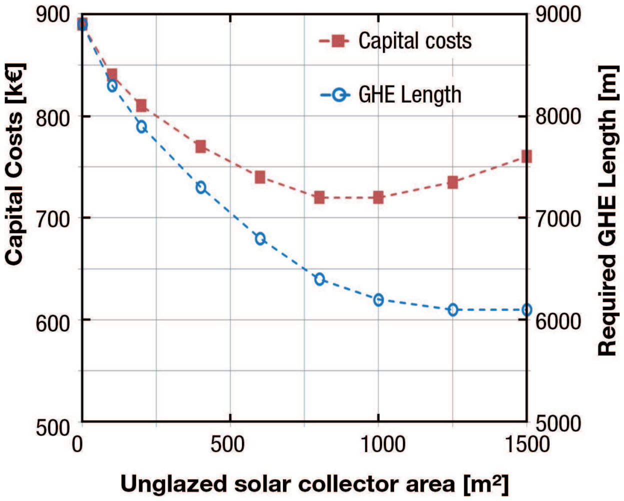

Figure 5. Impact of unglazed collectors on the required GHE sizing and the capital costs.

building (representative of new build) with 3 floors of 1 250 m² each, located close to Paris. The peak heating load is 284 kW. The sizing criterion for the GHE (both for the conventional GSHP and for the SA-GSHP) is a minimum ground return temperature of -1°C over 20 years of operation. The resulting required length is shown in **Figure 5**. This figure also shows the resulting capital costs based on average unitary costs: 100 €/m for GHE (installed and connected) and 100 €/m² for unglazed collectors (installed), taxes excluded.

These simulations show a maximal capital costs reduction of 20% with a corresponding GHE length reduction of 30%.

Discussion and conclusions

This paper presents a configuration of solar-assisted ground source heat pump (SA-GSHP) based on a series coupling of ground and unglazed solar collectors.

An experimental study carried out during an entire heating season on a field test platform validates this concept of hybrid heat source, with a reduction in required ground heat exchanger (GHE) length of 50% for a residential configuration with compact vertical GHE modules.

A simulation study was performed for a typical French office building in a heating-only application. The simulation compares the proposed SA-GSHP design with a classical GSHP system using a vertical borehole GHE. Initial results show that the required GHE length can be reduced by about 30%, delivering a 20% reduction in capital costs.

Our study shows that SA-GSHP systems have an interesting potential to deliver significant capital costs reductions in heating-dominated and heating-only applications in the French context. Further investigation is required to refine sizing methodologies and to better assess system performance for different building types, GHE configurations and geographical locations. A specific modeling tool for SA-GSHP sizing and performance simulation has been developed at for that purpose.

System operation in cooling mode should also be investigated, as there is a potential conflict between providing a low condenser inlet temperature to the heat pump and the need to circulate fluid through the solar collectors to protect them from too high stagnation temperatures. Different options are possible but they have not been investigated in this paper.

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The ground source heat pump project at Lakeshore, Bristol (UK)

– an example of a commercial turn-key heat pump project

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Introduction

The Lakeshore development[1] of eco homes is being realized in Bristol (UK), see **Figure 1**. The project converts the Grade II listed building, former home of Imperial Tobacco to modern apartments set over it's own lake and in 10 acres of green space.

Figure 1. The Imperial Tobacco building during refurbishment (2011).

The design of the building and building services are ambitious, the energy efficiency meets the best 'A' low energy criteria (BREEAM rating). One of the key systems to achieve this ambitious energy rating is the ground source heat pump system which, together with a biomass boiler, will provide the thermal energy for space heating and tap water production. When operational it will be among the largest residential installations in the UK.

As with any ambitious project, and especially with a project that retrofits an existing building, there are many design challenges and issues that need to be considered. One of these challenges is the fact that originally the ground source heat pump system would be used to provide a certain amount of cooling to the apartments, which could unfortunately not be realized due to limitations of the system. This means that the additional thermal regeneration of the ground will not be available. Another issue with the system was that the borehole heat exchanger system was already installed and could not be increased in size.

Groenholland Geo-Engineering was contracted to provide a turnkey heat pump system for this development. To be able to achieve the goals of energy efficiency

1 http://www.urbansplash.co.uk/residential/lakeshore

within the boundaries of the existing borehole heat exchanger system and functioning as a heating-only system, a new design study was undertaken. This study first of all calculated the energy use of the building, on an hourly basis, with a dynamical building simulation. This model was created in TRNSYS (Klein et al 1976) and was used to carry out a number of sensitivity analyses on different important parameters affecting energy usage profiles. Also, the model results were used to select the appropriate capacity and capacity steps of the heat pump system. Subsequently, the model results were used to calculate the possible thermal use of the ground store under different scenarios, for this analysis the standard program EED (Earth Energy Designer, Eskilson et. al 2000) was used.

The modelling we present here has been carried out more from an engineering point of view and not from a scientific point of view. Therefore different approaches have been used and combined in a practical way:

- A very detailed energy simulation study to correctly calculate the overall energy performance of the building, needed for the capacity selection and borehole heat exchanger thermal performance.
- A standard approach to the thermal analysis of the borehole heat exchanger system, allowing the rapid evaluation of different scenarios.
- A simple spreadsheet based approach to performance analyses and achieved energy savings.

After the design studies had been completed the heat pump plant was designed and constructed as a pre-manufactured turnkey plant room system. This system was adapted from the highly modularized Groenholland standard plant room modules, using sophisticated but standardized controls and control algorithms. This pre-manufactured and pre-commissioned system means only little time is spent in construction of the plant room on site while at the same time a high standard of manufacturing quality can be delivered. In this case for instance, full commissioning of the completed plant was carried out in less than one day.

In this paper we present these three aspects of the Lakeshore system in more detail: the building energy simulation, heat pump plant design and evaluation and some impressions of the turnkey plant room system.

Dynamical building energy simulation

The design of a borehole heat exchanger, or the thermal performance of an existing borehole heat exchanger system, depends to a large extent on the thermal load. One of the main challenges in ground source heat pump design is the fact that the source water temperature (the water entering the heat pump from the ground) is dynamically linked to the heat pump operation (capacity and running time in a typical cycle) as well as to the long-term cumulative loading.

The long-term thermal loading (seasonal loads during the complete operational life span of the system) affect the store temperatures in the whole ground volume. During winter, when heat is extracted, the total store will cool down, while in summer (during cooling operation or natural regeneration) the store will heat up. On top of this, during each operational cycle of the heat pump, the local temperature in and around the borehole will react to the heat being injected or extracted by that specific pulse.

It is therefore essential to have accurate energy use information. Usual practice, to design the plant on capacity needed for a transmission loss at one set of specific conditions, is not sufficient. Ideally hourly heating and cooling loads, or at least monthly loads and capacity, need to be available. The hourly heating and cooling loads can be used to select the total capacity of the heat pump system, the size of the individual heat pump stages and the size and configuration of the borehole heat exchanger ground source system.

To create a complete model of each space in the building would be very time consuming and expensive. In the simulation model therefore the building is structurally represented by different zones, where each zone represents a distinct unit (zone) made up of several spaces, which is defined by exposition and location in the building, size and boundaries with the environment or other spaces. In this way not every individual space needs to be modelled. The total load of the building is then calculated by multiplying the number of units of that specific type with the results from the model.

For every zone the following factors influencing the loads are considered:

1. Structural make-up of zone: floors, walls, roof, windows (materials and orientation).
2. External climate: temperature, irradiation, and relative humidity.
3. Boundaries with other spaces.
4. Infiltration and ventilation schedule.
5. Heating and cooling schedule.
6. Heating and cooling gains (persons, computers, lighting, other).

The model calculates the hourly heating and cooling demand for each zone. The building total demand is calculated by multiplying the load of each zone type by the number of times this zone occurs in the building.

The building (**Figure 2**) comprises seven floors, with a total of 286 apartments

The apartments are distributed over the different levels as follows:
Level 1: .... 72 apartments
Level 2: .... 87 apartments
Level 3: .... 31 apartments
Level 4-6: .... 25 apartments
Level 7 (top):... 21 apartments

The smallest apartment measures 28.7 m², the largest 115.4 m². Average size is 61.5 m², total apartment floor area is 17598 m².

For each floor 1, 2-4 (which are identical), 5, 6 and 7 several different zones have been defined in such a way that a representative sample of apartments has been obtained. In essence all different apartment types with different boundaries and different expositions have been selected. In total 67 distinct types have been defined.

For each modelled space the constructive data were taken from the architects drawings and translated to floor, wall, ceiling types, windows etc. The resulting thermal characteristics were compared with the building-specification of U-values as a check on the input.

The model uses the ambient conditions from the climate record of Cardiff (UK). The parameters ambient temperature, relative humidity, solar zenith and azimuth angle, total and beam radiation on the horizontal as well as total radiation and incidence angles on tilted surfaces are used. Minimum ambient temperature in the record is -4.78°C, maximum ambient temperature in the record is 24.6°C. The temperature graph for the model-year is given in **Figure 3**. Another important aspect of the simulation are the temperature set points and internal gains, these are summarized in **Table 1**.

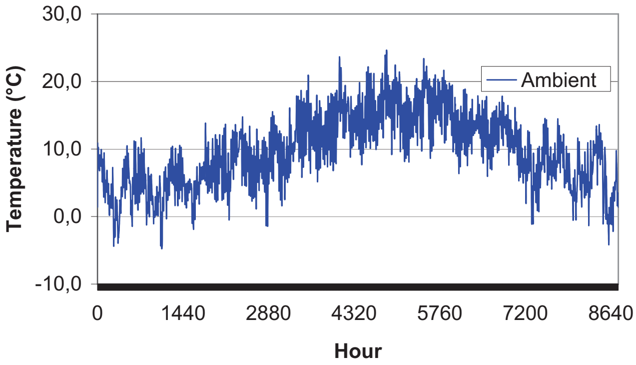

Figure 3. Ambient temperature TRY record Cardiff (Wales, UK).

Based on the calculations, the total heating load of the building is 831 MWh/year, with a maximum peak load of 570 kW. Average apartment load for each level is shown in **Figure 4**.

Loads per apartment for the lowest (P1) and highest (P7) levels are higher due to higher losses across the (unheated) foundation and roof boundaries. Also the size of the apartments plays a role.

Figure 5 shows the yearly load demand curve, we can see that the load curve is not very steep towards the higher capacities. Nevertheless, with only 200 kW capacity already over 70% of the load is covered, with 400 kW 98% of the total yearly demand is covered.

Figure 2. Vertical (side) view of the development.

Table 1. Internal load schedules used for the TRNSYS simulation.

Internal gain or set point	Value	Schedule	
Temperature set point heating (occupied spaces)	21°C	No heating June, July & August	
Temperature set point heating (unoccupied spaces)	16°C	No heating June, July & August	
Temperature set point cooling	-	-	
Infiltration	*Calculated from the ventilation and infiltration rates provided (VENTILATION PART F)*	-	
Ventilation			
People (low activity rate)	depends on apartment size & bedrooms (2, 3 or 4 persons)	between 7:00 and 17:00 only one person present	8.5 h/day
Electrical gains	230 W	11 h/day	
Lights	5 W/m^2		

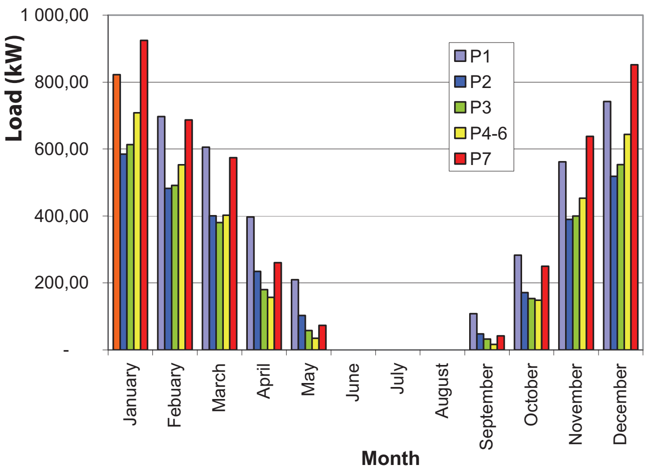

Figure 4. Average monthly apartment load per level.

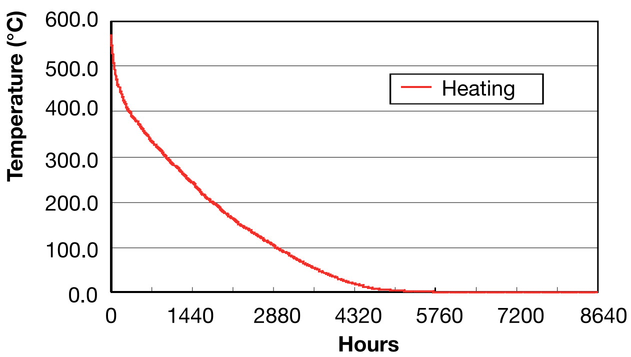

Figure 5. Load demand curve, space heating load.

Table 2. Sensitivity results, percentage total yearly load and peak load change.

Parameter	App. level 4, Zone V (K)		App. level 7, Zone III (P)	
	Load	Peak load	Load	Peak load
Infiltration +30%	+4	+1.9	+2.5	+1/5
Window frame insulation	-14.5	-4.7	-11.8	-5.5
Night-setback (23:00 - 8:00 - 18°C)	-34	+6.5	-26.5	+23.6

The maximum demand (peak capacity) per apartment type has also been extracted from the model results, a summary is presented in the full version of this article, available at www.rehva.eu. Peak capacities range between 1 kW and 4.3 kW. As is to be expected with apartments differing significantly in size and exposition the range of capacities if fairly large. At the same time however, one may conclude that the average capacity is not very big, attributable to the energy efficient design. With apartment sizes varying between about 40 and 115 m² the heating load varies between 20 W/m and 31 W/m.

The sensitivity of the model to certain boundary conditions has been investigated by running a number of simulations for the apartment with the lowest (level 3, zone 5 apartment type K) and highest (level 7, zone 3 apartment type P) heat loss. Results are given in **Table 2**.

Infiltration (leakage) has little effect on the total or peak loads, using aluminium frames on the outside instead of insulated frames clearly has a larger effect. If a night setback to 18°C is simulated large changes in load results, with lower total loads but higher peak demand (due to the need for warming up the spaces in the morning).

Although the sensitivity study performed is very limited in scope it does indicate that effects of constructive changes are relatively small, while changes in user behaviour may affect loads much more.

In addition to the space heating loads, also the domestic hot water (DHW) loads need to be covered by the system. These loads are not calculated by the dynamical TRNSYS model, but have been estimated based on a report issued by the BRE (June 2005). This report indicates that a household in the higher income range will use about 50 litres of hot water per person per day. The hot water demand for 286 apartments with, on average, 2 adults per apartment (574 persons in total), can be calculated by a further assumption of the temperature difference. Assuming source water supply is

10°C and needs to be heated to 60°C the total load is: 50 * 572 * 0.9998 * 4192 * 50 = 1.67 MWh/day.

Adding these loads to the previously calculated space heating demands results in the following total load profile (**Table 3**).

Normally the DHW load is met in a few hours per day, if additional capacity needs to be added to the base (heat pump and biomass boiler) capacity resulting from the space heating load profile analyses remains to be discussed.

Borehole heat exchanger model

The essence of the borehole design is to size the borehole heat exchanger so that it is able to maintain the required operating temperature bandwidth given the energy profile (heating and regeneration operation) and the associated heat pump equipment. This can be achieved by either changing the size of the BHE system to the full load profile or, in the case of a hybrid heat pump system, by balancing the amount of thermal energy exchanged with the ground, or by a combination of both.

For the present case the size (number of loops & installed depth) of the borehole heat exchanger system was fixed, therefore the design focused at optimizing the energy exchange with the earth, the amount of regeneration and heat pump capacity.

The operational temperature bandwidth selected will affect performance of the heat pump significantly. Running at low evaporating temperatures during heating should be limited, as the drop in performance (both efficiency and total output) is significant. At the same time, the heating system of the building should be configured for low temperature heating to achieve the highest performance rates from the heat pump equipment.

The installed borehole heat exchanger is made up of 88 standard single U-loop heat exchangers installed in boreholes of about 100 meters depth.

The target of the ground source heat pump installation was to provide about 50% of the total heating load with the ground source heat pump system, and achieve a reduction of CO_2 emissions of 15%. Using these data we can calculate the design parameters for the ground source heat pump system, including the required minimum performance factor. **Table 4** shows the energy savings calculation for the total load of 1441 MWh by comparison with a standard gas-fired boiler system (conversion factors based on DEFRA 2009 data).

Table 3. Space heating, domestic hot water and total load profile (MWh).

	Space Heating (MWh)	Domestic Hot Water (MWh)	Total (MWh)
January	180.11	51.77	231.88
February	140.41	46.76	187.17
March	113.51	51.77	165.28
April	54.56	50.10	104.66
May	17.78	51.77	69.55
June	0	50.10	50.10
July	0	51.77	51.77
August	0	51.77	51.77
September	6.36	50.10	56.46
October	40.30	51.77	92.07
November	115.00	50.10	165.10
December	163.11	51.77	214.88
Total	**831.14**	**609.55**	**1440.69**

From this table we can see that, with a heat pump system supplying 50% of the total heating load (720 MWh) the target of 15% savings on emissions is realized if the Seasonal Performance Factor of the heat pump system (including circulation pumps) is at least 3.2.

The performance of the heat pump depends typically on the source and sink temperatures. Typical data is given in **Table 5**, to achieve the required performance level the source temperature should, on average, be above 1°C when the sink (heating) temperature is 35°C and above about 5°C when the sink (heating) temperature is 45°C.

The temperature of the heating system, as the same loop is used for the DHW production, is required to be 45°C, therefore the design temperature for the ground source heat exchanger was set at an source temperature for the heat pump of 5°C, as the heat pump operates at a temperature difference of 5K this means the average fluid temperature is about 2.5°C.

Ground source heat pump plantroom design

A 350 kW heat pump installation is selected, this will mean that the heat pump system will have about 2150 full load hours per year. There are also a number of considerations with regard to the Domestic Hot Water Supply (in essence the heat pump heats the system to 45°C after which the boilers raise the temperature further to 55°C), therefore a fairly large buffer capacity (3 m³) was selected as well to provide sufficient buffer capacity for combined heating / DWH peak loads.

For the system two heat pumps were selected. Together these heat pumps provide about 355 kW capacity, with

Table 4. Energy savings (CO_2 Emission Factors 0.204 for gas, 0.543 for electricity, DEFRA 2009).

Scenario	MWh		COP-SPF	MWh expended	%	CO_2 factor (kg/kWh)	ton CO_2	%
Gas boiler	Heating	1,440	0.85	1,694		0.204	346	
	TOTAL			**1,694**	**100**		**346**	**100**
Heat pump	Heating 50%	720	3.2	225		0.543	122	
Gas boiler	Heating	720	0.85	848		0.204	173	
	TOTAL	**1,440**		**1,073**	**63**		**295**	**85**

a total of 8 compressor stages. Therefore the system not only provides the peak capacity but is also able to modulate down to fairly small loads for efficient running in part load conditions. Using two heat pumps in stead of one allows some optimization of pumping strategy as well as providing a more robust system as failure (or maintenance) on one heat pump will still leave the system with about 180 kW of base capacity.

The design was finished by calculating pressure losses across the different system circuits and selecting the appropriate pumps. Each heat pump has been fitted with individual circulation pumps for the evaporator and condenser circuit. These are connected to the heating buffer and to the low loss header of the Borehole / Solar array control unit.

In the case of Lakeshore the plant room consists of:

- Two heat pump units
- One main heat pump control unit with sensors, valves for the heat pumps and the main control panel.
- One heat transfer unit with secondary pump and plate heat exchanger
- One Borehole Heat Exchanger/Solar skid with circulation pumps, valves, heat exchanger.
- Pressurization units and expansion facilities.

The complete plant room was pre-manufactured and transported to site where it was piped-up, connected to the heat pumps and commissioned.

Conclusions

In this paper we describe a case study of the design and actual implementation of a ground source heat pump system for a large apartment building that is being completely refurbished. We have used several design techniques and approaches that are not fully "scientifically" accurate, but allow a robust and efficient system to be designed and constructed.

One of the main points that the design study needed to address was the calculation of the thermal loads of the building. For a successful ground source heat pump installation at this scale it is essential to have high-quality data on the projected energy use of the building. One of the main caveats with GSHP design is the fact that it cannot be designed on capacity alone, but actual total energy use is needed. In addition, over sizing the capacity will result in very poor performance of the system as the electrical consumption of compressors and pumps will not be matched by sufficient load from the building.

Table 5. Indicative heat pump Co-efficient of Performance (COP) for different source and load side temperature conditions.

COP efficiency	Evaporator in / out Water (°C)		Condenser in / out Water (°C)	
2.9	-5	-10	30	35
3.7	1	-4	30	35
5.4	7	2	30	35
1.9	-5	-10	40	45
2.2	1	-4	40	45
3.4	7	2	40	45

The strategy of using pre-designed and standardized design units that can be easily adapted to different uses has proven its worth on many occasions. The standard design allows the development of several sophisticated control algorithms without excessive cost as the development and testing time can be shared between many projects. The off-site construction allows a high level of quality control and efficient manufacturing as the work can be carried out in a workshop with all tooling and which is always accessible. The pre-commissioning and proven control strategy and software means that the "turn-key" quality of the system is real: if all components have been integrated in the plant room, the final commissioning is very quick and usually achieved in less than a day.

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Drilling at Brf Ljuskärrsberget, in south Stockholm, Sweden. Photo: ENSTAR AB

Ljuskärrsberget

- the largest ground source heat pump project in Sweden

ENSTAR AB is a Swedish company that designs, delivers and maintains large heat pump solutions for buildings. Last year, ENSTAR AB delivered the largest ground source heat pump project ever in Sweden, based on the total length of boreholes: 35.880 meters.

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The customer, Brf Ljuskärrsberget, consists of several buildings with a total of 500 apartments. The area is located in south Stockholm. Approximately 1000 residents live in these apartments, and all residents are represented by a board with the responsibility to insure that necessary improvements, investments and maintenance of the property are made in both the short term and, as in this case, long term. This kind of organisation and ownership is quite common in Sweden and involves all the apartment holders in larger investment decisions. The decision taken in May 2010 by the Brf Ljuskärrsberget board was definitely a large one - the total investment was 60 MSEK (approx 6.5 MEuro).

The easiest part of the decision was the ground source heat pump system which is, in Sweden, an ordinary solution from a technical point of view. The more difficult part to decide was if, when and how to convert the existing direct electric heating system to a modern distributed water heating system. 500 apartments and 1000 residents meant many different opinions and thoughts. The project started with a preliminary study in 2006. After two years with the help of energy consultants to make an evaluation of every applicable solution available on the market, the board concluded that a distributed water heating system in combination with ground source heat pumps would be the best solution in the long run. One component in the financial evaluation was the availability of a governmental subsidy worth approximately 10 MSEK (1 MEuro), based on the combination of heat pump technology and conversion to a distributed water heating system at the same time. However, this strategic decision taken by the board in 2008 required confirmation by all the residents. It took two years, a lot of information, meetings and voting to finally get full support for the project.

The contract was signed in late June 2010, and the project was initiated quickly with drilling activities started in early July 2010. The scope of the project allowed different phases of the work – drilling, installation of radiators, installation of heat pumps, etc. – to go on simultaneously, and by February 2011, all buildings were heated with the new system.

The inside-the-apartment heating system is quite conventional and we will here focus on the heat production part of the total solution, although the distribution part has a major role in the whole project.

System description

The facility is divided into 13 groups of four buildings, each served by its own central plant located in one of the four buildings. The heated water is distributed directly in the building housing the central plant room and through a culvert system to the other three. When designing the system, there was an option to build one single central plant to serve all 52 buildings. However it would have been a less efficient solution in this case, due to high transmission distribution losses and higher investment costs. The so-called satellite solution used here is preferable under some circumstances.

Each group of buildings has a borehole configuration with 12 boreholes connected through collection wells which reduce the number of pipes going into the central room. A very vital part of the design work was to simulate and analyze the whole system before deciding the required total length of active borehole and the exact locations and angles of the boreholes.

Domestic hot water is also provided by heat pumps and as a supplementary solution there are electric boilers in the water heaters if needed temporarily.

Integrated processors in each heat pump communicate via remote control units, and it is possible to monitor and manage all 13 systems remotely.

The Benefits and Outcome

Before the installations, the electricity consumption for heating and domestic hot water was approximately 5200 MWH per year. With the new ground source heat pump system the consumption is anticipated to drop to approximately 1626 MWh/year. Since the project is recently finished we are awaiting the result of a 12 month monitoring period next year. In economic figures the savings will be nominally near 4 MSEK (440 000 Euro) per year based on 2010 electricity costs. Since then the prices have increased and result in even larger savings. Taking into account capital costs and depreciation the savings are as large as 3 MSEK (330 000 Euro) per year when calculating on the part of investment which is dedicated to the ground source heat pump solution. All in all, based on a 60 MSEK (6.5 MEuro) investment there are still savings at 1,5 MSEK (160 000 Euro) per year after capital costs and depreciation for the complete system.

The environmental benefits are huge. The new solution will reduce CO_2 emissions by more than 350 tons per year. The figure is based on the 2010 average emission value from Nordic produced electricity which is traded at Nordpool. The customers have plans to convert the existing contract into a contract based on "Green Electricity". They have also investigated the possibility and benefits from investing in wind power, as a part ownership in a large scale wind power plant. In these both scenarios the CO_2 footprint will be nominally reduced to zero.

Another interesting and positive effect for the householders is the indoor climate. Before the installation of the new system, the electric radiators heated the space unevenly and with the new distributed water heating system the air temperatures are much more uniform and the indoor climate has become much more pleasant

To summarize, Brf Ljuskärrsberget has taken a big step from costly direct electrical heating to invest in a cost efficient ground source heat pump system. Even though the investment is high, the achieved cash flow effect from year one will be positive. In the long term they will save millions of Euros. However the biggest winner in this case is the environment.

Mathias Skoglund, chair of the Brf Ljuskärrsberget board and Jan Enegård, ENSTAR AB. Photo: ENSTAR AB

Fact box:

Total heat pump capacity: 1.3 MW

Supplemental electric boilers: 780 kW

Number of heat pumps: 26

Number of boreholes: 156

Borehole depth: 230 meters per borehole

System build up and description of the 2-stage DAIKIN Altherma Flex Type Air-to-Water heat pump for multi family houses

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Market situation

Over the recent years, the heating market has experienced some significant changes, mainly driven by the upward trend of energy costs and increasing ecological awareness amongst the general public, and amplified by several regulations and incentive schemes. Heat pump technology has been able to profit from this favourable market situation, and this has lead to the successful introduction of heat pumps in general, and air to water heat pumps in particular, as an ecological and economical alternative for traditional combustion based heating.

Economies of scale, easy transfer of available technologies from air to air heat pumps and boiler systems, shorter decision and sales routes and other reasons have put the market focus for air to water heat pumps for residential heating towards solutions for individual single family houses. Looking at building statistics, we see however that these individual houses only account for about half of the existing dwelling stock and even less of the new built dwellings.

For multi-family houses and apartment buildings, the integration of air to water heat pumps systems seems not so straightforward. Up till now, there were two options for integrating air to water heat pumps in multi-family houses or apartment buildings, each with several merits and demerits:

a) the installation of small individual air to water heat pumps in each apartment:

This option gives the greatest flexibility towards the end-user, since he will be fully in control of his own heating system. The end-user can individually decide when he wants to heat (or to cool). The hydraulic installation can remain simple, and there is no need for collective piping. Cost allocation is easy, providing that each apartment has its own electricity meter. The consumption of the heat pump is billed as part of the total electricity consumption of the apartment. The biggest limitation will lay in the installation of the evaporator units. Indoor installation will very often be impossible or unwanted. Outdoor installation might have an impact on the building aesthetics or cause noise disturbance towards direct neighbours (e.g. outdoor units on each terrace). Remote and grouped installation of multiple small outdoor units might be limited by available space (avoid airflow interference between units) or maximum allowable piping lengths.

b) the installation of a large capacity collective heat pump:

With this option, the end-user has no longer full individual control of his heating system. Cooling will only be possible in specific cases, especially if the heat pump is also used for the collective preparation of domestic hot water. Hydraulic installation will require a more complex distribution system, preferably with some buffer to eliminate hunting in times of low demand. Furthermore, if precise cost allocation by heat measurement is required, the hydraulic installation needs to be designed with a single entry to each apartment. Running and other operational costs will need to be allocated by fixed division keys or by individual heat meters. Installation of the fewer but bigger outdoor units will be less influenced by space limitations.

Preferred emitters for apartments remain radiators (or fan coils if cooling is required). The additional screed thickness an underfloor heating installation will require can in extreme cases reduce the number of storeys which can be built within the height limitations of the building. The use of radiators will require higher operating water temperatures.

Typically, apartments in multi-storey buildings will have lower heat loads, due to smaller outdoor wall surfaces and it is even more likely that additional cooling will be required during summer.

Concept explanation

In response of the typical requirements explained above, DAIKIN has developed a 2 staged R410A / R134a cascaded heat pump system for apartment buildings. The concept consists of high capacity VRV® based R410A outdoor units with heat recovery, in combination with individual small capacity R134a cascaded heat pumps. The commercialised product program includes a range of 5 outdoor units with 22.4 to 44.8 kW of heating capacity (20 to 40 kW in cooling) and 2 capacities of indoor units (5.6 and 9 kW heating capacity), available as heating only or as reversible units (with 5 and 8 kW of cooling capacity respectively).

In heating mode, both the R410A cycle of the outdoor unit as the R134a cycle of the indoor units will be operational. R410A will be evaporated in the outdoor heat exchanger, and will condensate in the R410A/R134a heat exchanger of the indoor units. The R134a will condensate in its turn in an R134a / water heat exchanger, allowing water temperatures from 25°C to 80°C. This temperature range allows the use of all types of heat emitters.

By using a cascade of 2 heat pumps, it becomes possible to overcome big temperature differences between source and sink temperature. R410A has better performance at low evaporation temperatures, but the performance drops at high condensation temperatures, whereas R134a will perform better than R410A at high condensation temperatures, but will be low performing with low evaporation temperatures.

Since the R134a cycle evaporates on the R410A heat exchanger, its operation and performance are basically independent from the ambient temperature. The R134a cycle will operate in function of the heating demands (both capacity as temperature), whereas the R410A operation will be focussed on maintaining a semi-fixed intermediate condensation temperature. At low ambient temperatures, the R410A compressor speed will boost to provide sufficient condensation enthalpy to the R410A/R134a heat exchanger[1], leading to only a small capacity drop, unlike single cycle heat pumps.

The capability of heating up the water to high temperatures is also exploited during domestic hot water preparation. The basic mode remains the same as for space heating, except that a 3 way valve will divert the heated water to a heat exchanger coil in a domestic hot water cylinder. Domestic hot water temperatures up to 75°C are possible, without the need to revert to joule effect heaters. A 200 liter tank can be heated up from 15°C to 60°C in 70 minutes, with a COP of 3.0. Once heated, a total of 320 liter of water at 40°C is available for use.

For cooling operation, the R134a circuit of the indoor units is bypassed, and heat is transferred directly between the system water and the R410A low pressure liquid in a separate heat exchanger, comparable to a standard R410A reversible heat pump and providing chilled water of 5 to 20°C.

Due to the use of heat recovery capable VRV® outdoor units, the heat transferred to the R410A circuit during cooling operation of a unit, can again be transferred to the R410A/R134a heat exchanger of any of the connected indoor units. As such, this heat absorbed from cooling can be recovered for the preparation of domestic hot water, or for the space heating of other apartments. To maximize the heat recovery potential, the indoor units can be parametered that the standard temperature setpoint for domestic hot water is bypassed to higher value when heat recovery is active.

The use of VRV® outdoor units allows for a big capacity modulation range, which is necessary in apartment applications (e.g. in summertime when only one unit is operating to prepare hot water). The combination of a variable Proportional Integral (PI) control system and

1 See also the article "New technology for high temperature heat pumps", David Steen, Jan Logghe, REHVA Journal November 2009

refrigerant pressure sensors abbreviate control steps into smaller units to provide precise control in both small and larger areas, continuously adjusting the circulating refrigerant volume in response to load variations in the connected indoor units. This allow also the indoor units of operating independently of each other, even with regards to their operation mode (heating or cooling), offering the end-user full control over his own heating system.

The indoor units are conceived as plug and play units. All hydraulic are included in the unit, which can directly be connected to the emission system of the apartment. The domestic hot water tank is a separate unit, but can be installed on top of the indoor heat pump unit by means of quick couplings, minimizing the installation workload and installation space.

Indoor and outdoor units are connected by a three pipe refnet system, with the possibility to use headers and Y-joints. The installation of this piping is less restrictive and less space consuming compared to a hydraulic distribution system for a collective boiler or heat pump.

By using this system, apartments now also can benefit from the advantages of heat pumps with regards to lower running costs and reduced environmental impact. The basic principles of heat pumps do apply. The quantitative merit is of course dependent of local variables, such as energy prices and CO_2 emission factors for electricity production. Projected in an example for Belgium for instance, we can see a potential running cost reduction of 36%, a reduction of 35% in primary energy use and a 71% in CO_2 emissions when compared to oil.

Conclusion

By combining two advanced heat pump technologies, DAIKIN has developed a unique heat pump concept for apartment buildings offering a unique combination of differentiating advantages:

- High efficiency at high Tlwc (space heating, DHW heating)
- Cooling function
- Providing optimal comfort (individual control per apartment)
- Space and time efficient installation
- Reduced environmental impact
- Savings on running costs

Most of these advantages are not only applicable and interesting for apartment buildings, but also in other applications where a combination of heating, cooling and DHW exist, such as hotels, offices, student dorms, wellness centers, big villas and so on.

Application examples

a) Hyde Park - 7 storey apartment building in Ostend (Belgium)

This would be the typical application for the DAIKIN Altherma Flex Type heat pump. Each apartment has a heat load between 4 and 6 kW, and can as such efficiently be heated by a single indoor module, combined with hot water tanks. The southern oriented large windows make cooling a necessity in summer, allowing for heat recovery in this period. The total heating capacity of 32.5 kW at -7°C can easily be provided by a single outdoor unit, conveniently installed on the roof.

b) HALTON project – social housing project UK

This project consists of the limited refurbishment of 4 buildings, each with 6 or 7 apartments. The existing radiators had to remain in place, which required higher water temperatures. Each of the 4 buildings can be equipped with a single outdoor unit. No cooling is required.

c) HORSELAND Project – France - Manège complex with hotel villas, conference rooms and spa/wellness functions.

Each hotel villa is equipped with several indoor units with associated hot water tanks. Heating and cooling is done by a ceiling heating/cooling system. Dimensioning has been done on the hot water requirements. In a single building, all the indoor units are hydraulically interconnected to one circuit, which distributes heating or cooling to each individual room.

d) XT Sports club – Legnano (Italy)

Replacement of old gas boiler and R22 chiller. Ten indoor units connected to two outdoor units provide the necessary cooling/heating of the fitness hall and the domestic hot water for 16 showers. Huge potential for heat recovery, due to a long cooling season (more than 6 months) and continuous hot water demand from the showers. The domestic hot water tanks will be connected to solar thermal panels. 3E

SB11 HELSINKI

World Sustainable Building Conference

Organised by

CIB iiSBE UNEP SBCI Sustainable Buildings & Construction Initiative VTT ril

October 18–21, 2011

SB11.org

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Old cooling methods benefit from using new technology

Cooling tower control systems depend on accurate and reliable humidity measurement to increase energy efficiency and reduce maintenance costs.

Yani Bettencourt
Vaisala Controlled Environment
Regional Market Manager, Americas.
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Cooling towers are among the oldest and most effective methods of removing heat from a building. Unfortunately, tradition can lead operators to use familiar but unreliable devices that result in inaccurate relative humidity (RH) measurements that compromise tower efficiency. Adopting advanced technology for accurate and reliable RH and temperature measurements is essential for lowering energy use and maintenance costs.

Purpose is to Remove Heat

In HVAC applications, evaporative cooling towers remove heat from the condenser water – water used to cool the refrigerant – in chillers of HVAC systems. During this refrigerant-to-water heat exchange, the refrigerant temperature decreases and the condenser water temperature increases. The heated condenser water is then circulated to the cooling tower, where it is sprayed or splashed onto complex ventilated surfaces, maximizing evaporation that removes heat from the water. The cooled condenser water is then returned to the chiller to continue the cycle.

Wet-bulb Temperature Sets Cooling Limit

How much the condenser water can be cooled is limited by tower design, tower quantity, operating equipment including fans and pumps, and by environmental factors – it can be cooled only as low as outdoor wet-bulb temperature, a function of RH and temperature.

In a perfectly efficient cooling tower, the water leaving the tower is as cold as the wet-bulb temperature. Since no tower is perfectly efficient, tower designers consider its limitations to determine the approach – the approach is the practical difference between the possible and realistic temperatures of water leaving the tower.

The approach is added to the wet-bulb temperature to determine the actual condenser water set point. For example, 21°C (70°F) wet-bulb temperature with 4°C (7°F) approach results in an actual set point of 25°C (77°F) for condenser water discharged from the tower.

"Wet-bulb temperature measurement is similar to a temperature gauge in your car. It tells you how hard you can

run the engine," says Tim Wilcox of WPI, a U.S.-based consulting firm specializing in energy efficiency on a broad range of projects.

"Its information is also used like the speed governor to avoid overrunning the equipment. Inaccurate measurement in either case can do great harm," he adds.

Sources of Error

Inaccurate RH sensors are a common source of erroneous wet-bulb temperatures, misleading control systems and operators. Another source of error is locating the RH sensor too close to the cooling tower, where it is affected by discharge air. Since the wet-bulb measurement must be true measurement of the outdoor ambient air, the RH device needs to be located away from any discharge air.

"If the control systems are receiving a wet-bulb reading much cooler than possible, the operating engineers or the controls will attempt to drive down the condenser water temperatures by engaging more pumps, fans and tower cells. The hardware can't achieve the bogus temperature but the false information will waste energy and risk fouling – if not harming – the cooling towers. A second-rate RH device will lead to an impossible condition," Wilcox says.

Costs of Overrunning

Excessive operation leads to several areas of avoidable operational and capital costs: wasting energy to run the fans more than needed, premature equipment repair, acceleration of mineral build up in the tower fill, and inefficient water use from adding more water to the sump to replace the evaporated water.

In one case that Wilcox cites, investigations concluded that inaccurate readings from an on-site RH device contributed to a cooling tower at a landmark hotel being so excessively run that the tower fill became nearly rock solid with calcium carbonate deposits.

Uneven air flow rising through the plugged fill caused the tower system to be on the verge of shaking apart, damaging the fans and fan shrouds. Operators used fire hoses to keep the chiller plant operating at the height of the summer tourist season. Avoidable capital costs added up to hundreds of thousands of dollars to replace the tower fill.

Vaisala Recommended

"Humidity measurements need to be accurate and maintainable. We specify Vaisala humidity sensors that

Vaisala HMT330 series transmitters deliver high accuracy and excellent long-term stability. RH accuracy is within 1% up to 90% RH and within 1.7% up to 100% RH. Temperature accuracy is within 0.2°C (0.36°F).

we can count on not to migrate into error. We avoid recommending instruments that can go out of calibration in six months, misinforming the control systems and building operators," says Wilcox.

"We see projects that can spend $200,000 a year on cooling tower-related operating costs operated by a $50 sensor that goes unreliable in months. Life is too short to deal with error-prone devices."

The Vaisala Humicap® HMT330 Series Humidity and Temperature Transmitter delivers high accuracy and excellent long-term stability, even in harsh outdoor conditions. RH accuracy is within 1% up to 90% RH and within 1.7% up to 100% RH. Temperature accuracy is within 0.2°C (0.36°F). The transmitters calculate wet-bulb temperature and can be field calibrated to meet the operator's quality management protocol.

Accuracy Leads to Free Cooling

Wilcox recently reviewed cooling tower performance at an undisclosed data center in Utah. One of the recommended upgrades was to replace their RH device with the more accurate Vaisala instrument.

Now using accurate RH in the wet-bulb temperature measurement, the facility could reduce energy costs by using more free cooling. Free cooling can be used when the outdoor wet-bulb temperature plus the approach is lower than the requirement for primary chilled water. Under these conditions, the condenser water cools the primary chilled water, bypassing the chiller entirely. Free cooling reduces mechanical cooling costs, is more energy efficient, and is recognized as a green energy effort.

With accurate wet-bulb temperature measurements, the data center was able to convert to free cooling for more than half the year and still meet its cooling requirements.

New Ways are Better

The value of accurate RH measurements is increasing as more cooling tower builders, operators, and HVAC professionals learn – still too often the hard way – that more reliable sensors using advanced technology can pay for themselves many times over. 3E

Definition of heat pumps and their use of renewable energy sources

The term "Heat Pump" is getting more popular as the use of this technology is expanding into buildings and houses. The general purpose and concept of heat pumps may be understood but how are they defined at the European level? Which EU documents introduce the heat pump technology as a solution?

Alex Vanden Borre
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REHVA,
avb@rehva.eu

Introduction

Heat pumps are part of the environmentally friendly technologies using renewable energy. They are quoted in the European Directives on the use of Renewable Energy (RES), on the Energy Performance of Buildings (EPBD) and on Energy related products (ErP). In addition, heat pumps are also referenced in the Directive on the promotion of the use of energy from renewable sources (2009/28/EC, RES Directive, § 2). The Directive recognizes the technology as using renewable energy sources from air, water and ground. Heat pumps are seen as a great opportunity to reach the EU target for a reliable, affordable and sustainable energy supply.

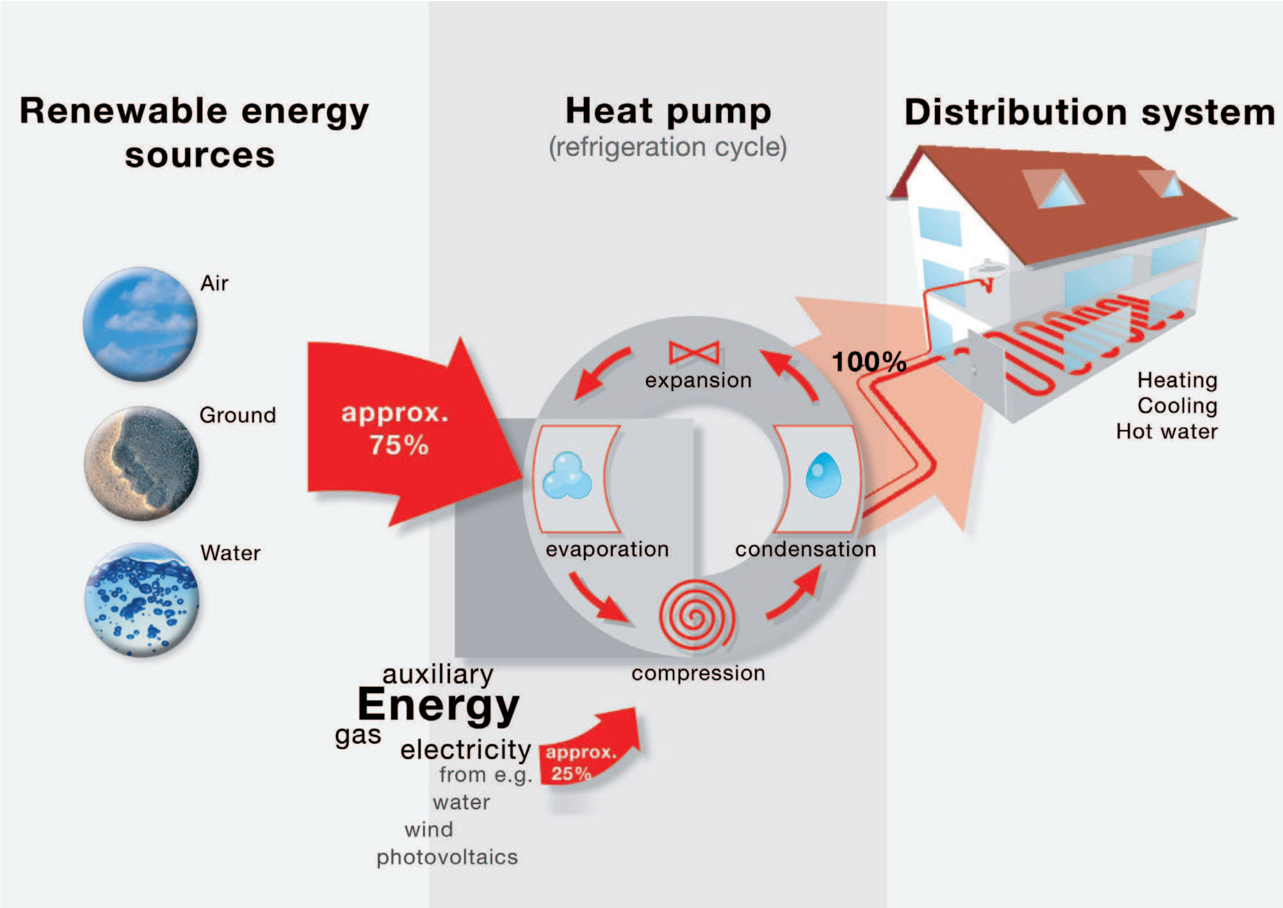
What are the definitions of heat pumps from the European commission?

In the Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the **energy performance of buildings** (EPBD) recast, *Article 2 point 18, 'heat pump' means a machine, a device or installation that transfers heat from natural surroundings such as air, water or ground to buildings or industrial applications by reversing the natural flow of heat such that it flows from a lower to a higher temperature. For reversible heat pumps, it may also move heat from the building to the natural surroundings;*

This definition of a heat pump is based on the physical characteristics of energy transfer. This definition is kept widely open to any machine, device or installation which will do the job of energy transfer. It leaves open doors to all existing or future technologies and hopefully improvements for innovative and more energy efficient models will show up. It does not set criteria how the upgraded low-temperature free heat is transferred to useful temperatures. Apart from all the natural sources of energy listed, the waste heat is not referenced but offers large opportunities for energy recovery from air or water side.

In the European Directives on the use of **Renewable Energy** (RES), point 31: *"Heat pumps enabling the use of aerothermal, geothermal or hydrothermal heat at a useful temperature level need electricity or other auxiliary energy to function. The energy used to drive heat pumps should therefore be deducted from the total usable heat. Only heat pumps with an output that significantly exceeds the primary energy needed to drive it should be taken into account."*

To achieve energy transfer, it requires auxiliary energy depending on the technology: there are electrical, gas driven or gas absorption heat pumps. The ratio between the auxiliary energy consumption and the thermal energy transfer is currently around one third depending on the technology used, the efficiency of the device and the temperature conditions. Obviously, a minimum level of efficiency should be established to ensure reduced energy consumption so that a heat pump deserves to be considered as a sustainable energy device. However, the definition is quite unclear about this as it only states that the energy output should significantly exceed the primary energy consumption. A tentative calculation method is defined in Annex VII but terms are not accurately defined yet and it is announced that they will be clarified for January 2013 by the Commission.



Operation principle of a heat pump. (Source: EHPA/Alpha Innotec)

In extreme cold conditions, the efficiency of aerothermal heat pumps dramatically drops. An alternative heating system thus needs to enter into action. This alternative may not be from a renewable energy source and therefore will reduce the global efficiency of the heat production through the year and its environmental sustainability. How to address this issue into heat pump qualification?

Larger definition of Heat Pumps

Gathering the above considerations and keeping the EU arguments and style, a broader and extended definition may be suggested:

A "*heat pump*" *is a machine, device or installation* using renewable natural energy sources from *aerothermal, geothermal or hydrothermal heat or non-natural processed wasted heat from water or air and which transfers it to buildings or industrial applications by reversing the natural flow of heat such that it flows from a lower to a higher useful temperature.*

Primary energy input from electricity, gas or fuel is needed to drive this process. In extreme climatic conditions, additional heating device must compensate the reduced heat production from heat pumps. Only heat pumps with an output that significantly exceeds the primary energy needed to drive them and the additional heating device energy should be considered. Obviously, an acceptable minimum level of efficiency should be established to ensure reduced energy consumption for the heat pump to deserve to be considered a sustainable energy device. *When heat pumps are reversible, it may also move heat from the building to the natural surroundings. This should be considered and maybe integrated into the efficiency factor. Not to multiply production systems into a same infrastructure."*

Due to the complexity and the multiple parameters to consider for heat pumps, the calculation of their efficiency is a real challenge. Efficiency will also be subject to local climatic conditions of where the device will be installed. This challenge is part of the road to reduce our impact on the environment by choosing the best heat pump technology or selecting the right equipment.

SB11 Helsinki World Sustainable Building Conference

SB11 HELSINKI
World Sustainable
Building Conference

The sixth World Sustainable Building Conference addresses new opportunities for improving quality of life, mitigating effects of climate change and making new businesses. The aim of the World Sustainable Building Conference in Helsinki is to share leading knowledge and also to find new solutions which can enhance sustainable ways of living and working within built environments.

To improve our current understanding on sustainable building and to develop innovative solutions for the present and future, SB11 Helsinki will provide a vivid forum for discussion and networking between all stakeholders. A global view of the industry and research will be offered through presentations structured according to SB11 Conference topics supervised by an international scientific committee. These topics relate to built environments of the present and the future and to developing countries and industrialized nations.

The World Sustainable Building (SB) Conference is a top event that every three years brings together the world's leading technical experts and researchers on sustainable built environments. The organizers are expecting about 1.200 participants daily. Registration has already started, please find out more at www.sb11.org and take a look at the interesting conference programme!

The SB11 Helsinki World Sustainable Building Conference will be held on the 18 - 21 October 2011 at the Helsinki Exhibition and Convention Centre in Finland.

http://www.sb11.org/ -> Venue

Rittinger Awardees for energy efficient heat pumping technologies

Professor Per-Erling Frivik, Norway, Mr John D. Ryan, U.S. and Professor-Doctor Hermann Halozan, Austria, have received the 2011 prestigious Ritter von Rittinger Medal, the highest recognition award in the air conditioning, heating and refrigeration field.

The award highlights outstanding contributions to the advancement of international collaboration in research, policy and market development and applications for energy-efficient heat pumping technologies that result in environmental benefits. It is awarded every three years in conjunction with the International IEA Heat Pump Conference. Due to the cancellation of the 2011 Heat Pump Conference scheduled for Japan, the awardees received the awards at a special banquet held in Paris.

Professor Hermann Halozan and Mr. John D. Ryan. Unfortunately, professor Frivik could not attend the ceremony. Photo: Heat Pump Centre.

Professor Per-Erling Frivik of Trondheim, Norway, is awarded for his outstanding achievements in the heat pump market development. As the Research Director at the SINTEF Refrigeration Engineering Division he built up a large group in heat pumps and refrigeration engineering. It is within this group the idea of using CO_2 as a working fluid was developed. Professor Frivik was instrumental for raising the funding necessary for the research and technology transfer with major international equipment manufacturers.

Professor Hermann Halozan of Graz, Austria, is recognized for providing his vast expertise in heat pumps to international associations and organizations for more than three decades. He has strongly influenced the European heat pump industry by supporting the development and dissemination of quality standards for heat pumps at European and national levels, but also pushing heat pumps in national and international political agendas. His role in heat pump market penetration in Europe has been indispensible.

Mr John D. Ryan of Bethesda, Maryland (U.S.), received the award for his life-long devotion to develop and promote adoption of heat pump technologies. Mr John Ryan was one of the initiators of the IEA Heat Pump Programme shortly after he joined the U.S. Department of Energy in 1978 and served as the US delegate to the Executive Committee until his retirement in 2007. Furthermore, Mr Ryan was chairman of the International Organizing Committee (IOC) for the 1996 and 2002 International Heat Pump Conferences.

Read more at www.heatpumpcentre.org

32nd AIVC Conference and 1st TightVent Conference

The joint conference '32nd AIVC Conference' and '1st TightVent Conference' aims to focus on **Optimal Air tightness Performance** will be held in Brussels, Belgium at the Hotel Crowne Plaza Brussels – Le Palace on the 12–13 October 2011.

The aim of the conference is to present new research, development, application and market implementation results to improve simultaneously the overall building ventilation and its energy performance, whereby there is a specific focus on airtightness issues.

REHVA is a sponsor of this conference, and encourages the participation in it.

The conference will focus on one the following topics:

- Energy and IAQ impact of envelope and ductwork leakage
- Quality management approaches for envelope and ductwork airtightness
- Product and method developments for envelope and ductwork airtightness
- Airtightness issues in existing buildings
- Ventilation and infiltration in mild climates
- Ventilation and infiltration in very low energy buildings (nearly zero energy buildings, passive houses)
- Innovative ventilation concepts and combined systems
- Demand-controlled ventilation
- Humidity control and moisture damage
- Summer comfort and ventilation

For more information, please contact www.aivc.org.

The 10th IEA Heat Pump Conference 2011 Tokyo rescheduled to a web conference

Due to the tragic after-effects of the earthquake on March 11 the 10th IEA Heat Pump Conference scheduled for Tokyo, Japan could not be held as planned. Instead the organizing committees decided that the conference will take place online between June 27 and August 31. At the beginning of July, two weeks before closing the registration on July 15, the conference had 370 registered participants.

About the International Heat Pump Conference

Every three years the IEA Heat Pump Programme stages the IEA Heat Pump Conference. It is an international Heat Pump Conference that was held for the first time in 1984.The HP conference offers a unique meeting place where advances and prospects in technology, applications and markets for heat pumps, air conditioning and refrigeration equipment and systems for residential, commercial and industrial applications are shared.

For further information, please contact the conference secretariat: hp2011@convention.jp

BUILD UP + www.buildup.eu

The Commission has decided to continue developing and updating the BUILD UP portal for building energy efficiency related information at least to the end of 2013. REHVA is one of the organisations updating the information at the portal.

Current status of the portal:

- Over 600 visitors a day
- English is the main language but material in all 23 EU languages is accepted (headlines in 22 languages)
- Search by language, theme, topic, keyword, date, country, etc.
- Status in March 2011: 1909 publications, 1130 links, 161 cases, 147 tools, 49 upcoming events, 27 communities

Fachhochschule Köln
Cologne University of Applied Sciences

Mit 17.000 Studierenden, 450 Professorinnen und Professoren, 1.200 Beschäftigten und 900 Lehrbeauftragten ist die Fachhochschule Köln die größte Hochschule für Angewandte Wissenschaften in Deutschland. Elf Fakultäten bieten 70 Studiengänge mit Bachelor- oder Masterabschluss an.

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In der Fakultät für Anlagen, Energie- und Maschinensysteme ist zum nächstmöglichen Zeitpunkt eine Professur mit folgendem Aufgabengebiet zu besetzen:

„Gebäudeautomation“ (Bes. Gr. W 2)

Die Professur ist im Institut für Technische Gebäudeausrüstung angesiedelt. Kennziffer: 09137/1

Ihre Aufgaben:
Sie vertreten die spezifischen Fächer Gebäudeautomation und technisches Gebäudemanagement, Regelungstechnik in der TGA und Prozessmesstechnik in der TGA im Studiengang "Energie- und Gebäudetechnik" in den Schwerpunkten "Technische Gebäudeausrüstung", "Elektrische Gebäudesystemtechnik" und "Green Building Engineering" in Lehre und Forschung.

Ihr Profil:
Sie haben ein ingenieurwissenschaftliches Hochschulstudium mit herausragenden Leistungen und mit einer Prädikatspromotion abgeschlossen. Sie weisen mehrjährige Berufserfahrung in der Gebäudeautomation oder Entwicklung ihrer Komponenten unter dem Aspekt von Energieeffizienz, Einsatz erneuerbarer Energien und Gebäudekomfort auf.

„Raumlufttechnik“ (Bes. Gr. W 2)

Die Professur ist im Institut für Technische Gebäudeausrüstung angesiedelt. Kennziffer: 09131/1

Ihre Aufgaben:
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Ihr Profil:
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Sie sind in der Lage, Lehrveranstaltungen auch in englischer Sprache zu halten.

Die Bereitschaft zur Übernahme von Verantwortung in der Selbstverwaltung der Fakultät und im Institutsmanagement wird erwartet.

Idealerweise haben Sie bereits eingehende Lehrerfahrungen gesammelt und sind am Einsatz von Methoden der modernen Hochschuldidaktik interessiert. Mit Ihren Forschungsaktivitäten stärken Sie das Forschungsprofil der Fakultät und werben aktiv Drittmittel ein. Sie besitzen die Fähigkeit zur Ausrichtung des eigenen Denkens und Handelns auf langfristige Ziele der Hochschule sowie die Fähigkeit, Lösungen gemeinsam und arbeitsteilig zuverlässig zu erarbeiten.

Bitte wenden Sie sich für Rückfragen an Herrn Prof. Dr. Sommer, E-mail: **klaus.sommer@fh-koeln.de**

Sie erfüllen die weiteren Einstellungsvoraussetzungen des § 36 HG NRW. Die Bewerbungen von Frauen sind ausdrücklich erwünscht und werden bei gleicher Eignung, Befähigung und fachlicher Leistung nach den Bestimmungen des Landesgleichstellungsgesetzes NRW bevorzugt berücksichtigt. Schwerbehinderte Bewerberinnen und Bewerber werden bei gleicher Eignung bevorzugt berücksichtigt. Wir freuen uns auf Ihre aussagefähige Bewerbung, die Sie bis 30.09.2011 unter Angabe der Kennziffer an den

Präsidenten der Fachhochschule Köln, z. Hd. Frau Meyer,
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richten.
Weitere Informationen zu Einstellungsvoraussetzungen, Bewerbungsunterlagen, W-Besoldung unter www.fh-koeln.de – Stellenangebote (wissenschaftlich).

REHVA Fellows

REHVA has granted the status of REHVA Fellow in recognition of the outstanding services to REHVA organisation and work for the improvements of energy efficiency and the indoor environment of buildings. The privileges/benefits of REHVA fellow are the following:

- Right to use with his/her name "REHVA Fellow"
- Name listed at REHVA Website – visit www.rehva.eu
- Right to wear REHVA PIN
- Right to get a certificate of fellowship
- Right to free subscription of the REHVA journal
- Reduced fee for REHVA publications
- Reduced fee to REHVA events

REHVA Journal congratulates new REHVA Fellows, and wishes their support during coming years. The names of the Fellows are published at www.rehva.eu

job advertisement:

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In der Fakultät für Anlagen, Energie- und Maschinensysteme ist zum nächstmöglichen Zeitpunkt eine Professur mit folgendem Aufgabengebiet zu besetzen:

„Sanitärtechnik und konstruktiver Rohrleitungsbau" (Bes. Gr. W 2)

Die Professur ist im Institut für Technische Gebäudeausrüstung angesiedelt. Kennziffer: 09134/1

Ihre Aufgaben:
Sie vertreten das genannte Aufgabengebiet in erster Linie im Studiengang Energie und Gebäudetechnik. Da Ihr Aufgabengebiet auch in den Studiengängen Maschinenbau sowie Rettungsingenieurwesen von Interesse ist, werden Sie bei Bedarf auch dort Lehraufgaben übernehmen.
Sie werden als Kernfach die Sanitärtechnik mit dem Schwerpunkt Anlagenplanung in der Trinkwasserversorgung, Entwässerung und Abwasserbeseitigung vertreten. Als Grundlagenfach sollen Sie darüber hinaus die Konstruktionstechnik (konstruktiver Rohrleitungsbau) eigenverantwortlich übernehmen. Sie sind in der Lage, Lehrveranstaltungen auch in englischer Sprache zu halten.
Die Bereitschaft zur Übernahme von Verantwortung in der Selbstverwaltung der Fakultät und im Institutsmanagement wird erwartet.

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Sie haben ein Hochschulstudium im Fachgebiet Technische Gebäudeausrüstung oder im Maschinenbau mit herausragenden Leistungen und mit einer Prädikatspromotion abgeschlossen. Sie besitzen mehrjährige Berufserfahrung in den Bereichen des Anlagenplanung, der Anlagenmontage oder der technischen Entwicklung. Mit Ihren Forschungsaktivitäten stärken Sie das Forschungsprofil der Fakultät und werben aktiv Drittmittel ein. Sie besitzen die Fähigkeit zur Ausrichtung des eigenen Denkens und Handelns auf langfristige Ziele der Hochschule sowie die Fähigkeit, Lösungen gemeinsam und arbeitsteilig zuverlässig zu erarbeiten.

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E-mail: rene.cousin@fh-koeln.de

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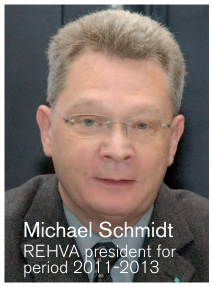
REHVA welcomes its new Board



During the REHVA General Assembly which was held in Tallinn on May 21, 2011, the following new Board members were elected:

Bjarne W. Olesen, DANVAC, Danish Technical University

Jan Aufderheide, TVVL

Stefano P. Corgnati, AICARR, Politecnico di Milan

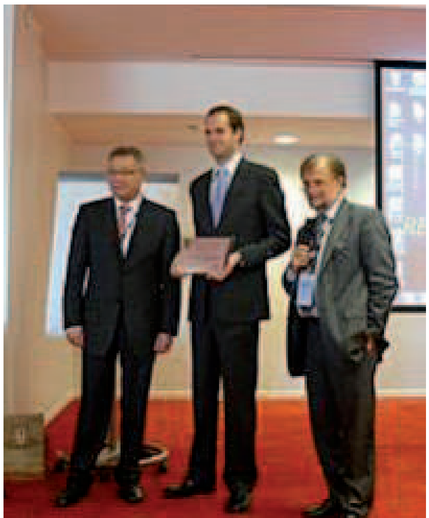
The leaving members were **Don Leeper**, **Maija Virta** and **Francis Allard**.

Prof. Olesen will chair the External Relations Committee after Don Leeper and Mr. Aufderheide will chair the new Members' Committee.

Prof. **Karel Kabele** from the Czech Technical University in Prague was reelected as Chair of the Education Committee. Dr.-Ing. **Zoltan Magyar** from the University of Pécs was reelected as co-Chair of the Technical and Research Committee and Treasurer. Prof. **Michael Schmidt** from the University of Stuttgart is REHVA's new President. He will continue in the Board until end of his term. Prof. **Francis Allard** from the University de La Rochelle has retired as President after serving his three year mandate.

REHVA Young Scientist Award 2011


Francis Allard, Michaela Lambertz, Morten Brunk, Michael Schmidt.


Micheal Schmidt, Joost van Hoof, Francis Allard.

On the occasion of the REHVA General Assembly on 20th May 2011 in Tallinn, Dr. **Michaela Lambertz** (Germany) and Dr. **Joost van Hoof** (The Netherlands) received the REHVA Young Scientist Award.

Dr. Lambertz was suggested for this Award by the German member society of REHVA "VDI-Society Civil Engineering and Building Services" in recognition of her outstanding scientific achievements on the topic "Sustainability of Office Buildings". She made her research at the University (RWTH) in Aachen at the faculty of Prof. **Marten F. Brunk**. The results of her research are published as VDI report Nr 212 "Entwicklung eines Verfahrens zur Bewertung der sozialen Nachhaltigkeitsdimension von Bürogebäude". The VDI Report can be ordered via the internet www.vdi.-nachrichten.com.

Dr. van Hoof was nominated by the Dutch member society of REHVA TVVL in recognition of his outstanding scientific achievements on integrated design of housing facilities for people with dementia. He made his research at the Eindhoven University of Technology (TU/e) at the faculty of Prof. Ir. P.G.S. Rutten unit Building Physics & Systems in fruitful cooperation with Prof. Dr. **Mia S.H. Duijnstee**, Utrecht University and Dr. **Helianthe S.M. Kort**, Hogeschool Utrecht University of Applied Sciences. He also was awarded the prestigious "B.J. Maxprijs" at the TVVL annual meeting 2010 in Amsterdam for his research and (inter)national lessons, lectures and publications on the crossroads of care for older adults, nursing home care and building services engineering. A catalogue record of his dissertation is available from the TU/e library. ISBN: 978-90-386-2326-9.

The Young Scientist Award was handed over to Dr. Lambertz and Dr van Hoof by the new REHVA President Prof. Michael Schmidt. Dr. Michaela Lambertz is the 2nd Engineer from Germany to receive this award, following 2008 awardee Dr. **Heiko Timmer**. Dr Joost van Hoof is the first Dutch awardee of REHVA Young Scientist Award.

REHVA Honorary Fellows and REHVA Professional Awards

Michael Schmidt and Francis Allard with Rehva Honorary Fellow Jorma Railio (middle).

On the occasion of the General Assembly 2011, the following members of REHVA national associations were recognized for their outstanding achievements:

Jorma Railio (FINVAC – Finland), **Atze Boerstra** (TVVL – Netherlands) and **Miro Georg** Trawnika (SWKI – Switzerland) were granted the title of REHVA Honorary fellow, and REHVA Professional Awards were handled to **Luis Malheiro** (ODE-Portugal) and **Vello Penjam** (EKVU – Estonia).

Atze Boerstra, Michael Schmidt, Francis Allard.

Michael Schmidt, Luis Malheiro, Francis Allard.

Michael Schmidt, Miro Trawnika, Francis Allard.

Michael Schmidt, Vello Penjam, Francis Allard.

REHVA Annual Conference in Tallinn, May 18-21, 2011

SUMMARY BY JAREK KURNITSKI
Sitra, the Finnish Innovation Fund
REHVA Fellow

REHVA Annual Meeting and Conference was hosted by the REHVA Estonian member EKVÜ. The conference focused on Zero Energy Buildings and Eco-labelling of Buildings. These themes brought about 300 participants to Tallinn, all highly satisfied with the smooth conference arrangements and high quality presentations.

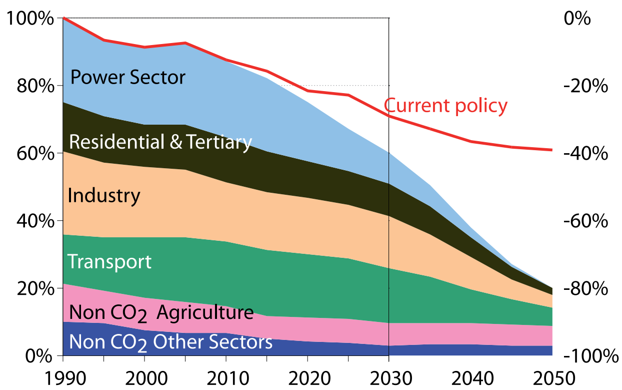
Highlights of the presentations

The Commission

Michaela Holl, the Commission: 20% Energy Efficiency target not on track must be delivered!

Following the EPBD recast, the Commission's regulation and guidance document on **cost optimal** methodology framework will be released on or close June 30th 2011. Member States have to conduct cost optimality calculation of current energy performance minimum requirements and report to the Commission due 30th June 2012. The regulation instructs MS for the first time on how to set minimum requirements by introducing a cost optimal policy which will shift away from only upfront investment cost. Some room is left for national adjustment; however the cost optimal methodology will be uniform. In the document, a global cost approach with net present value calculation is established, and necessary guidance is provided especially for harmonized input data, such as calculation period, interest rate, escalation etc.

In addition to the cost optimal policy, the EPBD recast established the political target of **nearly zero energy buildings** for all new buildings by 1 Jan 2021. Both requirements will have to be reconciled so that a smooth transaction from cost optimal requirements to nearly zero energy buildings could be guaranteed.



The 2050 roadmap for low-carbon economy explored pathways for key sectors and introduced midterm target of 40% reduction by 2030.

As only half of the 20% Energy Efficiency target will be achieved with current measures, new measures are introduced recently, including the Roadmap for moving to a competitive low-carbon economy in 2050 and the Energy Efficiency Plan 2011. The 2050 roadmap for low-carbon economy gives a crucial role to the building sector: Emissions could be reduced by 90% by 2050.

Download the presentations at www.rehva.eu

Ecodesign

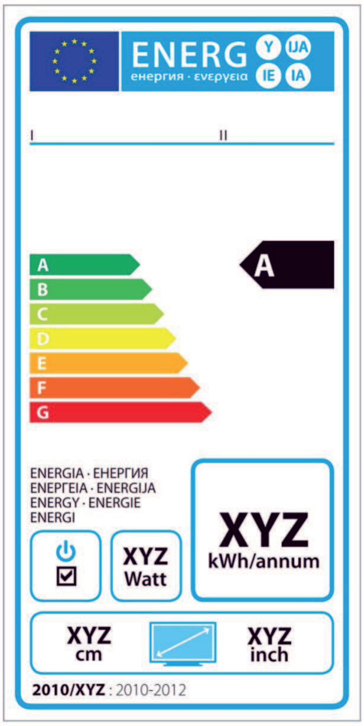
Ismo Grönroos-Saikkala, the Commission: A lot of Lots in Ecodesign – all major HVAC-products soon covered

In several presentations requirements for HVAC products in the EU's complex regulatory context were discussed. This regarded not only ErP (Energy-related-Product), but also EPBD and RES (Renewable Energy Source) directives. Estimated savings of the existing (9) Ecodesign implementing measures by 2020 are huge, 341 TWh electricity. These savings correspond approx to the electricity consumption of the UK. For some product Lots the measures are already adopted and for many product Lots the measures are under preparation.

René Kemna presented one preparatory study of Ecodesign for Larger Ventilation Systems. This study served as a good example how product groups are treated by Ecodesign with impact and saving potential assessment, specifying requirements, test and calculation methods.

Energy Labelling Directive 2010/30/EU

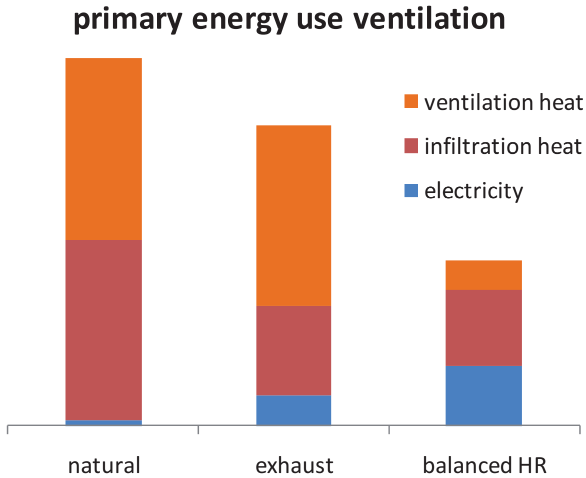
- **Information requirements** on the consumption of energy and essential resources
- **Target: end-users,** public and private demand (installers)
- Lisbon Treaty: consultation of stakeholders but no Committee with a vote by Member States
- EP and Council scrutiny



René Kemna: Preparing EU Ecodesign, Larger Ventilation Systems

Task 3: Usage, Key Message

- Mechanical ventilation indispensable in new efficient buildings (health)
- It costs electricity but can save up to 4 times as much primary energy in space heating (and cooling)



REHVA

Federation of European Heating, Ventilation and Air-conditioning Associations

EKVÜ

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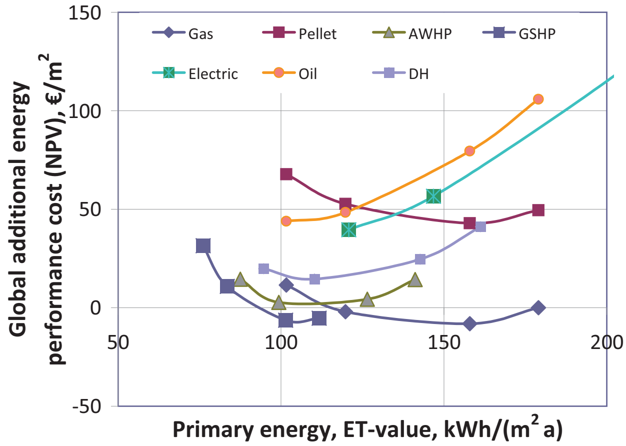
EPBD implementation

National implementation of EPBD and nZEB was reported by **Donald Leeper** (UK), **Jean-Christophe Visier** (France) and **Michael Schmidt** (Germany). Many countries have prepared long term roadmaps with detailed targets, and EPBD has established a common methodology as most of countries use primary energy for expressing energy performance. Still a huge legal, regulatory, engineering and economic effort is needed to prepare binding laws, codes, calculation methods, guidelines and training to move to nZEB construction.

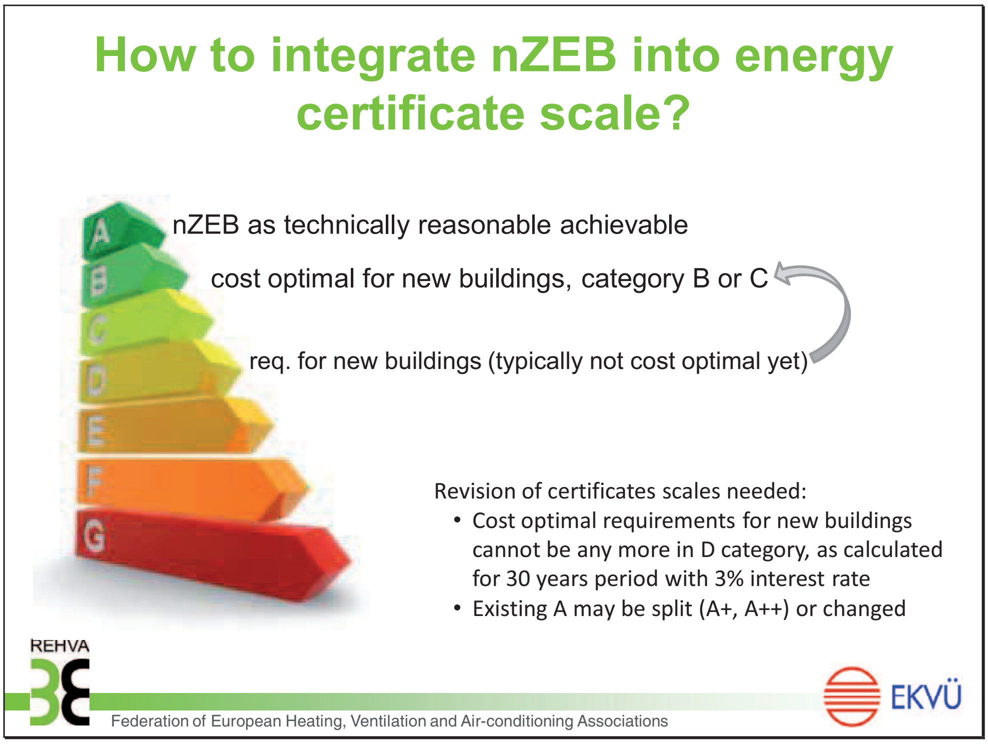
REHVA proposal for national implementation of nZEB

Jarek Kurnitski, the chair of the REHVA Task Force "Nearly Zero Energy Buildings" reported on the major content of the proposal. The main idea is to use uniformed methodology to define national performance levels, which will allow taking into account national conditions. Nearly zero energy and cost optimal performance levels were discussed as well as the integration into the energy performance certificate scale.

According to common understanding, nZEB is not yet cost efficient with current energy prices. However, if feed in tariffs exists for solar electricity, nZEB can reach close to cost optimal energy performance level. One of the first national cost optimal calculation results from an ongoing Estonian study, showed the distance between the cost optimal and nearly zero performance levels. Lowest primary energy use was achieved with passive house building envelope represented by the left-most dots on the graph and ground source heat pump (GSHP) (see figure above). The cost optimal primary energy level of 140 kWh/(m² a) was achieved with thermal insulation level only marginally improved from business-as-usual construction (the dots in the right) and without photovoltaic. In Estonian cold climate, technically reasonably achievable nearly zero performance level was about 40–50 kWh/(m² a) for detached houses, leading to about 20% extra construction cost with current prices.



Estonian cost optimal calculations for detached houses. For each heating system, the dots from left to right represent the building envelope insulation level from passive house to business-as-usual. (AWHP – air to water heat pump, GSHP – ground source heat pump, DH – district heating.)



Download the presentations at www.rehva.eu

Technical solutions for nZEB

Technical solutions with improved component and system performance needed for nZEB buildings were discussed in many presentations. It was shown that solutions with overkill complexity are not necessarily needed. An example reported by **Jonas Gräslund** showed that Skanska's experience and optimization has led to simple and reliable low speed constant pressure ventilation systems. These have large air handling units and ducts, without silencers and almost no dampers, illustrating that simple, reliable and energy efficient solutions do exist. **Jean-Louis Scartezzini** reported on a natural lighting solution where only 3.5 W/m² installed lighting power was achieved!

nZEB case studies

High performance office building nZEB case studies were reported by **Wim Zeiler** (Netherlands), **Ansgar Thiemann** (Germany) and **Mickael Freindorf** (France). Residential buildings were reported by **Jyri Nieminen** (Finland).

A large variety of energy sources were used (heat pumps, DH, bio-CHP, solar PV and thermal). Some common solutions for nZEB buildings were:

- Heat recovery ventilation, often demand controlled, by centralized or decentralized systems, sometimes combined with natural stack effect ventilation for ventilative cooling purposes
- Free cooling solutions combined with mechanical cooling via boreholes, water to water HP, evaporative or ventilative cooling etc.
- Optimized building envelope and effective external solar protection
- Utilization of natural light + effective demand controlled lighting
- High efficiency heat recovery and low specific fan power, CO_2, presence and temperature control typical in nZEB
- Water based distribution systems and VRV heat pumps
- Utilization of thermal mass and other passive measures

These highly efficient solutions reported were reduced delivered energy use for heating, cooling, ventilation and lighting to minimum. Therefore, the office appliances had become the major component in the energy balance of all reported buildings.

	Design phase			Measured 2009
	Net delivered energy use kWh/(m²a)	Primary energy factor –	Primary energy use kWh/(m²a)	Primary energy use kWh/(m²a)
Space, water and ventilation heating, wood boiler	3.3	0.6	2.0	6.3
Cooling, electricity to heat pumps	4.1	2.58	10.6	6.2
Fans (HVAC)	5.1	2.58	13.1	14.1
Pumps (HVAC)	0.4	2.58	1.1	2.6
Lighting	4.1	2.58	10.5	9.5
Elevators	1.4	2.58	3.6	3.6
Appliances (plug loads)	9.4	2.58	24.2	54.6
PV power generation	-16.0	2.58	-41.3	-40.2
TOTAL	**12**		**24**	**57**

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nZEB extra cost?

Extra cost of nearly zero was discussed in many presentations by **Wim Zeiler**, **Ansgar Thiemann**, **Mickael Freindorf**, **Michael Schmidt**, **Jyri Nieminen** and others. There was a general agreement that this is not a relevant question for existing buildings, as in existing buildings cost effective energy performance improvements are indeed possible, but not to nZEB performance level. In new buildings, extra costs of 0%, between 5-10% and up to 20% was reported. Some general agreement was established that in most cases the extra cost will not exceed 10%.

Large profitable energy savings in existing non-residential buildings, achieved in Swedish BELOK initiative with many completed projects were reported by **Mari-Liis Maripuu**.

The complete cost of Total Energy Projects	
Identification of measures Cost estimations Simulations of energy saving	3–4 EURO/m^2
Planning and design	2–3 EURO/m^2
Construction work, installations	40–80 EURO/m^2
Commissioning, function control	2–3 EURO/m^2
In total	47–90 EURO/m^2
Savings	7–11 EURO/(m^{2}a)

Green building labeling systems

The role and purpose of labeling systems was discussed in many presentations from a technical assessment and investor's perspectives. More than 100 labeling systems are today available globally, indicating a strong demand for voluntary labeling. Evidently following the principles of any system will have a positive effect, because in the construction projects these systems will lead the design and commissioning process so that all important factors – and there are hundreds of these – will be taken into account if the guidance is followed. As a new system, EU EcoLabel is under preparation. It was not yet clear, whether EU EcoLabel provides something new, or whether it rather be one among many others.

Benchmarking is limited even within the same systems, as ratings combine many categories which cannot be basically summed. For that reason, benchmarking will need more details than certificate score, i.e. category specific comparison. In the comparison between buildings one will need to calculate common metrics for key issues of each category. Two European projects Open house and Super buildings are working in that field in order to establish relevant and sound definitions for common metric. It is expected that such key indicators could provide more information for the investor for valuation, meaning also that investors' understanding about building performance has not to be underestimated. It was seen that this development is not in the conflict with labeling systems, as the purpose of the labeling systems is rather leadership in design, including guidance for design process and best practice technical measures, than establishing common metrics for key issues.

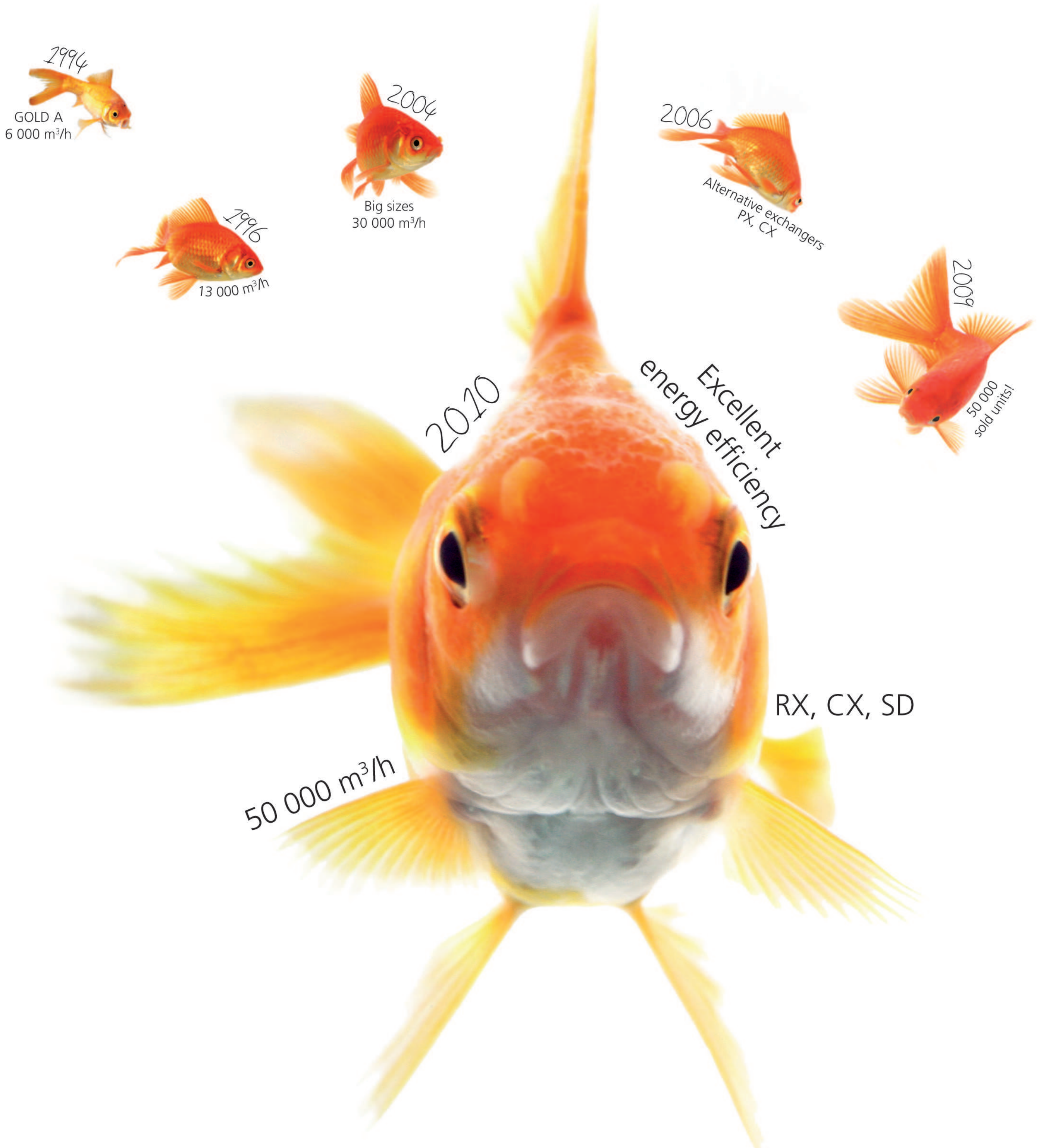
Download the presentations at www.rehva.eu

Upcoming HVAC Events

REHVA Technical Seminar on Recast EPBD and other EU Regulations will be organized in **Brussels October 27, 2011** for for REHVA Members and Supporters – More information and preregistration at www.rehva.eu

CLIMA 2013

The 11th REHVA World Congress CLIMA 2013 will take place in **Prague on 16-19 June 2013** with the theme of "Energy Efficient, Smart and Healthy Buildings". www.clima2013.org



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New REHVA website

During the REHVA Annual conference and meeting in Tallinn, Estonia in May, REHVA launched a redesign website with new sections like **EU regulations** and **REHVA Journal**. In the **EU regulations** section you can find information related to the heating, ventilation and air conditioning in buildings. There you will find out what's new in EU legislations, EPBD, Eco-design, Renewable sources directive, Building labeling, IEQ, CEN and ISO standards, F-Gas and EU Projects. In the **REHVA journal** section, you can view all the 2011 issues of the REHVA journal, totally free of charge. You can also download your preferred articles. To view or download the latest issue of the REHVA journal, please visit www.rehva.eu.

REHVA Dictionary

For professionals by professionals

The REHVA dictionary is a reliable glossary of technical words and terms used in the building services. The dictionary is made by professionals for professionals. Available **freely** to everyone, with more than 12 000 words translated in 14 languages, it is an up to date user friendly glossary. Romanian and Croatian are the two languages that will soon be added to the REHVA dictionary.

Current 14 languages:
Danish, Dutch, English, Finnish, French, German, Hungarian, Italian, Polish, Portuguese, Russian, Spanish, Swedish and Turkish.

www.rehvadictionary.com

Alex Vanden Borre is REHVA's new Senior Project Engineer

Alex Vanden Borre started to work at the Brussels office at mid-May as REHVA's new **Senior Project Engineer.** He holds a Mechanical engineering degree with automation specialisation. His career has been focused on the HVAC field within installers companies, engineering offices or suppliers of HVAC equipment. His last 5 years were dedicated to internal technical trainings on Controls of HVAC systems on the air and water side for fulfilment teams in Europe, Middle-East, India and Africa. You can reach him at: avb@revha.eu

REHVA Journal 2011 issues

5 The October issue of the REHVA Journal (5/2011) will focus on A/C systems & EU regulations for HVAC products - Articles are due by 15 September. The guest editor of this issue is Mr Jacques Benoist from AICVF (France). jacques_benoist@orange.fr

6 The December issue of the REHVA Journal (6/2011) is on Energy Efficient Heating - Articles are due by 30 October. The guest editor of this issue is Mr Karel Kabele from STP (Czech Republic). kabele@fsv.cvut.cz


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VDI - GUIDELINES PUBLISHED APRIL – MAY 2011

April:

VDI 2083/4.2: Cleanroom technology; Energy efficiency
This guideline deals with cleanroom-specific energy-saving potentials. Processes in the cleanroom are considered only in terms of their interfacing with cleanroom-specific building services.

By way of example, the guideline considers the energy-saving potential for utrapure steam. Evidently, the architecture of the building, the building services for the environment around the cleanroom, the centralised energy supply for the building and any option for recovering energy are part of a holistic consideration of energy saving. These areas have been dealt with comprehensively in other technical rules (such as VDI 2067, VDI 3807, DIN V 18599) and are thus only addressed in terms of their interfacing with the cleanroom.

VDI 3803/4: Air-conditioning, system requirements; Air filter systems (VDI Ventilation Code of Practice) *(Draft Guideline)*
This guideline deals with the application of filters in air-conditioning systems (A/C systems) in, e.g., residences and offices, in medical facilities, in pharmaceutical and food productions and in public buildings, service centers and commercial enterprises, schools and sports facilities.

It deals with the practical application of the technical rules EN 779, EN 1822 and VDI 2083 Part 3 and applies to all A/C systems for occupied areas where persons are present more than 30 days per year or more than two hours per day.

The guideline is primarily intended for use by planners, executing companies and operators of A/C systems. The requirements to be met by air filters in A/C systems primarily serve to protect the health of persons, but may also be determined by technological requirements.

This guideline adopts the technical specifications of the guideline SWKI VA101-01:2007-11.

VDI 3803/5: Air-conditioning, system requirements; Heat recovery systems (VDI Ventilation Code of Practice) *(Draft Guideline)*
The guideline applies to air-conditioning systems. The recovery of heat from exhaust air is an important step towards reducing the primary-energy demand for heating.

The guideline specifies the basic terminology for heat recovery systems and describes the required equipment, systems, techniques and their operation. To this end, it provides criteria for decisions and characteristics for selection and calculation. The guideline also enables statements regarding suitability and economic efficiency, as well as regarding the reduction of energy expenditure and CO2 emissions.

VDI 4706: Criteria for indoor air climate *(Draft Guideline)*
Regardless of the technical implementation, the guideline provides specifications for the design of the indoor environment. The details on the indoor environment exclusively refer to rooms which are used as a recreation area for home or work purposes. The guideline applies to the specifications of EN 15251, particularly category II of this standard. For a practical application of the specifications for a comfortable indoor environment there are given both, completing as well as modified planning directions for thermal comfort and air quality.

May:

VDI 2083/3.1: Cleanroom technology; Metrology; Monitoring *(Draft Guideline)*
This guideline deals with the permanent installation-specific monitoring of individual parameters of controlled environments. The monitoring may be continuous (pressure, temperature, humidity) or sequential (microbiology). The guideline applies to the classical monitoring, i.e. permanent checking of parameters, but not for recurrent measurements for qualification purposes. The guideline does not specify microbiological techniques. It specifies methods the measurements on cleanroom installations and the required instrumentation so as to define a standard. The specifications regarding monitoring measurements aim at aiding the user in selecting methods allowing to determine installation- and process-related deviations from requirements during operation. The guideline does not apply to data loggers which store data to be read out at intervals.

VDI 3813/1: Building automation and control systems (BACS); Fundamentals of room control
The guideline shows the basic principles of room automation. The paper offers definitions of terms and help to create a uniform basic understanding of building owners, designers and contractors in the field of room automation.

VDI 3813/2: Building automation and control systems (BACS); Room control functions (RA functions)
In this guideline, the basic functions of the room automation are described. From these basic features in the practice room automation macro function will have to be built.

VDI 3814/ 7: Building automation and control systems (BACS); Design of user interfaces *(Draft Guideline)*
The guideline is intended to create a unified basis serving to simplify the planning, execution and acceptance of management and operating equipment. It provides guidance for the design of user interfaces of building automation systems; insofar it is an aid for formulating contract specifications by the builder-owner and user as well as for the planner and BA manufacturer. Further tasks required for the use of a property such as energy and environmental management, reporting, maintenance, etc., which have to be represented by the user interface, are not described. These functions have to be implemented in accordance with this guideline as required by the specifics of the property, or project, in question.

VDI 6010/2: Technical safety installations; Automation and control of fire protective services
The guideline supports the planning, implementation and testing of cross-functional interdependencies of safety equipment in buildings. It takes into account the requirements of the individual systems and makes recommendations for the proper interaction of the building.

VDI/GEFMA 3814/3.1: Building automation and control systems (BACS); Guidance for technical building management; Planning, operation, and maintenance; Interface to facility *(Draft Guideline)*
This guideline is intended to offer the user of a building an overview of basic requirements, potential and applications of building automation for technical building management. Data and information required by the facility management or building management for service processes and tasks during the use of a facility or a building are recorded, processed and archived by an integrated planning, controlling, information and archival system.

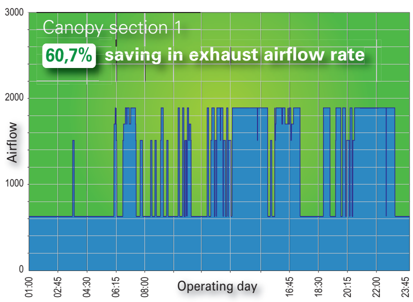
With up to 64% lower exhaust air flow rates, the combination of the Capture Jet™ and M.A.R.V.E.L. technologies represents the greatest energy savings potential in professional kitchens today. The system adjusts the exhaust flow rates to the real cooking status, canopy specifically. The need for supply air heating and the speed of the fan vary accordingly. Thus, the energy consumption is significantly reduced.

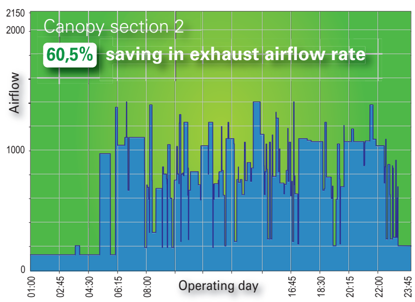
Unrivalled energy savings at Le Meurice Hotel.

Le Meurice is a five-star hotel, of 'Palace' class, created in Paris in 1835 by Charles-Auguste Meurice. It is considered to be one of the most famous historical pieces of palace-style architecture in Paris and a 'gastronomic rendez vous', thanks to its two fine-dining restaurants, one of which boasts three Michelin stars.

The kitchen ventilation has typically worked at 100% of the exhaust air flow rate during operation, but Halton M.A.R.V.E.L. changes this logic. An innovative Demand-Controlled Ventilation system, it adjusts every canopy according to the actual activity of the kitchen equipment. This means an average of 50% savings in energy consumption, which increases profitability. The history-steeped Le Meurice Hotel now gains advantage from this modern innovation.

The results of the real-time monitoring carried out at the hotel are as promised. The combination of the Capture Jet™ and M.A.R.V.E.L. technologies provides a nearly **61% reduction in exhaust air flow rates, corresponding to about 50% lower total energy consumption**.





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SEPEMO-Build - a European project on seasonal performance factor and monitoring for heat pump systems in the building sector

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Introduction

Heat pumps (HP) have a huge potential for saving energy, reducing CO_2-emissions using renewable energy as source for space heating, water heating in buildings, and other applications including industrial processes. According to IEA HPP, heat pumps can cut global CO_2 emissions by nearly 8% [4]. They are an essential technology for reaching the EU targets for renewable energy. This potential can be realised on short term at low costs, since the technology is already available. However, the awareness at policy level and in the market must increase.

The European heat pump market was around 450 000 sold units in 2006, and in 2008 about 580 000 heat pumps were sold in eight European countries. The market growth has been an average 30% per year since 2003. Since the economic crisis, the market has declined a little, but there are signs that the market is recovering. It is of outmost importance that the heat pumps installed are performing well, since bad installations could ruin much of the energy saving potential, and also damage the reputation of heat pumps. Today heat pump units in themselves are quite efficient (high COP), but installed in a building this efficiency may be ruined by poor system design and bad installations. As a consequence systems based on heat pumps with the same certified efficiency level are reported with HP system SPF between 2.0 and 5.5.

The performance of heat pumps (COP) is characterised at single operation conditions and full capacity, in stabilised conditions according to EN14511 1-4. These conditions do not always reflect the real performance of HP's in operation in heating systems. Heat pumps operate mainly at reduced capacity in climatic conditions that differ from the standard rating conditions. It is therefore important to study the seasonal performance factor (SPF) based on a number of operation conditions. The influence of reduced capacity operation on SPF is not fully covered by existing methods for calculation of SPF. There is hence a need for a harmonised field method for determining HP system SPF in real installations.

Field measurements

A field measurement method is vital in order to learn more about how heat pump systems can be improved, and to find explanations to reasons why the systems are not always as good as it could be.

In the past years it has become more and more common to use field measurements for the evaluation of the performance of heat pump systems. Unfortunately the results of the most field trials are not comparable due to the differences in the defined system boundaries used for the integration of the measurement equipment and the analysis of the measured data [3], [5], [1].

Therefore one part of the SEPEMO project is focused on defining common system boundaries for calculating the SPF for heating and cooling of heat pump systems. These borders directly impact on the necessary equipment needed to measure the essential parameters for the calculation of the different SPF. To allow system comparisons it is mandatory to develop a common monitoring methodology, which ensures a certain data quality. Consequently it is important to set the requirements on what to measure in order to make SPF calculations and to give information about the measurement quality that is needed. The aim is to improve insight in and better understand how the system design and installation influence the parameters which are critical to achieve a high performance and reliability of heat pumps in heating and cooling systems.

The quality of the measurements is directly influenced by the accuracy of the sensors and the sampling intervals for storing measured data. Due to the fact that the various past monitoring studies have not selected the same system boundaries, a transparent presentation of the boundaries will be necessary in the future. This will firstly simplify SPF calculations and should secondly allow the comparisons of the results of different field monitorings. However, in the course of the SEPEMO project standardized system boundaries for field monitoring has been defined.

System boundary description

For calculating the SPF for heating and cooling in heat pump systems, the system boundaries have been set to fulfill different needs. The definition of the system boundaries influences – in dependency on the impact of the auxiliary devices – also the results of the SPF. Therefore the SPF should be calculated according to different system boundaries (**Figure 1**).

This SPF-calculation method facilitates the quantification of the impact of the auxiliary devices like brine pumps and fans on the performance of the heat pump system. It also enables the comparison of heat pump system with other heating systems like oil or gas by allowing for the calculation of the CO_2- and primary energy reduction potential. Furthermore the quantity of renewable energy supplied by the heat pump system can be calculated and used for statistics. Therefore the system boundaries stretch from the heat pump refrigeration cycle to the whole heating system boundary in heat pump systems. The nomenclature defined in **Table 1** is used in the following figures and equations when describing the different system boundaries.

For systems with an additional heating system other than an electrical back up heater (e.g. oil, gas or bio-

Table 1. Nomenclature.

Parameter	Description	Unit
SH	Space heating	[-]
DHW	Domestic hot water	[-]
HP	Heat pump	[-]
Q_{H_hp}	Quantity of heat of the HP in SH operation	[kWh]
Q_{W_hp}	Quantity of heat of the HP in DHW operation	[kWh]
Q_{HW_bu}	Quantity of heat of the back-up heater for SH and DHW	[kWh]
$E_{S\_fan/pump}$	Electrical energy use of the HP source: fan or brine/well pump for SH and DHW	[kWh]
$E_{B\_fan/pump}$	Electrical energy use of the heat sink: fans or pumps for SH and DHW	[kWh]
E_{bt_pump}	Electrical energy use of the buffer tank pump	[kWh]
E_{HW_hp}	Electrical energy use of the HP for SH and DHW	[kWh]
E_{HW_bu}	Energy use* of the back-up heater for SH and DHW	[kWh]
	*For additional heating other then electrical back up heater the energy content of the fuel demand has to be taken	

mass) the quantity of heat and the energy content of the fuel demand have to be determined for the calculation of the SPF according to the system boundaries. For any additional (solar) thermal system, the auxiliary energy to run this system has to be measured. With the heat energy delivered to the heating system by the additional heating the energy supply ratio of the heat pump system is calculated.

System boundary heat pump unit

The system boundary shown in Figure 2 contains only the heat pump unit. SPF_{H1} evaluates the performance of the refrigeration cycle and allows a calculation of the SPF of the heat pump without the auxiliary drives to show the efficiency of the refrigerant cycle (**Figure 2**).

$$SPF_{H1} = (Q_{H\_hp} + Q_{W\_hp})/E_{HW\_hp} \qquad (1)$$

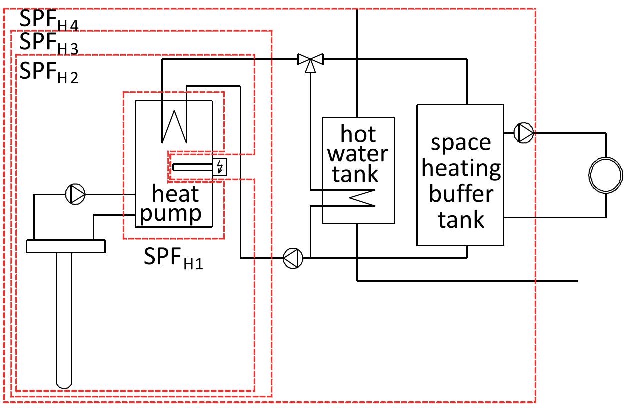

Figure 1. System boundaries for heating [8].

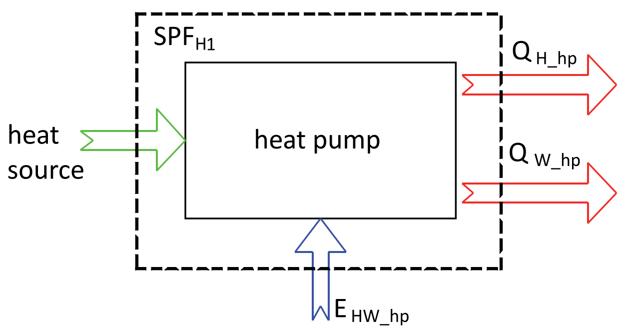

Figure 2. System boundary SPFH1 for heating [8].

System boundary use with RES-Calculations

The system boundary SPF_{H2} contains the heat pump unit and the equipment needed to make use of the source energy available for the heat pump. This level of system boundary responds to the RES-Directive [7] requirements for calculating the used renewable energy by the heat pump. SPF_{H2} allows the calculation of the SPF including auxiliary drives for the heat source, but without back-up heater (**Figure 3**).

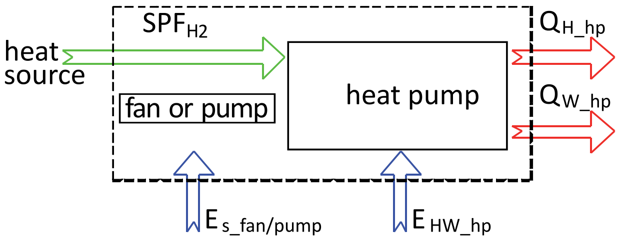

Figure 3. System boundary SPFH2 for heating [8].

$$SPF_{H2} = (Q_{H\_hp} + Q_{W\_hp})/(E_{S\_fan/pump} + E_{HW\_hp}) \quad (2)$$

The amount of RES supplied by heat pumps was set by the RES directive to be

$$E_{RES} = Q_{usable} * (1 - 1/SPF) \quad (3)$$

Only heat pumps for which SPF > 1.15 * $1/\eta$ shall be taken into account. η is the ratio between total gross production of electricity and the primary energy consumption for electricity production and shall be calculated as an EU average based on Eurostat data.

Based on 2007's value of η, that is 43.8% [2], the SPF required to pass the threshold is 2.63. Put into Eq. 3, the RES share of the usable heat is at least 62%. It should be noted that the RES share in the electricity used to operate the heat pump has not been accounted for in this calculation.

System boundary for comparing heating systems

The system boundary SPF_{H3} contains the heat pump unit, the equipment to make the source energy available and the back up heater (**Figure 4**). It represents the heat pump system and thereby can be used to compare heat pumps systems with conventional heating systems e.g. oil or gas fired systems.

$$SPF_{H3} = \frac{Q_{H\_hp} + Q_{W\_hp} + Q_{HW\_bu}}{E_{S\_fan/pump} + E_{HW\_hp} + E_{HW\_bu}} \quad (4)$$

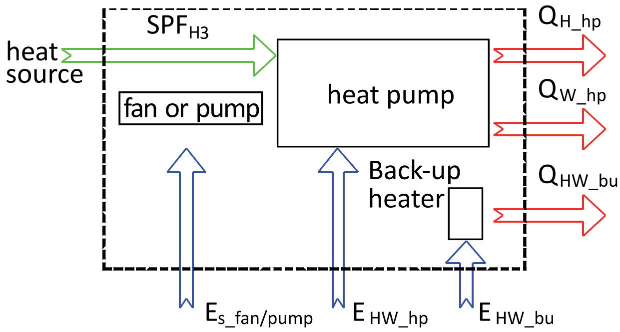

Figure 4. System boundary SPFH3 for heating [8].

System boundary including all heating system equipment

SPF_{H4} allows a calculation of the SPF with the total produced thermal energy divided by the total energy consumption (**Figure 5**). This system boundary contains the heat pump unit, the equipment to make the source energy available, the back up heater and all auxiliary drives including the auxiliary of the heat sink system. SPF_{H4} represents the heat pump heating system including all auxiliary drives which are installed in the heating system.

$$SPF_{H4} = \frac{Q_{H\_hp} + Q_{W\_hp} + Q_{HW\_bu}}{E_{S\_fan/pump} + E_{HW\_hp} + E_{bt\_pump} + E_{HW\_bu} + E_{B\_fan/pump}} \quad (5)$$

Measurement equipment

In order to implement a common system evaluation, it is not mandatory to use the same measurement equipment, but it is obligatory that during the measurements the same parameters have been recorded with comparable accuracies. The need for different measurement equipment derives from the different system boundaries [9].

It is important to define what to measure in order to apply SPF calculations, and to provide information about the measurement quality that is needed:

- Accuracy of the sensors
- Sampling intervals of the data acquisition system
- Measurement equipment quality (sensors)

Additionally, proper equipment integration into the system is highly important in order to gain accurate measurement.

Minimum monitoring results

For a common monitoring evaluation the following results (**Table 2**) should be mandatory, in order to compare the different systems in a reasonable way. To understand under which operating conditions the heat pump

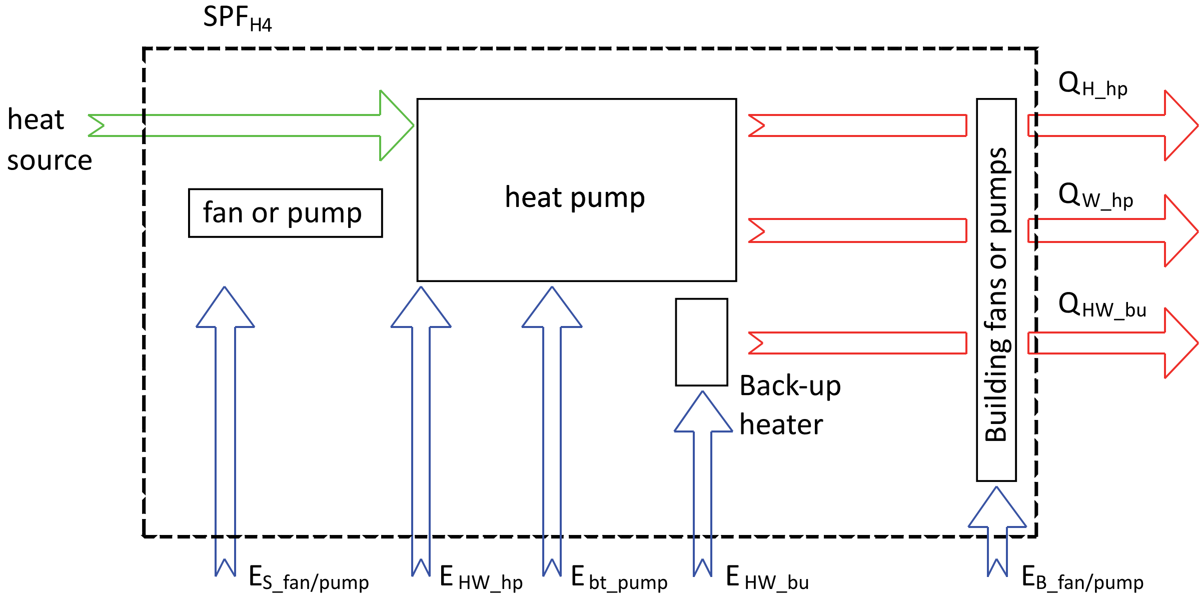

Figure 5. System boundary SPFH4 for heating [8].

system was running, it is important to record additional information e.g. average supply temperature, indoor temperature etc.

Measurement parameters

The measurement approach required consists of the determination of both, the heat delivered and the electrical energy consumed, by the heat pump. In **Figure 6** the mandatory measurement sensors needed to analyse the system according to the different system boundaries are described on the example of a ground coupled heat pump system for space heating and domestic hot water production.

According to the different system boundaries, different requirements on the mandatory equipment are given. The mandatory equipment in Figure 6 is highlighted in green. The equipment marked light grey is optional to get additional information about the system operation.

Example results according to different system boundaries

The first field measurements according to the "Concept for Evaluation of SPF", [8] and the "Field Measurement Guideline" [9] have been started by the end of 2010. For showing the influence of the different system boundaries as described above, the data of 10 ground coupled heat pump systems fulfilling as much as possible the criteria of the SEPEMO project have been selected. These sites have been measured by Fraunhofer ISE in the course of the project "Heat Pump Efficiency" [6].

Table 2. Required monitoring results [9].

Parameter	Unit
Electric energy input – total	[kWh]
Electric energy input backup heater	[kWh]
Electric energy input pumps/fans heat source side	[kWh]
Electric energy input pumps/fans heat sink side	[kWh]
Energy output heating / cooling	[kWh]
Energy output DHW	[kWh]
SPF2	[-]
SPF3	[-]
Average supply temperature heat sink*	[°C]
Average return temperature heat sink*	[°C]
Average supply temperature DHW*	[°C]
Average return temperature DHW*	[°C]
Average supply temperature heat source*	[°C]
Average return temperature heat source*	[°C]
Average outdoor temperature*	[°C]
Average indoor temperature*	[°C]

*during operation of the unit

The selected systems are typical ground coupled heat pump systems for the use in single family houses with heat pumps covering a range of heating capacities between 8 and 12 kW. All heat pump systems operate in DHW and SH mode.

Due to the fact that only four systems were operating an electric back up heater, the energy supply ration of the monitored systems is high and the results are between

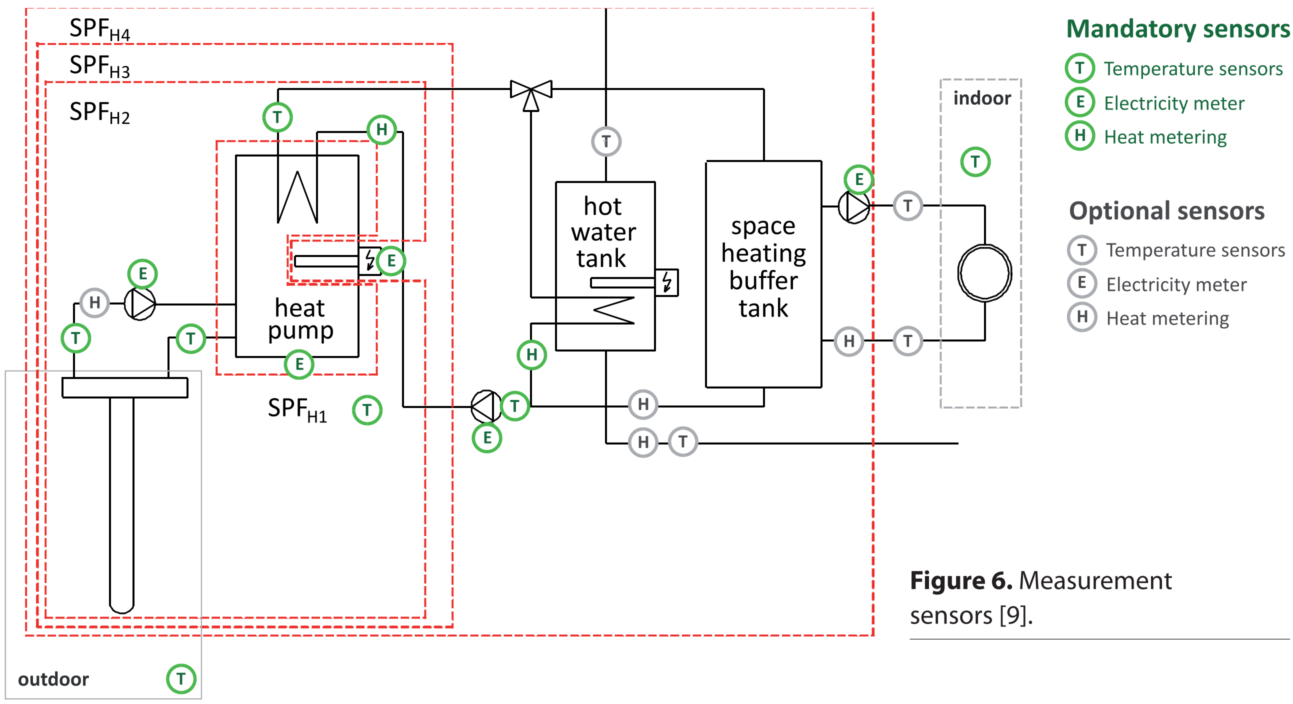

Figure 6. Measurement sensors [9].

95.5% and 100% (**Figure 7**). Additionally Figure 7 shows the ratio between heat used for space heating and domestic hot water production. The high demand on domestic hot water in site number 6 can be explained with different user behaviour. Excluding system number 6, the ratio between SH and DHW is between 6% and 25%, which is quite common for single family houses in mid-Europe.

Figure 8 shows the ratio between the total amount of electric energy needed to run the heat pump and the electric energy demand of the auxiliaries. The results for the electricity needed to operate the auxiliaries are between 8% and 27%. System number 7 has the highest demand for the electric back up heater of all the systems, whereas site number 1 has the highest need for electric energy to run the buffer tank pump.

The SPF calculated according to the four defined system boundaries SPF_{H1}, SPF_{H2}, SPF_{H3} and SPF_{H4} show how the efficiency of the different systems is influenced by the operating conditions and by the system design, which directly impacts on the auxiliaries needed (**Figure 9**). According to the system boundaries SPF_{H2} and SPF_{H3} result in the same values when the systems do not have an electric back up, therefore only the sites number 6 and 7 show different results for SPF_{H2} and SPF_{H3}.

Sites number 1 and 7 have the largest differences between SPF_{H1} and SPF_{H4}. This can be due to the highest ratios between the total amount of electric energy needed to run the heat pump and the electric energy demand of the auxiliaries as explained above. In system number 7 the operation of the electric back up heater influenc-

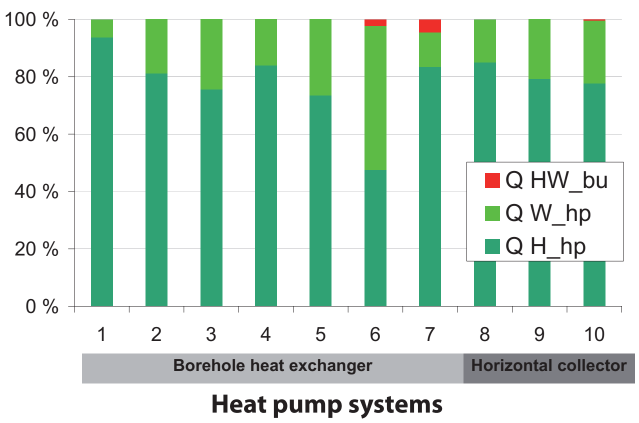

Figure 7. Ratio between heat delivered by the heat pump and the back up heater.

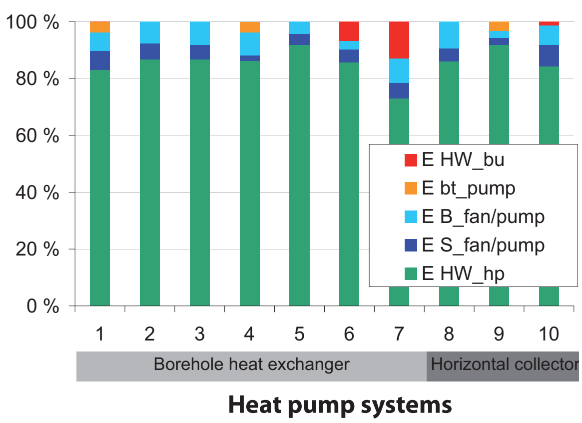

Figure 8. Ratio between electrical energy demand by the heat pump and auxiliaries.

es the result substantially. The big difference between SPF_{H1} and SPF_{H4}.at site number 1 can be best explained with the high amount of electric energy demand for the buffer tank pump and the circulation pump in the heat source. System number 4 shows the biggest drop between SPF_{H3} and SPF_{H4} of all the sites due to its highest amount of electric energy demand for the circulating pump in the heat sink and the buffer tank pump. Due to its lowest heat source temperature and the highest temperature level for DHW the heat pump system number 10 has the lowest SPF_{H1}. Also site number 6 reaches a quite low SPF_{H1} compared to the other systems, which can be explained by the rather high ratio for DHW of 51% as explained above. Generally Figure 9 points out that the different system boundaries show the impact of the integrated auxiliaries and that additionally for an interpretation of the SPF the operating conditions of the systems must be considered.

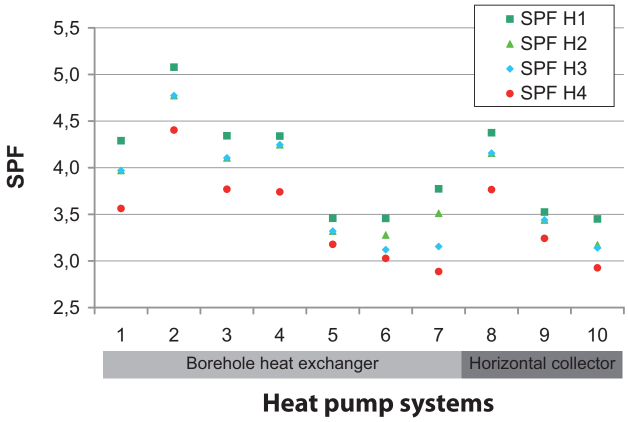

Figure 9. SPF according different system boundaries.

Conclusions

Measuring and reporting SPF of heat pump systems is an important means to determine the long term performance of the heat pump unit installed in the heating system. Depending on the specific topic to be reported, different system boundaries and hence different equations to determine the SPF should be used.

For comparing different field trials it is mandatory to use the same system boundaries for calculating the SPF as the definition of these boundaries directly influences the SPF of the system. In order to guarantee the quality of the recorded data to make a significant system evaluation it is highly important to set minimum requirements on the measurement equipment and in a second step, a proper equipment installation in the heat pump system is obligatory.

The efficiency of heat pump systems represented as SPF is mainly influenced by the operating conditions and the set system boundaries for calculating the SPF. Therefore it is important to define minimum results for field trials in order to get a hint under which conditions the heat pump was operated. Furthermore it is necessary to calculate the SPF according to different system boundaries display the impact of the auxiliaries integrated in the system.

The SEPEMO project deals with these two main points in the "Concept for Evaluation of SPF" [9] and the "Field Measurement Guideline" [10]. An analysis of the 10 selected ground coupled heat pump systems according to the defined system boundaries SPF_{H1} - SPF_{H4} together with the operating conditions shows, that the different system boundaries give a good overview on the impact of the different auxiliaries on the efficiency of the system, but to get the whole picture the operating conditions have to be taken into account.

By adopting this approach, different field measurements of heat pump systems will be much easier to compare in the future. It will also be easier to make comparisons to other heating systems efficiencies.

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Collection and analysis of HVAC system energy use in the EU Member States

The iSERV project aims to collect sub-hourly HVAC system energy use data from around 1600 HVAC systems in the EU Member States and analyse this information.

The overall objectives of iSERV:

- Is to provide some reward to HVAC system owners/operators and manufacturers for addressing the energy efficiency of these systems in their operation and design.
- To establish that the continuous monitoring and benchmarking of HVAC processes will provide energy saving benefits equivalent to or better than those achievable by Physical Inspection alone
- To produce benchmarks of energy consumption by HVAC systems against end use activities derived from measured data around Europe
- To encourage the rapid adoption of more energy efficient HVAC systems through demonstrating their in-use benefits

The main benefits for the project participants:

- Get feedback on their building energy use patterns and comparisons with similar systems
- Detailed understanding of their HVAC energy consumption
- Get key directions on how to improve in-use energy efficiency of their HVAC systems
- Know how to avoid HVAC system inspections when identified as performing

REHVA will play an active role to get participants enrolment in this project and disseminate the results of the study.

Should you be interested in a direct participation, please do contact the project via the iSERV website **http://www.iservcmb.info/** - or if prior to August 2011 then contact the project Coordinator, Dr Ian Knight, at knight@cf.ac.uk. *See all details in the announcement on the Build Up portal:* **http://www.buildup.eu/news/15861**

Please do spread the information around to possible interested organisations or companies.

About the Heat Pump Programme and the Heat Pump Centre

The Heat Pump Programme (HPP) is a non-profit organisation in which participants in different countries cooperate in projects in the field of heat pumps and related heat pumping technologies such as air conditioning, refrigeration and working fluids (refrigerants). The aim is to accelerate the use of heat pumps in all applications where they can reduce energy use for the benefit of the environment.

HPP is one of approximately 40 agreements known as Implementing Agreements which operate under the International Energy Agency (IEA), which in turn is linked to the Organisation for Economic Co-operation and Development (OECD).

The members of the Programme are governments, represented by designated entities such as national agencies, public organisations or private companies. Management is vested in an Executive Committee (ExCo), on which all member countries have representatives.

The Heat Pump Centre - the Programme's information centre

The role of the Heat Pump Centre (HPC) is to serve as the central information source of the Programme, by offering a worldwide information service to support all those who play a part in the implementation of heat pumping technology, on international and national levels. The target groups include policy-makers, agencies, manufacturers, researchers, utilities, designers, end users, installers, and other organisations.

The main activities of HPC include publishing an electronic newsletter, maintaining the Programme's website, creation and distribution of brochures and flyers, generating new activities, supporting the triennial International Heat Pump Conference and supporting the organisation of the Programme.

International collaboration through National Teams

Each member country has a National Team, which is responsible for promotion of the Heat Pump Programme in its home country. The teams are made up of experts in their countries and work to identify needs and opportunities for new activities within the Programme.

The Heat Pump Programme is the foremost worldwide source of independent information and expertise on the 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 environmental impact.

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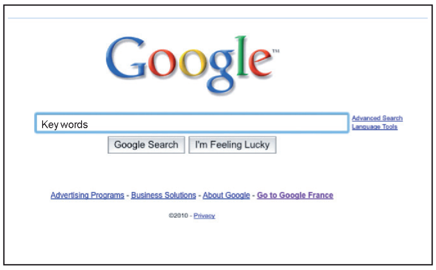

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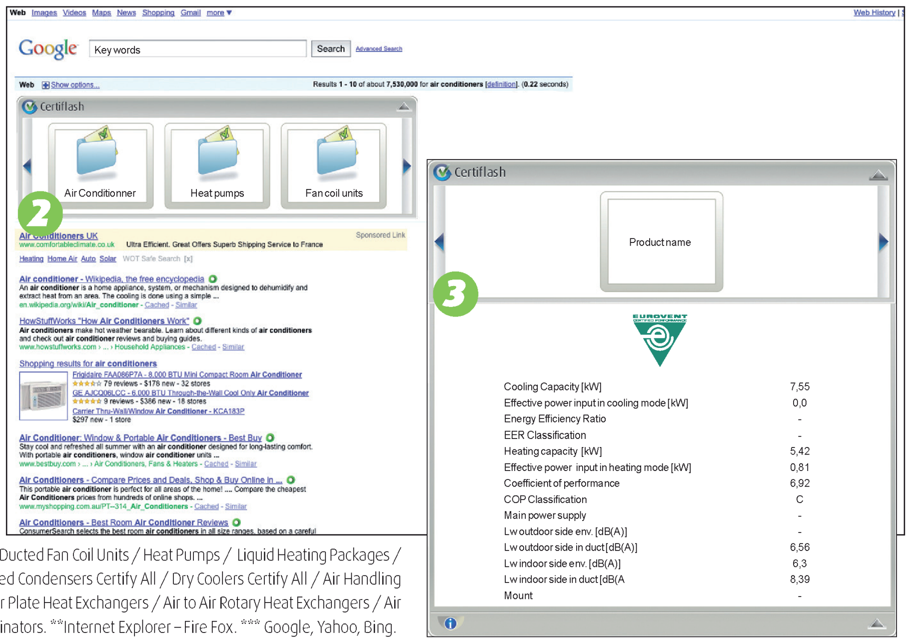

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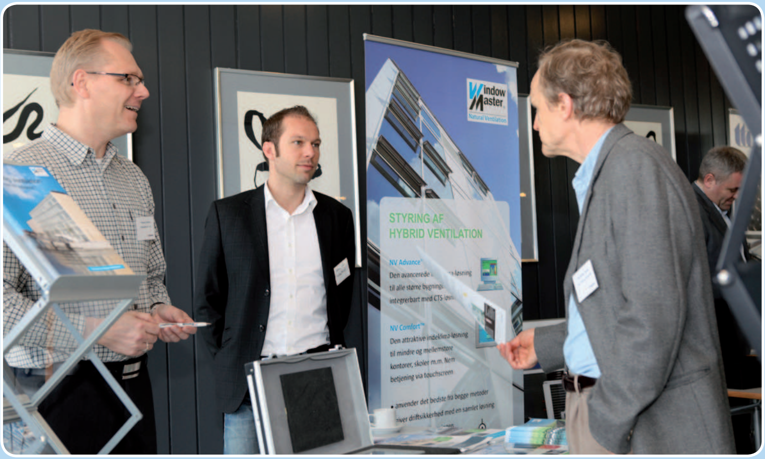

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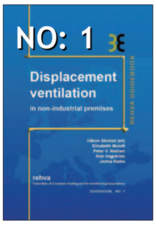
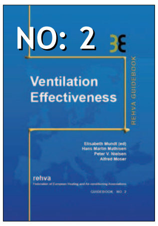
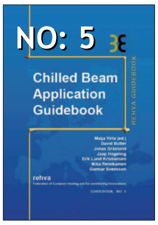


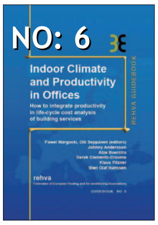
Displacement Ventilation Guidebook serves as a comprehensive and easy-to-understand design manual. It explains the benefits and limitations of displacement in commercial ventilation and outlines where ventilation should be applied. Various case studies are included. The benefits of displacement ventilation are that less cooling is needed for a given temperature in the occupied spaces, longer periods with free cooling and better air quality in the occupied spaces.



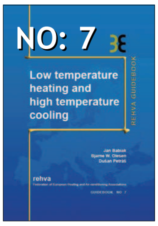
Improving the ventilation effectiveness allows the indoor air quality to be significantly enhanced without the need for higher air changes in the building, thereby avoiding the higher costs and energy consumption associated with increasing the ventilation rates. This Guidebook provides easy-to-understand descriptions of the indices used to mesure the performance of a ventilation system and which indices to use in different cases.



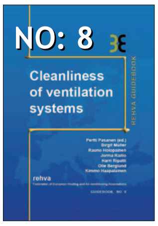
Chilled beam systems are primarily used for cooling and ventilation in spaces, which appreciate good indoor environmental quality and individual space control. Active chilled beams are connected to the ventilation ductwork, high temperature cold water, and when desired, low temperature hot water system. Primary air supply induces room air to be recirculated through the heat exchanger of the chilled beam. In order to cool or heat the room either cold or warm water is cycled through the heat exchanger.



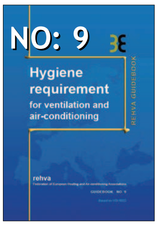
Indoor Climate and Productivity in Offices Guidebook shows how to quantify the effects of indoor environment on office work and also how to include these effects in the calculation of building costs. Such calculations have not been performed previously, because very little data has been available. The quantitative relationships presented in this Guidebook can be used to calculate the costs and benefits of running and operating the building.



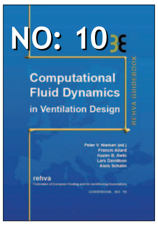
This Guidebook describes the systems that use water as heat-carrier and when the heat exchange within the conditioned space is more than 50% radiant. Embedded systems insulated from the main building structure (floor, wall and ceiling) are used in all types of buildings and work with heat carriers at low temperatures for heating and relatively high temperature for cooling.



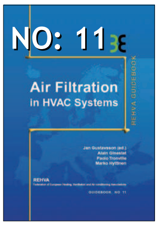
Cleanliness of ventilation systems Guidebook aims to show that indoor environmental conditions substantially influence health and productivity. This Guidebook presents criteria and methods on how to design, install and maintain clean air handling systems for better indoor air quality.



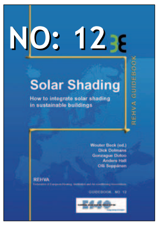
Hygiene requirement is intended to provide a holistic formulation of hygiene-related constructional, technical and organisational requirements to be observed in the planning, manufacture, execution, operation and maintenance of ventilating and air-conditioning systems. These requirements for ventilating and air-conditioning systems primarily serve to protect human health.



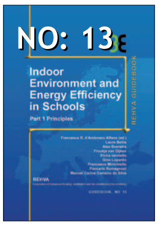
CFD-calculations have been rapidly developed to a powerful tool for the analysis of air pollution distribution in various spaces. However, the user of CFD-calculation should be aware of the basic principles of calculations and specifically the boundary conditions. Computational Fluid Dynamics (CFD) – in Ventilation Design models is written by a working group of highly qualified international experts representing research, consulting and design. CFD Guidebook is an excellent text book for various building professionals.



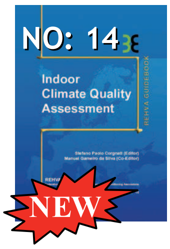
Air filtration Guidebook will help the designer and user to understand the background and criteria for air filtration, how to select air filters and avoid problems associated with hygienic and other conditions at operation of air filters. The selection of air filters is based on external conditions such as levels of existing pollutants, indoor air quality and energy efficiency requirements.



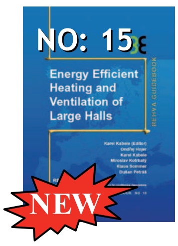
Solar Shading Guidebook gives a solid background on the physics of solar radiation and its behaviour in window with solar shading systems. Major focus of the Guidebook is on the effect of solar shading in the use of energy for cooling, heating and lighting. The book gives also practical guidance for selection, installation and operation of solar shading as well as future trends in integration of HVAC-systems with solar control.



School buildings represent a significant part of the building stock and also a noteworthy part of the total energy use. Indoor and Energy Efficiency in Schools Guidebook describes the optimal design and operation of schools with respect to low energy cost and performance of the students. It focuses particularly on energy efficient systems for a healthy indoor environment.



This new REHVA Guidebook gives building professionals a useful support in the practical measurements and monitoring of the indoor climate in buildings. Wireless technologies for measurement and monitoring has allowed enlarging significantly number of possible applications, especially in existing buildings. The Guidebook illustrates with several cases the instrumentation for the monitoring and assessment of indoor climate.



This guidebook is focused on modern methods for design, control and operation of energy efficient heating systems in large spaces and industrial halls. The book deals with thermal comfort, light and dark gas radiant heaters, panel radiant heating, floor heating and industrial air heating systems. Various heating systems are illustrated with case studies. Design principles, methods and modeling tools are presented for various systems.

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