ISSN 1307-3729

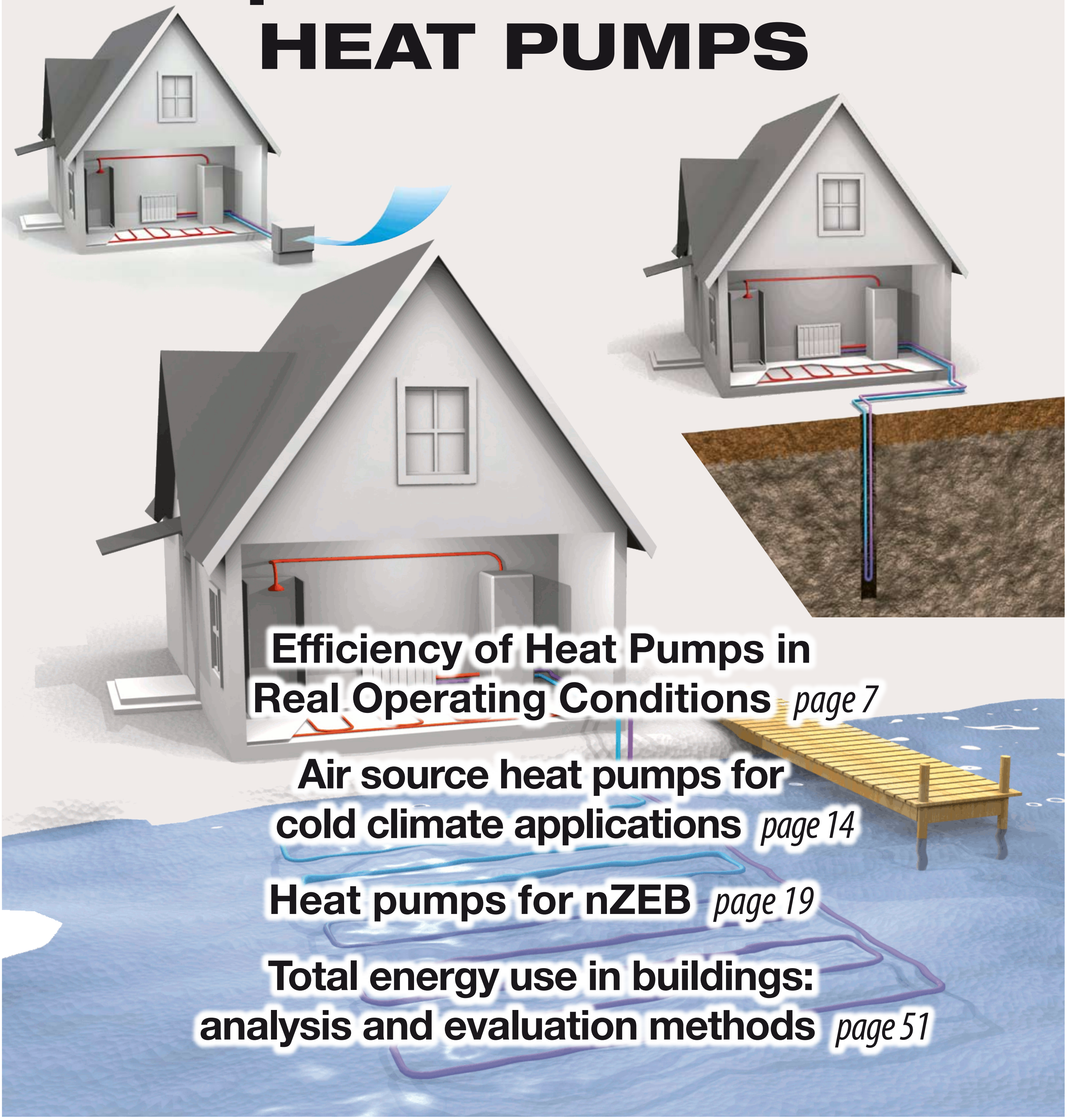
REHVA

Federation of European Heating, Ventilation and Air Conditioning Associations

The REHVA European HVAC Journal

Volume: 51 Issue: 5 September 2014 www.rehva.eu

Special issue on HEAT PUMPS



The REHVA European HVAC Journal

www.rehva.eu

Volume: 51 Issue: 5 September 2014

Editor-in-chief: Olli Seppänen
oseppanen@rehva.eu

General Executive: Süleyman Bulak

Associate Editor: Stefano Corgnati, Italy
stefano.corgnati@polito.it

Editorial Assistant: Cynthia Despradel

ADVERTISEMENTS
Ms Cynthia Despradel
cd@rehva.eu

SUBSCRIPTIONS and CHANGES OF ADDRESSES
REHVA OFFICE:
Washington Street 40
1050 Brussels, Belgium
Tel: 32-2-5141171, Fax: 32-2-5129062
info@rehva.eu, www.rehva.eu

PUBLISHER
TEKNİK SEKTÖR YAYINCILIĞI A.Ş.
Balmumcu, Barbaros Bulvarı Bahar
Sk. Karanfil Apt. No:2/9
Beşiktaş /İstanbul, Turkey

Cover photos: Thermia Heat Pumps

Contents

Download the articles from **www.rehva.eu** -> REHVA Journal

Advertisers

Next issue of REHVA Journal

Instructions for authors are available at **www.rehva.eu**
(> Publications & Resources > HVAC Journal > Journal information)

Send the manuscripts of articles for the journal to Cynthia Despradel **cd@rehva.eu**

Performance of heat pump systems in building applications

OLLI SEPPÄNEN
Professor,
Editor-in-chief

The theme of this issue is heat pumps. Part of the material in this issue has been compiled with the help of IEA Heat Pump Programme. The Programme plays an important role in accelerating the use of heat pumps in all applications where they can reduce energy consumption for the benefit of the environment.

In recent years there have been tremendous improvements in the performance of heat pumps, particularly in the efficiency of compressors and heat exchangers. Significant standardisation has helped the development.

However, the compressor is only one component in a heat pump system. Only with a good overall design and operation of the system is the predicted energy efficiency and good indoor environment achieved. When used in building applications, heat pumps are part of the heating and air-conditioning system with fixed boundary conditions. In building applications, a major challenge is to achieve good performance under varying conditions and temperature levels of heat source and sink.

A major advantage of heat pumps is their reversible operation. The need for cooling has been a driving force in the increasing use of residential, particularly air-to-air, heat pump applications. However, there remains a significant need for improvement in reducing their noise level and draft, to conform to commonly accepted standards for indoor environment.

Heat pump manufacturers often inform the customers only the peak performance efficiency of heat pumps. This is misleading in many cases, as operating hours at peak capacity are quite limited and heat pumps operate most of the time at part load conditions. This is why the European Union now requires data on the seasonal efficiency of the products sold in the EU area.

The effective use of heat pumps in buildings needs close cooperation between manufactures and building designers during the development of applications. Designers are represented nationally and internationally in several engineering associations. Standards should increasingly cover building applications, not only the primary components of heat pumps. Cooperation between designers and manufacturers is needed.

For the user of heat pumps, reliable performance data is crucial when making the purchase decision. For this purpose a third party independent certification is necessary. Such certification procedures are available in several countries, some of which, like European certification, are used in more than one country. Unfortunately for the manufacturers, all national certification systems have their own procedures and test conditions, and one certification is not accepted in another country. Hopefully, in the future, certification process can be standardised internationally and rationalised. This would benefit manufactures and customers. ■

TIME FOR FRESH AIR – my last issue

During the last six years, REHVA Journal has grown from a quarterly magazine with less than 200 pages to a well-recognized bi-monthly journal with close to 600 printed pages annually. Authors of the articles now represent the whole HVAC community in Europe with additional international input. Paper copies are sent to 6 000 addresses, mainly in Europe but also to important readers all over the world.

My target has been to develop a publication that offers readers good technical information, neither scientific reports nor commercial testimonies, but a balance between the two. Feedback from the readers shows that this approach has been widely accepted.

This is the last issue compiled by me as editor-in-chief. I have enjoyed working with the authors and am grateful for their contributions. I am now looking forward to devoting more time to my professional activities in Finland.

– OS

Lindab Pascal

Simplified VAV solution with full potential…

Lindab is now launching the next generation of VAV system with the purpose of simplifying and optimizing all phases of the building construction from design to operation. This solution saves you for unnecessary energy use, regulation equipment in the ducts and a complicated installation. Lindab Pascal, the most simplified solution on the market with all you need for an optimized VAV system.

Lindab – We simplify construction…

Lindab®

www.lindab.com

Efficiency of Heat Pumps in Real Operating Conditions

– Results of three Monitoring Campaigns in Germany

MAREK MIARA
Head of Group Heat Pumps.
Fraunhofer-Institute for Solar Energy Systems ISE, Freiburg, Germany
miara@ise.fraunhofer.de

DANNY GÜNTHER
Dipl.-Ing. (FH)

ROBERT LANGNER
Dipl.-Ing. (FH)

SEBASTIAN HELMLING
Dipl.-Ing.

Since 2006 Fraunhofer ISE in Freiburg, Germany, has been investigating electric heat pumps in single-family dwellings. Within three projects nearly 250 air-to-water and brine-to-water heat pumps system have been investigated under real operating conditions in houses with various energetic standards (from low-energy to un-retrofitted stock buildings with high energy demand).

Key Words: heat pumps, efficiency, SPF, monitoring, field test

The share of heating and domestic hot water production in residential buildings in Germany (representable for most European countries with high heating demand) constitutes in average more than 75% of overall energy consumption in residential buildings (Galvin 2010), (Graichen et al. 2012). Covering this demand in a possibly environmentally friendly way is thus key to fulfilling the climatic goals on the national and international level. Heat pumps is a technology which can meet this challenge (Hepbasli et al. 2009). Furthermore, the higher its efficiency, the better can it be achieved. It is thus crucial to have reliable data assessing the efficiency of heat pumps units under real operating conditions and to draw conclusions how to ensure the best possible efficiency of the systems.

Characteristic of the projects

The project "Heat Pumps in Existing Buildings" includes heat pumps in older, un-retrofitted buildings. All other projects have been performed predominantly in newly built single-family dwellings. The average heated area of the buildings in all projects is similar and amounts to approximately 190 m² (2 045 ft²). The average heat demand for older buildings amounts to 120 kWh/(m²a), and for newly built dwellings 70 kWh/(m²a).

Figure 1 shows the names of the performed projects with the number of investigated units in each project.

Each project has been different financing and also the projects partner varied. At the same time, all projects have been performed in a very similar way as to the methodology and measurement equipment used. More information about each project can be found in (Miara et al. 2011).

Characteristics of heat sources of investigated heat pumps units

Figure 2 shows the division of heat sources of the analysed heat pumps for the individual projects.

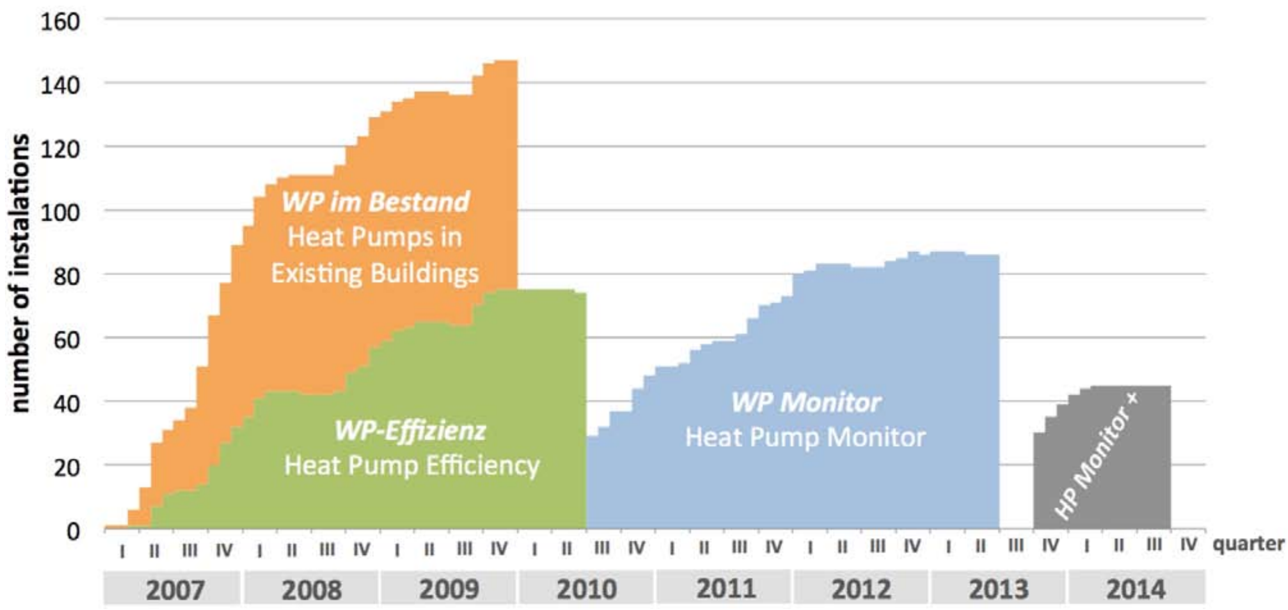


Figure 1. Performed projects with the number of investigated.

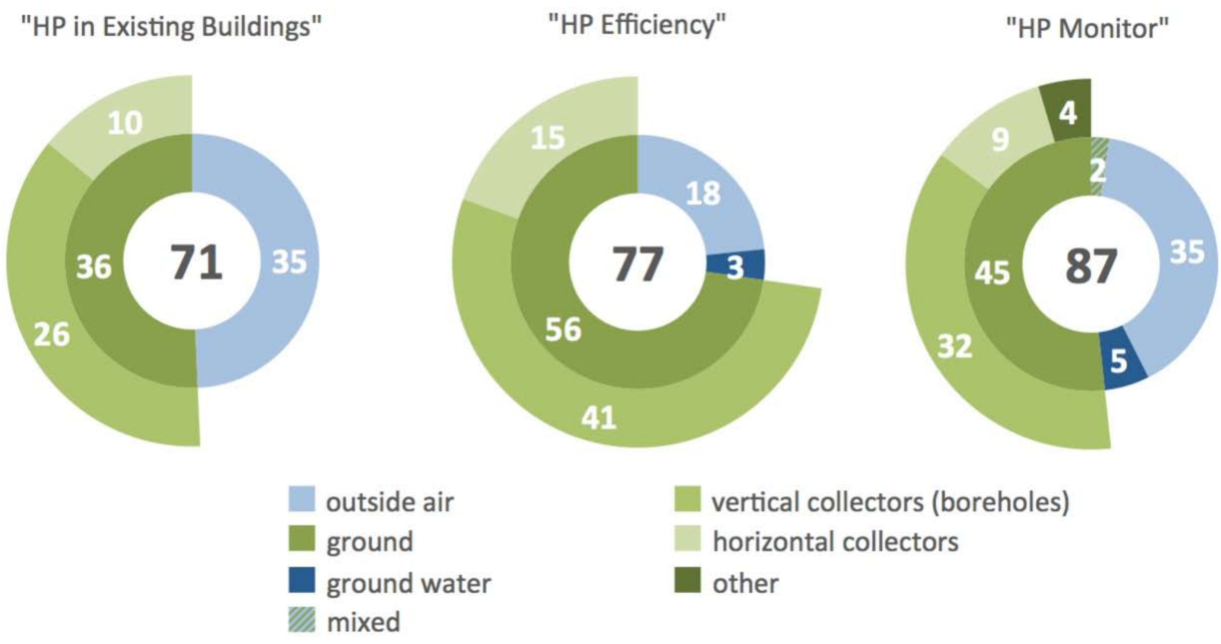


Figure 2. Heat sources of the heat pump systems.

In the project "HP in Existing Buildings" 71 units have been analysed. The number of the ground and of the outside air heat pumps examined was similar. Among ground heat pumps the units with boreholes (26) outnumbered those with horizontal collectors (10). In the second project ("HP Efficiency"), 77 units were examined. Most of them were ground heat pumps (56); among them 41 units with boreholes and 15 with horizontal collectors. Air heat pumps constituted 23% (18 units). Additionally, a small number of ground water heat pumps was investigated. The project "HP Monitor" was characterized by the greatest variety of heat sources. In addition to air and ground heat pumps, a small number of mixed and combined heat sources has been included.

Information concerning the buildings and the heat distribution systems, as well as buffer tanks is available in (Miara 2009).

Outcomes of the Seasonal Performance Factors (SPF)

System boundaries

Figure 3 shows the scheme of a typical heat pump installation and illustrates the system boundaries. There are various possibilities to calculate the efficiency of a heat pump system. The outcomes of efficiency calculations presented in sections below based on the boundary SPF 2, unless specified otherwise. The same calculation boundary was suggested as a main boundary for presenting the efficiency outcomes of heat pump systems in the European project SEPEMO-BUILD (Zottl and Nordman 2012).

The SPF is the ratio of the heat energy produced by the heat pump and the back-up heater and the corresponding energy need of the heat pump, back-up heater and source fans in case of the A/W heat pump, brine pump in case of the B/W heat pump and well pump in case of W/W heat pump.

Averages values of the SPF

Figure 4 shows average values of SPF values among individual projects, as well as the individual heat sources. The comparison takes into account outside air heat pumps and ground coupled heat pumps. Ground water heat pumps were omitted due to a little number of the examined installations. Calculation periods differ and are indicated for each project.

The differences in the average SPF values depend on a type of a heat source, type of a building and the period of installation (indicating advancement of technology). The difference between outside air heat pumps and ground heat pumps is evident to the benefit of ground heat pumps. The ground as a heat source is more beneficial from the point of view of its temperature in coldest periods with the most demand for heating.

Another important difference was noted between older and newer buildings. It results mainly from a type of the used heat distribution system. Under-floor systems, mostly used in newer buildings, enable lower supply temperatures compared to systems based on radiators in older buildings. Lower supply temperatures contribute significantly to higher efficiency of heat pumps.

In the framework of the "HP Monitor" project, a group of newly installed units was investigated separately (on the graph shown with the symbol * in black). The outcomes from this group indicate the improvement in the heat pump efficiency resulting from technology development in the recent years.

Ranges of the SPF

Figure 5 shows the range of the SPF values for each project and heat source.

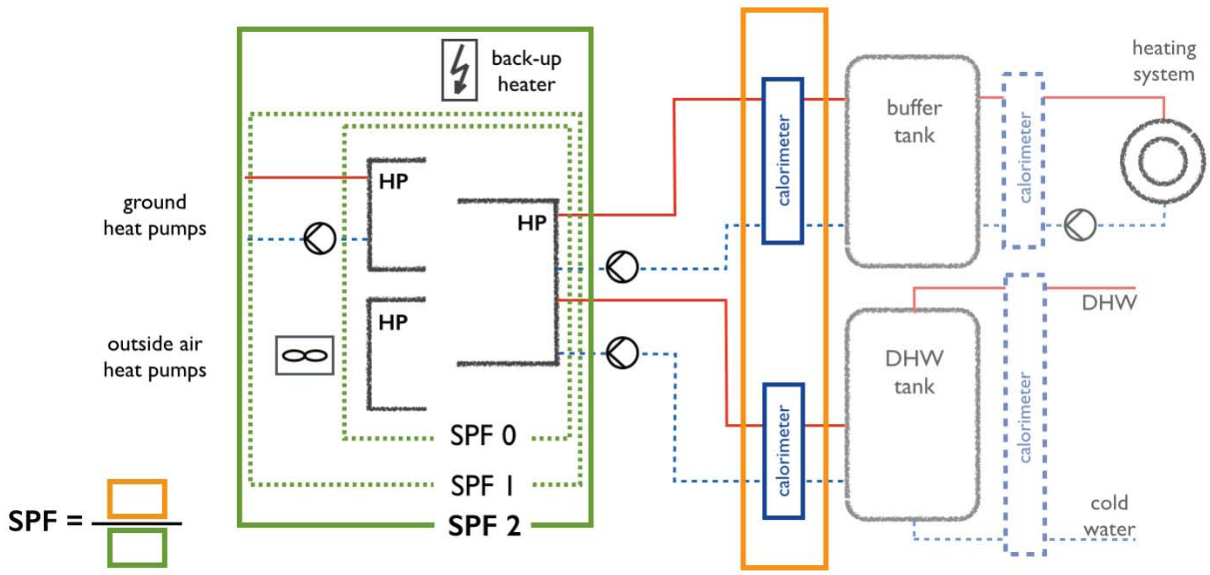


Figure 3. Heat pump installation and the system boundaries for calculation of SPF values.

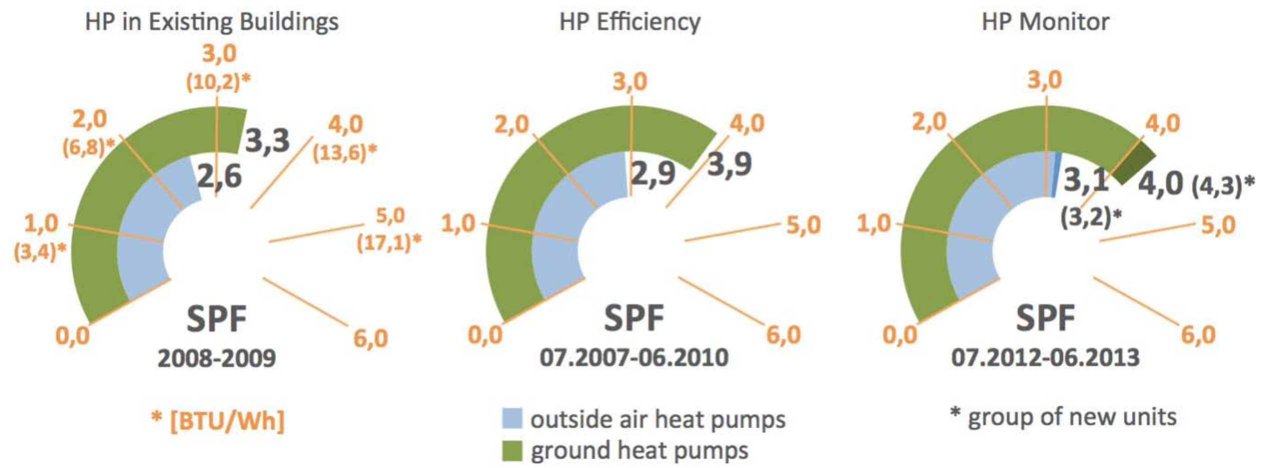


Figure 4. Averages values of SPF values.

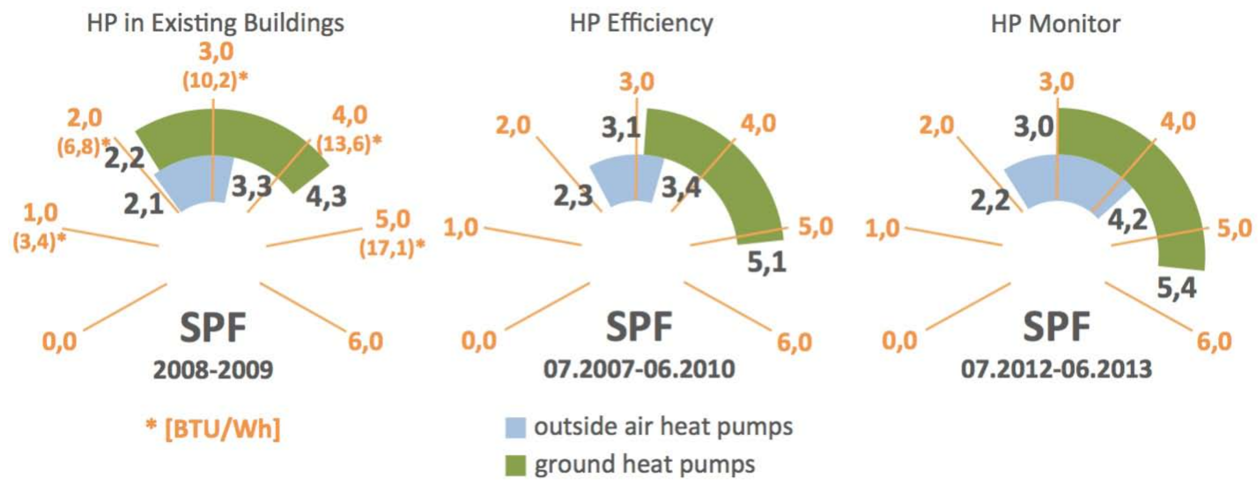


Figure 5. Range of SPF values of individual units.

The results of all projects indicate smaller range of outcomes for individual units with outside air heat pumps, compared with ground heat pumps. The wide range of SPF achieved by ground heat pumps (at least 2.0 points) indicates a high potential of efficient functioning of ground heat pumps. On the other hand, it shows that the choice of a heat source seems not to automatically guarantee a high efficiency. Errors in designing, installation and/or running process, result in decrease of potential efficiency and diminish economical and ecological benefits of theoretically more efficient, but at the same time more expensive, heat source.

SPF values for individual units

Figure 6 shows individual outcomes from 47 ground source heat pump installation from the project "HP Monitor". The number of the months in which measure data have been analyzed is indicated in the lower part of the bars showing the SPF value.

Most of the installations (light green) were taken over from the project "HP Efficiency" and analyzed in the framework of "HP Monitor" in parallel with the new units (dark green).

Nine installations used horizontal collectors and the remaining units were equipped in boreholes (1 to 4 per heat pump installation). Among the boreholes units, one consists of a 300 m borehole filled with water instead of brine together with another filled with CO_2. Further two installations were based on the direct evaporation principle.

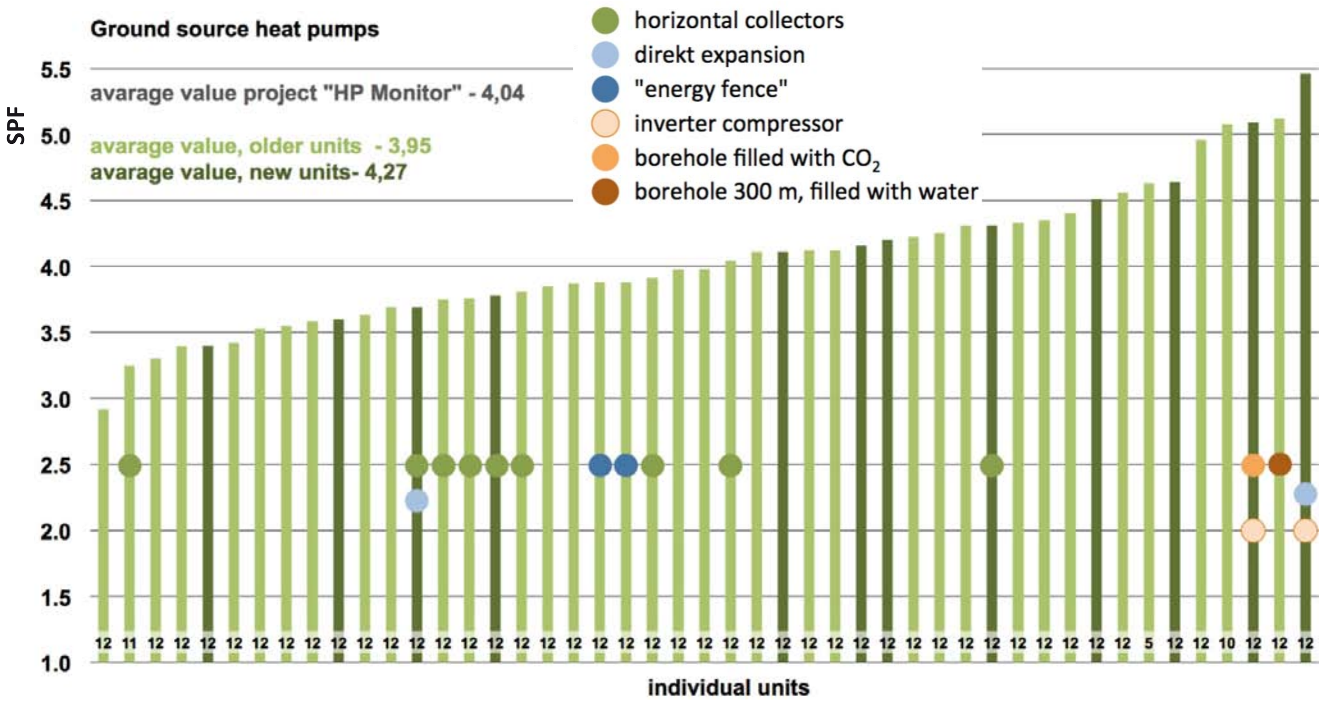


Figure 6. Individual SPF values of the ground HP with indication of the technology.

Another form of a non-standard installation was a so-called "energy-fence". The pipes filled with brine form a fence sank in 1/3 in the ground. This solution uses both outside air and ground as a heat source.

Two installations used relatively rare for ground source heat pumps inverter compressors.

SPF values for different calculation boundaries

Figure 7 shows outcomes from various calculation boundaries of the SPF values for ground source heat pumps.

Calculation of SPF 0 takes into account only the electricity consumption of a compressor and of a control system. Calculation of SPF 1 includes the consumption of a brine pump and the calculation of SPF 2 – of a back-up heater. On the graph the blue and orange colours indicate the efficiency savings achieved by the absence of the mentioned components. The average share of brine pumps is equal to 0.22, 0.26 and 0.20, respectively. The difference in the share between projects "HP Efficiency" and "HP Monitor" results from the increased use of high efficiency brine circulation pumps in recent years. For example, in the project "HP Monitor" brine pumps' share in the overall electricity consumption equals 4%. However, the range of the share for individual units amounted from 2% to 11%. It indicates the importance of use of energy-saving circulation pumps.

The values of SPF 1 and SPF 2 differ only insignificantly, showing that the electric back-up heaters do not cause a considerable consumption of electric energy, irrespectively of the type of a building. The same tendency was observed for outside air heat pumps with electric back-up heaters operating only during in the periods of extremely low temperatures, and even then not in all units.

Conclusions

Measurements of heat pumps in real operating conditions determined the average seasonal efficiency for different types of heat pumps. The results indicate a clear difference of efficiency between heat pumps operating in older buildings (un-retrofitted) and heat pumps in newly constructed buildings with heating systems based on surface heat distribution. The average SPF values for outside air and ground source heat pumps clearly reveal higher efficiency of ground heat pumps. However, SPF values achieved by individual installations of ground source heat pumps had a much wider range then the one noted for the outside air heat pumps, leading to a partial

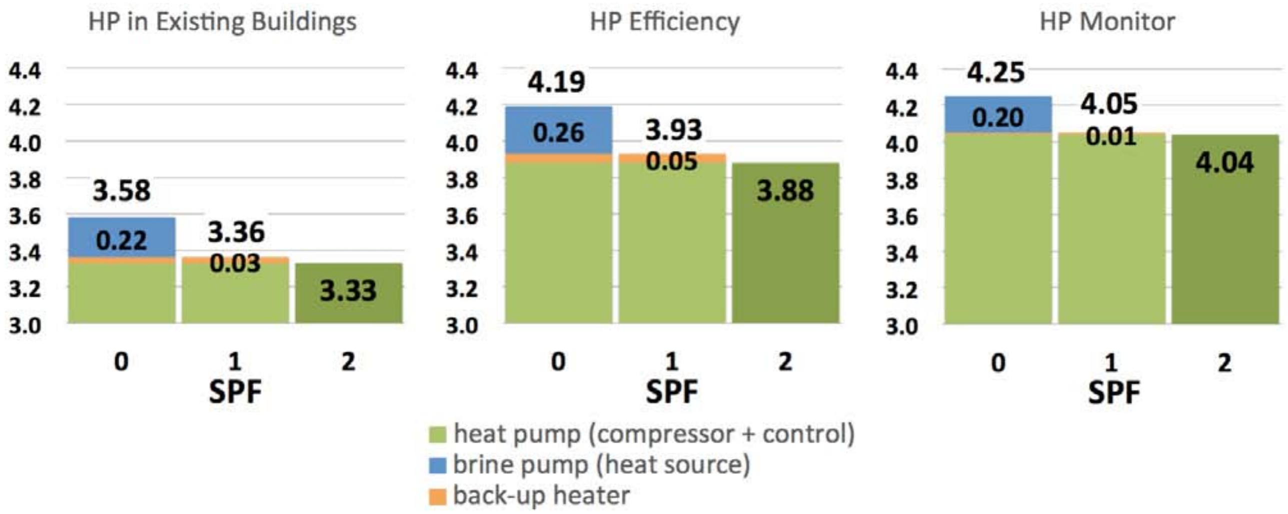


Figure 7. SPF values for various calculation boundaries.

overlapping of both ranges. It enables a conclusion that the choice of the heat source is not an automatic guarantee of a higher efficiency. Errors during the design, installation and operation process markedly decrease the achievable efficiency of heat pumps. Simple and robust units usually work with the highest efficiency.

The analysis of the measurement of electric energy consumption of individual components of the heating system based on a heat pump exposed a large range of energy consumption by fans and brine pumps among individual units. It has been shown that the optimization of heat pumps in terms of efficiency should not be limited to heat pump components (compressor, evaporator, etc.). It is advisable to apply possibly energy-saving fans and circulation pumps.

The results of long-term monitoring of both types of buildings (new and old) and all types of heat pumps (outside air and ground) revealed a very small share of electricity consumption by electric back-up heaters, thus not confirming the often formulated concerns about its high share.

The most recent test results obtained from measurements within the project "HP Monitor" confirmed the increase in efficiency of heat pumps resulting from developments of the technology. ■

References

Galvin, R. 2010. "Thermal Upgrades of Existing Homes in Germany: The Building Code, Subsidies, and Economic Efficiency." *Energy and Buildings* 42 (6) (June): 834–844.

Graichen, Verena, V. Bürger, S. Gores, G. Penninger, W. Zimmer, W. Eichhammer, T. Fleiter, B. Schlomann, and A. Strigel. 2012. "Energieeffizienzdaten Für Den Klimaschutz". Dessau-Roßlau.

Hepbasli, Arif, Z. Erbay, F. Icier, N. Colak, and E. Hancioglu. 2009. "A Review of Gas Engine Driven Heat Pumps (GEHPs) for Residential and Industrial Applications." *Renewable and Sustainable Energy Reviews* 13 (1) (January): 85–99.

Miara, Marek. 2009. "Heat Pumps in Action." *Renewable Energy World Magazine*, Volume 12, Number 5, pp. 74-78, September-October 2009.

Miara, Marek, D. Günther, T. Kramer, and H.-M. Henning. 2011. "Efficiency of Heat Pump Systems under Real Operating Conditions." In *10th IEA Heat Pump Conference*. Tokyo: Heat Pump Centre.

Zottl, Andreas, and R. Nordman. 2012. "Project SEPEMO, D4.2./D2.4. Concept for Evaluation of SPF." www.sepemo.eu.

Throughout the world, our solutions enrich people's way of life

At Uponor we understand modern buildings and work hard to future-proof our solutions. All our solutions are designed to enrich people's way of life: fast and easy to install, conserving water and energy, providing comfort and health, and giving peace of mind.

For more information, please visit us at

www.uponor.com

uponor
simply more

Air source heat pumps for cold climate applications

– Recent U. S. R&D results from IEA HPP Annex 41

Air source heat pumps are easily applied to buildings almost anywhere. They are widespread in milder climate regions but their use in cold regions is hampered due to low heating efficiency and capacity at cold outdoor temperatures. This article describes selected R&D activities aimed at improving their cold weather performance.

Keywords: Air source heat pump; cold climate heat pumps; vapour compression; economizer cycles; parallel compressor cycles; IEA HPP Annex 41.

V. BAXTER
Oak Ridge National Laboratory, USA
baxtervd@ornl.gov

E. GROLL
Herrick Labs, Purdue University, USA

B. SHEN
Oak Ridge National Laboratory, USA

The IEA Heat Pump Programme (IEA HPP) is a non-profit organisation with 15 member countries – Austria, Canada, Denmark, Finland, France, Italy, Germany, Japan, the Netherlands, Norway, South Korea, Sweden, Switzerland, United Kingdom and the United States http://www.heatpumpcentre.org/en/aboutHPP/Sidor/default.aspx. The Programme carries out a strategy to accelerate the use of heat pumps in all applications where they can reduce energy consumption for the benefit of the environment. It strives to achieve widespread deployment of appropriate high quality heat pumping technologies to obtain energy conservation and environmental benefits from these technologies. Under the management of an Executive Committee the member countries cooperate in projects (called Annexes) in the field of heat pumps and related heat pumping technologies such as air conditioning, refrigeration and working fluids (refrigerants). Over 40 Annexes have been or are being conducted under the Programme.

In 2012 the IEA HPP established Annex 41 to investigate technology solutions to improve performance of heat pumps for cold climates. Four IEA HPP member countries are participating in the Annex – Austria, Canada, Japan, and the United States (U.S.). The principal focus of Annex 41 is on electrically driven air-source heat pumps (ASHP) since that system type has the biggest performance challenges given its inherent efficiency and capacity issues at cold outdoor temperatures. Availability of ASHPs with improved low ambient performance would help bring about a much stronger heat pump market presence in cold areas which today rely predominantly on fossil fuel furnace heating systems. A primary technical objective of the Annex is to define pathways to enable ASHPs to achieve an "in field" heating seasonal performance factor or SPF_h ≥2.63 W/W (HSPF ≥9.0 Btu/Wh), the minimum level necessary in order to gain recognition as a renewable technology in the EU.

ASHPs based on the simple vapour compression cycle suffer both heating capacity (output) and efficiency (coefficient of performance or COP) degradation as the outdoor ambient temperature drops. At the same time, building heat demand is increasing so ASHPs require a supplemental heating source – usually direct electric resistance heating elements – to meet the building heat demand causing lower seasonal performance in areas that experience large numbers of hours at cold temperatures (loosely defined as ≤–7°C for purposes of Annex 41). Thus, the primary criterion for advanced ASHPs to achieve higher SPFh in cold climates is to achieve higher heating capacities at low ambients.

This article describes some of the recent R&D results from the U.S. for two advanced ASHP approaches; a two-stage vapor compression cycle with economizer and a single-stage cycle with two compressors in parallel. The capacity target for US R&D efforts is specified in **Table 1** below.

Two-stage economizer system

Research at Purdue University's Herrick Labs identified a number of cycle concepts that could be useful for ASHPs in cold climate applications (Bertsch et al., 2006). Of these, three were seen to have the highest relative efficiency and relative heat output with low or acceptable discharge temperatures and were selected for detailed comparison – the two-stage using an intercooler, the two-stage using an economizer and the cascade cycle. **Figure 1** illustrate the three cycles.

Table 1. U. S. cold climate heat pump performance targets.

Outdoor temperature	Heating capacity
8.3°C (47°F)	9 – 21 kW (2.5 – 6 tons), nominal rating
–25°C (–13°F)	≤25% reduction from nominal

System simulation models were created for each of the three technologies to simulate the heating capacity and performance for comparison. The heating supply temperature for each was fixed to 50°C (122°F) to match the heating supply air delivery temperature of a baseline gas-fired furnace per requirements of the project sponsor. All three cycles showed COPs above 2 at temperatures below 0°C (32°F) with the cascade cycle having slightly higher COPs than the others. All three cycles had similar capacities at the low ambient temperatures. The only noticeable difference between these technologies is at the warmer ambient temperatures. The cascade cycle COP at temperatures above 0°C is considerably lower than that of the economizer and intercooler cycles, and this is most likely due to the heating capacity sizing selected for the high stage cycle. Bertsch et al. assumed the cascade cycle has an additional smaller outdoor heat exchanger to allow for the high side cycle to operate without the low side

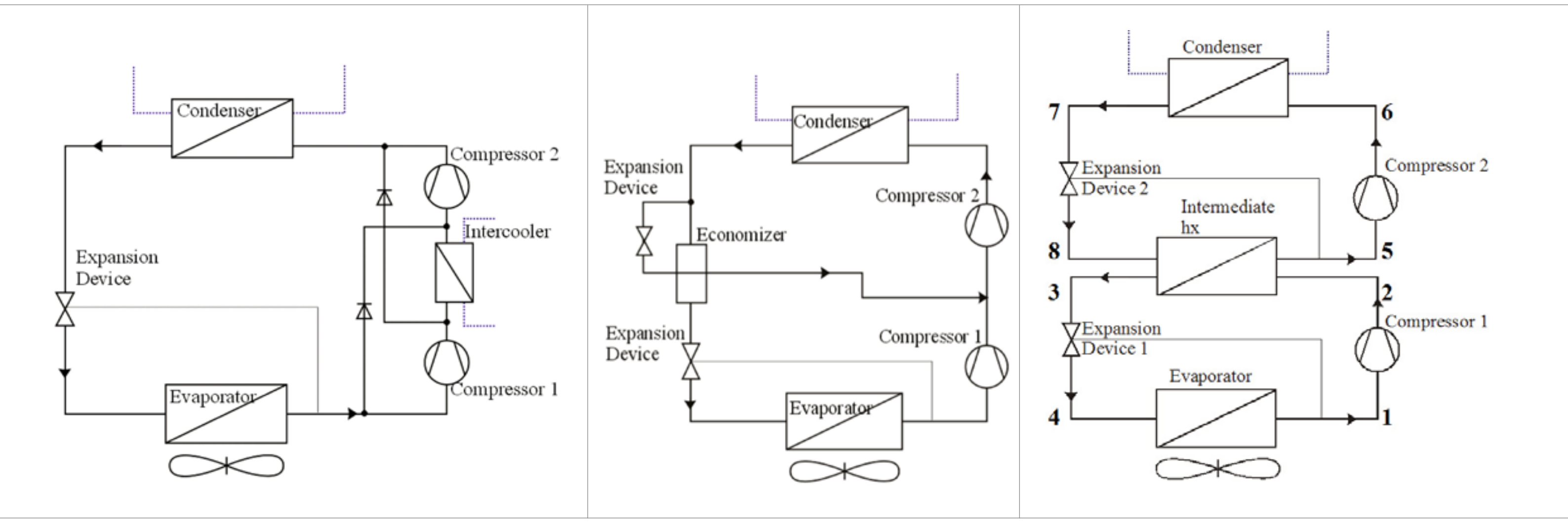


Figure 1. Heat pump cycle schematics – Intercooler (Left) – Economizer (Middle) – Cascade (Right). (Bertsch et al., 2006)

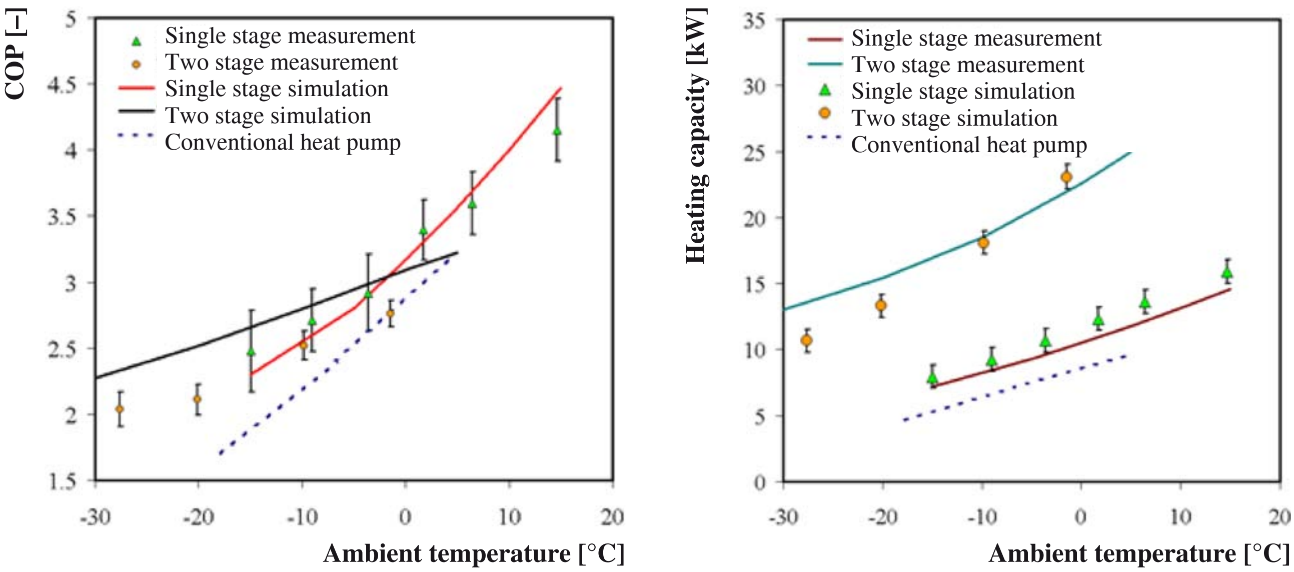


Figure 2. Experimental results of two-stage heat pump compared to simulation results; manufacturer's data was used to indicate performance of the conventional single-stage ASHP. (Bertsch et al. 2008)

cycle. Overall, all three cycles are predicted to be able to adequately satisfy the heating load. The conclusion made from these results and the equipment required (relative cycle complexity) is that the two-stage economizer cycle would be the best choice for an ASHP in colder climates.

A two-stage, economizer system using R-410A was experimentally tested down to ambient temperatures of −30°C (−22°F), achieving a heating capacity and COP of roughly 11 kW and 2.1 respectively (Bertsch et al., 2008). The plots of the experimental results compared to the simulation of the system heating capacity and COP are shown in **Figure 2**. The two-stage heat pump is shown to have much larger heating capacities than a conventional heat pump at low outdoor temperatures. For an outdoor air temperature of about −29°C (~−20°F) the tested capacity was ~11 kW or ~85% of the measured capacity at the U.S. nominal heat pump rating condition of ~8.3°C (47°F) compared to the desired target of 75% (**Table 1**). The test system could be easily built from off-the-shelf components with little modifications, showing promise for being manufacturable with relatively low cost premium compared to conventional ASHPs.

A field test of an advanced two-stage ASHP with economizer VI (vapor-injection) loop designed for cold climate operation has been completed at a U.S. Army base in Indiana (Caskey et al., 2013). The heat pump system is similar to the concept analyzed by Bertsch, et al. (2008). It features a large tandem scroll compressor (two parallel compressors) for low ambient temperature capacity boosting in series with a smaller variable-speed (VS) scroll compressor for cooling operation and moderate ambient heating. The originally installed HVAC system was a natural gas furnace with a split system air conditioner. A side-by-side performance comparison between the originally installed HVAC system and the two pre-commercial heat pump units developed at Purdue University was conducted during the 2012-2013 heating season.

For the monitored period at the Army site the ASHP system achieved about 19% source energy savings vs. the baseline gas furnace system. Using average Indiana residential electricity and gas prices the utility costs for the ASHP and baseline furnace would have been about the same. The ASHP used no electric back up heating during the test period. Furthermore, the installation and maintenance cost and complexity of the heat pump is comparable to those of conventional ASHPs.

Single-stage ASHP with two parallel compressors

Research at the Oak Ridge National Laboratory (ORNL) investigated sixteen different ASHP cycle configurations of which eight were determined to be able to meet the heating capacity degradation target listed in **Table 1**. Both variable-speed (VS) and dual, parallel single-speed compressors (Tandem compressors) were investigated. The VS-based designs offered somewhat greater low-temperature capacity capability while the Tandem approaches were less complex and had almost as much capacity capability. On this basis the Tandem approach appeared to offer the most cost-effective option, and was chosen for laboratory experimental investigation (Shen, et al 2014).

Figure 3 illustrates the cycle concept used for the laboratory prototype test unit. It includes a pair of identical, single speed scroll compressors capable of operating with discharge temperatures of up to 138°C (280°F). A conventional thermal expansion valve (TXV) is used for refrigerant flow control for space cooling mode, and a separate electronic expansion valve (EXV) is used for space heating mode. The EXV targets to control optimum

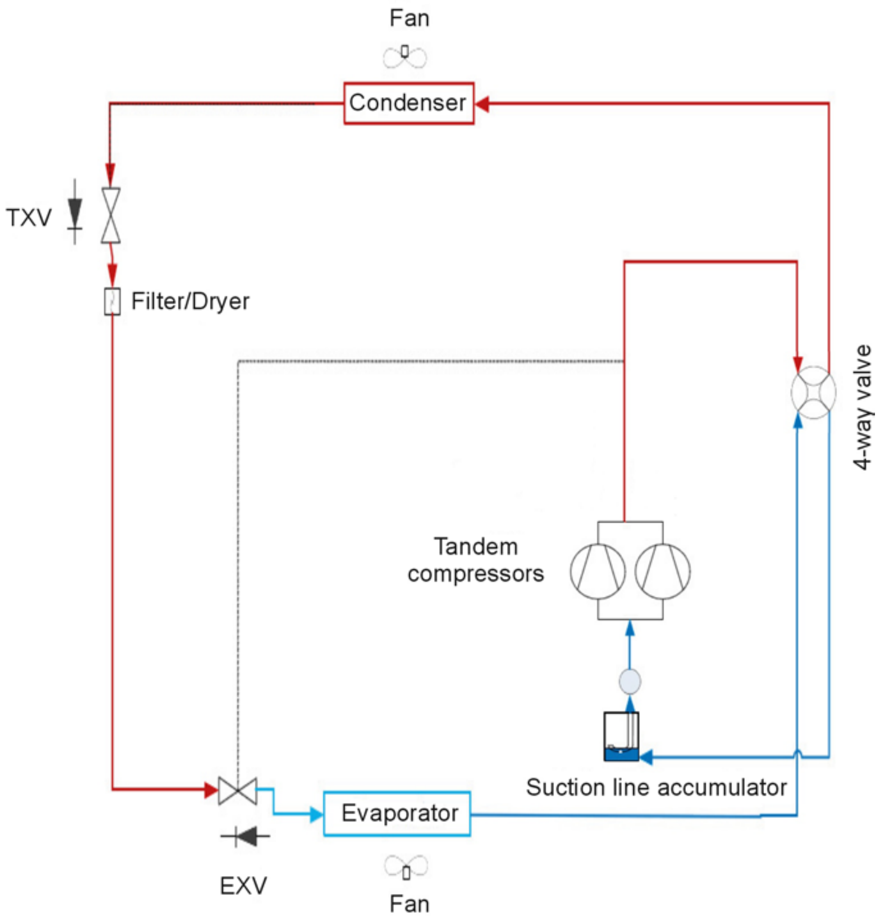


Figure 3. System concept – ASHP with dual, parallel compressors.

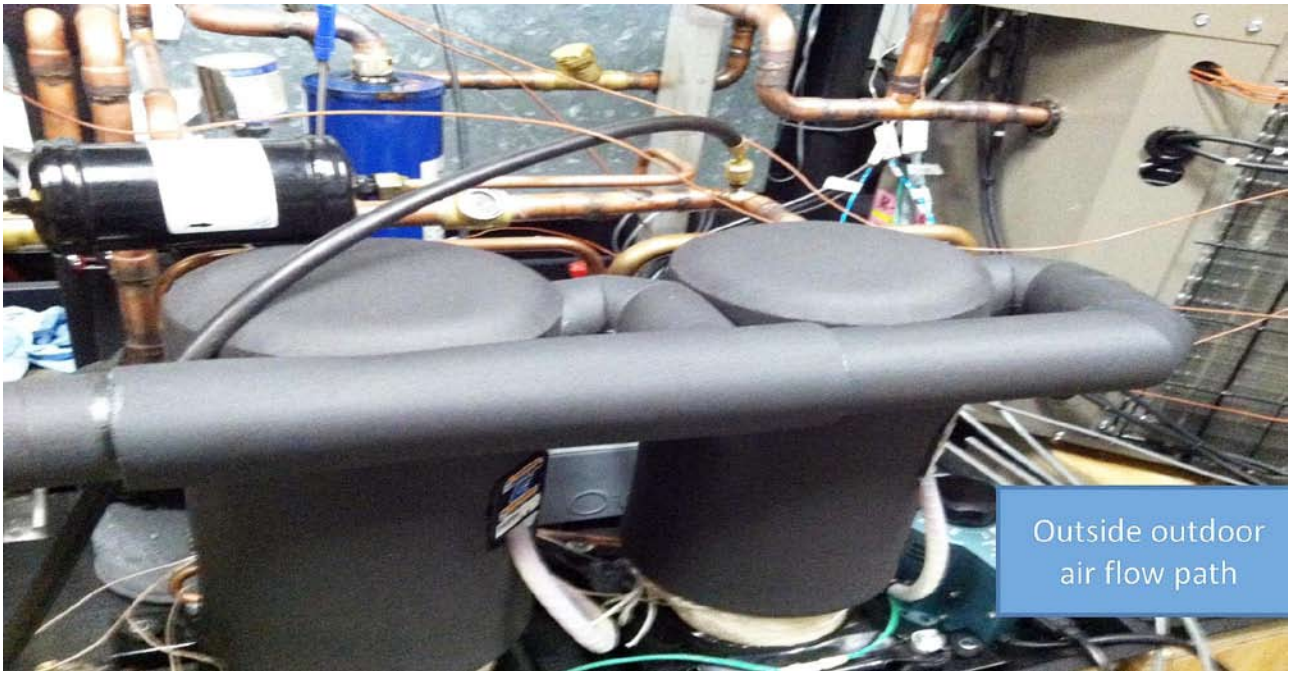


Figure 4. Insulation on test system compressors.

discharge temperature as a function of ambient temperature, rather than the evaporator exit superheat degree. The compressors were insulated and placed outside the outdoor air flow stream to minimize the compressor shell heat losses (**Figure 4**) – testing data confirmed that the insulation layer reduced the compressor heat loss by 50%, and boosts the capacity and COP at –13°F more than 5%.

Figures 5 and 6 below show the capacity and COP vs. ambient temperature, respectively, from the lab test results. This system met the heating capacity target, achieving 77% of the nominal rated capacity at –25°C (–13°F). **Figure 6** indicates that it maintains reasonably good COPs (~2.0) at –25°C as well.

Concluding remarks

The two advanced ASHP system concepts discussed above are both able to achieve the heating capacity improvement target noted in **Table 1** – ≤25% degradation of heating capacity at –25°C (–13°F) vs. the rated capacity at 8.3°C (47°F). But this capacity improvement comes at the cost of increased system complexity which will result in increased cost compared to conventional ASHPs. It is possible that either of these approaches could result in a technically feasible ASHP that meets the Annex 41 SPF_h goal (≥2.63) and may approach the SPF_h levels of GSHPs, gas-engine-driven ASHPs, gas absorption ASHPs, or other residential HVAC systems in cold climate locations. Whether this level of efficiency can be achieved at lower installed costs than the aforementioned alternative systems remains to be seen. ■

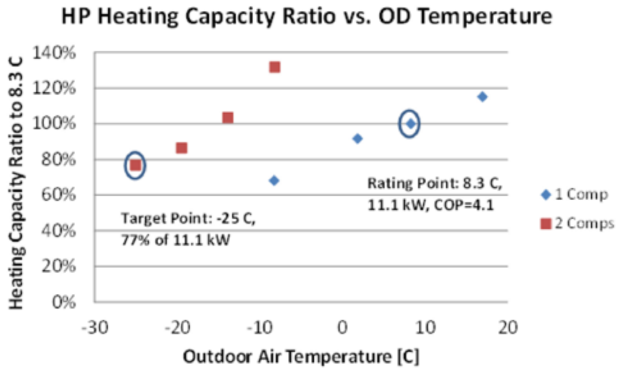


Figure 5. Lab prototype heating capacity ratio (relative to capacity at the nominal 8.3°C (47°F) rating point, with one compressor).

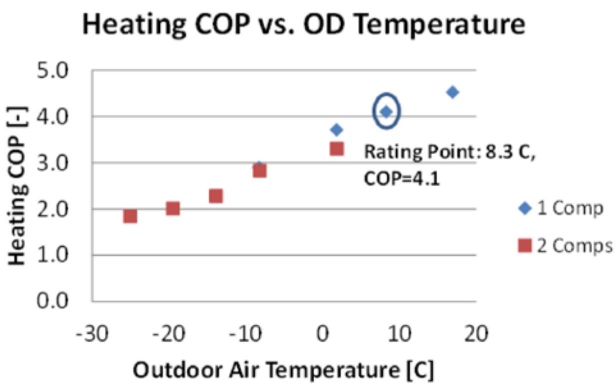


Figure 6. Lab prototype heating COP.

Acknowledgements

The assembly of this report and the ORNL technical activities described herein are supported by the U. S. Department of Energy, Building Technologies Office (DOE/BTO) under Contract No. DE-AC05-00OR22725 with UT-Battelle, LLC.

References

Bertsch S. S. and E. A. Groll. 2006. "Air Source Heat Pump for Northern Climates Part I: Simulation of Different Heat Pump Cycles," Proceedings of the 11th International Refrigeration and Air Conditioning Conference at Purdue.

Bertsch S. S. and E. A. Groll. 2008. "Two-stage air-source heat pump for residential heating and cooling applications in northern US climates," *International Journal of Refrigeration*, Vol. 31(7), pp. 1282-1292.

Caskey S. L. 2013. "Cold Climate Field Test Analysis of an Air-Source Heat Pump With Two-Stage Compression and Economizing," Master's Thesis, Purdue University, Ray W. Herrick Laboratories, West Lafayette, IN.

Shen, B., O. A. Abdelaziz, and C. K. Rice. 2014. "Compressor Selection and Equipment Sizing for Cold Climate Heat Pumps," paper No. P.6.11 in the Proceedings of the 11th IEA Heat Pump Conference 2014, May 12-16 2014, Montréal (Québec) Canada.

Heat pumps for nZEB in IEA HPP Annexes 32 and 40

Heat pumps for the application in low energy buildings and nearly Zero Energy Buildings (nZEB) are investigated and developed in two Annex projects in the Heat Pump Programme (HPP) of the International Energy Agency (IEA) due to the unique features of heat pumps regarding high system performance, multifunctional use for different building services and load management capabilities. The projects deliver prototypes of new components, field monitoring results and design recommendations.

Keywords: nZEB, low energy building, multifunctional heat pump, system design, field monitoring, simulation.

CARSTEN WEMHOENER
Professor, Operating Agent IEA HPP Annexes 32/40
Institute of Energy Technologies (IET)
HSR University of Applied Sciences Rapperswil
carsten.wemhoener@hsr.ch

Buildings are responsible for about 40% of the CO_2-emissions in the EU. Both heat pumps and low energy buildings (LEB) have growing market shares in different parts of the world. With the implementation of the EU Energy Performance of Buildings Directive EPBD (2002) LEB have become the standard new building in many European countries with space heating (SH) needs around 50 kWh/(m²a) prescribed by building codes. Passive building envelope design can further decrease the space heating needs to 15 kWh/(m²a).

Energy needs in LEB differ significantly from energy needs in the existing building stock. Due to significantly reduced needs, space heating (SH) energy can be supplied by low temperature emission systems. Domestic hot water (DHW) heating needs, though, constitute a bigger share of the total heating requirement, so DHW performance gets more important. Further functionalities of the building technology have been added such as mechanical ventilation systems, which are increasingly installed or are even a requirement in residential LEB. Moreover, a space cooling (SC) function may be added in residential buildings due to increasing internal loads by electric equipment and increasing request for indoor comfort in high performance buildings. In countries like Japan and the southern federal states of the USA, also a dehumidification (DH) function is a requirement for the building technology.

Therefore, system configurations shall be adapted to the changed loads and functionalities in LEB. Interesting concepts are integrated system configurations with the ability of multifunctional operation, since

- waste heat, e.g. from exhaust air or recooling, can be recovered for other building needs, e.g. recooling energy from the heat rejection of the condenser heat in dehumidification mode can be used to heat the DHW storage as depicted in **Figure 1**;
- different building needs can be covered simultaneously with efficiency gains, e.g. in case of a combined SH and DHW operation by a desuperheater or multiple gas cooler as shown in **Figure 2** and **Figure 3**;
- systems are more cost-effective as separate components for different needs are avoided.

In this sense heat pumps have some unique features for the use in LEB, since they are

- highly-efficient with adequate temperature design of the systems;
- available on the market down to very low capacity ranges;
- using renewable energy at a minimum seasonal performance factor (SPF);
- environmentally-sound and can be operated entirely CO_2-free with renewable electricity;
- the only generator for SH and SC, even as simultaneous supply of different building needs (e.g. SC and DHW).

The IEA HPP Annex 32 work started with a market overview on integrated heat pump systems, and the target was the assessment, development and evaluation of different multi-functional heat pump solutions in LEB by simulation, prototyping and field monitoring. From the results design and control recommendations are derived. **Table 1** gives an overview of the contributions of the participating countries to Annex 32. Developments in the USA and Canada are aiming at adequate systems for Net Zero Energy buildings (NZEB).

Results of prototype developments

Developed prototypes mainly address three aspects which were not covered by many of the marketable integrated heat pumps in the typical capacity range of residential LEB of 3–5 kW:

- Additional passive space cooling or simultaneous active SC and DHW function;
- Additional dehumidification function;
- Use of natural refrigerants with reduced global warming impact.

Integrated air-source and ground-source heat pump (IHP) prototype development in the USA

At the Oak Ridge National Laboratory (ORNL), USA, an air-source (AS) and ground-source (GS) IHP prototype covering all building services including DH has been developed, lab-tested and simulated. System configurations are depicted in **Figure 1**.

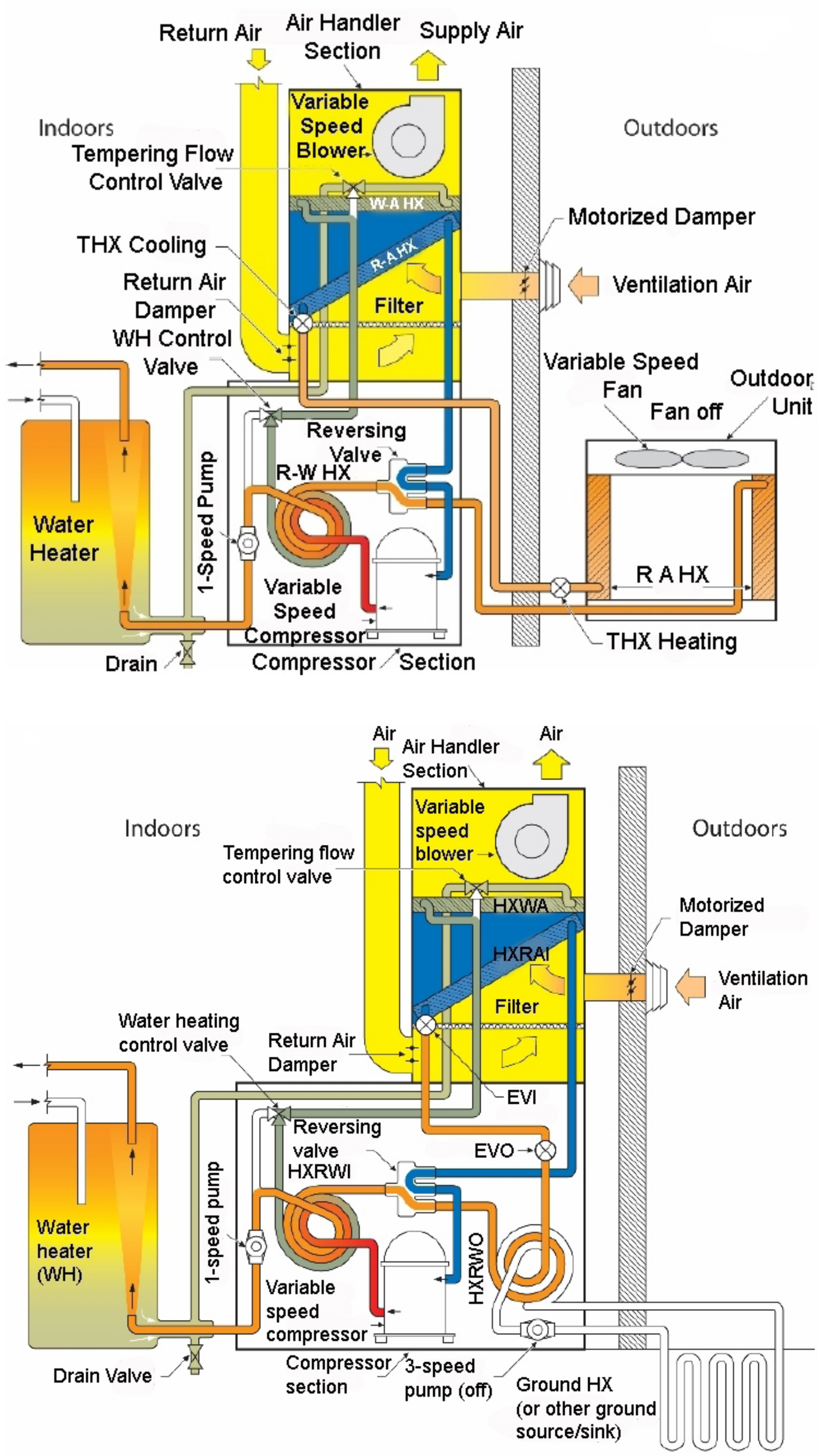


Figure 1. AS-IHP (top) and GS-IHP (bottom) in DH and DHW mode.
(Baxter et al., 2008)

Annual simulations for a 167 m² residential LEB for 5 climate zones of the USA show energy saving potentials of 47–67% (52–65%) for the AS (GS) IHP compared to common technology according to minimum efficiency requirements of the US Department of Energy DOE. Estimates of the simple payback time are 5–10 years (6–15 years incl. borehole) for the AS (GS) prototype. After a field test and redesign, the GS-IHP is now available on the market, while AS prototypes are in field monitoring.

Prototypes with natural refrigerants

At SINTEF Energy Research in Norway, feasibility studies of HP with natural refrigerants have been carried out. A 6.5 kW B/W-HP prototype with CO_2 refrigerant shown in **Figure 2 top** uses a tripartite gas-cooler for combined SH and DHW operation for pre- and reheating or the DHW and space heating. Lab-testing and simulations results showed that the CO_2-HP prototype outperforms the best conventional HP with HFC refrigerants at a DHW share of 55%. For improved CO_2-technology (improved compressor, ejector) with a 10% increased Coefficient of Performance (COP) the break-even point is shifted to 45% DHW share, see **Figure 2 bottom**. Since DHW shares are rising in LEB, CO_2 could be an interesting refrigerant.

Prototype B/W-CO_2 heat pump in Austria

Based on a system layout and refrigerant cycle comparisons, a 5 kW CO_2-B/W HP prototype depicted in **Figure 3** has been built and lab-tested in Austria. In this system, a bi-partite gas-cooler is used. System simulations for SH, DHW, passive and active SC operation in a typical LEB yielded an overall SPF of 3.2 at high DHW share of 30% based on the delivered energy to the floor SH and DHW heat exchanger without the distribution pumps. In case of higher cooling loads, the performance increases due to the high performance of the passive SC. System improvements are seen in improved components (compressor efficiency for low capacities, ejector) as well as in the system integration of the buffer storage and control.

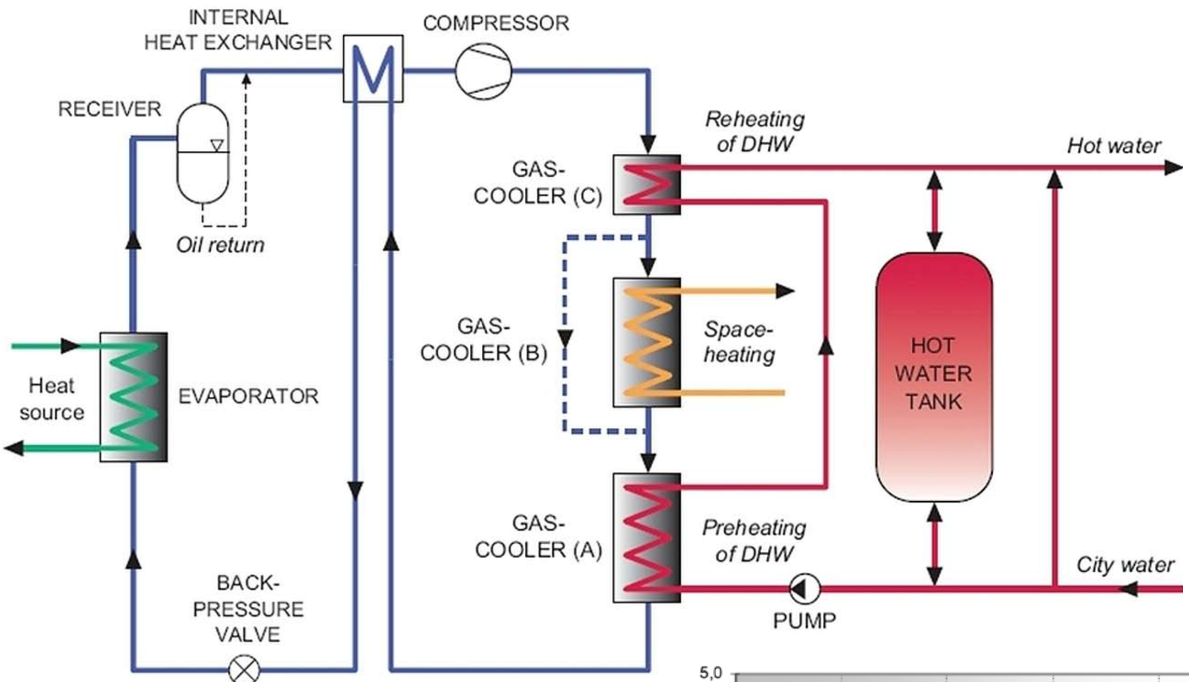
Results of field monitoring

A large number of results of about 200 field-monitored systems have been contributed to the IEA HPP Annex 32. In Germany two large field tests of 100 HP installed in LEB (HP Efficiency project) and 75 HP installed in existing buildings as replacement for boilers took place. Due to higher heating loads in the existing buildings, they are equipped with radiator emission systems of typical design temperatures of 70°C/50°C, while the LEB in the HP Efficiency project are mainly equipped with low-temperature floor heating of typical design temperatures of 35°C/30°C. **Figure 4 top** shows the overall seasonal performance factors (SPF) for SH and DHW operation and different heat pump types. The system boundary of the SPF includes produced heat of the heat pump and direct electrical back-up for the space heating and DHW operation and electricity supplied to the heat pump, the source pump and the electrical back-up. Auxiliary energies range between 3–7%, direct electrical back-up use is with 1–2% negligible. Measured DHW fractions are 10–15% in the existing buildings and 20–30% in the LEB. The number of the investigated systems is displayed in the bottom of the bars.

Figure 4 bottom shows the impact of the system design on the SPF. The complexity of the system has been determined depending on the number of installed pumps, valves etc.. From the field test results it can be concluded that more complex modular system designs tend to decrease the SPF due to possible installation errors and malfunctions. Also combined storages showed a lower

Table 1. Overview of contributions to IEA HPP Annex 32.

Country	Contribution to IEA HPP Annex 32
AT	• Prototyping, lab-test and simulation of a 5 kW CO_2 brine-to-water (B/W) heat pump; • Field test of 9 heat pumps for SH & DHW and 2 compact units with passive cooling.
CA	• Design and monitoring of two Equilibrium™ houses (NZEB) in Eastern Canada.
CH	• Integration of energy-efficient cooling in common heat pump systems for SH & DHW; • 2 field tests of heat pump systems for space heating and (passive) space cooling.
DE	• Field test of ≈ 100 heat pumps in low energy buildings and ≈ 70 heat pumps in existing buildings in co-operation with 7 manufacturers and 2 utilities.
FR	• Development of air-to-air (A/A) HP solutions for low energy houses.
JP	• Design optimisation of systems for moderate climate regarding capacity and operation; • Feasibility studies and field test of ground-source heat pumps for the cold climate zone.
NL	• Development of HP concepts for the market introduction of low energy houses.
NO	• Feasibility of heat pumps with natural refrigerants in Norwegian low energy houses; • Field test of propane water-to-water (W/W) HP prototype for passive houses.
SE	• Calculation and field test of Swedish heat pumps for low energy houses.
US	• Prototyping, lab-testing and simulation of highly-integrated multifunctional heat pump prototypes for SH, DHW, ventilation and SC incl. dehumidification for NZEB.



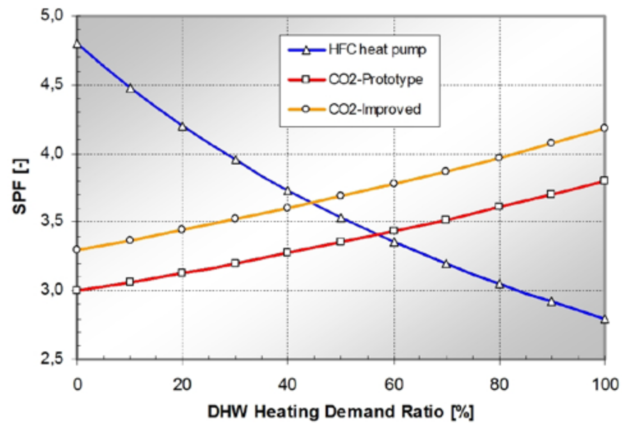


Figure 2. Layout of the prototype B/W-CO_2 heat pump (top) and comparison of a prototype and improved CO_2 heat pump to the state-of-the-art (right).
(Justo Alonso and Stene, 2010)

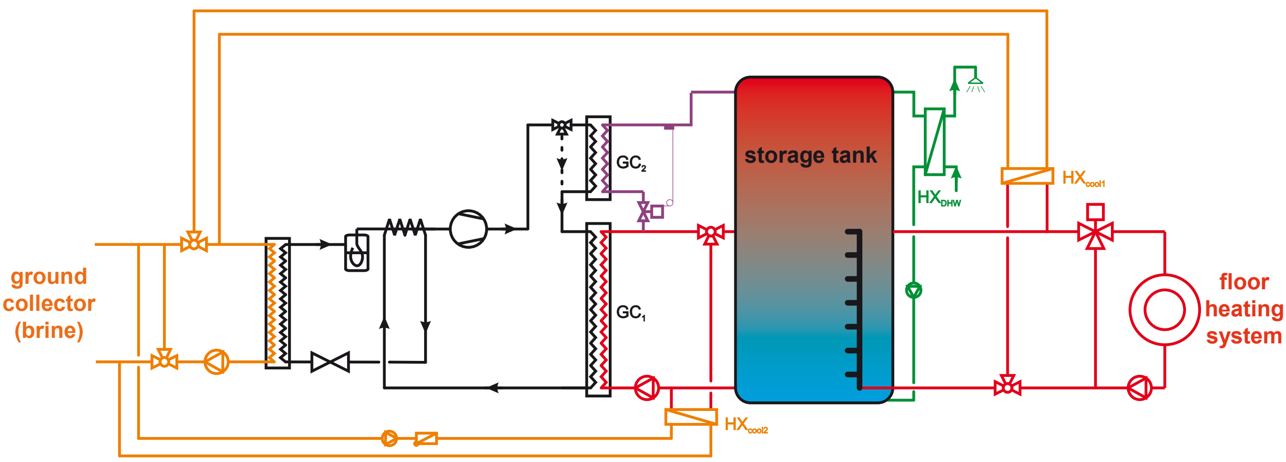


Figure 3. System layout of the Austrian prototype system (Heinz and Rieberer, 2010)

performance than other system configurations due to a possible increase of the supply temperature for the heat pump. Thus, modular system configurations with many components have to be installed carefully in order to avoid the decrease of the performance.

Moreover, 4 systems with ground-coupled passive SC have been monitored in residential passive houses. The performance of the passive SC mode is in the range of 8–15. The main impact on the performance is the rejected cooling load, since the pump power stays more or less the same independent of the cooling load. Several recommendations on the system integration, design and operation of passive ground-coupled cooling in LEB have been documented based on the monitoring and accompanying simulations.

All results of the Annex 32 have been summarised in four final reports (Wemhoener, 2011), which can be downloaded on the Annex 32 website.

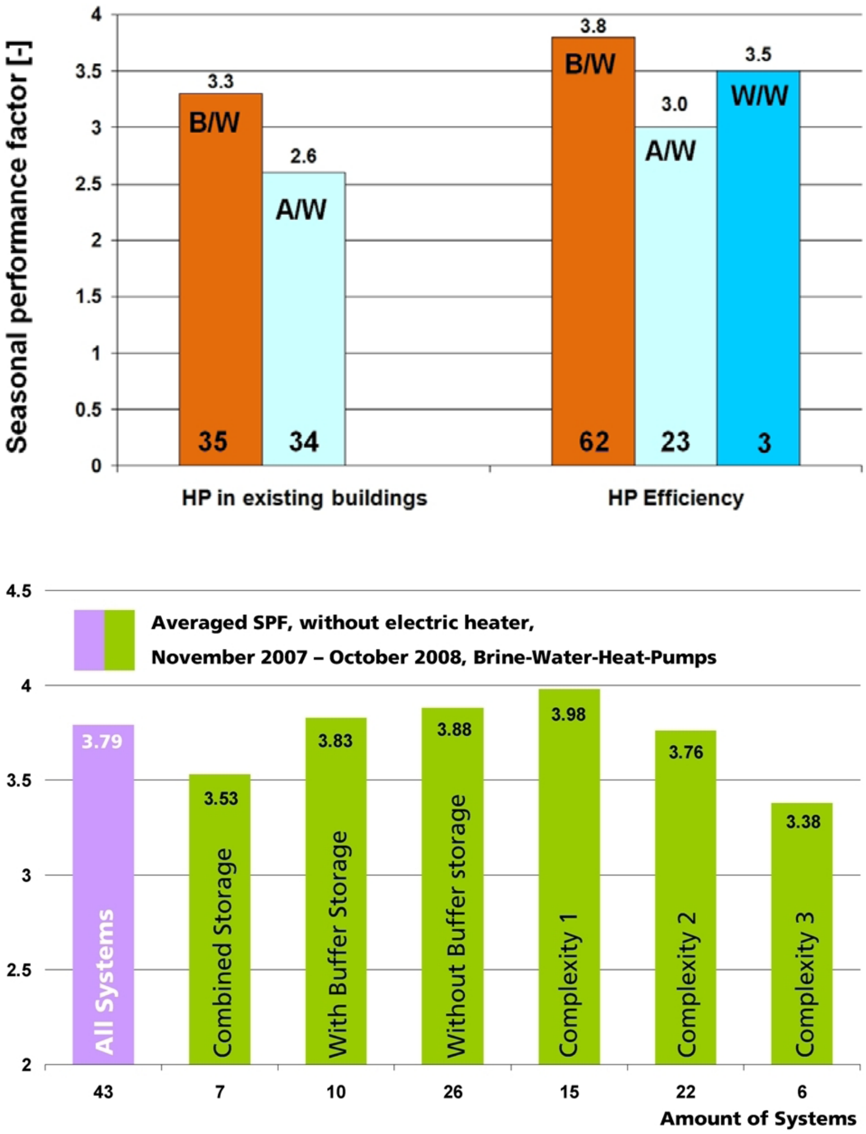


Figure 4. SPF of monitored heat pumps in LEB and existing buildings (top) and impact of system design on the SPF (bottom) based on Günther and Miara (2010).

Continuation of work in Annex 40

According the EPBD recast (2010) all new buildings in the EU shall be built as nearly Zero Energy Buildings (nZEB) by the beginning of 2021, while other countries like the USA, Canada or Japan are targeting the introduction of Net Zero Energy Buildings (NZEB) in the time horizon of 2020-2030. Concerning the nZEB requirements further integration and design options for heat pumps in these buildings occur:

- Integration of the heat pump operation with solar components installed in the building envelope on the source or sink side as well as heat and cold storage technologies
- Integration of the heat pump and the technical building system into energy grids, e.g. electricity grid (in the frame of smart grid activities) or district heating/cooling grids.
- Assessment of local load management and demand response capabilities of installed heat pumps in nZEB in order to maximise self-consumption of on-site renewable energy and improve grid interaction.

The IEA HPP Annex 40 started work in 2013 and is ongoing. Interim results are periodically published. The focus of the national projects is on the system comparison and improvement regarding integration of different heat generators, design and control of the systems as well as technology developments for the application in nZEB. **Table 2** gives an overview on the national contributions to Annex 40.

Table 2. Overview of national contributions to IEA HPP Annex 40.

Country	Contribution to IEA HPP Annex 40
CA	• Integration of HP and other generators (e.g. solar, CHP); • Analysis for different building types and uses; field test of nZEB with HP.
CH	• Integration of HP and solar for SH, DHW and SC for nZEB by simulations and testing; • Field monitoring of plus energy building with HP and electro-mobility.
DE	• Analysis and field monitoring of office buildings to optimise operation.
FI	• Development of energy-/cost-efficient HP solutions for nZEB in Finland.
JP	• Evaluation of HP and solar for nZEB buildings by simulations; • Derivation of technology and design recommendations.
NL	• Field test "Energy leap" and simulation of concepts for nZEB.
NO	• Prototypes/design tools of integrated HP with natural refrigerants in nZEB;
SE	• Prototype developments and field test of HP for nZEB in Swedish climate conditions.
US	• Field monitoring of IHP prototypes and variant developments. • Net Zero Energy Residential Testing Facility (NZERTF) for HP technologies; • Software development for comfort evaluation of radiant emission systems.

Conclusions

IEA HPP Annex 32 and the follow-up IEA HPP Annex 40 are dedicated to the development of heat pumps for the application in low energy buildings and nZEB. Due to the different building needs compared to existing building stock, heat pumps offer good performance values with adequate system design. Integrated heat pump concepts have particular advantages for these buildings and different concepts are developed, simulated, lab-tested and field-monitored in the Annex projects.

Heat pumps as an energy-efficient technology and flexible electricity consumer also enable the integration with storage and renewables energies (PV and solar thermal) in nZEB and provide flexibility for load management in smart grids. Multifunctional heat pumps can therefore become a key technology as a cost-effective way of creating high-sustainability carbon-neutral societies.

Acknowledgement

The Annex 32 and the Annex 40 are collaborative research projects and contributions of all participating countries and institutions are highly appreciated. The funding and support of the projects by the Swiss Federal Office of Energy is particularly acknowledged. Information and publications are found on the websites http://www.annex32.net and http://www.annex40.net on the Annex 32 and Annex 40, respectively. ■

References

Baxter, V.D., Rice, C. K., Murphy R. W. 2008. Small integrated heat pumps (IHP) for net zero energy homes (ZEH) - development status, Report USA IEA HPP Annex 32, Oak Ridge, May, US.

EPBD. 2010. Directive 2010/31/EU of the European Parliament and Council of May 19, 2010 on the energy performance of buildings (recast), Journal of the European Union L 153/13, 18.6.2010, EU.

EPBD. 2002. Directive 2002/91/EC on the Energy Performance of Buildings (EPBD), European Council, Journal of the European Union L 1/65,4.1.2003, EU.

Heinz A., Rieberer R. 2010.System assessment and prototyping, Final country report IEA HPP Annex 32, Austria, Graz, March, AT.

Justo Alonso, M., Stene, J. 2010. IEA Heat Pump Programme Annex 32 – Economical Heating and Cooling Systems for Low-Energy Houses, SINTEF Technical report TR A6966, Trondheim, May, NO.

Miara, M. 2010. Field monitoring, Final Country Report Germany IEA HPP Annex 32 Task 3, Fraunhofer Institute of Solar Energy Systems, Freiburg (Brsg.), August, DE.

Wemhoener, C. (ed.). 2011. Final reports IEA HPP Annex 32 part 1-4, IEA Heat Pump Programme, download at http://www.annex32.net/deliverables.htm.

Heat Pump or CHP – which one is *greener*?

Heat pump and combined heat and power (CHP) are two low carbon technologies that are used for heating buildings in order to reduce the operational costs and CO_2 emissions. The amount of CO_2 reduction achieved depends on the emission factor of the grid. In this article these two technologies are compared with each other considering the emission factor of the grid. The results show that there is a balance point for the grid emission factor, above which the CHP produces less CO_2 and below which the heat pump produces less CO_2.

Keywords: building heating system, renewable energy, combined heat and power, heat pump, CO_2 emission, grid emission factor.

FARAMARZ SADR
PhD
fasadr@yahoo.com

Buildings are responsible for 40% of total CO_2 emissions in the world. Combustion of fossil fuels produces CO_2 gas which is recognized as the major greenhouse gas causing global warming. There is a strong aim to reduce CO_2 emissions associated with the building sector. This mainly can be accomplished by increasing energy efficiency of the buildings and utilization of zero and low carbon energy technologies to supply the heating and electricity demands of buildings.

Heat pump and CHP are two low carbon technologies that have been proposed to be used in buildings. These technologies have been considered in the European Directive 2009/28/EC which is the main directive for promotion of renewable energy in the EU's building sector. In addition, the Feed in Tariff and the Renewable Heat Incentive are two significant incentives that have been considered by the UK government for the promotion of renewable energy utilization, including heat pump and CHP technologies.

Electrical heat pumps use grid electricity to extract heat from a heat source. In buildings most of the CHPs are fuelled by mains gas and generate heat and electricity simultaneously. The generated electricity can supply the electrical demand of the building and displace some of the electricity consumption from the grid.

The other major contributor to CO_2 emissions is the power sector. Under the Kyoto protocol, 37 industrialized countries and the European Community committed themselves to binding targets for greenhouse gas (GHG) emissions. In the UK, according to a report by the Committee on Climate Change (CCC), there is a need for early power sector decarbonisation in the context of economy-wide emissions reduction to achieve the 2050 target in the Climate Change Act (A net UK carbon reduction to at least 80% lower than the 1990 baseline). Specifically, the committee set out a range of scenarios for investment in low-carbon generation capacity, and proposed a planning scenario in which emissions are reduced from current levels of around 500 g CO_2/kWh to around 50 g CO_2/kWh in 2030 (**Figure 1**).This could be achieved through the addition of around 35 GW baseload equivalent low-carbon capacity through the 2020s, in addition to planned investments in renewables, carbon capture and storage (CCS) and nuclear generation over the next decade.

CO_2 emissions with a gas fired boiler

Where a gas fired boiler is used to supply the heating demand of building, the annual emission rate e_h can be calculated from the following equation:

$$e_h = F_b k_g = \frac{H}{\eta_b} k_g \qquad (1)$$

Where, F_b is the fuel energy input to the boiler, H is the heating demand of the building, η_b is the thermal efficiency of the boiler and k_g is the emission factor of the mains natural gas. From equation (1) the unit heating emission rate is:

$$\frac{e_h}{H} = \frac{k_g}{\eta_b} \qquad (2)$$

CO_2 emissions with a heat pump

Where a heat pump is used to supply the heating demand of the building, the annual emission rate e_h can be calculated from the following equation:

$$e_h = E_{hp} k_e = \frac{H}{COP} k_e \qquad (3)$$

where, E_{hp} is the electrical energy input to the heat pump, k_e is the grid emission factor, H is the heating demand of the building and COP is the heating coefficient of performance. From equation (3) the unit heating emission rate is:

$$\frac{e_h}{H} = \frac{1}{COP} k_e \qquad (4)$$

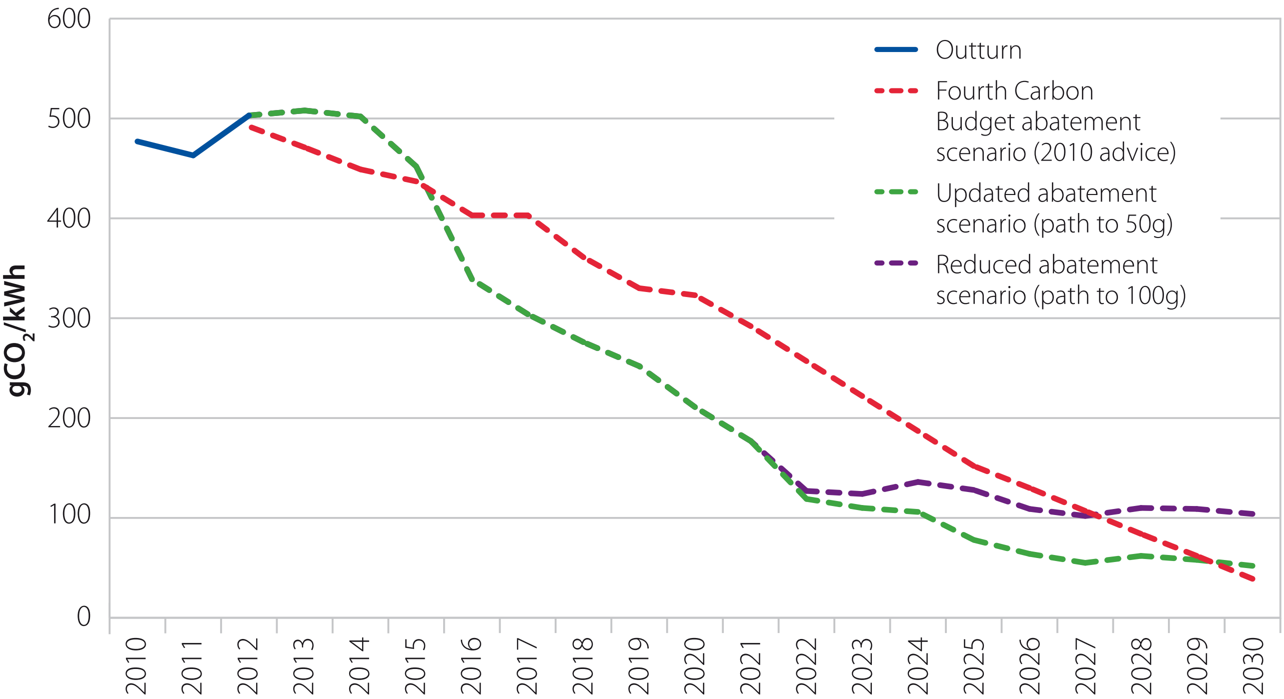
CO_2 emissions with a CHP

Where a CHP is used to supply the heating demand of the building (in heat led operation), the emissions associated the heat supply can be reduced by the displaced grid electricity emissions. It is assumed that the CHP is fuelled by mains natural gas. The annual emission rate e_h can be calculated from the following equation:

$$e_h = F_{chp} k_g - E_{chp} k_e = \frac{H}{\eta_h} k_g - \frac{H}{\eta_h} \eta_e k_e \qquad (5)$$

where, F_{chp} is the fuel energy input to the CHP, E_{chp} is the electrical energy generated by the CHP, H is the heating demand of the building, η_h and η_e are the heating and electrical efficiencies of the CHP respectively, k_g and k_e are the mains natural gas and grid emission factors respectively. From equation (5) the unit heating emission rate is:

$$\frac{e_h}{H} = \frac{k_g}{\eta_h} - \frac{\eta_e}{\eta_h} k_e \qquad (6)$$



Source: CCC calculations (2010 Fourth Carbon Budget advice); CCC calculations based on Redpoint (2012 & 2013) modelling.
Notes: Intensity is based on energy supplied from major power producers and all renewable generators and is net of transmission and distribution losses.

Figure 1. Predicted reduction of emission intensity of electricity (grid emission factor) in the UK according to three scenarios (2010–2030)

Grid emission factor at balance point

From equations (4) and (6) it can be seen that by reducing the grid emission factor, the unit emission of the heat pump is decreased and the unit emission of the CHP is increased. To determine at what grid emission factor (k_{eb}) these two emission rates are equal we equate the right hand side of the equations (4) and (6):

$$\frac{1}{COP}k_{eb} = \frac{k_g}{\eta_h} - \frac{\eta_e}{\eta_h}k_{eb}$$

$$k_{eb} = \frac{k_g}{\left(\frac{\eta_h}{COP} + \eta_e\right)} \quad (6)$$

We name k_{eb} *balance emission factor*. The unit emission of heat pump and CHP and the balance emission factor are graphically shown in **Figure 2**. In this figure, the unit emission of a gas boiler is shown as well. This emission rate is constant and independent from the grid emission factor. There are also 3 interesting points in **Figure 2**. At point a, the emission rates of the heat pump and gas boiler are equal:

$$k_e = \frac{COP}{\eta_b}k_g$$

Where k_e is greater than this value, the gas fired boiler produces less CO_2 than the heat pump. At point b the emission rates of the CHP and the boiler are equal:

$$k_e = \frac{k_g}{k_e}(1 - \frac{\eta_h}{\eta_b}),$$

and where k_e is less than this value, the boiler produces less CO_2. Finally at point c

$$k_e = \frac{k_g}{\eta_e},$$

the net emission rate of the CHP is zero.

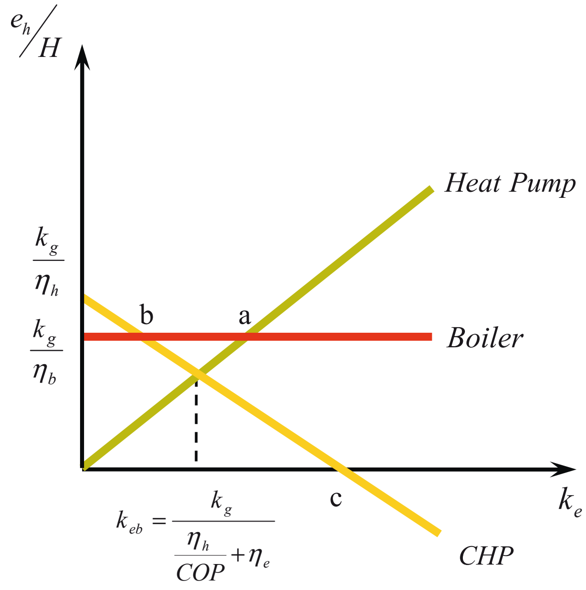


Figure 2. Balance emission factor k_{eb} is the value of the grid emission factor ke where the unit heating emission rate e_h/H is equal for heat pump and CHP.

Results

Equation (6) shows that the balance emission factor does not depend on the heat and electricity demands of the building; it only depends on the COP of the heat pump and the thermal and electrical efficiencies of the CHP.

In this section we calculate the balance point of electricity emission factor for a sample heat pump and micro-CHP in the UK. We select a heat pump with a COP of 2.4 and a micro-CHP with electrical and thermal efficiencies of 0.13 and 0.79 respectively. According to SAP 2012 the mains gas emission factor is 0.214 kg CO_2/kWh and the imported and displaced electricity emission factors is 0.502 kg CO_2/kWh. With these data the calculated balance electricity emission factor is 0.466 kg CO_2/kWh.

Currently the emission factor of the grid is 0.502 kg CO_2/kWh which is greater than the balance emission factor. If a residential building has annual heating and electrical demands of 20 000 and 4 000 kWh respectively, with a heat pump the unit heating emission rate and the total emission rate will be 0.209 kg CO_2/kWh and 6 191 kg CO_2 respectively. With CHP these figures will be 0.188 kg CO_2/kWh and 5 774 kg CO_2.

According to **Figure 1**, in 2020 the grid emission factor will be 0.33 kg CO_2/kWh. If we assume that the mains gas emission factor remains constant, the unit heating emission rate and total emission rate with heat pump will be 0.138 kg CO_2/kWh and 4 070 kg CO_2 respectively. With CHP these figures will be 0.217 kg CO_2/kWh and 5 652 kg CO_2. **Figure 3** shows the balance point and **Table 1** shows the summary of the calculations.

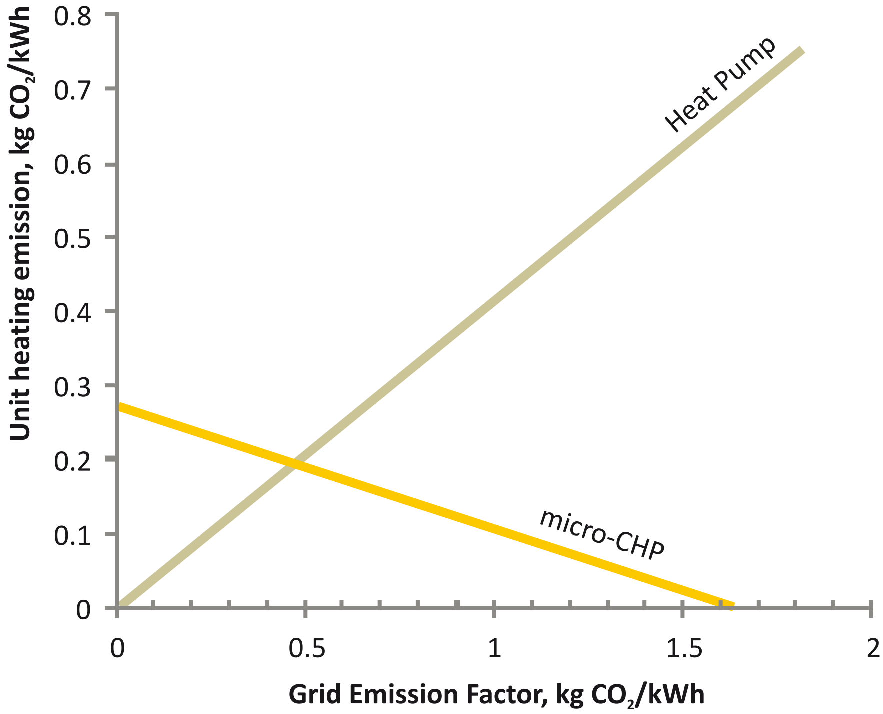


Figure 3. The balance point of a sample heat pump and CHP for grid emission factor.

Discussion

From equation (6) we can see that the balance point of the grid emission factor depends on the emission factor of mains gas, the COP of the heat pump and the electrical and thermal efficiency of CHP. So for each heat pump and CHP, the balance point of the grid should be calculated separately. It can also be shown that by increasing the COP, the balance emission factor is shifted to higher values. Higher values of COP can be achieved by reducing the supply flow temperature of heat pump. Also by increasing the electrical efficiency of CHP the balance emission factor will be shifted to the lower values.

Table 1. Unit heating and total emission in 2014 and 2020.

	2014		2020	
	Heat Pump	**CHP**	**Heat Pump**	**CHP**
e_h/H, kg CO_2/kWh	0.209	0.188	0.138	0.217
$e_t = e_h + e_e$, kg CO_2	6191	5774	4070	5652

Traditionally in Europe the use of heat pumps is common in the countries that have cheaper electricity due to the higher penetration of renewables like wind and hydropower in Scandinavian Countries (Denmark and Norway with 0.374 and 0.002 kg CO_2/kWh), or nuclear power plants (France with 0.0709 kg CO_2/kWh) or both (Sweden with 0.023 kg CO_2/kWh). In the UK, which had cheaper fossil fuel, use of micro-CHP (mainly natural gas fuelled) has been common more than heat pumps.

Deregulation of the electricity market and decarbonisation of electricity can alter the tendency to use heat pumps and CHPs in different countries which should be considered by the industry.

The author would like to acknowledge Katharine Scott for her contribution in preparing of this paper. ■

References

CCC. 2010. The Fourth Carbon Budget: Reducing emissions through the 2020s.

European Directive 2009/28/EC. http://eur-lex.europa.eu/. Last viewed March 2014.

SAP. 2012. DECC published by BRE, Garston, Watford, WD25 9XX.

New F-Gas Regulation

On April 14, the European Union (EU) adopted the revised F-Gas regulation that, by 2030, will reduce fluorinated greenhouse gas (F-gas) emissions by 79% from today's levels. The regulation will replace the older law with ambitious measures ensuring the EU's global leadership in phasing-down of HFCs. The new regulation foresees the introduction of HFC bans in certain sectors affecting air-conditioning and refrigeration products.

Keywords: fluorinated greenhouse gas (F-gas), hydrofluorocarbons (HFCs), F-gas Regulation, EU Climate Action, refrigeration

ANITA DERJANECZ
Senior project officer, REHVA, Brussels. Email: ad@rehva.eu

New F-gas Regulation from 2015

The new F-gas Regulation No 517/2014 was adopted by the Council of the European Union mid-April as final step on a long way of policy development. The new regulation was published on 20th May in the Official Journal of the European Union, entered into force on 9th June and will apply from 2015 onwards, replacing the older, ineffective version with new and ambitious measures:

- **Limiting the total amount** of the most important F-gases that can be sold in the EU from 2015 onwards and phasing them down in steps to one-fifth on today's values by 2030. This will be the main driver of the move towards more climate-friendly technologies;
- **Banning the use** of F-gases **in many new types of equipment** where less harmful alternatives are widely available, such as air-conditioning, commercial and industrial refrigeration or windows;
- **Placing on the market bans** on HFCs of certain products and equipment;
- **Ban on servicing and maintaining refrigeration** equipment with HFCs with >2,500 Global Warming Potential (GWP) as of 2020 (the use of recycled and reclaimed gases will be allowed until 2030);
- **Preventing F-gas emissions** from existing equipment by requiring checks, proper servicing and recovery of the gases at the end of the equipment's life.

It is expected that thanks to the regulation, the EU's F-gas emissions will be cut by two-thirds by 2030 compared to 2014 levels. The European Commission estimates cumulative emissions savings of 1.5 billion tonnes of CO_2-equivalent by 2030 and five billion tonnes by 2050 – this latter figure representing more than the emissions from one billion return flights between Paris and New York.

EC preparatory studies showed that, though ambitious, this reduction is achievable at relatively low cost because climate friendly alternatives are available for many of the equipment in which F-gases are commonly used today.

Table 1. State of technology in some AC and refrigeration sectors.

Sector	Conventional F-gas technology	Established alternative technology
Stationary AC	• HCFC-22 • R410A, R407C • HFC-134a (chillers) • R404A (chillers)	• R290 (room AC, chillers, heat pumps) • R717 (large chillers) • R744 (heat pumps)
Industrial refrigeration	• HCFC-22 • R404A, R407C	• Ammonia (R717) • Ammonia and CO2 cascade
	Commercial refrigeration	
Centralized systems	• HCFC-22 • R404A, R407C • HFC-134a	• R744 in LT-cascade systems • R744 for MT and LT • R290, R1270 or R717 with secondary loop systems, sometimes R744 LT cascade systems
Condensing units	• HCFC-22 • R404A, R410A • HFC-134a	
Stand alone units	• CFC-12 • HFC-134a • R404A	• R744 for a ice cream freezers and beverage vending machines • HC (hydrocarbon, mainly R290, sometimes R600a) for bottle coolers and LT cabinets, etc.

Source: Preparatory study for a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases.

HFC bans in new equipment

HFC bans will likely to have the most direct and immediate effect on speeding up the transition to climate friendly alternatives and innovative products. Bans on HFCs in new equipment include the following air-conditioning, commercial and industrial refrigeration sectors and buildings related products:

- ✓ Non-refillable containers for HFCs for refrigeration, air-conditioning or heat-pump equipment – as of 2017;
- ✓ Movable room AC, hermetically sealed (GWP ≥ 150) – as of 2020;
- ✓ Split AC containing < 3 kg of HFCs (GWP ≥ 750) – as of 2025;
- ✓ Refrigerators and freezers for commercial use, hermetically sealed – with GWP ≥ 2,500 – as of 2020, with GWP ≥ 150 – as of 2022;
- ✓ Stationary refrigeration equipment (expect that designed to cool below −50°C (GWP ≥ 2,500) – as of 2020;
- ✓ Multipack centralised refrigeration systems for commercial use with capacity ≥ 40 kW with GWP ≥ 150 – as of 2022, except in the primary refrigerant circuit of cascade systems where f-gases with a GWP < 1,500 may be used;
- ✓ Windows for domestic use that contain fluorinated greenhouse gases – as of 2007;
- ✓ Other windows that contain fluorinated greenhouse gases – as of 2008.

The bans don't apply to equipment which, during its life cycle, showed greater energy efficiency with lower CO_2 emissions than those in HFC-free systems, by applying the eco-design requirements contained in Directive 2009/125/EC.

Leak checking regime extended

The containment measures based on regular leak checking have been extended and now cover also stationary refrigeration, air-conditioning, heat pumps, and fire protection systems. To reinforce the climate impact the frequency of leak checks will be based on global warming potential in CO_2 equivalents rather than tonnes of F gas. This will potentially bring more equipment into the leak checking regime which is designed to encourage a switch to lower GWP alternatives.

EU leading role in global HFC phase-down

The new Regulation will also have a global impact by anticipating a global phase-down of the consumption and production of hydrofluorocarbons (HFCs) on the basis of proposals currently being discussed under the Montreal Protocol on protecting the ozone layer.

"Increased EU demand for alternative technologies is likely to spur innovation and economies of scale in other markets too, hence reducing the costs of a global phase-down of HFCs." – said EU Climate Commissioner Connie Hedegaard in the debate on F-Gas in the European Parliament. "This is crucial because, unless other major economies follow Europe's lead, global production and consumption of these extremely powerful greenhouse gases will continue to grow. The swift and effective implementation of the EU regulation as of 2015 will prove that ambitious measures on HFCs are feasible. With this domestic legislation, the EU has gained global leadership on this issue, and we are prepared to use this role in order to make progress at international level too."

While confirming the EU's position as a global leader in taking strong measures on F-gases, the new legislation is also meant to inspire others to take action. A number of countries are already developing similar approaches. Tackling HFC emissions is a priority of the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC), of which the Commission is a member. Similarly, the G20 countries have recognised the need to act on HFCs.

Market effects and new requirements for producers

The Regulation will affect endogen and global markets, in particular countries exporting to the EU. Through increased demand for climate-friendly technologies, the new Regulation creates new business opportunities and will accelerate innovation and economies of scale in producing such technologies, thus lowering their costs.

Companies will be allocated quotas that limit future sales of HFCs, as first step in preparing a phase-down of HFCs in the EU. To clarify the procedure to be followed by new entrants to become eligible to receive quota, the European Commission published a 'Notice to producers and importers of HFCs and to new undertakings intending to place HFCs in bulk on the market in the European Union' on May 21. The complete notice is available in all EU languages in the Official Journal of the EU.

The formal notice describes the process for registering with the new HFC Registry. This is required both for companies that have legally reported production or imports in the period 2009–2012 ('reporting companies') as well as for 'new entrants' to the market that have not done so.

References:

REGULATION (EU) No 517/2014 on fluorinated greenhouse gases.

Notice to producers and importers of hydrofluorocarbons and to new undertakings intending to place hydrofluorocarbons in bulk on the market in the European Union in 2015 (2014/C 153/07).

Preparatory study for a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases.

EC F-gas website: http://ec.europa.eu/clima/policies/f-gas/legislation/index_en.htm.

European Parliament debate on Fluorinated greenhouse gases (debate), Tuesday, 11 March 2014, Strasbourg.

Reporting companies will be given reference values based on their historic data. New entrants will have to declare their need for quota to the European Commission, which will allocate quotas on a pro rata basis until no more quotas are available. For reporting companies and new entrants alike, 1 July 2014 is the deadline for registration and 2015 quota applications, using the appropriate forms.

Further legislative steps

While the new Regulation repeals the original Regulation from 2006, the 10 implementing Regulations adopted under the original Regulation remain in force and continue to apply until new acts are adopted.

Currently the necessary new implementing acts are being prepared to render the Regulation properly applicable by January 2015. Official information can be obtained through the European Commission's website: http://ec.europa.eu/clima/policies/f-gas/index_en.htm

The new F-gas Regulation No 517/2014 is available online in the Official Journal of the EU: http://eur-lex.europa.eu ■


WE EMBRACE AND PRACTICE INDUSTRY CODE OF ETHICS
Innovative Products
For Sustainable Environment
Choose Friterm Class A
Products in Your Applications
Unit Cooler
Horseshoe Heat Pipe
High efficiency heat exchanger for run around loop heat recovery systems
V Type Dry Cooler
Horizontal Type Air Cooled Condenser
CO2 (R744)
Unit Cooler and
Gas Cooler Units
SME SUSTAINABLE
ENVIRONMENT FRIENDLY PRODUCT
FIRST PRIZE 2010
FRITERM®
since 1979
Head office / Factory:
İstanbul Deri Organize Sanayi Bölgesi Dilek Sokak No:10
X-11 Özel Parsel Tuzla 34957 İstanbul / TURKEY
Tel: +90 216 394 12 82 (pbx) Fax: +90 216 394 12 87
info@friterm.com
www.friterm.com
EUROVENT
member of
rehva
ISKID
ISKAV

Management of electricity and heating demand to match sustainable energy supply

This paper presents the Dual Demand Side Management (2DSM) concept as well as an implementation on a multi-energy co-simulation platform. 2DSM is a coordination approach to manage the energy demand on a city district level. The coordination strategy enables the balancing of volatile renewable electricity generation by exploiting the thermal flexibility provided by decentralized energy supply units coupled with storage systems. The investigation of a small city district of 34 houses shows the suitability and the potential of the 2DSM concept.

Keywords: demand side management, scheduling, renewable energies, mixed integer problem, co-simulation.

The transition of the German energy infrastructure towards sustainable and decentralized energy generation requires and already induced significant changes of the structure and the operation of the energy supply systems e.g. the impending nuclear power plant phase-out and the ambitious goals for CO_2 emission reduction and expansion of renewable energy sources (RESs). This energy reform, widely known as the 'Energiewende', is based on several national laws mainly the German Renewable Energy Act (EEG), the Renewable Energies Heat Act (EEWärmeG) and the Act on Combined Heat and Power (KWKG) which are responsible for a strong increase of renewable electricity generation and installation of decentralized energy sources over the past years. Accordingly, renewable capacities of approx. 83 GW are currently installed in Germany and up to 30 % of the generated electricity is based on RESs [1]. As a result, overload of distribution grids is already occurring due to strong renewable generation in off-peak demand phases which is counteracted by curtailing RESs. The challenges for ensuring the grid stability and the security of supply are set to increase as 80 % of the electricity production is to derive from RESs by 2050.

HASSAN HARB
hharb@eonerc.rwth-aachen.de

PETER MATTHES

HENRYK WOLISZ

RITA STREBLOW

DIRK MÜLLER

All authors are from RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings and Indoor Climate, Germany

Therefore, energy management concepts are required to cope with the volatile generation of RESs and match electricity production and consumption, through coordination of Distributed Energy Conversion Units (DECUs) i.e. Combined Heat and Power (CHP) and Heat Pump (HP) units.

Methodology

In this section, the concept of 2DSM is introduced. Further, the control strategy is presented, followed by a description of the co-simulation platform. The platform is used to implement the control algorithm and simulate the energy system of a city district.

Concept

2DSM is an approach to manage the electrical and thermal energy demand on a city district level. The aim is to enable the balancing of volatile renewable electricity generation, e.g. PV and wind turbine systems. In 2DSM thermal supply systems combined with thermal energy storages can be operated in a flexible manner to reduce the imbalance between electrical generation and demand. Thereby, the analysis focuses on heat supply systems like Heat Pumps (HPs), Combined Heat and Power units (CHPs) and Electrical storage Heaters (EHs) that are connected to the electrical grid and offer a potential for dynamic control.

The flexible operation of these units is enabled by the availability of storage capacity. Therefore, the technical potential and the economic feasibility of different storage systems mainly hot water tanks and the inherent thermal mass of buildings are investigated in [2–4]. This analysis shows that thermal storage is and will set to remain the most suitable and cost efficient technology. Electrical or chemical storages provide an alternative option for residential DSM, but are very expensive in comparison.

The analysis of using the thermal mass of the building itself as a storage shows promising results. These indicate that a suitable configuration of building type i.e. good insulation standard, heat delivery system e.g. under floor heating and control strategy allows for a considerable storage capacity in the buildings thermal mass without violating residents' comfort.

Control

The energy management scheme is formulated based on a Multi-Agent System (MAS) framework to ensure both the flexibility extendibility and scalability of the control strategy. MAS is a network of distributed software agents that interact to achieve collective tasks. In this system, a complex problem is broken down into smaller problems which are handled by the different agents. The flexibility feature means that the functions of individual agents can be changed easily in order to enhance the functionality of the system or to fix errors. Extendibility is an indicator for removing or adding agents flawlessly from the network. Scalability refers to the option of using the system for small networks as well as for large networks without modification of its functionality.

The execution of the control strategy consists of a scheduling phase for the next 24 hours in 15 minutes time steps and a short time balancing phase that reacts to unforeseen deviations from the operation plan according to the status of the distribution grid. Different scheduling strategies have been investigated in [5]. In this work, the scheduling is based on a cooperative MAS. This represents a demand side management concept in which the DECUs are scheduled collectively to achieve a common goal, while meeting the individual electrical and thermal demand. The corresponding MAS interactions are illustrated in **Figure 1**.

The MAS consists of five agent types with specific functionalities: Weather, renewables, market, buildings, and coordinator. The structure of this concept is kept general with no mapping onto actual stakeholders. Further, no assumptions on the ownership of the functions are made. Moreover, the interaction with other entities e.g. Distribution System Operator (DSO) to check the feasibility of the optimal scheduling is foreseen but not implemented.

The weather agent queries a forecast of the outdoor air temperature, solar irradiation, and wind speed at the location and forwards this information to the buildings and local renewable agents. A building agent uses the outdoor temperature prognosis to forecast the heat demand for the next day and forwards this result to the coordinator agent. The thermal demand forecast is a time series based adaptive algorithm which separates the heat demand into a systematic and a behavioral component [6]. The systematic component is determined by computing a heating curve which correlates the heat demand to the outdoor temperature forecast. The behavioral component is derived from the previously measured heat demand and outdoor temperature.

The renewable agent uses the wind speed and solar irradiation forecasts to determine the expected availability

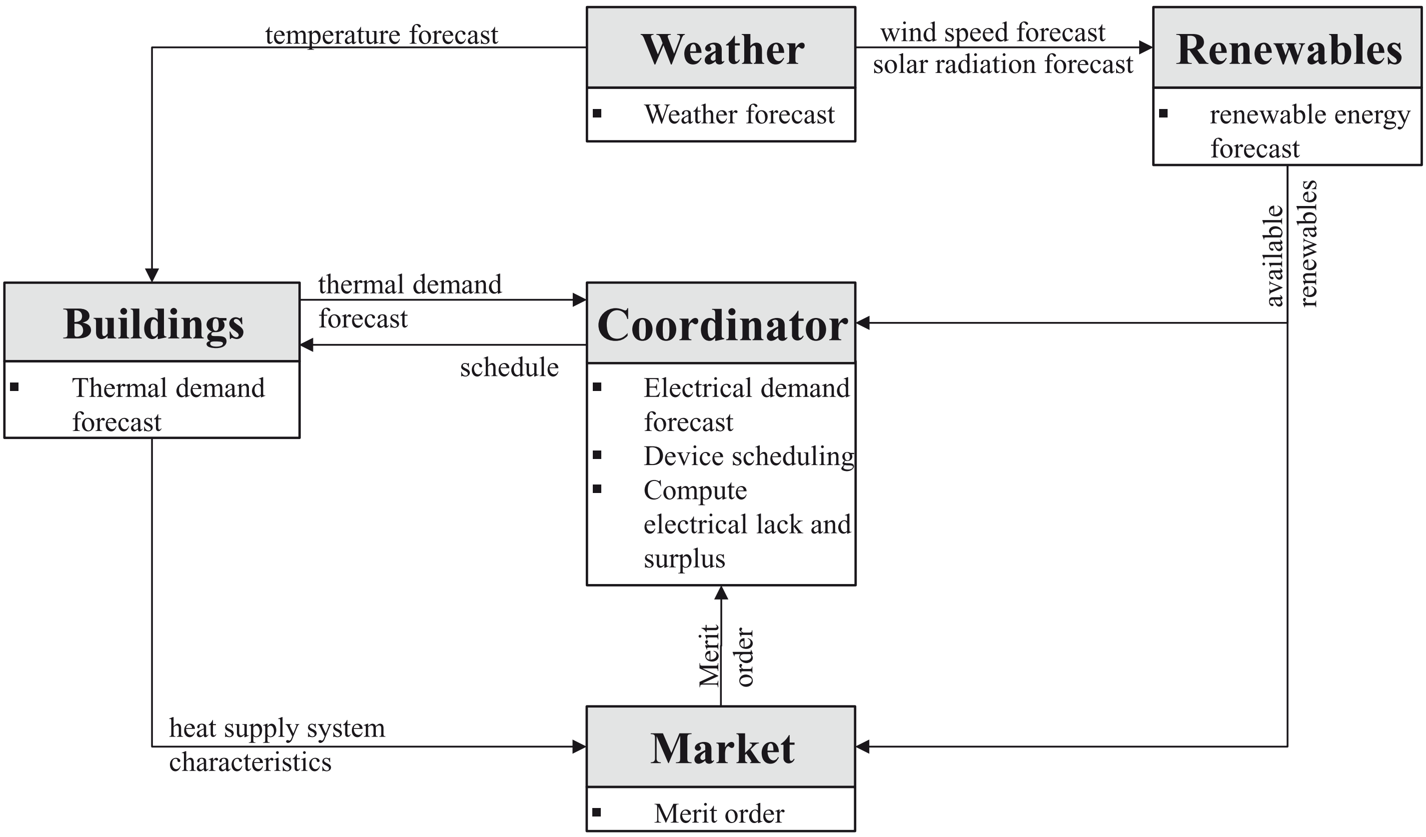


Figure 1. Structure of the multi-agent system.

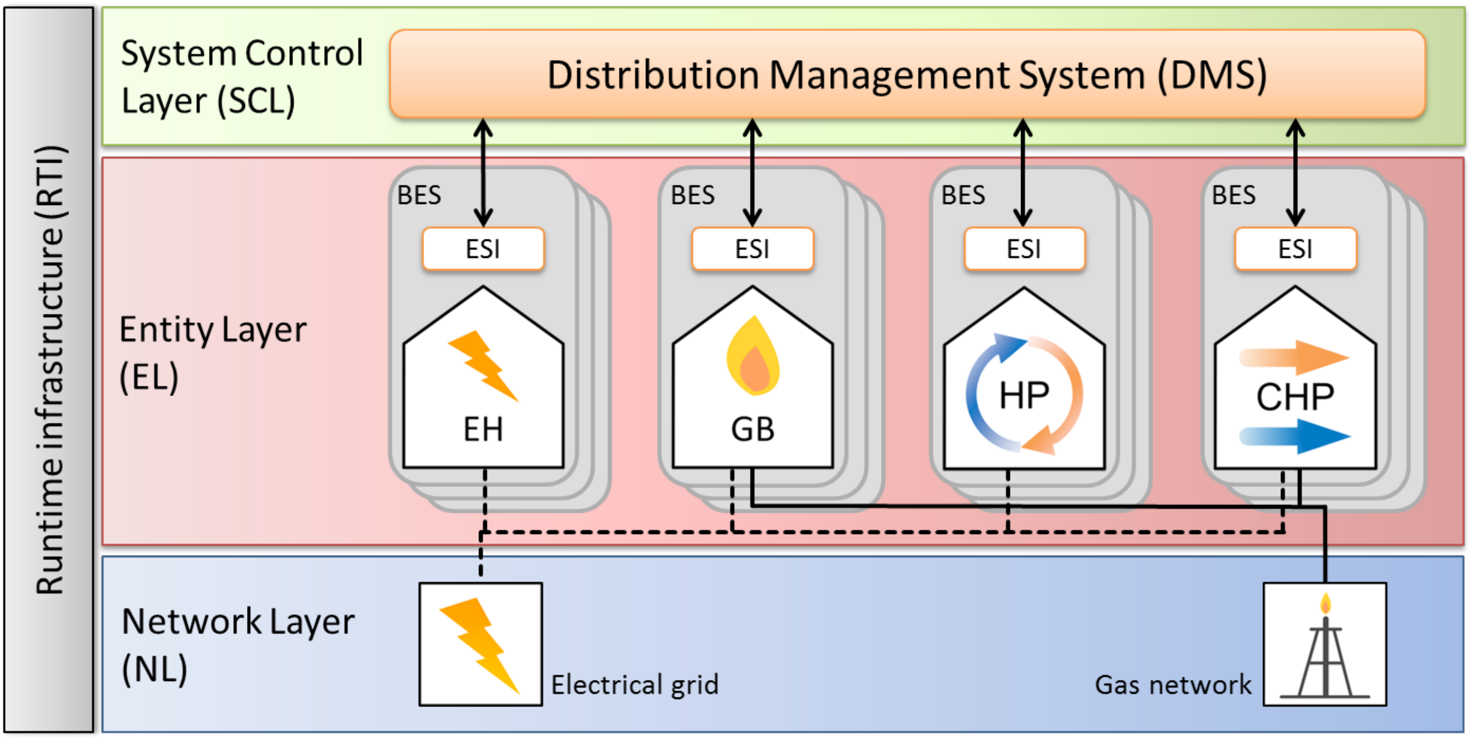


Figure 2. Co-simulation platform for multi-energy systems.

of solar and wind energy and forwards this information to the coordinator and market agents. The building agents send the heat supply systems' characteristics, mainly nominal power and efficiency to the market agent. The market agent determines the price of electricity, based on a merit order system.

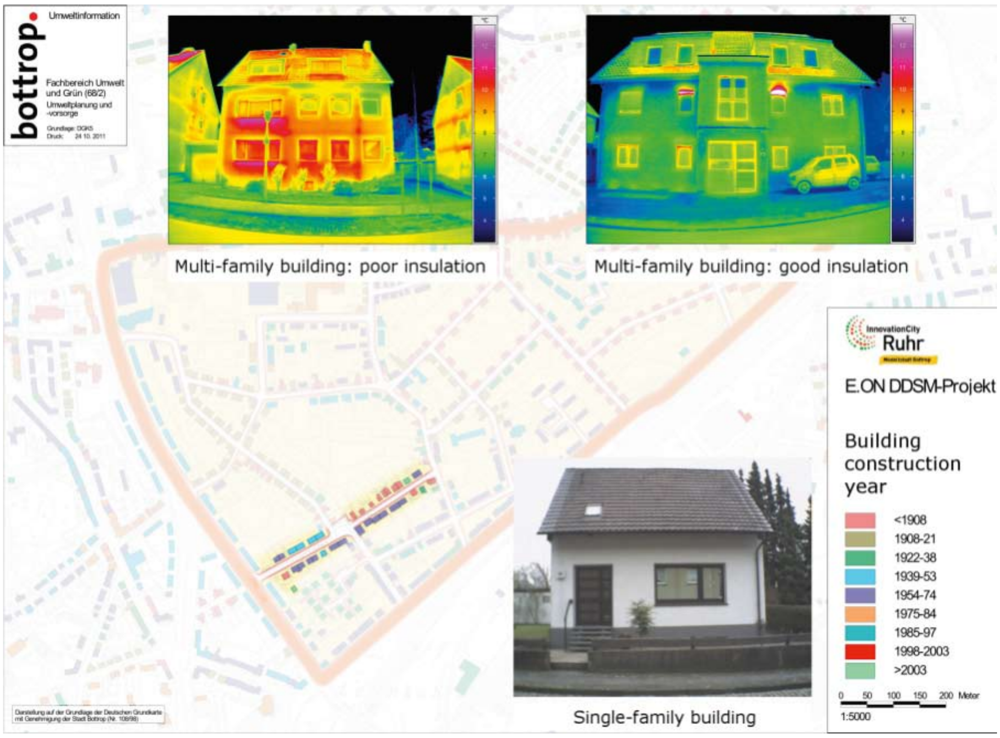


Figure 3. Location, images and age of the investigated group of buildings.

The coordinator makes use of the heat demand forecasts as restrictions for the schedules' optimization. Moreover, the coordinator computes a short term electrical demand forecast based on a double seasonal approach, i.e. daily and weekly, of the additive Holt-Winters method [7]. The Holt-Winters method is an exponential smoothing based model that assumes that the measured demand value can be decomposed into the sum of a level, a linear trend component and a seasonal term. The model presented in [7] is combined with a simulated annealing algorithm [12] to adaptively optimize the smoothing parameters and consequently improve the forecast's accuracy. Simulated annealing is a metaheuristic for global optimization problems, which uses a random driven search technique. The forecast is carried out for all participating buildings collectively, thus reducing the forecast error.

The schedule generation is formulated as a Mixed Integer optimization Problem (MIP) and computed using the solver CPLEX [5]. The objective of the optimization is to maximize the total profit of the participating building agents, which comprises costs for additional electricity and gas, as well as revenue generated from selling electrical surplus and governmental subsidies.

This control strategy is implemented on a multi-energy systems platform which is presented in the following subsection. This enables a co-simulation of the coordination scheme and the buildings' energy supply units as well as the electrical grid.

Implementation

A co-simulation platform was developed to approach the computational challenge for simulating a city district energy system comprising several hundreds of buildings, as well as the corresponding energy supply units and hydraulic systems. The platform makes use of parallel computing features and is based on a modular architecture which allows for the flexible integration of different simulation environments [8]. The architecture is depicted in **Figure 2** and consists of layers for system control, network e.g. electrical and gas grid, and an entity layer. The latter comprises the models of the building energy systems (BESs). The modeling approach of the BESs is presented in [9, 10]. The simulation platform is written in C++. It handles the communication between the different simulation tools. The entity layer's simulation models are programmed in Modelica, the (electrical) networks are modelled and simulated within Neplan and the control layer is implemented in Jade (Java agent development environment).

Investigation

In this section, a small city district comprising 34 buildings is used as a test case to investigate the potential of the energy management for balancing the fluctuating renewable energies and matching the electrical supply and demand.

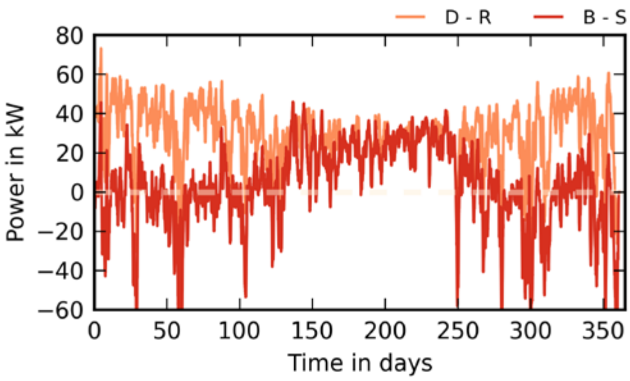


Figure 4. Grid interactions in the heat driven scenario. D-R = electricity demand (D) minus the available renewables (R), B-S = bought electricity (B) minus the surplus (S).

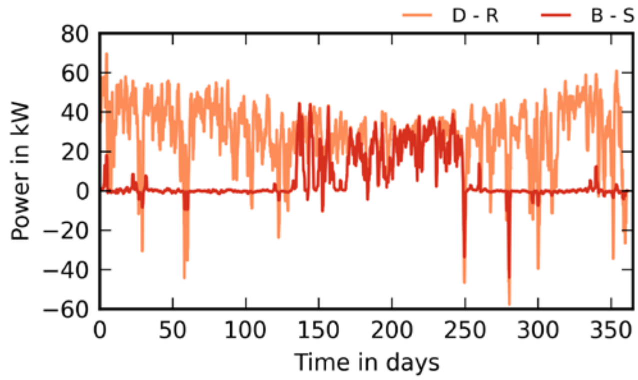


Figure 5. Grid interactions in the energy managed scenario. D-R = electricity demand (D) minus the available renewables (R), B-S = bought electricity (B) minus the surplus (S).

Figure 3 depicts the residential city district which is located in the area Bottrop. The group of 34 buildings comprises eight single family houses, 14 small multi-family buildings with three or four apartments and 12 large multi-dwelling units with five to eight apartments. The number of occupants varies between one to five residents within a single apartment and two to 25 on a building level. The electrical energy consumption for lights and appliances correlates with the number of occupants. Accordingly, the yearly electrical demand ranges between 2 850 kWh for an apartment of two residents and 5 310 kWh for a five person apartment. The profiles are assumed to follow the standard load profile for households and private consumer in North Rhine Westphalia. The thermal energy consumption is mainly related to the construction and insulation standards. The specific yearly energy consumption ranges from 80 kWh/(m² a) for well insulated buildings to 290 kWh/(m² a) for older buildings as indicated in **Figure 5**.

The buildings are equipped individually with a bivalent air-water HP or a CHP system assuming a parallel operation mode, combined with a heat storage tank. The design and dimensioning of the heat supply system is based on the optimization concept presented in [11] which ensures the economic feasibility of the setup. The simulations are carried out for a one-year period and comprise a reference scenario in which the heating generators are operated in the heat driven mode and a second scenario in which the energy management strategy is implemented.

Figures 4 and 5 illustrate the electrical balance on the grid side. The dark red curve shows the residual demand, which is the *electricity demand ('D')* minus the *available renewables ('R')*. If this line is below zero, the renewable supply is larger than the demand. The light red curve stands for the import or *additionally bought electricity ('B')* minus the *surplus ('S')* which comprises the excess energy of renewables or locally generated electricity from the CHP units. A negative value indicates a surplus which is exported to the grid.

The results of the heat driven scenario are depicted in **Figure 4**. The grid balance displays large peaks of imports and export. This is a clear indication of the lack in coordination. The energy supply units are operated in this scenario to meet the energy demand without any consideration of the availability of renewable energy or the peaks of electrical demands. As a result, it occurs that many CHPs are operated in periods of large availability of RESs which leads to large exports. Similarly, several HPs are activated in periods of large electrical demand, which induces large imports.

Figure 5 depicts the coordination results and the load shifting events of the energy management strategy. In this scenario, the imports and exports are reduced largely. As a result, an almost autarkic status is achieved. The export is mainly restricted to the phases in which a large amount of renewables is available. Additional energy is mainly imported when the demand greatly outweighs the renewable generation or during the summer period in which the CHPs cannot be operated to compensate the electrical demand due to the lack of heat demand and heat storage capacities. When renewables outweigh the demand, the coordination strategy attempts to shut down the CHPs and consequently avoid producing large surpluses. Simultaneously, the heat pumps are activated to take advantage of the availability of renewable energy. In times of high demand, the energy management strategy minimizes the additionally required amount of electricity by deactivating the HPs and activating the CHP units.

Conclusion

This work provides an introduction to the concept of 2DSM as well as its implementation on a multi-energy co-simulation platform. This platform enables the simulation and analysis of city district energy systems comprising a large number of buildings and energy supply units as well as the investigation of the performance of different control algorithms.

The 2DSM energy management strategy is based on exploiting thermal flexibilities for shifting the operation of electro-thermal DECUs to adapt to the fluctuating generation of RESs as well as matching the demand and supply. This allows for integrating large renewable capacity in the electricity generation infrastructure while ensuring the security of supply. Thermal storage capacities are identified as the main enabler of energy management. The inherent thermal capacity of building wall mass is a promising option, however further investigations are needed for the usage of this potential.

A multi-agent system is used as framework for the energy management system to ensure the flexibility, extendibility and scalability of the solution. The investigated control strategy displays a high coordination level allowing for a near autarkic performance. However, it can be foreseen that privacy issues arise with the implementation of such an approach as many input data are required. Moreover, future investigations are needed to analyze the technical implementation of this system. This includes testing of the performance and fault tolerance as well as the communication infrastructure. Additionally, an implementation on embedded systems is needed to pave the way for real life application. ■

Acknowledgement

Grateful acknowledgement is made for the financial support by E.ON gGmbH.

References

[1] Fraunhofer Institute for Solar Energy Systems (2014), "Electricity Spot-Prices and Production Data in Germany 2013".

[2] Wolisz, H., et al. (2013), "Performance Assessment of Heat Distribution Systems for Sensible Heat Storage in Building Thermal Mass", Proceedings of CISBAT Conference 2013.

[3] Wolisz, H., et al. (2013), "Dynamic simulation of thermal capacity and charging/discharging performance for sensible heat storage in building wall mass", Proceedings of the Building Simulation Conference 2013.

[4] Wolisz, H., et al. (2014), "Feasibility and potential of thermal demand side management in residential buildings considering different developments in the energy market", Proceedings of ECOS conference 2014.

[5] Harb, H., et al. (2014), "A Multi-Agent Based Approach for Energy Management in Microgrids", Proceedings of ECOS 2014.

[6] Harb, H., et al. (2014), "Adaptive model for thermal demand forecast in residential buildings", Proceedings of WSB 2014.

[7] Taylor, H. (2010), "Triple Seasonal Methods for Short-Term Electricity Demand Forecasting", European Journal of Operational Research, 204, pp. 139-152.

[8] Molitor, C., et al. (2014), "{MESCOS}-A Multi-Energy System Co-Simulator for City District Energy Systems", IEEE Transactions on Industrial Informatics.

[9] Harb, H., et al. (2013), "Modeling approach for city district simulation", Proceedings of CISBAT 2013.

[10] Lauster, M., et al. (2014). "Low Order Thermal Network Models for Dynamic Simulations of Buildings on City District Scale. " Building and Environment, Volume 73, pp. 223-231.

[11] Harb, H., et al. (2014), "Optimal Design of Energy Conversion Units for Residential Houses", Proceedings of BSO 2014.

[12] Kirkpatrick, S., et al. (1983), "Optimization by Simulated Annealing", Science, New Series, Vol. 220, No. 4598, pp. 671-680.

Policies to Limit European Air Conditioning Energy Consumption

Ownership of air conditioning in Europe has steadily increased over a number of decades and this trend looks set to continue (**Figure 1**). [1] Other things being equal, energy consumption will also increase. What could we do to constrain this increase?

Keywords: Energy Policy, Air Conditioning, Energy Monitoring.

ROGER HITCHIN
hitchinr@bre.co.uk
Building Research Establishment, Watford, Herts, WD25 9XX, United Kingdom

CHRISTINE POUT
Building Research Establishment, Watford, Herts, WD25 9XX, United Kingdom

This article asks:

- Where are the biggest opportunities for reducing air conditioning energy consumption?
- Do we have policy frameworks that address these opportunities?
- Are there important gaps? If so, do we know how to address them?

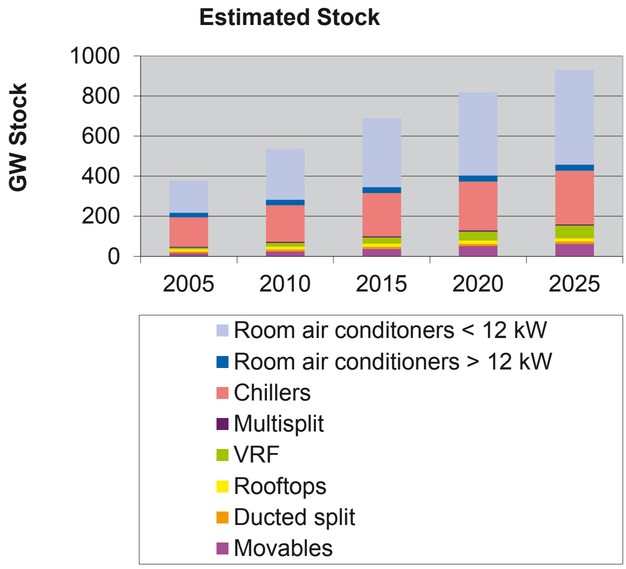


Figure 1. Air conditioning installed stock estimates. [1]

Where are the savings and how quickly could they be achieved?

The Intelligent Energy Europe Harmonac project and other studies have shown that there is significant potential for savings in three areas:

- Reduction of cooling loads
- Improved efficiency of systems and equipment
- More effective operation and maintenance

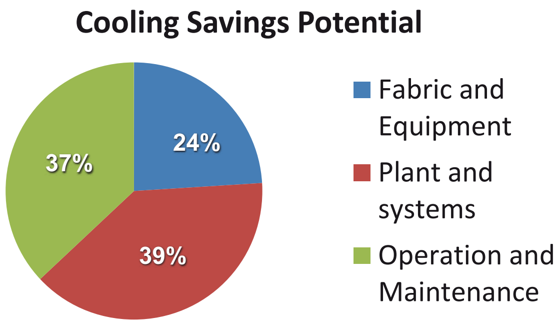


Figure 2. Relative air conditioning energy savings potential. [5]

Realising this potential is not straightforward. In particular, the relatively long operational life – typically of the order of 10 to 30 years - of air conditioning products and systems, and the equally long interval between building refurbishments are strong constraints on the rate at which energy-saving measures can be implemented.

This article considers “realisable 10-year potential savings” relative to a business as usual base case that could be achieved over a ten year period by applying measures and technologies that are already available in the market place. It summarises key results from a larger study [2,3]. Savings include both energy used for cooling and also that used for mechanical air handling within air conditioning systems.

The article concentrates on the six cases that were identified as having the largest energy-saving potentials. Unsurprisingly, these relate to the widespread use of the most energy-efficient products and procedures currently available. These are not always financially attractive to end-users, in which case regulatory measures may be needed to ensure their use. We therefore also consider whether these measures can be enforced by existing regulatory frameworks.

How did we estimate the potential savings?

The potential savings were derived using information taken from a number of published sources, including:

- IEE projects: Auditac, Harmonac, KeepCool, KeepCool II
- EC-funded Preparatory Studies for Energy Related Products Directive
- Other sources: Eurovent Certification database, other published reports

These data were used in a highly disaggregated model of European air conditioning energy consumption. The model takes account of the structure of the current installed stock of air conditioning systems, and of future sales into new buildings, existing buildings and as replacement systems and products. In particular, it breaks the market into: 30 countries; 14 air conditioning system types; 6 buildings per country; new-build, existing buildings, component and replacement rates. More details can be found in [3].

What are the most significant measures?

The six most significant types of measure are shown in **Figure 3**. The largest potential savings amount to about 30% of the 10-year base case consumption. They are subject to many assumptions and should be seen primarily as standardised indicators rather than projections. The measures overlap and interact and the potential savings cannot be simply added together.

How can these measures be implemented?

Consider each case in turn:

Demanding Minimum Performance Requirements for chillers and packaged cooling systems

This measure has a direct impact on series-produced products and is already covered by the existing policy framework supporting the Energy-related Products Directive, and the Energy Labelling Directive. The performance requirements assumed for products up to 12 kW cooling capacity are somewhat more demanding than those currently on place, but are still within the range of products that are on the market. The performance levels assumed for larger products are similar to those recently suggested by Preparatory Studies for the Ecodesign Directives. Our savings estimates are larger than those in the Preparatory Study as we have made the simplifying assumption that all policies could be implemented immediately. Realistically, the proposed levels of minimum performance would require many products to be taken off the market, which would require a phased implementation.

Performance requirements for air handling subsystems

This complements the previous case by extending minimum energy performance requirements to parts of larger air conditioning systems. Specifically, it covers requirements for duct and air handling unit leakage and for specific fan power. As air handling subsystems are tailored to different buildings, such requirements need to be implemented at national level through building energy regulations or codes. Although not explicitly required by the Energy Performance of Buildings Directive (EPBD), several European countries already implement such measures. The potential savings shown result from application of the same requirements across the rest of Europe. Current ERPD (Eco design of Energy Related Products Directive) proposals for requirements for air handling units have a narrower scope and would have a smaller impact. This case has a relatively small

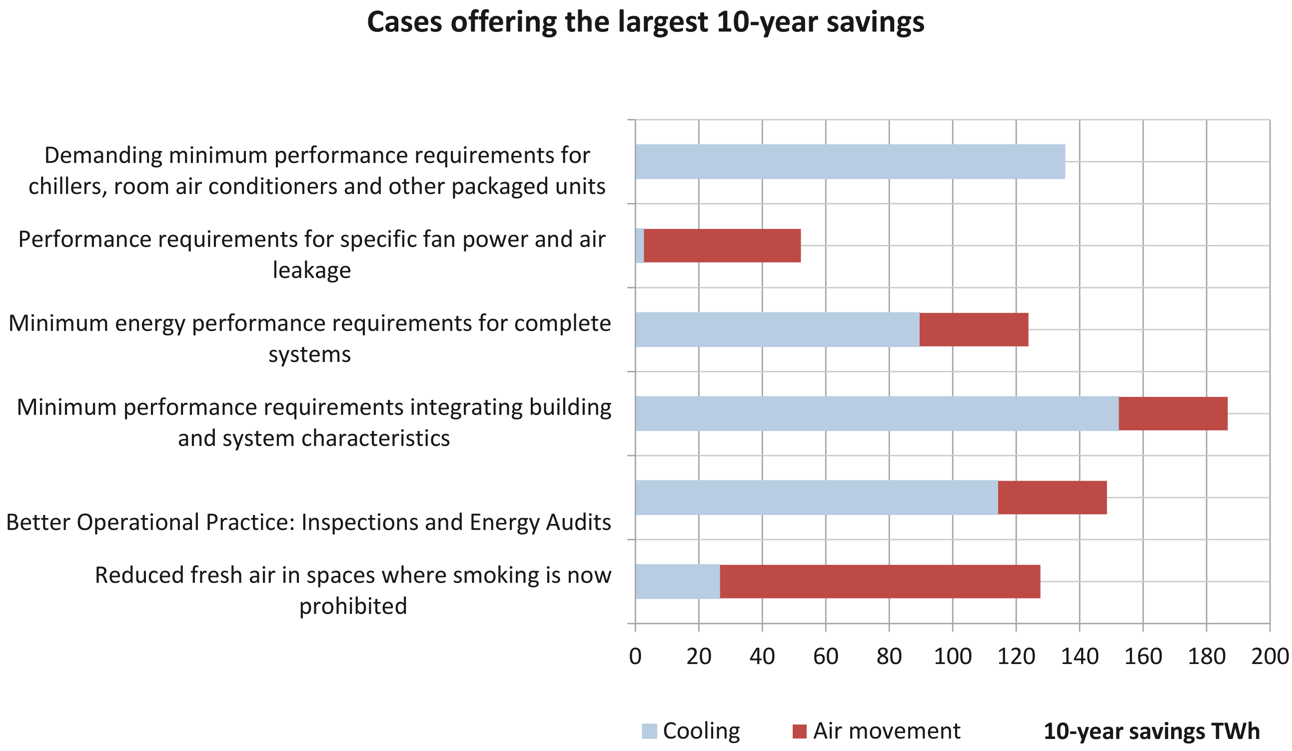


Figure 3. Largest opportunities for 10-year energy savings related to air-conditioning.

impact, but would be relatively easy to implement and provides a complement to requirements placed on series-produced products. The energy savings reported do not include the substantial additional savings that would result from applying the same requirements to mechanical ventilation systems that do not provide cooling.

Demanding Whole-system Minimum Energy Performance Requirements

Efficient components do not guarantee efficient systems and so a performance requirement placed on the system as a whole is a logical concept. A whole-system performance indicator is, in fact, required by the Recast EPBD. Since larger systems are specific to buildings, a requirement of this type would have to be implemented at national level. Modelling shows that this approach offers large 10-year potential savings. However, many of these savings overlap with those more easily achieved through performance requirements placed on products and air handling sub-systems.

There are also several practical implementation problems. The most fundamental of these is the need to agree a performance metric for systems that typically provide both cooling and heating, and often ventilation services. This might take the form of an integrated metric covering all three services (plus perhaps humidity control and air filtration). Alternatively it might consist of separate requirements for each service – in which case the apportionment of energy for components serving more than one service (notably fans) needs to be agreed. System performance cannot be measured on site, so agreement would also be needed on calculation methods and boundary conditions. Finally, there is the question of who is responsible for the calculation and for enforcement: the installation of an air conditioning system in an existing building does not always require building consent.

These hurdles are not insurmountable but do raise the question of whether the energy savings – over and above those achievable from existing policy frameworks – justify the effort to overcome them.

Demanding Integrated Minimum Energy Performance Requirements for Buildings and Systems

This case represents a tightening of the current EPBD minimum energy performance requirements in a number of countries, notably those in warmer climates with large numbers of air conditioning systems. Implementation is at a national level within the framework of the EPBD. In addition to incentivising the use of more efficient systems, the scope of the requirements includes the impact of load reduction measures from better building design and more efficient lighting systems, especially for new buildings and those undergoing major refurbishment. This case has the largest potential 10-year savings of the six that are described. However, the estimated savings are subject to the additional uncertainty associated with assumptions about the relative savings from air conditioning and other energy-using services.

Since the calculation of energy performance covers both the building and its "technical building systems", implementation of this case shares some of the challenges faced by whole-system requirements. However, these are reduced by the absence of a need for an explicit system performance metric and the existence of an established implementation infrastructure.

Better operational practice

There are substantial potential 10-year energy savings from better operational practice. Most such energy savings do not need substantial investments or new equipment. In principle, they can therefore be implemented quickly – and can disappear just as quickly. The estimated savings for this case are "demanding" in the sense that they assume that the majority of potential savings are identified and actions are taken to address them.

Existing policy instruments include the EPBD requirements for regular inspections of air conditioning systems larger than 12 kW cooling capacity (or the provision of advice in a way that can be shown to be equally effective) and more general advice campaigns including energy benchmarking. Energy Ratings based on measured consumption are also intended to impact on operational practice. Experience has shown that all of these have a limited impact. The Harmonac study showed that, while most of the savings potential identified by inspections was operational savings, most operational savings potential was not identified. [4, 5]

There is therefore a significant gap in effective policy measures. Remote energy monitoring combined with feedback that is building-specific has been shown to be capable of producing significant operational savings at economic costs (see for example the iSERV project [6, 7] and is a possible way forwards. This approach also allows the identification of high-consumption systems that could benefit most from inspection and provides diagnostic information to make inspections more effective. Building managers have proved to be somewhat reluctant to adopt the approach and implementation may require regulatory incentives such as less frequent inspections for low consumption systems.

Reduction of outdoor air supply

The final case is one that tends to be overlooked. Many existing air conditioning (and ventilation) systems were designed to deal with tobacco smoke, but smoking is often now prohibited in buildings or parts of buildings. There is scope for reducing outdoor air supply rates in new systems and, providing that issues of control and balancing can be handled, in some existing systems too. Most of the savings come from reduced fan energy use but, in hot climates, there are also cooling energy savings.

Policies to implementation these savings in new buildings would need to address design practice (the required air supply rates for smoking and non-smoking spaces are already defined by standards). For existing buildings, the same (rather weak) measures that are in place for operation savings seem to be the most appropriate option.

As information on the prohibition of smoking and the extent to which this opportunity has already been recognised is fairly sparse, the exact size of the opportunity is relatively uncertain.

Summary

- There is substantial energy savings potential through improved technical efficiency which could be achieved through the ERPD and EPBD. Extension of EPBD to include air handling subsystems looks desirable.
- Additional savings through the reduction of cooling loads is achievable through the EPBD, though implementation rate will be slow in existing buildings – but further saving in this are will accrue after the end of the 10-year period considered here. Further cooling demand savings are available from the impact of the ERPD on lighting and appliances.
- There is substantial energy savings potential through better operation and maintenance, but the impact of current policy instruments is weak.

As **Table 1** shows, existing policy frameworks mainly impact on system and product efficiency and, to a lesser extent, on load reduction. Policy measures addressing operational practice are few (and as we have seen weak).

The cases highlighted overlap and interact and we would suggest that the following combination of measures offers a reasonably balanced portfolio:

For new-build and major refurbishment: Integrated building plus system performance requirements in the form required by the EPBD.

Table 1. Summary of impacts and implementation routes.

Case	Impacts on:			Implementation route
	Cooling load	System efficiency	Operation	
Demanding minimum performance requirements for chillers, room air conditioners and other packaged units		XXX		Ecodesign
Performance requirements for specific fan power and air leakage	X	XXX		National codes (under EPBD)
Minimum energy performance requirements for complete systems		XXX		National codes (under EPBD)
Minimum performance requirements integrating building and system characteristics	XXX	XXX	XXX	National codes (under EPBD)
Better operational practice	XX	XX		National programmes (under EPBD)
Reduced fresh air in spaces where smoking is prohibited	XXX	XX		National design codes and audits

For installations in existing buildings: performance requirements for new products, packaged systems, and air handling subsystems, implemented by the ErPD and an extension of the EPBD.

For existing systems: there is a need for policy instruments that incentivise better operation. It not clear what form these should take, although remote metering and diagnostics looks a promising option. ■

Acknowledgement

The work on which this article is based was financially supported by CLASP (Collaborative Labeling and Appliance Standards Program, 2021 L St NW, Washington, DC 20036, United States).

References

[1] Roger Hitchin, Christine Pout, Philippe Riviere 'Assessing the market for air conditioning systems in European buildings', Energy and Buildings, Volume 58, March 2013.

[2] Christine Pout, Roger Hitchin, David Butler, "Study to assess barriers and opportunities to improving energy efficiency in cooling appliances/systems." BRE Report 264072, March 2012 http://www.bre.co.uk/searchresults.jsp?category=5&q=energy+management.

[3] Roger Hitchin, Christine Pout, David Butler, "The practical scope for reducing air conditioning energy consumption in Europe: policy opportunities and priorities" EEDAL 2013 Conference Coimbra, Portugal Sept 2013 http://www.eedal-2013.eu/?q=node/21.

[4] Knight, Ian Paul and Masoero, Marco 2011. Inspection of air-conditioning systems - Results of the IEE HARMONAC project. REHVA Journal (European Journal of Heating, Ventilating and Air Conditioning Technology) 48 (2) , pp. 49-54.

[5] I. Knight et al, 'HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Energy Consumption in European Air Conditioning Systems and the Air Conditioning System Inspection Process' FINAL REPORT 2010 http://www.harmonac.info/fileadmin/downloads/docs/home/HARMONAC%20FINAL%20Report%20-%20Public%20Version.pdf.

[6] iSERV - Inspection of HVAC systems through continuous monitoring and benchmarking project http://www.iservcmb.info/.

[7] Knight, I. P. 2012. Assessing electrical energy use in HVAC systems. REHVA Journal (European Journal of Heating, Ventilating and Air Conditioning Technology) 49(1), pp. 6-11.

Energy Savings and Energy Efficiency through Building Automation and Control

MARTIN BECKER
Prof. Dr.-Ing.
Biberach University of Applied Sciences, Institute for Building and Energy Systems, Germany
becker@hochschule-bc.de

PETER KNOLL
Dipl.-Ing. (FH)
Biberach University of Applied Sciences, Institute for Building and Energy Systems, Germany

In addition to the improvement of building physics/building envelope and building systems (heating, cooling, etc.), the targeted use of room and building automation contributes significantly to the energy-efficient operation of buildings. This potential is based on the application of bus systems and automation technologies. Building automation in particular is a necessary instrument for maintaining the energy-efficient operation of buildings through continuous energy and building management. In order to analyze and advance this topic systematically, Biberach University of Applied Sciences has performed a variety of experimental and theoretical research work.

Keywords: room automation, building automation, energy, efficiency, savings, energy-saving potential, EN 15232, energy management

For the sustainable operation of a building, it is important to understand the interplay between the essential parameters. These parameters can be grouped into four categories.

a) **Aspects of use**
The comfort conditions in the rooms are an essential requirement for the overall planning and operation concept. This includes the thermal conditions (e.g. set-point temperature: 20°C), adequate illuminance (daylight and artificial light) and the possibility of adjusting the parameters.

b) **Energy-efficient operation of buildings**
The focus here is on the efficient use of energy (electricity, heating, cooling). This efficiency can be achieved with suitable functions of room and building automation.

c) **Building envelope**
The envelope is the interface with the environment (e.g. facade systems or building physics).

d) **Building systems**
This includes all technical systems which are used for heating, cooling, ventilation and the power supply of a building.

In the context of the EPBD (Directive 2010/31/EU of The European Parliament and of the Council of 19 May 2010 on the energy performance of buildings), the standard EN 15232 "Energy performance of buildings - impact of Building Automation, Controls and Building" was developed.

This standard divides the functions of room and building automation into four BACS (Building Automation and Control Systems) efficiency classes:

- Class D corresponds to BACS that are not energy-efficient. Buildings with such systems must be retrofitted. New buildings may no longer be built with such systems.
- Class C corresponds to standard BACS.
- Class B corresponds to advanced BACS and some specific TBM functions.
- Class A corresponds to highly energy-efficient BACS and TBM.

The standard provides two basic methods: the detailed and the simplified method (BACS factor method). The simplified BACS factor method allows the use of factors to calculate the final energy demand, depending on the BACS efficiency class.

This approach allows easy explanations, e.g. for owners, of how much the energy demand can be reduced for a given type of building through the functions of room and building automation.

To analyze these standardized methods under real-life conditions, Biberach University of Applied Sciences has performed theoretical research (simulation studies) as well as experimental analyses in seminar rooms in order to demonstrate the possible energy savings.

Measurement campaign

The goal of the measurement campaign is to answer the key question of whether it is possible to determine a potential for savings, in rooms in which different BACS efficiency classes (according to the standard EN 15232) have been realized, during the building's actual operation, and if so, how high the potential savings are.

For that purpose, the University of Applied Sciences Biberach has organized a measurement campaign involving three seminar rooms (G0.02, G0.03, G1.03, **Figure 1**) in the "Technikum G" building with comparable boundary conditions over a longer period of time. These three rooms have different functions in terms of room and building automation according to the norm EN 15232.

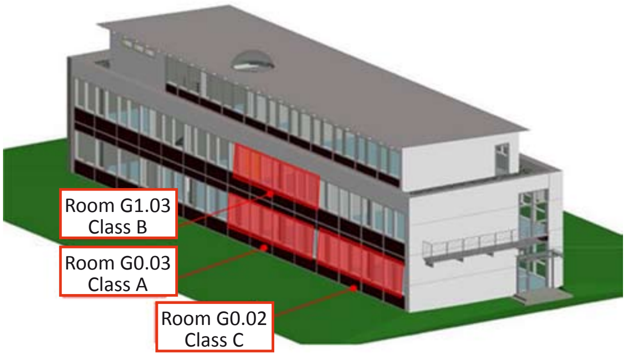


Figure 1. Spatial arrangement of the seminar rooms for the measurement campaign in the "Technikum G" building at Biberach University of Applied Sciences.

For the results, only the BACS efficiency classes C, B and A are compared. Class D no longer complies with current technical standards.

The seminar room G0.02 was chosen as the reference room. The functions in this room are based on the BACS efficiency class C. In the other seminar rooms, different functions of room and building automation were realized according to BACS efficiency classes B and A, making it possible to determine potential energy savings through technical measurements.

Table 1 lists the functions which were implemented. BACS efficiency class A has the most extensive functional configuration. Class C is the reference value for the energy savings.

Table 1. Combined functions of the measurement campaign for the three test rooms according to the standard EN 15232.

G0.02 **BACS efficiency class C**	**G0.03** **BACS efficiency class A**	**G1.03** **BACS efficiency class B**
Manual lighting on/off, without dimming	Manual lighting on/off, without manual dimming automatic off (presence, daylight), constant light control	Manual lighting on/off, without manual dimming automatic off (presence, daylight)
Temperature control with a thermostatic valve	Individual room control with three different set values: • 14°C night setback/window opening monitoring • 19°C stand-by • 21°C normal mode	Individual room control with three different set values: • 10°C night setback/window opening monitoring • 16°C stand-by • 21°C normal mode

Results of the measurement campaign

Figure 2 shows the electrical energy consumption which was measured in the three previously mentioned rooms with the different functional configurations. The figures have been adjusted to account for the different occupancies of the rooms.

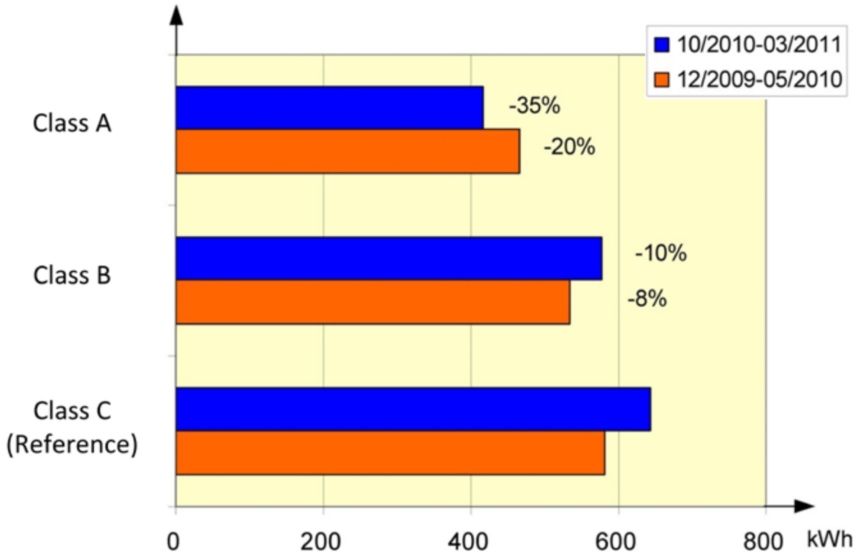


Figure 2. Electric energy consumption with percentage savings of the BACS classes A, B, C

While the lighting in the reference room (G0.02, Class C) is controlled manually, the other rooms have an automatic control which takes occupancy and available daylight into account. In addition to this, there is a constant light control in Room G0.03 (Class A). The clear improvement in the savings for Class A (G1.03) is due to the optimization of the constant light control which took place between the measurements "December 2009 – May 2010" and "October 2010 – March 2011". This optimization was based on experiences made during the first measurement period and involved the correction of sensor placement, among other things.

This illustrates the high importance of continuous improvement during operation.

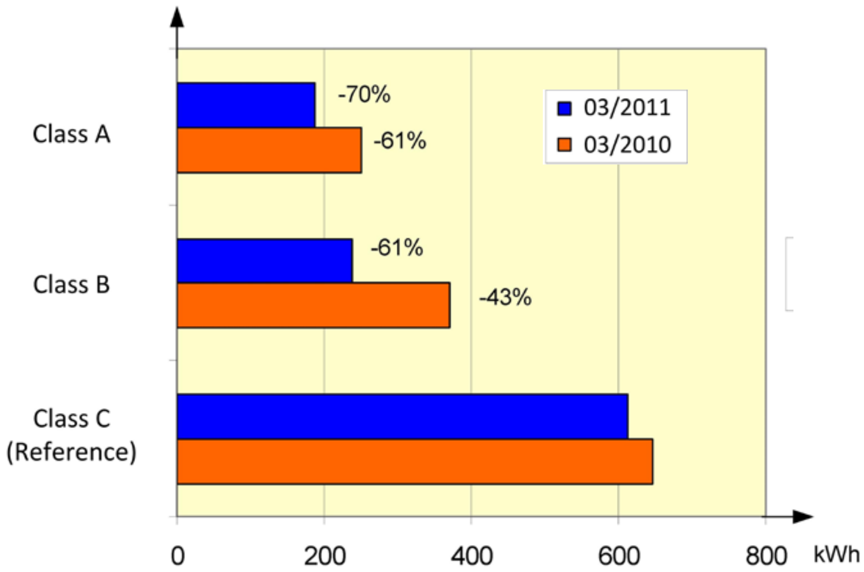


Figure 3. Comparison between the months March 2010 and March 2011; reduced consumption of heating energy (adjusted)

The data for heating energy consumption was analyzed analogously to the method used for electrical energy consumption. While the control in the reference room (G0.02) is realized with thermostatic valves, the room with the BACS class C (G1.03) has an individual room control with a zone valve which is blocked if a window is open. In addition to this, room G1.03 (BACS class A) has an optimized set point if the room is unoccupied.

Figure 3 shows the comparison between the measurement data for heating energy consumption. For the analysis, it was necessary to adjust for internal loads (e.g. lighting, occupancy), geometrical dimensions and building physics during the measurement periods.

The savings are based on the reference room G0.02. The data for March was very well suited for the analysis, because the weather conditions were similar in both years. You can see high energy savings between the reference room and the rooms with constant light control. While the savings in Room G0.03 were similar in both years, Room G1.03 shows clear improvements between March 2010 and March 2011. The reason for this is the realization in the first measurement period that the installed valve didn't fit to the valve gear. As a result, the control behavior was very bad.

This optimization process which was identified with the installed energy monitoring made it possible to achieve a huge improvement in energy efficiency. This example shows once more that continuous monitoring is very important. Continuous monitoring is the basis for straightforward optimization during building operation.

Importance of continuous energy monitoring

A major advantage of integrated building automation systems lies in the ease with which different types of data on the building and its systems can be analyzed. These possibilities are more than the usual error messages and energy analyses. For example, it is possible to check whether the automation strategy suits the room (occupancy) profile.

The following section contains an example which demonstrates how differently users can control the lighting of a room.

So-called carpet plots were used for the illustration. A carpet plot is a type of chart which is very well suited for concentrated information analysis. The abscissa of the chart is used for the day in a month or year and the ordinate for every hour of a day. This makes it possible to display a mean value (e.g. temperature) for data which is color-coded, allowing the analysis of electrical power or the runtime of components such as pumps or fans over a longer period of time at a glance.

A very clear example is shown in **Figure 4** and **Figure 5**. The electrical power for the lighting and the occupancy of Room G0.02 are color-coded. As noted in **Table 1**, the lighting in this room can only be switched on and off manually (BACS class C). The occupancy sensor is only used to determine occupancy, not control the lighting.

Figure 4 shows that the users switched the lighting on and off in a fairly exemplary fashion in December 2010. During this period, users switched off the lighting as soon they left the room. An occupancy sensor would not result in any energy savings in this case.

In contrast to this, the situation with the same boundary conditions is shown for October 2010. **Figure 5** shows that the lighting was almost never switched off from 14 October 2010 onwards, even if nobody was in the room. The light green color shows an electrical power consumption of about 500 W. This amount may represent a single light-band in the room which users forgot to switch off. In this example, an occupancy sensor would save a lot of energy by deactivating the light-band as soon as no one is in the room.

Summary

Along with good building physics and building systems, building automation is the third pillar in the energy-efficient operation of a building. Building automation combined with energy monitoring is a particularly important tool for showing potential for optimization in regard to users' behavior.

As a basis for this, it is necessary that building automation be considered during the planning process. The standard EN 15232 with the defined BACS efficiency classes provides a foundation for planning which has to be considered for the realization of new and modernized buildings in order to arrive at energy-efficient solutions.

Biberach University of Applied Sciences has analyzed the energy consumption of three seminar rooms with different BACS efficiency classes in order to determine the possible energy savings in the norm.

The analysis shows high potential energy savings through the use of room and building automation. An additional insight is that a process (e.g. a building) which has changing boundary conditions (e.g. the weather) or different disturbances (e.g. user behavior) can only be operated with an automation system which includes every building system.

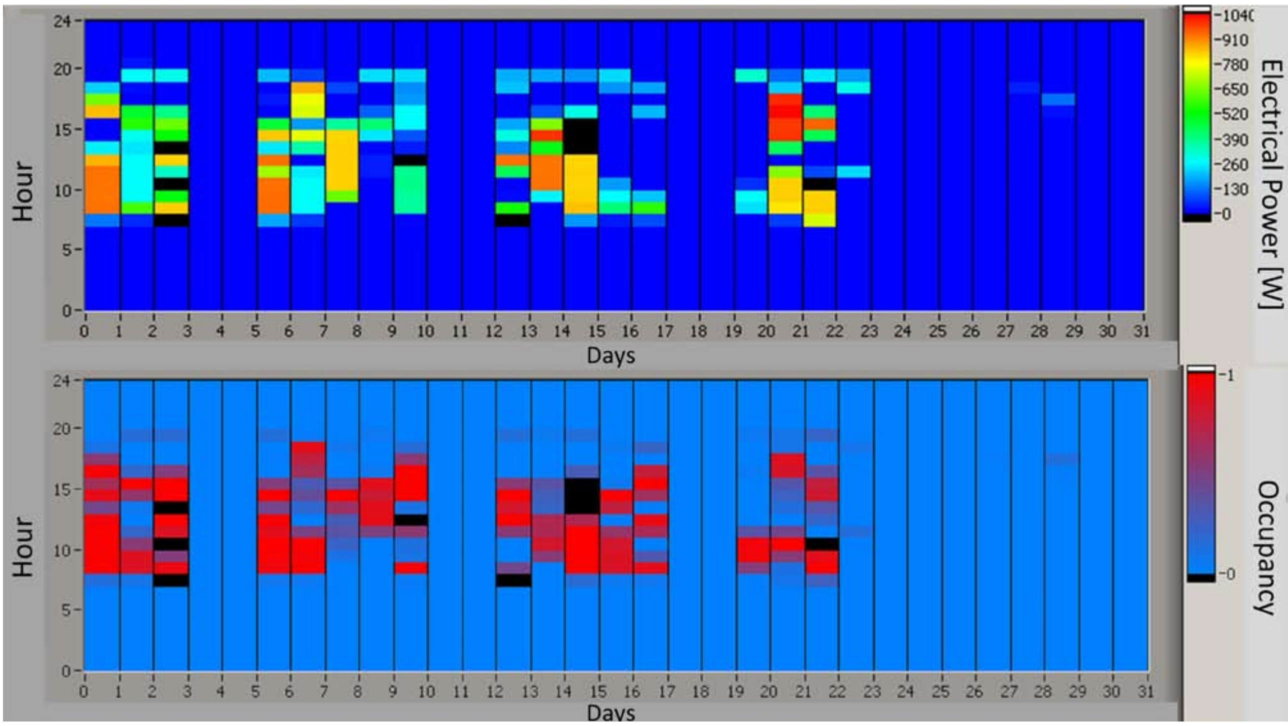


Figure 4. Carpet plot with an example of energy-efficient user behavior (December 2010)

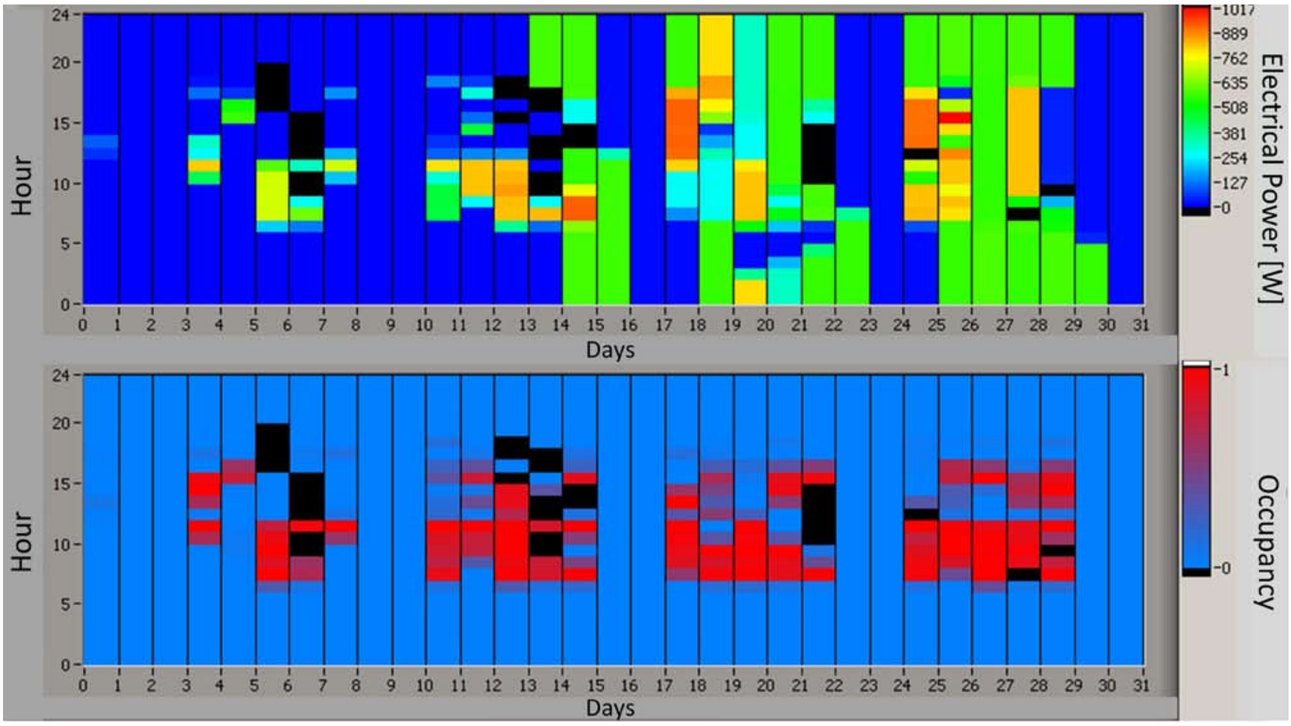


Figure 5. Carpet plot with an example of inefficient user behavior (October 2010)

The results of the analysis show very well that user behavior has a huge influence on measurements during the actual operation of a building. Even the prediction of the possible energy savings and the analysis of the results are dependent on this user influence.

Another important insight for practical applications is the high influence that the positioning of the sensor systems and the correct use of actuators have on the potential energy savings. ■

Total energy use in buildings: analysis and evaluation methods

Main findings from IEA EBC: Annex 53

One of the most significant barriers for achieving the goal of substantially improving energy efficiency of buildings is the lack of knowledge about the factors determining the energy use.

Keywords: energy use, monitoring, data collection.

SHUQIN CHEN
Research Center of Green Building and New Energy, Shanghai, China

HIROSHI YOSHINO
Department of architecture and building science, Tohoku University, Japan
yoshino@sabine.pln.archi.tohoku.ac.jp

A limitation of much current research is that it usually focuses on the three factors of climate, building envelope, and building services and energy systems, which have a direct influence on building energy use, while the quantitative influence of building operation and maintenance, occupants' activities and behaviour on energy use is still unknown [1]. Detailed comparative analysis on building energy data, concerning the six factors, would provide essential guidance to identify opportunities to save energy. However, a pivotal problem hindering to realize this is that there is a lack of a scientific method to account for interactions between the six influencing factors and energy use in a clear and thorough way and to predict the expected energy use as well when all influencing factors are taken into account. Aiming at this situation, an IEA EBC (International Energy Agency's Energy in Buildings and Communities Programme) project of "Annex 53: Total Energy Use in Buildings - Analysis and Evaluation Methods" was commenced in January 2009 and completed in a total of five years, intending

IEA EBC

In recognition of the significance of energy use in buildings, in 1977 the International Energy Agency has established an Implementing Agreement on Energy in Buildings and Communities (EBC-formerly known as ECBCS). The function of EBC is to undertake research and provide an international focus for building energy efficiency. Tasks are undertaken through a series of 'Annexes', so called because they are legally established as annexes to the EBC Implementing Agreement.

The largest benefits arising from participation in EBC are those gained by national programmes, such as leverage of R&D resources, technology transfer, training and capacity-building. Countries lacking knowledge can benefit from the experiences of those with more expertise, thereby avoiding duplicated research efforts. In particular, countries can most easily realise the benefits of participation if their own experts have taken part in projects and have assisted in producing deliverables taking into account their national requirements and priorities.

EBC has currently 26 member countries. All member countries have the right to propose new projects, and each country then decides whether or not to participate on a case by case basis. Most EBC projects are carried out on a 'task shared' basis, in which participating organisations arrange for their own experts to take part. Certain projects are 'cost shared' in which participants contribute funding to achieve common objectives.

EBC Secretariat (ESSU)
Mr. Malcolm Orme
+44 (0)121 262 1920
essu@iea-ebc.org

to improve the understanding of how these six factors together can influence the energy use, and also to what extent influence on the building energy use, especially on occupant behaviour.

The main objectives of this annex are to develop and demonstrate the following with respect to energy use:

1) Definitions of terms related to energy use and the influencing factors of building energy use;
2) An approach to describing occupant behaviour quantitatively and to setting up a model for occupant behaviour;
3) Database of energy use and influencing factors for existing typical buildings in different countries;
4) Methodologies and techniques for monitoring total energy use in buildings including hardware and software platforms;
5) A statistical model for national or regional building energy data including the influence of occupant behaviour;
6) Methodologies to predict total energy use in buildings and to assess/evaluate the impacts of energy saving policies and techniques.

Definition of terms relating to energy use and influencing factors

The inconsistency in the terms related to building energy use is a serious barrier to understanding of the influencing factors and analysis of real energy use. For instance, it is essential that the ambiguity in the meaning of kWh/m² for a building whose energy needs are served by both electricity and fossil fuels be removed by reporting electricity and the different fuel forms separately. Many similar problems exist, related to the terminology of building energy use and the influencing factors, and clear definitions of the terminology is in great need, which can provide a uniform language for the building energy efficiency analysis. In this situation, the consistent definitions related to the building boundary, energy use uses, energy conservation factors, six categories of influencing factors of energy use, and energy performance indicators have been developed. Building boundary is divided to E_b, E_t and E_d, where E_b represents the energy actually required (namely net energy need, or energy demand) within the building space, and E_t is the energy delivered to all the technical systems in the buildings, while E_d captures the energy use of space heating, cooling and hot water in district heating and cooling systems. When the energy carriers have to be combined in order to express the energy consumption through an "aggregated and synthetic" energy parameter, calorific value approach, primary energy approach and electricity equivalent approach are suggested to use [2]. The calorific value approach and primary energy approach traces the heat of on-site energy carriers and the original energy resources respectively. The electricity equivalent approach calculates the maximum ability of electricity generation by each energy carrier, so as to compare the capacity of different energy resources to do work, where it is defined as the heat amount of the energy carrier multiplied by the conversion coefficient of converting the unit energy carrier to the equivalent electricity. Energy performance indicators are defined in three ways to show energy use, that is (1) to list site energy separately, (2) aggregate energy into primary energy, (3) correct energy use by the factors of floor area, number of persons, etc.

As for the influence factors, three-level typologies of definitions have been developed from the simple level, the intermediate level, to the complex level, where the simple level serves large scale statistical analysis, and intermediate level is considered the minimum level for case studies, and the complex level is used for simulation or detailed diagnostics. **Table 1** shows three levels and categories of influencing factors. Aiming at the research subjects of residential buildings and office buildings in Annex 53, the definitions in each level figure out the important items in different kinds of influence factors, the quantitative and qualitative parameters of each item. Moving from Level A to Level C increases the quantity and specificity of the defined parameters and generally goes from large samples of buildings (often thousands) to small numbers (typically one to the low tens).

Definitions of energy-related occupant behaviour and modelling

Energy use in residential and office buildings is influenced by the behaviour of occupants in various ways. In order to achieve better understanding of total energy use in buildings, the identification of the relevant driving factors of energy-related occupant behaviour and a quantitative approach to modelling energy-related occupant behaviour and energy use are required. Energy-related occupant behaviour, as meant here, refers to observable actions or reactions of a person in response to external or internal stimuli, or actions or reactions of a person to adapt to ambient environmental conditions. These actions may be triggered by various driving forces , which can be distinguished into biological, psychological, and social contexts, time, building/installation properties, and physical environment [3-5]. These driving forces can provide a quantitative understanding and allow modelling of energy-related

Table 1. Three level typology definitions for residential buildings and office buildings (Mark Levine & Shuqin Chen). [1]

Typology	Energy use data	Categories of influencing factors			
		I	II	III	+(Optional)
Level A (Simple; for statistics with large scale datasets.) Datasets with small number of data points per building	Annually or monthly	**IF1.** Climate **IF2.** Building envelope and other characteristics **IF3**. Building service and energy system	**IF4.** Building Operation		**IF7.** Indirect factors (for residential buildings)
Level B (Intermediate; for case studies)	Monthly or daily	Same categories as Level A, more detail	**IF4.** **IF5.** Indoor environmental quality	**IF6.** Occupant behaviour	**IF7.** Indirect factors (for residential buildings)
Level C (Complex; simulations or detailed diagnostics)	Daily or hourly				

Note: Levels B and C includes six categories of influencing factors, besides the optional indirect factors, while more extensive set of definitions are covered in Level C.

occupant behaviour and energy use. Generally, the purpose for modelling occupant behaviour in this annex is to reveal the relationship between energy demand and usage, as well as the driving forces for variations. The different reasons for modelling occupant behaviour with respect to total energy use in buildings are design (conceptual, preliminary, and final), commissioning (initial and ongoing), and operation (control). Based on the aforementioned reasons, model types for the various purposes are defined. The selection of a model type is strongly dependent on the number of buildings, the user profile, and the time scale. The different models include psychological models, average value models, deterministic models, probabilistic models, and agent based models combined with action based models [6-8].

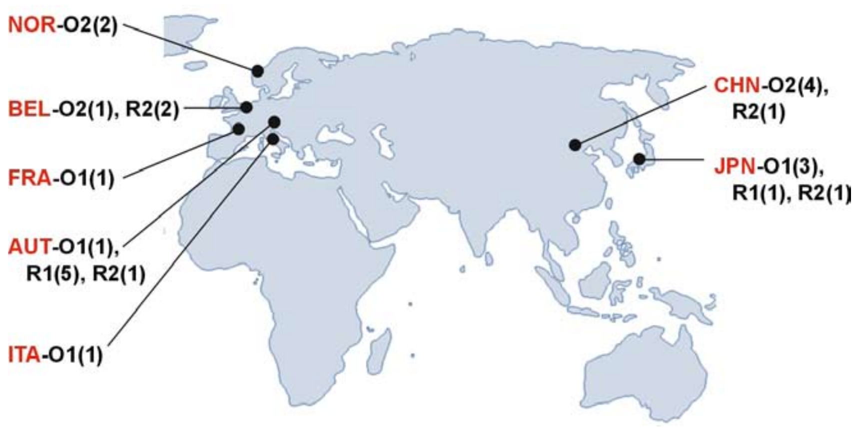


Figure 1. Locations of the 24 case study buildings from the seven contributing countries (Yi Jiang & Qingpeng Wei). [1]

Total energy use for analysis and evaluation

Collecting, reviewing and selecting case studies that document and analyse energy use data is a critical aspect of this annex. 12 office buildings and 12 residential buildings are finally confirmed and collected, as shown in **Figure 1**. The data collection of the 24 case studies follows the office and residential building definitions and typologies of Subtask A and the key results of total energy comparison and occupant behaviour of office and residential buildings are presented.

Table 2 shows the detail information of 10 selected office buildings, and **Figure 2** compares their energy use expressed in the electricity equivalent approach. The office buildings of AUT-01, FRA-01, JPN-01, and JPN-02 has the smallest floor areas of less than 5,000 square meters among the 10 buildings, and the buildings of BEL-01 and NOR-02 have the floor areas around 17,000 square meters, while the four Chinese buildings have the largest area of more than 30,000 square meters. It is found from the figure that there is no obvious relationship with the floor area and energy use intensity. Further analysis indicates that huge differences in electricity uses in the case study buildings are also seen in the following systems: air conditioning, ventilation (including the fans of air-handling-unit, primary air unit, and exhausting fans of toilet, parking

Table 2. Detailed information of 10 office case buildings (Yi Jiang & Qingpeng Wei). [1]

Code	Photo	Basic information	Code	Photo	Basic information
AUS-01		• Location: Melk, Austria • GFA: 4,811 m^2 • No. of floors: 3 • Construction year: 2007 • Cooling source: mechanical ventilation with a ground source heat exchanger, decentralized AC for server rooms • Heating source: district heating from biomass, mechanical ventilation with a ground source heat exchanger	**CHN-04**		• Location: Beijing, China • GFA: 54,500 m^2 • No. of floors: 21 • Construction year: 1980's • AC: VAV, PAU • Cooling source: water-cooled chiller • Heating source: district heating
BEL-01		• Location: Brussels, Belgium • GFA: 18,700 m^2 • No. of floors: 9 • Construction year: 1970's • AC: AHU, CAV, VAV • Cooling source: water-cooled chiller • Heating source: natural gas boiler	**FRA-01**		• Location: Lyon, France • GFA: 1,290 m^2 • No. of floors: 2 • Construction year: 1970 • Renovation year: 1993 • Heating source: no heating demand
CHN-01		• Location: Hong Kong, P.R. China • GFA: 30,968 m^2 • No. of floors: 23 • Construction year: 1998 • AC: AHU, CAV, VAV, FCU, PAU • Cooling source: water-cooled chiller • Heating source: no heating demand	**JPN-01**		• Location: Shimada, Japan • GFA: 2,734 m^2 • No. of floors: 4
CHN-02		• Location: Hong Kong, P.R.China • GFA: 141,968 m^2 • No. of floors: 68 • Construction year: 2008 • AC: AHU, CAV, VAV, FCU, PAU • Cooling source: water-cooled chiller • Heating source: no heating demand	**JPN-02**		• Location: Suzuka, Japan • GFA: 3,695 m^2 • No. of floors: 4
CHN-03		• Location: Beijing, China • GFA: 111,984 m^2 • No. of floors: 26 • Construction year: 2004 • AC: FCU, PAU • Cooling source: water-cooled chiller • Heating source: district heating	**NOR-02**		• Location: Trondheim, Norway • GFA: 16,200 m^2 • No. of floors: 6 • Construction year: 2009 • AC: AHU, VAV, FCU • Cooling source: heat pump • Heating source: district heating

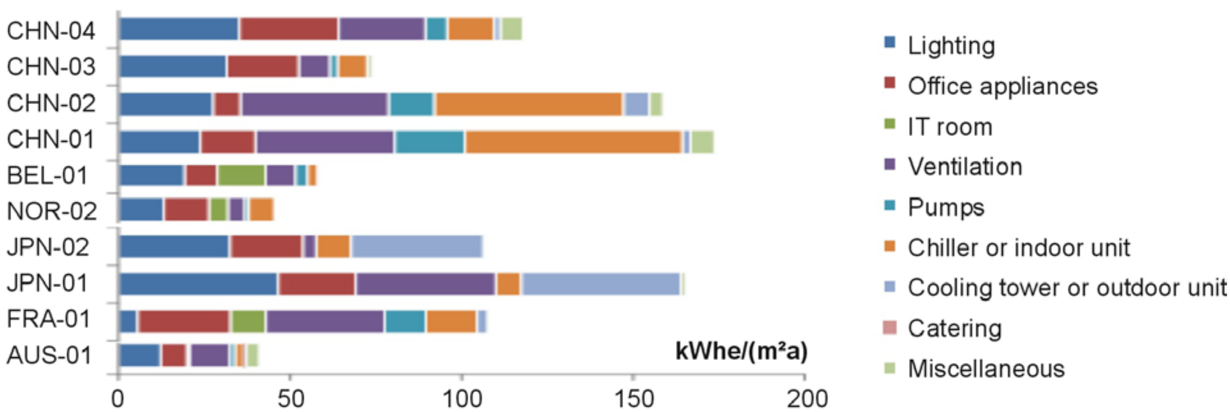


Figure 2. Electricity consumption of case study office buildings (Yi Jiang, Qingpeng Wei & Xiao He). [1]

area, etc), and lighting. The building operator behaviour (i.e. set point temperature, air change rate, control strategy of circulating pumps and fans, etc.) and the architecture design (such as no operable external windows in some large-scaled buildings) are the decisive factor in electricity consumption of AC systems consumption.

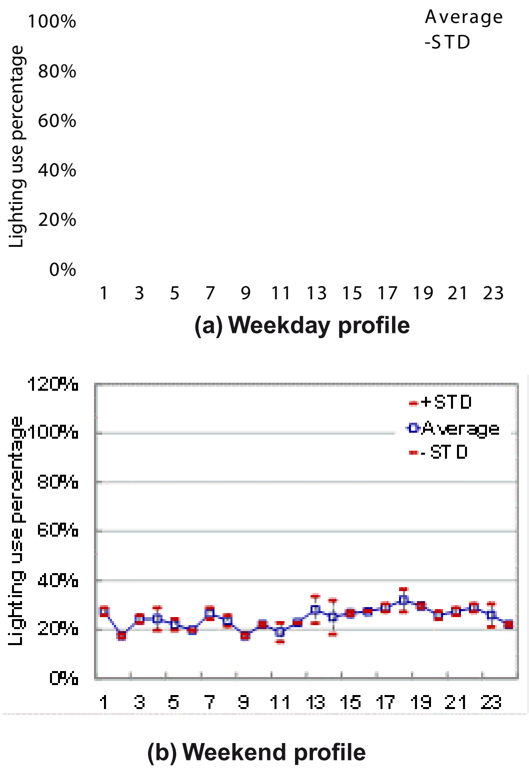


Figure 3. Average lighting profile of weekday and weekend of a case building in Norway (Yi Jiang & Qingpeng Wei).

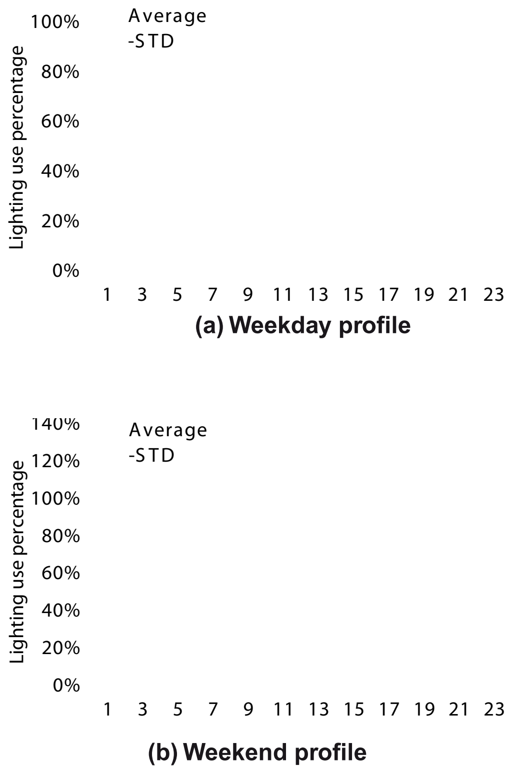


Figure 4. Average lighting profile of weekday and weekend of a case building in China (Yi Jiang & Qingpeng Wei). [1]

Occupant lighting behaviour in office buildings is studied through the comparison of the schedule of artificial lighting in weekdays and weekends in a case building in China and a case building in Norway. As shown in **Figure 3** and **Figure 4**, the impact of occupant behaviour on energy consumption in office buildings shows a weak relationship between external illuminance and the use of artificial lightings. Occupants usually turn on artificial lighting during working hours. Data analysis shows that more than 80% of artificial lighting is on during working hours from 10am to 17pm, and 20% of lighting remains on during unoccupied hours in two cases. There is a small difference that some of the lights are turned off during lunch breaks and turned on gradually in the afternoon in the office building in China.

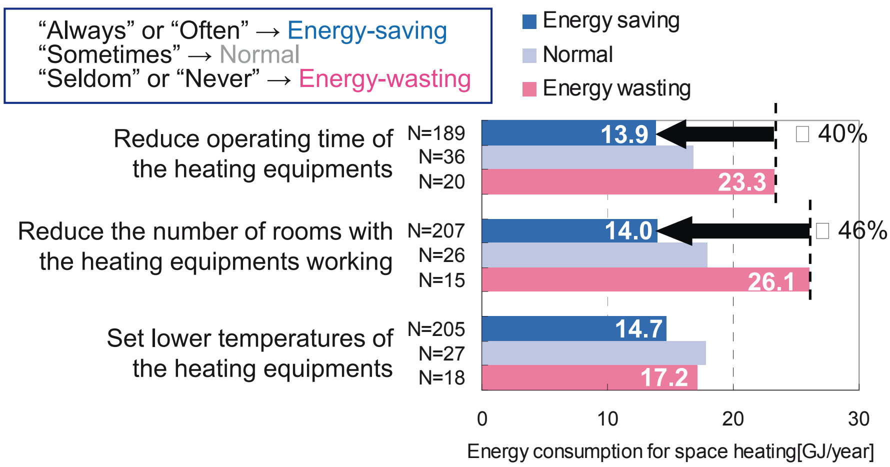


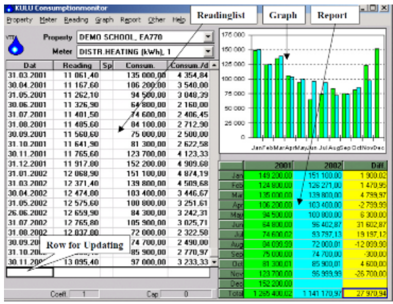
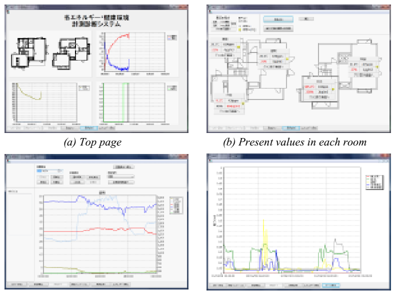
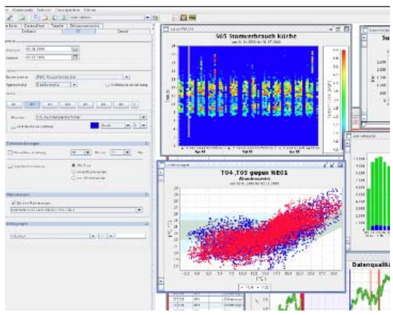
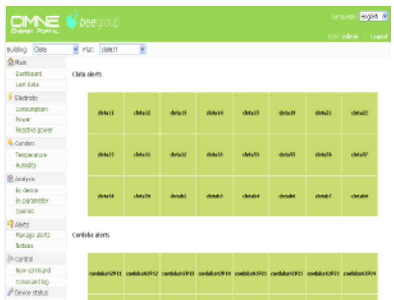
Figure 5. Impact of behaviour on space heating energy use in residential buildings in Japan. [1]

The occupant schedule is the major investigation target that has been surveyed in residential buildings. According to questionnaire surveys, three scenarios named "Energy-saving", "Normal" and "Energy-wasting" are compared. Occupant behaviour in multi-family houses shows that by reducing the operating time or amount of space heating can decrease space heating energy use by 40% to 46% compared to the "energy-wasting" scenario, as shown in **Figure 5**.

Data collection systems for the building energy system management

Monitoring is fundamental when aiming at better knowledge and understanding of the energy behaviour of buildings. One of the main works in this annex was to review state-of-the-art online data collection systems and technologies, and to analyze a particular Windows application developed by different countries, in order to identify the main features and characteristics of online data collection and monitoring systems. All online data collection systems normally require five components: measuring, obtaining external data (such as weather information), data transfer, data analysis, and reporting. Individual and open access systems are the two types of monitoring systems mostly widely used [9]. Data and information provided by smart meters, including energy data and the information about the influencing factors, should be integrated in real time with building automation systems in order to optimize the use of energy in various building systems to capture the full potential for environmental and energy savings. Mass production of sensors often offers cheap and flexible means for measuring both environmental factors and occupation of buildings. So far, five online data collection systems, from Finland, China, Japan, Germany, and Spain, have been reviewed, as shown in **Table 3**.

Table 3. Summary of different on-line data collection systems (Jorma Pietilainen & Guangyu Cao). [1]

	Main features	User Interface
Finnish version: VTT Kulu For public buildings	• Versatile monitoring tools in standard web browsers. • No installations - only access to the internet required. • Updating of meter readings, analysis, and reporting can be carried out over the internet. • Readings from smart meters and other data sources can be transferred automatically to the Kulu database.	
Chinese version: Energy Sage 1.0 For public buildings	• Electricity distribution system and energy consumption features of terminal equipment. • Multi-layer data collection system. • Breakdown of HVAC system electricity consumption. • Hourly data in one sub-system of the data collection system.	
Japanese version: For residential buildings	• Real time measurement system that includes information on energy consumption and indoor environment. • • Diagnostic system: Real-time diagnosis and long-term diagnosis.	 (a) Top page (b) Present values in each room (c) Indoor environment of a room (d) Electric consumption by use
German version: MoniSoft monitoring software For all buildings	• Unified, scalable database structure for all buildings. • Automatic interpolation of different measure intervals. • Calculation of specific consumptions with user-definable reference values.	
Spanish version: For multi-family residential buildings	Three-level system: The measured parameters range from overall electric and gas consumption (first level), through sub-metering of main electrical consumption, comfort parameter measurement (second level), to energy for heating, hot water, and solar system energy input (third level).	

Statistical analysis of total energy use

Suitable statistical models are important for building energy use analysis and prediction. In order to carry out a critical examination of the potential and limitations of applying statistical and predictive inverse models to estimating the energy consumption of buildings and exploring the influencing factors, the experiences of the different partners of Annex 53 are collected and shared. A total of 17 contributions that deal with both residential and office buildings were gathered, and the database structure, influencing factors, investigation method and overall judgment of the potential for the investigation method were summarized in each contribution. Examining the contributions, the main goals of the analysis can be synthetically divided into two types: (1) Descriptive analysis, including statistical characterization of the subject, benchmarking, identification of driving variables that contributed to energy use, determination of an accurate profile of user behaviour etc.

Energy Performance Evaluation

In order to get a better benefit from the use of simulation models to analyze total energy use in buildings, a number of specific methodologies were developed considering different phases of the building life cycle. These methodologies complement the use of simulation tools with resources like sensitivity analysis, uncertainty analysis, and model calibration in order to get more reliable results and to adapt the presentation of the results to the specific user of the simulation tools. A more realistic consideration of the impact of the user of the building is also pointed out by the methodologies.

The main simulation methodology and the application are as follows:

(1) By running simulation models on different case study buildings, to identify the cause and effects relationships between the influencing factors and the energy performance of buildings are identified.

(2) A simulation methodology targeting the design of residential buildings was developed. It is based upon the a priori realization of a large number of simulations of typical cases (generic buildings) followed by the identification of a simplified regression model expressing performance in terms of the dominating parameters. An uncertainty can be attributed to each parameter and the final performance is given as a range around a central value.

(3) Monte Carlo simulation is developed based on performing multiple model evaluations with probabilistically selected model inputs. The results of these evaluations can be used to determine the uncertainty in the model output (prediction) and to perform sensitivity analysis.

Conclusions

This annex contributes to a better understanding of how to robustly analyze and predict the total energy use in buildings, thus enabling the improved assessment of energy–saving measures, policies and techniques. The definitions of terms related to energy use and the influencing factors of building energy use are developed for office buildings and residential buildings, which provide a uniform language for building energy performance analysis. On this base, database of case buildings in different countries are established, and the building energy use and influencing factors are analysed. The statistical models for national or regional building energy data including the influence of occupant behaviour are summarized, to figure out the ability and limitations of statistical tools to better describe the energy uses in buildings and the main factors that affect the energy end-use in buildings. Methodologies to predict total energy use in buildings and to assess/evaluate the impacts of energy saving policies and techniques are also developed. The beneficiaries of the annex results and deliverables will be policy decision makers, property developers, energy contracting companies, financers and manufacturers, and designers of energy saving technology, with the following benefits:

(1) Substantially improved understanding of effective energy data on real, long term performance of buildings and building systems in the context of evaluating and developing new energy saving measures and technologies;

(2) Knowledge about the main determining factors of total energy use in buildings and about the specific interactions between them in order to develop new energy saving strategies, technologies, methodologies, and policies;

(3) Opportunities for the development of energy saving technologies that take into consideration building related as well as user related energy use, and the prediction of both expected energy use in new and renovated buildings and the cost-benefit relationship of energy saving measures to increase implementation of energy contracting and management; and,

(4) Support for standardization and benchmarking of total energy use in buildings, so as to establish indicators for energy use in buildings that take occupant related factors into consideration, to achieve better acceptance of energy labelling systems among the public, and to improve the ability to communicate to the public the behaviour that influences energy use in buildings. ■

Acknowledgements

Authors would like to acknowledge Annex 53 participants, especially Dr. Xiao He, Tsinghua University for contributing to make this article. It is noted that almost all of the figures and tables cited in this article come from reference [1].

References

[1] International Energy Agency, Programme on Energy in Buildings and Communities, Total Energy Use in Buildings: Analysis and Evaluation Methods, Final report of Annex 53, 2014.11.

[2] ISO 12655 Energy performance of buildings – Presentation of real energy use of buildings. 2013.

[3] M. Schweiker, M. Shukuya, Comparison of Theoretical and Statistical Models of Air-Conditioning-Unit Usage Behaviour in a Residential Setting under Japanese Climatic Conditions, Building and Environment 44, 2137-2149, 2009.

[4] V. Fabi, S.P. Corgnati, R.V. Andersen, M. Filippi, B.W. Olesen, Effect of occupant behaviour related influencing factors on final energy end uses in buildings. Proceedings of the Climamed11 Conference, Madrid, Spain, 2011.

[5] C. Peng, D. Yan, R. Wu, C. Wang, X. Zhou, Y. Jiang, Quantitative description and simulation of human behaviour in residential buildings, Building Simulation 5, 85-94, 2012.

[6] I. I. Ajzen, The theory of planned behavior, Organizational Behavior and Human Decision Processes 50, 179-211, 1991.

[7] Yun G, Steemers K. Time-dependent occupant behaviour models of window control in summer. Building and Environment, 43 (2008): 1471-1482.

[8] T. Bednar, A. Korjenic, H. Konder, C. Deseyve, M. Kirchweger, N. Morishita, Performance and Experiences with Austrian Demonstration Projects for Lowest-Energy Houses (Passive Houses) in Social Housing, Lecture: ASHRAE Buildings XI Conference, Clearwater Beach, Florida, US, 2010.

[9] e3Portal Information for the building energy management in municipalities. http://e3portal.vtt.fi.

Clean indoor air for health and sustainability

The term 'Indoor Air Quality' is much used but not always considered carefully. For people to live and work happily inside a building they should have a comfortable environment and as part of that the air should be at the optimum temperature, humidity and cleanliness to allow them to carry on with their daily activities efficiently. Air for people to breathe should be sufficiently clean for them to inhale without risk to health. New buildings need flexible and efficient air systems.

Keywords: fine particles, air cleaning, filters, $PM_{2,5}$.

PETER DYMENT
Building IAQ and HVAC
energy consultant, Camfil Ltd.
peter.dyment@camfil.co.uk

Today there is an overriding need for people to breathe clean healthy air in both residential and commercial buildings. Many buildings may be located in polluted industrial city locations or maybe in relatively clean rural settings. There is an increasing trend for many people to work from remote locations or from their place of residence.

Buildings in use by people can also vary greatly in age, size, type of construction, the materials used, and also the air leakage rate of the building envelope. Other variables to be considered include location, building orientation and climate.

Even from the North to the South of the UK there are local climate variations and this is further emphasized if we consider the differences between climates in mainland European countries such as Spain, Portugal and Italy and compare them to the Nordic countries such as Norway and Sweden.

The central European countries share the bulk of the recent population growth and where there is a larger concentration of people and more industrial activity the problem of increased levels of air pollution will almost certainly result.

There are many types of air pollution particle as the chart shows and they are spread over many different sizes. The particles that can most easily penetrate into the lungs are those below 2.5 microns in diameter they consist of a mixture of toxic traffic emissions and also bio-particles such as airborne spores, pollen, bacteria and virus that can cause allergic reaction, asthma, disease and infection.

Studies such as the US six cities survey and the more recent studies at University of Edinburgh by Anil Shah and Nicholas Mills have shown the main threat to public health is from fine combustion particulate matter 2.5 microns diameter and below in size, known as $PM_{2.5}$ These particles are composed of a mixture of carbon, heavy metals, Volatile organic compounds (VOC's) and a toxic cocktail of numerous other combustion products. They are able to make deep lung penetration and thus enter the bloodstream causing infections, cancers and heart disease.

The recently completed European HealthVent project considered in detail the Burden of Disease (BoD) that could be attributed to outdoor sourced pollution that ends up indoors, as opposed to indoor sourced air pollution. The BoD was about a 2:1 ratio weighted towards outdoor sourced pollution. A result surprising to many but showing the need for action to remove the $PM_{2.5}$ that is responsible for a large part of the outdoor sourced BoD. Of the strategies considered by the project use of air filters to remove 50% of $PM_{2.5}$ was the main intervention action that was advised as the most effective. Long term aims such as reducing emissions at source would be difficult to achieve because $PM_{2.5}$ comes mainly from burning of fossil fuels in transport systems, power stations and heating systems. There is a lack of political impetus to make difficult policy decisions regarding limiting $PM_{2.5}$ emissions at the current time. This type of air pollution is closely linked to the level of economic activity in each country.

Many designers and engineers advocate use of ventilation methods that utilise naturally occurring air currents in buildings. Broadly these design solutions can be grouped under the name of passive ventilation. The great attraction of these types of solution is that they have low levels of energy use but the main drawback is that they are usually unsuitable for use in locations with high levels of air pollution.

Where air pollution is a problem it is usual to have a mechanically ventilated building to not only reduce carbondioxide (CO_2) levels and replenish oxygen (O_2) but also to clean the air and remove air pollution. Air filtration by mechanical means is the usual method employed to remove airborne particles and where necessary also gas phase and molecular airborne contaminants.

The rising cost of electrical energy has increased the focus of national governments on ways to improved energy efficiency in buildings. Heating ventilating and air conditioning (HVAC) systems can use as much as 50% of the energy consumed in buildings. The opportunity and challenge is clear and if energy efficiency is to be achieved then clear performance benchmarking is needed for assessment of energy using components such as air filters.

Theoretical costing models such as Life Cycle Costing (LCC) or Total Cost of Ownership (TCO) will give a good indication of energy use benchmarked against working performance but they will only get you so far towards assessing real life performance.

Working performance in the case of air filters is gauged by particle removal efficiency. Unfortunately this particle removal efficiency varies greatly between the artificial conditions of a laboratory test and the real life working conditions in a city centre based Air Handling Unit system used for ventilating or full air conditioning.

Another problem with air filter particle removal efficiency is that it can, with some products, vary greatly over the life of the filter. This is not ideal if we are relying on a consistent high particle removal efficiency to remove as much toxic $PM_{2.5}$ as possible and thereby protect the health of people in buildings.

There is an increasing trend towards direct measurement of airborne particles in buildings to make an assessment of how clean the air is and how it compares to the limits set for commonly experienced health damaging pollutants such as $PM_{2.5}$.

Readings taken with a particle counter at several key locations inside and outside a building are useful in constructing a comparative graph of the numbers of fine airborne particles and their sizes. The data from the readings taken can be used to construct a profile diagram to determine the effectiveness of the building envelope plus the air filter system in maintaining a reduced level of particles compared to the outside air. This diagram is a useful tool in determining whether improved air filtration is required in the HVAC system or improved air sealing at weak points in the building envelope.

As previously mentioned many people are now working from home or in small buildings where there is no large HVAC system supplying clean air on demand. What can be done in this situation? One solution that is gaining increased consideration and acceptance is the use of standalone air purifiers.

These are air filter units that combine High efficiency particulate air (HEPA) filtration to remove $PM_{2.5}$ and NO_2 as well other commonly experienced pollutants. These air purifiers or air cleaners if they remove just particles are used in residential situations or healthcare applications. Removing *aspergillus* spores to protect vulnerable children and pollen removal to prevent asthma attacks are two recent needs that have been met.

Using a standalone air purification unit that delivers clean air at point of need if often a quicker more effective IAQ solution than trying to get a large unmanageable centralised HVAC system to service a small area in a large building with air. It can also save energy if the main HVAC system can be stepped down.

Sick building syndrome is often encountered in new or newly refurbished buildings and if often due to poor IAQ due off-gassing of molecular contaminants. This can often come from new carpets, varnishes, wall coverings or cleaning fluids. There are diagnostic kits available that can test for these emissions and identify the problem.

Bodies responsible for research and advice on public health such as the WHO are responding to demands for improved information on the health damaging effects of exposure to monitored levels of air pollution. They have recently included $PM_{2.5}$ and NO_2 as Group 1 carcinogens as they are a major part of diesel engine traffic emissions. Also pressure from the EU on national governments is leading to improved levels of city air monitoring network information being made available. This is a virtuous circle of communication, information, education and research that is putting pressure on governments to reduce airborne pollution at source, where possible, but also introduce firm legislation to improve air indoor air quality.

The challenge for engineers is to come up with an easy to understand test methods that can deliver clean IAQ with minimal energy use and running costs. These aims can all be reached with practical measurements and use of the solutions available.

Adopting the principals in ISO 50001 and motivating everybody in the building concerned to take an interest in IAQ as well as energy efficiency is a good start. ■

The perfect choice for almost any globe valve

Smart universal retrofit concept from Belimo

Replacing actuators on globe valves has just become a whole lot easier, quicker and more efficient. And it's all thanks to the new retrofit globe valve actuators from Belimo. Featuring customisable parameters and equipped with a universal valve neck and stem adapter, they can be installed quickly and easily on virtually all the valves currently available from manufacturers worldwide.

As HVAC units start to age, installers and maintenance service companies see the prospect of more and more business developing in the form of replacing and retrofitting older globe valves. Sourcing the right actuators, however – and the adapters and brackets that go with them – is often a laborious, time-consuming process. Keeping equipment and accessories in stock for every valve brand and model range is virtually impossible, not to mention costly, and the result is that many jobs can be subject to significant delays – a frustrating situation for the customer and the service provider alike.

Lower costs, faster service

Now, the new generation of Belimo retrofit globe valve actuators has made this problem a thing of the past in virtually every scenario. The MP and MF types can be adjusted to suit the valves in question using the practical PC-Tool or the handy ZTH EU service tool, working in your own workshop or at the unit location itself. As a result, you only need a few basic types to ensure that your service staff always have the right equipment type on hand when they need it.

Thanks to the pre-assembled universal valve neck and stem adapters, the days of hunting for the right adapter are gone. Not only that, but the smart concept also makes installation a breeze. Installing the new Belimo actuators on an existing globe valve takes no time at all, and all you need is a hexagon socket screw key: simply fix the adapter plate on the valve neck, align the valve stem adapter and fasten it, and screw on the universal bracket. Then push the actuator into the bracket, tighten the screws and attach the valve stem. The self-adjusting function will then do all the other commissioning work for you.

Better performance, outstanding quality

The Belimo retrofit globe valve actuators are available in performance classes from 1,000 to 4,500 N and with stroke lengths of 20, 32 and 50 mm. In addition to the standard types, there are also bus-compatible (MP) models available for easy integration into higher-level systems. The technology and operating concept are of the same standard as those found in the rotary actuators produced by this world-leading manufacturer, which have proven themselves millions of times over. This ensures the equipment can deliver the very best performance, as well as outstanding quality that comes with a 5-year warranty.

More information: **www.belimo.eu**

The smart universal concept for replacing and retrofitting older globe valves.

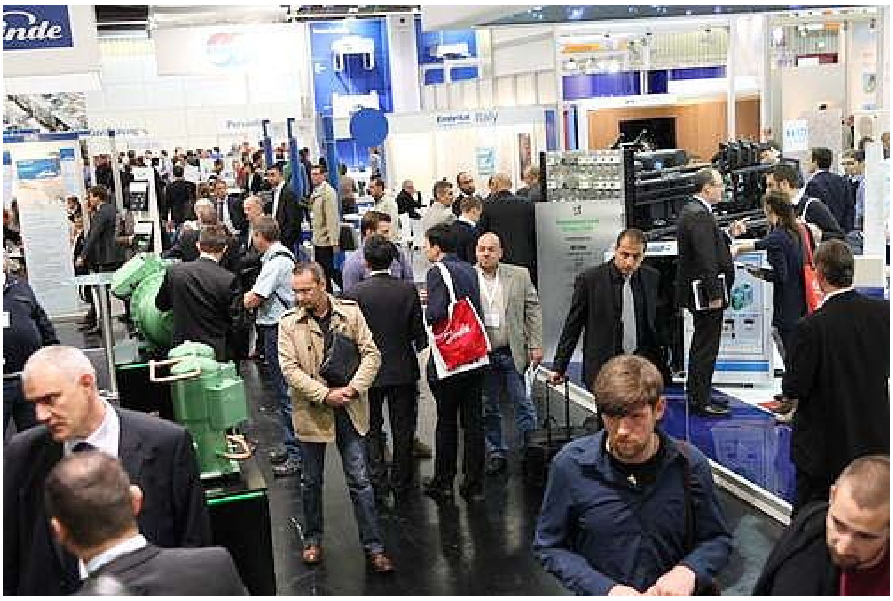
feel the elements of CHILLVENTA 2014

The preparations for Chillventa 2014 are entering the hectic phase. Experts from all over the world will come to Nürnberg from Tuesday to Thursday, **14–16 October 2014**. Chillventa Congressing takes place the day before on Monday, 13 October. The fourth round of the International Trade Fair for Refrigeration, Air Conditioning, Ventilation and Heat Pumps will accordingly confirm its importance as the sector's global gathering once again.

The exhibiting companies at Chillventa 2014 present the whole variety of products from the industry's broad-based spectrum for refrigeration, air conditioning, ventilation and heat pumps. The themes in 2014 are both innovative and pioneering: energy efficiency, F-gases, ecodesign, energy stores and the amendment of the German Energy Conservation Act (EnEV) determine the trends at Chillventa 2014.

The heat pump is also of special importance in 2014. "Over the past years the heat pump has established itself as an attractive alternative to other fossil heat producers despite rising electricity prices. The growing demand in this segment makes further technical development almost inexorable. This innovation is pioneering, especially in commercial and industrial production processes. The visitors can get to know the energy world of the future at Chillventa: Whenever and wherever heat and cold are required at the same time, the hybrid use of a refrigeration or heat pump system is highly efficient and sustainable right from the first days. The special show in hall 7 focuses mainly on these hybrid systems in 2014.

How to carry out the energy inspection of air conditioning and ventilation systems in practice as defined by Art. 12 of the German Energy Conservation Act (EnEV) is almost unknown. The amendment of EnEV will make the inspection in conjunction with the then applicable DIN SPEC 15240 a general obligation. The transition periods for existing systems have either already expired or will expire shortly. A training line will be available at Chillventa, where visitors can familiarize themselves with the manual tasks necessary for the inspection. The line will also be used to measure temperatures, volume flows, air quality and power consumption and to assess the mechanical energy status of a real existing system.



Chillventa Congressing the day before Chillventa on 13 October 2014 again provides extensive and highly qualified information and detailed know-how covering all sectors of refrigeration, air conditioning, ventilation and heat pumps. The international refrigeration sector geared to the energy of the future is still THE key topic, likewise environmental and climate protection. Professionals from research and practice identify trends, analyse changed political frameworks, present the current state of research and development, and show solutions that point the way to the future. A workshop on Energy Reduction in Data Centers builds on the results of the last Chillventa. Other focuses include Energy of the Future, Risks and Opportunities for Refrigeration, Air Conditioning, Ventilation and Heat Pumps. The programme also covers markets, challenges and research & development for heat pumps. ■

More detailed information is available at **www.chillventa.de/en**

Status of new CEN (and ISO) standards for implementation of EPBD

by Jaap Hogeling, Chair CEN TC 371 Program Committee on EPBD

The CEN Working Groups started July 2013 to work on this set of nearly 50 CEN-EPB standards. Most of the CEN-Working Group drafts have been completed by spring 2014 with the final target for delivery for enquiry to CEN Management Centre summer 2014. It is expected to start the enquiry stage of most or, if possible, all EPB-standards before the end of 2014.

The connected Technical Reports (TR):

All standards are companied by a TR, some standards may share one referenced TR. It is our intention to finish these TR's after the enquiry of the standards, which allows us to include the results of the enquiry in these TR's. To support the enquiry a draft version of these TR's will be available as CEN-TC document. This to allow access during the enquiry because the TR's include essential background information, justifications, explanations and showing worked out examples.

How can one access and deliver their comments to these draft standards?

The EPB standards will be published by the national standard bodies (NSB's) as prENxxxxx. It is the NSB's task to ask for comments and formally react on these draft-standards based on a national consensus opinion.

As all revised EPB standards are now formulated in a more normative format, most of the background information and explanations is not any more included in these standards. The standard refers to the connected TR which should be considered before commenting the standard.

These draft TR's are only available as "CEN Committee Drafts" the so called N-numbered documents at the CEN/TC- livelink. The NSB's have access to this and they should provide these documents to persons interested to give their expert opinion on the prENxxxxxx.

The commenting period is 5 months

The closing date is 5 month after the reported date on the cover of the prENxxxxx.

At this moment the exact releasing dates for enquiry are not yet known, but it is expected that during the period September – November 2014 most of the enquiries will start.

Many of the prEN's and draft-TR's will just be available in English, some will be translated in German and French. This is depending on the decisions of DIN and AFNOR.

The list of EPB standards to be released for enquiry the coming months is given is given in the web version of this article, see REHVA Journal at www.rehva.eu. ■

ASHRAE's new president and officers in 2014–2015

ASHRAE's new president is Thomas H. Phoenix. P.E., Fellow ASHRAE, ASHRAE-Certified Building Energy Assessment and Building Energy Modeling Professional, principal and vice president, Moser Mayer Phoenix Associates, Greensboro, N.C. His presidential theme is *People, Passion, Performance*.

Thomas H. Phoenix, *new President of ASHRAE*

In his inauguration speech President Phoenix stressed the importance of the volunteers in the success of ASHRAE.

"- - the members who have the greatest impact for us are our volunteers – those of you who become part of our ASHRAE family. The ones who invest their time and talent into making ASHRAE a premier engineering organization.

So, how do we engage our members? How can we use our volunteers more efficiently and respect their volunteer time? What are we going to do to demonstrate that participating in ASHRAE activities is a valuable use of their time?

In a recent Board of Directors survey, more efficient use of volunteer time ranked as one of the most important issues facing the Society. Volunteers drive ASHRAE, and we must make sure volunteer time is used as efficiently as possible. There are 3,000+ volunteers who work at the Society level and another 7,000 or so that work within our chapters. If we can earn a small percentage gain in the productivity, motivation and recognition of these people who work so hard for Society, we will make a huge impact on our overall productivity. "

Other officers installed for a one-year term included:

President-Elect: T. David Underwood, P.Eng., Fellow ASHRAE, Life Member, ASHRAE-Certified Commissioning Process Management Professional, Oakville, Ontario, Canada

Treasurer: Timothy G. Wentz, P.E., Fellow ASHRAE, ASHRAE-Certified High Performance Building Design Professional, associate professor, University of Nebraska – Lincoln, Neb.

Vice President: Bjarne W. Olesen, Ph.D., Fellow ASHRAE, Life Member, professor, Technical University of Denmark, Kongens Lyngby, Denmark ■

A record-breaking of 41,238 visitors highlight the conclusion of ISH China & CIHE 2014

Regarded as Asia's largest event for the HVAC, plumbing & sanitation industry, ISH China & CIHE – the China International Trade Fair for Sanitation, Heating, Ventilation & Air Conditioning concluded its 2014 edition with record-setting visitor attendance and exhibitor participation. The 2014 show was held from 13–15 May at Beijing's New China International Exhibition Center. Organised by Messe Frankfurt (Shanghai) Co Ltd and B & D Tiger Exhibition Co Ltd, the fair attracted 999 exhibitors from 18 countries and regions.

Visitor attendance totalled nearly 42,000 from 40 countries and regions. During the three-day show, visitors were able to source items including boilers and wall-hung boilers, heat pumps, solar energy devices, radiators and fittings, heat exchangers, floor-heating, pipes, valves, ventilation systems, control systems, heat meters as well as energy-saving HVAC products. At the 2014 show, exhibitors expressed unanimous praise in the fair's ability for bringing together both industry leaders and decision making buyers. The increasing popularity of ISH China & CIHE had once again drawn the return of the Italian Pavilion with an even stronger line-up to display their specialised technology in HVAC, ventilation as well as plumbing sectors.

Concurrent events have played a significant role in ISH China & CIHE. The sector's leading players from business and academia were invited to share their views on current industry developments and future trends. In 2014, 50 events were held alongside the fair and categorised into four major themes, including technology exchange, idea innovation, match-making and technology display.

ISH China & CIHE is headed by the biennial ISH event in Frankfurt, the world's leading trade fair for

the Bathroom Experience, Building, Energy, Air-conditioning Technology and Renewable Energies, taking place from 10–14 March 2015. The next ISH China & CIHE will be held from 13–15 May 2015.

Furthermore, the next edition of ISH Shanghai & CIHE is scheduled to take place from 3–5 September 2014, concurrently with Shanghai Intelligent Building Technology Fair, Building Solar China and Shanghai International Lighting Fair at the debut edition of the Shanghai International Expo Center. ■

For more information, please visit **www.ishc-cihe.com** or email **info@ishc-cihe.com**.

International Societies form Indoor Environmental Quality – Global Alliance

Signing memorandum of understanding creating the Indoor Environment Quality – Global Alliance.
Christine Lorenzo, president, AIHA; Max Sherman, Board member, AIVC; Bill Bahnfleth, president, ASHRAE; and Donald Weekes, immediate past president, IAQA.

A memorandum of understanding creating the Indoor Environment Quality – Global Alliance was signed Sunday, June 29, at ASHRAE's 2014 Annual Conference in Seattle, Wash. Other groups joining the Alliance are the American Industrial Hygiene Association (AIHA), Air Infiltration and Ventilation Centre (AIVC), the Air & Waste Management Association (A&WMA), the Indoor Air Quality Association (IAQA) and the Federation of European Heating and Air-Conditioning Associations (REHVA).

A newly formed alliance seeks to serve as a global source for information, guidance and knowledge on indoor environmental quality. More information can be found at **www.ieq-ga.net**.

The Alliance was formed by an ad hoc committee appointed by ASHRAE 2013-14 President Bill Bahnfleth to explore ways in which industry groups could work together to address all aspects of indoor environmental quality and health.

"In the built environment, indoor environmental quality must be our first concern," Presidential Member Bahnfleth said. "Before we address impacts of buildings and transportation systems on energy consumption and the environment – which, make no mistake, are also critically important – we must ensure that we are providing indoor environments that are safe, healthy, productive and comfortable for occupants. Today, and for some time, we have strongly emphasized energy conservation and protection of the environment to such an extent that the need for progress in indoor environmental quality has been obscured. A broad, coordinated effort is needed to fill gaps in research, transfer the results of science to practice, advocate for higher standards and better educate both the built environment professions and the public. I believe that formation of this Alliance is a key to meeting those objectives. ASHRAE is eager to contribute its expertise to this group and to once again be a leader in the field of indoor environmental quality, beginning with a focus on indoor air quality."

"Contemporary European architecture is undergoing fundamental changes caused by increased pressure to reduce energy consumption of buildings," Karel Kabele, REHVA president, said. "Modern approaches, methods and technologies are capable of saving energy, but also affect other functions of the building i.e. indoor environmental quality. In energy efficient buildings we can resolve problems with thermal comfort, air quality and other components of IEQ. I firmly believe that joint efforts of IEQ-GA will contribute not only to saving energy but also to improve IEQ in buildings, we build for next generations."

"The Air & Waste Management Association (A&WMA) is pleased to be a part of this partnership," Jim Powell, executive director, A&WM, said. "We see the IEQ-GA as a forum to better focus efforts on improving the indoor environment. Efforts to support this partnership will be coordinated with our Health Effects & Exposure Technical Coordinating Committee. This committee is responsible for all of the indoor environment programming within A&WMA."

"The Indoor Air Quality Association, IAQA, is proud to join key organizations in signing the IEQ-GA agreement," Kent Rawhouser, president of IAQA, said. "This alliance of organizations will lead to collaboration between the best minds in our industry to ensure an improvement in indoor environmental conditions for people around the world. IAQA's members are experts in the implementation, investigation and remediation of indoor environmental issues."

"While substantial progress in the energy efficiency of our building stock is crucial, we must guarantee at the same time a good indoor climate in these buildings, including air quality, thermal comfort, visual comfort and acoustics. Given the complexity of the issue and the various challenges, we are very pleased to see the creation of this alliance," AIVC Operating Agent Peter Wouters said.

"AIHA is very excited to join ASHRAE and other international stakeholders in the IEQ Global Alliance," Christine A.D. Lorenzo, CIH, president, AIHA, said. "The Alliance brings together key groups, each of which has members with unique sets of skills and knowledge. We look forward to working within the Alliance to identify new ways to collaborate, and expand international alignment in this important area of occupational hygiene and engineering practice."

The Alliance will provide guidance on the definition of acceptable indoor environmental quality, with an emphasis on thermal conditions and indoor air pollution, to ensure that the knowledge gathered from indoor environmental quality (IEQ) research is promulgated to and implemented by IEQ practitioners and regulatory bodies worldwide.

The mission of the alliance IEQ-GA is to provide an acceptable indoor environmental quality (thermal environment-indoor air quality-lighting-acoustic) to occupants in buildings and places of work around the world and to make sure the knowledge from research on IEQ gets implemented in practice.

The establishment of the Alliance is supported by the World Health Organization and the U.S. Environmental Protection Agency, who will cooperate with the Alliance in the future.

Bahnfleth said the Alliance will also seek cooperation from other organizations whose work directly impacts the indoor environment on people's well-being and health.■

REHVA signed a Memorandum of Understanding with Korean professionals

REHVA signed Memorandum of Understanding with SAREK – Society of Air-conditioning and Refrigerating Engineers of Korea. The purpose of this action is to strengthen the relationship between REHVA and SAREK, and to promote substantial and tangible actions to increase the co-operation between the two associations.

SAREK, established in 1971, represents with about 7,000 experts in the area of air-conditioning and refrigerating engineering as well as the area of building and plant facilities engineering.

Main objectives of MoU: REHVA and SAREK enter into this MoU with the following

1. Promote communication and information exchange between the organizations and their respective members through announcements in journals, websites, and other communication vehicles.
2. Encourage participation at official meetings through formal participation by the other organization as often as is possible. Members of one organization can attend at conferences and general meetings of the other organization on the same basis as members of the other organization.
3. Promote the knowledge of standard development activities in Korea and in Europe.
4. All publications are available to members of the other organization at member rates.
5. Promote the co-operation between SAREK technical committees and REHVA Standing Committees and Task Forces.
6. Sponsor and jointly organize training and educational seminars and other educational activities when appropriate.
7. Strive to develop and harmonize Korean, European and international standards.
8. Cooperation in the development and participation in conferences and exhibitions globally which may be mutually beneficial and which strengthen the bonds of international cooperation between the organizations and their respective members.
9. Promote communication and information exchange regarding building energy certification and engineer certification.

MoU signing ceremony was held at the occasion of the 7th Asian Conference on Refrigeration and Air Conditioning (ACRA 2014) on 21 May 2014 in the presence of REHVA presidents and members of the SAREK Board. During the conference, attended by more than 200 experts from Korea, China, Taiwan, Singapore and Japan, presented prof. Kabele, REHVA president in a special section lecture on the topic Energy and Ecology – Indoor Environment and Energy Efficient Buildings, focused on issues related to reduction the energy performance of buildings in terms of the quality of the indoor environment and presented recent REHVA Guidebooks and activities. ■

REHVA Student competition 2014

Under the same perfect leadership as he did last year in Prague, Prof. Robert Gavriliuc from Romania chaired the REHVA 2014 Student competition. Eleven candidates representing nine countries were in competition this year, Romania and Italy being represented by a team of two students.

Jakob Hahn presented his work on the development and application of technical monitoring methods; Jana Kmetkova on technical and economic assessment of complex renovation of an apartment building; Willem Mazzotti on secondary fluids impact on ice rink refrigeration system performance; Martin Minin on Energy performance and design guidelines for hollow core slab air distribution system; Nikola Miletic on the analysis of energy performance improvement measures for national museum building in Belgrade; Michela Motta and Elena Anna Ragni on the HVAC energy auditing of three university buildings in Italy; Renars Milles described the sizing principles and benefits of a low pressure terminal device pressure drop ventilation system; Kristian Gvozdenović presented the roadmap to nearly Zero Energy Buildings in 2020 and Nicolae Bajanaru and Andrei Ene presented an experimental and numerical study on achieving a high indoor environmental quality in a classroom.

The winners receiving the award prize from REHVA President.

All competitors with their certificate of participation in REHVA 2014 student competition.

The Jury was composed of Anatolijs Borodinecs, Manuel Gameiro da Silva, Michal Krajcik, Michael Schmidt, Marija Todorovic, Hans Besselink and Robert Gavriliuc. It was very difficult and hard to come to the winner. After a tight deliberation, the jury declared winner the Romanian team of Nicolae Bajenaru and Andrei Ene from the Technical University of Civil Engineering of Bucharest for their work "Achieving a high indoor environmental quality in a classroom: Experimental and Numerical Study".

All other participants in this competition where awarded with the 2nd prize.

The next day, during the Conference Nicolae Bajenaru and Andrei Ene gave an oral presentation of their work. After this presentation, REHVA President, Karel Kabele, offered a check of 500 € to the winners, a certificate and the Trophy Cup for their university.

President Kabele also thanked all contributors emphasizing the high quality of the works presented and the members of the jury for their excellent task. ■

Danvak Conference on hot HVAC Topics

According to tradition, Danvak – the Danish Society of Heating, Ventilation and Air Conditioning – held its annual conference on HVAC topics in April. The Conference, called Danvak Dagen (The Danvak Day) was attended by 140 people and included a small exhibition, which added an exciting atmosphere to the event.

The aim of the annual conference is to provide a forum for academics, professionals, engineers, architects and journalists from the HVAC field to meet and exchange their ideas, results and latest research. This year, the conference was arranged in collaboration with the Danish Building Research Institute who had put together a track of sessions addressing exiting issues within the field of indoor climate research in the Northern countries.

Other conference session topics were Commissioning, Noise from HVAC equipment in low energy buildings, Nudging (behavior change in relation to HVAC installations), Hospital installations, Renovation of lighting plants, Design of radiators, KNX (OSI-based network communications protocol for intelligent buildings) and Energy renovation of Schools, private homes and office buildings.

According to tradition, the recipient of the prestigious Professor P.O. Fanger's Award was announced at the conference. This year the award winner was Ongun Berk Kazanci, a PhD. student at Technical University of Denmark who had demonstrated excellent results during his academic career. Ongun Berk Kazanci was nominated by his supervisor Professor Bjarne W. Olesen for his study on "Low Temperature Heating and High Temperature Cooling in Buildings". – ***Zosia K. Lav***

Chairman of Danvak Mr Jørn Schultz (right) together with Ongun Berk Kazanci who received the prestigious Professor P.O. Fanger's Award at the conference Danvak Dagen on 9 April 2014.

Appointment news

New Secretary General for SuLVI

Ms Tiina Strand

SuLVI has a new secretary general from June 2014. Ms **Tiina Strand** took over the position from which Mr Hannu Sipilä retired. Tiina Strand has experience of SuLVI activities as a board member since 2012. Tiina has graduated from Helsinki University of Technology majoring in HVAC technology.

Suomen LVI-liitto, SuLVI ry (The HVAC Association of Finland) is the biggest member of FINVAC which is an organization with four major Finnish professional organisations, representing over 6,000 experts in Finland. FINVAC is member of REHVA, dedicated to international connections of HVAC in Finland. SuLVI improves and enhances professional skills of its members by sharing information by arranging training, seminars and events along with creating and publishing professional literature. SuLVI has 33 member associations which include about 5,000 members. Also SuLVI acts as a partner organization of FISE Lt which recognizes qualifications in building design as well as in site supervision and management based on Finnish legislation and complementary building act and code. In the future Ms Strand wishes to see SuLVI as a more dynamic and recognized organization which has good connections to its member associations and especially young members. – ***Anne Ruostetsaari***

New professor at NTNU

Dr **Guangyu Cao,** Senior Scientist, Fellow REHVA, vice-chair of the REHVA Committee of external relations, from VTT Technical Research Centre of Finland, was appointed as a professor at the Department of Energy and Process Engineering at NTNU, Norway. Dr Guangyu Cao will start his new career in the field of energy and indoor environment at NTNU in October, 2014. Dr Cao got his PhD from Helsinki University of Technology, Finland.

Dr Guangyu Cao – new professor of NTNU, Norway

VDI-Guidelines published June–September 2014

VDI 6022/1.2 "Ventilation and indoor-air quality; Hygiene requirements for ventilation and air conditioning systems and units; Requirements for underground components (VDI Ventilation Code of Practice)"

The series of standards VDI 6022 permits for a holistic health assessment of air conditioning systems in their installation and operating conditions. Up to now, VDI 6022 Part 1 excludes geothermal heat exchanger. This standard describes how hygiene can be ensured in HVAC systems with underground air pipes. This standard applies to all air conditioning systems and components within the scope of VDI 6022 Part 1. It describes the hygiene requirements for underground air pipes, especially in structurally related fresh-air inlets without thermal insulation and heat exchangers. It includes information about design and hygienic construction of underground air ducts in accordance with the protection goals made by the set of standards VDI 6022.

D VDI 6040/2 "Air conditioning; Schools; Practical guidance (VDI Ventilation Code of Practice, VDI Code of Practice for School Buildings)"

During the renovation of schools often only energetic aspects are considered, the result is the deterioration of air quality in schools. The application of the standard helps to improve the indoor air quality in schools. It gives concrete requirements and instructions for implementation, a guidance for architects and planners. It provides guidance on planning and operation of ventilation systems in schools with the aim of complying with the requirements specified in VDI 6040 Part 1. Information about non-mechanical ventilation as well as for mechanical ventilation is given. Described solutions are to be considered as examples, and do not release designers and operators of the responsibility to develop an optimal solution for individual cases.

VDI 2035/3 "Prevention of damage in water heating installations; Corrosion by fuel gases"

This standard deals with the exhaust-side corrosion of metallic materials in directly heated hot-water systems in hot-water heating systems and the associated exhaust systems. The application of this standard helps to minimize the probability of component failure or malfunction through proper planning, design and operation. This standard is intended for use by manufacturers, planners, erectors and installation operators. Corrosion at high temperatures, such as oxide scaling, is not covered by this standard.

VDI 2074 "Recycling in the building services"

This standard takes an integrated approach focusing on the creation of value. Guidance is given, relating to the stages in the life-cycle of a building or installation, for establishing cycles by pointing out potential contributions to be made by all parties involved in the planning, erection, use and refurbishing or demolition. By giving preference to material reuse, the standard supports the idea of recycling. The avoidance of costs for treatment and repositories, overall savings are possible.

VDI 4704 "Water heating installations; Water quality, pressure maintenance, de-aeration; Trainings"

Owing to the increasing complexity of modern hot-water heating installations, the specifications given in the series of standards VDI 2035 and VDI 4708 must be observed for function, energy efficiency and service life to conformably meet the requirements. The standard provides the concept for a training intended for all technical personnel involved in planning, erecting, operating and maintaining hot-water heating installations. Training categories are defined for various target groups with given required professional experience, specifying the syllabus and boundary conditions.

VDI 2073/3 "Hydraulics in building services installations; Trainings"

Hydraulic compensation in building services installations is often carried out insufficiently or not at all. It is, however, vital to achieve optimized, and particularly energy-efficient, operation. This VDI Standard offers a concept for trainings for all experts involved in the planning, execution, operation, and maintenance of building services installations. It conveys knowledge which has to be taken into consideration in the conceptual design of hydraulic distribution systems and various applications. The trainings are tailored to various groups; mandatory previous qualifications are given, as are the syllabus and the boundary conditions.

VDI 3802/1 "Air conditioning systems for factories"

This standard applies to ventilating and air-conditioning systems in production facilities. It covers supply and extract air systems as well as capture devices for process extract air. Recommendations for the implementation of ventilating and air-conditioning systems are given for all types of production facilities, in order to largely protect man at the workplace from avoidable stress. In production facilities where the process affords heat loads, acceptable thermal conditions must also be observed. Also the application of the standard helps to ensure thermal and air-quality requirements required for the process using ventilating and air-conditioning systems in production facilities.

VDI 3810/1.1 "Operation and maintenance of buildings and building installations; Fundamentals; Operator's responsibility"

The series of standards VDI 3810 gives recommendations for the various building services and trades regarding safe, specified, demand-oriented and sustainable operation of buildings and building installations. The standards describe the prerequisites for fulfilling the operator's obligations, safe operation of installations, economic efficiency and environmental compatibility. This standard illustrates the legal context of the owner's accountability. It supports the owner in realizing owner's accountability in the context of his individual situation, to define and conceptually structure it so as to ensure legally sound operation of a building or premises.

D VDI 6022/1.3 "Ventilation and indoor-air quality; Hygiene requirements for ventilation and air-conditioning systems and units; Cleanliness of ventilation systems (VDI Ventilation Code of Practice)"

The standard gives information on the practical assessment of the broom cleanliness of HVAC systems in the scope of VDI 6022 Part 1. Preferred measurement methods in European standardization are evaluated in terms of known measuring method according to VDI 6022. In addition, instructions for cleaning of HVAC systems are given with the aim of broom cleanliness.

D = Draft Guideline

Magazines and journals published by REHVA members – part 2

Collected and edited by Olli Seppänen

REHVA is a Federation of 27 associations in heating, ventilation and air conditioning. All the associations publish journals on the practical application of HVAC&R technology. These journals publish articles from a range of contributors, including journalists, experts in the field, building services professionals, academics, consultants and product makers.

These journals provides news, analysis, comments, special features, interviews, technical articles, regulatory advice and learning tools needed by the wide range of professionals working in the modern building services world. These journals are circulated to all their members. The introduction of HVAC&R journals continues in this second article. Part 1 was published in the REHVA Journal issue 4/2014 in June.

Denmark

Danvak The Danish Society of Heating, Ventilation and Air Conditioning (Danvak) - journal

Name of the HVAC Journal**: HVAC Magasinet**
Number of issues per year**: 13 issues per year**
Number of copies per issue**: 6,350 copies per issue**

Danvak has entered into a collaborative agreement with the trade magazine called "HVAC Magasinet". It is a trade journal of HVAC installations, energy, climate and environment.

Contact information:
Editor in Chief: Dann Bjarke Jensen
email: dbj@techmedia.dk
website: http://www.techmedia.dk/HVAC-Magasinet

Poland

Polish Association of HVAC Engineers and Technicians (PZITS) - journal

Name of the HVAC Journal**: District Heating, Heating, Ventilation** *(Polish name: Cieplownictwo, Ogrzewnictwo, Wentylacja)*
No of issues per year**: 12 issues per year**
No of copies per issue**: 3,000 copies**

A leading periodical dealing with district heating, heating, ventilation and air conditioning. The first number was issued in 1969. The following publications may be found in the periodical:

- publications of recognized scientists,
- full scientific and technical information concerning district heating, heating, ventilation and air conditioning,
- results of the latest investigations,
- news concerning conferences, conventions and branch fairs,
- rich advertising offers of leading firms and companies.

Subject matter: heat sources, power engineering, district heating, heating systems and thermal centers, converting stations, central heating and usable hot water systems, ventilation, air conditioning, industrial ventilation, local exhausts, pneumatic transport, industrial systems, heat exchange, physics of building structures, heat recuperation, refrigeration, automation of thermal and air systems and installations.

Authors: distinguished scientists from the Polish and foreign universities and institutes as well as recognized practitioners in the field of district heating, heating, ventilation and air conditioning.

Readers: highly qualified engineers and technicians, designers, builders, process engineers and advanced university students. Design offices, municipal economy companies, housing cooperatives, executive companies, municipal and commune offices, high schools, research institutes, schools, libraries and individual recipients.

Contact information:
e-mail: redakcja.cow@cieplowent.pl
cieploogrzewwent@sigma-not.pl
Website: www.cieplowent.pl

Romania

Romanian Installation Engineers Association (AIIR) - journal

Name of the HVAC Journal**: Instalatorul**
Number of issues per year**: 8 issues per year**
Number of copies per issue**: 4,000 copies per issue**

Instalatorul Journal is the publication of the Romanian Association for Building Services Engineers from Romania - AIIR, which is a member of REHVA and affiliated to ASHRAE. Founded in 1993, by two publishing houses, Gentner Verlag from Germany and Bohmann Verlag from Austria, the Journal soon became an important brand on the market, due to the information presented and its improving format.

The target readership of the journal are the decision makers, managers and specialists in the construction industry, traders and distributors, architects, designers, students, highly trained professionals in HVAC, investors, contractors, sales and representative companies, public authorities etc. Articles within Instalatorul Journal are focused on new technological solutions, new equipment and material for the HVAC market in Romania and abroad.

The paper has always brought to its readers' attention the latest products, news and trends regarding facilities for buildings, interviews with the key people of the market, using also the information provided by GB Consult, the prestigious consulting company focused on HVAC market.

Also, the publication provides information on EU regulations, technical articles and case studies written by Romanian & European experts, professors of the top universities in the country and abroad.

Being invited to participate as a media partner in the most European & Romanian events, coverage of the most important national and international fairs - the journal has every year articles regarding ISH Frankfurt, MOSTRA CONVEGNO Milan, INTERCLIMA Paris, RCEPB (Romanian Conference on Energy Performance of Buildings), ROMTHERM Bucharest, etc.

Contact information

Editor in Chief: Mr. Prof.hon.dr.eng. DHC Liviu Dumitrescu
email: office@artecno.ro
website: http://instalatorul.artecno.ro/

Spain

Spanish Technical Association of Air Conditioning and Refrigeration – publication

Name of the HVAC publication**: bn Atecyr**
Number of issues per year**: 6 issues per year**
Number of copies per issue**: This publication is available online**

For years ATECYR has been publishing a Bulletin of News "BN ATECYR" every 2 months, which summarizes the various contents we approach in our meetings of the Governing Council, the Board and meetings with all the Presidents of the ATECYR's chapters.

In the newsletter we also include the most significant news concerning to our partners and associates; events in which we participate as association as well as a summary of all the activities, and courses that takes place in the different ATECYR chapters.

This enables our associates to be constantly informed of the decisions, agreements and activities undertaken within the organization.

Contact information

Marta Satrústegui
Website – www.atecyr.org

The Netherlands

TVVL Dutch Society for Building Services – journal

Name of the HVAC Journal**: TVVL Magazine**
Number of issues per year**: 11**
Number of copies per issue**: 3,200**

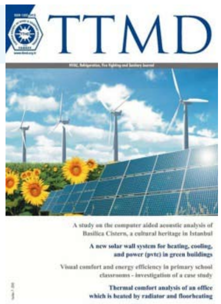
TVVL Magazine is the official journal of the Dutch association for technical installations in buildings, TVVL. For decades it has been a highly rated journal and reference for the engineering sector. The following sectors are covered: air conditioning, electrical engineering, building automation & management and sanitary techniques. The circulation is almost entirely personally addresses to those who are responsible for the building industry-related installations.

TVVL Magazine is distributed to highly targeted officials responsible for advising, designing, purchasing and maintenance of technical installations in buildings. This target group is characterized by major decision in selecting and purchasing products or services. These include: installation consultants, installers and project managers of medium up to architects and installers, end users, heads of technical departments and employees of housing and property companies.

Contact information

Carina Mulder
Email: c.mulder@tvvl.nl
Website: www.tvvl.nl/tvvl-magazine

Turkey



Turkish Society of HVAC and Sanitary Engineers (TTMD) – journal

Name of the HVAC Journal**: HVAC, Refrigeration, Fire Fighting and Sanitary Journal**
Number of issues per year**: 6 issues per year**
Number of copies per issue**: 3,250 copies**

TTMD Journal is published bimonthly by TTMD and sending members and the important people for the HVAC sector. Publishing number is 3250. Turkish Society of HVAC & Sanitary Engineers (TTMD) has been founded at 1992 for the purpose of "developing HVAC & Sanitary engineering" and has turned into an association having nearly 2000 members. The members of TTMD are mainly mechanical engineers (in the area of HVAC) and the services of the society (in the HVAC field) are being conducted in the areas of management, application, manufacturing, education (academician), design, material supply and selling, testing and operation and others. This journal is reaching to these readers. The rate of the advertisements in the journal is 1/3. There are 3 articles in the each journal.

The articles in TTMD journal are issued in according to the criticism by three technical judges. Once a year the Journal is introduced to our association partners (REHVA, ASHRAE, VDI, etc.) with an English version.

There are articles about HVAC systems, hospitals, environmental technologies, energy fire systems, building automation systems, fire protection and acoustics earthquake measures in mechanical installations.

Contact information

Manager of the Journal: B. Hakki Buyruk
email: hbuyruk@ttmd.org.tr
website: www.ttmd.org.tr/journal.aspx

eBooks from Swegon

All Swegon Air Academy books in English are now available in eBook format (designed for iPad, iPhone and iPod touch, and Kindle Amazon devices). Visit Swegon web page* to find more detailed information about SAA eBooks for iPAD and Kindle. Visit iTunes´ iBookstore or Amazon Kindle Store to purchase Swegon Air Academy eBooks.

As a special treat for Swegon Air Academy members, five redeem vouchers for free Simply GREEN eBook for iPAD devices will be published between July 21–25 (10:00, UTC +1:00). Follow **www.swegonairacademy.com** to obtain the codes and redeem eBook for free!

*** http://www.swegonairacademy.com/wp-content/uploads/2014/06/SAA-eBooks-for-iPAD-and-Kindle.pdf**

International Journal of Air-Conditioning and Refrigeration from Korea (IJACR)

The International Journal of Air-Conditioning and Refrigeration (IJACR) offers comprehensive reporting of original research in science and technology related to air-conditioning, refrigeration, and the equipment for controlling indoor environment. It includes broad range of applications and underlying theories including fluid dynamics, thermodynamics, heat transfer, and Nano/Bio-related technologies. In addition, it covers future energy technologies, such as fuel cell, wind turbine, solar cell/heat, and geothermal energy.

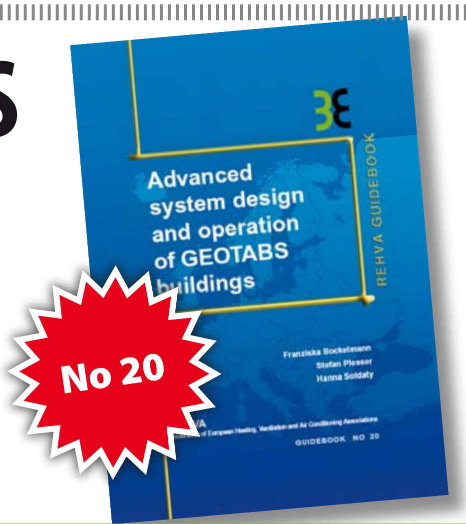
The IJACR established in 1993 and published quarterly by World Scientific on behalf of SAREK (Society of Air-Conditioning and Refrigerating Engineers of Korea). The IJACR presents the latest achievements in developing research and tries to offers a platform for exchanging experiences and information in academic and industrial area. The IJACR aims to maintain an advanced peer-reviewed system and leading source of original research related to air-conditioning and refrigeration at all time. The IJACR is Abstracted & Indexed in Chemical Abstracts Service and Korea Citation Index (KCI) and serving as a great resource for researchers and students around the world.

The IJACR welcomes all authors to submit their original research papers in term of exchanging and spreading the latest researches and innovations.

In addition, the IJACR is seeking review papers and reviewers. If you are interested in writing a review paper or serving as a reviewer, please kindly send us your willingness to **sarek@sarek.or.kr**. ■

For more information or help, please visit our support pages:
www.worldscientific.com/worldscinet/ijacr

REHVA Guidebook on GEOTABS



This REHVA Task Force, in cooperation with CEN, prepared technical definitions and energy calculation principles for nearly zero energy buildings requi-red in the implementation of the Energy performance of buildings directive recast. This 2013 revision replaces 2011 version. These technical definitions and specifications were prepared in the level of detail to be suitable for the implementation in national building codes. The intention of the Task Force is to help the experts in the Member States to define the nearly zero energy buildings in a uniform way in national regulation.

REHVA - Federation of European Heating, Ventilation and Air Conditioning Associations

www.rehva.eu ● info@rehva.eu ● REHVA Office: 40 rue Washington, 1050 Brussels—Belgium ● Tel + 32 2 514 11 71 ● Fax +32 2 512 9062

REHVA Guidebooks are available at www.rehva.eu

Send information of your event to Ms Cynthia Despradel cd@rehva.eu

Events in 2014 - 2015

Conferences and seminars 2014

August 31–Sep 2	11th IIR-Gustav Lorentzen Conference on Natural Refrigerants – GL2014	Hangzhou, China	
September 7–9	14th International Symposium on District Heating and Cooling	Stockholm, Sweden	http://svenskfjarrvarme.se/dhc14
September 10–12	ASHRAE/IBPSA-USA Building Simulation Conference	Atlanta, GA, USA	http://ashraem.confex.com/ashraem/emc14/cfp.cgi
September 10–12	Building Services Summer School	Cesky Sternberk, Czech Republic	tzb.fsv.cvut.cz
September 21–24	Licht 2014 – Den Haag Holland	Den Haag, The Netherlands	www.licht2014.nl
September 24–25	35th AIVC Conference – 4th TightVent Conference – 2nd venticool Conference	Poznań, Poland	www.aivc.org
October 15–17	The 49th National Conference on Building Services	Sinaia, Romania	www.aiiro.ro
October 19–22	Roomvent 2014	Sao Paulo, Brazil	www.roomvent2014.com.br
October 28–29	9th International ENERGY FORUM on Advanced Building Skins	Bressanone, Italy	www.energy-forum.com/fr.html
October 29–31	XXXI ABOK conference and exhibition "Moscow - Energy Efficient City"	Moscow, Russia	http://events.abok.ru/meeg
October 29–31	CCHVAC 2014 conference	Tianjin, China	
November 5	REDAY 2014 – Securing our Energy Future through ambitious Renovation of Building	Brussels, Belgium	www.renovate-europe.eu
December 3–5	45 HVAC&R International Congress	Belgrade, Serbia	www.kgh-kongres.org
December 10–12	9th International Conference on System Simulation in Buildings – SSB2014	Liege, Belgium	www.ssb2014.ulg.ac.be

Exhibitions 2014

October 1–3	Finnbuild 2014	Helsinki, Finland	www.finnbuild.fi
October 14–16	Chillventa 2014	Nuremberg, Germany	www.chillventa.de/en/

Conferences and seminars 2015

February 25–27	World Sustainable Energy Days 2015	Wels, Austria	www.wsed.at
April 16–18	International Conference Ammonia and CO_2 Refrigeration Technologies	Ohrid, Republic of Macedonia	
May 7–8	Advanced HVAC and Natural Gas Technologies	Riga, Latvia	www.hvacriga2015.eu
May 6–7	REHVA Annual Meeting	Riga, Latvia	www.lsgutis.lv/
May 18–20	Healthy Buildings 2015 Europe	Eidhoven, The Netherlands	www.hb2015-europe.org
June 14–17	International Building Physics Conference	Torino, Italy	
August 16–22	IIR International Congress of Refrigeration	Yokohama, Japan	www.icr2015.org
September 10–11	CLIMAMED	Juan Les Pins, France	
October 20–23	Cold Climate HVAC	Dalian, China	www.coldclimate2015.org
October 26–28	11th International Conference on Industrial Ventilation	Shanghai, China	www.ventilation2015.org

Exhibitions 2015

January 26–28	2015 AHR Expo	Chicago, Illinois, USA	www.ahrexpo.com
February 3–6	AQUATHERM Moscow	Moscow, Russia	www.aquatherm-moscow.ru/en/
February 17–19	AQUATHERM Novosibirsk	Novosibirsk, Russia	www.aquatherm-novosibirsk.ru/en/
February 26–28	ACREX India	Biec, Bangalore, India	www.acrex.in
March 10–14	ISH	Frankfurt, Germany	http://ish.messefrankfurt.com
March 18–21	AQUATHERM St. Petersburg	St. Petersburg, Russia	www.aquatherm-spb.com/en/
November 2–6	Interclima+Elec	Paris, France	www.interclimaelec.com

Conferences and seminars 2016

May 22–25	12th REHVA World Conference - CLIMA 2016	Aalborg, Denmark	www.clima2016.org
July 3–8	Indoor Air 2016	Ghent, Belgium	twitter @IA2016

Exhibitions 2016

January 25–27	2016 AHR Expo	Orlando, Florida, USA	www.ahrexpo.com
March 1–4	AQUATHERM Prague	Prague, Czech Republic	www.aquatherm-praha.com/en/
March 13–18	Light and Building	Frankfurt, Germany	http://ish.messefrankfurt.com
March 15–18	Mostra Convegno Expocomfort	Milan, Italy	www.mcexpocomfort.it/

The REHVA European HVAC Journal

Register now for free!

Company:	Department:
Last name:	First name:
Address:	
Postal Code:	City:
Country:	
E-mail:	
Signature:	Date:

☐ YES! I would like to register to the **REHVA JOURNAL**. Please, return your subscription form or change of address to REHVA office.

REHVA – Rue Washington, 40 – 1050 Brussels – Belgium
Telephone: +32 2 514 11 71 – Telefax: +32 2 512 90 62
E-mail: info@rehva.eu – website: www.rehva.eu

☐ I want to register for the REHVA e-newsletter.

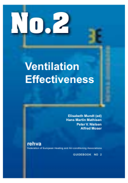
*Shipping information will not be used for any other purpose than mailing of REHVA Journal and will not be given to third party.

REHVA

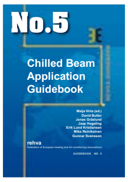
Federation of European Heating, Ventilation and Air Conditioning Associations

REHVA GUIDEBOOKS

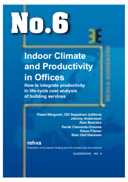
REHVA Guidebooks are written by teams of European experts



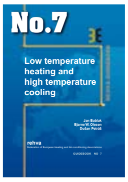
Ventilation Effectiveness. Improving the ventilation effectiveness allows the indoor air quality to be significantly enhanced without the need for higher air changes in the building, thereby avoiding the higher costs and energy consumption associated with increasing the ventilation rates. This Guidebook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



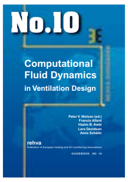
Chilled Beam Cooling. Chilled beam systems are primarily used for cooling and ventilation in spaces, which appreciate good indoor environmental quality and individual space control. Active chilled beams are connected to the ventilation ductwork, high temperature cold water, and when desired, low temperature 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.



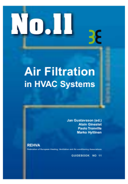
Indoor Climate and Productivity in Offices. This Guidebook shows how to quantify the effects of indoor environment on office work and also how to include these effects in the calculation of building costs. Such calculations have not been performed previously, because very little data has been available.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



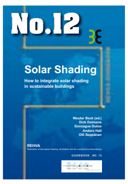
Low Temperature Heating And High Temperature Cooling. This Guidebook describes the systems that use water as heat-carrier and when the heat exchange within the conditioned space is more than 50% radiant. Embedded systems insulated from the main building structure (floor, wall and ceiling) are used in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



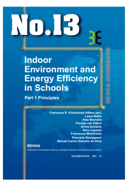
Computational Fluid Dynamics in Ventilation Design. CFD-calculations have been rapidly developed to a powerful tool for the analysis of air pollution distribution in various spaces. However, the user of CFD-calculation should be aware of the basic principles of calculations and specifically the boundary 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.



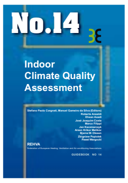
Air Filtration in HVAC Systems. This Guidebook will help the designer and user to understand the background and criteria for air filtration, how to select air filters and avoid problems associated with hygienic and other conditions at operation of air filters. The selection of air filters is based on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



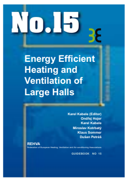
Solar Shading – *How to integrate solar shading in sustainable buildings.* Solar Shading Guidebook gives a solid background on the physics of solar radiation and its behaviour in window with solar shading systems. Major focus of the Guidebook is on the effect of solar shading in the use of energy for 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.



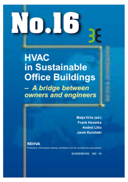
Indoor Environment and Energy Efficiency in Schools – *Part 1 Principles.* School buildings represent a significant part of the building stock and also a noteworthy part of the total energy use. Indoor and Energy Efficiency in Schools Guidebook describes the optimal design and operation of schools with respect to low energy cost and performance of the students. It focuses particularly on energy efficient systems for a healthy indoor environment.



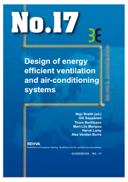
Indoor Climate Quality Assessment. This Guidebook gives building professionals a useful support in the practical measurements and monitoring of the indoor climate in buildings. Wireless technologies for measurement and monitoring have allowed enlarging significantly number of possible applications, especially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



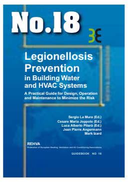
Energy Efficient Heating and Ventilation of Large Halls. This Guidebook is focused on modern methods for design, control and operation of energy efficient heating systems in large spaces and industrial halls. The book deals with thermal comfort, light and dark gas radiant heaters, panel radiant heating,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



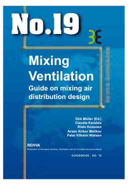
HVAC in Sustainable Office Buildings – ***A bridge between owners and engineers.*** This Guidebook discusses the interaction of sustainability and heating, ventilation and air–conditioning. HVAC technologies used in sustainable buildings are described. This book also provides a list of questions to be asked in various phrases of building's life time. Different case studies of sustainable office buildings are presented.



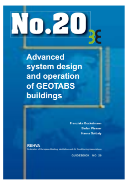
Design of energy efficient ventilation and air-conditioning systems. This Guidebook covers numerous system components of ventilation and air-conditioning systems and shows how they can be improved by applying the latest technology products. Special attention is paid to details, which are often overlooked in the daily design practice, resulting in poor performance of high quality products once they are installed in the building system.



Legionellosis Prevention in Building Water and HVAC Systems. This Guidebook is a practical guide for design, operation and maintenance to minimize the risk of legionellosis in building water and HVAC systems. It is divided into several themes such as: Air conditioning of the air (by water – humidification), Production of hot water for washing (fundamentally but not only hot water for washing) and Evaporative cooling tower.



Mixing Ventilation. In this Guidebook most of the known and used in practice methods for achieving mixing air distribution are discussed. Mixing ventilation has been applied to many different spaces providing fresh air and thermal comfort to the occupants. Today, a design engineer can choose from large selection of air diffusers and exhaust openings.



Advanced system design and operation of GEOTABS buildings. This Guidebook provides comprehensive information on GEOTABS systems. It is intended to support building owners, architects and engineers in an early design stage showing how GEOTABS can be integrated into their building concepts. It also gives many helpful advices from experienced engineers that have designed, built and run GEOTABS systems.

REHVA nZEB Report. In this REHVA Report in cooperation with CEN, technical definitions and energy calculation principles for nearly zero energy buildings required in the implementation of the Energy performance of buildings directive recast are presented. This 2013 revision replaces 2011 version. These technical definitions and specifications were prepared in the level of detail to be suitable for the implementation in national building codes.

REHVA – Rue Washington, 40 – 1050 Brussels – Belgium
Telephone: +32 2 514 11 71 • Fax + 32 2 512 9062 • E-mail: info@rehva.eu • website: www.rehva.eu