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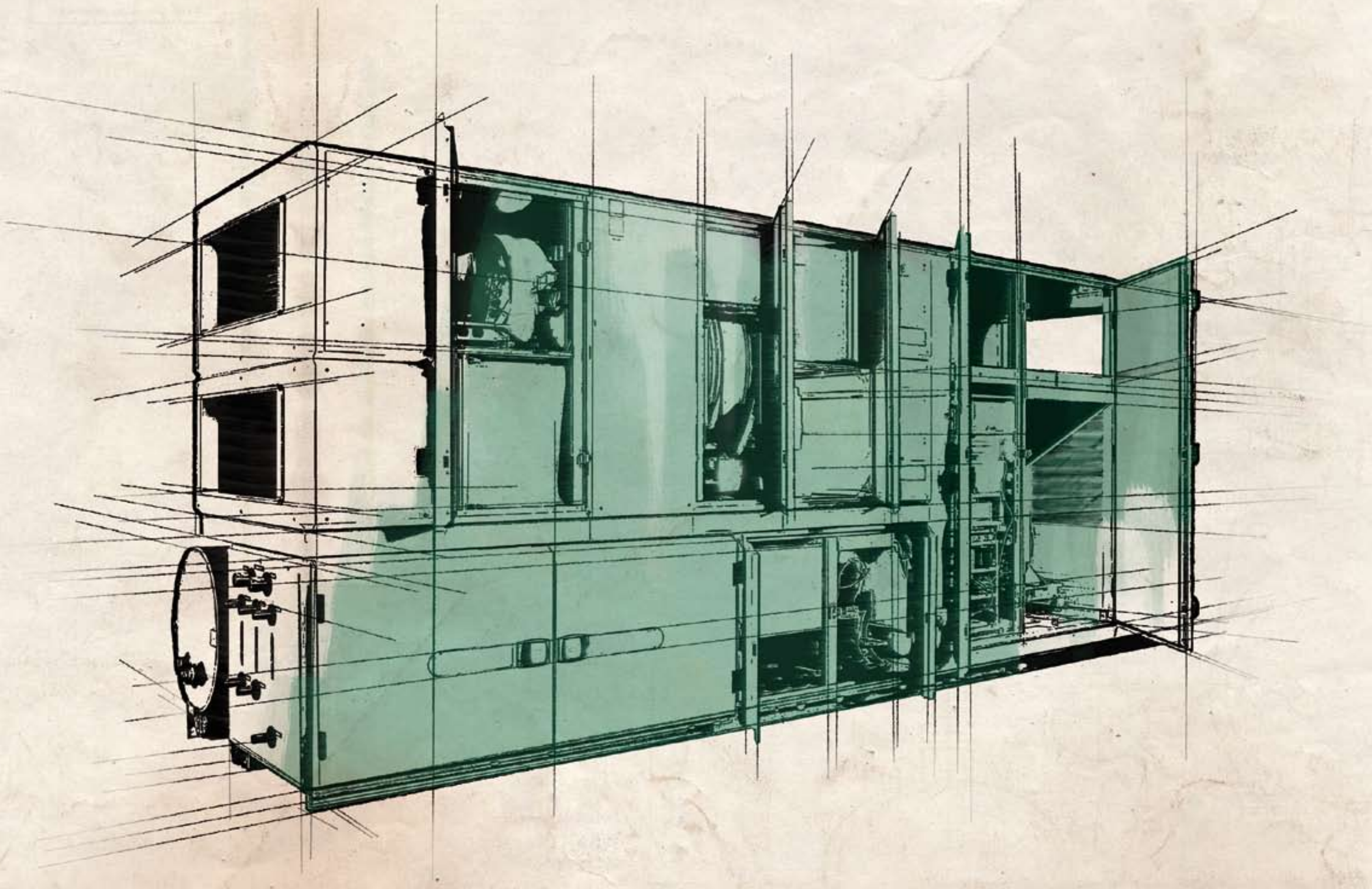

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REHVA in the 2000 millennium

OLLI SEPPÄNEN
Professor,
Editor-in-chief

REHVA, the Federation of European HVAC Associations representing close to 100 000 experts in Europe, has developed significantly its technical and professional activities during the 2000 millennium to respond better to challenges posed by a united Europe, the need to protect the environment and the demand for better indoor climate and energy efficiency of buildings. A significant and visible beginning of these technical activities was the publication of the REHVA Guidebooks, intended to disseminate new technology in Europe. The first Guidebook on Displacement Ventilation was published in 2002, and was translated into twelve languages. Now more than 20 Guidebooks with over 50 translations are well recognized as sources of non-commercial, technical information. Current REHVA Guidebook activities are described in detail in an article in this issue.

The Guidebooks are created by REHVA Task Forces working under the Technology and Research Committee. The Committee structure of REHVA has been expanded and strengthened significantly during last ten years. In addition to the two original committees (Technical and Education), REHVA has established five more committees: Marketing and Publication, Awards, Supporters, External Relations and Membership. These committees are the backbone of REHVA activities, and allow everybody to participate in REHVA activities.

A significant impact of REHVA on European Technology and its development has been its participation in EU funded projects (close to 30 projects), mainly in the area of energy efficiency of buildings but also related to Indoor Environment. Participation in these projects has also been helpful in establishing the professional reputation of REHVA and a European network. The most significant projects are described at www.rehva.eu. Among these, one of the most significant is the European Portal BUILD UP (www.buildup.eu), which aims at providing information services to help the implementation of the European Energy Performance of Buildings Directive (EPBD) and energy efficiency of buildings.

The close connection with the EU has allowed REHVA to have an impact on European legislation and regulations. REHVA has participated in the development of Energy Performance of Buildings Directive and Regulations based on Eco-design of Energy Related Products Directive. REHVA is now recognized as an independent professional federation by the European Commission. The REHVA secretariat was transferred to Brussels in 1990´s but the increasing activities called for its own office which was established in 2006, and professional personnel to run the EU project and take care of the increasing activities. A Secretary General for REHVA was appointed in 2008.

REHVA is a Federation of national professional associations, and independent of the industry; however, REHVA has felt that its impact would be greater if its relationship with the HVAC industry is strengthened. That was behind the REHVA Supporters programme which was launched in 2005. Now about 50 HVAC manufacturers, design offices and contractors are REHVA supporters, with close connections to REHVA but without voting rights. The information exchange is in both directions; REHVA supplies independent technical information and the HVAC industry points out the areas where neutral, reliable information is needed. REHVA also gives some publicity to its supporters through its website, REHVA Journal and various seminars.

REHVA Journal, the only pan-European HVAC Journal, has a long history and is now producing its 50th volume. REHVA Journal has changed significantly during the last few years. It offers an overview of the entire HVAC technology in Europe, focusing during the last few years on energy efficiency and indoor environment of buildings. The journal has found its role as an independent technical periodical between scientific and commercial publications. It is truly pan-European with authors from 25 countries in 2012. The authors include scientists, practitioners and industry professionals, especially the experts from REHVA supporters. The journal is still distributed free of charge to subscribers, which limits its circulation; it is mailed only to selected top experts and decision makers.

REHVA Journal is published six times a year focusing on technology. The journal does not cover all the society news. This was the reason for establishing a special bimonthly newsletter (2007) for members and a specific bulletin (2010) for REHVA supporters focusing on EU regulations. The REHVA website plays an even more important role than the newsletter, journal and bulletin. In the 2000 millennium it was first established in Denmark, then transferred and developed further in Czech Republic, and recently transferred to Belgium where the revised website was launched in May 2013. Important discussion forums for information exchange are also the platforms of social media where REHVA is visible.

REHVA was originally established for information exchange between its members. In the 2000 millennium it was realized that relations between other European and international organizations are also important. A series of framework agreements (memorandums of understanding) have been signed with several organizations including International Institute of Refrigeration, Eurovent Association, ASHRAE, International Energy Agency (AIVC/INIVE), China Committee of HVAC (CCHVAC), Indian Society of Heating, Refrigeration and Air-conditioning Engineers (ISHRAE), and Society of Heating, Air-conditioning and Sanitary Engineers (SHASE). In addition to these, REHVA has working relations with almost all European Associations related to HVAC, and has liaison status in several CEN technical committees.

International activities of REHVA have been boosted with the series of Clima Conferences. The first International Clima 2000 conference was organized in Milan, Italy in 1975. Since then, it has been held in Budapest (1980), Copenhagen (1985), Sarajevo (1989), London (1993), Brussels (1997), Naples (2001), Lausanne (2005), Helsinki (2007) and Antalya (2010). The 11th Conference was held in June 2013 in Prague. A steady increase in the number of presentations and papers can be seen, especially in the 2000 millennium. A significant change was seen also in the programme of the conference when workshops were included for first time in Naples, 2001. They allow the industry, especially REHVA Supporters, to participate and contribute on topical issues. The workshops (reports available at www.rehva.eu) have had significant impact on REHVA activities.

In addition to Clima conference, now organized every third year, REHVA began to organize Annual REHVA seminars concurrent to its Annual meetings, first in Tallinn in 2011, then in Timisoara 2012 and Dusseldorf in 2014. REHVA also organizes, in cooperation with international exhibitions, workshops on topical issues during the exhibitions; the partners include ISH, Light and Building, ACREX, Sodex, Mostra Convegno, and FinnBuild.

Education has been a part of the REHVA agenda from the beginning. A visible activity in this area has been the student competitions between REHVA member countries. They have been organized concurrently with the Clima Conference and REHVA Annual meetings, beginning Lausanne, 2005. The REHVA competitions are preceded by national competitions where the winners are selected for the European competition.

REHVA Presidents in the 2000 millennium:

Per Rasmussen	Denmark (DANVAC)	1999 – 2002
Dušan Petráš	Slovakia (SSTP)	2002 – 2005
Olli Seppänen	Finland (FINVAC)	2005 – 2008
Francis Allard	France (AICVF)	2008 – 2011
Michael Schmidt	Germany (VDI)	2011 – 2013
Karel Kabele	Czech Republic (STP)	2013 –

An important tool to improve the information exchange between European multilingual nations has been the HVAC dictionary. The second and last printed version of the REHVA dictionary from the year 1994 had 3 151 HVAC related terms in 12 languages. A new expanded web-based REHVA International Dictionary on Building Services terms was launched in 2006. The content of the dictionary was expanded from the former REHVA Dictionary to 11 758 terms, and was published in an electronic format. The dictionary website, www.rehvadictionary.eu, is regularly updated to include the additional translated terms. In 2013 it includes 15 languages.

REHVA has established several awards to recognise its national experts in the advancement of HVAC in the areas of science, technology and design. These awards are presented annually at REHVA Annual Meetings. The results of REHVA activities depend on the voluntary work of national experts. To recognise the contribution of the most active experts, REHVA launched the REHVA Fellows programme in 2011. The REHVA Fellows and recipients of awards are listed at www.rehva.eu.

REHVA was established on Sept 27, 1963 by representatives of technical associations of nine European countries in The Hague.

REHVA 50 1963 2013 Federation of European Heating, Ventilation and Air Conditioning Associations

REHVA celebrates its 50th anniversary in 2013.

The full history of REHVA is available at www.rehva.eu ■

Refrigerants – Part 1: Properties and air-conditioning applications

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Abstract

The paper on refrigerants has been divided in two parts. Refrigerants' thermodynamic, physical, chemical, safety – related and environmental properties have been presented and discussed in the first part of the paper. Influence of those properties, which is of the utmost significance on the vapor – compression process efficiency and design has been presented. The design of HVAC system is influenced by the choice of the vapor – compression process, which means that refrigerant choice defines HVAC design as well. Throughout the history, refrigerant development took place due to different reasons, such as safety, stability, durability, economic or environmental issues, thus giving the boost to new research and equipment improvement in terms of safety and efficiency. Recent legislation worldwide and in EU is still not quite completed concerning refrigerant issues. The delicate subject of refrigerants is widely discussed, viewpoints of different parties are opposite, depending on positions and interests, and compliance on that issue is not easy to achieve. In the second part of the paper about refrigerants, past present and future of refrigerants and suitable applications will be discussed, with emphasis on natural refrigerants.

Introduction

Refrigerants are the working fluids used in the counter clockwise thermodynamic working cycles. Depending on temperature levels of the heat source and the heat sink, the application area of the working cycle can be refrigeration, air- conditioning, or heat-pumping. Refrigerant circulates within the refrigeration machine, absorbs the heat from the heat source at lower temperature level and rejects it into the heat sink at higher temperature level. In absorption and mechanical vapor compression systems refrigerants usually pass the phase change, namely evaporation or condensation. Gas refrigeration cycles are also available and phase change of the working fluid in such cycles does not occur. Gas refrigeration cycles are less efficient compared to vapor – compression cycles and will be omitted in the considerations that follow.

The choice of the refrigerant is not only the technical problem, it is subject to lot of interests, public and industrial groups advocate their positions and neutral position in all that multiple source information is not always easy to achieve.

Throughout the history of refrigeration organic and inorganic natural working fluids, chlorofluorocarbons CFCs, hydro chlorofluorocarbons HCFCs, fluorocarbons HFCs have been used and some of them abandoned for certain reasons, such as security, cost or environmental, defining in some way the direction of development of refrigeration and HVAC industry.

The refrigerant issue is becoming more important in present time due to the fact that refrigeration or heat pumping can contribute to better utilization of renewable heat contained in the environment on low temperature level, thus making possible easier design of zero energy buildings.

Refrigerant properties

Refrigerant selection involves compromises between conflicting desirable properties. The working fluid desirable properties are related to thermodynamic and physical properties which lead to efficient cooling or heating factor and effective design of equipment, such as high evaporation heat, high volumetric refrigeration capacity, low temperature at the end of the compression. Other physical properties comprise the favorable position of critical and the freezing point, low specific heat capacity, low specific volume, low viscosity and high thermal conductivity. Desirable chemical and safety properties comprise chemical stability within the working conditions in the refrigeration unit in the presence of used materials and lubricating oil, non-flammability, non-toxicity, good miscibility with oil. If possible, the refrigerant must be odorless, but easy detection in the air is desirable. Safety properties of refrigerants considering flammability and toxicity are defined by ASHRAE standard 34 [1]. Toxicity classification of refrigerants is assigned to classes A or B. Class A signifies refrigerants for which toxicity has not been identified at concentrations less than or equal to 400 ppm by volume, and class B signifies refrigerants with evidence of toxicity at concentrations below 400 ppm by volume. By flammability refrigerants are divided in three classes. Class 1 indicates refrigerants that do not show flame propagation when tested in air (at 101 kPa and 21°C). Class 2 signifies refrigerants having a lower flammability limit (LFL) of more than 0.10 kg/m³ and a heat of combustion of less than 19 000 kJ/kg. Class 3 indicates refrigerants that are highly flammable, as defined by an LFL of less than or equal to 0.10 kg/m³ or a heat of combustion greater than or equal to 19 000 kJ/kg.

Table 1. Safety classification of refrigerants as defined by ASHRAE standard 34.

increasing flammability→	SAFETY GROUP	
higher flammability	A3	B3
lower flammability	A2	B2
	A2L*	B2L*
no flame propagation	A1	B1
	lower toxicity	higher toxicity
	increasing toxicity→	

* A2L and B2L are lower flammability refrigerants with a maximum burning velocity ≤ 10 cm/s.

New flammability class 2L has been added since 2010 denoting refrigerants with burning velocity less than 10 cm / sec.

Desired environmental properties comprise that refrigerants should not affect the ozone layer (the presence of chlorine in the working fluid molecules is not acceptable), that the impact on global warming should be as low as possible and that working fluid decomposition by-products should not have negative effects on the environment.

Some refrigerants (chlorofluorocarbons CFCs and hydro chlorofluorocarbons HCFCs) can affect the ozone layer. Ozone (O_3) is naturally formed in the atmosphere and it absorbs the sun's harmful UV rays. The chlorine contained in CFCs and HCFCs distorts the natural equilibrium of the ozone in the atmosphere and affect its concentration, which, in turn, increases the risk of skin cancer, weakens human immune system leading to diseases, causes the flora and fauna imbalance, plankton depletion and species count decrease.

Another negative effect of HFCs, which belong to the greenhouse gasses (CO_2, CH_4, NO_2, HFCs, PFCs and SF_6) is the global warming. The greenhouse gasses emitted into atmosphere allow the short wave radiation of the Sun passing through, but are less permeable for the long wave radiation of the Earth's surface. This is why the certain amount of energy reaching the surface of the Earth through the atmosphere stays trapped as if in a greenhouse and causes the temperature to rise. This distorts the total energy balance of the Earth and causes dramatic climate change.

The refrigerant impacts on the environment are evaluated with the ozone Depletion Potential (ODP) and the Global Warming Potential (GWP). ODP is expressed as a relative potential of ozone depletion compared to influence of R-11 which has ODP=1. The Global Warming Potential (GWP) is the relative measure of the substance impact on the greenhouse effect in relation to the impact of a kilogram of CO_2. The CO_2 is retained permanently in the atmosphere, which is why the GWP of greenhouse gasses which can have lower lifetime in the atmosphere is calculated over a specific time interval, commonly 20, 100 or 500 years.

Finally, some demands of economic nature, such as low price and good availability are also important for refrigerant selection.

There is no "ideal" working fluid available. Neither one among working fluids has all the required properties and the above – mentioned requirements are fulfilled only partially. When selecting the refrigerant, the device application and temperature range must always be analyzed in order to be able to determine the optimal refrigerant. In technical practice, which is subject to changes over time, priority is always given to certain refrigerants for certain purposes.

Influence of refrigerants on process efficiency

The design and efficiency of the refrigeration equipment depends strongly on the selected refrigerant's properties. Consequently, operational and equipment costs depend on refrigerant choice significantly. Vapor – compression unit consists of compressor, condenser, expansion device and the evaporator, connected with refrigerant pipelines.

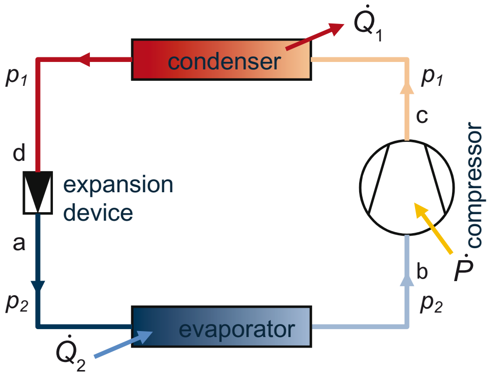

Figure 1. Single-stage compression refrigeration unit schematics.

The basic vapor – compression cycle is considered to be one with isentropic compression, with no superheat of vapor and with no subcooling of liquid (**Figure 2**).

When zeotropic mixtures are used as refrigerants, gliding temperatures influence cycle efficiency as well as system design. An example of the process operating with zeotropic mixture is given on **Figure 3**. Temperature glide appears during evaporation and condensation at constant pressure. Use of counter flow heat exchangers can sometimes help to utilize that temperature glide efficiently, but problems can appear with leakage of refrigerants from such systems as the initial refrigerant composition and thus properties can be disturbed.

The specific compression work w, the specific cooling performance q_2, volumetric refrigerating capacity q_{0v}, the cooling factor COP_2 are calculated for above presented processes as follows:

$$w = h_c - h_b \quad \text{[kJ/kg]}, \tag{1}$$

$$q_2 = h_b - h_a = h_b - h_d \quad \text{[kJ/kg]} \tag{2}$$

$$q_{0v} = \frac{q_2}{v_b} = q_2 \rho_b \quad \text{[kJ/m}^3\text{]} \tag{3}$$

$$COP_2 = \frac{q_2}{w} = \frac{h_b - h_a}{h_c - h_b} \tag{4}$$

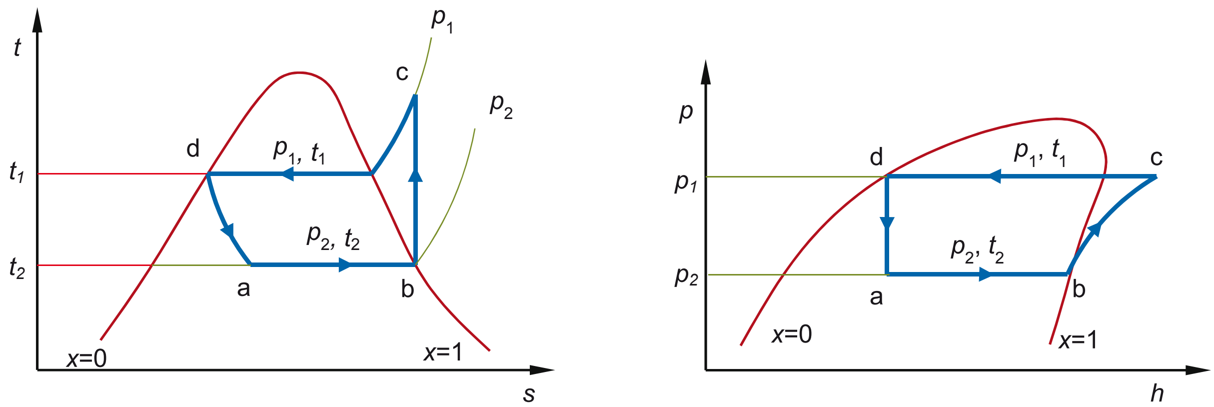

Figure 2. Single-stage vapor - compression subcritical process with a single – component or azeotropic refrigerant in temperature - entropy ***t,s-*** and pressure – enthalpy ***p,h-*** diagrams.

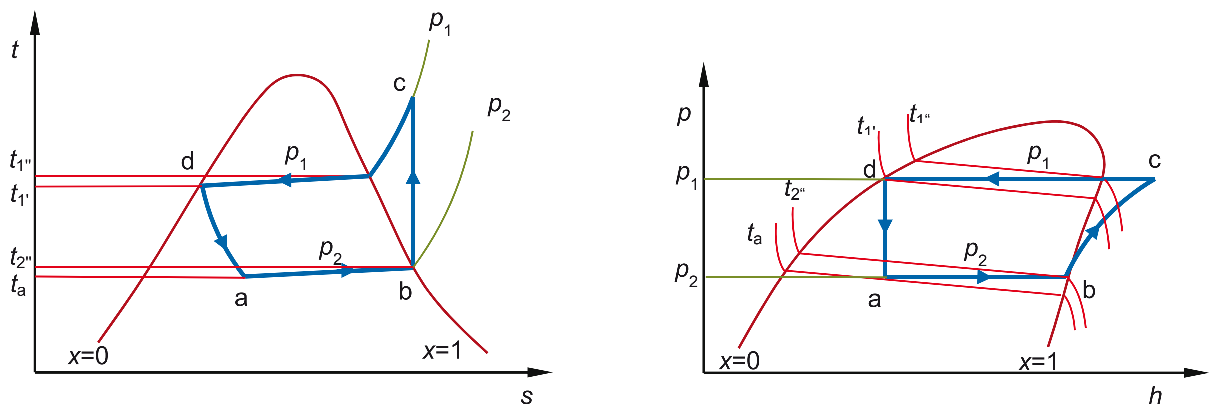

Figure 3. Single-stage vapor – compression subcritical process with a zeotropic mixture refrigerant in temperature – entropy ***t,s-*** and pressure – enthalpy ***p,h-*** diagrams.

The refrigerant mass flow is calculated from the required cooling capacity and the specific cooling performance.

$$\dot{M} = \frac{\dot{Q}_2}{q_2} \quad [\text{kg/s}] \tag{5}$$

The power necessary for the isentropic compression may be calculated as

$$\dot{P}_{is} = \dot{M}\, w \quad [\text{kW}] \tag{6}$$

The effective power on the compressor shaft is bigger and is calculated as

$$\dot{P}_{ef} = \frac{P_{is}}{\eta_{is}} \tag{7}$$

Comparison of different refrigerants gives a good overview of achievable cycle performance for a basic reference cycle. **Table 1** gives comparison for refrigerating reference cycle with evaporation temperature −15°C and condensing temperature +30°C. Cycle data for zeotropic refrigerants in **Table 1** are given for combination of temperatures $t_{2''}$ and $t_{1'}$ [2]. Cycle data are available from different sources, e.g. IIR - Refrigerant cycle data [2], ASHRAE Fundamentals Handbook [3], or can be evaluated from suitable software such as REFPROP [4]. The selection of refrigerants in **Table 2** has been made in order to present the overview of cycle data for historically used natural inorganic refrigerants such as ammonia R-717, carbon dioxide R-744, sulfur dioxide R-764 (which is not in use anymore), chlorofluorocarbons CFCs such as R-11 or R-12 and hydro chlorofluorocarbons HCFCs such as R-22, and azeotropic mixture R-502 which dominated in 20th century and are also phased out. Amongst newly used refrigerants hydro fluorocarbons HFCs R-32 and R-134A are presented as well as zeotropic mixtures of HFCs R-404A, R-407C, R-410A, and azeotropic mixture of HFCs R-507. Finally, natural hydrocarbons HCs R-600A and R-290, together with propylene R-1270 are listed.

As it can be seen from data presented in **Table 2** pressures in the system are temperature – dependent and are different for each particular refrigerant. Evaporation and condensing temperatures are close coupled with corresponding pressures for single – component refrigerants, while for zeotropic mixtures temperature glide appears during the phase change at constant pressure. Pressures influence design and thus equipment costs, but also the power consumption for compression and thus operational costs. Refrigerant transport properties, such as liquid and vapor density, viscosity, thermal conductivity or surface tension, define heat transfer coefficients and consequently temperature differences in heat exchangers thus directly influencing pressures in the system as well as necessary heat transfer surface of heat exchangers. Molecular mass or volumetric refrigerating capacity of some refrigerants influences application of certain compressor types. For example, ammonia systems are not suitable for application of centrifugal compressor due to low molecular mass of ammonia. On the contrary, R-11 with relatively high molecular mass and low volumetric refrigeration capacity represented a good candidate for application of centrifugal compressors. The higher the volumetric refrigeration capacity is, the smaller compressor displacement can be, which results in smaller compressors for refrigerants with high volumetric refrigeration capacities. Excellent example is R-744 with highest volumetric capacity among all the refrigerants presented in **Table 2**. R-744 compressors are smaller compared to compressors for some other refrigerants.

Achievable efficiency of the entire process is in a great deal a consequence of the refrigerant used. For example, R-11 which has been banned since 2006 can produce highest COP among all other refrigerants for the temperature range considered. Effective energy consumption or cooling factor is not equal to the one of the theoretical cycle. Isentropic efficiency η_{is} in equation 7 is also dependent on refrigerant properties. Discharge temperature on the compressor outlet depends on refrigerant and systems pressures, and it must be limited in order to avoid deterioration of oil properties, or even the oil burnout. For the −15/30°C cycle that problem is not so obvious, but when heat pump applications come into consideration, with evaporation temperatures close or significantly lower than 0°C, and condensing temperatures up to 60°C which is approximately upper level of achievable condensing temperatures for most of refrigerants in cycles with a single – stage compression, that can for certain refrigerants result in high temperatures at the end of the compression, which must be avoided by use of modified cycles (e.g. economizer cycle) or different type of the cycle (e.g. two – stage compression). Behavior of some refrigerant during the compression can result in no or low superheating of the vapor at the end of the compression (e.g. R-134A with low superheating, or R-600A where final refrigerant state at the end of the compression can end in saturated area unless proper superheating at the compressor inlet is provided). Systems with such refrigerants are not suitable for utilization of superheated part of vapor heat content in refrigeration cycles with heat recovery for sanitary water

Table 2. Parameters of –15/30°C cycle with different refrigerants.

R number	p_1 bar	p_2 bar	p_1/p_2	q_{0v} kJ/m³	COP_2 –15/30°C	t_c °C
R-717	11,672	2,362	4,942	2 167,6	4,76	99,08
R-744	72,1	22,9	3,149	7979	2,69	69,5
R-764	4,624	0,807	5,730	818,8	4,84	96,95
R-11	1,260	0,202	6,233	204,2	5,02	42,83
R-12	7,437	1,823	4,079	1 273,4	4,70	37,81
R-22	11,919	2,962	4,024	2 096,9	4,66	52,95
R-32	19,275	4,881	3,949	3 420,0	4,52	68,54
R-134A	7,702	1,639	4,698	1 225,7	4,60	36,61
R-404A	14,283	3,610	3,956	2 099,1	4,16	36,01
R-407C	13,591	2,632	5,164	1 802,9	3,91	51,43
R-410A	18,893	4,800	3,936	3 093,0	4,38	51,23
R-502	13,047	3,437	3,796	2 079,5	4,39	37,07
R-507	14,60	3,773	3,870	2 163,2	4,18	35,25
R-600A[1]	4,047	0,891	4,545	663,8	4,71	32,66
R-290	10,79	2,916	3,700	1 814,5	4,55	36,60
R-1270	13,05	3,630	3,595	2 231,1	4,55	41,85

[1] Superheating at compressor suction port 5°C.

heating during the cooling operation. Analyses become more complicated when superheating and subcooling of refrigerant occurs within the cycle. Liquid subcooling and vapor superheating can be intentionally produced by introducing liquid – vapor heat exchanger into the cycle. With heat exchange between the low – pressure vapor and high pressure liquid refrigerant, efficiency increases for certain refrigerants, while for other refrigerants the decrease of efficiency appears.

Finally, pressure drops within heat exchangers and in pipelines connecting refrigeration machine components are essential for system efficiency and are also dependent on refrigerant properties. All presented examples illustrate the fact that refrigerant properties are essential for the refrigeration equipment design and that gives the refrigerant choice the most important position in design of the refrigeration equipment.

Conclusion

Influence of refrigerant properties and refrigeration system design is significant and those properties influence the design of HVAC systems which contain refrigeration subsystems as well. In the future we may expect changes in regulation concerning refrigerants, the construction of systems that are suitable for the use of newly developed and natural refrigerants, the optimization of the system in the sense of compensating the lower efficiency of some refrigerants, but with keeping cost within acceptable limits. ■

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Practical experience with a fuel cell unit for Combined Heat and Power (CHP) generation on the building level

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Introduction

The previous REHVA Journal article "Micro-Combined Heat and Power (Micro-CHP) Appliances for one- or two-family houses for more energy efficiency" [1] described the common technologies "Stirling Engine"," Internal Combustion Engine" and "Fuel Cell" with the help of available CHP-units. With this article the authors would like to discuss their experience with a fuel cell-based micro-CHP Unit that is highly efficient in terms of electrical output. This experience was gained during research work at the laboratory of heating technology at Cologne University of Applied Sciences [2]. Some of the findings were already presented in 2012 ([3] and [4]).

Figure 1. The test arrangement of the BlueGEN natural gas fired fuel cell-based CHP unit manufactured by Ceramic Fuel Cells. Data sheet performance: 0.5–1.5 kW electrical output and 0.3–0.54 kW thermal output. The heating water buffer tank is oversized for test purposes. Laboratory of Heating Technology at Fachhochschule Koeln.

The Tested Fuel Cell Unit

Figure 1 shows the test arrangement of the investigated fuel cell unit. This unit is called BlueGEN and is manufactured by CFC Ltd. an Australian-German company. It simultaneously generates heat and power. On the electrical side it is connected, in parallel, to the public grid in order to export power or obtain power. On the fuel side it is connected to the public natural gas grid. A heating water circuit delivers the generated heat from this fuel cell unit directly to the connected 680 L heating water buffer tank displayed below. The thermal performance of this unit is being tested by buffer tank heat loading via the fuel cell unit and the heating water circuit. **Figure 2** shows the schematic depiction of how the test arrangement works.

Electrical Performance

Several fuel cell stacks have been tested. **Figure 3** shows the data for the tested fuel cell unit after a new fuel cell stack was installed after roughly 9 800 hours of operation. The electrical export of this fuel cell has been set at a constant value of 1 500 W from the beginning. With a fuel input of around 2.5 kW the power was generated with an electrical efficiency of around 60%, see also the calculation. Due to degradation of the fuel cell, the gas input has to be increased after approximately 2 000 hours in order to maintain 1 500 W of power export. After 6000 hours of fuel cell operation,

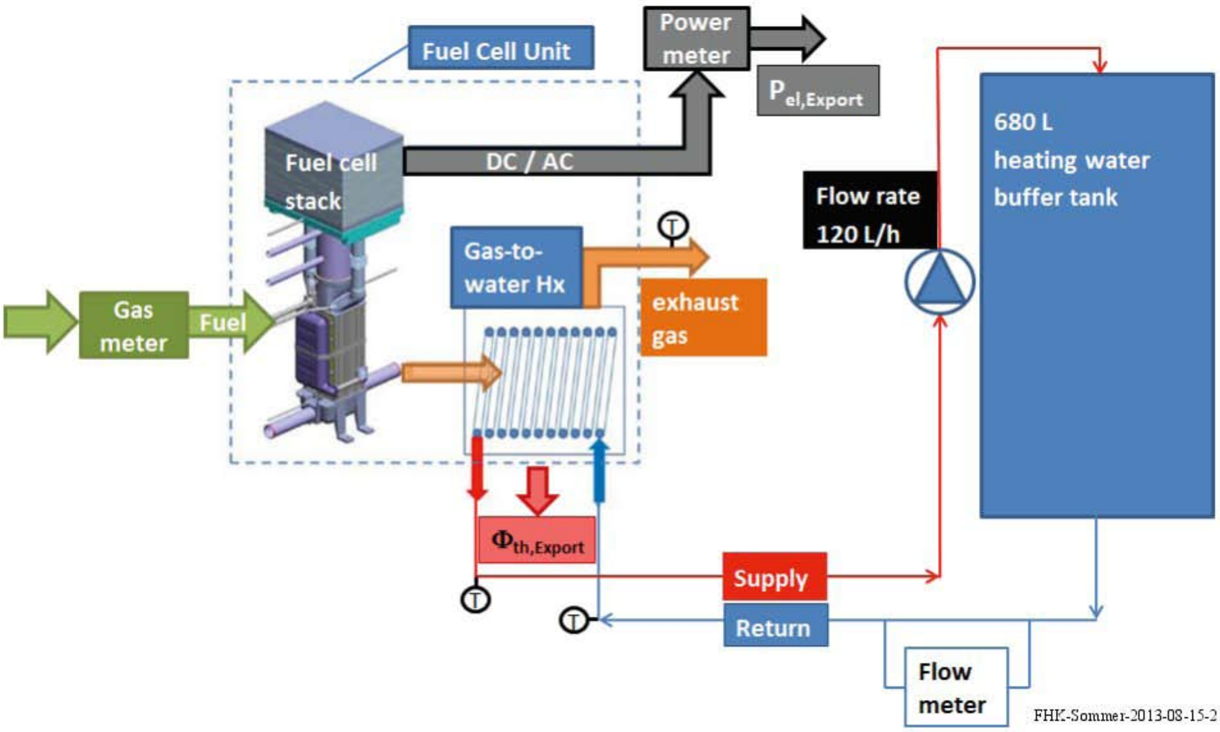

Figure 2. Schematic depiction of the test arrangement presented in figure 1. The fuel cell unit began to be operated in the laboratory of heating technology on October 10, 2011, it had previously been in operation for 150 hours. In the meantime the unit has been tested for more than 16 000 hours of operation. A number of high temperature solid oxide fuel cell stacks have been installed for test purposes during this time. Additional details regarding this fuel cell unit can be found in [1].

2.67 kW of fuel input are required to achieve the same output and the electrical efficiency has decreased to a value of around 56%.

Calculation of the electrical efficiency η_{el} of the fuel cell unit:

$$\eta_{el} = \frac{P_{el,Export}}{\dot{V}_{Gas} \cdot LHV_{Gas}}$$

where

$P_{el,Export}$: Net power (AC) to grid

$\dot{V}_{Gas}$: Flow rate of fuel (standard conditions)

LHV_{Gas}: Lower heating value for this test arrangement ≈ 9.1 kWh/m³ (standard conditions)

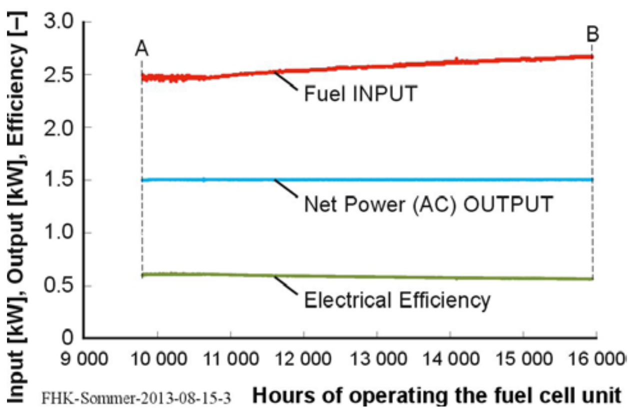

Figure 3. Electrical performance of the fuel cell unit together with a newly installed stack that started working at "A" and was taken out of operation at "B".

The development of the stack's efficiency from the first hour of operation at "A" to "B" has been quantified as follows:

$$\eta_{el,A} = \frac{1.5\,kW}{2.50\,kW} = 0.6 \text{ or } 60\%$$

$$\eta_{el,B} = \frac{1.5\,kW}{2.67\,kW} = 0.56 \text{ or } 56\%$$

Figure 4 demonstrates another one of the fuel cell stacks that was installed and tested for over 3 000 hours from "A" to "B". Here the focus of the test was on the part load capability of the fuel cell stack for the following levels of exported power (AC): 0.1 kW; 0.3 kW; 0.5 kW; 0.7 kW; 0.9 kW; 1.0 kW; 1.1 kW and 1.3 kW.

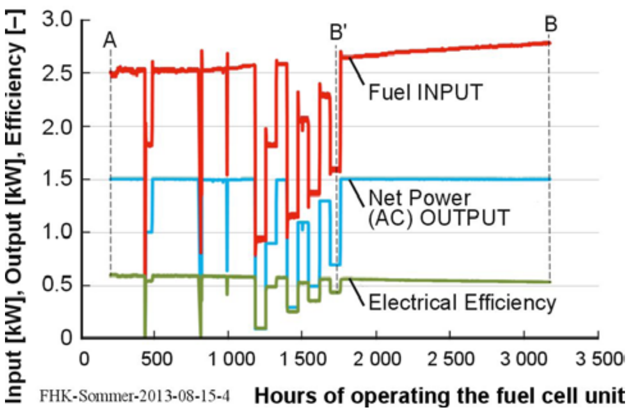

Figure 4. Electrical performance of the fuel cell unit together with the first installed stack that started working at line A and was taken out of operation after line B. Note: Experimental data registered by the unit's power management system and provided by the manufacturer.

These tests were rather stressful for this newly installed fuel cell stack. Hence, after around 700 hours of operation, the new stack ("A" + 700 hours) already required increasing fuel input in order to maintain 1 500 W of power export. At "B" this fuel stack required 2.78 kW of natural gas for 1.5 kW of electrical output, which equates to an electrical efficiency of 54%. The decrease of the performance of this fuel cell was faster than that of the fuel cell in figure 3 because of degradation along with the various part load operation levels to which it was subjected.

Figure 5 displays the part load efficiency versus the net power (AC) export for the time range "A" to "B' " in **Figure 4**.

The higher the power export of the fuel cell unit, the higher the electrical efficiency of the fuel cell. The curve of **figure 5** is described by the following equation:

$$\eta_{el} = 0.1177 \cdot (P_{el,Export})^3 - 0.542 \cdot (P_{el,Export})^2 + 0.9257 \cdot (P_{el,Export}) + 0.0222$$

In order to achieve optimal electrical efficiency and to reduce stress on the fuel cell, the unit should always be operated at a constant level of 1.5 kW power (AC) export.

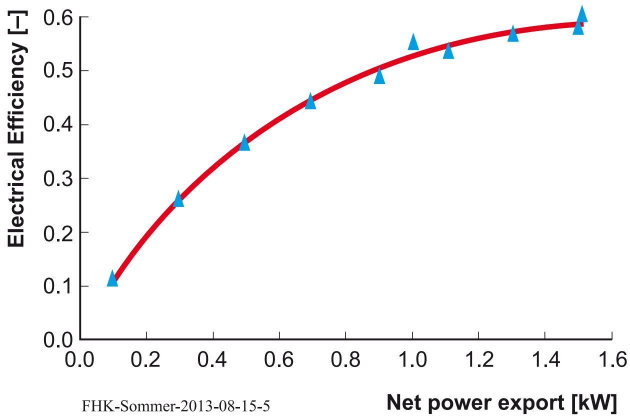

Figure 5. Electrical efficiency of the fuel cell unit versus the net power (AC) exported to the grid for the range of A to B' in figure 4. Note: Experimental data generated by the unit's power management system and provided by the manufacturer.

Thermal Performance at 1500 W net power (AC) export

The thermal output of the fuel cell unit has been measured in a very practical way (thermocouples in thermowells in the heating water loop between the fuel cell and the heating water buffer tank, thermocouples directly in the exhaust gas and an electromagnetic flow meter to measure the heating water loop flow rate), see **figures 1 and 2**. The thermal loading process of the buffer tank is very slow because the water loop flow rate is only 120 litres per hour (manufacturer's recommendation) between the fuel cell unit and the 680 L buffer tank.

The thermal performance of the fuel cell has only been tested at 1 500 W power (AC) export because electrical efficiency for this fuel cell unit is highest under these conditions. **Figure 6** displays the exhaust gas, supply and return temperatures of the fuel cell unit versus time during the thermal loading of the buffer tank by the fuel cell unit (see also **Figure 2**). Starting the loading process with a return temperature of around 17°C from the buffer tank, the fuel cell unit requires around 2 800 minutes to heat up the supply heating water to around 47°C; by this time the return heating water reaches a temperature of around 44°C. No further increase in the temperatures will take place because, from this point on, the thermal output of the fuel cell unit only serves to compensate for the heat losses of the heating water loop and the heating water buffer tank.

The fuel cell unit generates temperature differences of 6 K at the beginning of the loading process, which gradually fall to 3 K at the end of the loading process. **Figure 7** demonstrates a very close relationship between the temperature of the return heating water and the temperature of the supply heating water when leaving the fuel cell unit.

In **Figure 8** the data from **Figure 6** have been used to calculate the heat export of the fuel cell versus the return heating water of the buffer tank. These results clearly illustrate that the lower the temperature of a heating water buffer tank, the higher the thermal benefit that results from the fuel cell unit.

The example illustrated in **Figure 8** indicates that in order to achieve 500 W of thermal output from the fuel cell unit, the returning heating water of the hydronic system should not exceed 40°C.

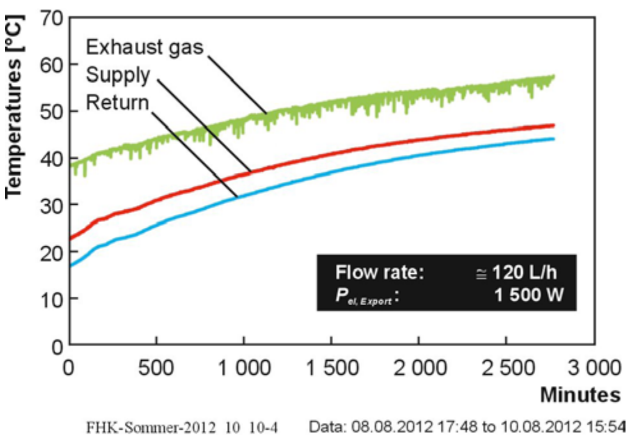

Figure 6. Measurement of the thermal performance of the fuel cell unit by means of thermal loading of the 680 L heating water buffer tank (see also figure 2). Fuel INPUT = 2,6 kW for the fuel cell unit.

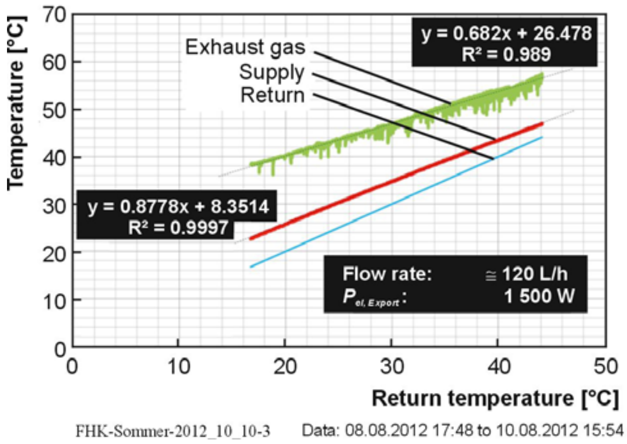

Figure 7. Measured temperatures from figure 6 plotted here against the return temperatures.

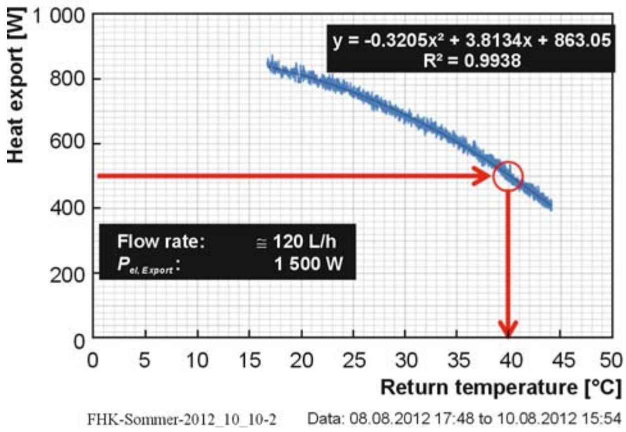

Figure 8. Thermal export of the fuel cell unit versus the return temperature of the heating water from the heating water buffer tank. This result has been derived from the data in figure 6.

The thermal efficiency η_{th} can be calculated in a manner similar to the electrical efficiency mentioned above.

$$\eta_{th} = \frac{\Phi_{th,\,Export}}{\dot{V}_{Gas} \cdot LHV_{Gas}}$$

where

$\Phi_{th,\,Export}$: Thermal output to the system

$\dot{V}_{Gas}$: Flow rate of fuel (standard conditions)

LHV_{Gas}: Lower heating value of this test arrangement ≈ 9.1 kWh/m³ (standard conditions)

For the example presented in **Figure 8** this means:

$$\eta_{th} = \frac{0.5\,\text{kW}}{2.6\,\text{kW}} = 0.19 \;\; or \;\; 19\%$$

Or for the total energy efficiency of this example:

$$\eta_{tot} = \eta_{el} + \eta_{th} = \frac{1.5\,\text{kW}}{2.6\,\text{kW}} + \frac{0.5\,\text{kW}}{2.6\,\text{kW}}$$

$$= 0.58 + 0.19 = 0.77 \;\; or \;\; 77\%.$$

Figure 9 shows η_{tot}, η_{el} and η_{th} for the whole range of data from **Figure 8** versus the returning heating water of the hydronic system (buffer tank). The electrical efficiency is not influenced by the return temperature but the lower the returning heating water, the higher the total efficiency.

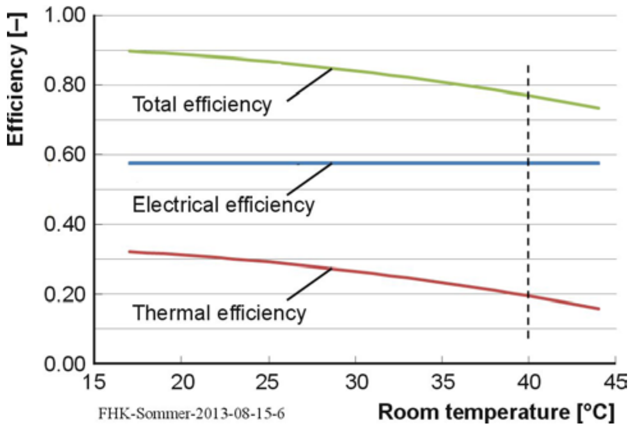

Figure 9. Electrical, thermal and total efficiency of the tested fuel cell unit derived from the data in Figure 8.

Lessons learned

The BlueGEN fuel cell CHP unit manufactured by Ceramic Fuel Cell Ltd. that was tested achieved an electrical efficiency of around 60% when it is new and when exporting 1 500 W net power (AC). This represents its peak efficiency and is outstanding. Degradation reduces the electrical efficiency during the time of operation. When the unit is constantly operated at peak efficiency, degradation reduces the electrical efficiency from 60% to 56% after 6 000 hours of operation. Electrical part load operation leads to additional reductions in electrical efficiency by subjecting the fuel cell stack to stress, thus further accelerating the loss of electrical efficiency over the long term.

The thermal output of the fuel cell depends on the return temperature of the heating water from the connected hydronic system (heating water buffer tank). The lower this return temperature, the higher the thermal efficiency of this fuel cell. Operation at peak electrical efficiency and return heating water temperatures of 35°C from the connected hydronic system lead to a total efficiency of around 81% (LHV). Under these conditions, the net power (AC) export of the fuel cell is 36 kWh per day, or 13 140 kWh per year, with a simultaneous thermal output of 14.5 kWh per day, or 5 290 kWh per year, when providing supply heating water temperature of 39°C. ■

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The cost optimal methodology applied to an existing office in Italy

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Summary

While new buildings should be designed as intelligent low or zero-energy buildings, refurbishment of existing building stock has many challenges and opportunities of saving because, in the building sector, most of the energy is consumed by existing buildings. Since the replacement rate of existing buildings by the new-build is only around 1–3% per annum, a rapid enhancement of taking up retrofit measures on a large scale is essential for a timely reduction in global energy use and promotion of environmental sustainability. Consequently, defining the most cost and energy effective retrofit measures for the existing buildings represents a key element in European energy policies. The cost optimal methodology can be used as a useful tool for this aim. The present paper reports the first outcomes of an application of this methodology to a reference building for an existing office customized to the Italian context. The Rehva Task Force "Reference Buildings for Energy and Cost Optimal Analysis" deals with this topic.

Introduction

The recast of the Directive on the Energy Performance of Buildings defined all new buildings will be nearly zero-energy buildings by the end of 2020. However, the transformation of the EU's building stock will not be completed until well after 2020 and this target can only constitute an intermediate step. The renovation of existing buildings stock offers significant potential for both cost-effective CO_2 emissions mitigation and substantial energy consumption reduction. Therefore energy efficiency can be seen as Europe's biggest energy resource. The cost optimal methodology may be a useful tool able to identify the more appropriate retrofit measures in order to launch the renovation of the existing building stock on a large scale [1].

Therefore, hereby the application of the cost optimal methodology to a reference building (RB) for existing offices customized to the Italian context is presented. The identification of the most suitable energy efficiency measures (EEMs) becomes a key element of national energy policies, in order to guide the possible introduction of specific subsidies or financial tools. Specifically, different EEMs involving the improvement of the building envelope thermal performances and the systems efficiency were considered. Moreover, the utilization of renewable energy sources was taken into account with the installation of a PV system on the building roof. Then, the energy consumptions of the RB and the impact of the improvement measures were assessed with a dynamic simulation software tool. Finally, the costs of the different packages were estimated, according to the European Standard EN 15459:2007, in order to establish which of them has the lowest global cost and, consequently, represents the cost optimal level.

The case study

The main purpose of a RB is to represent the typical and average building stock in a certain Member States, since it is impossible to calculate the cost optimal situation for every individual building [2]. Hence, it must be chosen to reflect as accurately as possible the present national building stock so that the methodology can deliver representative calculation results.

The case study hereby analyzed is a theoretical Reference Building that is a fictional building composed of disaggregated statistical data related to the main building features gathered together to create a typical Italian office building [3]. It is the results of a national survey carried out by ENEA (Italian National Agency for New Technologies Energy and Sustainable Economic Expansion) and finalized to a quantitative and qualitative analysis of the Italian office building stock [4]. The RB is representative of office buildings located in the North of Italy and built since 1970 until today.

The RB is a five-storey office building with an unconditioned basement and it is located in Turin and characterized by a total net conditioned area of 2 300 m². The gross area of a typical floor is equal to 480 m², while its gross height is equal to 3.5 m. The building has a rectangular plan (16 m x 30 m), with an interior layout characterized by cellular offices on the perimeter areas and a central core for the services areas. It is oriented N-S on its cross-section. It has an aspect ratio of 0.33 m^{-1}; it is thus a quite compact building. The ratio of the transparent area to the opaque envelope is 38%.

It consists of a reinforced concrete structure, brick walls with insulation (U = 0.75 W/m²K), plane insulated roof (U = 0.81 W/m²K) and double glazing windows with aluminum frame with thermal break (U = 3.19 W/m²K) and with internal blinds.

The primary system is constituted by a condensing boiler and a chiller with cooling tower; the terminals of heating and cooling system are four-pipe fan coil units.

The energy efficiency measures

The definition of the EEMs, that are all technically feasible, was carried out on two stages. The EEMs were aimed first to the improvement of the building envelope performances and then to the improvement of systems efficiency and to the exploitation of renewable energy sources. The latter measures were applied to some of the previous models, and in particular, to the RB, which is the solution with the lowest global cost, and to the model which reported the lowest primary energy consumption (EEM3).

Table 1. Description of Energy Efficiency Measures affecting the lighting system efficiency and the exploitation of renewable energy sources.

EEMs description		1st stage EEM	ID
Package 1	ALC[1]	RB[2]	EEM13[3]
		EEM3	EEM14
		EEM8	EEM15
Package 2	PV: 100% roof	RB	EEM16
Package 3	PV: 50% roof	RB	EEM17
Package 4	PV: 25% roof	RB	EEM18
Package 5	ALC PV: 100% roof	RB	EEM19
		EEM3	EEM20
Package 6	ALC PV: 50% roof	RB	EEM21
		EEM3	EEM22
Package 7	ALC PV: 25% roof	RB	EEM23
		EEM3	EEM24

[1]Artificial lighting control; [2]Reference building; [3]EEM xx= energy efficiency measure – see text

The first set of 12 EEMs consists in an improvement of the thermal insulation of the building envelope; EEMs are distinguished into "homogenous measures" that regarded the whole building envelope or "not homogeneous measures" that concerned just selected building components. Since the RB is assumed to be located in Turin (climate zone E), the considered U-values correspond to the requirements established by the new regulations on energy performance of buildings in Piedmont Region [5]. Indeed the U-values applied for the EEM1 are the U-value limits set by the Piedmont Region regulation: (U_{wall} = 0.33 W/m²K; U_{roof} = 0.29 W/m²K; $U_{ground\ slab}$ = 0.30 W/m²K; U_{window} = 2 W/m²K); the U-values applied for the EEM2 are the optional U-value targets set by the Piedmont Regional regulation [5] (U_{wall} = 0.24 W/m²K; U_{roof} = 0.22 W/m²K; $U_{ground\ slab}$ = 0.26 W/m²K; U_{window} = 1.5 W/m²K); the U-values applied for the EEM3 are the optional U-value targets set by the Turin city regulation [6] (U_{wall} = 0.14 W/m²K; U_{roof} = 0.15 W/m²K; $U_{ground\ slab}$ = 0.16 W/m²K; U_{window} = 1.2 W/m²K).

In regard to the "not homogeneous measures", an improvement of the thermal insulation only of the windows is considered by EEM 4 (U_{window} = 2 W/m²K), EEM 7 (U_{window} = 1.5 W/m²K) and EEM10 (U_{window} = 1.2 W/m²K). An improvement of the thermal insulation of the roof and of the ground slab is evaluate by EEM 5 (U_{roof} = 0.29 W/m²K; $U_{ground\ slab}$ = 0.30 W/m²K), EEM 8 (U_{roof} = 0.22 W/m²K; $U_{ground\ slab}$ = 0.26 W/m²K) and EEM11 (U_{roof} = 0.15 W/m²K; $U_{ground\ slab}$ = 0.16 W/m²K).

An improvement of the thermal insulation of the external walls and of the windows is considered by EEM 6 (U_{wall} = 0.33 W/m²K; U_{window} = 2 W/m²K), EEM 8 (U_{wall} = 0.24 W/m²K; U_{window} = 1.5 W/m²K) and EEM12 (U_{wall} = 0.14 W/m²K; U_{window} = 1.2 W/m²K).

The EEMs considered within the second stage consisted in the introduction of an artificial lighting control (ALC) and in the installation of PV panels on the plane roof. Three different configurations were studied for PV panels: covering of the entire, of one half and of one fourth of the roof (**Table 1**).

Calculation assumptions

The objective of the energy evaluation was to determine the annual overall energy use in term of delivered energy (divided by sources) and primary energy, which includes energy use for heating, cooling, lighting and equipment. The energy consumption of the RB and the impact of the improvement measures were assessed with the dynamic simulation software EnergyPlus.

Unlike other various studies that are being developed on this topic, this work is characterized by the use of dynamic simulation in order to accurately estimate the energy demand for heating, cooling, electric lighting, electricity from renewable sources, and especially the trade-off between heating energy and cooling energy, that is particularly important in an office building. Given the use of dynamic simulation and the inherent calculation times, a study based on a limited amount of technically feasible packages of energy efficiency measures, rather than a parametric study, was conducted.

Finally the calculation of the global cost of the RB and of the different packages of EEMs was developed in order to establish which of them has the lowest global cost and, consequently, represents the cost-optimal level. The evaluation was developed in a macro-economic perspective; carbon price were not taken into account. The calculation period was set equal to 30 years. According to the Guidelines [7] the discount rate was fixed equal to 4%. The investment costs of EEMs were evaluated by referring to the price list of the Piedmont Region of 2012 [8].With regard to the data on the duration of the system components and their maintenance cost the reference was made to Appendix A of EN 15459:2007 [9]. According to the European trends until 2030 [10], an annual increase in gas prices of 2.8% and in electricity prices of 2% was taken into account; the inflation rate was also considered and put equal to 2.17%. Subsidies related to renewable sources were considered [11].

Results and conclusions

In order to find the cost optimal level, the primary energy consumption was plotted versus the global cost (**Figure 1**). In the graph, in correspondence to the reference building a vertical line that represents the maximum primary energy consumption was drawn. The position of the EEMs that were studied permitted to draw the trend of dotted broken line that represents the cost curve, the minimum of which may be considered as the cost optimal level.

The analyzed energy efficiency measures allow savings from 6 to 97 kWh/m²y (primary energy) in absolute terms; in percentage terms, savings are between 4 and 58%. In particular, EEMs 8, 5 and 11 (characterized approximately by an energy consumption of 160 kWh/m²y and a global cost of 545 €/m²) allow to achieve the minimum energy savings that can be obtained with the analyzed efficiency actions; these measures considered different levels of roof and ground slab thermal insulation. Instead, the minimum value of consumption is achieved with the EEM20 (69 kWh/m²y and 614 €/m²), which combines the maximum level of thermal insulation of the whole envelope with the introduction of the artificial lighting control (ALC) and the installation of PV panels covering the entire roof.

With regard to the global cost, EEM1 and EEM13 represent respectively the uppermost (649 €/m²) and the lowest (499 €/m²) extreme points. EEM1 consists in a thermal insulation improvement of the whole building envelope according to the current Italian regional regulation; EEM13 doesn't deal with building envelope efficiency measures but consists in the installation of ALC on the reference building. The graph underlines that EEMs have both lower and higher global cost values compared to the RB. Global cost values higher than RB tend to be the ones of the envelope EEMs, because the investment costs for the different efficiency measures cannot be repaid by the economic savings associated with energy savings obtained. Global costs lower than the cost of the RB tend to be associated with EEMs concerning the systems because of their lower investment costs, as shown in **Figure 2**. Indeed, EEMs 13, 15, 21 and 23 have approximately the same value of global

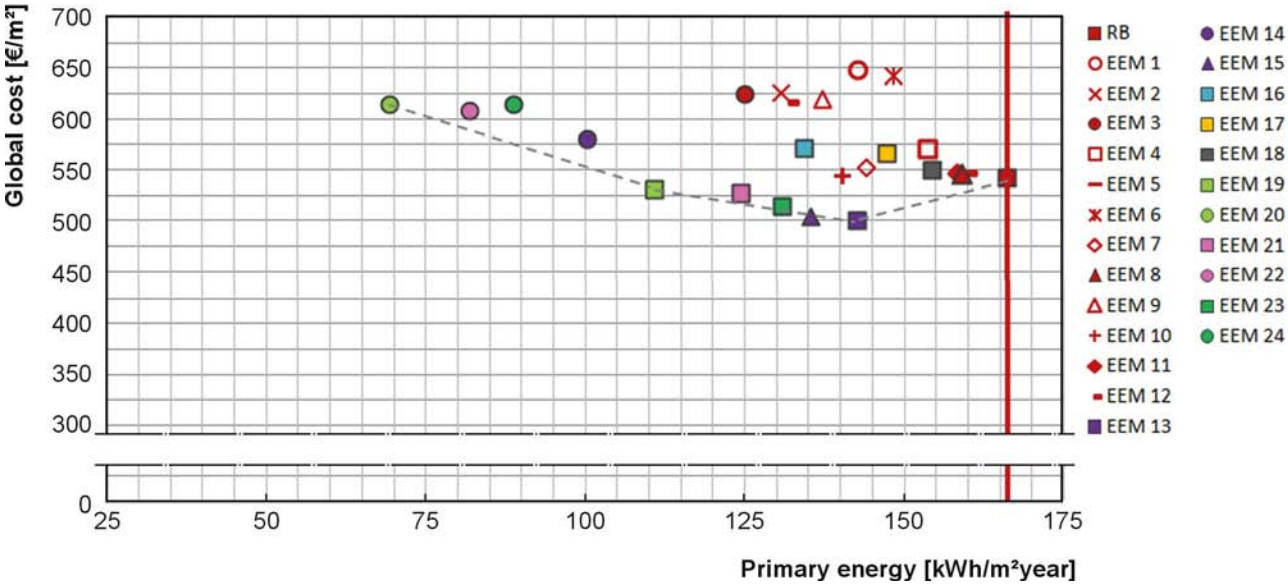

Figure 1. Global cost graph for the existing office.

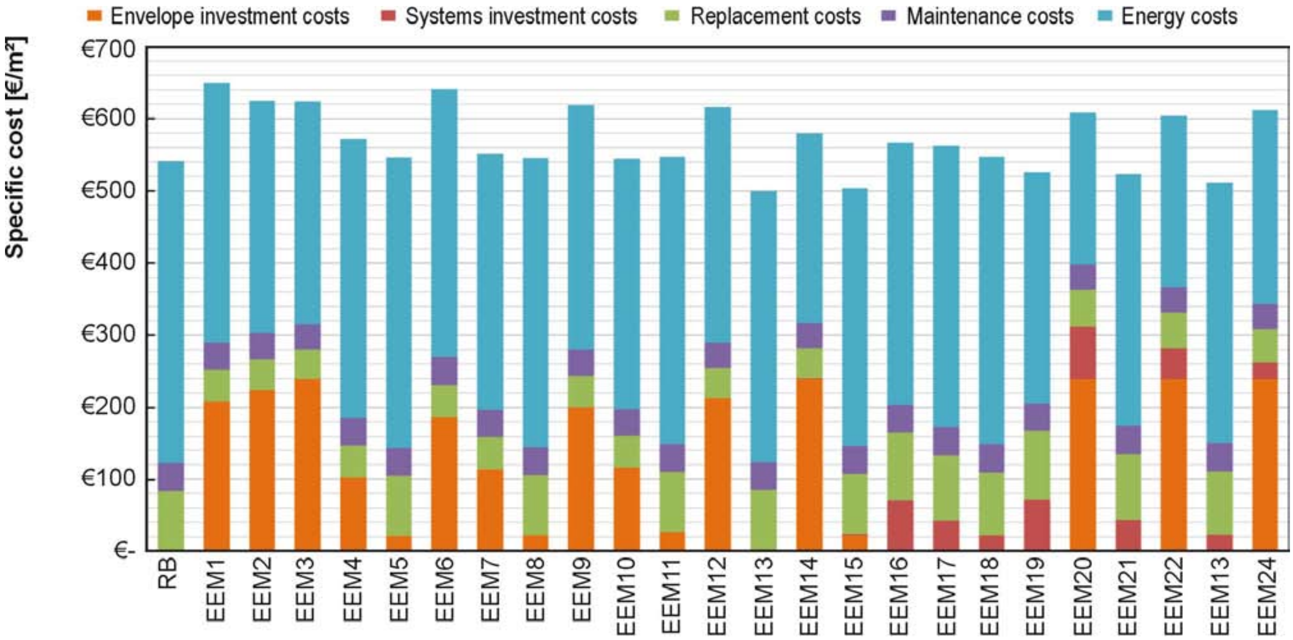

Figure 2. Costs breakdown analysis for Reference Building (RB) and different Energy Effciency Measures (EEMs) for the existing office.

cost, that ranges between 499 and 527 €/m². EEM15 consists in the improvement of roof and ground slab thermal insulation (according to the optional U-values targets set by Italian regional regulations) and in the introduction of ALC; while EEMs 21 and 23 are characterized by the installation of ALC and different PV system configurations. The EEM with the lowest global costs is EEM13 and has a primary energy consumption of 143 kWh/m²y. It does not improve the thermal insulation of the building envelope but considers only the introduction of ALC.

Further studies are needed to simulate different EEMs which combine various levels of thermal insulation for the envelope components (windows, walls, roof, slab) and EEMs related to the building system, and to carry on sensitive analyses on the discount rates and, in particular, on different developments of energy price. ■

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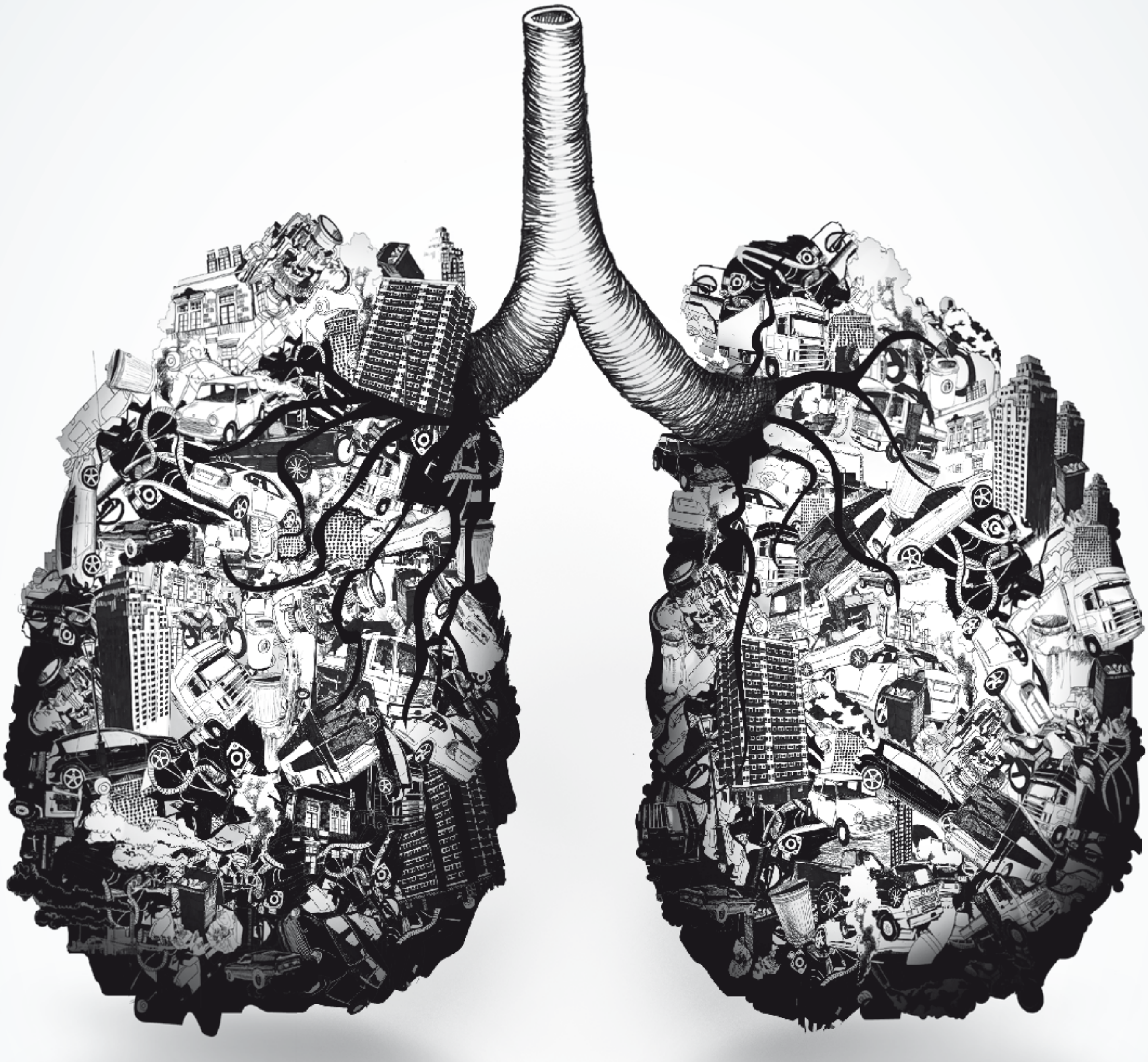

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This article is based on a presentation in the 3ENCULT workshop at Clima 2013 Conference, June 2013, Prague

Special HVAC solutions for the refurbishment of historic buildings

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Introduction

Where space is limited and invasive interventions have to be avoided – be it historic buildings in particular or refurbishment projects in general – particular awareness and special solutions for HVAC systems are needed. Within FP7 project 3ENCULT a number of such solutions have been developed and tested at case studies.

Values and potential in historic buildings

Historic buildings are the trademark of numerous European cities, they are a living symbol of Europe's rich cultural heritage & diversity and reflect the society's identity and need to be protected. They do, however, also show a high level of energy inefficiency and thus contribute with considerable CO_2 emissions to climate change. And they do not always offer "comfort" – to people as well as to artworks contained in them. The research project 3ENCULT (Efficient energy for EU cultural heritage, cofunded by the European Union Seventh Framework Programme FP7/2007-2013, see http://www.3encult.eu/en/project/welcome/default.html) aims at demonstrating that a considerable reduction in energy demand – by factor 4 to 10 – is achievable, also in historic buildings, respecting their heritage value. Besides solutions for the building envelope, such as internal insulation, special HVAC solutions (ventilation with heat recovery in particular) where developed. To demonstrate the application in real buildings, one of the sulutions was realized in a case study (CS5, Innsbruck, Austria).

How HVAC can improve building existing buildings

The following examples show, how HVAC can improve building existing buildings. These solutions are useful not olnly for historic listed buildings but also for refurbishing of other existing buildings. New products, such as flat heat recovery systems are available, which can be integrated in a space saving way at the wall (see **Figure 1**) or ceiling.

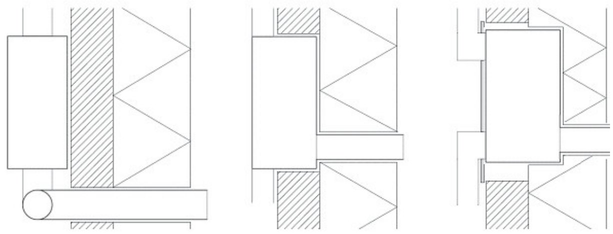

Figure 1. The heat recovery system can be placed at the wall (wall mounted (left)) or in the wall (wall integrated (middle and right)). This way, the outdoor air and the exhaust air duct are as short as possible (cost, energy and space saving).

The advantage of the application of mechanical ventilation systems in historic buildings is not only the high indoor air quality and saving of ventilation losses by heat recovery, but also the low indoor air humidity to be guaranteed during the heating season. This is an important boundary condition, especially if internal insulation is applied. Damages by humidity and mold growth can largely be avoided.

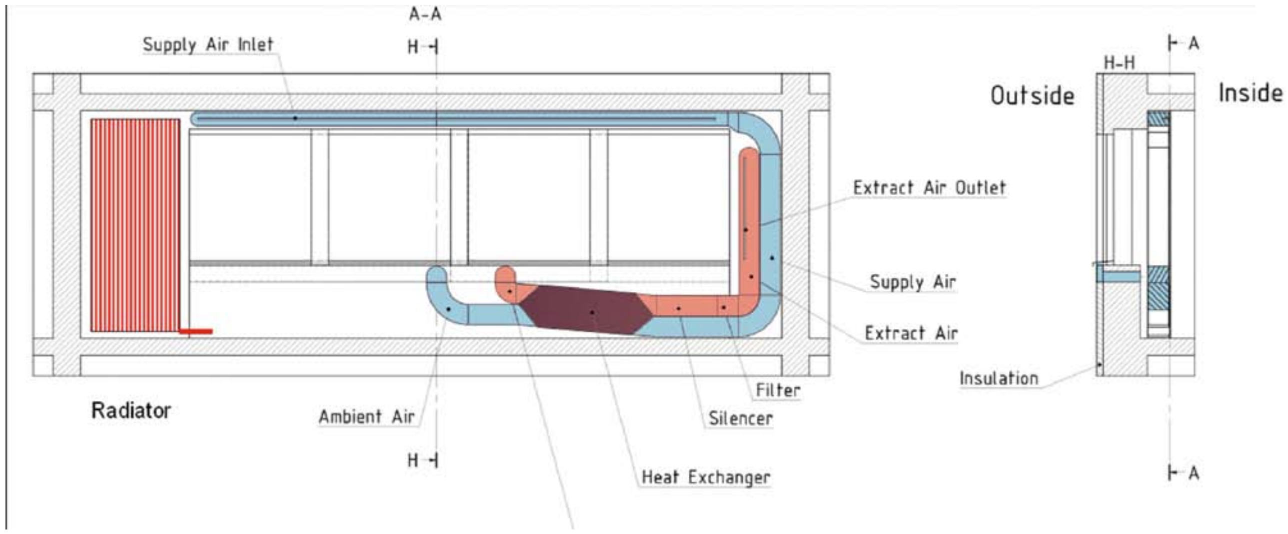

Figure 2. Wall integrated decentral ventilation system for school buildings (supply air inlet at the window lintel, extract air outlet besides the window.

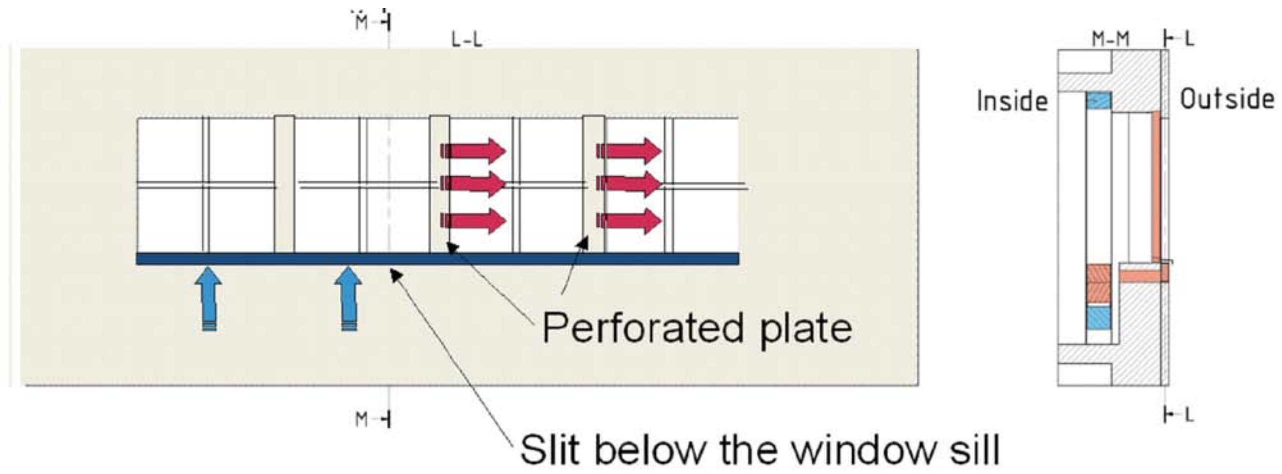

Figure 3. Wall integrated decentral ventilation system (view from outside). Exhaust air outlet via perforated plate, outdoor air inlet via slit below the window sill.

Decentral versus central mechanical ventilation

Decentral systems can help to avoid ductwork (horizontal and vertical distribution ducts). The drawback is the number of holes to be drilled for outdoor and exhaust air ducts (see **Figure 2**).

A flat counter flow heat exchanger can be mounted at the parapet, whereas the supply air inlet and the exhaust air outlet are placed above and besides the window respectively. In order to avoid any grill at the façade for ambient air intake, a slit below the window sill can be applied. For exhaust air outlet, this possibility is not valid, because condensation and freezing problems at the wall surface would occur. Therefore a perforated plate or a cover plate in front of the window post is suggested as exhaust air outlet (see **Figure 3**).

The suggested design can be realized for buildings where an external insulation is applicable. In this case, the flat air ducts for ambient and exhaust air can be integrated in the insulation layer. After finishing the plaster (outside) and dry walling (inside), no ductwork is visible

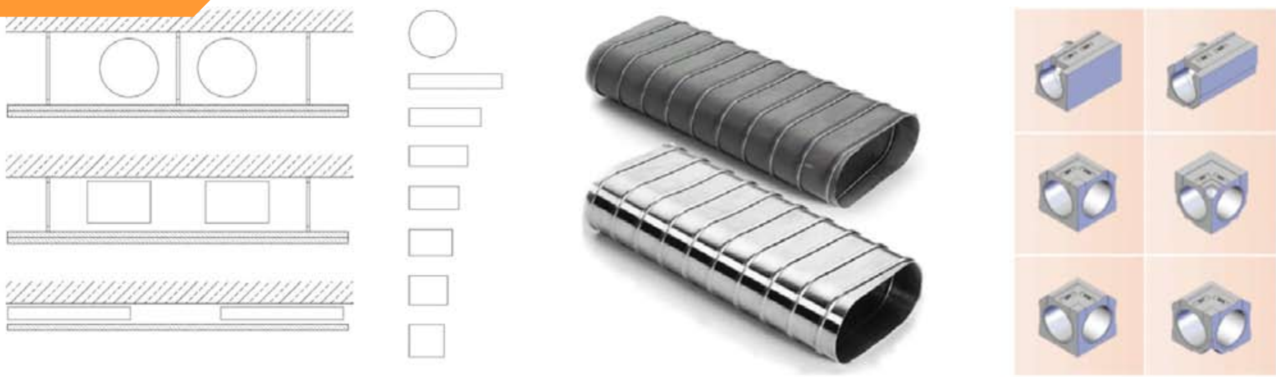

Figure 4. Reduced clear height of suspended ceiling by application of rectangular silencers (left). Pressure drop equivalent cross sections of round and flat ducts (second left); Special ductwork for integration in existing buildings (right).

from both sides. For most of the listed buildings however, no external insulation is appropriate. In those cases a central heat recovery should be preferred.

Vertical ducts with a horizontal distribution at the attic might be a good compromise for historic buildings. Suspended ceilings have to be avoided, if the original height of the room and/or the original state of the original ceiling itselve is to be preserved.

Special ductwork for renovation

Flat ducts and prefabricated ductwork helps to integrate ventilation systems in existing buildings, where space for installations is limited. It was shown, that the pressure drop of flat ducts can be equivalent to round ducts with slightly higher cross section area. New products especially for the refurbishing market are available (see **Figure 4**).

As shown in **Figure 4** (left), the cross section of a flat duct can be chosen in such a way, that the pressure drop per meter is equivalent to that of a circular shaped ducts. With this space saving design, the ducts can be placed behind a suspended ceiling without changing the clear height of the room significantly.

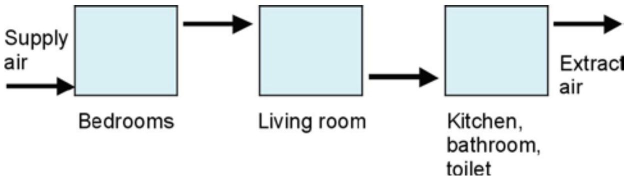

Figure 5. Principle of cascade ventilation (supply air only in bedrooms, living rooms are regarded as overflow zones).

Figure 6. Active overflow ventilation in prototype class room in Innsbruck, air inlet via textile diffuser and fan from corridor (preheated supply air from central heat recovery unit at the attic without duct via staircase and corridor).

Principle of cascade ventilation

The principle of cascade ventilation is to guide the air from the sleeping room via overflow openings to the living rooms and the corridor to the extract air rooms (such as toilet, bathroom and kitchen). This principle helps to avoid ductwork and to build energy and cost efficient ventilation systems (see **Figure 5**).

Principle of active overflow ventilation – adapted to school buildings

This principle is frequently used for residential buildings, within the 3ENCULT project, it was transferred to the use in school buildings (see [Pfluger 2013a]. A fan is used to duct the air from the corridor to the class rooms and back again (see **Figure 6**). A central heat recovery unit, placed at the attic, takes the air from the toilets and wardrobes for preheating the outdoor air, which is ducted to the staircase. This way, vertical and horizontal ducts can be avoided, because the staircase and corridors are used as a duct.

Coaxial duct system for ambient-/exhaust air

Coaxial duct systems, developed by University of Innsbruck can help to minimize the number of holes through the external walls The outdoor air is ducted through the annular gap whereas the exhaust air flows through the central duct (see **Figure 7**). As shown by ▶

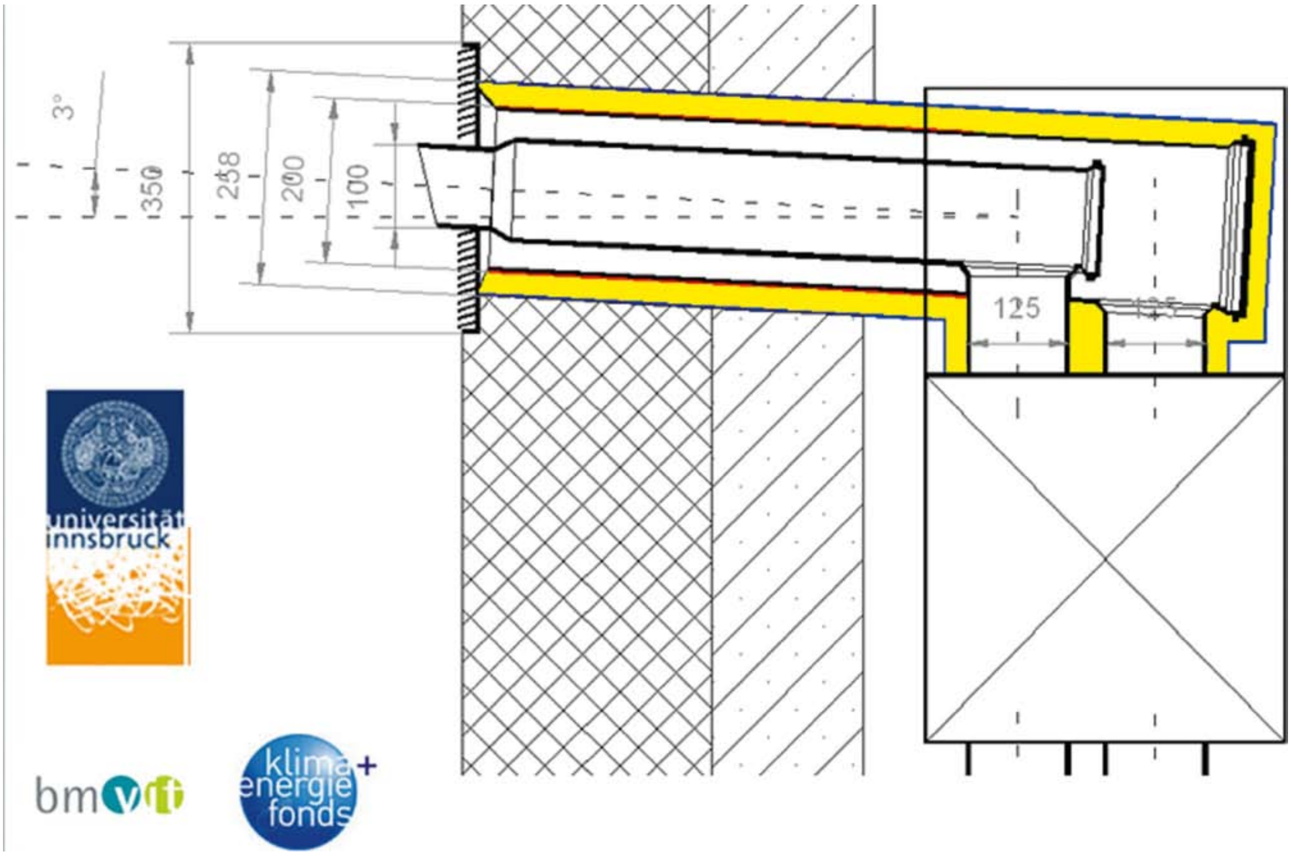

Figure 7. Coaxial duct for outdoor air intake and exhaust air outlet developed by University of Innsbruck within the research project low_vent.com; prototype built by company POLOPLAST.

▶ tracer gas measurement, there is no danger of short circuit flow from exhaust air outlet to outdoor air inlet.

The use of coaxial ducts in ventilation systems was published in [Pfluger 2013b].

Combined fan and heat recovery

New types of space saving heat recovery systems will help to integrate high efficient ventilation systems in existing buildings. The innovative development of a combination of fan and heat exchanger (see **Figure 8**) by University of Innsbruck is an example of that type of unit which can be integrated in the external wall. This will help to save space, energy and money.

A detailed description of the system as well as the calculations and results are given in [Pfluger 2013c]. ■

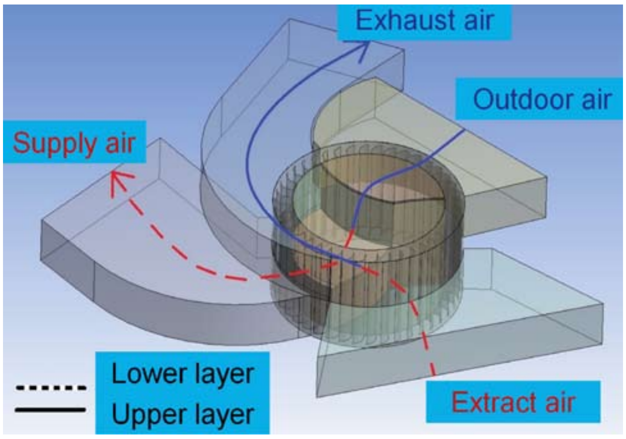

Figure 8. Heat recovery fan developed by Univerity of Innsbruck within the research projekt Vent4Reno (INTERREG)

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Acknowledgement

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News flash: Windsor Conference 2014

10th- 13th April 2014, Cumberland Lodge, Windsor, UK

The 8th Windsor Conference will focus on bringing the academic comfort research into the real world context.

Themes for 2014 include

1) Comfort and productivity
2) Occupant behaviour
3) Modelling
4) Simulation and monitoring
5) The future of comfort research

ABSTRACTS: Contributing authors should submit an abstract of no more than one page to the organising committee **30th October 2013**.

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French building regulation sets 50 kWh/(m²a) a limit for primary energy use

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Foreword

Since 1974 several regulations have progressively strengthen thermal performances of buildings in France. But the latest one called RT 2012 based on requirements settled by the 2008 national convention "Grenelle de l 'Environnement" is a significant step towards nZEB buildings.

RT 2012 which has been in force since January 1st, 2013 applies to all new heated or cooled buildings, except

- provisional buildings
- buildings heated with an indoor temperature lower than 12°C
- buildings heated or cooled for other reasons than comfort, for example industrial processes
- farms
- churches
- buildings located in French overseas territories.

General

Three main requirements

RT 2012 building regulation includes mainly three major requirements which must be respected simultaneously.

1. The first one deals with the intrinsic features of the structure and the envelope of the building without considering the HVAC system and other technical facilities. Such features are specified with the **Bbio Factor (bioclimatic needs factor).**

2. The second one involves the maximum permitted **annual consumption of primary energy** of the building taking into account performances of HVAC system, DHW production and, if any, artificial lighting through the **Cep factor.**

3. The third corresponds to requirement for thermal comfort in summer based on the compliance with a maximum comfort calculated temperature Tic.

RT2012 also includes some specific prescriptive requirements (see example in the end of the article).

Two main categories of buildings

Two main categories of buildings are considered in the RT 2012 regulation.

Category CE2

Buildings belonging to category CE2 mainly depends on the usage type of the building, noise exposure and geographical location. It is defined in detail in the decree. Basically buildings built in noisy areas where it may be necessary to install air conditioning system in order to ensure thermal comfort in summer while the windows are kept closed are allowed to be included in category CE2.

Roughly it can be considered that dwelling, school and office buildings located in noisy areas in the hottest regions of France falls within CE2 category.

Category CE1

All others buildings belong to category CE1.

Bbio Factor

Bbio factor is a dimensionless number expressed by a number of points calculated using the following relationship:

Bbio =
2 x (Heating needs + Cooling needs) +
5 x (Artificial lighting needs)

in which heating, cooling and lighting needs of the building, are calculated by an hourly dynamic analysis software.

Energy consumption of ventilation system and lighting facilities are based on conventional values included in the software.

Bbiomax
Bbiomax is the maximum permissible value of *Bbio* for a given building project, the regulatory requirement being

Bbio building project < *Bbiomax*

Bbiomax satisfies the following relationship:

$$\text{Bbiomax} = \text{Bbiomaxmoyen} \times (Mb_{geo} + Mb_{alt} + Mb_{surf})$$

where
- *Bbiomaxmoyen* is a coefficient depending the use and the category (CE1 or CE2) of the building
- Mb_{geo}: geographical location coefficient
- Mb_{alt}: altitude location coefficient
- Mb_{surf}: a modulation factor, in terms of surface of the premises. Mb_{surf} is only used for housing, commercial buildings and sports halls.

For example, in case of sports halls building, Mb_{surf} is given by the following rule:

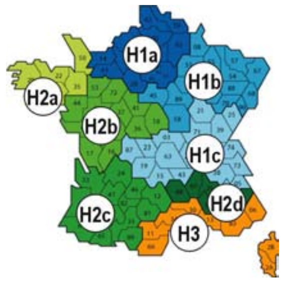
If Building Floor Surface (*BFS*) ≤ 1 000 m² then $Mb_{surf} = -0.008 \times BFS + 0.8$.

If *BFS* > 1 000 m² then $Mb_{surf} = 0$

Bbio factor for an office building
- *Bbiomax* = 70 if the building belongs to category CE1, *Bbiomax* = 140 for category CE2.
- $Mb_{surf} = 0$
- Mb_{alt} (altitude location coefficient):

Altitude	Mb_{alt}
From 0 to 400 m	0
From 401 to 800 m	0.1
801 m and over	0.2

The values of Mb_{geo} (geographical location coefficient) are given in the table below depending on the area in the map:



Category	Geographical areas							
	H1a	H1b	H1c	H2a	H2b	H2c	H2d	H3
CE1	1.10	1.20	1.10	1.10	1.00	0.90	0.80	0.80
CE2	1.00	1.00	1.00	1.00	1.00	1.00	1.20	1.20

Cep coefficient

Cep coefficient represents the conventional annual consumption of primary energy of a building, reduced to the floor surface. The counting of floor surface is stated in a government ordinance.

Only two primary energy factors are applied, for electricity 2.58, and for all other fuels 1.

Cep, expressed in Watts_{ep} /m² per year takes account energy used to meet the following needs of the building:

- heating
- cooling
- domestic hot water
- lighting
- auxiliaries (fans , pumps).

If any, energy produced on-site from renewables may be deducted from the calculation of *Cep*.

Regulatory requirement
The regulatory requirement is met if:

$$Cep \leq Cep_{max}$$

Cep_{max} is defined with the following equation:

$$Cep_{max} = 50 \times Mc_{type} \times (Mc_{geo} + Mc_{alt} + Mc_{surf} + Mc_{GES})$$

Where:
- Mc_{type} is a coefficient depending the type and the category (CE1 or CE2) of the considered building to which it belongs
- Mc_{geo} is geographical location coefficient
- Mc_{alt} is altitude location coefficient
- Mc_{surf} is a coefficient depending the floor surface for housing, commercial buildings and sports halls
- Mc_{GES} is a coefficient depending on the greenhouse potential of the fuel used.

Typical values of Mc coefficients

Housing buildings

Values of the various coefficients which have to be used in the Cep_{max} relationship, for housing buildings, are given below.

- Mc_{type} = 1
- Mc_{geo} values, depending on the region of the country, are given in the table below:

Geographical area

	H1a	H1b	H1c	H2a	H2b	H2c	H2d	H3
Mc_{geo}	1.20	1.30	1.20	1.10	1.00	0.90	0.90	0.80

- Mc_{alt} (altitude coefficient) depends on the altitude of the building location:

Altitude	Mc_{alt}
From 0 to 400 m	0
From 401 to 800 m	0.2
801 m and over	0.4

- Mc_{surf} is given by formula, depends if it is a detached house or a collective residential building
- Mc_{GES} is fuel greenhouse potential
- Wood fuel Mc_{GES} = 0.3
- When building is linked to a District Heating Network Mc_{GES} = 0 to 0.3 (depending the fuel used for the district heating plant)

Case of office buildings

- Mc_{type} = 1.4 if building belongs to CE1 category, 2.2 if CE2 category
- Mc_{geo} = values depend on both region of location and category of the building:

Geographical area	Category	H1a	H1b	H1c	H2a	H2b	H2c	H2d	H3
Mc_{geo}	CE1	1.10	1.20	1.10	1.10	1.00	0.90	0.80	0.80
Mc_{geo}	CE2	1.00	1.00	1.00	1.00	1.00	1.00	1.20	1.20

- Mc_{alt} (altitude coefficient) depends on the altitude of the building location:

Altitude	Mc_{alt}
0 to 400 m	0
401 to 800 m	0.1
801 m and over	0.2

- Mc_{surf} = 0
- Mc_{GES} When building is linked to a District Heating Network = 0 to 0.3 (depending the fuel used for the district heating plant)

Maximum Cep values for individual houses and non air-conditioned office buildings

The figures below show the maximum permitted values of Cep_{max} for individual houses and non-air conditioned office buildings (CE1 category) depending the geographical region. On sea level altitude = 0 m, in the case with Mc_{GES} = 1.

Individual houses:

Non air conditioned office buildings:

Maximum indoor temperature

The third performance requirement set by the new regulation is the respect of a maximum indoor operative temperature called *Tic* (for "Temperature intérieure conventionnelle"). This requirement is only requested for non air-conditioned buildings.

Tic is calculated by a module of the regulation software. Corresponding requirement is that hourly calculated value of Tic might not be upper than Tic_{ref}.

Tic_{ref} can never be less than 26°C.

The calculation method of Tic_{ref} is being revised. A new version should be available in the coming months.

Complementary prescriptive requirements

Besides the three main performances requirements described above some wherewithal exigencies are listed in RT2012.

Some of them are given below as examples.

- **Thermal insulation of walls**

Albeit the thermal quality of the building envelope is already considered in the *Bbio* coefficient some complementary exigencies are intended:

- **U-value of a wall separating** an unheated room and an heated room must not be higher than 0.36 W/m²K
- **Overall linear thermal transmission ratio** (thermal bridges) of the whole building must be less than 0.28 W/m^2_{floor} K:

$$\Sigma(\Psi,L) \ / \ m^2_{\text{Building overall floor surface}} < 0.28 \ (W/m^2_{Floor}K)$$

- **Thermal bridges between** intermediate floors and facades less than 0.6 W/m K

- **Air tightness of the building envelope**

Airtightness of the building envelope measured according to EN 13829 measuring method (Blower door) must be in accordance with the values of the next table.

	Q ($m^3/h,m^2$)
Individual or attached houses	0.6
Collective housing buildings	1.00

It must be underlined that surface being considered is that of internal walls, floor surface being excluded.

- **Natural lighting**

For housing buildings the total windows area must be more than 1/6 of the floor surface area of the flat.

- **Thermal comfort in summer**

In bedrooms Solar Heat Gain Coefficient of the windows is limited according to the orientation of the façade. Lower values of *SHGC* are required when the building is located in a noisy area.

Application of the regulation

All calculation must be compulsorily performed by an authorized software based on the official rules Th BCE-2012 established by Centre Scientifique et Technique du Bâtiment (CSTB). ■

Next Ventilation Conference in Shanghai China October 2015

Ventilation 2015

The 11th International Conference on Industrial Ventilation will be in Shanghai, China from October 26 to 28, 2015, organized by Tongji University and VTT Technical Research Centre of Finland, co-organized by Tsinghua University. Four main topics of the conference are:

- Occupational Health
- Ventilation and Sustainable Development
- Specialized Applications and Clean Air Technology
- Design and Control

You are invited to submit an abstracts (300–400 words) via online webpage http://www.ventilation2015.org. The abstract template and further information can be found also later on the website. October, 1, 2014 is the abstract submission deadline and May, 1, 2015 is the final paper deadline.

The Ventilation 2015 Conference will offer a platform to scientists, researchers, professionals like consultants, engineers, designers and architects together with policymakers for the exchange of scientific knowledge and technical solutions. The Ventilation conference will also offer the opportunity to view the state-of-the-art ventilation technologies. In addition, Shanghai as the conference place is the largest city of China, situated at the Yangtze River Delta, with East China Sea in the east and Hangzhou delta in the south. It is a very beautiful and prosperous city. It is a shining pearl in China as well as in the world. We are looking forward to meeting you in the Ventilation 2015 conference in Shanghai, China.

October 26-28, 2015, Shanghai, China

Heat pump options for low energy office buildings in cold climate

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Introduction

In order to achieve ambitious targets for energy efficiency and zero energy/emission buildings (ZEB), various combinations of energy-efficient technologies have been highly recommended. A trend in Norway is that all new buildings will be built according to the passive building standard. Low-energy buildings require application of energy-efficient technologies like high quality building insulation, energy-efficient building services, and high level of heat recovery. Also, there is a requirement that energy supply systems for the new buildings should be based on renewable energy. Therefore, it is important to analyze energy performance of the building integrated with renewable technologies. To achieve the full potential of energy efficient solutions, it is necessary to study the economic and technical feasibility of the complete energy system.

Heat pump water systems are a promising technology in both residential and commercial applications. Ground coupled heat pump system is also a very effective energy saving technology. The effectiveness of such plant is proven by performing detailed measurements in [1]. There have been several research studies related to solar assisted heat pumps since 1976 [2]. For example, in the work of Trillat-Berdal et al. [3] an experimental study of a ground coupled heat pump combined with a thermal solar collector is presented for residential purposes. The optimally designed solar assisted ground coupled heat pump for domestic hot water and space heating can obtain 36% of the annual space heating from solar and 75% of the annual domestic hot water [4]. However, practitioners and building users are skeptical to novel ideas regardless of the trends for new energy supply solutions, because a lack of documentation on the best practice experience in new technologies [5]. Therefore, it is necessary to study and document such solutions of good practice.

The aim of this study was to define energy supply solutions for a new low-energy office building in cold climates. Heat pump and solar supported heat pump systems were considered relevant energy supply solutions. The following four solutions were analyzed: an air-to-water heat pump, a geothermal water-to-water heat pump, a solar assisted air-to-water heat pump, and a solar assisted geothermal water-to-water heat pump. The working fluid in the heat pumps was R-410A. Since it is not economical feasible to let a heat pump cover all the building heating requirements and heat pump operation is not good under a highly variable load, an electrical boiler was used to cover peak load. The analyzed building is equipped with a variable air volume (VAV) system and a hydronic heating system. In order to minimize the installation cost of the building energy service system, an integrated solution with a VAV box and ceiling heating was implemented. Since *EnergyPlus* is able to simulate heat pump solutions and the building service system, it was chosen as the simulation tool in this study. Improvements in the heat pump and the ventilation control were also analyzed.

Case study

A new low-energy office building located in the south of Norway was analyzed by using *EnergyPlus*. The case study is a 3 000 m² office building on the coast in the Mandal municipality in the south of Norway. The building is in use since recently and the tenants have moved in. The sizing conditions for Mandal are the following: heating degree day is 3 266°C·h at 20°C indoor temperature; the average annual outdoor temperature is 6.9°C; and design outdoor temperature is −19°C [6]. Solar radiation data used for the simulation are provided from [7]. The total solar yearly radiations per m² for different orientations are the following: at the east side 418 kWh/m², at the west side 460 kWh/m², at the north side 262 kWh/m², and at the south side 644 kWh/m². The building was planned for 100 users. The building is shown in **Figure 1** [8].

Figure 1. Office building in Mandal. [8]

The idea in this project was to implement high quality building insulation better than the Norwegian passive building standard, with U-values of 0.71 W/m²K and 0.1 W/m²K for windows and walls respectively. Infiltration was chosen to be 0.5 1/h which was also based on the Norwegian passive building standard [9].

In order to minimize the installation cost of the building energy service system, an integrated solution with a VAV box and ceiling heating was implemented. This way, ventilation and hydronic heating was installed as one device in the ceiling of each office. This installation with the integrated heating and ventilation system has been developed by a contractor company [10]. The water heating system was design to perform with supply/return temperature of 40/35°C. The energy supply system including the heat pump and the electric boiler is shown in **Figure 2**. It was drawn based on a display figure from the building energy management system. Since the building is recently in use, some changes might appear in the future. Therefore, the energy supply solution as in **Figure 2** should not be considered as the final.

In this study, it was assumed that air handling unit consisted of the following elements: an inlet and an outlet damper, a supply and an exhaust fans, filters, a high capacity rotating heat exchanger and a heating coil. Cooling coils were avoided to decrease building energy use and to simplify air handling unit. The idea was to perform night air cooling with the ventilation air. An air flow rate of 6 m³/hm² during working time and 1 m³/hm² during non-working time were assumed, based on the Norwegian passive building standard [9].

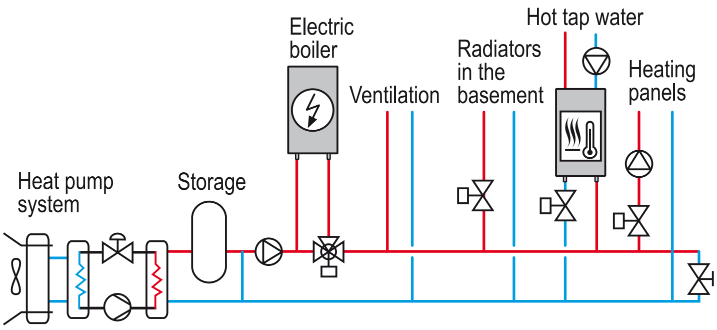

Figure 2. Energy supply system.

Operation of the heat pump in the low energy office building

In order to find suitable energy supply solution for the analyzed low-energy office building, operation parameters and energy use were analyzed. Consequences of the heat pump control strategy on the load duration curve distribution are shown.

Based on the HVAC heating demand and heat pump manufacturer data, the following heat pump performance was chosen: for the air-to-water heat pump a nominal heating capacity of 57.4 kW and COP 3.9, and for the water-to-water heat pump, a nominal heating capacity 50.8 kW and COP 5.6.

Night setback is recommended as a simple energy-efficiency measure. However, dynamic operation with a highly variable load is not preferable for a heat pump. Therefore, control strategies, with night setback and without night setback, were tested. The strategy without night setback assumed a constant indoor temperature. The results of this analysis are shown in **Figure 3** for the air-to-water heat pump.

The night setback strategy required the high peak effect in the morning when the indoor temperature was increased, as shown in **Figure 3**. This peak effect was provided by the additional electricity boiler as explained in Introduction. The constant indoor temperature neither caused a high electricity peak or a high heat pump effect. The consequences of the night setback on the total energy use for the HVAC system can be noticed in the duration curve in **Figure 4**. Further, the results of the control strategy without the night setback are shown in **Figure 5**.

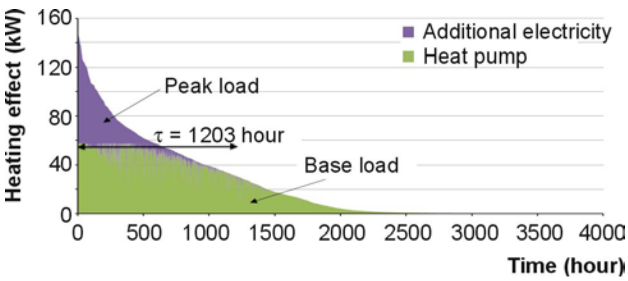

Figure 4. Duration curve for air-to-water heat pump with night setback.

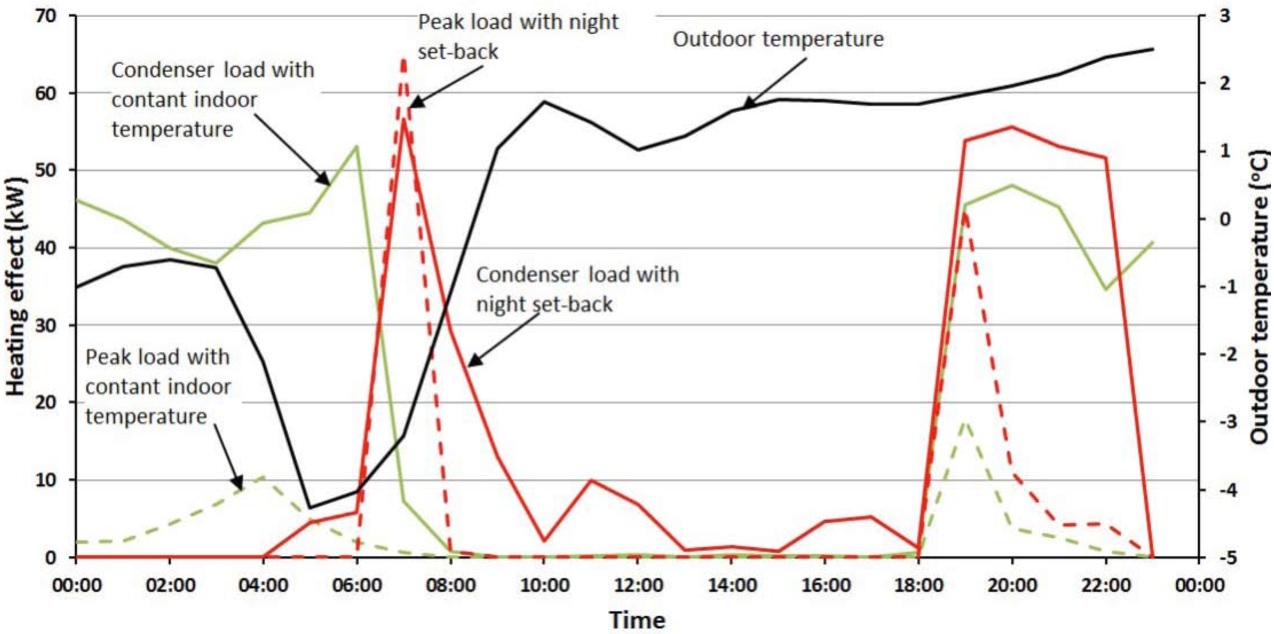

Figure 3. Control strategy for heat pumps.

The duration curve in **Figure 4 and 5** are valid for the air-to-water heat pump. In **Figure 4**, it is possible to notice that the part of energy supplied by the additional electricity boiler is considerably big compared to the total energy use for the HVAC system. Further, the utilization time of only 1203 hours for the heat pump is low. For the same heat pump with constant indoor temperature, the utilization time was 1 775 hours and electricity use was lower as shown in **Figure 5**.

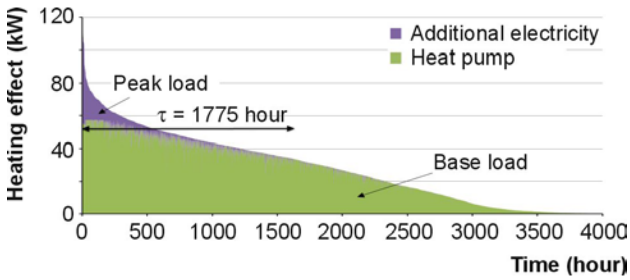

Figure 5. Duration curve for air-to-water heat pump without night setback.

To fully utilize the heat pump technology possibilities and avoid unnecessary use of the electric boiler, the control strategy without night setback was preferable. This conclusion could be relevant for other building types supplied by heat pumps. The summarized results on the utilization time and the total energy use for HVAC for air-to-water and water-to-water heat pumps are shown in **Table 1**.

Since the results in **Table 1** show that the constant indoor air temperature influenced the heat pump operation positively, the constant air temperature was implemented further in the study. The positive influence on the heat pump operation meant that the heat pump utilization time was longer, while the total electricity use for HVAC was lower. The analyzed heat pumps achieved a COP of 2.2 to 5 during a year.

Table 1. Utilization time and total energy use of the heat pumps.

Heat pump	Control strategy	Utilization time (hour/year)	Heat pump electricity use (MWh/year)	Additional electricity use (MWh/year)	Total electricity use (MWh/year)
Air-to-water	Night setback	1203	15.9	21.9	37.8
Air-to-water	No Night setback	1775	24.2	9.1	33.2
Water-to-water	Night setback	1276	15.0	25.1	40.1
Water-to-water	No Night setback	1927	22.8	13.0	35.8

Discussion

The techno-economic analysis of the energy supply solutions was performed by using the net-present value (NPV). The lifetime of 20 years was assumed for the air-to-water heat pump, while 40 years for the water-to-water heat pump because of the borehole installation. The real interest was assumed to be 6%. In the NPV method the complete electric heated building was the reference case. The investments for the analyzed technologies were: 246 000 Norwegian krone (NOK) for the air-to-water heat pump, 425 000 NOK for the water-to-water heat pump including the borehole installation and the heat exchanger, and 3 050 NOK/m² for the solar collectors. The electricity price was about 1 NOK/kWh [11]. 1 EUR = 7.36 NOK at date. To estimate the analyzed solutions, an average global electricity price increase up to 50% was considered. The results on the techno-economic analysis are shown in **Figure 6**.

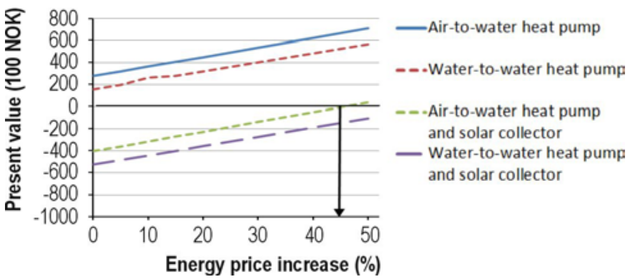

Figure 6. Techno-economic analysis.

The techno-economic analysis showed that the best energy supply solution seemed to be the air-to-water heat pump without solar assistance, **Figure 6**. A 50% increase in the energy price could mean the solution with the solar assisted air-to-water heat pump become attractive. This energy price increase is higher than the predicted of 15% in [14]. A similar trend might be predicted for other building types under the same economic conditions, because the relative ratio between the savings and the total energy use would be similar. A low-energy building has low energy demand, while a building with high energy demand would require a bigger energy supply plants.

Conclusions

The energy supply solutions for a new low-energy office building in cold climates were analyzed. The results show that an increase in ventilation air flow was necessary during the summer in the new low-energy office building. The control strategy without night setback was preferable for the heat pump technology and to avoid unnecessary use of the electric boiler. Since excess solar energy was not injected into the ground as in [3, 4], the potential of the totally received solar energy of 20 MWh/year was not utilized. The techno-economic analysis showed that the best energy supply solution seemed to be the air-to-water heat pump without solar assistance under the assumed economic assumptions, while a 50% increase in the energy price could make the solution with the solar assisted air-to-water heat pump economically attractive. For other building types similar energy supply solutions could be relevant, under the same economic conditions. ■

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Frost-protection measures in energy recuperation with multiple counterflow heat exchangers

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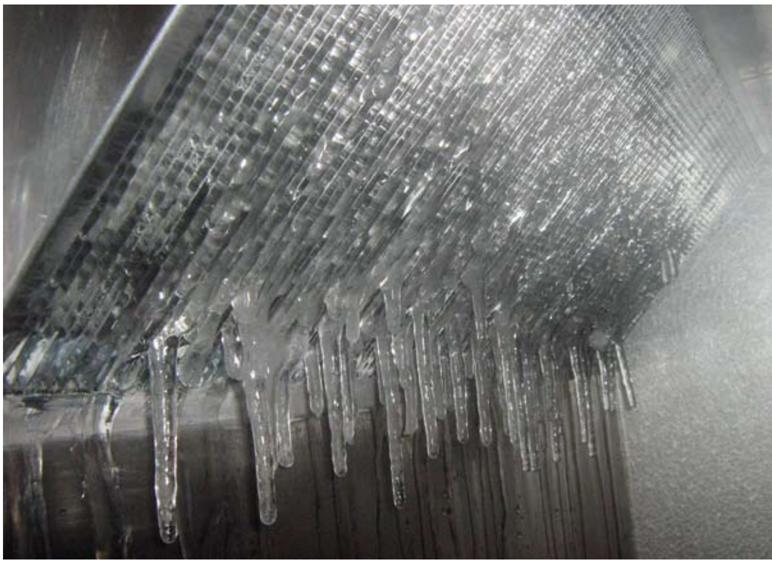
Manufacturers of air handling units (AHUs) continuously improve the electrical and thermal efficiency of their systems. These efforts include the optimization of energy recovery. The new GEA multiple counterflow principle is intended to achieve high energy-recovery coefficients in conjunction with low pressure drop. Additionally, the new system allows a bypass cycle that prevents pressure drop in the energy-recovery system with free cooling – and offers various possibilities for frost protection. The authors describe the energy costs of several frost protection solutions, in accordance with various climate conditions.

Energy-recovery systems in air handling units (AHUs) now on the market can in some cases already satisfy the high levels of heat-recovery efficiency stipulated by the upcoming ErP Directive. It is important to note, however, that greater heat-recovery efficiency – as a rule – is also associated with greater pressure drop, with negative effect on power consumption. In addition, increasing heat-recovery efficiency will cause extract air to be cooled nearer to the outdoor temperature. This extract air has greater humidity than the outdoor air. On winter days with freezing temperatures, condensate from the extract air may develop on cold surfaces of the energy-recovery system. High heat-recovery efficiencies and therefore lower outgoing air temperatures accordingly raise the risk of ice formation in the energy-recovery system. This, in turn, leads to reduced effectiveness and to even greater pressure drop. The objective is therefore to reach a satisfactory compromise among high levels of heat recovery, low pressure drop, and effective frost protection, to enhance the total efficiency of an air handling unit.



An iced-up energy-recovery system reduces heat-recovery efficiency and increases pressure drops. Effective frost-protection strategies are therefore crucial for efficient operation of an energy-recovery system on cold winter days.

Multiple counterflow heat exchangers

This new energy-recovery system should offer a high heat-recovery coefficient and, at the same time, should be easily kept free of ice. Also desirable here is an energy-recovery system that can be simply circumvented in free cooling mode, so that the system does not cause pressure drop in the transitional period. The GEA multiple counterflow heat exchanger, now in development, offers all these characteristics with a heat-recovery coefficient of more than 80%.

The GEA multiple counterflow heat exchanger is based on a solution with several layers or levels, and with a modular-configured counterflow principle (see **Figure 1**).

If use of the energy-recovery system is not essential, the bypass flaps open on the supply-air and on the extract-air side, and the air flows unimpeded pass the energy-recovery heat exchanger – for example, in free cooling mode. During operation of the energy-recovery system, typical pressure drop can be expected at the order of magnitude of Δp = 80 – 140 Pa (at an AHU face velocity of 1.5–2 m/s).

One energy-recovery system but many possible frost-protection measures

Multiple counterflow technology offers a selection from various feasible continuous frost-protection variants. Alternatives 1–5 are described and illustrated below.

1. Opening of the outside-air bypass (**Figure 1**), in accordance with the value given by a surface-temperature sensor, with setpoint value ≥ 0°C.
2. Configuration as shown in **Figure 1**; but instead of a fixed setpoint ≥ 0°C, the system takes the dewpoint temperature of the extract air into account. If there is no risk of condensation in the extract air, frost protection remains out of operation.
3. Preheating of the outside air, without re-heater. Before its entry into the multiple counterflow heat exchanger, the outside air is pre-heated to –2°C. (**Figure 2**).
4. Preheating of the extract air, to prevent the outgoing air temperature from falling below 2°C. (**Figure 3**)
5. Recirculation of outside air for preheating of this air to –2°C before entry into the multiple counterflow heat exchanger, by admixture of supply air (**Figure 4**).

The selection of the most effective frost-protection strategies to be used will depend in good part on the climate conditions of the installation location. The following will illustrate these interrelationships by describing simulation of the various frost-protection strategies for different climate conditions. Simulations are based on the following data:

- GEA CAIRplus® SX 096.064 AHU
  - Maximum air flow: 4,000 m³/h
  - Air velocity in free cross-section: approx. 1.8 m/s
  - Energy recovery system: GEA multiple counterflow; heat-recovery coefficient 0.807 at balanced air flows

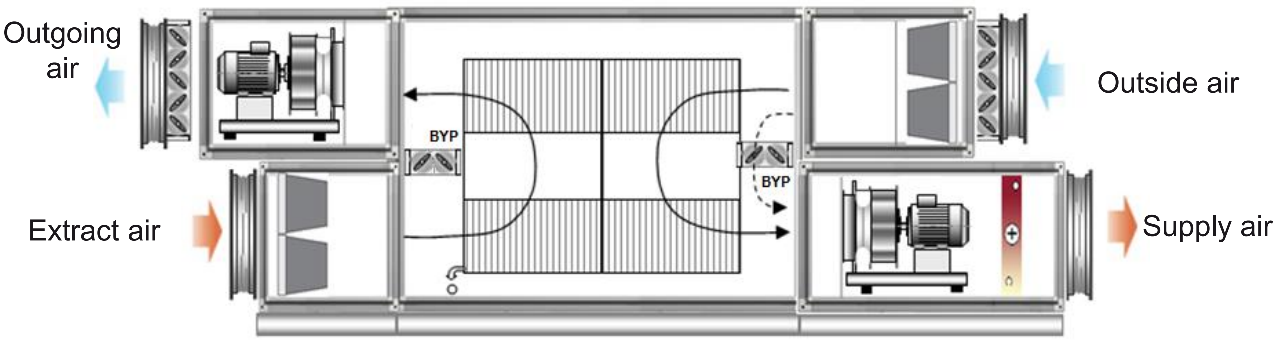


Figure 1. Frost protection by ourdoor air bypass.

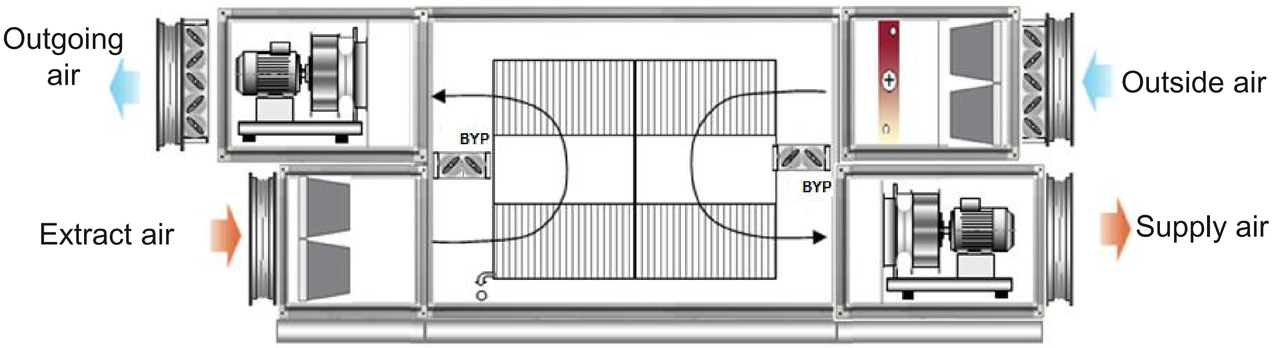


Figure 2. Frost protection with preheating of outdoor air.

- No cooling coil
- Fan efficiency: 60%

- Additional equipment for frost-protection types 3 to 5: secondary-circuit pump for the heater
- Operation: 8,760 h/a at full load
- Supply-air temperature: 17.7°C; extract-air temperature: 22°C
- Humidity load: + 1.5 g/kg

Energy prices were assumed to be 0.06 €/kWh for heat and 0.18 €/kWh for electricity.

Cost of frost protection alternatives in various locations

Barcelona, Spain

At the Mediterranean location of Barcelona, the outside temperatures are so high that, even on winter days, frost protection is not necessary.

Frankfurt am Main, Germany

The simulation situation for Frankfurt am Main is more differentiated. The most expensive frost-protection variant was no. 4, with extract-air preheating, in which the heating and power costs added to 3,773 €/a. This variant is not practically relevant, since heating of the extract air to 54.3°C would be necessary. The supply-air temperature would in this case rise to 42°C. To reduce the flow of supply air to comfortable temperature levels, the air would have to be cooled – or cold outside air would have to be mixed in. Neither solution would be technically feasible.

On the basis of prevailing outside winter temperatures, variant no. 5, with 3,399 €/a, would be the most cost-effective: i.e., for outside-air recirculation. This is effective only for temperatures down to approx. –9°C at maximum recirculation of 45%. During cold winters, temperatures can fall below this limit. Raising the recirculation rate would result in higher costs.

The remaining variants nos. 1, 2, and 3, feasible for Frankfurt, would lead to slightly different energy costs of 3,550 €/a, 3,587 €/a, and 3,436 €/a, respectively. The energetically most favorable solution – i.e., preheating of the outside air – does not feature a re-heater and therefore allows only supply air temperatures below the extract air temperature (here approx. 18°C). This is usually sufficient due to existent internal loads and additional systems for individual temperature control in the particular zones of the building. An extra re-heater would mean additional investment and operating costs due to further pressure drop. For variants 1 and 2, on the other hand, the re-heater is already available. With respect to flexibility of the supply air temperature, solutions with

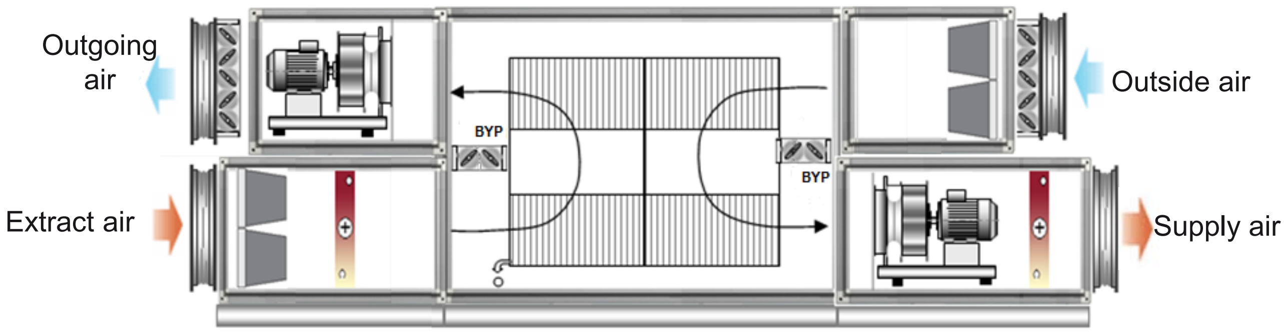


Figure 3. Frost protection with preheating of extract air.

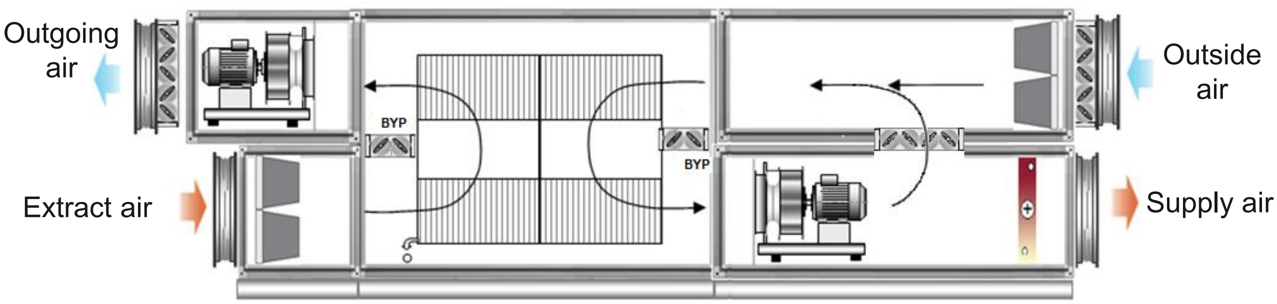
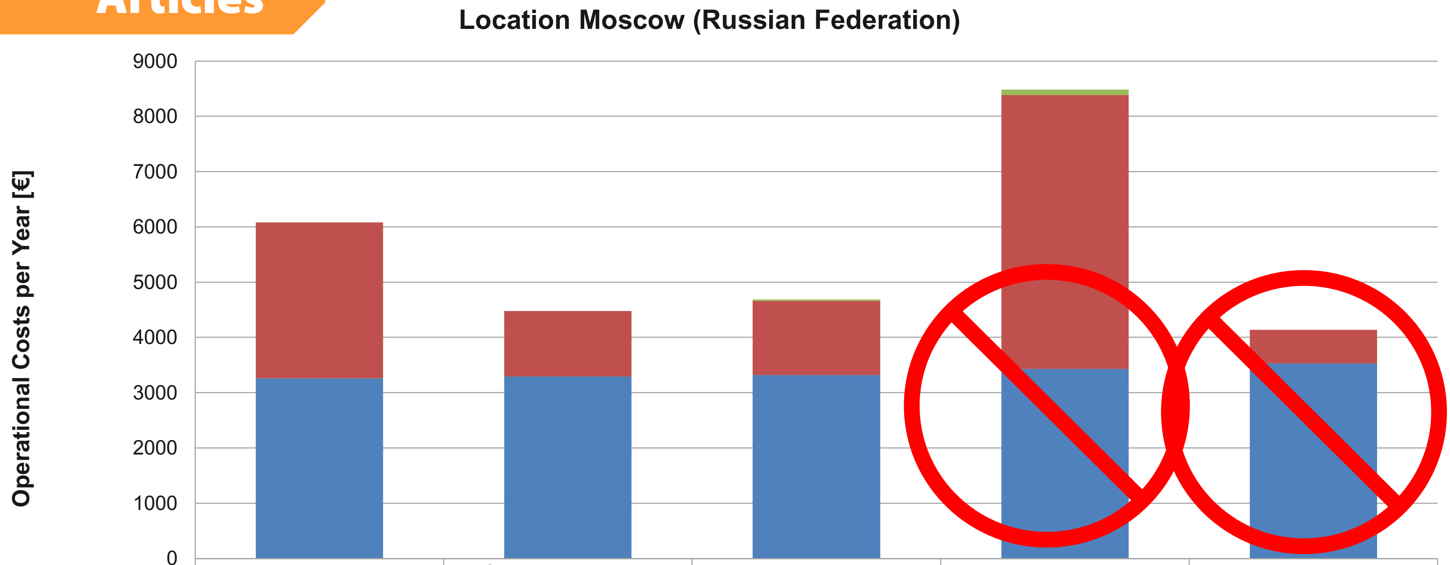


Figure 4. Frost protection with recirculation.



	Outside Air Bypass Concerning Temperature of PHE Surface	Outside Air Bypass Concerning Dew-Point Temperature of PHE Surface	Outside Air Preheating	Extract Air Preheating	Outside Air Recirculation
Auxiliary Energy	0	0	26	98	0
Heating	2821	1184	1339	4958	612
Fans	3261	3292	3320	3428	3527

Figure 5. The operational cost (heat and electricity) of frost protection in the case study with an air handling unit of 4 000 m^3/h.

frost protection via outside-air bypass are advisable; with respect to operating costs, however, variant no. 3 applied without re-heater is the most favorable.

Moscow, Russian Federation

The exclusion criteria applied for Frankfurt am Main also apply to Moscow, which is much colder in winter (daily low outside temperatures of down to –24°C, according to weather statistics). Variants 1 to 3 would be feasible for selection here as well. Of these three options, the purely temperature-controlled outside-air bypass (variant 1) would represent by far the most expensive. The air heater in this case would necessarily provide heating duty of 56 kW to raise the air temperature to 17.7°C, due to heat recovery being completely bypassed under extreme winter conditions.

If surface dewpoint temperatures were used to control the bypass (variant no. 2), the operating costs would be 26% lower compared to the purely temperature-controlled outside-air bypass (variant no. 1) – and would moreover represent the strategy with minimal expenses. The bypass would be in operation 500 h/a less, and the flap would never have to be opened 100%. This is because a temperature drop below the dewpoint could hardly be expected, owing to the dry cold in conjunction with the assumed humidity load of only 1.5 g/kg. For cases with higher humidity load or AHUs with humidifiers, the results would be worse and tend more to those of variant 1.

For the case of frost protection by outside-air preheating, the operating expenses would not be even 5% more expensive than variation no. 2. Despite the disadvantage of only being able to provide supply air temperatures below the exhaust air temperature if no additional re-heater is applied, a factor in favor of outside-air preheating is the fact that the outcome of energy consumption is independent of extract-air humidity. For this reason, this variant is likewise advisable – or in cases with humidification – even superior. This solution is also supported in terms of investments by the fact that the heating coil and the heat generator can be dimensioned at 30 kW, which is 46% less than required for variant 1 or 2. A detailed consideration of the individual case may lead either to the most economic variant of dewpoint controlled bypass, or to outside-air preheating.

Conclusion

These simulations reveal that one preferable frost-protection strategy for all of Europe is not possible. Only extract-air preheating and outside-air recirculation do not come into consideration at all. The multiple counterflow solution enables the possibility of implementing two cost-effective frost-protection strategies, high heat-recovery coefficients, and low-loss free cooling. Product launch of the new GEA multiple counterflow system is scheduled for late 2013. ■

This article is based on presentations in a workshop at Clima 2013 Conference, June 2013, Prague

Achieve superior energy performance of hydronic systems by enabling the latest pump technology

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Introduction

Energy improvements can be achieved in many ways, but especially optimisation of hydronic systems has proven to offer a remarkably quick return on investment. However, ultimate energy performance is achieved only by utilising intelligent products and components throughout the total hydronic system.

Accordingly, this article will revolve around how innovative pump technology can significantly improve the energy efficiency of the total hydronic system, but also that of the pumps itself.

EuP goals and requirements for pumps and motors

The Eco-design requirements of the directive for **E**nergy **u**sing **P**roducts (Directive 2005/32/EC)* are very ambitious and determined on reducing the energy consumption of a wide range of products. Surprisingly for many, 10% of all electrical power consumption in Europe is used by motors that drive pumps.

Annual Saving potential by 2020 with regulations based on Eco-design of energy using products directive:

Motors	135 TWh (EC 640/2009)
Circulator pumps	23 TWh or 11 million tonnes CO_2 (EC 641/2009) (EU 622/2012)

This will be achieved by gradually increasing the energy efficiency demands:

For motors without frequency drive

- Large motors (7.5 kW-375 kW): IE3 efficiency demand in 2015.
- Smaller motors (down to 0.75 kW) IE3 efficiency demand in 2017.

IE2 motors must be fitted with frequency drives (integrated or external)

Energy efficiency index for circulators

- 2013: EEI ≤ 0.27
- 2015: EEI ≤ 0.23

Act NOW and achieve profitable energy savings immediately

Behind the great savings potential lies the fact that about 2/3 of all pumps run at full speed all the time, when the actual need for full speed is only 4-5% of the time. By optimising water pump systems, energy savings up to 60% can be achieved. Within circulation of water for heating, energy savings of up to 75% are possible, simply by replacing out-dated circulator pumps with new ones that automatically adapt to the

* Editors note: This directive was replaced in 2009 with Eco-design of Energy Related Products Directive (2009/125/EC)

variable flow. These savings can be achieved with a relatively low investment. In fact, the return on investment is most often as short as 1-3 years.

The EuP legislation will undoubtedly result in massive energy savings, but not realised until the natural replacements happen due to tear and wear. So, the EuP savings process is relatively long-term.

Accelerate the process

If energy renovations of pump (and hydronic) systems are accelerated NOW, the energy savings will also be achieved much faster.

> **"Just by switching to high-efficiency pumps, 4% of the world's total electricity consumption can be saved – equivalent to the residential electricity consumption of 1 billion people!"**

Achieving the EU triple 20 energy-efficiency target also requires an extra effort within energy renovation, as it must contribute with 15% out of the 20% energy reductions. Optimising the hydronic energy performance could be an obvious and profitable place to start.

Complete system optimisation – the new MAGNA3 pump

The EuP legislation was of course an obvious reason for developing the new MAGNA3 pump (**Figure 2**), and one of the results was an amazing reduction of energy consumption. The new Grundfos MAGNA3 uses only 25% of the electricity (**Figure 1**) compared to a typically installed circulator (standard UPS). What's more, the new MAGNA3 use 40% less that than what is required from Jan 2013 in EuP regulations.

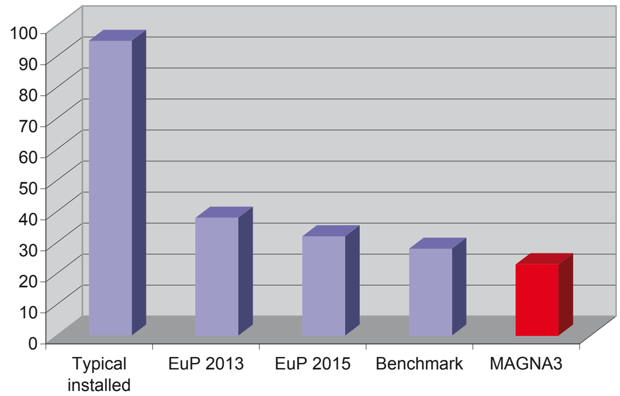

Figure 1. Relative energy use with the existing, new and latest pump generation.

Thus, the pump alone accounts for significant energy savings. Combined with the latest pump technology features of MAGNA3, it is possible to improve the efficiency of the entire hydronic system, and therefore achieve even higher energy savings.

Utilisation of a built-in heat energy meter

The new MAGNA3 pump (**Figure 2**) is equipped with the Grundfos patented direct sensor, which constantly monitors both the media temperature and the differential pressure, across the pump. Doing so, makes it is possible to measure the circulating flow in the system. And by adding a second temperature sensor to the return pipe, the delta T and the energy flow can be calculated (**Figure 3**). ▶

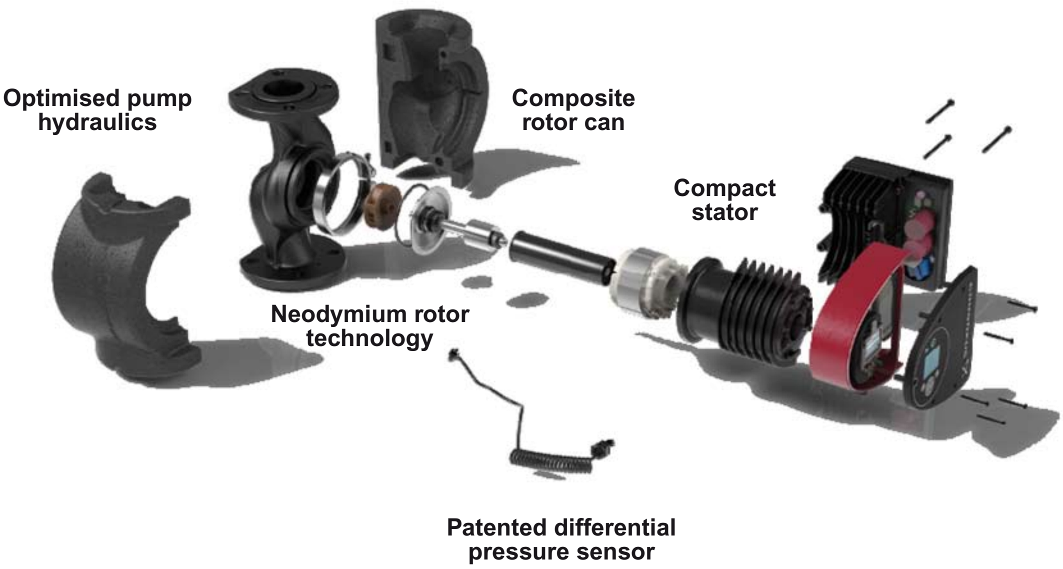

Figure 2. Components of the MAGNA3 pump.

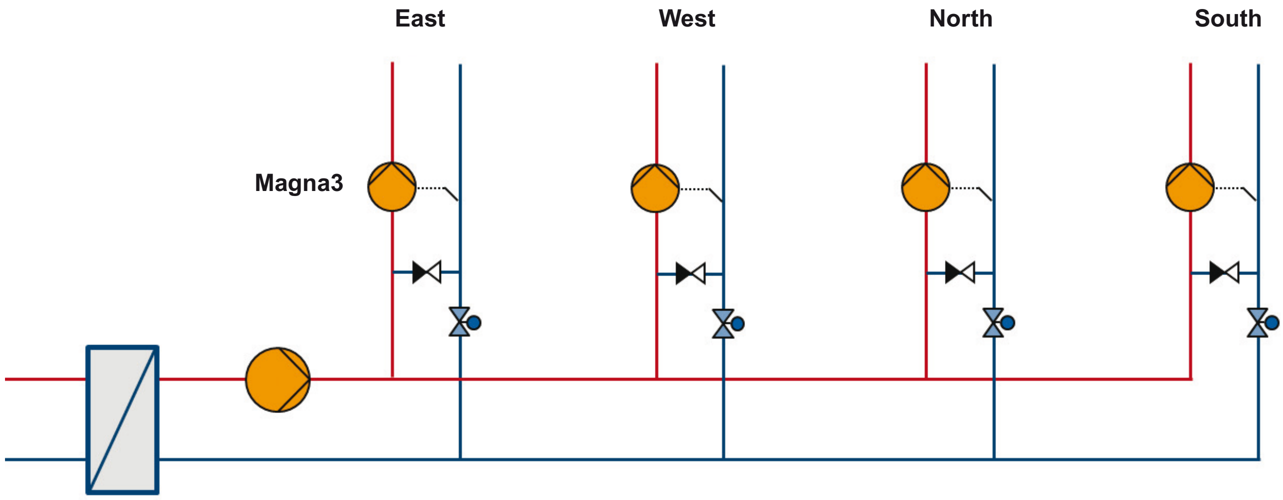

Figure 3. Illustration of how the MAGNA3 pump is installed in a heating system.

Renovation case showing the importance of hydronic systems – an example

According to Prof. Dušan Petráš from the Slovak University of Technology**, looking at the hydraulic balance in the buildings has a huge impact on the energy performance. Below are the savings data of a Romanian renovation case, consisting of a 32 apartment building with 9 floors.

Intelligent functions to improve the energy performance in hydronic systems

Until now, valid information about energy flows in hydronic systems have only been obtainable by investing in costly metering systems. However, the latest pump technology offer functionalities such as integrated energy metering and flow limit control modes that can:

- improve the quality of commissioning (and reduce the costs),
- increase the overall hydraulic balance
- reduce risk of by-pass flow
- make pump throttling valves redundant.

All these benefits have a significant impact on the overall efficiency of hydronic systems.

** Successful retrofitting of dwellings, Presentation REHVA Annual Conference, Timisoara, 2012.

Table 1. Comparison of renovation activities and return on investment in a Romanian renovation case.

Energy efficient measures	Investmens (€)	Yearly savings (€)	Share of yearly savings	ROI*** (years)
Insulation façade	83 590	3 448	24%	24.2
Insulation roof	23 510	603	4%	39.0
New windows	22 218	1 664	12%	13.4
Hydraulic balance	**13 146**	**7 508**	**53%**	**1.8**
Temperature set back	2 618	905	6%	2.9

Nominal interest rate = 5%, inflation = 4.2% *** Return on Investment.

Controlling the flow without throttling valves

Monitoring the circulating flow with the built-in differential pressure sensor enables users to set a maximum flow for each branch served by the MAGNA3 pump. In the past, (and still today) this was accomplished by adding a pump-throttling valve, which was both costly and complicated to operate. With the new FLOWLIMIT feature in the MAGNA3 this is easily set by either a smart phone or directly on the pump display.

In addition to user-friendly benefits, there are also savings in pump operations to be harvested. The power needed to operate pumps can be explained by the following equation: $P = q \times \Delta p$ (hydraulic power consumption = flow x pressure), which means that the more pressure/head needed, the more power will also be needed for the pump operation.

Saving of pumping energy by avoiding throttling and using high efficiency pump – an example

In this example a standard three speed pump is compared with the new MAGNA3. The flow demand is 22.5 m³/h x 4.1 mVc (the orange dot in **Figure 4**) and the duty point is just between speed two and three. If nothing is done, the actual flow in the system will be 24 m³/h by approximately 4.9 mVc. To ensure not to exceed the desired 22.5 m³/h, a pump throttling valve is usually installed and partly closed, which increases the resistance in the system. So the new duty point, illustrated by the blue dot, will be 22.5 m³/h x 5.2 mVc. The associated additional pressure, 1.1 mVc leads to an extra 0.14 kW, every hour the pump is in operation.

So as "all head/pressure comes at a cost", an additional cost of 0.14 kW will be added every hour the pump is operating. If this is an "all-year-situation", the additional cost will be 1 226 kWh/year.

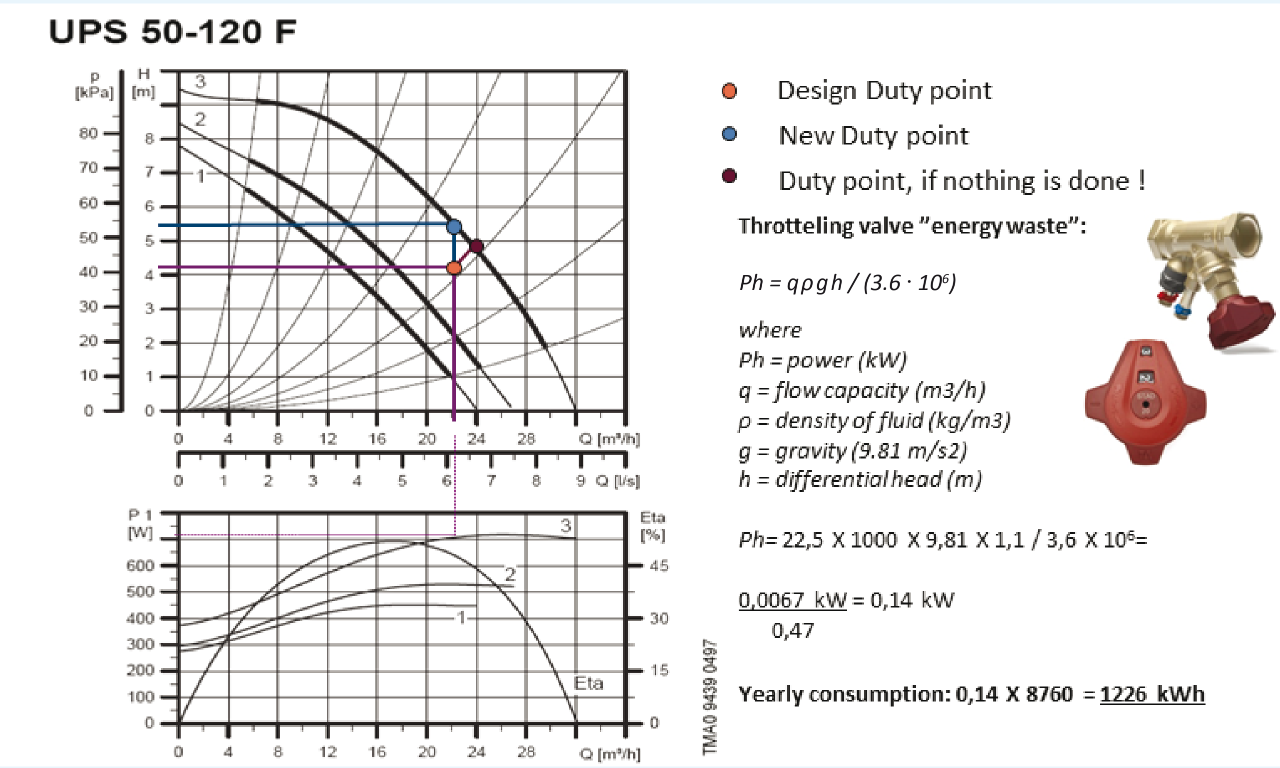

Figure 4. Calculation of energy consumption in a throttling valve.

With the MAGNA3 pump this can easily be eliminated by setting the FLOWLIMIT to the exact needed flow (22.5 m³/h). The red vertical line illustrates the FLOWLIMIT, which is easily set, either directly on the pump or by a smart phone.

Another benefit is the overall increased efficiency by the MAGNA3 that has an annual power consumption of 3,124 kWh (**Figure 5**). Compared to the standard UPS pump this gives energy savings of 3,008 kWh/year or 49%. So of the 6,132 kWh the standard pump consumes yearly, 20% is related to overcome the resistance in the throttling valve.

On top of this, the savings would have been even greater if the application had been with variable flow, which most often would be the case. So, what this example also shows is that a variable flow is no longer a pre-requisite for having higher energy efficiency on an electronic and variable flow controlled pump – with FLOWLIMIT it also goes for constant flow!

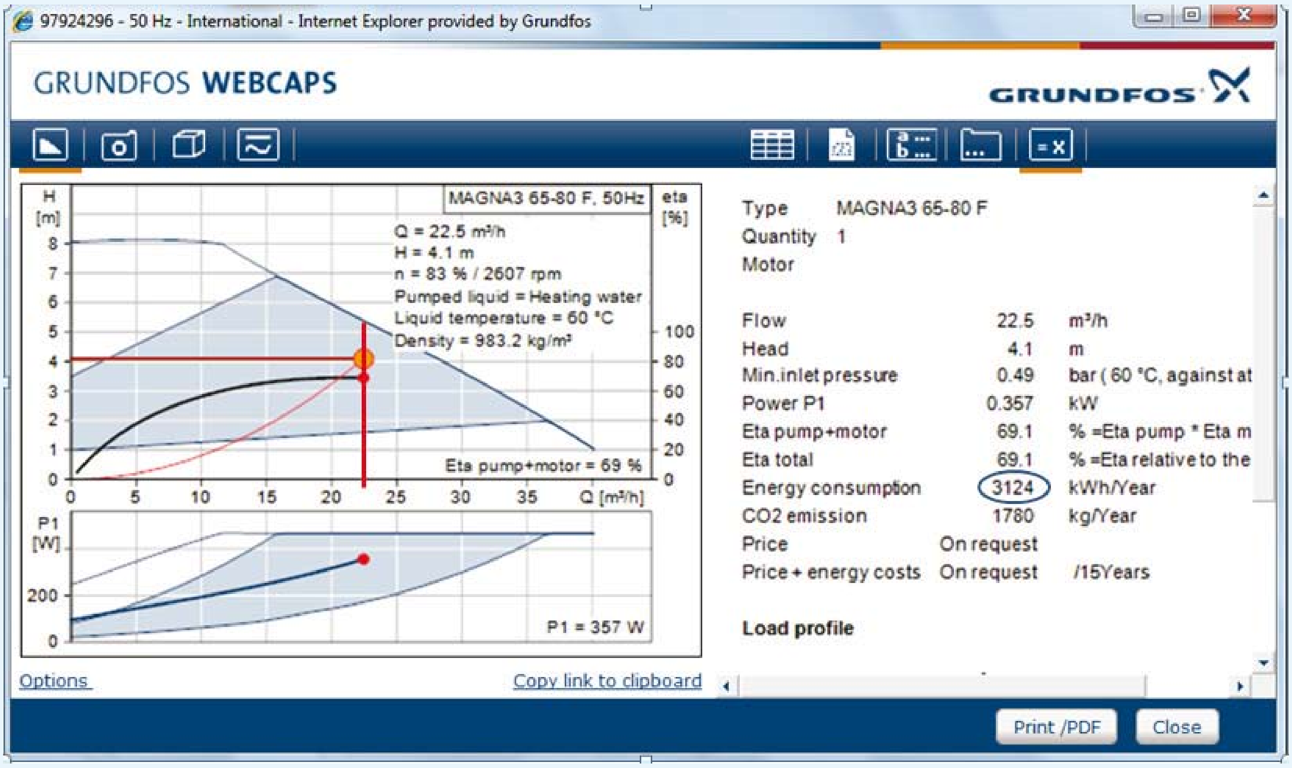

Figure 5. MAGNA3 characteristics.

Table 2. Summary of MAGNA3 pump application benefits.

MAGNA3 built-in heat energy meter	Benefits
• Monitoring of heat energy distribution and consumption within the system. • Temperature input from sensor on return pipe. • Flow limitation function. • Advanced logging.	• Information will help tracking imbalances in the system and that way avoid excessive energy bills. • Save cost of a separate energy metering device in the system. • Easy commissioning • Throttling valves redundant • Work log (3D) makes it possible to see the actual duty points of the pump over time to be used in replacement situations, for building extensions etc.

Future challenges for designers and installers

Maybe the biggest challenge for designers in the coming years will be to utilise the different features (see **Table 2**) in sophisticated products to the maximum, in order to secure cost optimum solutions for users. Accordingly, designers, consulting engineers, and installers will have to work closely together to secure the highest user satisfaction at the lowest possible costs. ■


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Personal control over heating, cooling and ventilation

– Results of a workshop at Clima 2013

This article presents a summary of a Workshop at the 11th Clima World Conference 2013 in Prague. The workshop was organised by REHVA in cooperation with ISIAQ (International Society of Indoor Air Quality and Climate), and chaired by

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Objectives
The main idea of the workshop was to gather the opinions and ideas amongst the workshop participants about personal control over indoor climate and user behaviour. The workshop followed the introduced program reporting in details below.

Core of the workshop (2/3 of the total time) was devoted to a guided group discussion, between the participants. The discussion evolved around several prepared statements which were presented one-by-one (by the moderators). Every time a statement was presented the participants voted to indicate whether they agreed or not. Individuals were pointed out to explain their positions further, which lead to an additional group discussion.

Below the statements that were discussed are presented, with a description of the general response and 'average' opinion given by the participants.

Statement #1. We know how building occupants use their adjustable wall-thermostats and other controls
The majority of the participants disagreed (90%). Examples given to prove that we still have limited knowledge about the use of controls (specifically adjustable thermostats) were:

- In open-plan office buildings occupants may not adjust the thermostat as they believe that their uncomfortable thermal sensation is too subjective and an adjustment may cause complaints between colleagues. Additionally, it seems a common experience that many people (notably women) do not have a good idea of the functionality of control devices.
- In residential buildings: occupants often compare the use of the thermostats with the direct contact and perception and as a consequence they may adjust it wrongly. In fact, often people react to the instant thermal sensation because they do not know

the functionality of the HVAC system that is behind the control tool (it is not explained to them how the system works and how they can adjust it).

An additional opinion in the audience was that often we don't know where the thermostat is located and what it is really measuring. In fact, often it is attached to a wall at a very high or low place resulting in measuring some air temperature that is very different than the one perceived by the occupants.

One participant referred to the use and intrinsic logic design of smart phones. It would be nice when HVAC interfaces became as simple and intuitive as these phones.

Statement #2. Occupant behaviour and man-environment interaction related to indoor climate is complex

75% of participants agreed with the statement, the rest didn't express any opinion. The main comment was that the technical side of HVAC systems may be easy, but when looking at the interaction between building users and systems, things become complicated. Occupants should be free in their natural behaviour and HVAC systems and their control should allow for adaptation.

Statement #3. 100% satisfaction over the indoor climate (and a PD of 0%) is possible

A long discussion followed on this statement as the participants were split (50/50) between agrees and disagrees. The main discussed point was to choose on what to focus: building systems or occupant satisfaction?

The main argument of those that agreed was based on a few studies that showed that 100% of satisfaction can be achieved although, in that context, full control and local personalized environments must be provided to the occupant. From those that disagreed, it was believed that after some time of providing the perfect environment, human may start to complain, against any building service. In addition, psycho-social factors and other things that building scientists still do not see may make it near impossible to create 100% indoor climate satisfaction.

Statement #4. If you want to boost the productivity in an office building, give individual office workers control over their temperature and fresh air supply

The participants had very different opinions with 40% agreeing, 10% disagreeing and 50% no opinion. In particular, while 40% agreed, the rest 60% pointed out that other aspects (e.g. psychological and sociological) also can influence productivity. The issues that should be considered could be divers (e.g. solar shading control) and also connected to the temperature and fresh air supply control (e.g. size/location of the controls).

Another considered aspect was the work distraction that the occupant can perceive when focusing at the different controls and spending time on adjusting them (or trying to adjust them). From that point of view, even if some scientists believe that occupants can learn and later have an easy fix of controls with high work productivity, others were more sceptic.

Statement #5. Building occupants want control over their indoor climate at all times

Most of the attendants (95%) disagreed with the statement. Many participants stated: "as long as the thermal environment is in the range of comfort conditions, the users' don't want to have control". This declaration was supported by real life experienced examples, e.g.: (1) in landscape offices, even if people feel the need to adjust the thermal environment they tend not to do it if they notice that the rest of the occupants are satisfied with the present conditions; (2) in homes or single office environments, people tend to use controls more often to reach a comfort state, however usually they have other priorities (work, family, etc.) and don't want to be bothered from a continuous room control need. Moreover, it was also noted that there are large difference between people: some want personal control others actually prefer central control. A conclusion was reached, that: "some building users may want to control their environment but certainly not all the time".

Statement #6. HVAC engineers want control over building occupants at all times

About 50% of the participants disagreed and only 10% agreed, 40% had no opinion. The 10% that agreed with the statement believe that HVAC engineers would like to have some control over buildings and their occupants so that they can guarantee e.g. a certain energy performance. On the other side, those who disagreed explained that the need for control is due to project budget issues and a false idea that engineers can avoid occupants complains.

Statement #7. The average HVAC professional knows how to select an adjustable wall-thermostat

Most of the audience (80%) didn't have an opinion; while the rest (20%) disagreed. The disagreements were explained by a lack of knowledge amongst HVAC professionals on ergonomics and user behaviour. Everyone seems to agree that more should be done in training HVAC-professionals better in the selection and installation of controls. Besides, developments of indoor environmental controls (like wall thermostats) should be supported for fast reading of the physical parameters that must be representative of the occupied zone (perceived temperature by the occupant).

Statement #8. Operable windows should be avoided

No doubts that operable windows should be mandatory, as almost all the audience quickly disagreed with the statement (95%). The main argument was that it is not just important to offer control over the thermal environment but also over fresh air supply and indoor air quality. One participant mentioned that this can be provided by other means than operable windows (e.g. boost knobs that influence the fresh air supply by a mechanical ventilation system).

Statement #9. Buildings with a user-adjustable indoor climate are more expensive

At this point the audience split almost equally in three groups: 30% agreed, 30% disagreed, 40% had no opinion. Many ideas and opinions were shared between the participants while explaining the different points of view. Statements in terms of agreement and disagreement are presented below:

- Yes, the building is more expensive and requires higher investment to provide more and adjustable personal controls.

- No, the building on the long run will be cheaper, because the building owner will have an immediate return on investment due to higher productivity of the building's users.

The discussion focussed on the fact that the price (initial costs) may be less relevant if end-results are perceived as important, e.g. more satisfied occupants.

Finally, the discussions turned on "occupant expectation". Expectations in expensive, high quality buildings are usually high and to reach high levels of satisfaction possibilities for adjustable indoor climate should be provided. In cheaper, less luxurious buildings on the other side, occupants usually have lower expectations, and are more tolerant of the sub optimal indoor environments. However, compromising with occupants´ satisfaction and acceptability in cheaper buildings is not always the best solution.

Statement #10. Including user control in HVAC system design will lead to higher energy use

About 40% disagreed; the rest mostly had no opinion. The discussion mainly focussed on the estimation of the energy savings that may change in connection with low temperature settings in winter and higher temperature setting in summer when using micro-climatisation systems. Conditions resulting from climate changes versus near zero energy buildings types are raising other issues as summer overheating. At the end the group agreed to disagree, meaning that the impact on energy use from inclusion of options for personal control depends very much on local climate, building design, etc.

Statement #13. There are business opportunities out there related to unfulfilled climate control needs

More than 90% of the participants agreed. There was general consensus that there are opportunities both in terms of products (e.g. more easy to use adjustable thermostats) and in terms of services (e.g. service contracts that include explanations and trainings to e.g. households on how to get the most out-off new complex energy systems).

Statement #15. REHVA should produce a separate 'Personal Control Guidebook' with concrete examples on how to design user-adjustable heating, ventilation and cooling systems

A total of 80% agreed, one person was against, the rest had no opinion. The general conclusion was that it is worth investigating the feasibility of a new REHVA guidebook on the subject of personal control and user behaviour related to the design / installation of HVAC systems.

Final conclusion

Exchange of knowledge, experiences and ideas on personal control over indoor climate between HVAC designers, component manufactures, building service system scientists, and others, was the main idea of the workshop. Indeed the workshop resulted in very good and interactive discussions.

Articles

There was consensus that personal control over indoor climate and user behaviour in the context of design and operation of HVAC is an important issue that needs further attention within the HVAC community both in terms of design and research. ■

The full version of the Workshop summary is published in REHVA Report No 5, Sevela P, Aufderheijde J (Editors) REHVA Workshops at Clima 2013 – Energy efficient, smart and healthy buildings, 2013. Available at REHVA Bookstore at www.rehva.eu.

News flash:

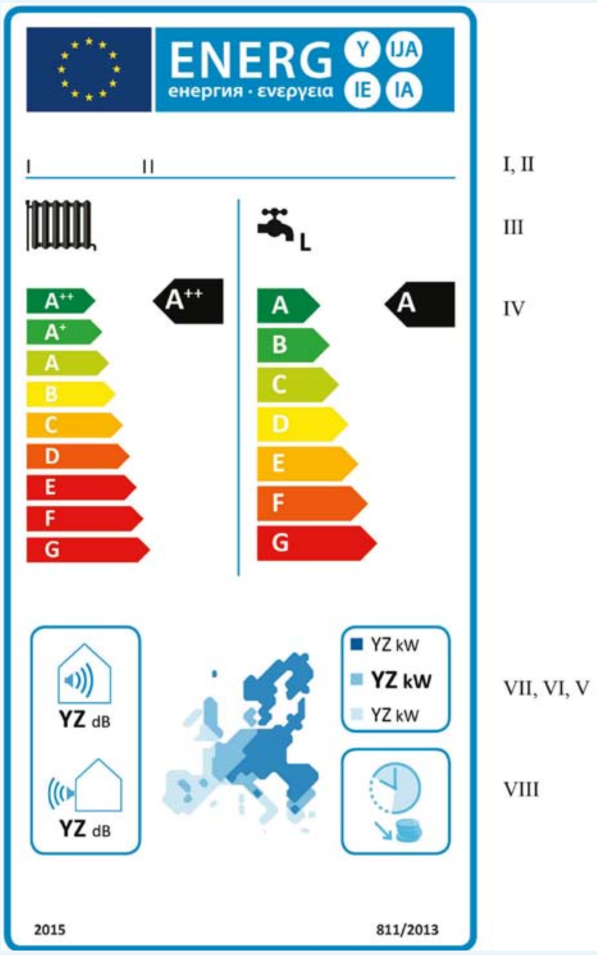
EU Regulations on space heaters and water heaters published on Sept 6th in the Official Journal of the European Union

After several years of discussions and preparatory work the Commission completed earlier this year the important regulations of space heater and domestic water heated like boilers, heat pumps and water tanks. The final versions of the Regulations were prepared at DG ENTER. The regulations are based on Energy Labelling and Eco-design of Energy Related Products Directives.

Regulations apply to all EU Member States without any further national legislation. The contetns of the Labelling Regulations was as agreed in February and the Eco-design regulations in August 2013. The technical contents of the boiler regulations were introduced to the readers of the REHVA Journal in the March issue of the REHVA Journal

The regulations include:

- Energy labelling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device
- Energy labelling of water heaters, hot water storage tanks and packages of water heater and solar device
- Ecodesign requirements for space heaters and combination heaters
- Ecodesign requirements for water heaters and hot water storage tanks



An example of the mandatory energy label for heat pump combination heaters in seasonal space heating energy efficiency classes A ++ to G and in water heating energy efficiency classes A to G.

The full text of the regulations is available in the Official Journal, totally 188 pages.

Energy use and thermal comfort of two apartment buildings before and after refurbishment in Slovakia

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Summary

This article analyzes the actual condition of building constructions, building equipment and heating system of apartment buildings. Two apartment buildings are compared; the first building is before renovation and it uses its own boiler to generate energy for heating, the second building was recently reconstructed and the energy for heating is supplied by a central heat source After the insulation of building was carried out, economic and energy savings measures were suggested in order to renovate the building and to find out probability of the same. Moreover, the residents of the two apartment buildings completed questionnaires regarding building constructions, indoor environment and ventilation behavior, and a connection was made between the energy saving measures and the subjective evaluations in order to investigate the impact of the renovation on perception of the indoor environment.

Buildings description

The investigated apartment buildings are situated in Bratislava, Slovakia. They contain flats with two and three rooms on each floor, and there are eighty flats in each building in total. The construction height of a typical floor is 2.8 metres. **Figure 1** shows the buildings before and after the refurbishment [1].

Apartment building before refurbishment

The building construction is in original condition. The walls are made of aerated concrete with the thickness of 0.3 m, which does not fulfill current technical standards on thermal insulation, because of the criteria on thermal insulation much lower in the time when the building was built. Fifty percent of windows have been replaced with energy efficient windows with plastic frames and the heat source was renovated significantly in 2009, when the building was disconnected from district heat-

Figure 1. Front sides of the two buildings: a) Before refurbishment b) After refurbishment. [1]

ing and a local heat source for heating and domestic hot water (DHW) was built in a boiler room located in the apartment building.

Apartment building after refurbishment

Energy saving measures were carried out on an identical apartment building, adjacent to the apartment building in original condition. The envelope of the building was insulated with foam polystyrene with the thickness of 0.08 m. Insulation of the roof is made of mineral wool, with the thickness of 0.05 m. All of the old windows were replaced by new energy efficient windows with a plastic frame, except for the entrance door and windows on the first floor. After renovation the U-value improved significantly and currently it satisfies the requirements on thermal protection in accordance with Slovak standards.

A significant decrease of heat loss after insulation and replacement of the windows can be seen in **Figure 2**. The specific heat loss by heat transmission (HT) decreased by 40%, while the specific heat loss by infiltration (HV) decreased by 45% after replacement of the windows, compared to the situation before refurbishment.

Table 1. Comparison of heat transfer coefficients before and after refurbishment. [1]

	U-value (W/m².K)	
Construction	**BEFORE**	**AFTER**
Facade	0.78	0.31
Side walls	0.74	0.29
Roof	0.28	0.2
Old wooden windows	2.4	1.3
Original doors to loggias	2.4	1.5

Energy certificate

Energy certification of these two buildings was carried out in 2012 in accordance with Slovak laws and regulations. Energy need for heating was optimized after implementation of energy saving measures of the building after refurbishment. Energy need for DHW increased

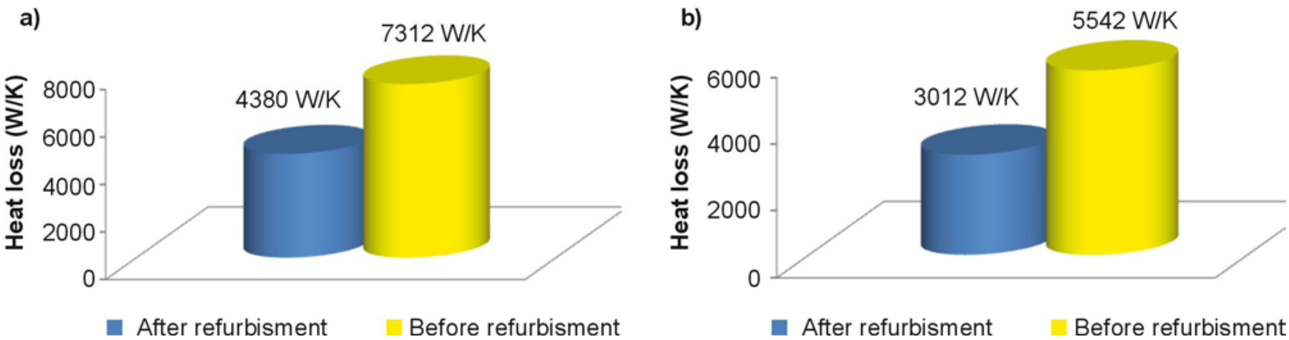


Figure 2. Comparison of specific heat loss before and after implementation of the energy saving measures. a) transmission, b) ventilation. [1]

Table 2. Energy certificate of apartment houses before and after refurbishment.

Monitored data		Building before refurbishment	Energy class	Building after refurbishment	Energy class
Heating	Energy need for heating system	597 235 kWh/a	C	390 992 kWh/a	B
	Specific energy requirement	70 kWh/m².a		45.6 kWh/m².a	
DHW	Energy use for DHW	143 960 kWh/a	D	143 960 kWh/a	D
	Specific energy needs	45 kWh/m².a		51 kWh/m².a	
	Primary energy	150 kWh/m².a		125 kWh/m².a	
	CO_2 emissions	26.45 kg/m².a		22.08 kg/m².a	
	Total energy	115 kWh/m²	C	96 kWh/m²	C

in the refurbished apartment building, because of insufficient insulation of the distribution pipes.

Heating energy consumption and cost

The data to compare the cost of heating are for the year 2010. Following figures compare the cost of heating in the apartment building connected to district heating with the cost of heat in the apartment building with own local heat source.

Cost of heating in the apartment buildings

The cost of heat generated in the local heat source is lower than the cost of heat generated by district heating, when the saving per GJ is up to 44% in the building with own local heat source.

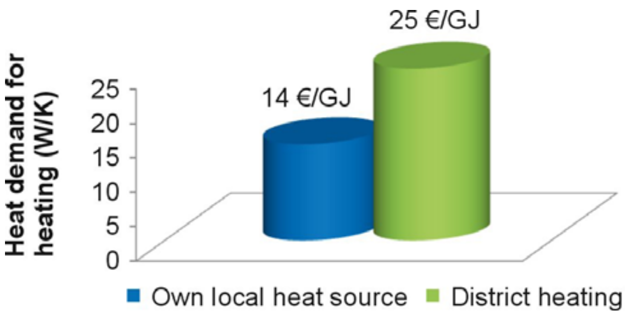


Figure 3. Cost of heating for the apartment building with own local heat source (left) and the building connected to a district heating system (right). [1]

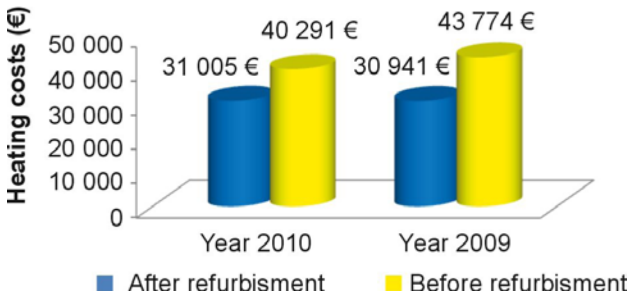


Figure 4. Comparison of heating costs for the two apartment buildings in 2009 and 2010. [1]

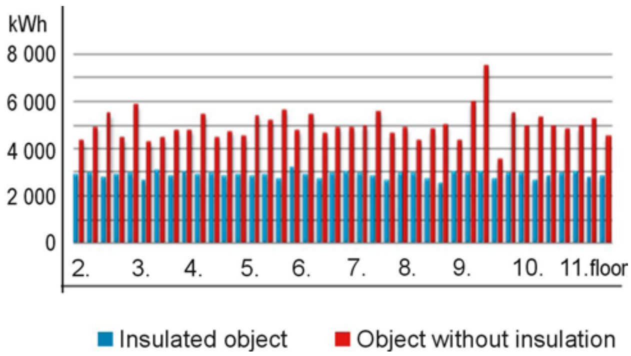


Figure 5. Comparison of measured heat consumption in flats. [1]

Analysis of energy consumption

The measured energy consumption in 2010 shows that the energy consumption of the building before refurbishment was about 28% higher than the total energy consumption of the refurbished building.

Figure 5 shows comparison of the measured energy consumptions of the buildings in 2010; the results are shown separately for each floor. The difference between the highest and the lowest heat consumption of flats was about 40% in the building before refurbishment, causing dissatisfaction between residents of the building. On the other hand, the highest difference in heating costs was only 12% in the apartment building after refurbishment with the insulated facade and roof.

Energy monitoring

After implementation of an energy saving project it is often found that the energy consumption has increased one or two years after refurbishment. Energy

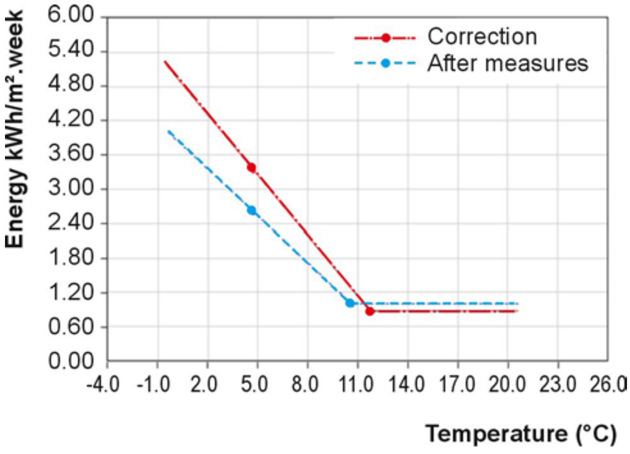


Figure 6. ET-curve of the two apartment buildings. [1]

monitoring is a management tool to keep the energy consumption at low level and to prevent the energy consumption increase after the refurbishment. It is based on a regular readout of the energy meters. In the present case the energy monitoring was performed by the Ensi EAB 8.1 software, developed in Norway. The energy consumption depending on mean daily outdoor temperature (or eventually it can be also mean weekly outside temperature if the readout is done on weekly basis) is graphically represented by the ET-curve (Energy-thermal curve). The energy consumption for heating in **Figure 6** is represented by the sloped line, whereas the horizontal line represents the energy consumption for DHW, which does not depend on the outside temperature. **Figure 6** shows that the calculated weakly consumption dropped from 5.19 kWh/(m^2.week) to 4.00 kWh/(m^2.week) in the insulated building, at the mean daily outside temperature of 0°C. The hot water consumption is higher in the refurbished building, because of the insulation of horizontal pipes being too old and damaged (insulation of DHW distribution pipes was not part of the refurbishment).

Table 3. Evaluation of thermal sensation and thermal comfort.

Indicator	Before refurbishment	After refurbishment
PMV index	0.74	0.92
PPD index	16.57%	22.88%
Perception of temperature	0.14	0.52

Thermal comfort

In order to achieve comfort of the occupants in the enclosed environment, it is necessary to fulfill several requirements at the same time. A questionnaire survey was performed by the occupants of the buildings, containing questions regarding various aspects of their indoor environment to allow complex assessment of their satisfaction with their living environment.

The questionnaire survey

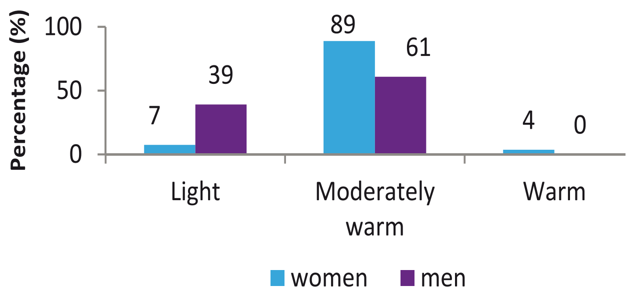
The questionnaires used to evaluate the indoor environment and the condition of building constructions consisted of four main parts, containing questions regarding building constructions, indoor environment, natural ventilation and basic information about occupants. The questionnaire survey was conducted in January 2012 and was completed during working days in the period from 04.00 pm to 07.30 pm [2].

Thermal comfort

Evaluation of thermal comfort was carried out using the seven-point thermal sensation scale, as defined in EN15251 and EN ISO 7730. The results are shown in **Table 3**.

Typical clothing ensembles of the inhabitants at home

Figure 7 shows that the greater part of men and women prefer moderately warm clothing in apartment building



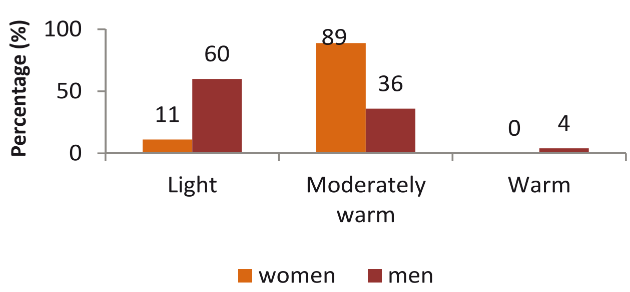


Figure 7. Typical clothing ensembles of residents in the apartment buildings.
a) Before refurbishment. b) After refurbishment. [2]

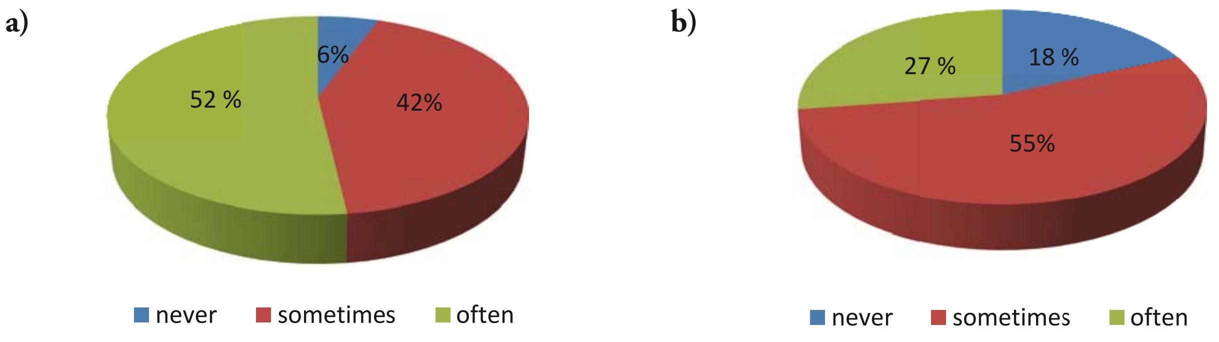


Figure 8. Utilization of temperature settings in apartment buildings: a) Before refurbishment b) After refurbishment. [2]

before refurbishment. Majority of women prefer moderately warm clothing and greater part of men prefer light clothing in apartment building after refurbishment.

Temperature settings in the apartment buildings

In both apartment buildings the inhabitants have the possibility to set the air temperature in each apartment. The following charts show how often people adjust the temperature in their apartments.

Conclusion

The energy need for heating system in the apartment building after refurbishment can be classified into a better energy class. Residents of the refurbished apartment building perceived the thermal conditions in the building as more acceptable than residents of the apartment building before refurbishment. The present study indicated that refurbishment of a building can contribute to the improvement of the indoor environment, however, it must be planned and implemented with care, otherwise it might affect the indoor environment adversely.

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This article is based on the thesis of the finalist in the REHVA Student Competition in 2013, the work was supervised by Ph.D. Eng. Aleksander Panek.

Conceptual design of plus energy single family house in Warsaw, Poland

Plus energy house concept is already well explored but still inspiring a lot of discussion not only in Europe. This study answers the question about the possibility and viability of implementation of a plus energy house in Polish conditions in front of the draft of new Polish legislations.

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The first plus energy house was built 28 years ago in Freiburg as a private house of architect Rolf Disch. It was his form of manifest against German government plans of building new nuclear power plant close to this hometown. It was manifest which shown the world that each single family house can be a small eco-friendly power plant – plus energy house.

The simplest concept of a plus energy building is that it produces more energy on site than it uses on annual basis. This includes energy for heating, cooling, ventilation, lighting and all devices that are plugged in [**1**]. The system boundary of energy balance, which is used to evaluate building energy consumption, was set in EPBD recast and EN 15603:2008. The delivered energy is the electricity, district heating/cooling, and other fuels (renewables and non-renewables). Energy produced is on site renewable energy (solar, wind, hydro). The net energy is energy delivered minus exported energy [**2**].

Objective

The main purpose of this study was to investigate the possibility and viability of implementation of plus energy house concept in Polish conditions. Evaluation of the work objective was based on an energy and economic analysis based on the concept design of the building. Concept includes architectural, mechanical and energy design of the building. To minimize the costs of the house, it was assumed that all of the construction, mechanical and energy solutions proposed in design will be well known and common used on Polish market. The availability of the materials and products to construct the building were checked during its concept design.

Method

Architecture

The architecture of the building was inspired by the "home for life" house constructed in Aarhus, Denmark [**3**] **Figure 1**. The floor plan was adjusted to the needs of average Polish family.

Figure 1. The design of the Polish plus energy house was based on this Danish "Home for life", Arhus, Denmark [3].

Building shape, layout and orientation on the plot were design to maximize the passive solar gains and the natural daylight. Large glazed areas were located on the South and West façade of the building. Glazing on the north façade was minimized. Layout of the rooms was design to allow users to fallow natural sun path and to daylight rooms in time of their natural time of use during the day. To protect the building against overheating, external shutters were design. Closed during night/winter will decrease the heat transfer coefficient of windows up to 0,3 W/m²K [**4**].

Building envelope

Reducing the amount of energy needed to heat and cool the house is the essential consideration, and means a tight, well insulated building envelope. Following the idea of energy efficient building, the building external partitions (roof U=0.685, walls U=0.123, ground floor U=0.122 and windows U=0.6) were designed to meet the heat transfer coefficient standard of passive house. For the best performance of the envelope detailed solutions eliminating thermal bridges were undertaken. This included connections between external walls and windows, roof and ground floor. Precise sealed construction connections allowed to achieve high airtightness of the construction (assumed to be 0.3 air changes per hour for the 50 Pa of pressure) [**5**].

Ventilation

The mechanical ventilation system with air-to-air heat exchanger coupled with ground heat exchanger was designed **Figure 2**. The chosen solution will minimize the amount of energy necessary for heating and cooling of air supply to the building. As Poland has moderate climate with both

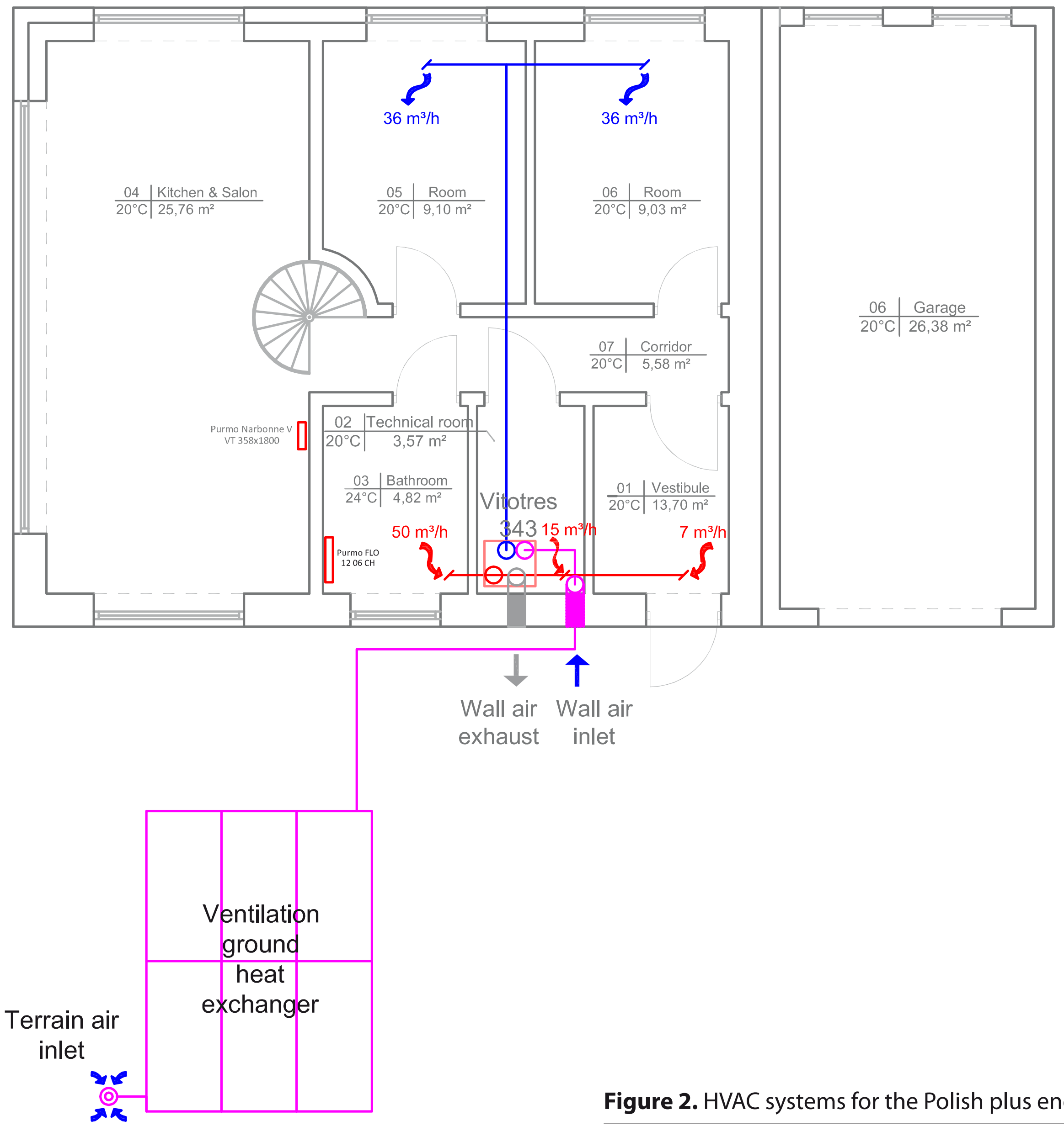

Figure 2. HVAC systems for the Polish plus energy house.

maritime and continental elements, together with mechanical ventilation, a natural ventilation system was designed. The roof windows and windows on the ground floor will be equipped with automatic motors, which through the BMS and readings of internal and external conditions will regulate the openings of the windows.

The volume of the supply and extracted air was designed in accordance to the Polish standard PN-83/B-03430 [**6**]. For the design ventilation, in order to maximize its efficiency, four modes of work were distinguished [7]:

- t_e below 6°C – supply air goes through ground heat exchanger (where is heated) and air-to-air heat exchanger (heat transfer from exhaust air to supply air),
- $t_e \in$ (6°C; 19°C) – ground heat exchanger is not used; air is supplied from wall air intake and goes to air- to-air heat exchanger,
- $t_e \in$ (19°C; 24°C) – mechanical ventilation is not working, building is naturally ventilated (supply and extract fans are off)
- t_e od 24°C – supply air goes through ground heat exchanger (where is cooled) and it passes next to the air-to-air heat exchanger through the summer circumvent; air supply temperature is lower than the external temperature; ventilation system works as a cooling system.

Building heat load and HVAC design

In order to maximize the efficiency and to minimize the space required for the HVAC system the compact HVAC Vitotres 343 was chosen [**8**]. It is designated specially for low energy buildings and it's used for ventilation, central heating and DHW heating with solar backup.

The high thermal performance of building envelope and energy efficient ventilation system results in low final energy demand for heating $\Phi_{HL,A}$=30,2 [W/m²].This is a condition to adopt air heating system in the building. Traditional hydronic radiators will be used only in the rooms with the highest energy losses (bathrooms and saloon with kitchen). The air will be supplied at the temperature of t_h=35 –45°C [9]. It will be customized by a BMS to meet building heating demand based on the external and internal air temperature readings.

In order to reduce energy demand for domestic hot water a solar installation for the building was designed. The installation with Viessmann, Vitosol 200-F type SV2 panels, was sized for a 4 person family according the Viessmann technical guidance [**10**]. Installation consisting of two solar panels will be located on the south roof surface with inclination of 35°.

Building energy consumption

Based on the design of HVAC system the total building energy consumption was calculated. This includes energy necessary for heating, ventilation, domestic hot water preparation, HVAC equipment, lighting and plug in loads. The only form of energy required for the building is electricity.

Heating demand for the building was calculated according to PN-EN-ISO 13790 [**11**] and covers energy needed for air heating and convection heating. The heating demand for the DHW was calculated assuming the average hot water consumption of 50 l/day/person for 4 person family. The calculations of heat produced by solar panels and heat demand were undertaken in the Polysun 5.6 Edu simulations software. Total building electricity consumption was calculated as 7456.80 kWh/year, that gives result of 75.25 kWh/m²/year **Figure 3**.

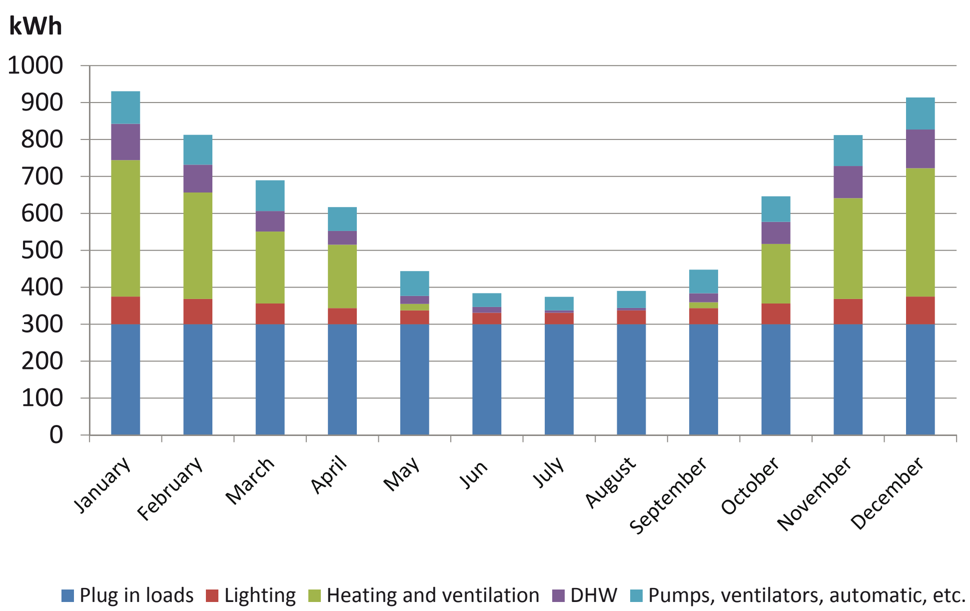

Figure 3. Break down of building electricity consumption by month.

Energy system

The building energy system will consist of solar and photovoltaic panels, installed on its roof. The size of the PV system was determined to offset annual building energy consumption. To maximize the economic efficiency of the investment it was decided that the building will be connected to the local electric grid.

Tied up installations according to Polish government plans for the new energy law, will introduce the feed-in tariffs for every kWh generated from renewables (for small installations up to 10KW – 0,31 €/kWh) [**12**].

Polycrystalline photovoltaic solar panels Vitovolt type 2P235RA of Viessmann Company were chosen for the energy production system [**13**]. The PV panels will be located on the south roof surface with inclination of 35°. With 38 panels total generator output is P = 9.93 kWp. Connection of the modules was based on the calculation of the voltage limits. Panels will be in 4 strings with three strings with 10 modules and 1 string with 8 modules.

The simulation of the PV system was performed in the Polysun 5.6 Edu software. Based on the proposed design the amount of the electricity generated by the system was simulated as 88 033.5 kWh/year. The simulation included already the energy losses during the AC conversion to DC and energy losses related to energy distribution.

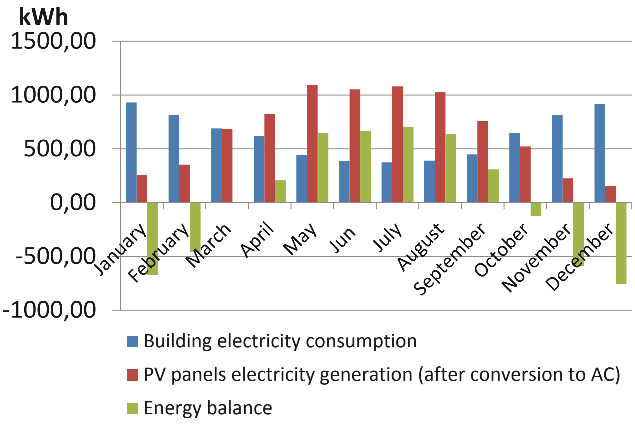

Figure 4. Building energy balance.

PRELINARY RESULTS - Building energy balance

For the designed building energy production (88033.5 kWh/year) exceed energy consumption (7462.10 kWh/year) on the annual basis over 8%. However the results for the individual months show huge disproportion between energy generated and energy demand. The biggest energy demand occurs in the winter months, when the heating demand for the building is the biggest (energy for running of the heat pump and support equipment). Also winter is time when artificial lighting consume the most. Short days and low sun radiation during winter months (November – February) cause that this is the time of the year with the lowest energy production. With the increasing time of sun operation and with increasing solar angle the amount of the electricity produced by PV increase rapidly. Decreasing heating demand and the need for artificial lighting result that from April till September energy generated exceed building energy needs.

FINAL RESULTS - Economical analysis

One of the main important factors for the investor (developers and private person) for choosing the exact solution is the feasibility of the investment. For the design of plus energy house a simple financial analysis was performed. It includes calculation of the construction and annual energy costs.

In the calculations of the building energy costs all of the existing financial incentives were taken into account. That include non-refundable surcharge of 30 000 PLN from Polish Fund for Environmental protection for achieving the high performance building standard (18.55 kWh/m²/year final energy demand for heating and ventilation [**14**]), as well as the refundable of 45% of credit for solar panel installation [**15**].

The final costs of construction of the plus energy house were calculated as 29% higher than the costs of traditional house constructed nowadays in Poland (final energy demand for heating and ventilation =105 kWh/m²/year) [**16**] **Table 1**.

Table 1. Total cost of plus energy and standard house.

Plus energy house	Standard house
Net area: 99.1 m²	Net area: 99.1 m²
EUco* =18.55 kWh/m²	EUco*= 105 kWh/m²
Total costs of construction: 72 971.93 €	Total cost of construction: 56 896.03 €
The difference in cost compared to a standard home	
16 075.9 €	0
28.25%	0%

*EUco - Useful energy demand for heating and ventilation

The big differences in costs cause the barrier which might be hard to overcome. But, when we look at the annual energy costs which include the planned feed-in tariffs, we find that the designed building against to the traditional house is not generating costs, what's more, it's bringing profit to its owner. Based on the annual energy consumption and annual energy generation from PV's it was calculated that the annual energy generated will bring profit of 1612.43 €/year.

Calculation of simply payback time shows that the additional investment costs (16 075.9 €) will be paid after 10 years of building operation. As feed-in tariffs are valid for 15 years, for next 5 years building will bring clear profit to its owner. A detailed financial analysis including inflation and changes in energy prices might show shorter payback time. The final results might be close to the American experience, where for single plus energy family houses the SP is no longer than 8 years [**17**].

SUMMARY

The presented work proves that the construction of plus energy houses in Poland is possible and economically reasonable. With plans of a new energy law (will introduce to the market feed-in tariffs) and with the already existing financial incentives (promoting energy efficiency), Polish construction and energy industry is staying right now in front of the big changes. Final government decision will move them towards sustainability or back to times when coal was main energy source. ■

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Is CO_2 an indoor pollutant?

Higher levels of CO_2 may diminish decision making performance

WILLIAM J. FISK [1], USHA SATISH [2], MARK J. MENDELL [1], TOSHIFUMI HOTCHI [1], DOUGLAS SULLIVAN [1]
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[2] State University of New York Upstate Medical University, Syracuse, NY

Prior research has found that with higher indoor levels of CO_2, indicating less outdoor air ventilation per person, people tend to be less satisfied with indoor air quality, report more acute health symptoms (e.g., headache, mucosal irritation), work slightly slower, and are more often absent from work or school. It has been widely believed that these associations exist only because the higher indoor CO_2 concentrations occur at lower outdoor air ventilation rates and are, therefore, correlated with higher levels of other indoor-generated pollutants that directly cause the adverse effects. Thus CO_2 in the range of concentrations found in buildings (i.e., up to 5 000 ppm, but more typically in the range of 1 000 ppm) has been assumed to have no direct effect on occupants' perceptions, health, or work performance. A small study from Hungary [1] cast doubts about this assumption. The results from Hungary stimulated our effort to evaluate effects of variation in CO_2 alone on potentially more sensitive high-level cognitive functioning.

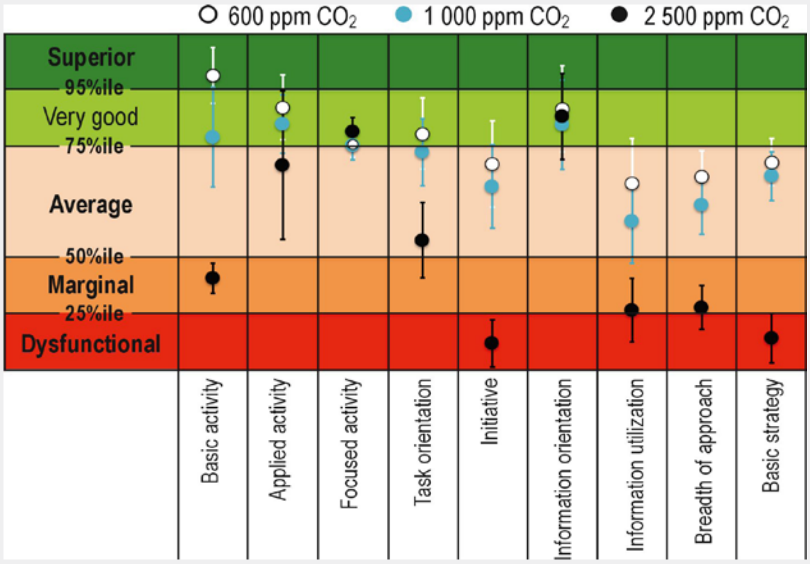

Figure 1. Impact of CO_2 on human decision-making performance. Error bars indicate one standard deviation.

In our experiment 22 subjects completed tests of decision making performance when exposed to low, medium, and high CO_2 concentrations for 2.5 h periods in an exposure chamber. During sessions with low CO_2, subjects and outdoor air were the only sources of CO_2, and measured CO_2 concentrations were approximately 600 ppm. In sessions with CO_2 at the medium and high levels of pure CO_2 was added to increase the CO_2 concentration to either 1 000 or 2 500 ppm. All other conditions remained unchanged. Each subject experienced all three CO_2 conditions on the same day and the order of sessions (low, medium, high; medium, low, high; etc.) was varied, as needed, among the subjects to cancel out effects of order of exposure.

The main results are depicted in **Figure 1**. The data indicate that at 1 000 ppm CO_2, relative to 600 ppm, there were moderate and statistically significant decrements in six of nine scales of decision-making performance. At 2 500 ppm, large and statistically significant reductions occurred in seven scales of decision-making performance, but a small increase in performance was seen in the focused activity scale. For some scales of performance, the reductions were dramatic. More details are provided in reference [2].

The dramatic direct influence of CO_2 on decision making performance was unexpected and the study needs to be replicated. The findings of this study, if replicated, have implications for the standards that specify minimum ventilation rates in buildings, and indicate the need to adhere more consistently to the existing standards. There is a current interest in reducing ventilation rates to save energy and reduce energy costs. Yet large reductions in ventilation rates could lead to increased CO_2 concentrations that adversely affect decision-making performance, even when indoor air concentrations of other air pollutants are maintained low through implementation of pollutant source control measures or application of gas-phase air cleaning systems. ■

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SAVE THE DATE!

REHVA Technical Seminar 2014 – 13 February 2014, Brussels

REHVA is organising its 2014 Technical Seminar together with the iSERV project consortium around the topic: Energy efficient operation of HVAC systems. iSERV is approaching to its end, so it is time to discuss project results and their further use in an EU-level seminar inviting also high level EC speakers.

The final programme and speakers will be confirmed soon in the REHVA website.

Preliminary programme of the seminar:

Section 1: Energy efficient buildings - EU policies and implementation
European policies of buildings energ efficiency – challenges and policy updates. • *DG Energy*
Supporting EPBD in the 2014-2020 financial period. The future of Intelligent Energy Europe. • *European Commission Executive Agency for Competitiveness and Innovation (EACI)*
National level implementation of EPBD • *Building Performance Institute Europe*
Section 2: Energy efficient operation of HVAC systems – the iSERVcmb project
Inspection of HVAC Systems through continuous monitoring and benchmarking – outcomes of the iSERVcmb project • *Project coordinator*
Lessons learnt from iSERV • *HVAC industry representatives*
Energy efficient operation of buildigs - good practices from IEE projects • *European Commission Executive Agency for Competitiveness and Innovation (EACI)*
Section 3: Parallel discussions about the deployment of iSERV results – policy and indusrty perspective
Legislation and policy recomendations from iSERV
What can producers and system operators gain from iSERV?

Have your say on the Energy Labelling and Ecodesign Directives

The European Commission is conducting a review of the Energy Labelling Directive and certain aspects of the Ecodesign Directive. REHVA as an acknowledged stakeholder was invited by Directorate-General for Energy to submit a two-page position paper by end of September elaborated with the contribution of Member Associations and Supporters.

Views from stakeholders on the effectiveness of the Directives, as well as on ways to improve the regulatory framework is collected also via an online consultation from end of August until end of November 2013. The online consultation includes multiple-choice questions tailored to different stakeholder groups and many free text fields to provide your views. The survey is available in the website: http://www.energylabelevaluation.eu/eu/online-survey/

Jarek Kurnitski appointed as a NZEB professor at Aalto University, Finland

Prof Dr **Jarek Kurnitski**, vice president of REHVA, has served as full professor of energy performance and indoor climate at Tallinn University of Technology since January 2012, after his career at Finnish Innovation Fund SITRA. In August 2013 he has been invited to Aalto University in Finland for the professorship of Nearly Zero Energy Buildings, by the initiative of Finnish HVAC industry. Dr Kurnitski will continue at Tallinn University of Technology and will expand his nearly zero energy building research group to Aalto University. The aim is to utilize the resources of both countries/universities in order to strengthen the joint research group with strong scientific ambition. Professor Kurnitski is known as the main contributor of performance based energy regulation enabling the use of dynamic simulations in both Finland and Estonia. Prof Kurnitski is also a vice chair of the REHVA Technology and Research Committee.

Aalto University was formed in 2010 when three existing universities (Helsinki University of Technology, Helsinki Business University and School for Arts and Design) were combined to get benefits from joint research and teaching, and savings in administration.

REHVA Task Forces

– backbone of the REHVA Technical activities

JORMA RAILIO
Chair of the REHVA
Technical and Research Committee

JAREK KURNITSKI
Vice-chair of the REHVA
Technical and Research Committee

LIVIO MAZZARELLA
Vice-chair of the REHVA
Technical and Research Committee

REHVA Task Forces

The objective of REHVA Technology and Research Committee is to develop and disseminate technical information for the benefit of REHVA members and supporters, enhance development of standards and research on European level, and increase the REHVA participation and visibility at European level activities.

To achieve these objectives, REHVA has established Task Forces, each with a specific topic. Each Task Force will prepare a REHVA publication, and REHVA Guidebooks are the main outcome of Task Forces. In some cases, a Technical Report is a more suitable outcome, especially in rapidly changing or developing issues.

The tradition of REHVA Task Forces and Guidebooks is rather young. The idea of Guidebooks matured at the end of last Millennium, after several discussions about the needs of practical and reliable documentation of European good HVAC practices, targeted directly to designers and other HVAC practitioners and also to other stakeholders. Finally, in spring 2000, the first action towards a REHVA Guidebook started, with the topic of **Displacement Ventilation**. This topic had been dealt with in numerous research reports, articles in professional journals, commercial brochures etc., but the information there was either fragmented, unpractical or commercially biased.

The format of Guidebooks, and also working practices of Task Forces, developed during the first project and still are much the same: first make a clear working plan and establish a working team, prepare a manuscript within a realistic schedule, and also make sure that the publication will sell.

In late 2002 the first Guidebook was published, and it still is one of the bestsellers. The principles of displacement ventilation are still the same, but technologies have developed and new applications have been commercialized, so the Guidebook No. 1 will be subject to revision which is currently about to start.

Since year 2002, teams of experts from all parts of Europe have participated in the work of Task Forces, often on a voluntary basis. A typical team consists of 4-6 experts, but in a few guidebooks or reports the number of contributors has been up to 20 or even more. All manuscripts are reviewed independently by well recognized experts.

The number of printed Guidebooks reached 20 in June 2013, when three new books were published and on display at Clima 2013 in Prague. At the same time, a Technical Report containing a proposed all-European framework definition of **nearly zero energy building** was published, this is TR 4 but actually the first one resulted from an "ordinary" Task Force – the first three were the collections of Workshop summaries from Clima conferences in 2005, 2007 and 2010. The decision to make a Technical Report was relatively easy: the need to disseminate the TF results was urgent, but the outcome is subject to change very soon, due to many changes "around".

The most successful Guidebooks have one common feature: strong "push" and commitment from the industry.

The working language in the Task Forces is English, as well the official original version of the Guidebook. But as a European organization over 20 languages are spoken within REHVA member associations. To reach better the national professionals the Guidebooks can be translated to national languages. REHVA offers this opportunity as a membership benefit to its members. More than 50 translations (see table below) are available through REHVA National members (contact information at www.rehva.eu).

Translations of REHVA Guidebooks

GB no.	Title	Language
1	Displacement Ventilation	Dutch Finnish German Italian Japanese Latvian Norwegian Portuguese Russian Slovenian Spanish Turkish
2	Ventilation effectiveness	Japanese Latvian Portuguese Slovenian/Serbian
4	Ventilation and Smoking	Portuguese Spanish
5	Chilled Beam Application	French Hungarian Italian Polish Portuguese Slovenian Spanish Turkish
6	Indoor Climate & Productivity in offices	Dutch Italian Japanese
7	Low Temperature Heating and High Temperature Cooling	Portuguese Finnish Hungarian Slovenian Italian Turkish Chinese

GB no.	Title	Language
8	Cleanliness of ventilation system	German Portuguese Italian
9	Hygiene Requirement for ventilation and air conditioning	Italian Portuguese
10	COMPUTATIONAL FLUID DYNAMICS (CFD) CALCULATIONS in Ventilation Design	Japanese Italian
11	AIR FILTRATION IN HVAC SYSTEMS	Portuguese Italian
12	Solar Shading	Finnish French Swedish Portuguese
13	INDOOR ENVIRONMENT AND ENERGY EFFICIENCY IN SCHOOLS - Part 1 Principles	Portuguese Italian
14	INDOOR CLIMATE QUALITY ASSESSMENT - Evaluation of indoor thermal and indoor air quality	Italian French
16	HVAC IN SUSTAINABLE OFFICE BUILDINGS - A BRIDGE BETWEEN OWNERS AND ENGINEERS	French
17	DESIGN OF ENERGY EFFICIENT VENTILATION AND AIR-CONDITIONING SYSTEMS	Portuguese Turkish

Active REHVA Task Forces (TF) August 2013

Name of the Task Force, Schedule and Chair/contact person	Descriptive objective of the Task Force
Air Conditioning inspections - Technical Guideline, 2012-2015 Chair: Vincenc Butala University of Ljubljana Slovenia vincenc.butala@fs.uni-lj.si	This TF aims to prepare a technical guideline for inspections of air conditioning systems, to support the implementation of Article 15 of the EPBD recast.
Reference Buildings for Energy Performance and Cost-Optimal Analysis, 2012-2014 Chair: Stefano P. Corgnati, Politecnico di Torino, taly stefano.corgnati@polito.it	This TF aims to develop, on the bases of the national experiences, a set of European Reference Buildings/benchmark buildings in order to suggest European wide harmonized database of building types which could be used for cost optimal calculations according to EPBD recast at European level by technicians and researchers. So far ongoing activities on the definition of national approved RBs are being developed and they are still far from being closed. Due to this fact, TF is now focusing in conducting cost optimal analyses and comparing the results of these between different MS in order to give some useful information to policy makers and investors.
Environmental-friendly Refrigerants in HVAC Applications, 2012-2014 Chair: Attila Zoltán Hungarian Coordination Association of Building Engineering attila.zoltan@t-online.hu	This TF aims to prepare a Refrigerant Guidebook which will help to define the optimal system-equipment-refrigerant couple for dedicated applications. The guidebook will introduce how to reduce, optimise the cooling power needed, the environmental impacts and energy efficiency of the equipment, including global parameters of refrigerants (ODP, GWP), energy efficiency (EER, ESEER, COP, SCOP), direct-indirect environmental impacts of equipment, systems, the TEWI (CO_2eq) and TEEI (inversed TEWI, kWheq) comparison methods.
HVAC systems long term impact in buildings valuation, 2013-2015 Chair: Frank Hovorka Caisse des Depots, France frank.hovorka@caissedesdepots.fr	HVAC related building performance is often insignificant in the context of an overall building evaluation made by potential investors. The TF thus aims at bridging the gap between HVAC engineers and building investors by translating typical HVAC system benefits into tangible financial benefits for the overall valuation of real estate. "Global costs" considering functionalities, investments costs and operation & maintenance issues are taken into account and the methodologies for translating the HVAC benefits to real-estate valuation will be presented and demonstrated with real life examples.
Energy refurbishment, 2013-2015 Chair: Marija S. Todorovic Academy of Engineering Sciences of Serbia deresmt@eunet.rs	EnRef TF aim is to prepare guidebook/s on the topic of the energy refurbishment encompassing holistic approach to the deep energy renovation of existing buildings, to the level of energy efficiency and renewable energy sources (RES) integration that ensures clear "zero" or "net zero" energy quality of the refurbished buildings status. TF promotes large-scale RES integrated buildings structure/ HVAC refurbishment technologies development, as well as necessary R&D to commercialize "RES Integrated Energy Refurbishment Construction/HVAC - Industry" as a whole integrated engineering process.
nZEB Nearly Zero Energy Buildings, 2012-2015 Chair: Jarek Kurnitski Tallinn University of Technology, jarek.kurnitski@ttu.ee	nZEB TF revised REHVA nZEB technical definition during 2012-2013, with the aim to help the experts in the Member States to define the nearly zero energy buildings in a uniform way. The revision, coordinated with CEN project group preparing 2nd generation EPBD standards, was published in June 2013 (REHVA REPORT NO 4, 2013). The work will continue as a new task force focusing on nZEB case studies/ technology with on site and nearby production and trying to find assessment method/indicator for "real addition" of RE energy and optimal performance on energy system level.

Name of the Task Force, Schedule and Chair/contact person	Descriptive objective of the Task Force
Combined Heat and Power (CHP) for buildings, 2012-2015 Chair: Klaus Sommer Cologne University of Applied Sciences Germany klaus.sommer@fh-koeln.de	In order to achieve the EU targets on energy savings and on reduction of greenhouse gas emissions the decentralized cogeneration (CHP) on individual building level can play an important role. This TF will produce a REHVA guidebook that covers different technologies of small and middle size CHP for different applications. Key aspects are system engineering and control, system operation and economic feasibility that will be derived from field tests and practical applications.
Fire safety in buildings: Smoke management guidelines, 2012-2014 Chair: Othmar Braendli Belimo Switzerland othmar.braendli@belimo.ch	This TF aims to prepare state of the art guidebook on fire & smoke solutions. It will provide approved fire & smoke solutions and show latest status of European fire & smoke standards and regulations.
Heat pump applications in refurbishment, 2012-2014 Chair: Branimir Pavkovic Croatia branimir.pavkovic@riteh.hr	This TF will produce a new guidebook on heat pump applications for new buildings and for refurbishment. Heat pumps can in some cases efficiently be implemented in existing systems of heating and cooling, providing cost effective solution in refurbishment. Limits of such application and proper system design will be discussed. General information suitable for target groups will be provided.
Cold climate design guide (ASHRAE/REHVA), 2012-2015 Chair: Bjarne Olesen, Technical University of Denmark bwo@byg.dtu.dk	This TF aims to prepare a cold climate design guidebook in cooperation with ASHRAE.
Weather Data Directory, 2012-2014 Chair: Livio Mazzarella, Italy Livio.mazzarella@polimi.it	The aim of this task force is to develop, on the bases of the worldwide available information, a weather data directory for HVAC design and performance simulation, which collects in a simple and concise way all references to national and/or regional weather data, their availability, statistical validity and application purposes.
Commissioning process Reactivation of the old TF, contact person: Ole Teisen, Ole.Teisen@grontmij.dk	In spite of the many standards there are different approaches to the commissioning process, and a lot of work is done in the name of Commissioning that is not adding any value to the buildings. We need more stringent requirements for verification of buildings and systems in order to verify planned energy savings and achieve sustainability certification. To achieve these aims, this TF will prepare guidelines and guidance on the Commissioning process. Besides supporting the Commissioning requirements of various sustainability certification programmes, the guidebook shall serve as a tool when doing a commissioning process on refurbishments.
Indoor environment in the implementation of policies and technologies for energy efficient buildings New proposal by FINVAC	There is a need a position paper on indoor environmental issues aimed at policy makers and authorities to point out the potential conflict between energy efficiency and indoor environment and to develop protocols and criteria for design and construction and operation practice.
Displacement ventilation New proposal by TRC	Existing displacement ventilation guidebook is sold out and already so old that needs to be updated. TRC will initiate new TF with the aim to revise and publish new displacement ventilation guidebook.

Product news

GEA Fricostar *Micro*: comfortable swimming

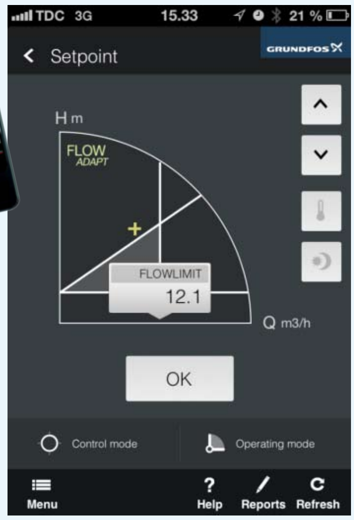
GEA Fricostar *Micro* climate control systems from GEA Heat Exchangers guarantee a feel-good atmosphere in indoor swimming pools. These pre-assembled units, which are virtually ready to plug in, provide energy-efficient air conditioning of small indoor swimming pools and therapeutic baths with water surface areas of approx. 30 to 110 m². They enable swimming guests to enjoy air temperatures of two or three degrees above the water temperature, and relative humidity below 60%.

Thanks to their intelligent control systems, these units operate on a demand-controlled basis. When many swimmers are in the pool, the wave amplitude increases, accompanied by greater evaporation. The GEA Fricostar *Micro* climate control system thereby increases its dehumidification performance and provides the additionally required amount of outdoor air. When the pool is closed to the public, only quiescent evaporation takes place. In this case the control system reduces the supply of outdoor air and regulates the humidity in the pool at a constant level, with maximum energy savings.

The dehumidification performance of Fricostar *Micro* climate control systems ranges from 5 to 33 kg/h, depending on model size. The corresponding maximum amount of circulating outdoor air is around 800 to 6 500 m³/h. The GEA Fricostar *Micro* requires only a small footprint, since the ventilation ducts are connected at its upper side. These compact systems can also be installed in small machine rooms. Despite their compact dimensions, they offer air conditioning comfort equivalent to large systems. They are equipped with multi-stage heat recovery. Depending on model they are obtainable for heat pump operation. The ventilator systems already meet the requirements (2015) based on the Eco Desing of Energy Related Products Directive. The Fricostar *Micro* series is available in various corrosion-protection classes, and is therefore effective for use in salt-water and ocean-water swimming pools. This equipment can also be integrated into building automation and utilities systems.

Further info see www.gea-heatexchangers.com

Grundfos GO - a smart device to optimise pump operation



FLOWLIMIT can easily be set on the Grundfos GO. The vertical line can simply be pushed back and forth to set the maximum flow in the system.

Grundfos has developed a new GO smart device for pump set-up, pump commissioning, total pump control, and monitoring. It works with all Grundfos e-pumps and communicates both via radio and infra-red technology. It provides data such as duty point monitoring, power consumption, media temperature, water flow, head and running hours etc. The remote app is available for Apple iOS and Android devices.

DuTreat Roof Top Unit

Advantix Systems' dehumidification & cooling products are based on liquid desiccant's natural removal of moisture from air. This non-toxic, brine solution dehumidifies, cools, and cleans the air in a simultaneous process (Conditioner).

Benefits

- ❖ Powerful, precise humidity control
- ❖ Lower operating costs: 20-40% less than outside air/high latent mechanical systems,
- ❖ 30-60% less than desiccant wheel systems
- ❖ Comparable (or lower) upfront cost to alternative equipment
- ❖ Low maintenance (no UV lights, drip pans, condensate lines or other coil treatments required)
- ❖ Naturally filters and disinfects air for improved indoor air quality (IAQ)

About Advantix Systems

- ❖ More than 800 installations commercially worldwide with proven performance of 5 years+
- ❖ Pioneered liquid desiccant technology in early 1980's for cooling and dehumidification with broad patented portfolio
- ❖ Headquarters in Miami, offices/reps in Israel, India, Singapore, China, Taiwan, Thailand, Europe, Latin America
- ❖ Winner of Bloomberg's New Energy Pioneer Award, AHR's Most innovative Cooling Product Award, IFT's Most Innovative Technology, Alliance to Save Energy's Super Nova Award
- ❖ Featured in New York Times, Engineered Systems Magazine, ACHR News as Product of the Week, The Economist

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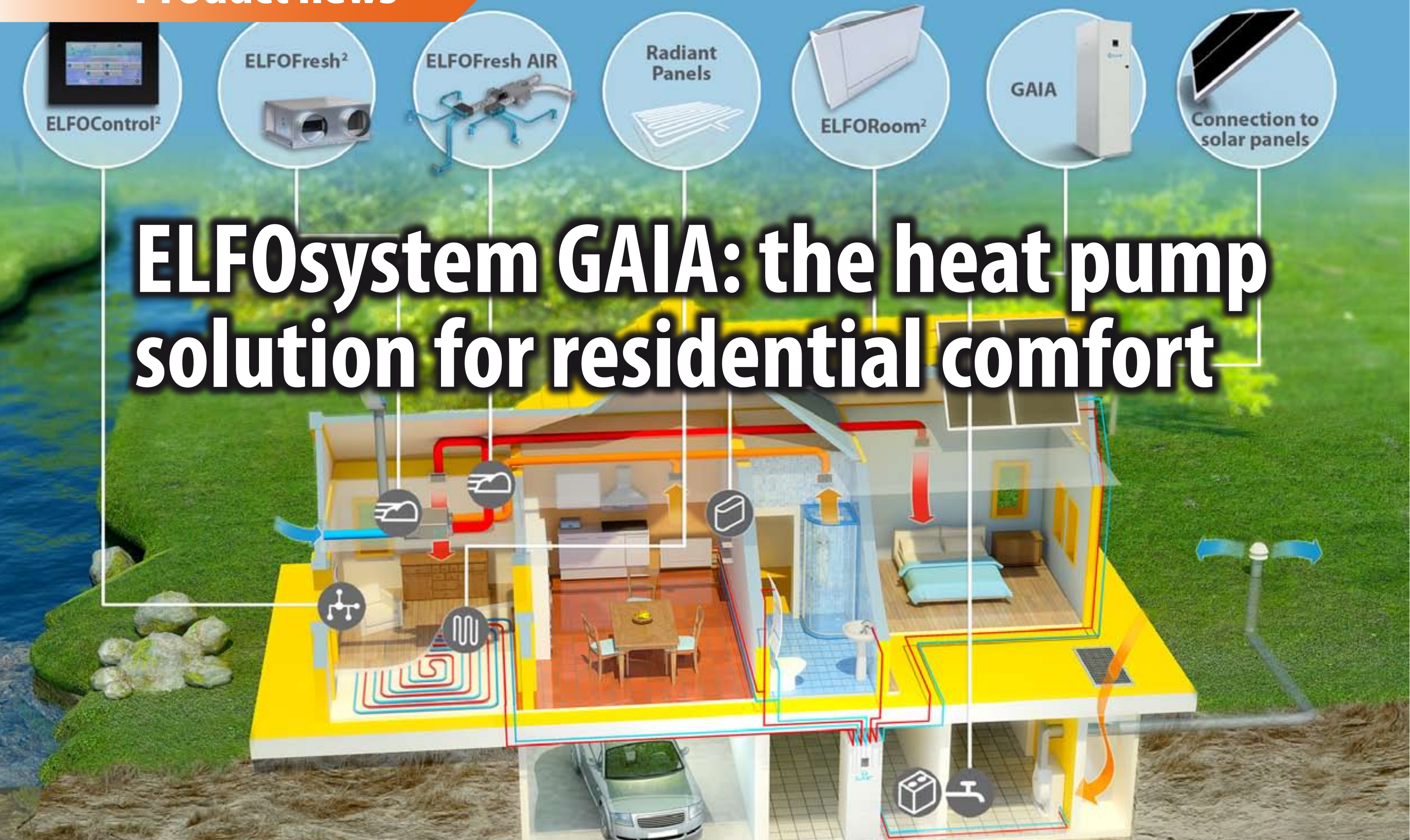
Environmentally Friendly Products from Friterm

With over 30 years of experience in industrial and commercial refrigeration as well as air conditioning, Friterm is today one of the leading manufacturers of finned tube type heat exchangers.

As a result of innovative approach, Friterm has been manufacturing products with stainless steel tubes since August 2012. It is also known that selecting suitable material has great importance in refrigeration and air conditioning technology. It is clear that copper and copper-bearing materials are attacked by ammonia NH_3. Stainless steel has superior corrosion resistance and high tensile strength, resulting in lower tube thickness. However, stainless steel tubes have lower conductivity and they are relatively expensive. Those negative effects could be compensated by using aluminium fin providing low cost, lightweight and high thermal conductivity. Furthermore, the low density of aluminium decreases total heat capacity of the product, which means less energy requirement during a defrost cycle resulting in less power consumption. Moreover, the maximum fin space, 19 mm, is reached; meaning that less defrost demand that can be used for freezers effectively.

Product news

ELFOsystem GAIA: the heat pump solution for residential comfort



Clivet presents ELFOSystem GAIA, the complete system for heating, cooling, fresh air and purification and hot water production, which uses renewable energies.

ELFOSystem GAIA is the residential air conditioning system which guarantees all year round comfort in a single heat pump system: heating, cooling, fresh air and purification and production of hot water.

It allows an average **yearly reduction in energy** consumption and **CO_2 emissions of 50%, increases the energy efficiency class** and eliminates CO_2 and NO_X emissions for fresh air in our cities.

The elements of the system are:

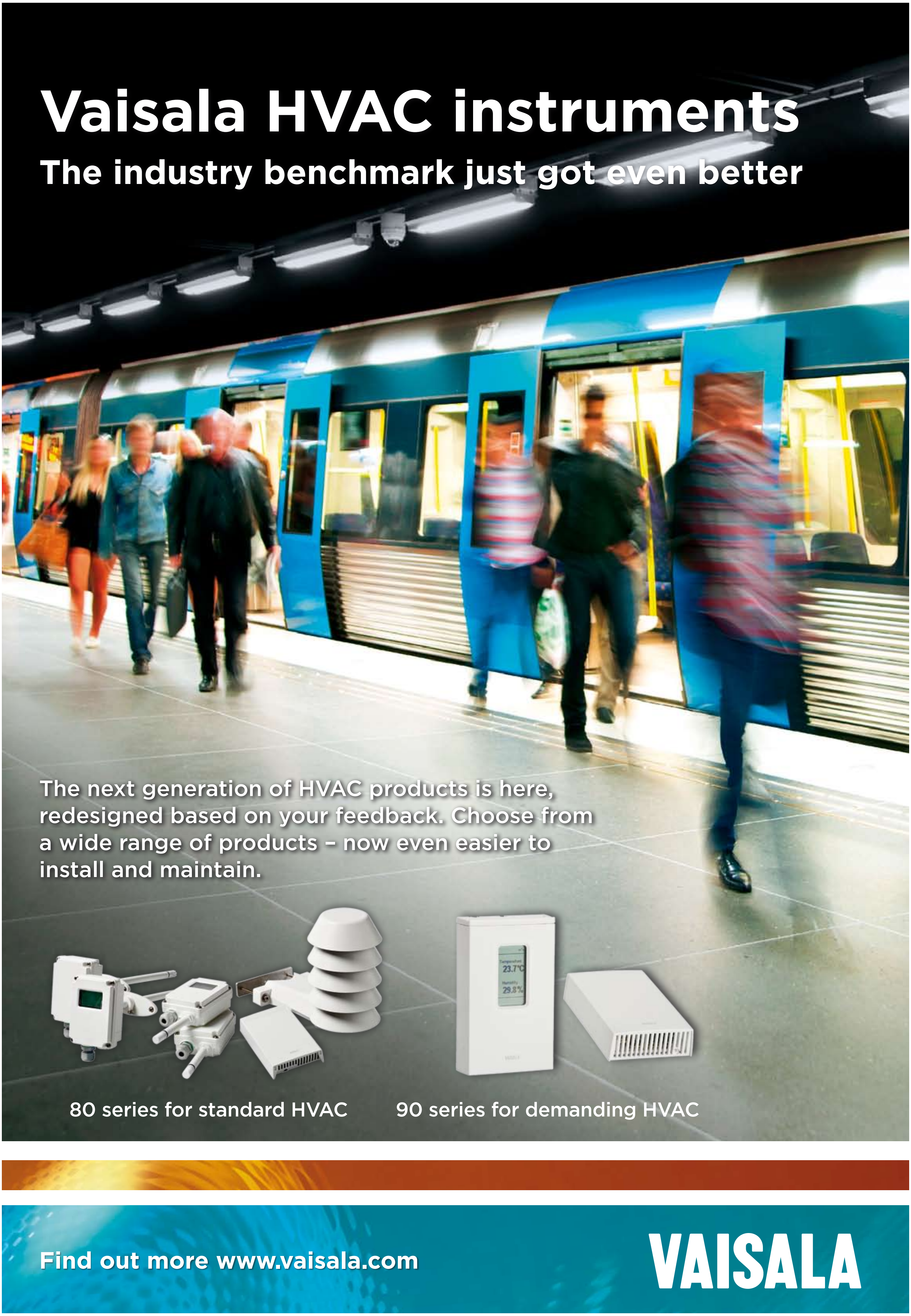
GAIA, the heat pump with inverter DC technology which produces heating and cooling energy, integrating all components of an heating plant (including the production of hot water with 186 litre storage tanks and pumping groups). GAIA derives 75% of the energy necessary to the plant from the sun through heat pump technology which captures the energy contained in air, ground or water with just 25% of electricity. The unit is suitable for connection to solar panels, so that the domestic hot water can be produced with high savings. If combined with photovoltaic panels GAIA can become 100% renewable energy.

- **ELFOFresh²**, the unit for air renewal and purification with thermodynamic recovery and electronic filters (equal to H10 classification) to cool and heat the fresh air with minimum energy consumption.
- Distribution of hot and cold temperatures through radiant panels, radiators or **ELFORoom²** fan coil units (Clivet's terminal units are equipped with an exclusive electric motor which drastically reduces electricity consumption compared with a traditional fan coil unit).
- **ELFOControl²**, the comfort control unit with temperature probes for each room, which allows you to define the operating conditions for the whole plant as far as for each element of the system.

The system which meets the most varied requirements of new and existing systems, doesn't use gas or other fuels, eliminating the risk of dangerous substances in the air.

For further information:

Clivet UK LTD - Paul O'Gorman, tel. +44 (0) 1489 572238 – e-mail: p.ogorman@clivet-uk.co.uk
Clivet SPA - Barbara Casagrande, tel. +39 0439/313235 – e-mail: b.casagrande@clivet.it - www.clivet.com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The industry benchmark just got even better
The next generation of HVAC products is here, redesigned based on your feedback. Choose from a wide range of products – now even easier to install and maintain.
80 series for standard HVAC
90 series for demanding HVAC
Find out more www.vaisala.com
VAISALA

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

Events in 2013 - 2014

Conferences and seminars 2013

September 22 - 27	8th Conference on Sustainable Development of Energy, Water and Environment Systems	Dubrovnik, Croatia	www.dubrovnik2013.sdewes.org
September 25 - 26	34th AIVC- 3rd TightVent- 2nd Cool Roofs' - 1st Venticool	Athens, Greece	www.AIVC2013Conference.org
September 25 - 27	5th International Conference Solar Air-Conditioning	Germany	www.otti.eu
September 25 - 29	International Conference on Sustainable Building Restoration and Revitalisation	Shanghai, China	www.wta-conferences.org/conference/1869
October 3 - 4	CLIMAMED - VII Mediterranean Congress of Climatizacion	Istanbul, Turkey	www.climamed.org
October 15 - 16	European Heat Pump Summit	Nürnberg, Germany	www.hp-summit.de
October 15 - 18	IAQ 2013 - Environmental Health in Low Energy Buildings	Vancouver, Canada	www.ashrae.org/membership--conferences/conferences/ashrae-conferences/iaq-2013
October 16 - 18	Building Services for the Third Millenium	Sinaia, Romania	www.aiiro.ro
October 18 - 19	COGEN Europe Annual Conference & Dinner	Brussels, Belgium	www.cogeneurope.eu
October 19 - 21	ISHVAC	Xi'an, China	www.ishvac2013.org
October 20 - 21	Energy Efficiency & Behaviour	Helsinki, Finland	www.behave2012.info
November 5 - 6	8th ENERGY FORUM on Solar Building Skins	Bressanone, Italy	www.energy-forum.com
December 4 - 6	44 International Congress of HVAC&R	Belgrade, Serbia	www.kgh-kongres.org

Conferences and seminars 2014

January 18 - 22	ASHRAE 2014 Winter Conference	New York, NY, USA	www.ashrae.org/membership--conferences/conferences
February 24 - 26	First International Conference on Energy and Indoor Environment for Hot Climates	Doha, Qatar	www.ashrae.org/HotClimates
February 26-28	World Sustainable Energy Days 2014	Wels, Austria	www.wsed.at
February 26 - 28	49th AiCARR International Conference	Rome, Italy	www.aicarr.org
April 3 - 4	4th CIBSE ASHRAE Technical Symposium 2014 - "Moving to a New World of Building Systems Performance"	Dublin, Ireland	www.cibse.org/symposium2014
April 7 - 8	ASHRAE High Performance Buildings Conference	San Francisco, California	www.hpbmagazine.org/hpb2014
April 10 -13	2014 Windsor conference - Counting the cost of comfort in a changing world	Windsor, United Kingdom	http://nceub.org.uk
April 29	REHVA Annual Conference	Dusseldorf, Germany	www.rehva.eu
May 13 -15	11th IEA Heat Pump Conference 2014	Montreal, Canada	www.geo-exchange.ca/en/canada_to_host_the_11th_international_energy_agenc_nw211.php
July 7 - 12	Indoor Air 2014	Hong Kong	www.indoorair2014.org
August 31 - Sep 2	11th IIR-Gustav Lorentzen Conference on Natural Refrigerants - GL2014	Hangzhou, China	
September 10 - 12	ASHRAE/IBPSA-USA Building Simulation Conference	Atlanta, GA, USA	http://ashraem.confex.com/ashraem/emc14/cfp.cgi
October 18 -19	CCHVAC Congress	China	
October 19 - 22	Roomvent 2014	Sao Paulo, Brazil	www.roomvent2014.com.br

Exhibitions 2013

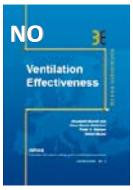
September 3 - 6	Aqua-Therm Almaty	Almaty, Kazakhstan	www.aquatherm-almaty.com
September 25 - 27	ISH Shanghai & CIHE	Shanghai, China	www.ishc-cihe.com
October 23 - 26	Aqua-Therm Baku	Baku, Kazakhstan	www.aquatherm-baku.com
November 4 - 8	Interclima+Elec	Paris, France	www.interclimaelec.com

Exhibitions 2014

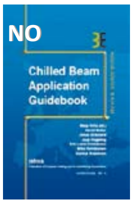
January 21 - 23	AHRI Expo	New York, NY, USA	www.ahrexpo.com
February 4 - 7	Aqua-Therm Moscow	Moscow, Russia	www.aquatherm-moscow.ru/en/
Feburary 27 - March 1	ACREX 2014	New Delhi, India	http://acrex.in/
March 4 - 7	Aqua-Therm Prague	Prague, Czech Republic	www.aquatherm-praha.com/en/
March 18 - 21	MCE - Mostra Convegno Expocomfort 2014	Fiera Milano, Italy	www.mcexpocomfort.it
March 30 - Apr 4	Light + Building	Frankfurt, Germany	www.light-building.messefrankfurt.com
April 1 - 4	NORDBYGG 2014	Stockholm, Sweden	www.nordbygg.se
May 7 - 10	ISK - SODEX 2014	Istanbul, Turkey	www.hmsf.com
May 13 – 15	ISH China & CIHE	Beijing, China	www.ishc-cihe.com
September 30 - Oct 3	Finnbuild 2014	Helsinki, Finland	www.finnbuild.fi
October 14 - 16	Chillventa 2014	Nuremberg, Germany	www.chillventa.de/en/

REHVA GUIDEBOOKS

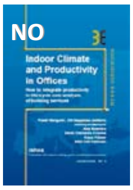
REHVA Guidebooks are written by teams of European experts



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

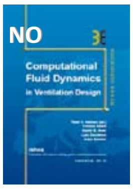


Chilled beam systems are primarily used for cooling and ventilation in spaces, which appreciate good indoor environmental quality and individual space control. Active chilled beams are connected to the ventilation ductwork, high temperature cold water, and when desired, low temperature hot water system.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

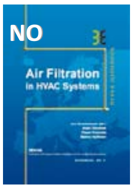


Indoor Climate and Productivity in Offices Guidebook shows how to quantify the effects of indoor environment on office work and also how to include these effects in the calculation of building costs. Such calculations have not been performed previously, because very little data has been available. The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

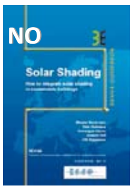
This Guidebook describes the systems that use water as heat-carrier and when the heat exchange within the conditioned space is more than 50% radiant. Embedded systems insulated from the main building structure (floor, wall and ceiling) are used in all types of buildings and work with heat carriers at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



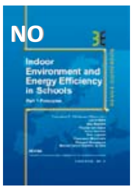
CFD-calculations have been rapidly developed to a powerful tool for the analysis of air pollution distribution in various spaces. However, the user of CFD-calculation should be aware of the basic principles of calculations and specifically the boundary conditions. Computational Fluid Dynamics (CFD) –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



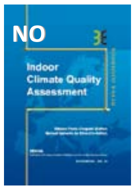
Air filtration Guidebook will help the designer and user to understand the background and criteria for air filtration, how to select air filters and avoid problems associated with hygienic and other conditions at operation of air filters. The selection of air filters is based on external conditions such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



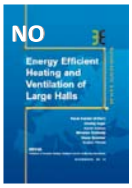
Solar Shading Guidebook gives a solid background on the physics of solar radiation and its behaviour in window with solar shading systems. Major focus of the Guidebook is on the effect of solar shading in the use of energy for cooling, heating and lighting. The book gives also practical guidance for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



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

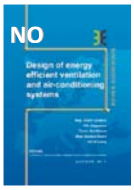


This new REHVA Guidebook gives building professionals a useful support in the practical measurements and monitoring of the indoor climate in buildings. Wireless technologies for measurement and monitoring has allowed enlarging significantly number of possible applications, especially in existing buildings.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

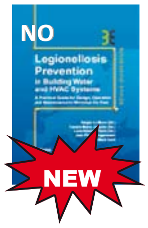


This guidebook is focused on modern methods for design, control and operation of energy efficient heating systems in large spaces and industrial halls. The book deals with thermal comfort, light and dark gas radiant heaters, panel radiant heating, floor heating and industrial air heating systems. Various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

This guidebook talks about 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.



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.



This Guidebook is a practical guide for design, operation and maintenance to minimize the risk of legionellosis in building water and HVAC systmes. It is devided 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.

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.

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.

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.