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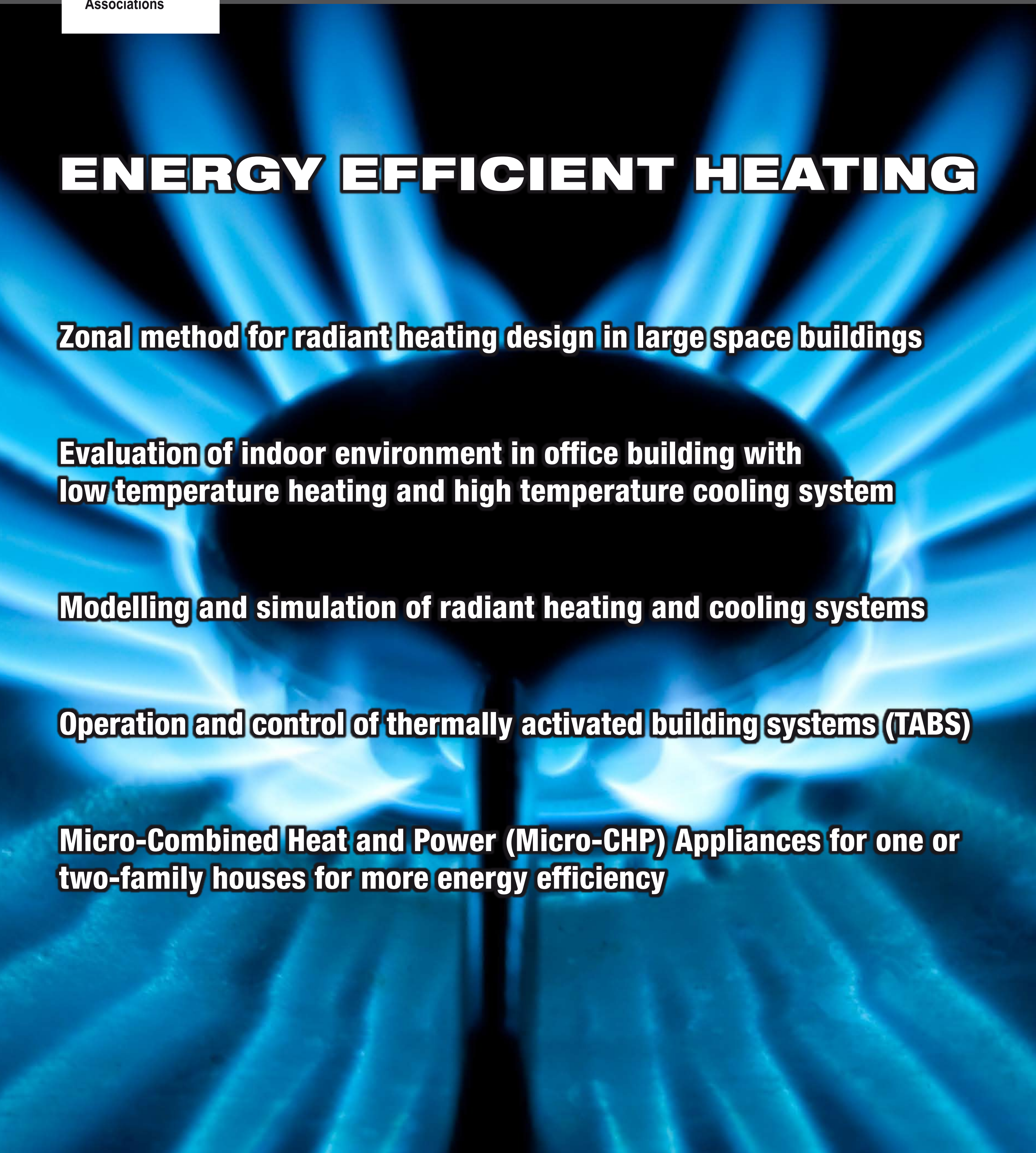

ENERGY EFFICIENT HEATING

Zonal method for radiant heating design in large space buildings

Evaluation of indoor environment in office building with low temperature heating and high temperature cooling system

Modelling and simulation of radiant heating and cooling systems

Operation and control of thermally activated building systems (TABS)

Micro-Combined Heat and Power (Micro-CHP) Appliances for one or two-family houses for more energy efficiency

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Heating and nearly zero energy buildings

Karel Kabele
guest editor

CSc. Prof. Ing.
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Energy performance of buildings directive aims to "20-20-20" in the year 2020. The main focus is on greenhouse gases production and energy use decrease in buildings by 20% coupled with the increase of renewable energy sources ratio up to 20% in energy production. To fulfill this ambitious target several steps in building design, construction, commissioning and operation have to be done.

At first it is necessary to reduce energy needs of buildings expressed by their energy performance. Energy performance of buildings describes inter alia annual energy use for heating, ventilation, air conditioning, hot water generation and lighting. Heating in moderate and Nordic climate regions is a significant energy user. Its reduction is based on improving building envelope thermal resistance along with enhancing the ability of a heating system to respond sensitively to a random heat gain that may reduce the total energy need. Development of new technologies in this field focuses on an intelligent control of a heating systems, which allows an output control of the system during the whole heating period within 0–100%. Typical examples of such a high efficient flexible system are radiant heaters for industrial halls. A big challenge for office and residential buildings is an integrated low temperature heating/ high temperature cooling system and thermal activated building structures using low potential energy sources. Nowadays it is possible to find a lot of examples of these technologies and ongoing measurements and tests indicate expected behavior of these systems.

The second issue is the use of high efficient or renewable sources to cover remaining energy needs. In this field we can expect wider development of micro-cogeneration, the use of biomass and of course solar and wind energy use.

Frequently asked question is whether a heating system in an almost zero energy building in Central or North Europe will be ever necessary. The answer is not simple and of course depends on the final definition of almost zero energy building. Detailed analyses based on computer models and in-situ measurements indicate massive reduction of heating demand. However will we be by 2020 really ready to discontinue a 400 000 years long period of human settlements development based on fire and heating?


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Zonal method for radiant heating design in large space buildings

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Introduction

Designers of HVAC systems for industrial and other large space buildings tackle these days with the same pressure for energy consumption reductions as in residential area. However especially for large space buildings there was at least in Europe lack of a design methodology that is not directly connected to any particular manufacturer and offers potential of significant energy consumption reductions when followed. This spring was published a new REHVA Guidebook (No. 15) that addresses exactly the topic and offers completely new approach for design of various heating systems used in large space buildings. In this paper the basics of the methodology are shown on a simple example - heating of a 3-bay industrial hall with radiant panels. Details of the methodology including evaluation procedure for the most broadly used heating systems can be found in the guidebook.

Zonal approach from history to present

The major development in radiant heating systems in Czech Republic had come after 1952, when Mr. Cihelka from Czech Academy of Sciences formulated, based on extensive experimental work, first methodology for radiant panel's design. His work was first published in 1957 and republished in 1961 in even today very often cited book called Radiant Heating (Sálavé vytápění) [1]. The concept of creating the thermal zones in larger spaces had first appeared in Czech Republic already in 1958, when Mr. Kotrbatý had published paper on that issue related with view factors calculations done by Mr. Cihelka. During time this concept was further improved and appeared also later in 1980s in Germany in work done by prof. Glück [2]. The problem of this methodology was the fact that designers and manufacturers didn't accept it in larger scale and therefore it went slowly forgotten. The change has come after turnover in Czech Republic in 1991 when Mr. Kotrbatý had founded a company firstly designing and importing, but soon after also manufacturing and assembling heating systems for large space buildings and started to use the thermal zones methodology for all products (plaque and tube gas radiant heaters and radiant panels). During recent years the methodology was proved on real assemblies, corrected and improved in cooperation with Czech Technical University in Prague (prof. Bašta, prof. Kabele), Slovak University of Technology in Bratislava (prof. Petráš) and Cologne University of Applied Science (prof. Sommer). Later on the methodology was discussed on Clima 2010 congress in special workshop initiated for that purpose [3]. The work was summarized in creation of a universal methodology, applicable to most of the heating systems used for large spaces. The methodology was published IN REHVA Guidebook No. 15 [4].

Standard approach - Uniform distribution of heating surfaces in large space

The difference between standard methodology and the zonal method is at best observable from particular example. At the **Figure 1** there can be found the most frequently used approach for design of heating systems in large space buildings. There is a typical 3-bay industrial hall with dimensions 60 x 18 x 7 m per each bay. At the front side there is an annexed office building. The hall building is normally insulated with standard windows and skylights. From the figure it is obvious that placement of radiant panels is completely uniform. At first sight everything is ok, installed power output perfectly covers heat losses and hence there is no indication of any problem. However in reality there are two variants of operation. Let's consider for example bay A:

a) The globe temperature control sensor is placed either in zone 1 or 2 or 3;
b) The globe temperature sensor is placed in zone 4.

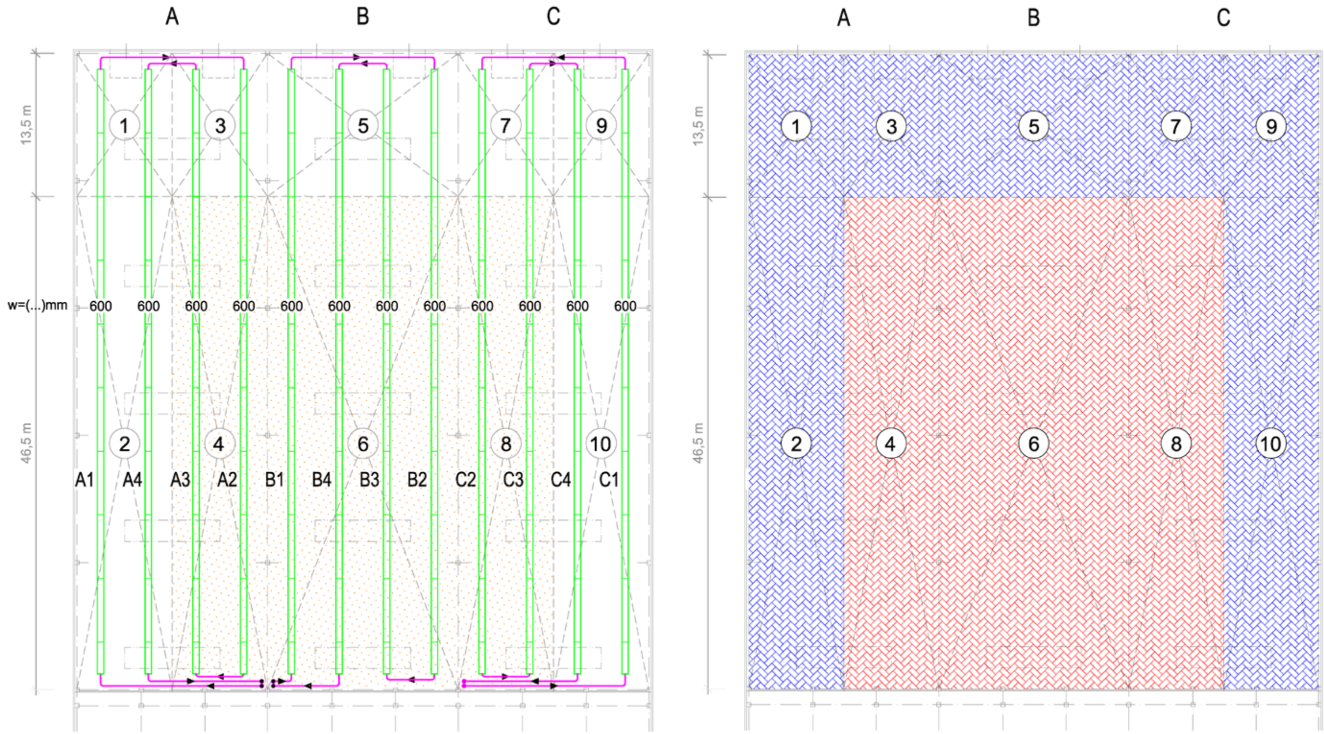

Figure 1 Uniform location and connection of radiant strips related with resulting temperature distribution at nominal conditions.

It results in general in two possible operation statuses:

a) If the design was done with sufficient reserve there is significant **overheating** in zone 4. However, if the design was done to the edge, the desired temperature in zones 1, 2 and 3 **will never be reached** (when external temperature is at design value);

b) Zones 1, 2 and 3 will be heated **insufficiently**;

Particular values of design heat losses Φ_i and installed power outputs of radiant panels $\Phi_{HL,i}$ are shown in **Table 1** for each zone of the hall. Visually, it is easier to observe results at **Figure 1** on the right hand side. For example in zone no. 1 installed radiant panels deliver at nominal conditions of about 30.3% less heat than needed. On the other hand in zone no. 4, and 8 radiant panels deliver 41.3% more heat than needed. That means that however the heating surface is designed uniformly, the thermal comfort conditions will not be uniform at all.

Table 1. Ratio r between installed power output $\Phi_{HL,i}$ and total heat losses Φ_i in every zone in case of uniform design.

Zone no.	Φ_i [W]	*l* [m]	$\Phi_{HL,i}$ [W]	r [%]
1	17 280	24	12 036	69.7
2	56 340	90	45 270	80.4
3	12 729	24	12 024	94.5
4	31 871	90	45 045	141.3
5	25 458	48	24 060	94.5
6	63 742	180	90 315	141.7
7	12 729	24	12 024	94.5
8	31 871	90	45 045	141.3
9	17 280	24	12 036	69.7
10	56 340	90	45 270	80.4
Σ	325 640	684	343 125	

l … length of radiant strips in a zone.

Resulting statement is simple: **In order to obtain uniform thermal comfort conditions all over the considered space, it is necessary to design heating system non-uniformly.**

Zonal method - Adapted sizes of heating surfaces

To be able to satisfy different heat delivery demands in each zone, the heating surfaces have to be designed differently. Because the length of radiant panels is given by space requirements, the parameter that can be adapted is the width of the heating surface (in case of radiant panels). In the design process suitable sizes (widths) of radiant panels have to be adapted in all zones according to the thermal requirements and simultaneously connection of radiant strips plays also the role. From the **Figure 2** it is obvious that the whole building has in different places (thermal zones) different requirements on heat delivery. However also in such situation it is necessary to keep whole heating system as simple as possible at least for the control and maintenance. Hence, the system was divided in three separately controllable sections. After initial concept was done, thermal zones had to be determined. The rules for boundary setting are described later on. Finally, it resulted in two sections lengthwise and in total five sections crosswise (two per marginal bays plus one per inner bay).

Following aspects are significantly influencing effectiveness and efficiency of whole heating system:

a) Connection of radiant strips into water circuits (the warmest inlet connected first to the marginal strips – this aspect has already been discussed in detail in [5]);
b) Increase of heat delivery in lengthwise marginal zones by means of wider radiant strips;
c) Increase of heat delivery in crosswise marginal zones by means of wider radiant panels at the end of each strip.

Connection of radiant strips into water circuits

In the bay A, the connection order starts from the very side strip and goes inward one after another. As the distance from the external wall increases the heat delivery needed to achieve thermal comfort for occupants is decreasing.

The bay C is vice-versa.

In the bay B there are different requirements. There is a need to supply heat uniformly and therefore the connection order is different. First the heat is delivered to the side strip at one side (strip B1), but then the connection leads to the opposite side of the bay (strip B2). Just after that the inner strips (B3 and B4) are connected. This way, uniform mean water temperature in a cross-cut is achieved.

Increase of heat delivery in lengthwise marginal zones

The connection itself doesn't always have to be enough. In some cases the difference in heat losses between marginal thermal zone and inner one is so large that in order to maintain uniform thermal comfort there have to be considered also changes in radiant panels' width.

Increase of heat delivery in crosswise marginal zones

In crosswise direction, there have to be considered also zones in the neighborhood of the front wall. Gates and windows located there can cause significant increase in local heat losses that has to be somehow covered. There is a possibility to make changes in width of strips even along one strip.

Table 2 shows how the reallocation of heating surfaces can influence thermal conditions in each zone.

Table 2. Ratio r between installed power output $\Phi_{HL,i}$ and total heat losses Φ_i in every zone in case of thermal zones-based design.

Zone no.	Φ_i [W]	*l* [m]	$\Phi_{HL,i}$ [W]	*r* [%]
1	17 280	24	19 104	110.6
2	56 340	90	61 335	108.9
3	12 729	24	13 728	107.9
4	31 871	90	36 315	113.9
5	25 458	48	29 208	114.7
6	63 742	180	70 290	110.3
7	12 729	24	13 728	107.9
8	31 871	90	36 315	113.9
9	17 280	24	19 104	110.6
10	56 340	90	61 335	108.9
Σ	325 640	684	360 462	

l … length of radiant strips in a zone.

It can be easily seen that the situation is significantly better, because the heat delivery much more follows the demands of the space. The highest overheating is about 14.7% and wherever the temperature sensor might be placed there will be almost no zone with lack in heat delivery. The difference among zones is not higher than 6.8%.

How to determine boundaries of the thermal zones

The only question remains, where are the boundaries of outer and inner thermal zones? The answer is in the way how heat is delivered to the considered space. In case of convective systems it is difficult to separate thermal zones within the space because as the amount of delivered air increases the mixing causes hardly separable conditions. On the other hand radiant heating systems are for these purposes ideal. In case of smaller local sources (electric or gas radiant heaters) it can be easily considered so, that to every heating source can be assigned a specific thermal zone. In case of larger systems (low temperature & long tube gas radiant heaters and water/steam radiant panels) the situation is a little bit more difficult. It is obvious that as the distance from the external wall increases, the total irradiation from different heating surfaces increases as well. This can be mathematically expressed by summary view factor calculation from all the heating surfaces. The view factor can be presented on a graph as a function of distance from the external wall. As we follow the curve shape from the beginning, it rises significantly and, at some certain point, the view factor reaches its maximum. From that point on it fluctuates around a mean value. So ideally the boundary of the marginal thermal zone can be set at the point where the curve changes from rising towards constant value. In reality the curve may have various shapes (depending on the location and sizes of heating surfaces) and therefore there is a necessity of designers' decision.

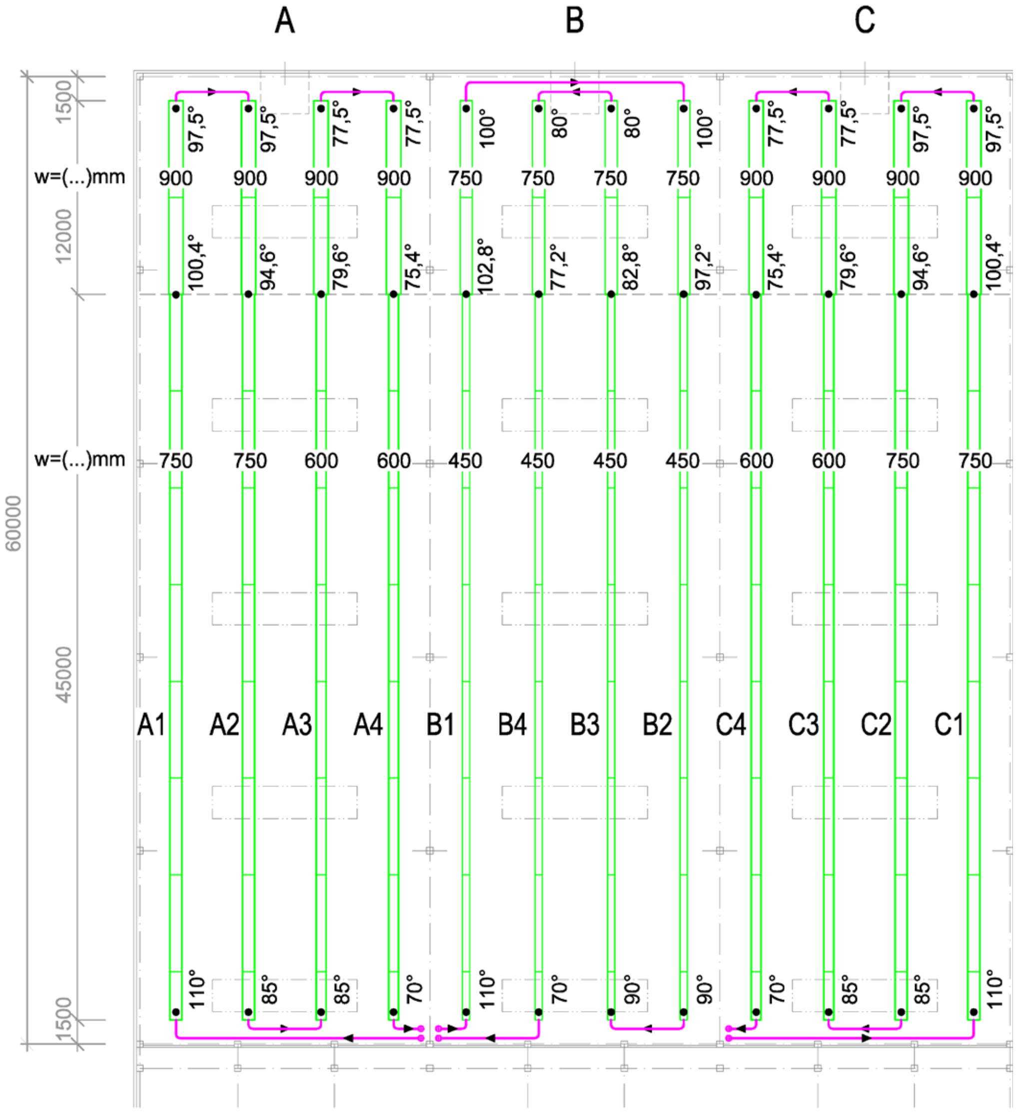

Figure 2. Optimal location and connection of radiant strips.

Conclusion

Proposed design methodology is based on practical experience with many real projects as well as theoretical backgrounds. It was written to be easy to use without complicated mathematical formulas. The methodology is applicable and has similar effects both for the low end and high end products. It provides much more energy efficient heat delivery for large spaces than standard, uniform approach and requires just slightly higher effort from the designers. It covers electric, gas, water and even steam based radiant heating systems. It was proposed for radiant heating systems as they are themselves more efficient than most of the convective heating systems in large (especially high) spaces.

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Evaluation of indoor environment in office building with low temperature heating and high temperature cooling system

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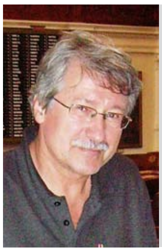

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Introduction

This paper regards to basic indoor environmental parameters in administrative spaces of two office buildings in Bratislava, Slovakia in summer and in winter period.

A large number of people often experience discomfort due to draught, low or high temperatures when they are at work. Office buildings with facades made in high extent of glass are influenced by outdoor conditions. Therefore it is necessary to equip them with some of the systems of building services in order to ensure optimal indoor conditions. One of such systems is the low-exergy system, what means low temperature heating and high temperature cooling in one system. This system is one of types of radiant surface heating and cooling and consists of radiant heating and cooling panel systems with integrated pipes suspended under the ceiling or embedded id building construction. Thermal energy is exchanged between the room and people present in the space and the heated / cooled surface.

Low temperature heating and high temperature cooling

Building A

The office building is located in Bratislava, Slovakia. It is a new administrative building (**Figure 1**), built in 2008. The building has two underground floors and 8 floors above the ground. The Office building has a completely glass facade.

Figure 1. Office building.

In the administration part the fresh air is supplied to office spaces by means of under floor air distribution system. Radiant heating and cooling panel systems with integrated pipes suspended under the ceiling are installed (**Figure 2**). Thermal energy is exchanged between the room and people present in the space and the heated / cooled surface.

The radiant heating/cooling panels are with pipes Ø 8 mm and 12 mm, made of copper.

Radiant ceiling are installed by means of a hangers in order to fix the pipes, which are made by copper. The ceiling is composed by: insulation, hangers, pipes, wire net, plaster. These ceiling panels are usually used for

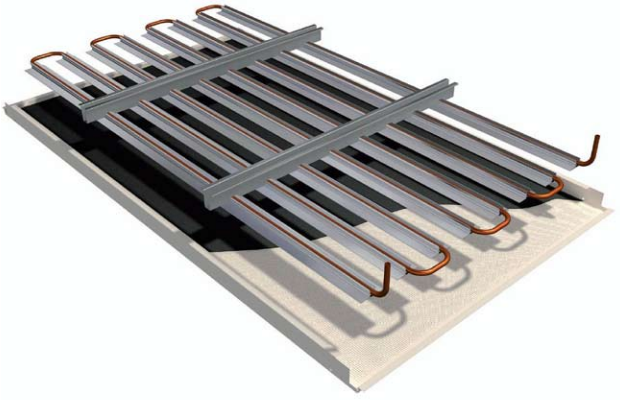

Figure 2. Radiant heating/cooling panel [11]

open space offices like here. The maximum surface temperature depends on the criteria for radiant asymmetry or direct contact with the surface [2]. Suspended, radiant ceiling systems cover the whole ceiling surface. The insulation over the panel is used to avoid the heat losses to the construction above. [1].

Building B

The second building was built in 2009 and has two separate blocks: block A (5 floors) and block B (8 floors).

There is applied system of capillary pipes embedded in a layer at the inner ceiling surface (Type F).

Cooling grids made of small plastic tubes of 5 mm in diameter placed close to each other can be embedded in additional plaster or gypsum board attached to the slab. The heat transfer from the room above is higher than in the case of cooling panels. The heat transfer to the concrete slab couples the cooling grid to the structural thermal storage of the slab, thus the building structure is secondarily activated. It means that the system is faster in response than TABS, because the smaller part of the slab is deeply activated.

Figure 3. Building B.

Adding a layer of insulation below the floor reduces the cooling the floor of the room above [1].

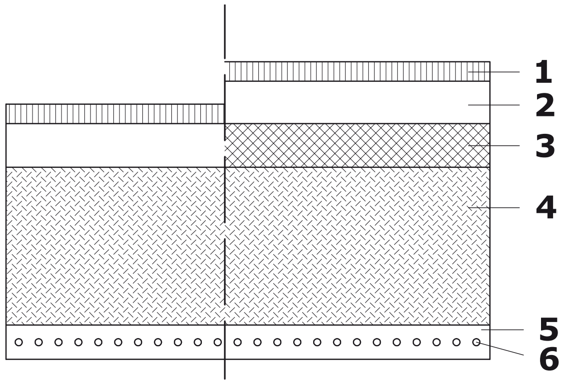

Figure 4. TABS "F" with and without acoustic insulation: 1 = Floor surface covering, 2 = Screed material, 3 = Acoustic insulation, 4 = Building structure, 5 = Plastic micro pipes, 6 = plaster or gypsum [1].

Purpose of evaluation of indoor environment

The purpose is to provide a healthy and comfortable indoor environment, which enhances the performance of the occupants at low energy consumption.

A dominant assumption in the design of many modern buildings is that indoor environmental parameters can and must by carefully controlled within the limits established in the prevalent codes, standards (EN 15251) and guidelines [1].

In indoor environment four major factors are evaluated:

- Thermal environment
- Air quality
- Acoustics
- Lighting

These four factors are usually dealt with individuality. Actually, they are all closely coupled and determine the effects of the building on the occupants [13].

The aim of this study is thermal comfort.

The environmental parameters of temperature, thermal radiation, humidity and speed of air velocity necessary for thermal comfort depend upon the occupant clothing and activity. The thermal environment is acceptable, if is satisfaction with them 80% of the occupants. The individuals who feel general thermal discomfort also feel local thermal discomfort, therefore the percentages of dissatisfied are not additive. It is assumed than 20% will be dissatisfied when the recommendations of the standard AHSRAE 55 are followed [13].

Indoor environmental parameters, which directly affecting the heat balance of human body and directly related to the thermal comfort:

- Insulation of clothing
- Metabolic rate
- Air temperature
- Mean radiant temperature
- Relative air velocity
- Relative humidity

Methods

Evaluation of the indoor environment is based on time and space temperature distribution in the room. Measuring positions and devices must comply with requirements according to CEN CR 7726. Measurements of indoor environment parameters are necessary for evaluation of thermal environment at working places and its influence on people and their performance. Thermal environment is evaluated according to thermal conditions in winter – recommended values of indoor environment during heating period (EN 15 251). Sampling points were located in corner offices and in the middle of the disposition, and there were compared with each other.

Two types of measurements were performed:

Long-term measurements

Long-term measurements were performed with device HOBO logger to obtain the following parameters in office building:

- Indoor air temperature in °C;
- Relative humidity in %;

The measurements in both buildings were done during 7 days (according weekend) in winter period (January) on the typical floor and on the last floor.

Short-term measurements

Short-term measurements were done by B&K 1213 indoor climate analyzer with sensors. The following parameters were measured at selected working places to find out potential discomfort due to vertical air temperature difference:

- Operative temperature in °C
- Relative humidity in %
- Indoor air velocity in m/s

Operative temperature was measured with an ellipsoid, whose projected area represents the shape of human body. The settlement of measuring device takes 25 minutes before measurement. Measurements were performed at the workplace 0.6 m above the floor. The load on a person is an aggregate of thermal conditions, activities and clothing.

The measurements of the relative humidity were performed with dew-point transducer in height of 0.6 m above the floor at workplace, measurements of the air velocity were done with transducer 0.1 m above the floor – in the area of human ankles, and 1.1 m above the floor at workplace– in the area of the seated person's head.

Short-term measurements were done on the same days as long-term measurements, in winter conditions, in the same offices, on the typical floors, and on the last floors. Measurements were done on sitting (working) places and on standing places (corridor in the office). Measurement points in the corner were situated in the most critical working place; other points were located in the middle of the disposition.

Results

Air temperature

In **Figures 5 and 6** is comparison of air temperature behaviour within 2 working days in building A and B.

The minimum room temperature is in the morning (22°C). Then the heat gains from occupants, equipment and the solar radiation from the outside push the air temperatures up (mainly in corner offices – blue line) (25–26°C).

The heat gains are removed and the room temperature falls down to the necessary starting point after occupants leave the offices. The average air temperatures in most of the offices are around 24°C, which respond to II. category of the standard EN 15 251.

In building B is behaviour of the air temperature very similar to building A. The average temperature during working time is 24 °C, which respond to category II of the standard EN 15 251 as well.

Operative temperature

Results of short-term measurement of operative temperature are in **Figures 7 and 8**. There is a percentage of working places in frame of operative temperature according to EN 15 251 for category III. In some offices is temperature a little bit above this range, but this offices are in the corner and in the time of measurements were there sunny shine.

Operative temperatures in building B with capillary pipes are in most of the offices around 23°C. On some places was the temperature higher, because of the sunshine during the measurement.

Relative humidity

Relative humidity in building A with suspended heating panels is between 30 and 40%, which is in the range of requirements of CR 1752.

Figure 10 shows that the relative humidity in building B is on the lowest limit, 20 to 30%. The reason for this is dehydrating of indoor air per consequences of heating in heating season. It may be appropriate to control the humidity in the mechanical ventilation system.

Too low humidity may cause compliance, especially if would the air humidity of indoor air decrease below 20%.

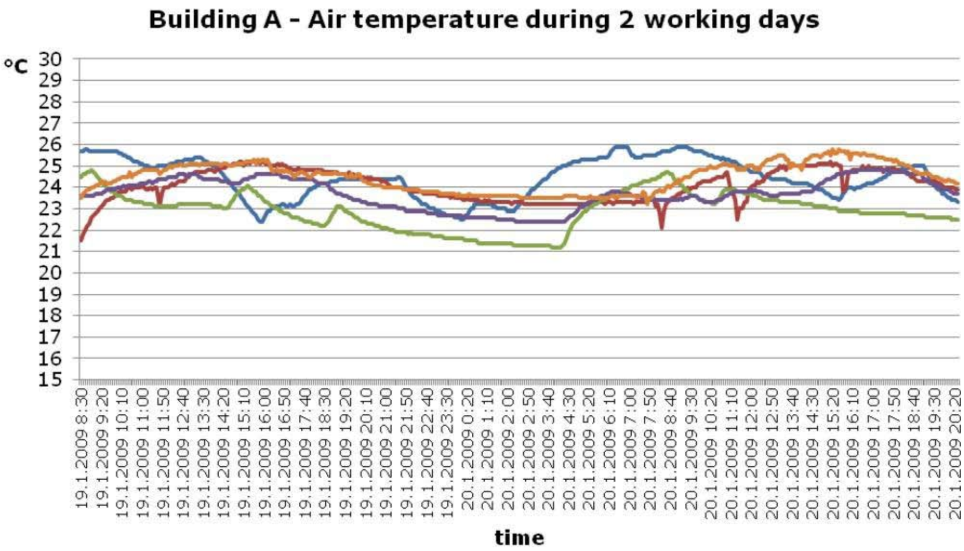

Figure 5. Long-term measurements - air temperature in 2 working days – Building A.

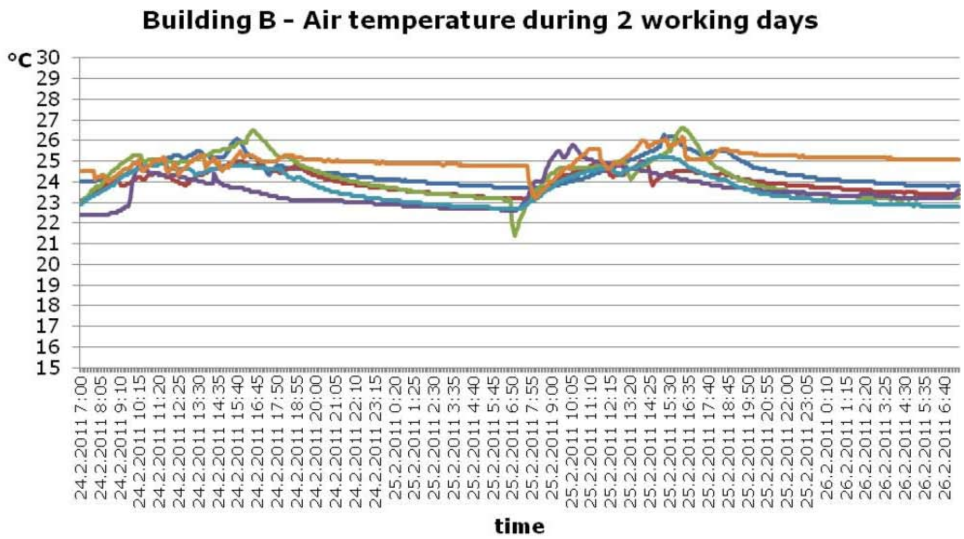

Figure 6. Long-term measurements - air temperature in 2 working days – Building B.

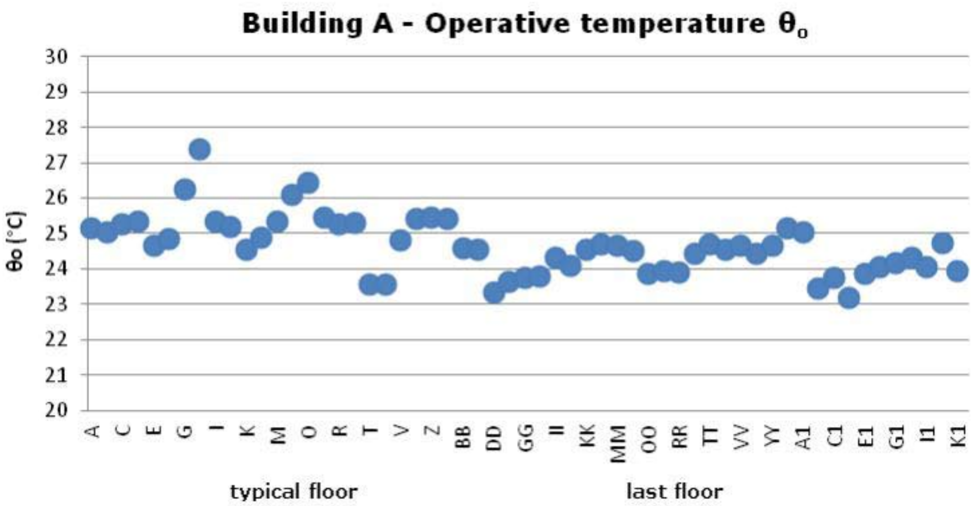

Figure 7. sort-term measurements - operative temperature – Building A.

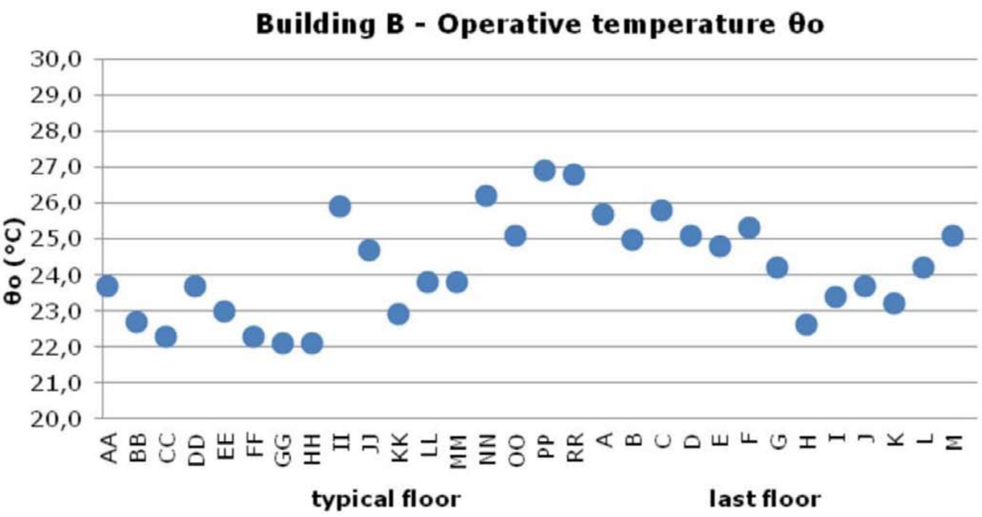

Figure 8. Sort-term measurements - operative temperature – Building B.

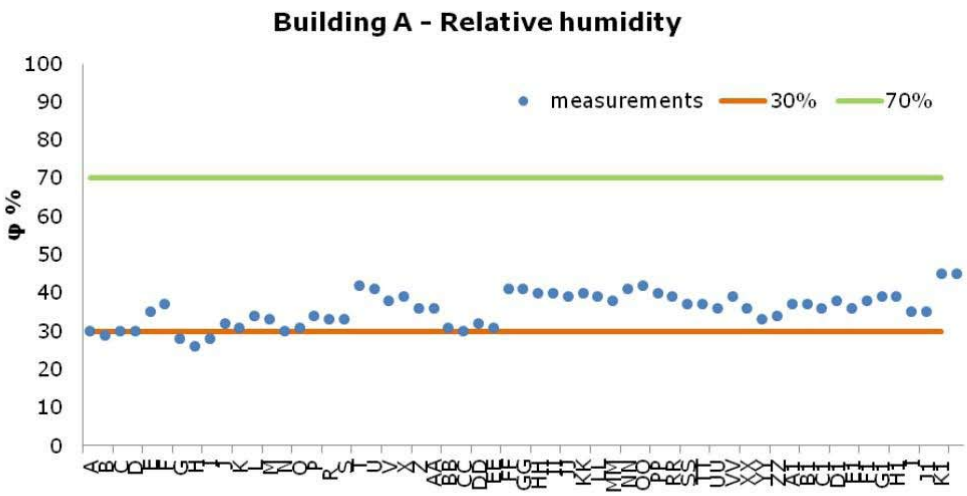

Figure 9. Sort-term measurements – relative humidity – Building A.

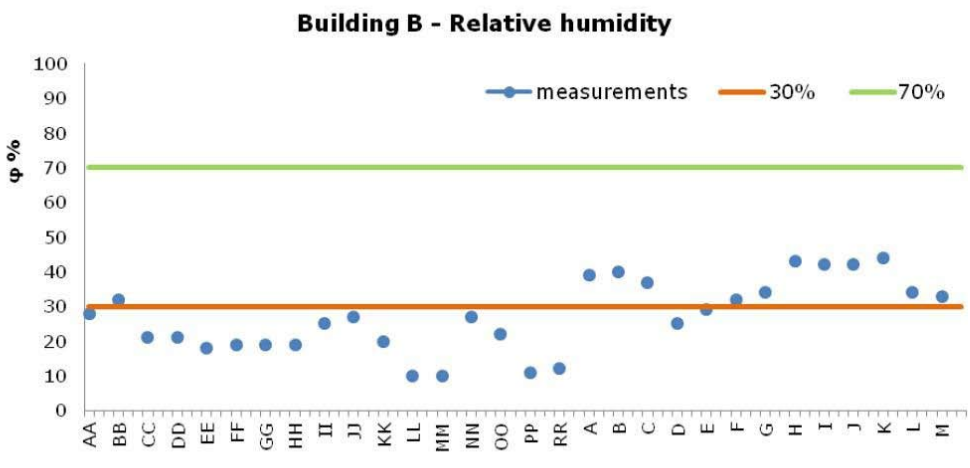

Figure 10. Sort-term measurements – relative humidity – Building B.

Air velocity

Figures 11 and 12 shows the results of short-term measurements of air velocity in occupied zone (on working places) on the last floor. The average air velocity varied between 0.05 to 0.08 m/s, which agree with A category of CR 1752 Ventilation for buildings. The different between height of occupants head and ankles are I average 0.05 m/s. A little bit higher is the value on the working places near the corridor, but still in range of the requirements and without significant risk of draught.

The situation in the building B are similar as in building A, the average of air velocity is between 0.05 to 0.1, which come under category A of CR 1752, the differences between head and ankles are 0.05 m/s and there is no significant risk of draught.

Conclusions

Most of the parameters of indoor climate are on good level according to international standards EN 15 251 and CEN CR 1752 during winter season. This means, that using low-exergy system seems to be a good choice for buildings with glass facade, where it is more difficult to ensure good indoor environment conditions. Because of the good indoor environment quality, people can feel comfortable, which may have positive influence on their performance. For this type of system correct operation is very important, because of the relatively long time reaction of indoor environment parameters on the operation changes, especially in transition periods.

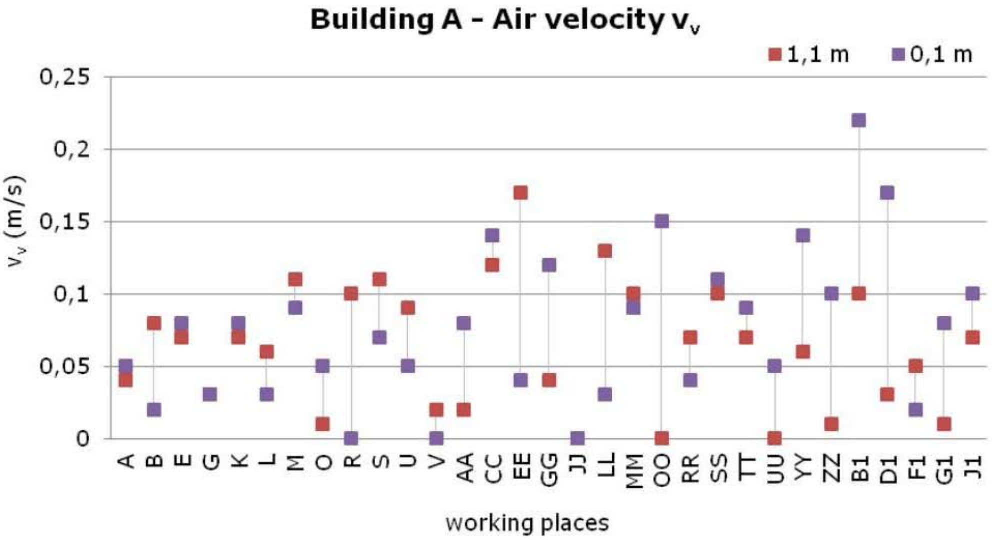

Figure 11. Sort-term measurements – air velocity – Building A.

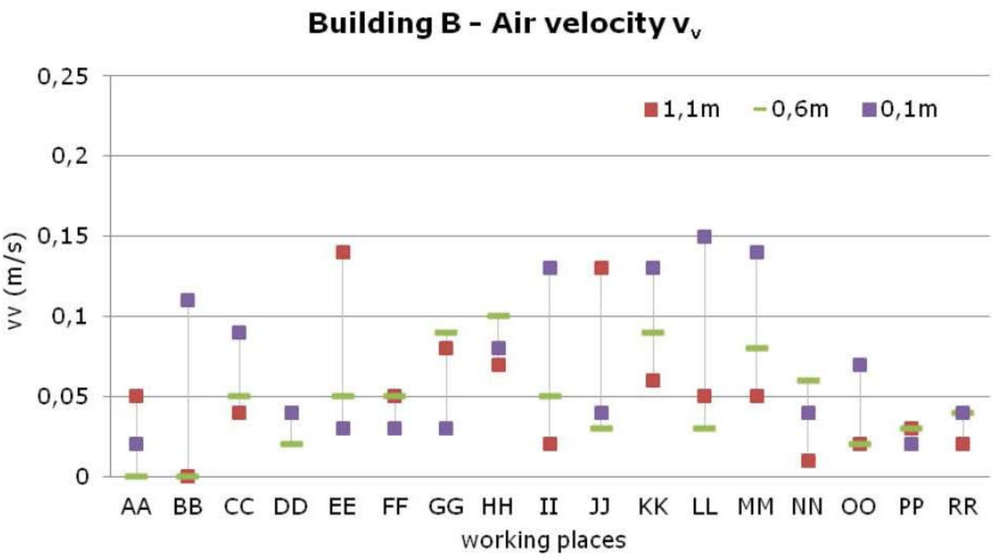

Figure 12. Sort-term measurements – air velocity – Building B.

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Modelling and simulation of radiant heating and cooling systems

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Introduction

There are several aspects that emphasises the application of radiant heatig/cooling systems in form of embeded capillary mats (**Figure 1)** to be an up-to-date topic in Central Europe. Desired reduction of energy consumption including primary energy, a recently formed demand for active cooling systems in this region and general expectations of high indoor environmental quality open a wide area for integrated radiant systems. Hand in hand with more and more common applications of these systems various questions arise. This paper has ambitions to answer often asked questions about radiant heating/cooling applications.

Buildings in Central Europe

The typical need for climate conditions of Central Europe (Czech Republic) is space heating during heating period (approx 230 days a year). Up till recent days there were no active cooling systems considered for a traditional building. Due to low internal gains, high thermal inertia and optimised glazing ratio such a building could be operated without any active cooling. For up-to-date buildings (especially office buildings) with high internal gains, high galzing ratio, low mass and well-insulated walls (U value less than 0.3 W/m²K) and windows (U value less than 1.8 W/m²K) an active cooling system seems to be essential whenever we want to follow the comfort requirements during summer period. Numerous of these buildings demonstrate the cooling load to be higher or much more higher than the heating load.

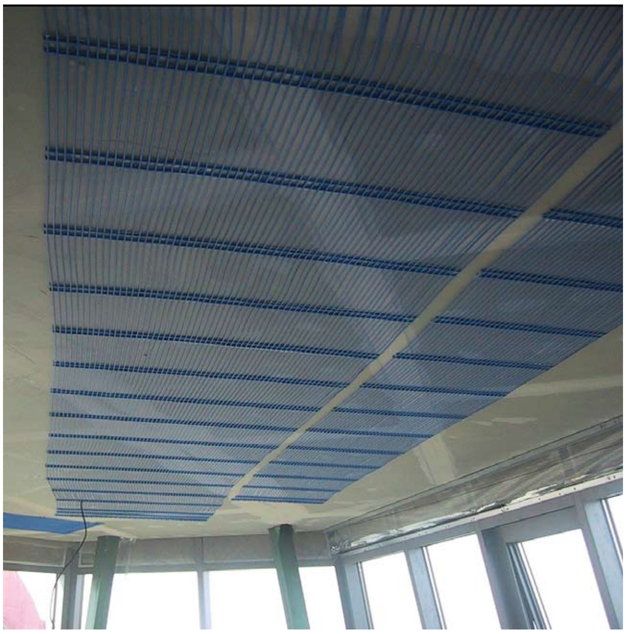

Figure 1. Integrated heating/cooling ceiling system with capillary mats before covering with the plaster.

Traditional approach to the technical solution of a heating /cooling system is to design two independent systems - radiator heating and split units cooling. One of the latest technical solutions, which could be considered as a sustainable one, is an integrated radiant heating/cooling system.

Radiant heating/cooling systems

Heat transmition to a room equipped with this system is mainly by radiation and convection. Final assesment of the room thermal comfort should not be based just on dry bulb temperature but it is adequate to asses it according to the room resultant temperature – numerical values of these two paramenters might differ significantely during both the winter and the summer period. This fact means that by using this system it is possible to reach lower air temperature in winter and higher air temperature in summer to get the same perception of indoor climate.

Radiant systems are used as ceiling, wall or floor systems.

Comparing to a traditional system, this technical solution integrates two systems into one and it may reduce air change rate to hygienic minimum. The strong point of this solution is a significant reduction of used material or

Figure 2. Integrated heating/cooling ceiling system with capillary mats.

Figure 3. Four pipe system – connection circuits.

better to say reduction of embodied energy in a heating, cooling and ventilating system (Roulet et al. 1999).

There are several limits for application of these systems. During the heating period the ceiling system output is limited by a hygienic limit reducing highest intensity of radiation on the skull-cap up to 200 W/m². For under-floor heating there is a limit for floor surface temparature – it should not exceed 29°C. In case of wall heating system the surface temperature should be within 35–50°C, based on the room operation. During the cooling period the surface temperature should not drop below the dew point temperature to avoid condensation.

The whole system solution must not cause any local discomfort like asymmetric thermal radiation, large vertical temperature gradient or draught.

Capillary mats

Furthermore paper deals with the radiant heating/cooling system in form of capillary mats.

Capillary mats, embedded in the gypsum plaster layer of the ceiling structure (**Figure 2**), are supplied by both the heating and the cooling water (four-pipe system) (**Figure 3**). Ceiling surface transmits energy into the heated/cooled room via radiation and convection heat transfer modes. As the output of radiant system is limited by acceptable surface temperature, often asked question is whenever is this system suitable to use.

Let´s list the elements that might infuense the applicability of integrated radiant systems. These factors come from the limits mentioned above taking into account the type of building and its operation.

Factors with crucial impact to the system applicability (Figure 4)

- Indoor sensitive heat load
- Indoor latent heat load
- Fresh air volume for ventilation
- Total air volume for ventilation
- Indoor humidity control
- Glazing ratio
- Glazing quality – U-value, g-value
- Active shading
- Room geometry
- Building orientation
- Heating setpoint
- Cooling setpoint
- Activity and clothing level of building inhabitants
- Climate

All of these listed parameters affect the design and operation of HVAC systems. Forgetting these parameters may result in undesirable state of indoor environment. The system does not cover all the demands (heating/cooling) or surface condensation appears.

Modelling and energy performance simulation

One of the ways how to investigate the performance of a radiant heating/cooling system is the use of computer modelling and simulation. By a virtual model with various cases of application it is possible to reach the knowledge about the system operation under different boundary conditions. Several methods and approaches to the building energy performance modelling and simulation are available. However, the issue is very complex, full of bonds between different factors with the basic impact to indoor environment and final applicability of the system. Therefore it is necessary to use simulation tools that can cover all of these effects. Regarding energy performance, control algorithm and whole year IEQ assessment it seems that tools based on method of dynamic heat balance are the best to fulfil our expectation. We can find program ESP-r in this category. It provides time dependent energy flow patterns, temperature and humidity levels in processed parts of the building and some other important values for overall analysis.

If we are looking for a detailed description of temperature and velocity airflow patterns in defined closed space, tools based on the CFD (Computational Fluid Dynamics) method seems to be the best choice e.g. Fluent or Flovent.

Capillary mats modelling

It is possible to find several studies aimed to the applicability of the system with capillary mats in Czech climate conditions. Modelling and simulation of energy performance is effective for complex systems, but it is very sensitive to the way of the task and boundary conditions definition.

To build a model of a room fitted with a heating/cooling ceiling system it is necessary to specify dimensions, building envelope characteristics, environment behind the envelope and orientation of the building. Furthermore it is necessary to set ventilation, lighting, inner loads, activity and presence of users with relevant timing and loads. For the heating/cooling part it is necessary to define maximum output and control loops. Thus defined, the model is loaded with effects of climate conditions of the site, which are again defined by the time dependence of air temperature, relative humidity, wind direction and speed and intensity of solar radiation. Length of the simulated period is chosen depending on which parameters we are interested in. For either only heating or only cooling focused models a characteristic winter or summer week usually provides enough information. A whole year period is preferable for integrated systems. This will also affect the transition period and can alert the otherwise hardly identifiable marginal stages.

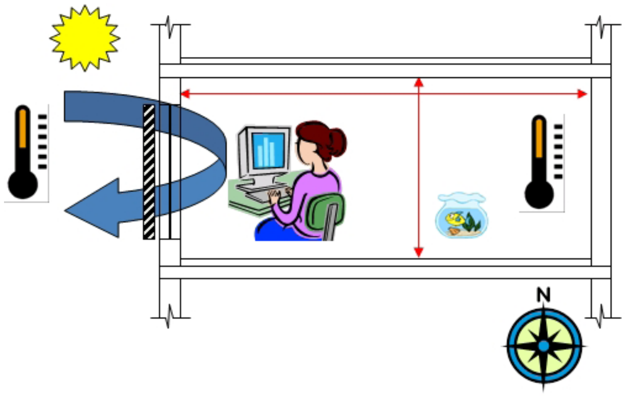

Figure 4. Factors influencing indoor environment in the rooms with radiant heating /cooling.

Attached **Case study** is an example of using the ESP-r simulation tool to analyse energy performance of a room equipped with integrated heating/cooling ceiling system. ▶

Case study

Problem description

The main purpose of the study is to investigate integrated heating/cooling system performance during typical Central Europe climate conditions with office operation load profile. This task arose from common practice, when several problems with system application occured despite following all the common recommendations (Kabele et al. 2002).

The issue appeared with following questions. Is the integrated ceiling heating/cooling system able to secure compliance with comfort requirements during the whole year operation in a modelled case? Are the current design recommendations in terms of maximum heating/cooling output of the ceiling applicable particularly in climate conditions of Central Europe? (**Figure 5**)

Research method

Problem analysis followed by computer simulation of an annual building energy performance was used on a case study to analyse selected parameters, that may have any influence on the possibility of system application. ESP-r, an energy system performance simulation tool, was used for this purpose (ESRU 2004).

Modelling and simulation

Model Description

A five - zone model was created (**Figure 6**). The model contains four equal zones with following dimensions 5 m x 9 m x 3 m, each facing different cardinal point, and a corridor in the centre with following dimensions 4 m x 4 m x 3 m. Each of the zones has a window 5 m x 1.6 m in a longer exterior wall. Medium-heavy constructions were considered with the value of overall coefficient of heat transmission according to Czech building regulations (ČSN 730540 2005). For an external wall U = 0.239 W/m²K, for an internal wall U = 1.561 W/m²K and for a window it is 1.198 W/m²K.

No heat flux through ceilings and floors was assumed.

Heating and cooling system is radiant low temperature heating/high temperature cooling system with capillary mats placed inside the layer of gypsum plaster on ceiling construction and defined by heating capacity controlled according to established practice in a range of 0-130 W/m², cooling capacity 0–80 W/m² in each of the rooms (Jeong et al. 2004). This technical solution is carried out in the model by placing a cooling and heating capacity to the axis of gypsum plaster layer. (R.K. Strand and K.T. Baumgartner 2005) The active ceiling construction contains layers according to **Figure 7.**

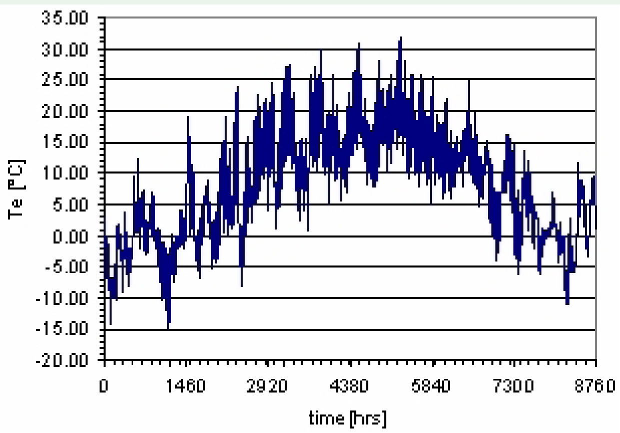

Figure 5. Annual ambient air temperatures in the Czech Republic.

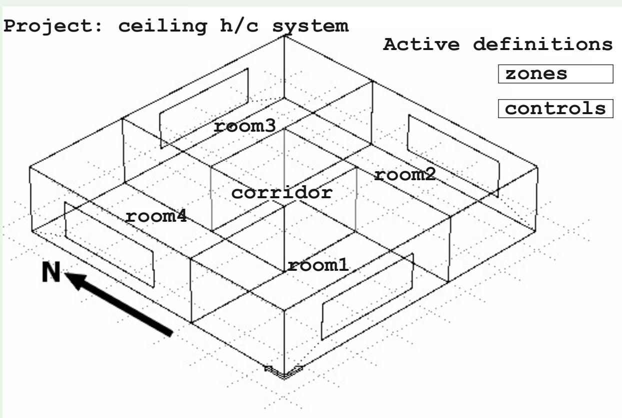

Figure 6. ESP-r model of the building.

Figure 7. Active Ceiling/Floor construction: 1 Flooring, 2 Polyurethane foam board, 3 Heavy mix concrete, 4 Gypsum plaster with capillary mats.

The control of the system is running as basic heat and cool controller according to sensors, located in each of the rooms sensing dry bulb temperature. Set point for heating is 22°C; for cooling 26°C. There is no humidity control considered.

Ventilation. Mechanical ventilation 0.7 h^{-1} and infiltration 0.3 h^{-1} is considered. Supply air temperature is 20°C.

Occupation and casual gains. Sensitive and latent heat load by persons is 7.8 W/m² during working hours (weekdays 7:00-18:00), sensitive heat load by equipment is 15 W/m² and by lights 25 W/m² during the whole day.

Simulation

The whole year period was studied using Prague (Czech Republic) ASHRAE IWEC climate files. An integrated building simulation was used, with time step of 1 hour and initial period of 11 days. The discussion of the results was focused on heating/cooling energy consumption. PMV and PPD parameters were used to evaluate thermal comfort (Yang 1997, ČSN EN ISO 7730 2005). The third thing to follow was the possibility of condensation on the ceiling surface during the cooling period.

Simulation results and discussion

In following tables and diagrams there are selected simulation results from ESP-r.

Energy

From the point of annual energy consumption the results show a significant impact of the internal heat loads which decrease energy demand for heating and increase cooling demand comparing to unoccupied space. The effect of building orientation for both the heating and the cooling energy demand is also significant (**Table 1**)

Thermal comfort – resultant temperature

The temperature curve confirmed the ability of the heating/cooling system capacity to guarantee set temperatures inside all of the zones almost during the whole year. Set point for cooling was exceeded only in several hot days during summer with maximum value 31.5°C (**Table 2**)

Table 1. Annual energy h/c consumption.

Zone	Energy for Heating [kWh]	Operating time [h]	Energy for Cooling [kWh]	Operating time [h]
room1	283	264	-12211	4455
room2	436	392	-11049	4146
room3	253	282	-11415	4247
room4	328	301	-13007	4633
Total	**1301**		**-47682**	

Table 2. Resultant temperature extremes.

Zone	Maximum [°C]	Minimum [°C]	Mean value [°C]	Standard deviation
room1	29.7	22.5	25.3	1.2079
room2	28.5	22.5	25.1	1.1186
room3	27.8	22.5	25.1	1.0106
room4	31.5	22.5	25.4	1.3316
corridor	27.5	23.9	25.7	0.85953

Thermal comfort – PMV, PPD

Thermal comfort evaluation is based on PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied) classification of heated/cooled spaces. PMV is defined by six thermal variables for indoor-air and human condition. It is air temperature, air humidity, air velocity, mean radiant temperature, clothing insulation and human activity. The value of PMV index has range from –3 to +3 which corresponds to human sensation from cold to hot. The null value of PMV index means neutral. It is desirable to maintain the PMV at level 0 with a tolerance of ±0.5 to ensure a comfortable indoor climate. Comfort evaluation is based on activity level 1.2 met with clothing level equal to 0.7 clo (ASHRAE 2005, CSN EN ISO 7730) in this case study.

The results show PMV index to be from 0.0 to 2.0. Index PPD in 48% of the time is up to 10% which means that during this time the number of dissatisfied occupants will not exceed 10%. Index PPD during 99% of the time is up to 50%.

From the point of heating there is no problem with thermal comfort in all of the examined cases; minimum value for PMV during heating period is 0.0, which means neutral.

On the other hand several problems with thermal comfort during cooling period were detected. In this case the maximum PMV index reached 2.0, which means warm (**Figure 8**).

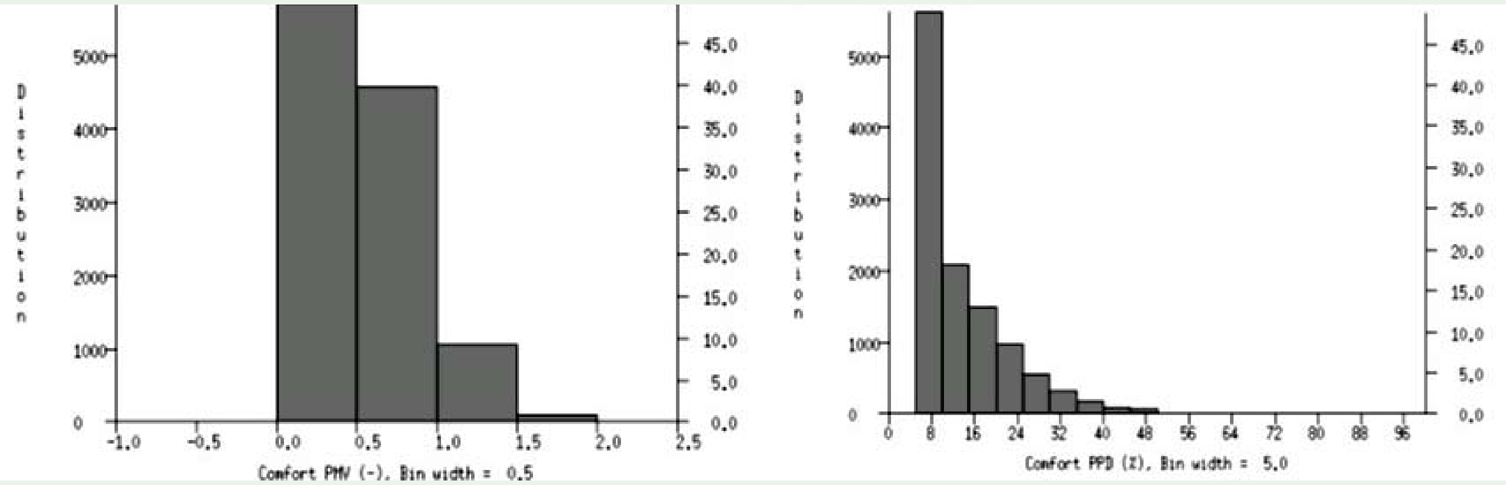

Figure 8. Annual distribution of PMV and PPD index (ESP-r).

Active ceiling surface temperatures and surface condensation

The active ceiling surface temperatures coming out from the simulation are in figures. **Figure 9** shows temperature difference between active ceiling surface temperature and the dew point temperature during the year. Critical period (the value is below zero) is marked with circle. Detailed analysis of critical time is on the **Figure 10**.

The possibility of surface condensation occurred in a range of one or two hours during one critical day of the year in summer when the exterior relative humidity was very high.

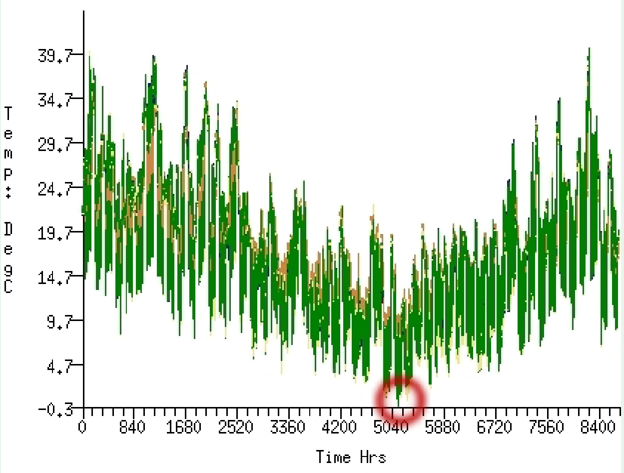

Figure 9. Temperature difference between active ceiling surface temperature and the dew point temperature.

Conclusion

Is it possible to use an integrated heating/cooling ceiling system in a modern building, built according to valid Czech standards with respect to energy efficiency in Czech climate conditions? The question has been analysed. The purpose of created case study was to predict thermal behaviour of the room heated/cooled with this system and to describe thermal comfort behaviour in time during a whole year operation. ESP-r, a modelling tool was applied.

Based on the simulation results no problems with the heating were detected anywhere. The system can reliably guarantee the required temperature during the whole year. At the same time the simulation shows that common designed heating/cooling capacities (130 and 80 W/m²) of the ceiling surface are appropriate. Several problems appeared with the cooling. The designed capacity was not able to cover the temperature requirements and occasionally a short-term condensation appeared. This means that the application of this integrated system is limited by its capacity. Especially in the buildings with higher internal gains this application is arguable. Following the effect of building orientation individual control of the zones is recommended.

The results from above and the conclusions made from them are valid for the conditions of the simulation.

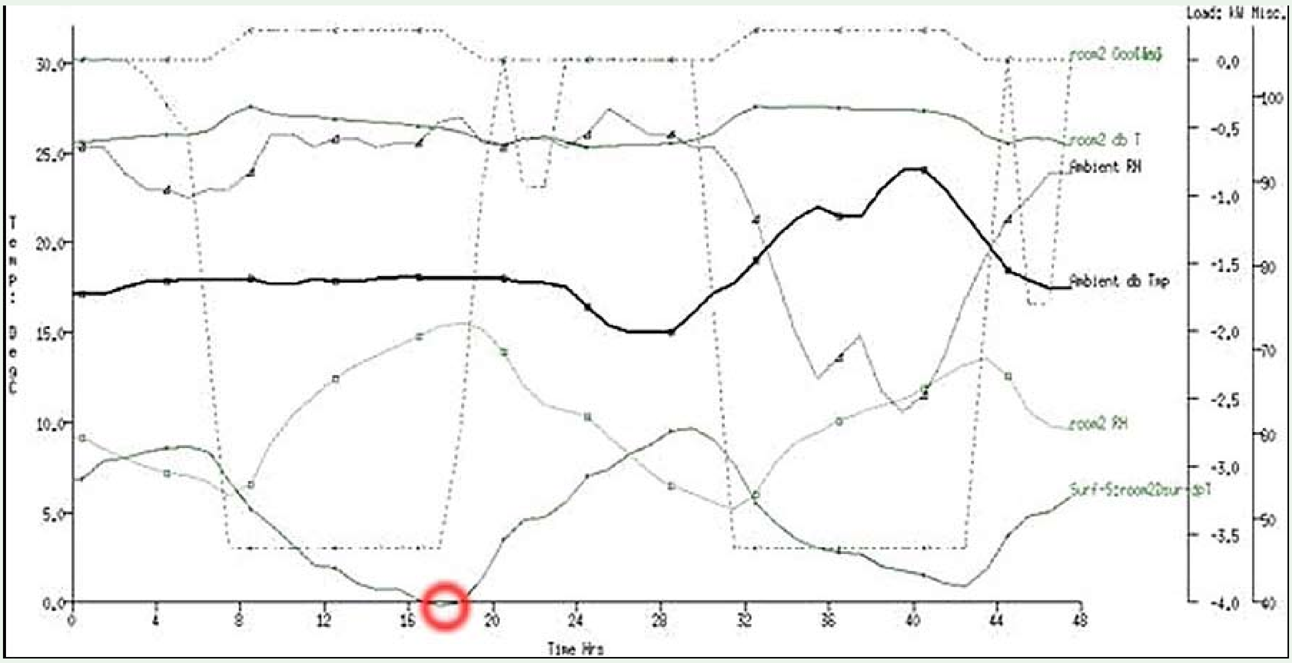

Figure 10. Integrated look at energy and environmental performance during critical days. OccCasG - internal heat gains, CoolInj-cooling system injection, AmbientRH-ambient air relative humidity, dbT- zone dry bulb temperature, Ambient dbTmp- ambient dry bulb temperature, room1RH- zone relative humidity, Surf-5:room1Dsur-dpT difference between cooling surface temperature and dew point. Critical hours marked with circle.

Acknowledgments

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Operation and control of thermally activated building systems (TABS)

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Introduction

A trend, which started in the early nineties in Switzerland (6, 7), is to use the thermal storage capacity of the concrete slabs between each storey in multi storey buildings to heat or cool buildings. Pipes carrying water for heating and cooling are embedded in the centre of the concrete slab.

By activating the building mass there will not only be a direct heating-cooling effect, but due to the thermal mass also the peak load will be reduced and transferring some of the load is transferred to outside the period of occupancy will be possible. Because these systems for cooling operate at water temperatures close to room temperature, they increase the efficiency of heat pumps, ground heat exchangers and other systems using renewable energy sources.

Relatively small temperature differences between the heated or cooled surface and the space are typical for surface heating and cooling systems. This results in a significant degree of self control, because a small change in the temperature difference will influence the heat transfer between the cooled or heated surface and the space significantly.

In an earlier study Olesen et. al. (8) studied for the summer season different control parameters (time of system operation, intermittent operation of circulation pump and supply water temperature control) by dynamic computer simulation. It was found that operation of the system during the night was sufficient, intermittent operation of the pump was possible and that the water temperature should be controlled over the season based on outside temperature.

The present paper presents the results of additional dynamic computer simulations of such a system. In the present study two different climatic zones (Würzburg, Germany and Venice, Italy) are studied both for summer and winter season. Further algorithms for water temperature control and the effect of a room temperature dead-band are investigated.

Method

The study was performed with the aid of the dynamic simulation program (9).The multidimensional heat transfer processes in the slab were modelled via a special module developed by Fort (4). The following describes the test space and other boundary conditions, which were very similar to the conditions reported by Olesen et. al. (8) and Hauser et. al. (5).

Description of system and test space

The system considered is shown in **Figures 1 and 2**. The ceiling/floor consists of an 18 cm thick concrete slab with 20 mm plastic pipes embedded in the middle with 150 mm spacing. The slab is finished with 20 mm of acoustical insulation and 45mm screed. Heat is supplied or removed by the heated or cooled water flowing in the embedded pipes. The mass flow rate of the system is constant at 350 kg/h.

The effect of heating and cooling the ceiling is described using a central room module in an office building with offices on either side (west and east) of the corridor. This characterises the thermal behaviour of all rooms that are at least two rooms away from the roof, corner and ground floor rooms. The geometrical dimensions of the room module are shown in **Figure 1**.

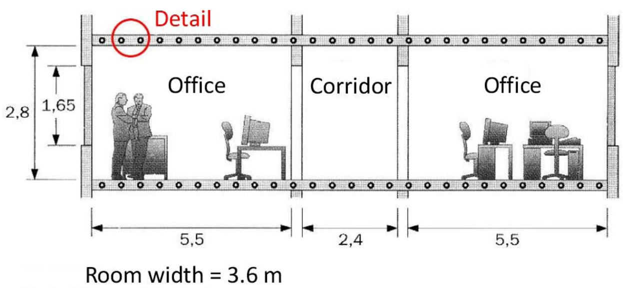

Figure 1. Central room module used for the computer simulation of a building with concrete slab cooling. All dimensions are in meter.

The floor (**Figure 2**) consists of 45 mm screed (λ = 1.4 W/m²K, c = 1 kJ/kgK, ρ = 2000 kg/m³), 20 mm insulation (λ = 0.04 W/m²K, c = 1.5 kJ/kgK, ρ = 50 kg/m³) and 180 mm concrete (λ = 2.1 W/m²K, c = 1 kJ/kgK, ρ = 2400 kg/m³). The outside pipe diameter is 20 mm and the spacing is 150 mm. The window has a U-value = 1.4 W/m²K.

The room volume is 55.44 m³ with a thermal capacity of 700 kJ/K.

Boundary conditions

The meteorological ambient boundary conditions correspond to those of Würzburg/Germany and Venice/Italy. The external temperature data for winter and summer design days are shown in **Table 1**. Summer was the period May 1 to September 30, winter was the period October 1 to April 30.

Table 1. Design day outdoor temperatures for Würzburg, Germany and Venice, Italy.

City	Lat. [°]	Long. [°]	Elev. [m]	Heating Dry Bulb [°C]		Cooling Dry Bulb [°C]	
				99.6%	99%	0.4%	2%
Venice	45.30 N	12.20 E	6	–4.9	–3.1	30.8	28.2
Würzburg-Frankfurt	50.05 N	8.60 E	113	–11	–8.2	30.3	26.7

Time of occupancy was Monday to Friday from 8.00 to 17.00, 12.00 to 13.00 lunch break.

System was only in operation outside the occupancy from 18:00 to 06:00.

Internal heat sources: During occupied periods 550 W corresponding to 27.8 W/m².

This corresponds to two occupants, two computers, a printer and light. During the lunch break 350 W corresponding to 17.7 W/m², 50% convective, 50% radiant.

Moisture production: During occupation, 100 g/h.

Ventilation (ach): Outside time of occupation 0.3 h⁻¹ (infiltration). During occupation 1.5 h⁻¹ (~11 l/s per person).

Sun protection: During occupation by direct exposure of sunlight and operative temperature above 23°C, reduction factor z = 0.5.

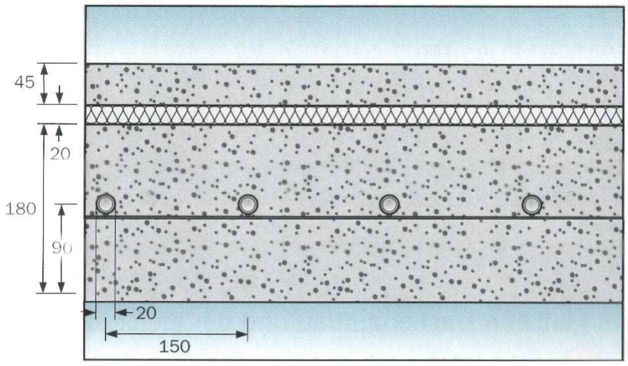

Figure 2. Position of the plastic pipes in the concrete slab between two stories.

Control parameters studied

Two control parameters were studied:

- Control of water temperature
- Dead-band for room temperature.

Control of water temperature

The goal for the system used in the present study is to operate water temperatures as close to the room temperature as possible. If very high or very low water temperatures are introduced into the system it may result in over heating or under cooling.

In the present study supply water temperature was limited not to be lower than the dew point in the space. For this purpose a humidity balance (latent loads from people, outside humidity gain from ventilation) were also included in the simulation. It was then possible to calculate the dew point in the room for each time step in the simulation.

Instead of controlling the supply water temperature it may be better to control the average water temperature. The return water temperatures are influenced by the room conditions. By constant supply water temperature an increase in internal loads from sun or internal heat sources will increase the return temperature. The average water temperature will then increase and the cooling potential will decrease. If instead the average water temperature ($\frac{1}{2}(t_{return} - t_{supply})$) is controlled an increase in return temperature will automatically be compensated by a decrease in supply water temperature.

In well designed buildings with low heating and cooling loads it may be possible to operate the system at a constant water temperature. The following concepts for water temperature control were studied:

Supply water temperature is a function of outside temperature according to the equation:

$t_{supply} = 0.52\ (20 - t_{extenal}) + 20 - 1.6\ (t_o - 22)$ °C (case 801)

Average water temperature is a function of outside temperature according to:

$t_{average} = 0.52\ (20 - t_{extenal}) + 20 - 1.6\ (t_o - 22)$ °C (case 901)

Average water temperature is constant and equal to: 22°C in summer and 25°C in winter. (case 1201)

Supply water temperature is a function of outside temperature according to the equation:

$t_{supply} = 0.35\ (18 - t_{extenal}) + 18$ °C Summer (case 1401)

$t_{supply} = 0.45\ (18 - t_{extenal}) + 18$ °C Winter (case 1401)

Dead-band of room temperature

To avoid a too frequent change between cooling and heating it is recommended to stop the circulation pump during a certain room temperature range, dead-band. In the study by Olesen et. al. (8) a dead-band of 22°C to 23°C was used. This means when the room operative temperature increases above 23°C the system will start in the cooling mode. If the room operative temperature is less than 22°C the system will start in the heating mode. In between the circulation pump is stopped.

In the present study following dead-bands were tested:

22–23°C (case 0901-1)
21–23°C (case 0901-8)
21–24°C (case 0901-9)

Results and discussion

The simulations were done for both an East and a West facing room. Only results for a West facing room are presented in this paper. In a pre-test it was found that the highest exposures occurred in the room facing West.

Results from the summer period May 1st to September 30th and the winter period October 1st to April 30th are presented.

The total number of hours in each period is ~ 3690, number of working days ~ 109 and number of working hours ~ 981. The results will be evaluated based on comfort (operative temperature ranges, daily operative temperature drift during occupancy) and energy (running hours for circulation pump, energy removed or supplied by the circulated water)

The calculated operative temperatures may be compared to the comfort range 23 to 26°C recommended for summer (cooling period) and 20 to 24°C recommended for winter (heating period) (1, 2, 3). This is based on a fixed level of clothing insulation for summer (0.5 clo) and winter (1.0 clo), which may not be relevant for the whole period.

Study of water temperature control

The results of the simulation are shown in **Table 2** for summer conditions and in **Table 3** for winter conditions.

The operative temperature of the cases *0801*, *0901* and *1401* (**Table 2**) is for most of the time (>85%) in a comfortable range (22–26°C). In Würzburg 27°C is never exceeded and 26°C is exceeded less than 5% of the time. In Venice only 5% of the temperatures are above 27°C. The difference between controlling the supply water temperature (case 0801) or the average water temperature (case 0901) is very small. In the case 1401 the control do not take into account the internal operative temperature, but the results are almost identical to case 0801 and 0901. With a constant average water temperature (22°C) the cooling effect is too low and the operative temperature is often too high (60% of the time above 27°C in Venice and 27% in Würzburg).

The energy use is the same for the cases *0801*, *0901* and *1401* in Venice. For Würzburg case 1401 is the energy use however about 10% lower than case 801 and 901. Energy use the case 1201 with constant water temperature is relatively high.

The pump running time for case 1401 is equal or lower than the other cases.

In the summer case *1401* is overall better than the others. Due to the warmer climate in Venice (Table 1) the room temperatures are higher, energy use and pump running time are also higher compared to Würzburg.

Also for the winter period (Table 3) the cases 801, 901 and 1401 results in the most comfortable conditions. In Venice the room temperatures exceed the interval 20–24°C less than 12% of time. In case 1401 the room temperature is, however, below 20°C for 4% of the time.

Table 2. Operative temperatures, temperature drift, pump running time and energy transfer for different water temperature control strategies. Summer conditions. Dead-band 22–23°C. Ventilation rate: 0.3 ach from17:00 to 8:00, 1.5 ach from 8:00 to 17:00.

May to September
Time of operation 18:00–06:00

Water temperature control		Venice				Würzburg			
		Supply = F (outside) 0t801	Average = F (outside) 0901	Average = 22°C 1201	Average = F (outside) 1401	Supply = F (outside) 0801	Average = F (outside) 0901	Average= 22°C 1201	Average = F (outside) 1401
Operative temperature interval	°C	%	%	%	%	%	%	%	%
	<20	0	0	0	0	0	0	0	0
	20–22	0	0	0	0	3	3	1	5
	22–25	56	58	8	56	75	78	30	77
	25–26	26	25	13	25	18	16	21	14
	26–27	13	12	19	14	5	4	22	4
	>27	5	5	60	5	0	0	27	0
Temperature drift [days]	<1	0	0	0	0	3	2	6	4
	1–2	9	9	14	10	26	27	26	24
	2–3	56	54	65	49	33	33	46	35
	3–4	35	37	21	41	38	38	22	37
	4–5	0	0	0	0	1	1	0	1
	5–6	0	0	0	0	0	0	0	0
	>6	0	0	0	0	0	0	0	0
Pump running	hours	1254	1190	1417	1214	1091	971	1327	953
	% of time	34	32	39	33	30	26	36	26
Energy kWh	Cooling	1104	1109	1297	1106	763	785	978	749
	Heating	1	2	0	0	29	41	2	2

Table 3. Operative temperatures, temperature drift, pump running time and energy transfer for different water temperature control strategies. Winter conditions. Dead-band 22–23°C. Ventilation rate: 0.3 ach from17:00 to 8:00, 1.5 ach from 8:00 to 17:00.

October to April
Time of operation 18:00–06:00

Water temperature control		Venice				Würzburg			
		Supply= F (outside) 0801	Average= F (outside) 0901	Average= 25°C 1201	Average= F(outside) 1401	Supply= F (outside) 0801	Average= F (outside) 0901	Average= 25°C 1201	Average= F (outside) 1401
Operative temperature interval	°C	%	%	%	%	%	%	%	%
	<20	0	0	0	1	0	0	4	4
	20–21	1	1	6	14	9	7	19	24
	21–23	72	75	50	63	77	80	50	63
	23–24	14	15	5	14	8	7	7	7
	24–26	12	10	23	8	6	5	15	2
	>26	0	0	16	0	0	0	5	0
Temperature drift [days]	<1	33	34	30	32	57	57	58	57
	1–2	44	43	49	41	29	29	28	29
	2–3	21	21	20	23	12	12	13	13
	3–4	2	2	0	4	2	2	1	2
	4–5	0	0	0	0	0	0	0	0
	5–6	0	0	0	0	0	0	0	0
	>6	0	0	0	0	0	0	0	0
Pump running	hours	837	642	1487	1166	813	664	1533	1322
	% of time	16	13	29	23	16	13	30	26
Energy kWh	Cooling	144	144	143	143	57	64	63	45
	Heating	551	554	407	421	816	834	684	717

Table 4. Operative temperatures, temperature drift, pump running time and energy transfer by different room temperature dead-bands. Control of water supply temperature according to outside and internal temperature (case 0901). Summer conditions. Ventilation rate 0.8 ach.

May to September
Time of operation 18:00–06:00

Room temperature dead-band		Venice			Würzburg		
		22–23°C 0901-1	21–23°C 0901-8	21–24°C 0901-9	22–23°C 0901-1	21–23°C 0901-8	21–24°C 0901-9
Operative temperature interval	°C	%	%	%	%	%	%
	<20	0	0	0	0	0	0
	20–22	0	0	0	2	6	5
	22–25	58	58	38	81	78	69
	25–26	25	25	33	14	14	20
	26–27	12	12	22	2	2	6
	>27	5	5	7	0	0	0
Temperature drift [days]	<1	0	0	0	0	0	0
	1–2	5	5	5	19	19	19
	2–3	44	44	44	31	31	32
	3–4	51	51	51	49	49	48
	4–5	0	0	0	1	1	1
	5–6	0	0	0	0	0	0
	>6	0	0	0	0	0	0
Pump running	hours	1094	1094	878	709	657	378
	% of time	30	30	24	19	18	10
Energy kWh	Cooling	1035	1035	983	669	657	606
	Heating	0	0	0	50	25	15

On the energy side case 1401 is again about 10% better than case 801 and 901, but the pump running time is significant higher.

In winter the energy use in Würzburg is as expected higher than in Venice.

It is clear that with the proper control the activated slab system is not only capable of reducing the indoor temperatures to a comfortable range, but also capable of heating up the space to the comfort range as the only heating system.

Study on room temperature dead-band

To minimise the risk for both heating and cooling within the same day and also decrease pump running time it is recommended to let the building float within a certain room temperature interval, i.e. dead-band. In the study by Olesen et. al. (8) it was always 22–23°C. In this study too additional dead-bands, 21–23°C and 21–24°C was tested. The results for the summer period are shown in **Table 4** and for the winter period in **Table 5**. In all cases the supply water temperature was controlled according to case 901 and with a constant ventilation rate of 0.8 ach the whole day.

For the summer period a dead-band of 22–23°C and 21–23°C give the same results regarding operative temperature distribution, energy use and pump running time. The dead-band 21–24°C results in somewhat higher room temperatures especially in Venice. The pump running time decreases significantly, but the energy use is about the same as for the two other dead-bands.

In winter the biggest effect is lowering the dead-band from 22 to 21°C. This reduces the energy for heating with 20% and a more time with operative temperatures in the range 20–21°C, but always higher than 20°C. Conclusions of the dead band analysis

With an optimisation of the dead band the energy use for heating-cooling and running the pump can be reduced without sacrificing the comfort. The dead band should not be larger than 2 K.

Table 5. Operative temperatures, temperature drift, pump running time and energy transfer by different room temperature dead-bands. Control of water supply temperature according to outside and internal temperature (case 0901). Winter conditions. Ventilation rate 0.8 ach.

October to April

Time of operation 18:00–06:00

Room temperature dead-band		Venice 22–23°C 0901-1	Venice 21–23°C 0901-8	Venice 21–24°C 0901-9	Würzburg 22–23°C 0901-1	Würzburg 21–23°C 0901-8	Würzburg 21–24°C 0901-9
Operative temperature interval	°C	%	%	%	%	%	%
	<20	0	0	0	0	0	0
	20–21	1	8	8	2	13	13
	21–23	62	71	68	78	77	77
	23–24	27	13	12	16	7	7
	24–26	10	7	11	4	2	2
	>26	0	0	0	0	0	0
Temperature drift [days]	<1	0	0	0	5	1	1
	1–2	49	47	47	64	69	69
	2–3	43	44	44	22	22	22
	3–4	8	9	9	9	9	9
	4–5	0	0	0	0	0	0
	5–6	0	0	0	0	0	0
	>6	0	0	0	0	0	0
Pump running	hours	761	526	443	841	634	594
	% of time	15	10	9	17	12	12
Energy kWh	Cooling	101	83	61	35	19	11
	Heating	842	713	695	1194	1138	1113

Conclusion

The results of a dynamic computer simulation of different control concepts for a water based radiant cooling and heating system with pipes embedded in the concrete slabs have been presented. The system was studied for both the summer period May to September and the winter period October to April in two geographical locations, Venice, Italy and Würzburg, Germany.

The best performance regarding comfort and energy is obtained by controlling the water temperature (supply or average) as a function of outside temperature. There is no need to take into account the room temperature.

The energy performance (energy use for heating and cooling, pump running time) can further be reduced by introducing a 2 K room temperature interval (dead band), where the circulation pump is stopped.

The system was able to keep the room temperatures within a comfortable range, both summer (cooling) and winter (heating) and in both climatic zones.

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Micro-Combined Heat and Power (Micro-CHP) Appliances for one- or two-family houses for more energy efficiency

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Introduction

With the transition towards energy supply which has to be based more and more on energy efficiency and CO_2 reduction the decentralized energy systems will play an important role now and in the future. In general the combined heat and power (CHP) technology is a well-known and established engineering solution for energy efficient energy supply. But it is new that the market is getting ready now also for small-sized CHP units for one- or two-family houses as it was presented at this year´s ISH in Frankfurt/Germany for example under the topic of Micro-CHP appliances. This article describes these appliances only for the three different technologies "Stirling Engine", "Internal Combustion Engine" and "Fuel Cell" with the help of some product examples.

Stirling Engine

The Viessmann Vitotwin 300-W (**Figure 1**) is an example for a Micro-CHP appliance with a Stirling engine (**Figure 2**) which is hermetically sealed and almost maintenance-free. It runs quietly and therefore it allows an installation close to the living space.

The gas fired stirling engine generates 6 kW heat with an efficiency of 81% (gross cv) and 1 kW power with an efficiency of 15% (gross cv) simultaneously. The integrated gas fired peak load boiler of the Vitotwin 300-W can generate heat between 6 kW and 20 kW in

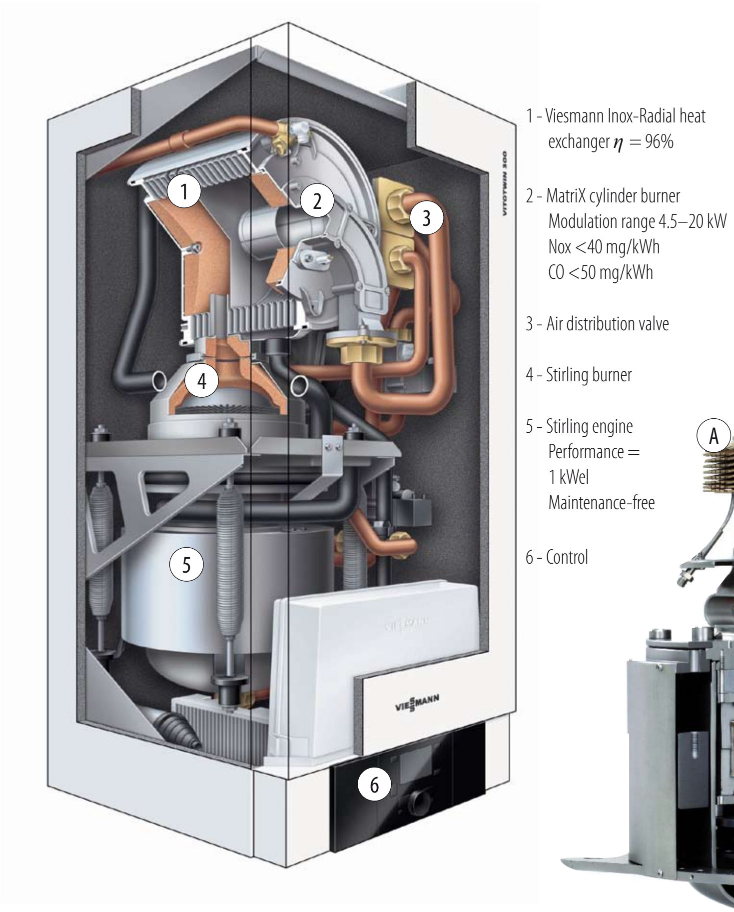

Figure 1. Wall mounted Viessmann Vitotwin 300-W Micro-CHP appliance with a Stirling engine (lower half) and with integral peak load boiler (upper half). Image source: www.viessmann.com

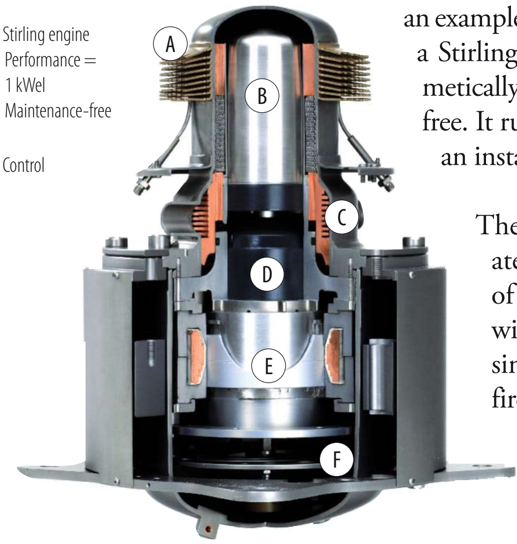

Figure 2. Hermetically sealed Stirling engine with the heating-up heat exchanger (hot area) and the displacer piston in the upper part, water-cooled heat exchanger (cold area) in the middle part and working, piston, springs (cylinder retriever), coil and magnets (Linear Generator for electrical output) in the lower part. The displacer piston moves the operating gas 50 times per second from the hot to the cold area. The alternately heated and cooled operating gas expands and contracts what creates pressure waves and that then again let the working piston move. The working piston is a part of the linear generator which produces electricity while the working piston is moving. Image source: www.viessmann.com

addition with 98% efficiency (gross cv). Therefore this high-efficient Micro-CHP is suitable for old and new detached houses and also for two-family houses. With an annual consumption of gas of 26 000 kWh or more and power consumption above 3 000 kWh per year the Micro-CHP works with exceptional economy.

Figure 3. Viessmann Vitotwin 300-W Micro-CHP appliance with a heating water buffer cylinder. Image source: www.Viessmann.com

Figure 4. Gas-Internal Combustion Engine (single-cylinder four-stroke piston engine). Electrical output 1 kW with efficiency of 26.3%, thermal output 2.5 kW with efficiency of 65.7% and total efficiency of 92% (nett cv). Image source: www.Vaillant.com

The stirling engine operates in a heat-led mode. The constantly generated power of 1 kW covers the base load of the electricity demand on site and surplus power is exported to the public grid, which is remunerated.

Due to the daily fluctuation of the heat consumption on the one hand and the constantly generated heat during the operation of the Micro-CHP on the other hand the combination with a heating water buffer cylinder is essential (**Figure 3**).

Internal Combustion Engine

The Vaillant ecoPOWER 1.0 is an example of a Micro-CHP appliance with an internal combustion engine (**Figure 6**).

Figure 5 demonstrates all the components which belong to the Vaillant ecoPOWER 1.0 system. It operates in a heat-led mode and is suitable for single-family and two-family houses with an annual heat demand of 15 000 to 25 000 kWh per year. Together with the different available peak load boilers the Micro-CHP system can generate a thermal output of 2.5 to 28.3 kW (60/40°C). With an annual operation above 4 500 hours per year the Micro-CHP works with exceptional economy.

In Figure 6 two scenarios of heat and power supply of a building are compared. On the one hand there is a

Figure 5. Components of the Micro-CHP system of Vaillant ecoPower 1.0: wall-mounted gas-fired peak-load condensing boiler (left), Micro-CHP unit and heat-transfer module with system controller (center), multi-function cylinder with 300 liter or 500 liter capacity and external heat exchanger for domestic hot water (right). Image source: www.vaillant.com

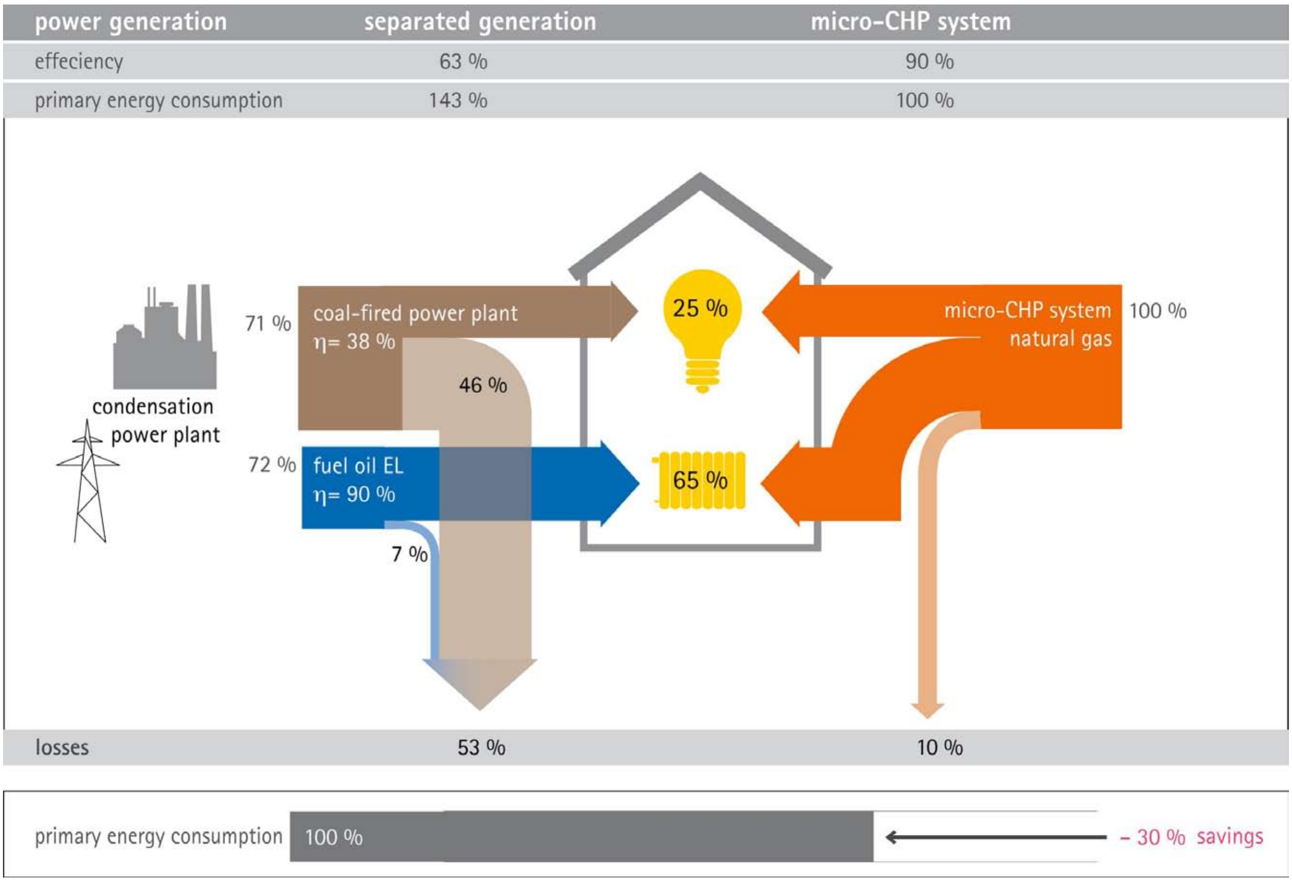

Figure 6. Comparison between a separated and a micro-combined heat and power generation.
Image source: www.ASUE.de

power generation with a coal-fired power plant together with a gas boiler on site and on the other hand there is a micro-CHP on site. In this example it turns out that the micro-CHP appliance can save 30% of the primary energy compared with the low-efficient power plant solution.

Fuel Cell based micro-CHP unit

A product example of a fuel cell-based micro-CHP unit called "BlueGen" is shown in **Figure** 7. The natural gas-fired unit works with a high temperature solid oxide fuel cell (**Figures 8 and 10**) and can generate up to 2 kW electrical output with up to 60% efficiency (nett cv). Then with the utilization of the simultaneously gener-

Figure 7. In front with about the size of a washing machine the fuel cell-based micro-CHP unit "BlueGen" of Ceremic Fuel Cells Ltd. together with a different heating water test buffer cylinder (1). Laboratory of Heating Technology at Cologne University of Applied Sciences/Germany (http://www.f09.fh-koeln.de/fakultaet/personen/profs/klaus.sommer/00835/). Image source: www.Rheinenergie.com

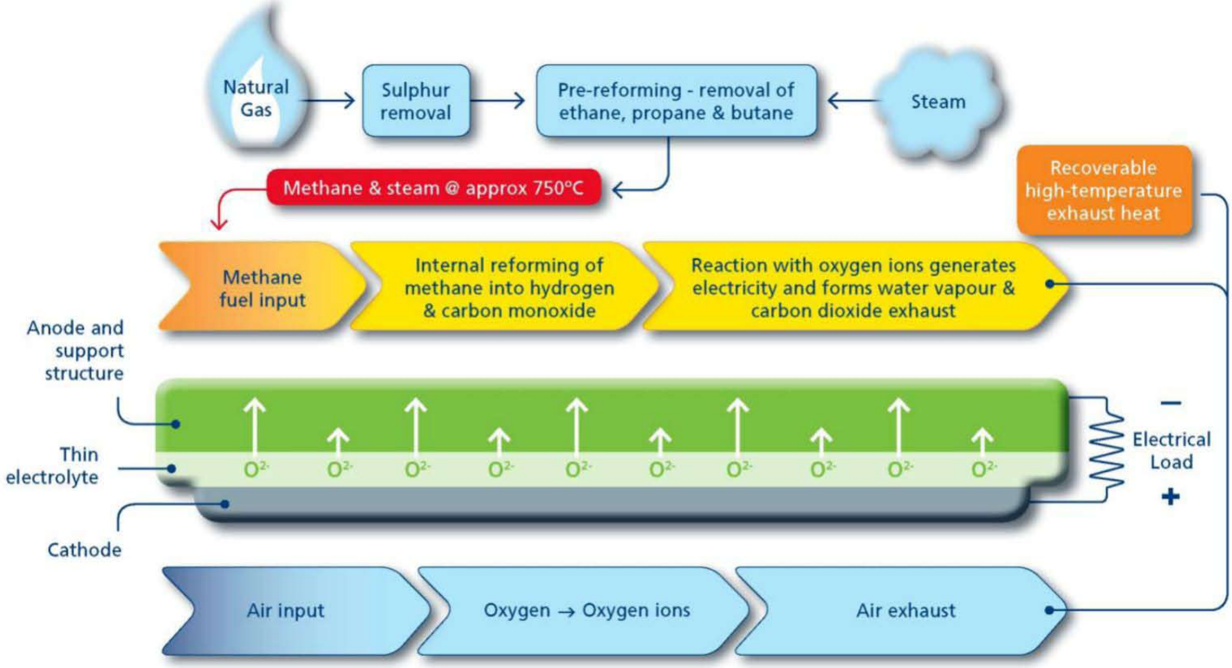

Figure 8. Functional principle of the high temperature Solid Oxide Fuel Cell (SOFC); source: Ceramic Fuel Cells Limited. Image source: www.cfcl.com.au

ated thermal output up to 1 kW W the total efficiency of the "BlueGen" can increase above 80%. For this case of operation the CO_2-reduction could be 50% and more compared with a separated heat and power generation of average existing energy efficiency.

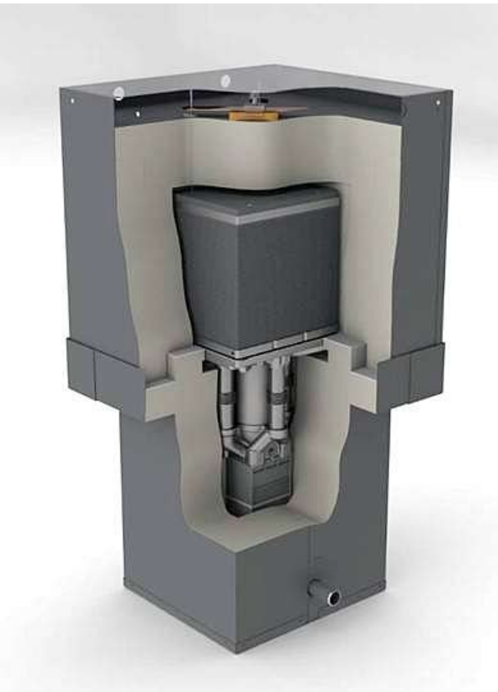

Figure 9. Hot module of the "BlueGen" with the high temperature solid oxide fuel cell stack in the upper part. Image source: www.cfcl.com.au

Ongoing tests just try to find out how far the "BlueGen" can cover the annual heat consumption and also the annual electrical consumption of single-family or two-family houses in a power-led mode with a peak load boiler and an optimized heating water buffer cylinder in addition (1).

Conclusion

Compared with separately generated heat and power the gas-fired micro-CHP appliances with stirling engine, internal combustion engine or high temperature solid oxide fuel cell save energy and reduce CO_2-production for old and new one- or two-family houses. The heat-led "Stirling engine" and "Internal combustion engine" are designed for 1 kW electrical output with an electrical efficiency of 15% and 26.3% and CHP-generated thermal output of 2.5 kW or 6 kW. Together with a peak load boiler the thermal output of these appliances varies up to around 28 kW dependent on the chosen performance of the peak load boiler. The high temperature solid oxide fuel cell is designed for power-led operation with a very high electrical efficiency up to 60% and an electrical output up to 2 kW together with a thermal output up to 1 kW.

Sources

(1) Two-year research project (2011-2013) "Analyzing of the real operating characteristics of a high-efficient fuel Cell-based Micro-CHP in order to find out the best possible application for residential buildings and to get real system characteristics"; project leader Klaus Sommer. Funded by Klimakreis Koeln (www.klimakreis-koeln.de), Rheinenergie (www.rheinenergie.com) and Cologne University of Applied Sciences (www.fh-koeln.de).

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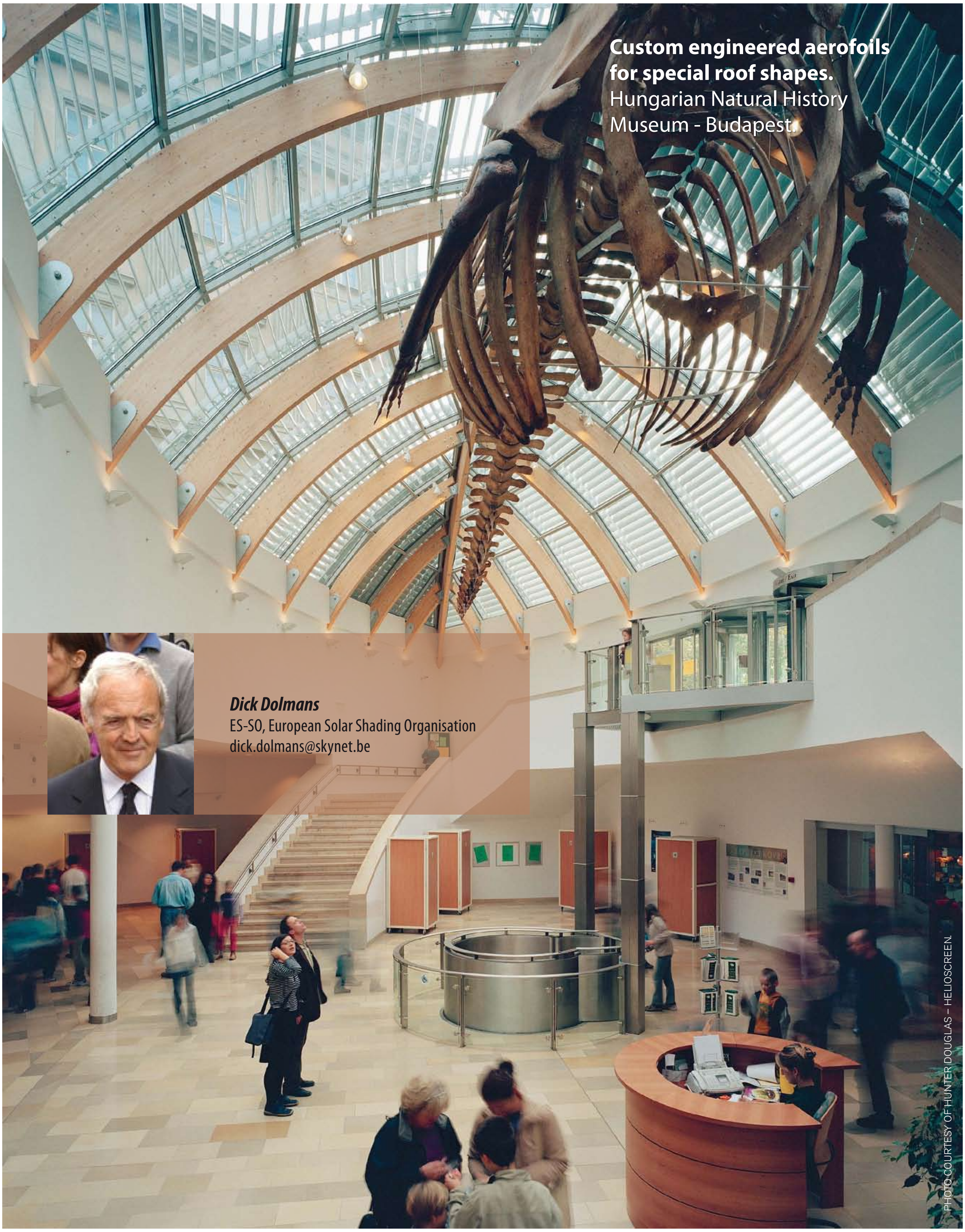
A Change is going to come

A New Mandate: nearly zero energy buildings



Custom engineered aerofoils for special roof shapes. Hungarian Natural History Museum - Budapest.

PHOTO COURTESY OF HUNTER DOUGLAS – HELIOSCREEN.

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In the hot debate about climate change and energy savings, it is a well-known fact that the built environment is the focus of much attention. As the largest energy user, at more than 40%, and the most potent carbon emitter, at some 36%, its 200 million-odd buildings in the EU hold the most promising potential for savings. The recently adopted Recast Energy Performance of Buildings Directive (Recast EPBD) will help unleash this potential if it is implemented properly and timely. But some items need clarification and harmonization.

From Directive 2010/31/EU, art 2,2:

"Nearly zero- energy building" means a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on site or nearby.

To combat climate change, increase the security of energy supply and strengthen the competitiveness of the Union, the European Commission in 2007 launched its Climate and Energy Package, agreeing on the "20-20-20" targets, to be reached by the year 2020. Specifically, these are a reduction in EU greenhouse gas emissions of at least 20% below 1990 levels, a share of 20% renewable resources in the EU's energy consumption, and a 20% reduction in total primary energy use compared with projected levels, to be achieved by improving energy efficiency. Buildings – residential and commercial, new and existing – offer a particularly attractive potential for improved energy efficiency and could help reduce energy use by 20 to 40% in the coming decades. Carbon emissions, obviously, would follow, possibly by a higher percentage if renewable energy sources are brought into the equation.

Recast EPBD

In 2002, among the original EPBD's objectives to improve the energy performance of buildings, were better energy efficiency, minimum requirements and certification. The implementation, to say the least, has been slow and hesitant. Some member states have been less than enthusiastic and the building sector is 'critically fragmented with significant inertia to change', as an Intelligent Energy Europe Publication states[1]. That is why a 'recast' of the EPBD (2010/31/EU) was needed and published in the June 18, 2010 issue of the Official Journal. It will have to be in full application in all Member States by mid-2013. The Recast EPBD maintains the principles of the original directive but intends to clarify and streamline a number of provisions, to extend the scope, to strengthen certain requirements, and to emphasize the leading role of the public sector in promoting energy efficiency. Among the key new elements of the Recast EPBD:

- It covers all buildings irrespective of size (the original EPBD's threshold of 1000 m² in case of renovation is removed; it excluded all single family homes and therefore missed a large part of the building stock);
- All new build must be 'nearly zero energy' by the end of 2020 (two years earlier for the public sector);
- Member States must set minimum energy performance requirements for all existing buildings that undergo renovation, at building, system and component level - which mainly applies to the building envelope;

1 Nearly Zero Energy Buildings in Europe, Brainstorming Workshop Intelligent Energy Europe, 2010

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- Minimum energy performance levels are required for new buildings (until 2020) and for refurbishment, with a benchmarking method to achieve 'cost-optimal levels';
- Cost-optimal levels' is defined as the energy performance level which leads to the lowest cost during the life cycle of the building, including not just the investment costs, but also maintenance and operating costs as well as disposal costs.

Nearly zero-energy

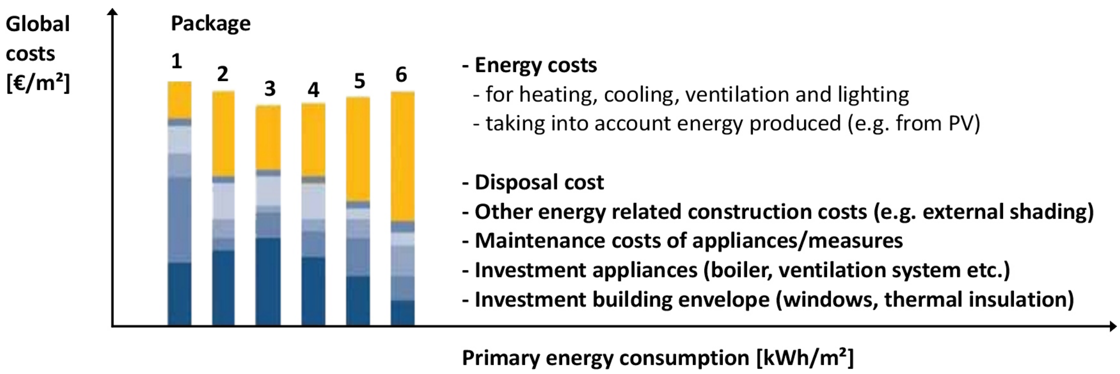
It seems obvious that two new elements will lead to fierce discussions: both 'nearly zero energy buildings' and 'cost-optimal levels' leave room for interpretation. The Directive states that 'nearly zero-energy building' means that a building has a 'very high energy performance', but that leaves the door wide open for many interpretations. As Michaëla Holl, policy officer in DG Energy[2], stated:

"Since we do not give minimum or maximum harmonized requirements, it will be up to the Member States to define what for them exactly constitutes a 'very high energy performance'". Even the more precise term 'zero net energy building' has different definitions. IEA's Jens Laustsen proposes that 'zero net energy buildings are buildings that over a year are neutral, meaning that they deliver as much energy to the supply grids as they use from the grids'[3]. The European Council for an Energy Efficient Economy (ECEEE) suggests showing that the concern is additional carbon emissions by proposing that 'a zero carbon building is one that, over a year, produces sufficient carbon-free energy to offset the carbon emitted from all fossil-fuel derived energy consumed by the building'[4]. Let's wait and see how the building sector will handle this problem. They've got ten years or so to work on it – and on their 'inertia to change'.

Nearly zero energy building.

Cost-optimal

The term 'cost-optimal' will raise many questions. The usual way to look at 'cost' is to consider only the upfront investment, while maintenance cost, operating expense and disposal cost must also be included over the whole lifetime. The method to establish cost- optimal levels, as referred to in the Recast EPBD, is not yet available. A benchmarking framework must be presented by the Commission to the Member States by June 30, 2011, dealing with the calculation of the energy performance and the cost computation, based on Net Present Value in EN Standard 15459. Member



Cost calculation for different packages, example only
Source: BPIE: Cost Optimality, Discussing Methodology and Challenges within the Recast EPBD, 2010.

2 REHVA Journal 5/2010, September 2010
3 As quoted in Steering through the maze n°2 ', ECEEE, September 2009
4 Steering through the maze n° 2, ECEEE, September 2009

From Directive 2010/31/EU, art 2,14:

'Cost-optimal level' means the energy performance level which leads to the lowest cost during the estimated economic lifecycle, where:

(a) the lowest cost is determined taking into account energy-related investment costs, maintenance and operating costs (including energy costs and savings, the category of building concerned, earnings from energy produced), where applicable, and disposal costs, where applicable; and

(b) the estimated economic lifecycle is determined by each Member State. It refers to the remaining estimated economic lifecycle of a building where energy performance requirements are set for the building as a whole, or to the estimated economic lifecycle of a building element where energy performance requirements are set for building elements.

The cost-optimal level shall lie within the range of performance levels where the cost benefit analysis calculated over the estimated economic lifecycle is positive.

States then must complete this framework to reflect their own variable national parameters, such as labour cost, interest rate, energy prices, etc. Net Present Value (NPV), says one definition shows if an investment is profitable: taking into account the interest rate, it is the discounted value of an investment's cash inflows minus the discounted value of its cash outflows. To be adequately profitable, an investment should have an NPV greater than zero.

An example of what such a calculation could result in is shown in the excellent report "Cost Optimality, Discussing Methodology and Challenges within the Recast EPBD 2010 by BPIE (the Buildings Performance Institute Europe)". Different possible packages of measures on a theoretical reference building are shown and the bar chart illustrates the costs of packages as global costs related to the primary energy used. The global cost calculation method is described in EN 15459: (Energy performance of buildings – economic evaluation procedure for energy systems in buildings).

A new approach

It will take some time for some of our industries to get familiar with this way of thinking and investing. For the solar shading industry, for instance, a quintessential SME industry, this is a whole new world. Yet it is essential for the future. The buildings in which we live and work are expected to be comfortable, practical, safe, healthy, energy-efficient and sustainable, all at the same time. For the existing buildings, this is a great challenge. It is to be expected that the refurbishment market will get a great boost from the Recast EPBD, as the ambitious energy savings targets can never be reached from the new build only. Existing houses and commercial buildings often show an annual energy use of 250 kWh/m² or more. Today's readily available building techniques allow for numbers well below 100, with recent or soon-to-be regulations in France, Germany and Switzerland – to name but a few -- requiring numbers at 50 or below for new buildings. That's a wide gap. But economic calculations provide a powerful incentive for successful investments in energy savings.

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New Ways of Working: Linking Energy Consumption to People

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Summary

Studies have estimated that residential energy consumption can be reduced by up to 30% if minor changes are made to our daily lives. In our study we aim to support positive behaviour change by enabling energy users to benchmark their consumption level and to compare energy consumption with their peers. We shall propose that consumption should be related to people and not exclusively to area and that by providing a new metric we shall empower people with the ability to claim and prove that they are living a low energy or low carbon lifestyle. We shall highlight the importance of understanding the dynamics of occupation when measuring the consumption of a building to ensure that people are not penalised for occupying their space efficiently, as is the case when only energy per unit area is considered. This paper proposes the new metric, Wh/m²h, in which the conventional annual energy consumption metric, kWh/m², is divided by total person hours. Total person hours is the total number of hours that all people have spent in the building during the year in question. The close relationship between measuring occupancy and controlling energy consuming systems is also examined. The benefits of this new metric are demonstrated by displaying the energy consumption results of a simulated case study building, which have been calculated for alternative population densities and alternative working hours per day. We also show that if occupancy is measured in order to understand our energy consumption then we can also use this knowledge to automatically turn on or off the energy consuming systems that are directly related to people. Finally, additional items to be developed in order to further support behaviour change are highlighted.

Keywords: Wh/m²h, occupancy measurement, peer comparison, low energy lifestyle, behaviour change

Introduction

Supporting behaviour change

The European Union has legally committed to reduce greenhouse gas emissions by 20% by the year 2020 and Finland has targeted a reduction of at least 80% by 2050, these figures are both with reference to the 1990 level of emissions [1]. So how do we motivate the public to play their part in these reductions? The traditional method has been to offer financial incentives to encourage actions that reduce energy consumption such as installing energy efficient or renewable equipment. However, these incentives fail to establish a long term demand or interest in energy efficiency, as once the scheme comes to an end there is no longer any motivation to improve energy using components. Also, these schemes only reward discrete actions and fail to encourage small daily improvements in how we consume energy. Another drawback is that these programs do not appeal to all sections of society evenly, as the more affluent may be less motivated.

Behavioural scientists in the United States have estimated that domestic energy consumption can be reduced by up to 30% if minor changes are made to our daily lives. [2,3] These changes relate to household energy consumption and personal transportation. They are not expected to affect our standard of living and they include actions such as using low energy light bulbs, washing clothing at a lower temperature and having the correct tyre pressure in our cars. Our study focuses on supporting behaviour change by enabling energy users to benchmark their consumption level and to compare energy consumption with their peers. If the public are encouraged to reduce energy consumption but they cannot compare behaviour with their peers then how else can people evaluate success? Also if we are to create a society that values low energy living or low carbon living then this will become a precious social commodity. It will facilitate positive change to empower people with the ability to claim and prove that they are living a low energy lifestyle.

Current reward schemes

At present people receive prizes for living low energy lifestyles through reward schemes such as Earth Aid and My Emissions Exchange. When home owners first join the scheme, Earth Aid (www.earthaid.net) requests them to publically declare their energy and water bills for 1 year. This first year's energy consumption, derived from the bills, becomes the baseline consumption level that all future years are compared to. If the building users reduce consumption relative to this first year then they receive rewards. These rewards are generally vouchers offering free consumer products and the value of these rewards increases relative to how much consumption has been reduced. The scheme is a powerful way to reward members of the public who have actively sought to reduce their consumption by actions such as turning unnecessary energy consuming items off, installing higher efficiency equipment or by installing renewable energy generation systems. My Emissions Exchange (www.myemissionsexchange.com) works in a similar way. A carbon footprint is calculated for each participant based on their first year's energy billing and rewards are assigned by turning energy savings into carbon credits. These carbon credits are then sold to a third party on behalf of the homeowner.

If these schemes have a flaw, it is that rewards are allocated relative to each person's own energy consumption history. If person A was once a high energy consumer and person B has consistently lived energy efficiently, then it is possible that person A will receive more rewards than person B even if person A consumes dramatically more energy per household. In other words those with a low consumption level are at a disadvantage as they can only improve their lifestyle by a smaller margin. In order to provide an understanding of how appropriate a household's consumption level is, we require a format that justly compares energy consumption with that household's neighbours regardless of the type of home, number of occupants or history of consumption.

Residential Buildings

Relating consumption to people

Through this study we aim to create a metric that facilitates domestic energy users to evaluate their consumption. We aim to empower and motivate people by enabling the following questions to be answered: am I living a low energy lifestyle? How does my consumption compare relative to my peers?

When we consider the current methods of evaluating and rewarding residential energy consumption, such as energy performance certificates or rebates for reducing energy consumption, these methods focus on the amount of energy consumed relative to the area of the household. They do not relate energy consumption to the amount of people who are responsible for the consumption. Energy metrics that relate energy to area, such as kWh/m², are extremely useful when considering the physical properties of a building that influence energy consumption such as wall and window u-values, building air tightness or the efficiencies of the heating and lighting systems. However, these metrics do not provide an understanding as to how effectively a household is being utilised once it is occupied, or in other words during the operations phase.

If we consider a simple scenario of a residential reward scheme in an apartment complex where all apartments are the same size and have two bedrooms. If the management company of the apartment complex were to offer a reward for the apartment that consumes the lowest amount of energy in a six month period who would win? Would it be an apartment occupied by a person living alone or an apartment that is occupied by a family of four people? If we evaluate energy consumption via the traditional method, by measuring it relative to area, then the apartment with only one occupant has a much greater chance of winning this competition due to the fact that one person can be expected to consume less energy than four people. Therefore, if we do not consider the dynamics of occupation of the spaces, the family of four are being punished for occupying their space more efficiently.

It stands to reason that the greater the number of people that occupy the fixed area of a residential household, the more efficient that household will be. This is due to the fact that many energy using systems consume a similar amount of energy regardless of how many people they serve. This concept of overlapping energy consumption applies to heating, lighting and appliances such as television. The energy consumption of other devices such as cooking appliance may increase marginally when serving more people but the energy consumption when cooking for two is not double that of when cooking for one person. There are also energy consumptions that relate directly to the number of people such as domestic hot water demand. This paper is not arguing that households should be occupied as densely as is practical but rather that residential energy consumptions could be evaluated in a fairer manner by considering occupancy. If we do not consider the number of building users when measuring residential energy consumption then we cannot compare our energy consumption with our friends, neighbours, or our

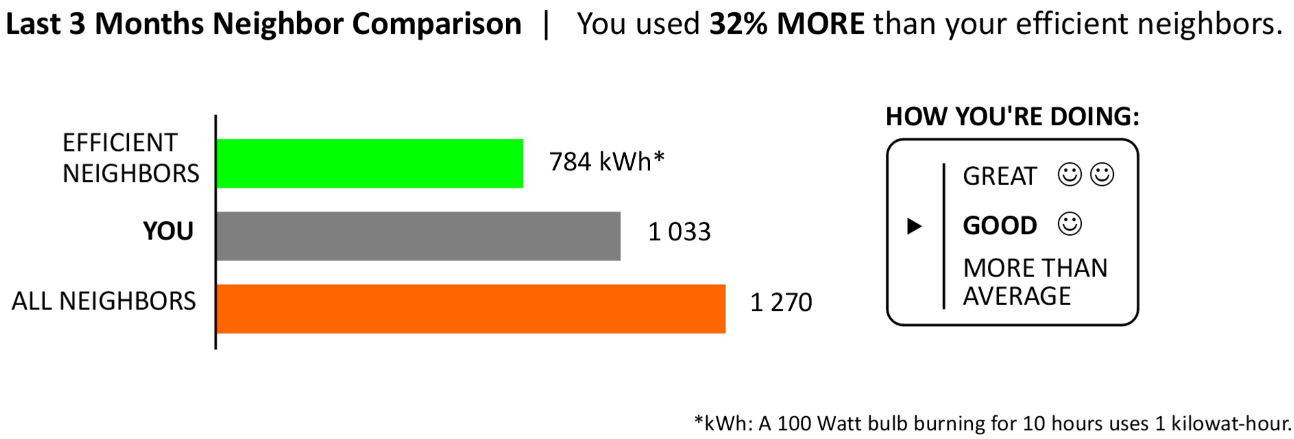

Figure 1. Comparative billing example (Source: Opower.com)

fellow inhabitants of the city or country we live in. It is this social pressure that shall bring about the most effective change and shall engage the majority of citizens, not just those who are interested in sustainability or those who understand the opportunities for saving money.

The development of smart grid technologies (such as smart meters and smart systems) shall enable easier ways of sharing energy consumption data and controlling our energy consumption. Also, it is in the interest of environmental ministries around the world to promote the next generation of online social networking websites similar to Carbon Rally (www.carbonrally.com), Carbon Diet (www.carbondiet.org) or Step Green (www.stepgreen.org) which encourage the public to declare their carbon footprint and to compete with their friends to actively try to reduce it.

Measuring occupancy

Unlike commercial buildings, where time clocks are used to measure the movement of staff, occupancy is not readily measured in residential buildings. The closest example may be modern hotel key cards that provide power when the hotel key is in the correct location. These key cards are used to evaluate if the room is occupied but they do not measure how many people are occupying the room. It must also be noted that the data required to fully understanding the dynamics of residential occupancy can lead to fears of privacy invasion and security risks. For the purpose of this paper we shall assume that any data recorded shall be sufficiently encrypted as to dispel these fears.

Existing residential consumption comparison techniques compare household consumption with similar households. Similar households are generally considered as similar sized homes with the same number of people. The British Columbia Hydro power company enables their customers to compare their energy consumption through a program called Team Power Smart [4]. Customers can select type of building, home size (a range of areas is offered), home and water heating type and number of occupants. The scheme is optional and data is inputted by the customer to provide feedback as to how they are performing. Other companies provide their customers with bills that compare a household's consumption with the average consumption of households that have the same number of people over the billing period.

If we are to empower people with the ability to claim and prove that they are living a low energy lifestyle we require a measurement that can be compared to all our peers and not just those who have similar sized families and homes. In the future this may be done through technologies similar to hotel key cards or by weighting our energy consumption by using an occupancy conversion factor. An occupancy conversion factor may be a simple method of relating energy to people. A list of indicative occupancy conversion factors may be seen in **Table 1**. The estimated annual energy consumption ratios shown in this table are not based on empirical data and have been chosen only to illustrate the benefit of such a factor.

Non-residential Buildings

Relating consumption to people

Non-residential buildings also suffer when performance is measured relative to area. In this section we shall consider energy consumption; however the methodology shall also apply to other environmental impact factors such as carbon generation, water consumption and waste generation.

Table 1. Annual energy consumption conversion factors for residential buildings relative to number of occupants (indicative only).

Case	A	B	C	D	E	F
Number of adults	1	2	3	4	2	2
Number of children under 14 years of age	0	0	0	0	1	2
Estimated annual energy consumption in kWh relative to an adult living alone	100%	180%	260%	320%	220%	250%
Proposed conversion factor (1 / relative energy %)	1	0,56	0,38	0,31	0,45	0,40

When analysing the energy use of non-residential buildings with a view to reducing building operating costs and reducing energy consumption the most common metric is kWh/m². As discussed earlier, this metric is extremely useful when considering the steady state properties of a building design but it does not provide an understanding as to how effectively a building is utilised during the operations phase. When considering how effectively and efficiently a building is being used we must consider (a) the number of hours per day the building is occupied and (b) how densely the space is populated.

If kWh/m² are used to assess an office building's performance, then a building that has a shorter work day than is normal and provides a large area per person is perceived as being more energy efficient than a building that operates longer hours and has a more efficient floor plate. Therefore buildings that operate more efficiently are punished when we measure energy efficiency through a metric that does not relate energy to people. This shall be demonstrated in the case study described in section 3.5.

Occupied hours per day

When the number of hours a building is occupied per day is considered from the viewpoint of sustainability, it is highlighted that buildings contain significant amounts of embodied carbon emissions, they are associated with light and noise pollution and they are located on a plot that once was a greenfield site. It is clear that encouraging companies to combine departments with different working hours together to use the same space shall have a positive effect. Increasing the number of hours a building is used per day also has a positive effect from an energy efficiency point of view, as even when buildings are not occupied they consume energy in the form of systems such as: background heating, lighting (security, car park, corridor), exhaust ventilation (toilets, waste areas, staircases, technical spaces), reserve power systems such as UPS, servers and other communication equipment. It stands to reason once again that using buildings for as many hours as is possible shall have a positive effect and that we must begin to relate building performance to the number of hours per day, per month or per year it is occupied. Thus it is important to reward those who are using their buildings more efficiently. For example the total annual energy consumption of hospitals that operate for 24 hours a day should not be compared to similar hospitals that operate for 12 hours a day without some allowance being made for hours of operation.

Population density

Similarly to residential buildings, the energy consumption of commercial buildings consists of portions that are related to size of the building (heating, lighting), elements that are related to people (equipment energy such as computers, ventilation) and elements that are related to both of these (cooling). Buildings that have an efficient internal plan and hence have a low amount of floor area per person are also punished without considering people in the performance metric. If people are not considered then excessively large buildings shall continue to appear more energy efficient as energy consumption is divided by area. Therefore the larger the building, the lower the amount of kWh/m² shall be, as the energy related to the building population is spread over a wider area.

An alternative to kWh/m²

We require a metric that relates energy to density of population so that those who are utilising their buildings more efficiently are rewarded and not punished as is the current situation. This paper proposes the metric, Wh/m^2h, where the conventional annual energy consumption metric, kWh/m^2, is divided by total person hours as shown in equation 1 below:

Energy per area per occupied hours:

$$\frac{Wh}{m^2h} = \frac{\frac{kWh_1}{m^2}}{h_2} \times \frac{1}{1000} \qquad (1)$$

where kWh_1 is the annual energy consumption, m^2 is the area of the building that is being measured, and where h_2, known as total person hours, is the total number of hours that all people have spent in the building during the year in question, h_2 is calculated as shown in equation 2 below:

$$h_2 = \sum_{1}^{n} t \qquad (2)$$

where t is the number of hours that a person spends in the building during the year and n is the total number of people that visit the building during the year.

Case study: office building in Helsinki

By applying this metric to a conventional office building located in Helsinki, Finland, we can demonstrate the benefit of the new metric relative to kWh/m^2. Using dynamic thermal simulation software the annual energy consumption of an office building, whose geometry is shown in **Figure 2** below, has been calculated for alternative population densities and alternative working hours per day. The results of the 9 comparison cases which were calculated may be seen in **Table 2**.

If we consider cases 1, 4 and 7, which have similar working hours per day, the results show that when kWh/m^2 is used for the evaluation the building seems 3.1% more efficient when the building layout provides more area per person (12 m^2/person compared to 8 m^2/person). However, when kWh/person is considered the 12 m^2/person configuration consumes 45% more energy than the when the population density is 8 m^2/person. Wh/m^2h provides a similar result as the 12 m^2/person configuration consumes 45% more energy.

If cases 1 – 3 are considered, which have a similar population density, the results indicate that when kWh/m^2 is used for the evaluation the building seems 28% more efficient when the working day is shorter (6 hours compared to 12 hours). If Wh/m^2h is used then the opposite is true and the working day of 12 hours is calculated as using 30% less energy when compared to a working day of 6 hours. Thus, the area only related metric is rewarding a shorter working day even though a longer working day is considered more efficient.

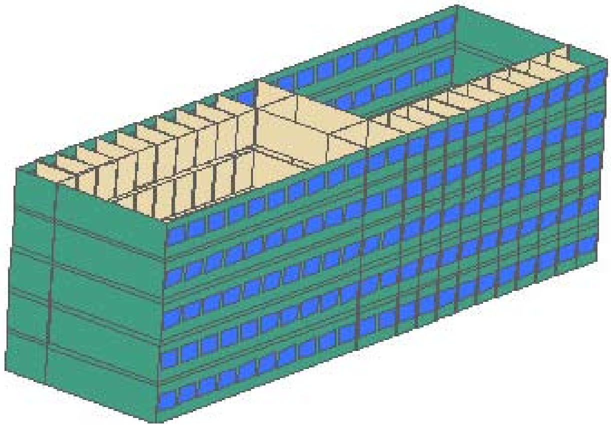

Figure 2. The geometry of the building used in the thermal simulation.

In order to promote a reduction in greenhouse gas emissions an alternative energy efficiency metric to kWh/m^2 is required that does not penalise buildings for incorporating a dense floor layout or a longer working day. It is important to note that the simulated energy results are based on the same building and only the population densities and hours of occupation are altered.

Controls

There is a close relationship between measuring occupancy and controlling energy consuming systems. If we measure occupancy in order to understand our energy consumption then we can also use this knowledge to automatically turn on or off the energy consuming systems

Figure 3. RTLS employee security card example. (Source: 9solutions.com)

Table 2. Simulated energy consumption results of an office building showing kWh/m², kWh/person and Wh/m²h.

Case	1	2	3	4	5	6	7	8	9
Population density (m²/person)	8	8	8	10	10	10	12	12	12
Working hours per day (h)	6	9	12	6	9	12	6	9	12
Energy consumption (kWh/m²)	86	102	120	84	99	115	83	98	112
Energy consumption kWh/person)	799	951	1114	981	1150	1330	1166	1368	1569
Energy consumption (Wh/m²h)	0,110	0,087	0,077	0,135	0,105	0,091	0,16	0,125	0,108

that are directly related to people, similar to the hotel key card mentioned earlier.

For example if a company requires employees to register their arrival and departure from an office building via an electronic time clock system then this data can be used to calculate occupied hours per year and also to control energy consuming equipment. If an employee arrives at the office at 09.00 and leaves at 17.00 on a particular day then the occupancy data software can record 8 occupied hours for that person on that day. In addition the occupancy data can also be used to turn off equipment dedicated to that person before 09.00 and after 17.00. When that employee is not on the premises then the lighting over that person's desk and the power to their computer can be automatically turned off. If that person had a single person office room then the ventilation and heating could be turned down to a minimum level or if that person was the last person to leave their particular floor or wing of the building then all systems could be automatically set to the night time mode. Understanding occupancy data such as when and where a person is on the premises does not only provide transparent energy consumption data but this data can be actively used to reduce energy consumption.

Discussion

Technology such as real time location systems (RTLS) can also be used to measure occupied hours while providing the additional benefit of presence detection and increased levels of security. Electronic tags can be added to employee security access cards and a dedicated wireless network within the building can track the real- time location of each employee. This enables energy consuming items dedicated to each employee to be turned off based on location. For example if an employee is more than 10 meters away from their desk for more than 15 minutes then their desk could go to sleep mode by turning off lighting and other energy consuming systems associated with that person.

In this paper we have highlighted the potential flaws of relating energy consumption exclusively to area and we have proposed a new metric, Wh/m²h, that does not penalise buildings for incorporating a dense floor layout or a longer working day. However, there are many areas of the subject matter discussed in this paper that must be developed further such as: (a) deciding upon a method of measuring residential occupancy, (b) encouraging the public to openly declare their carbon foot- print and to compete with their friends to actively try to reduce it and (c) to develop integrated occupancy measurement and control technologies for commercial buildings.

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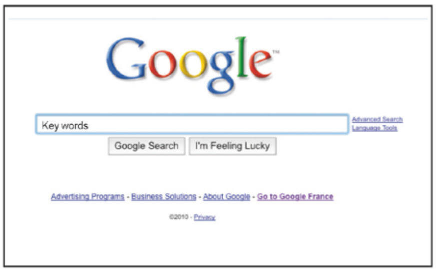

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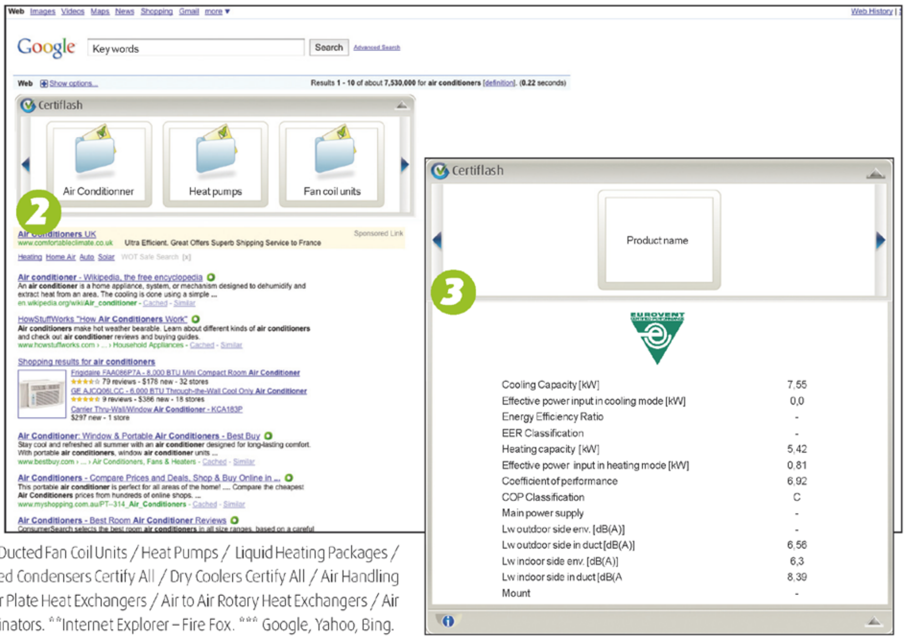

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Air conditioning of clear coin showcase

View of the interior of the "Ilion Melathron" – Numismatic Museum of Athens and former residence of Heinrich Schliemann.

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Summary

The below study concerns the electromechanical installations the Air Conditioning of the Coin Exhibit Case so as the coins to be kept in an absolute clean environment, humidity and stable temperature. The Air Conditioning is achieved with inlet of warm or cold air at the Coin Exhibit Case through ducts from pipelines ∅15 mm/0.6 in that independent on automation, separate for each Coin Exhibit Case. The production of the clean air under the required pressure is realised by Medical Air Cylinders.

Introduction

The construction of the "Ilion Melathron" (the "Trojan Mansion") begun in 1870, a few years after Schliemann has settled into Athens. It was designed by his friend and compatriot Ernst Ziller. The mansion floors are tessellated which depict geometric motifs and representations of the artifacts coming from the excavations of the Mycenae and Troy. The wall and ceiling paintings are either exact copies of Pompeian themes or illustrations of Schliemann's excavations and finds in the same style.

As the residence of a distinguished archaeologist the "Ilion Melathron" housed the fruits of the labours of his remarkably adventurous life, as well as his dreams and his visions. It also housed amid publicity and splendour solitude and family tranquility, in the same area where the coins of Schliemann's collection delighted the eyes of their possessor and the eyes of his select visitors.

Today the Numismatic Museum of Athens is one of the very few of this kind all over the world and the only one in Greece and the Balkans. Possessing about 600 000 coins which come from the ancient Hellenic world, the Roman era, Byzantium, the medieval European West and the modern times, as well as a great number of hoards, excavational finds, lead seals, medals and gems (acquired either by donations or by purchase), the Numismatic Museum, is called to preserve and secure these treasures and present them to the audience.

And here it comes this study to accomplish this task. The object of the study is the creation of a proper environment for the preservation and exhibition of the coins. In particular, the coins will be exhibited inside showcases, where will be, in parallel, preserved too. Consequently, the showcases must, on the one hand, permit the exhibition of the coins to the visitors of the Museum, and on the other hand, provide the proper conditions for the coins preservation. At the same time, the showcases must secure the coins against theft during the opening hours of the Museum, regardless of the general security system, which is "not operative" during the Museum's opening hours. Each showcase has two compartments. In the upper compartment, will be placed the coins and it is airtight in the lower compartment, the air conditioning organs, the air ducts, the cables and everything its necessary, this part of the showcase is not airtight.

The object of the study is the creation of a proper environment for the preservation and exhibition of the coins. In particular, the coins will be exhibited inside showcases, where will be, in parallel, preserved too. The cause of the study is the design of a system of air-conditioning (heating, cooling, humidity, air filtering) and lighting of the showcases. In particular, the air-conditioning system must secure inside the show-cases the proper conditions for the preservation of the copper and metallic coins, namely:

- temperature 21 +/–1°C (69.8 +/–1.8°F), without sudden changes;
- humidity less than 25%, i.e. dry air, without sudden changes;
- elimination of the atmosphere pollutants, i.e. ozone, sulphur oxide and nitric oxide, fume etc.

Problems

The place itself of the Coin Museum is a "museum place", namely the floors bear mosaics, the walls are painted, the frames, the doors and windows etc. have been restored to their initial condition. Consequently, any intervention in the building elements is impossible resulting to the difficulty of connection of the showcases with the electricity, air-conditioning ducts networks etc.

The Museum is situated at the centre (most polluted) area of Athens and as it is known, the pollutants are the enemy number one of the museum exhibits. Consequently, the external air which will be used for the air-conditioning of the showcases, must be filtered not only from particles, fume etc. but also from chemical combinations, namely molecules. And the removal of molecules and smells by conventional bug filters or even by absolute filters 99.995% is impossible. Only activated carbon filters can eliminate the smells.

The areas of the Museum are not air-conditioned and as a result, the fluctuations of temperature and humidity are great. Therefore the air-conditioning of the showcases must offset the lack of air-conditioning of the surrounding areas.

Brief description of the proposed solution

All the showcases will be connected between them by a bar made of aluminium profile, achieving in that way the following:

- support of the showcases;
- creation of a control zone (prohibition) of the circulation behind the bar;
- indication of the course of the visitors inside the Museum;
- march inside the bar of the required cables and air-ducts for the electric power supply to and the air-conditioning of the showcases. Inside the bar two (2) air-ducts will proceed, one (1) with hot air (25°C/77°F) and one (1) with cold air (15°C/59°F).
- With "T" junctions inside the bar, each showcase will be connected with both air-ducts. Through proper automatons, the showcase will be gated up or cooled, according to its internal temperature.

Analytical description of the air-conditioning installation

For the air-conditioning of the showcases compressed air will be used Medical Air Cylinders. The two (2) cylinders will be placed at the building' s engine-room. Apart from the two compressed air cylinders, the production centre will include:

- an alternating-current generator for the alternation of the two compressed air cylinders;
- a pressure eliminator 20 000/800 kPa (2 940/118 psi) with regulation of 300–500 kPa (44–73.5 psi);
- a gate valve for the isolation of the cylinders;
- metallic bracket for the cylinders.

The air after the pressure eliminator will have a temperature of approximately 15°C/59°F. Via a special "T" fitting, the air will be branched and one (1) branch will remain at 15°C/59°F. (cooling air) and the other branch will pass through a pot containing water at a stable temperature of 25°C/77°F, which is achieved by a thermostat and electric resistance, in order that its temperature may be increased at 25°C/77°F (heating air). In this way we succeed the following:

1) air heating and cooling with small difference of temperature, so that no sudden alterations of the show-cases temperature be presented;
2) stable zero humidity of the air letting in the showcases, because the air of the cylinders is dry;
3) inlet of clean air without pollutants in the showcases;
4) possibility of use of gas nitrogen without control of the temperature when the whole Museum is air-conditioned;
5) economic operation with only consumable the compressed air cylinders;
6) simple installation without automatons, electrical consumption and maintenance by unskilled persons;
7) stable quality of the produced air during all the hours of operation

The ducts network will proceed inside the bar and will be made of a flexible plastic pipeline ∅12 mm/0.45 in. Operation pressure of the network: 300–500 kPa (44–73.5 psi). The network will start from the building' s engine-room, where the cylinders will be installed, will proceed through the existing air-conditioning ducts and will end up at the ground-floor where it will be inserted in the show-cases connection bar (See **Figure 1**). The air-ducts network will proceed exclusively inside the bar. In the crossing through the frames, doors and windows, the air-ducts and the cables will proceed in the existing vacuum of the frames. As it was mentioned above, in each showcase both ducts will be inserted for heating and cooling respectively. The heating 21+/–1°C (69.8+/–1.8°F) and cooling of the showcase, for the achievement of a stable temperature of will be realized by air and with small difference of temperature, Dt=5°C/9°F so as no sudden changes of the temperature be created. In the entrance of the showcase the heating (cooling) air will

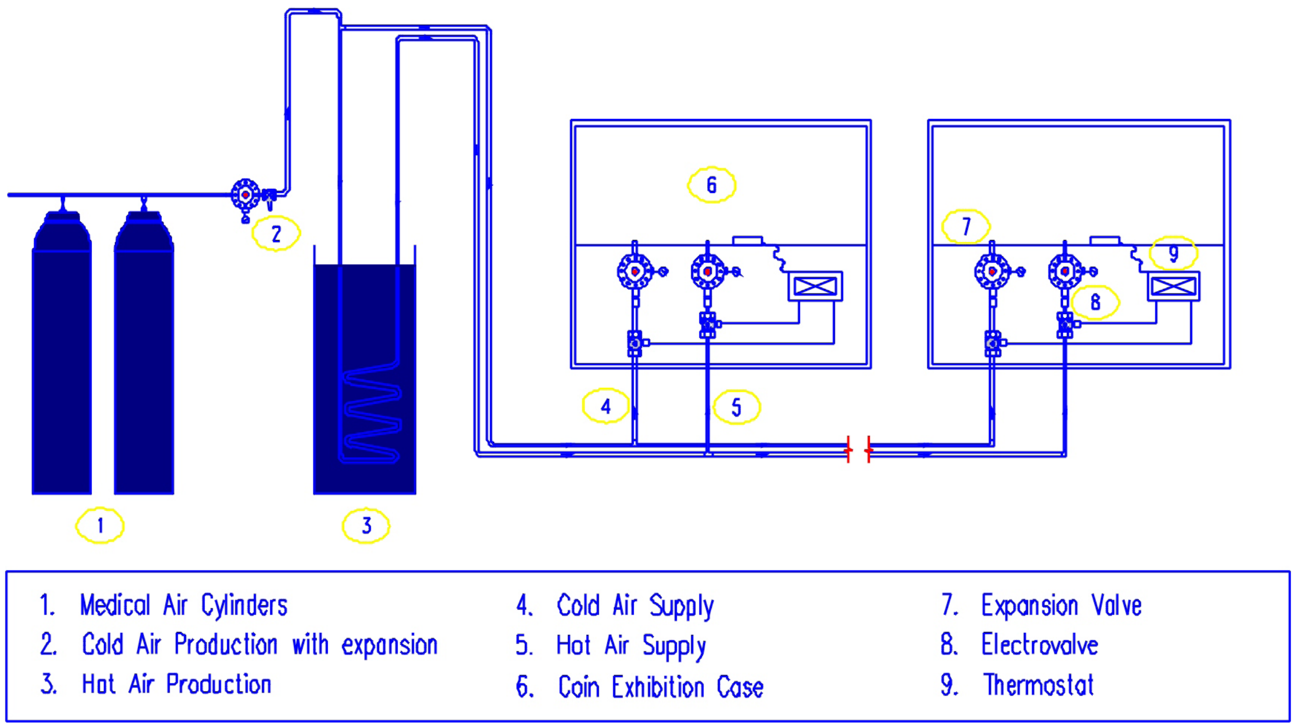


Figure 1.

have a pressure of 300–500 kPa (44–73.5 psi), therefore a pressure regulator will be placed, so that the pressure be reduced at 2 kPa/0.3 psi. After the pressure regulator the air will pass through an electro driven sluice valve "on-off" which is controlled by a thermostat adjusted at 20°C/68°F(22°C/71.6°F for cooling). When the temperature falls below 20°C/68°F (raises above 22°C/71.6°F), then the thermostat gives a signal and the hot (cold) air sluice valve opens (See **Figure 2**). When the temperature is restored to the desired level, the thermostat gives the proper order and the heating (cooling) sluice valve shuts. The expansion (ventilation) valve will be placed at the bottom of the airtight division of the showcase, permits the exit of the air when some sluice valve is open, so that the overpressure of the showcase be stable. All the organs, namely the pressure regulators, the electric sluice valves and thermostats are placed at the lower division of the showcase. The above-mentioned operation of the air-conditioning system attains: stable temperature, small changes of temperature, overpressure in the showcase, so that no air from the environment may enter, which carriers' pollutants, humidity and dust.

Calculations

In the present phase only approximate calculations will be made, which will justify the sizes of the air-ducts. In the phase of the application study, accurate calculations will be made. Given that many controlled factors affect the operation of the air-conditioning system, e.g. temperature of the Museum area etc. in the phase of construction there is the possibility of adjustment of the installation to the real operative conditions due to the pressure regulators in each show-case and in the beginning of the air-ducts.

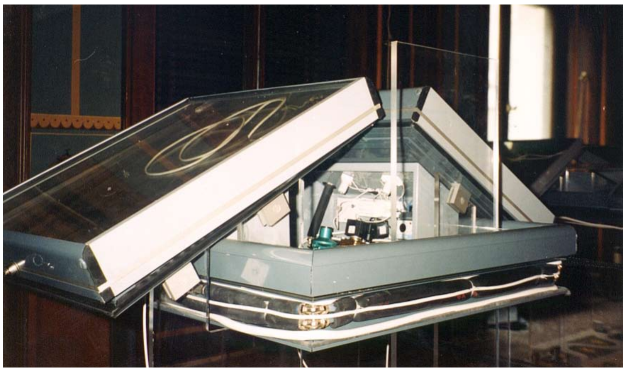


Figure 2. Instruments under the exhibition boxes.

Volume of show-case: V = 0.6 x 0.6 x 0.03 = 0.0108 m^3 (1.97 x 1.97 x 0.1 =0.38 ft^3)

Total volume: V = 40 x 0.0108 = 0.432 m^3 (40 x 0.38 = 15.2 ft^3)

With 6 alternations/hour of the air in the air-conditioning system we have a total supply of:

Q = 6 x 0.432 = 2.6 m^3/h (6 x 15.2 = 91.5 ft^3/h = 1.52 cfm.

With a velocity of approximately 10 m/s (1970 fpm), which is usual for medical air installations, the following cross section of the air-duct results:

S = 2.6 m^3/h/10 m/sec = 0.72 cm^2 (1.52 cfm/1970 fpm = 0.0008 ft^2) or diameter:

d = (4 x S/π) = 10 mm/0.4 in. So, the choice 0.45 in is correct. 3E

Two new EU ordinances under the Ecodesign Directive

Pumps in Europe: Step by step to more energy efficiency

WILO Romania
marketing@wilo.ro

The ErP or Ecodesign Directive is an important component in achieving the "20/20/20" climate and energy targets set by the European Union – up to 2020, greenhouse gas emissions should be reduced by 20%, the proportion of renewable energies increased by 20% and energy efficiency improved by 20% – in each case compared to the 1990 figures. As far as glanded pumps and glandless circulation pumps are concerned, two new EU ordinances will ensure that "energy guzzlers" which are no longer up-to-date will gradually be withdrawn from sale in Europe – as in the case of the light bulb ban.

Two new EU ordinances under the European ErP ("Eco Design") Directive will strictly regulate the energy efficiency of newly sold pumps in the next few years. The first of these will come into force quite soon, on 16 June 2011. Ordinance (EC) no. 640/2009 by the EU Commission is concerned with the efficiency of electric motors, i.e. also for units used in landed pumps for heating and ventilation as well as for water supply and pressure boosting. On 1 January 2013, a second ordinance (EC) no. 641/2009 especially for glandless circulation pumps will ensure that practically only high-efficiency pumps with particular energy-saving properties will be allowed to be marketed.

The timetable for both ordinances provides for only high-efficiency pump technology to be available for practically all requirements of building services by 2020:

Motors for glanded pumps

Ordinance (EC) no. 640/2009 of the EU Commission dated 22 July 2009

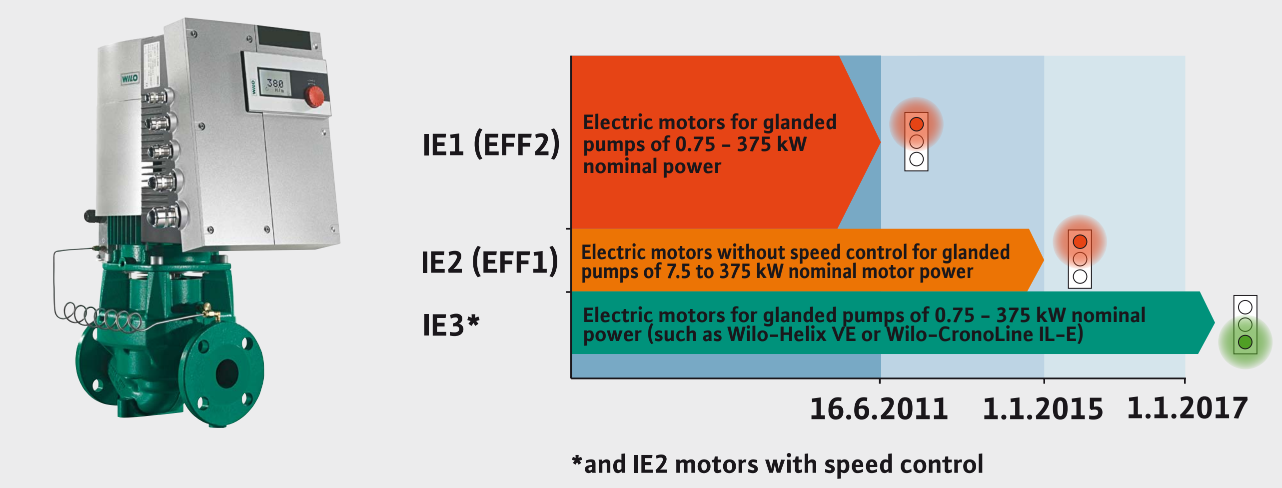
Based on the new EN 60034-30:2009 standard. This phases out the subdivision into three efficiency classes EFF3 to EFF1 that has been used in Europe since 1998, and replaces it with a new "IE" classification. This acronym stands for International Efficiency and defines globally applicable efficiency classes for three-phase AC squirrel cage motors in the power range from 0.75 to 375 kW.

The following motor efficiency classes have been defined to date:

- IE1 = Standard efficiency, approximately comparable to EFF2
- IE2 = High efficiency, approximately comparable to EFF1
- IE3 = Premium efficiency
- IE4 = Future efficiency class that is set to be the highest (according to IEC TS 60034-31 Ed.1)

The new motor efficiency requirements will be introduced in three steps:

16 June 2011:
All new electric motors brought onto the market – with the exception of a few designs and application areas – must comply with efficiency level IE2. Pump motors with the previously applicable efficiency level EFF2 – to be referred to in future as IE1 – will then no longer be permitted to be marketed in the European Union.



<u>**1 January 2015:**</u>
An even stricter efficiency level IE3 must be achieved, initially by motors with a rated output power from 7.5 to 375 kW. Alternatively, they must meet at least the efficiency level IE2 and be equipped with speed control.

<u>**1 January 2017:**</u>
The aforementioned requirements will apply to motors with a rated output power from 0.75 to 375 kW.

For planning and tendering, it is important to note that in glanded pumps it is only the electric motor used for the drive that is affected by the new EU ordinance. As of this point in time, no efficiency requirements have been placed on other pump components e.g. hydraulics – which perhaps can also be sold without a motor if necessary. An ordinance on the efficiency of the hydraulic component of glanded pumps is currently being prepared by the EU Commission. At present, however, only the motor efficiency is decisive.

Since 1 January 2011, the pump specialist WILO SE has only supplied glanded pumps equipped with IE2 motors in all its series. This means not only the requirements of the first stage of the ErP Directive have been met at an early stage, but also that cases of uncertainty relating to the deadline on 16 June 2011 will be avoided. As the pump manufacturer has emphasized, the low electricity consumption of the newest generation of glanded pumps means that owners who renew their outmoded pump models before the deadline will also find their decision pays off particularly quickly.

New glanded pumps: High requirements in the efficiency class IE4 far exceeded

What is more, Wilo is taking account of the objectives of the EU Commission in a particularly consistent way with regard to sustainable climate protection, by means of new series. The level of energy efficiency of the motors even outclasses the limits of the upcoming efficiency class IE4 (acc. to IEC TS 60034-31 Ed.1) that is set to be the best, as a result of which they exceed all future specifications of the new EU ordinance on the energy efficiency of electric motors.

According to the manufacturer, the completely newly developed high-efficiency pump series, "Wilo-Stratos GIGA" for the upper performance range in heating, air conditioning and cooling applications, sets new standards in energy efficiency for inline pumps. For the first time in this case, glanded pumps are driven by EC motors with extremely low current consumption. Based on a motor efficiency of 94% the "Wilo-Stratos GIGA" achieves particularly high levels of overall efficiency, when teamed up with new hydraulics which have been optimally adapted to the drive. The energy efficiency of the motor is based on the new high-efficiency HED drive concept (HED – High Efficiency Drive) from Wilo. The hydraulic system and drive are systematically adapted to one another, something which also forms the basis for the very high overall efficiencies of the new series. Compared to old, uncontrolled pumps available on the market, the upshot is that the new ones can achieve an energy saving of up to 70% based on the manufacturer's figures. The saving potential compared to conventional speed-controlled pumps is up to 40% (calculated according to the "Blauer Engel" load profile).

In the category of high-pressure centrifugal pumps, use of EC motors with extremely low current consumption for the new "Wilo-Helix EXCEL" series also represents an innovation. Here too, the high-efficiency drive allows current consumption to be cut by up to 70% in certain applications, so that the payback time for the investment costs is correspondingly rapid compared to a standard pump. The fields of application of the "Wilo-Helix EXCEL" are water supply, pressure boosting, industrial circulation systems, process water, cooling water circuits, washing systems and irrigation systems. In future, new pressure boosting systems are available with two to four vertical "Wilo-Helix EXCEL" pumps. They offer particularly straightforward operation due the Red Button technology that has proven effective in Wilo pumps and systems, and a display – both on the pumps and a control unit. This permits especially user-friendly pressure boosting system management which means only one minute is required for commissioning.

Glandless circulation pumps

Ordinance (EC) no. 641/2009 of the EU Commission dated 22 July 2009

The basis for the assessment of which pump models will be allowed to be used in the future is what is referred to as the energy efficiency index (EEI). The index will be determined by the pump manufacturer using a calculation method defined in the ordinance (EC) 641/2009. For this, the electrical power consumption of the pump measured using a load profile is compared to a reference pump, i.e. an average high-efficiency pump with the same hydraulic output. As a rule, the future limit values will be stricter than the requirements of the current energy efficiency class A for glandless circulation pumps.

1 January 2013:
The Energy Efficiency Index (EEI) limit value of glandless circulating pumps installed outside the heat generator (external pumps) will be defined as 0.27. The energy efficiency classes specified up to now will then no longer exist. Pumps should then normally be better than the minimum requirements of the current class A pumps.

1 August 2015:
The EEI limit value will be reduced to 0.23, and will then also apply to glandless circulation pumps designed to operate in newly installed heat generators or solar thermal systems (integrated pumps), for example.

1 January 2020
In the last implementation stage, the requirements will also apply to the replacement of integrated pumps in existing heat generators. All glandless circulation pumps in heat generation and air-conditioning systems will be affected.

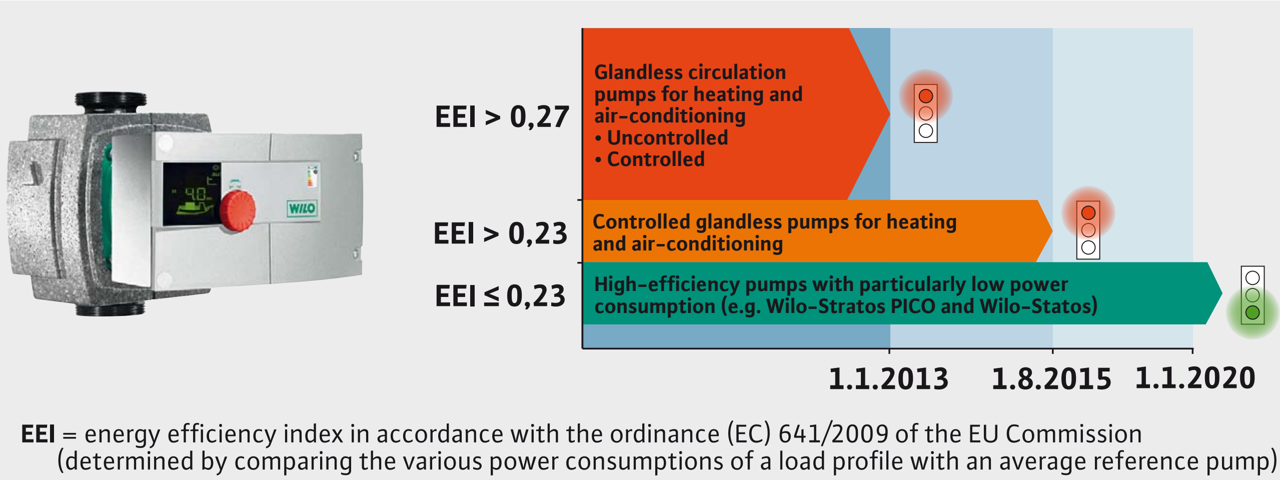
Secondary hot water circulation pumps are an exception.

Radical change in the market requirement

As a consequence of this ordinance, the assortments of glandless circulation pumps will change significantly from 2013 onwards, if not before. Because over 90% (status 2009) of the glandless circulation pumps available on the market for heating and air-conditioning will no longer comply with the future limits. Most of the pumps without speed control currently on the market, as well as conventional pumps with speed control, will no longer be allowed to be offered for sale from 2013 onwards.

Even though about one and a half years still remain until when the first stage comes into effect, this ordinance already applies to planning and tendering by TGA specialist planners – above all where major building projects are concerned. Experience shows that many months can elapse between planning, tendering and placement of the specific order. Therefore, the time when components for many projects are finally introduced into the building services may well be only during 2013. However, even in case of an earlier implementation, i.e. before the new EU ordinances come into force, bottlenecks may be encountered with the "phase-out models" in advance – due to market players concentrating on the most energy-efficient pump models. In view of this situation, investors should already be informed about the changeover now, and be steered in the direction of energy efficiency even with glandless circulation pumps.

Wherever the use of high-efficiency pumps, for example, is connected to higher construction costs, pointing out the considerably lower costs for electricity is a convincing argument. The LCC check from Wilo is useful in these cases. The life cycle costs of the various circulation pumps can be compared with Wilo high-efficiency pumps at lcc-check.wilo.com. It is usually shown that the achievable savings in electricity costs quickly pay for the additional costs.



In future, the Energy Efficiency Index (EEI) will be the central point of reference with regard to the electricity consumption of glandless circulation pumps. It can also be used for differentiating within the product group of high-efficiency pumps, because this new mandatory information can also be used for detecting particularly energy-efficient models (EEI ≤ 0.20).

High-efficiency pumps with scope for future expansion are already state-of-the-art

With the current "Wilo-Stratos" and "Wilo-Stratos PICO" high-efficiency, single pump series, WILO SE, the Dortmund-based pump specialist, offers a complete range of products for the diverse building services requirements that fulfil the particularly strict limit values of the second stage in the regulation for glandless circulation pumps under the ErP Directive applicable as of August 2015. The "Wilo-Stratos" already set standards in 2001, and the series has been continually supplemented and optimised ever since.

Even the "Wilo-Stratos PICO" high-efficiency pump presented in 2009 for detached and semi-detached houses is particularly economical. It achieves energy savings of up to 90% compared to heating pumps without speed control. Thanks to "Dynamic Adapt", the latest generation of this high-efficiency pump presented at the ISH 2011 very quickly adjusts its capacity on a continuous basis to the particular demand in the heating system. Not only does this reduce noises from the thermostatic valves, it also achieves additional energy savings.

Together with the "Wilo-Stratos GIGA" glanded pump with IE4 electric motor for larger heating and air conditioning circuits, planners and investors can cover all the requirements of building services using Wilo high-efficiency pumps with particularly low current consumption. This is why the performance ranges of the three "Wilo-Stratos" series blend seamlessly into one another.

Conclusion

Regulations governing the energy efficiency of newly sold pumps are going to be tightened up step-by-step for almost all designs and applications. The European Union is pursuing a clearly defined schedule up to 2020 with two EU ordinances under the ErP Directive. Each of these contains three milestones for electric motors and glandless circulation pumps. At the end of the regulation process, inefficient "energy guzzlers" will definitively be banned from the market; exclusively energy-saving pumps will be available for new installations and replacements. As a consequence, for example, the Dortmund-based pump specialist WILO SE has already embarked on a policy of "high efficiency" at an early stage. The models with the greatest electricity savings already exceed the strictest requirements of both EU ordinances, indeed they do so by far in some cases. This offers numerous advantages: After all, where the efficiency requirements of the Eco Design Directive are significantly rather than only just exceeded, these benefits will be made apparent through additional electricity consumption savings and therefore a further reduction in life cycle costs.

News from the European Commission

Energy Efficiency Directive

A new set of measures for increased Energy Efficiency is proposed by the European Commission to fill the gap and put back the EU on track. This proposal for this new directive brings forward measures to step up Member States efforts to use energy more efficiently at all stages of the energy chain – from the transformation of energy and its distribution to its final consumption.

The Commission proposes simple but ambitious measures:

- Legal obligation to establish energy saving schemes in all Member States
- Public sector to lead by example
- Major energy savings for consumers

The Policy concepts in the new EED:

- Energy efficiency obligation: Member States make sure that an equivalent of 1.5 % of annually energy sales are saved through energy efficiency measures
- Public sector lead by example: annual renovation works covering at least 3% of total floor area of their buildings
- Consumers: individual metering for better energy management
- Industry: obligations for larger companies to undergo energy audits, incentives for small and medium sized companies
- Energy generation: monitoring of new energy generation capacities
- Energy transmission and distribution: national energy regulators should decide taking energy efficiency criteria into account

See the proposed directive at: www.rehva.eu/en/energy-efficiency-directive

Energy performance of buildings directive EPBD

What are the recent developments on EPBD?

Regulation on the cost optimal framework methodology:

Cost-optimal framework methodology was introduced at the previous issue of the Journal. The final version for Cost optimal framework has been accepted and will be published soon. REHVA has established a Task Force to help defining the required national reference buildings.

The EPBD recast instructs Member States on how to set energy performance requirements "with a view to achieving cost optimal levels". The Cost optimal is define as "the energy performance that leads to the lowest cost during the estimated economic lifecycle" (the latter determined by MS) Art 2 (14) EPBD. The purpose is to establish the cost optimal benchmark for every MS through calculation and using this to assess the current requirements of that MS. The purpose is not to compare across MS. The framework is to be used by MS authorities and not by the market.

There is an equivalent level of ambition in all MS, but no harmonisation of requirements. Cost optimality will also become the reference point for EU funding (EEE-F, ERDF).

Cost optimal and nearly zero energy building: Art 4 and Art 9(6) state MS may not be obliged to set net cost effective requirements over the estimated economic lifecycle. The method needs to ensure the phase in of nZEB and its technology. Boundary definition in CEN standard also needs to be adjusted to account the active RES. What is the priority for the Energy Efficiency?

- **Transposition of recast Directive** (deadline July 2012), 2002/91/EC to be repealed by Feb 2012: ongoing
- **Member States have to report on financial and other supporting measures** to the Commission: Deadline for 30 June 2012
- **CEN received mandate** for revision of 31 CEN standards
- **Development of a voluntary EU-wide certification scheme** for non-residential buildings: ongoing

News News News News News News News

Ecodesign of energy related products directive (ErP)

Lot 6 Air conditioning and ventilation systems

The preparatory study, analysing whether and which ecodesign requirements should be set for large air-conditioning and ventilation products (ENTR LOT 6), is running from 01/2010 until 5/2012. The selected contractor is Armines, France (Contact : Philippe Rivière, philippe.riviere@mines-paristech.fr). Stakeholders are encouraged to register at the website of the study: www.ecohvac.eu and contact the contractor.

The second stakeholder meeting was held on 30 September 2011 in Brussels. The documents for the meeting, including presentations, are available on the website of Lot 6. The "Ventilation" part of the study is now concentrating on air handling units (AHU's), possibly also including the heating function (see Lot 21). There are discussions ongoing among stakeholders about the ecodesign criteria, including how to deal with characteristics like SFP (Specific Fan Power) that depend on the air distribution system. Another "hot" discussion topic is about the borderline between "large" and "small" units/fans, or between "residential" and "non-residential" ones. Of course any fixed borderline is more or less artificial, but it is now under discussion to solve this borderline question by giving the manufactures an advice to state the intended use of the product (residential vs non-residential). One reason to this borderline discussion is the fact that standards for "residential" and "non-residential" ventilation are somewhat different. The discussions still go on.

Lot 21 Central heating products – Lot 20 Local room heating.

For both studies, second stakeholder meetings were held in the end of September 2011. The documentation as well as the presentations are linked on the websites of the studies (these are also linked to each other). The "Documents" pages. According to the slide presentations, the scope and products concerned are now clearly proposed for both studies. Here just the main product groups:

- Lot 20 – Residential room heaters (electric, gas, liquid fuel), non-residential room heaters (warm air unit heaters, radiant heaters, air curtains)
- Lot 21 – Gas, oil and electric furnaces, multi-fuel furnaces, various heat pumps

The Lot 21 Documents page also contains an interesting document dealing with air handling units, advising to consider AHUs only in the ventilation part of ENTR Lot 6 study. This would be very welcome, avoiding a total split-up of product functions.

Lot 10, air conditioning: The launch of Inter Service Consultation happened in November 2010. The vote in Regulatory Committee was made on 31 may 2011. Scrutiny and right of objection ended in October 2011.

EU Ecolabel and Green Public Procurement Criteria for office buildings

Labelling of products and buildings – The second stakeholder workshop for office buildings will be held in Brussels on 30 November 2011. Documents for the meeting will be posted in the relevant webpage in early November. The second stakeholder workshop for Hydronic Central Heating Generators will be held in Brussels on 29 November 2011, documents also expected on the project webpage in early November.

Green Public Procurement Procurement workshop tentatively for Wednesday 18th of January 2012 in Brussels.

Find more on:
www.rehva.eu/en/labelling-of-products-and-buildings

MCE – MOSTRA CONVEGNO EXPOCOMFORT

The leading exhibition dedicated to domestic and industrial installations and HVAC looks ahead to its 2012 edition with a new duration and new initiatives

Preparations for MCE – the leading International exhibition dedicated to domestic and industrial installations, air-conditioning and renewable energy, scheduled for 27th – 30th March 2012 at Fiera Milano Exhibition Centre in Rho, are in full swing. Organized by Reed Exhibitions Italia, every two years this worldwide event brings together the manufacturing and distribution arms of the plumbing, heating, sanitary ware, renewable energies, air-conditioning, refrigeration, sanitary technology, hardware, water treatment and bathroom sectors.

MCE 2012 benefits from the excellent numbers recorded by the 2010 edition: 157 447 professional trade visitors, 33 383 of whom coming from 138 countries outside Italy; traditional visitors, and new emerging professional figures such as Energy Managers (2%) and a large audience composed of architects, surveyors, engineers, condominium administrators, design engineers (14.9%), the real protagonists of a market that is witnessing an increasingly intimate relationship between a building and its installations.

MCE 2012 scheduled for 27th – 30th March 2012 at Fiera Milano Exhibition Centre in Rho, will offer novelties of great interest. Amongst the key features proposed for MCE 2012 is the duration of the exhibition, namely 4 days instead of 5, from Tuesday to Friday in order to meet the actual market requests.

"The main goal of MCE 2012, declared Massimiliano Pierini, Exhibition Director MCE, is to be not only an exhibition but an integrated system enriched by a synergic calendar of events, so far more than 1 500 companies have confirmed their participation with a 15% rise in foreign exhibitor numbers. This international benchmark event offers an exhaustive overview of the reference sector to showcase best-in-class products, solutions, provides training and professional development opportunities.

For this reason, a rich calendar of conferences that in synergy with the completeness of the exhibits will play an essential role for updating and debate of all those professional categories attending the exhibition." There will be three institutional conferences focused on issues of great impact related to integrate building design addressed to low energy buildings, up to the nearly Zero Energy Buildings as introduced by the recent European directives.

The first conference of the series, by FCE-Forum Nazionale on the Energy Certification for Buildings in collaboration with CTI – Comitato Termotecnico Italiano (Italian Thermotechnical Committee), will be a valuable occasion to update data and critically evaluate the evolution of the implementation of the directive in Italy, after a very successfully first edition. The second day of the conference programme will focus entirely on "Installations and sustainable works of architecture from around the world", aimed to highlight the works of famous architects who are revolutionizing the world of installation components, less visible but essential for a sustainable planning. The conference will be attended by internationally well-known architects offering professionals an exhaustive overview on

REHVA and AICARR seminar at MCE – MOSTRA CONVEGNO EXPOCOMFORT

– HVAC in Zero Energy Buildings, Congress centre Stella Polare, Milan, Wednesday 28 March 2012, 14.00–17.00

In this seminar, the topic of Zero Energy Building as defined by the European Community is firstly clarified and the targets that have been set are illustrated and critically discussed. After this general introduction, the focus is addressed to the innovation related HVAC system: new technologies and equipment able to answer to the request of increasing energy efficiency and reducing CO_2 emissions are investigated and analysed, also by means of the presentation of significant case studies.

concrete examples of architectural planning and design of the next generation. The third lecture will focus on renewable energy sources, integration of "photovoltaic and solar thermal systems", a mixture of technologies required for energetic valorisation in the near future. The rich conference programme will include a series of lecturers organized by trade associations from the sector that will provide an exhaustive overview of domestic and industrial installations on display at MCE 2012. Furthermore, the two synergic and complementary events: "Percorso Efficienza & Innovazione" and "Verso La Classe A 2012", will join the busy programme of conferences providing a unique opportunity for all professionals to have hands-on experience with the products and innovative worldwide solutions the market has to offer.

The main target of MCE 2012 is to propose the market a complete platform for meeting between offer and demand. www.mcexpocomfort.it is the online point of reference, a virtual showcase providing professionals any updating of "Percorso Efficienza & Innovazione", the conference calendar, and a full panorama of latest news and novelties about products and solutions promoted by exhibiting companies at MCE.

SB11 Helsinki World Sustainable Building Conference

SB11 HELSINKI
World Sustainable
Building Conference

The aim of the World Sustainable Building Conferences is to share leading knowledge, and find new solutions which enhance sustainable ways of living and working within built environments, while addressing new opportunities for improving the quality of life and mitigating effects of climate change.

Two weeks ago REHVA participated to the SB11 Helsinki where the conference certainly delivered on its aim, additionally ensuring greater involvement by developing countries in discussions on evidence based design and new theories for sustainable buildings, communities and cities.

The SB conference series have been running since 1998, bringing together the world's leading technical experts and researchers on sustainable built environments. This year was attended by leading thinkers in the sustainability sector, architects, designers, scientists, ecologists, academics, researchers and those applying sustainable development, training and housing in developing countries.

The conference provided a feast of new ideas and case studies, and the opportunity to connect with those at the forefront of sustainable development.

Key note sessions began each of the four days individually themed including: recapping our past and speculating on the future 40 years; new scientific product developments; sustainable rebuilding activities in developing countries; and recent northern European sustainable developments.

Key note speakers included international experts such as Richard Lorch, Raymond J Cole, Alfred Ngowi, Li Baizhan, Bill Bordass, but also speakers such as Christophe Lalande from UN-HABITAT and Cameron Sinclair, co-founder of CEO of **Architecture for Humanity** speaking about sustainable building, training and job creation in the developing world.

SB11 Helsinki clearly demonstrated a move towards assessing communities and cities, embedding sustainable development at all scales from housing to whole cities, from access to safe and healthy food, transport, housing and jobs, to improve the quality of life for all people.

With the next World Sustainable Building Conference set for SB14 Barcelona in early October and regional conferences in 2013, we can look forward to progressing sustainable cities and communities across both developed and developing countries in the coming years.

Nordbygg 2012

20–23 March 2012 in Stockholm, Sweden

The most important Nordic meeting place for the construction industry

March 20–23, 2012
Stockholm, Sweden

Record bookings for Nordbygg

Over 700 exhibitors already booked for 2012!

Continued optimism in the construction sector: Industry fair Nordbygg 2012, which will be held on 20–23 March at Stockholmsmässan, is experiencing the greatest level of interest in the Swedish fair's 30-year history – despite stock market anxieties and debt crises in the global economy.

Already by early September 2011, over six months before the fair, almost all of Stockholmsmässan's exhibition space was booked up. With all the latest extensions and expansions, the total stand area is now around 36 000 square metres.

"During the record sales of spring and summer, we've encountered a fantastic confidence in the future from companies and organisations across the construction sector – from material suppliers and contractors to developers and consultants," says Peter Söderberg, Project Manager at Nordbygg.

Companies queuing up

"Naturally, recent stock market turbulence and debt concerns have affected the industry. But we've not yet had any cancellations due to economic worries in the US and Europe."

Peter Söderberg knows from experience that internationally owned companies can quickly be instructed to shift the focus of their marketing in the face of global economic uncertainty.

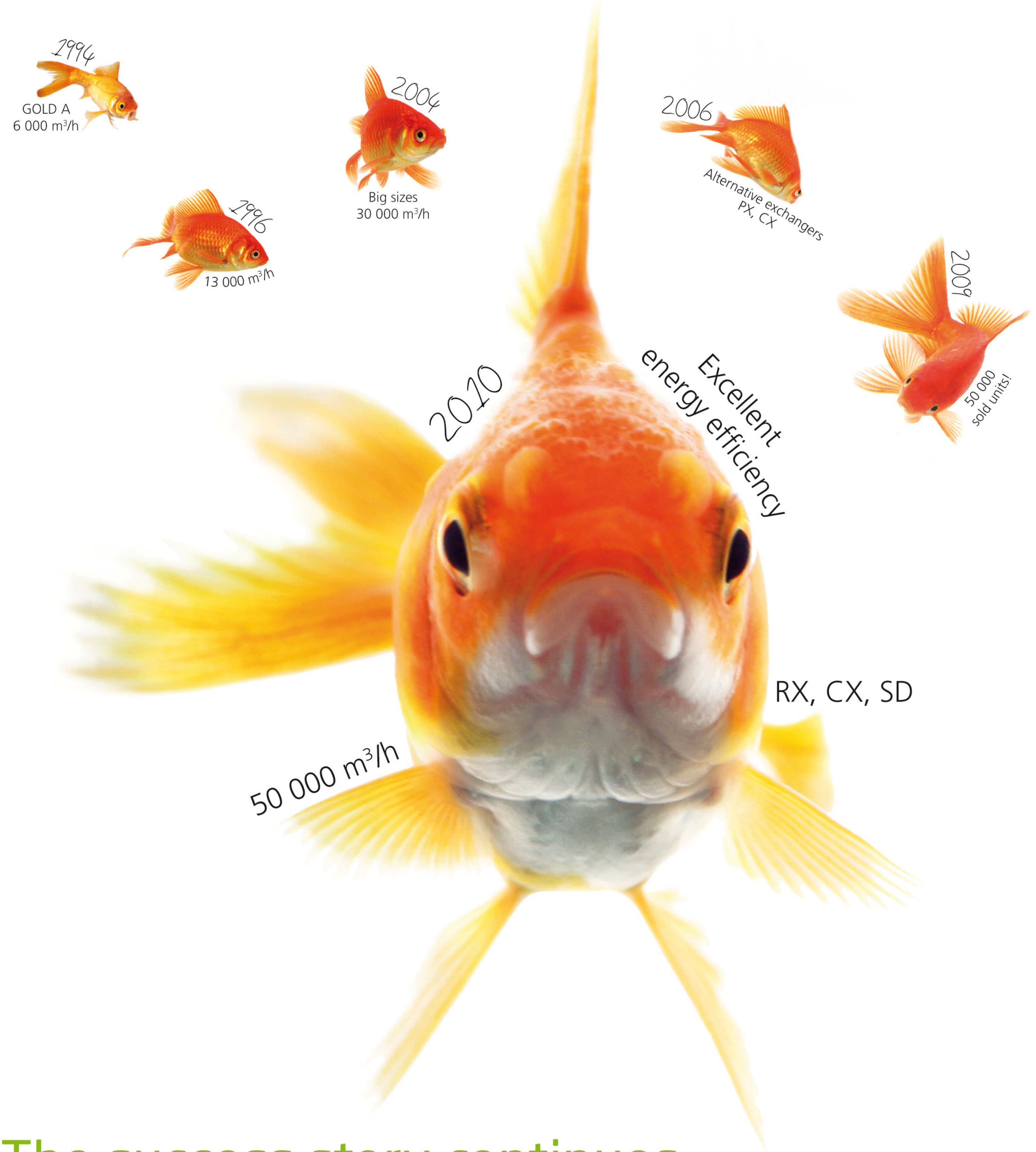
"But we have a queue of companies ready to exhibit at Nordbygg 2012 if anyone drops out. The booking situation for Nordbygg 2012 feels like a clear indication that there is still plenty of optimism and confidence in the Swedish construction industry."

Many major projects

Peter Söderberg points out that there is a clear need for extensive homebuilding over coming years, and the Million Programme housing estates of the 60s and 70s will finally have to be renovated. Alongside this, energy efficiency will continue to be a key area of investment.

"The larger construction companies have longstanding orders on their books for projects agreed at better prices, generally speaking, than are possible nowadays. What is more, the industry is entering a period of strong innovation, a trend driven by major projects such as the New Karolinska Solna and Stockholm Royal Seaport, which will embody the new sustainable building of the future," explains Peter Söderberg.

"Hopefully, we stand at the brink of an exciting and enduring period of new investment and innovations in our sector, a fact that will be reflected at Nordbygg's record event in 2012." To book stand space and for other information, visit www.nordbygg.se



The success story continues...

Sometimes small ideas can make big impact: In 1994 Swegon introduced the GOLD series – compact and complete air handling units which have been setting standards in modern and energy-efficient ventilation technology ever since. The successful concept of air handling units with built-in controls sold more than 50 000 times all over Europe. That is what we call big impact.

This autumn we continue our success story and present the biggest chapter in the history of GOLD so far: GOLD 120 for air volumes up to 50 000 m^3/h. The new and powerful GOLD-unit is equipped with state of the art, efficient Wing+ fans, which are fitted with the latest EC-technology. GOLD 120 offers outstanding performance data for your projects where big air volumes and excellent energy efficiency are required.

Become part of the story and find out more about GOLD 120 and our other products for the world's best indoor climate!

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REHVA signed a memorandum of understanding with China Committee of HVAC

On Friday October 28th 2011, in Brussels a Memorandum of Understanding was signed by the Federation of European Heating, Ventilation and Air-conditioning Associations (REHVA) and China Committee of Heating, Ventilation and Air-conditioning (CCHVAC). The purpose of this Memorandum of Understanding (MoU) is to strengthen the relationship between REHVA and CCHVAC and to promote substantial and tangible actions to increase the co-operation between the two associations. In the opening speech of the ceremony Ms Pirjo-Liisa Koskimäki from the EU Commission considered the cooperation with China one of the top priorities and welcomed the coming activities between REHVA and CCHVAC.

Top: Ms. Pirjo-Liisa Koskimäki, Advisor to the director of DG energy- Renewable, Research, Innovation, Energy efficiency. **Below:** REHVA President Prof. Michael Schmidt (left) and CCHVAC Chairman Prof Xu Wei.

CCHVAC is a Chinese organisation with approximately 30 000 members dedicated to advancing heating, ventilation, air conditioning and refrigeration to serve humanity and to promote a sustainable technology in China.

Both organisations enter into this Memorandum of Understanding with several objectives amongst other to sponsor and jointly organize training, educational seminars and other educational activities when appropriate; to cooperate in the development and the participation in conferences and exhibitions which may be mutually beneficial and to promote communication and information exchange regarding building energy certification and engineer certification.

Both organisations enter into the dialogue in a positive and constructive attitude knowing that a positive outcome will strengthen both parties, ultimately resulting in technological advancement for the benefit of humanity.

REHVA Annual Conference HVAC key role in energy retrofitting

April 19 — 20, 2012 Timisoara, Romania

The REHVA Annual Conference and meeting is organized in cooperation with the Romanian Installation Engineers Association (AIIR) and the Romanian General Association for Refrigeration (AGFR) in Hotel Timisoara and the "Politechnica" University of Timisoara in downtown Timisoara. Both are situated in the cultural and historic center of Timisoara overlooking the Opera Square.

The 2012 REHVA Annual Conference will focus on HVAC key role in energy retrofitting.

The range of topics includes:

- EU policy and regulations for building retrofitting
- Energy use of buildings and systems
- Cost effective inspections for better energy
- efficiency
- Energy efficient HVAC systems and equipment for retrofitting

Many other interesting topics will be covered and some case studies will also be presented. If you are interested in recent development in energy retrofitting, then you should attend the REHVA Conference and Annual Meeting in Timisoara. The conference brings together an international group of researchers, professionals and practitioners and who routinely improve the energy efficiency, operating costs, and environmental impacts of buildings. The organizers are striving to make the 55th conference in Timisoara a great and memorable event!

Registration and information
For more information and online registration please visit www.rehva-am2012.ro or contact office@dosetimpex.ro.

Programme committee
Adrian Retezan, chair
Olli Seppänen, co-chair
Ioan Silviu Dobosi, secretary general

Travelling to Timisoara
Timisoara Airport offers nonstop flights to 32 cities. Please visit http://aerotim.ro/ for more information on flights.

REHVA, The Federation of European Heating, Ventilation and Air conditioning Associations is the leading professional organization in Europe, dedicated to the improvement of health, comfort and energy efficiency in all buildings and communities. It encourages the development and application of both energy conservation and renewable energy sources. REHVA connects European professionals in the area of building engineering services and represents more than 110 000 engineers from 26 European countries. REHVA´s main activity is to develop and disseminate economical, energy efficient and healthy technology for mechanical services of buildings.

More information on www.rehva.eu.
Contact information: info@rehva.eu

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

EVENTS 2011-2012			
21–25 January 2012	ASHRAE Winter Meeting	Chicago, USA	www.ashrae.org
28–29 March 2012	Airtightness workshop	Brussels, Belgium	http://www.aivc.org
9–11 April 2012	5th International conference on energy research & development (ICERD-5)	Kuwait	http://tightvent.eu
17–20 April 2012	REHVA Annual Conference and Meeting	Timisoara, Romania	www.rehva-am2012.ro
26–27 April 2012	Focus on Renewable District Heating and Cooling	Copenhagen, Danmark	www.euroheat.org
30 April–2 May 2012	X. International HVAC+R Technology Symposium	Istanbul, Turkey	www.ttmd.org.tr/2012sempozyum
19–21 June 2012	EU Sustainable Energy Week 2012 in Brussels	Brussels, Belgium	www.eusew.eu
25–27 June 2012	10th IIF/IIR Gustav Lorentzen Conference on Natural Refrigerants	Delft, The Netherlands	www.gl2012.nl
8–12 July 2012	Healthy Buildings	Brisbane, Australia	www.hb2012.org
17–19 September 2012	Ventilation 2012	Paris, France	www.inrs-ventilation2012.fr
10–11 October 2012	AIVC-TightVent conference	Copenhagen, Denmark	http://tightvent.eu
12–14 November 2012	7th International HVAC Cold Climate Conference	Calgary, Alberta, Canada	http://ashraem.confex.com/ashraem/icc12/cfp.cgi

FAIRS 2011-2012			
12–13 January 2011	ACRECONF India	New Delhi, India	www.acreconf.org/
23–25 January 2012	AHR Expo	Chicago, USA	www.ahrexpo.com
7–9 February 2011	Chillventa Russija	Moscow, Russia	www.chillventa-rossija.com/en/
7–10 February 2012	Interclima + elec	Paris, France	www.interclimaelec.com
7–10 February 2012	Aqua-Therm	Moscow, Russia	www.aquatherm-moscow.ru
23-25 February 2012,	ACREX 2012	Bangalore, India	www.acrex.org.in/
29 February –3 March 2012	SINERCLIMA 2012	Batalha, Portugal	www.eventseye.com
20–22 March 2012	Ecobuild 2011	London, United Kingdom	www.www.ecobuild.co.uk
20–23 March 2012	NORDBYGG 2012	Stockholm, Sweden	www.nordbygg.se
27–30 March 2012	MCE - Mostra Convegno Expocomfort 2012	Fiera Milano, Italy	www.mcexpocomfort.it
15–20 April 2012	Light + Building	Frankfurt, Germany	www.light-building.messefrankfurt.com
2–5 May 2012	ISK - SODEX 2012	Istanbul, Turkey	www.hmsf.com
9–11 October 2012	Chillventa 2012	Nuremberg, Germany	www.chillventa.de/en/
9–11 October 2012	Finnbuild 2012	Helsinki, Finland	

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A REHVA supporter is a company or an organisation that shares the same objectives as REHVA. Our REHVA supporters use the latest European technologies to make their products. The REHVA Supporters are also members of reHVAClub. For more information about REHVA supporters' program, please contact info@rehva.eu or call +32 2 5141171.

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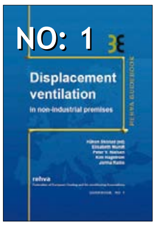
REHVA

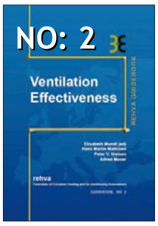
Federation of European Heating, Ventilation and Air-conditioning Associations

REHVA GUIDEBOOKS

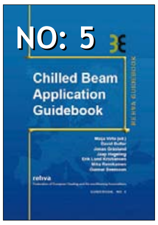
REHVA Guidebooks are written by teams of international experts



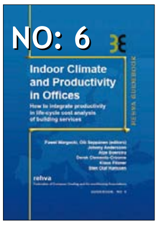
Displacement Ventilation Guidebook serves as a comprehensive and easy-to-understand design manual. It explains the benefits and limitations of displacement in commercial ventilation and outlines where ventilation should be applied. Various case studies are included. The benefits of displacement ventilation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



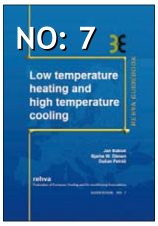
Improving the ventilation effectiveness allows the indoor air quality to be significantly enhanced without the need for higher air changes in the building, thereby avoiding the higher costs and energy consumption associated with increasing the ventilation rates. This Guidebook provides easy-to-understand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



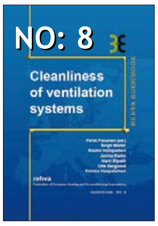
Chilled beam systems are primarily used for cooling and ventilation in spaces, which appreciate good indoor environmental quality and individual space control. Active chilled beams are connected to the ventilation ductwork, high temperature cold water, and when desired, low temperature hot water system.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



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

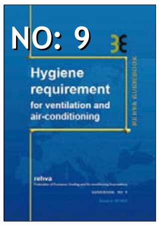


This Guidebook describes the systems that use water as heat-carrier and when the heat exchange within the conditioned space is more than 50% radiant. Embedded systems insulated from the main building structure (floor, wall and ceiling) are used in all types of buildings and work with heat carriers at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

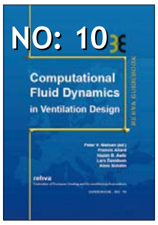


Cleanliness of ventilation systems Guidebook aims to show that indoor environmental conditions substantially influence health and productivity. This Guidebook presents criteria and methods on how to design, install and maintain clean air handling systems for better indoor air quality.

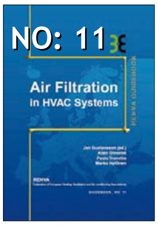
New REHVA eGuidebooks available at www.beuth.de!



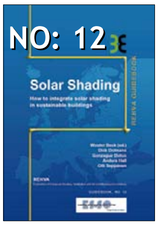
Hygiene requirement is intended to provide a holistic formulation of hygiene-related constructional, technical and organisational requirements to be observed in the planning, manufacture, execution, operation and maintenance of ventilating and air-conditioning systems. These requirements for ventilating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



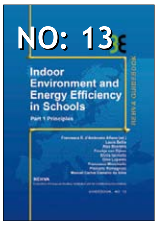
CFD-calculations have been rapidly developed to a powerful tool for the analysis of air pollution distribution in various spaces. However, the user of CFD-calculation should be aware of the basic principles of calculations and specifically the boundary conditions. Computational Fluid Dynamics (CFD) –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



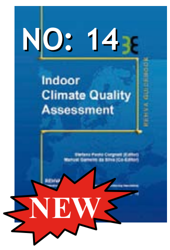
Air filtration Guidebook will help the designer and user to understand the background and criteria for air filtration, how to select air filters and avoid problems associated with hygienic and other conditions at operation of air filters. The selection of air filters is based on external conditions such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



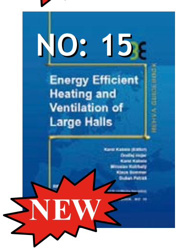
Solar Shading Guidebook gives a solid background on the physics of solar radiation and its behaviour in window with solar shading systems. Major focus of the Guidebook is on the effect of solar shading in the use of energy for cooling, heating and lighting. The book gives also practical guidance for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



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



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



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

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