ISSN 1307-3729

REHVA

Federation of European Heating, Ventilation and Air-conditioning Associations

The REHVA European HVAC Journal

Volume: 49 Issue: 1 January 2012 www.rehva.eu

VENTILATION AND AIR CONDITIONING SYSTEMS

REHVA Seminar on EU regulations related to energy efficiency of buildings

European ventilation standards

Assessing electrical energy use in HVAC systems

Optimal thermal environment improves performance of office work

Ventilation system types in some EU countries

Ventilation rates and IAQ in national regulations

Electricity use in two low energy office buildings in Norway

CASE STUDIES:

- How to reach less than 15 kWh/m² annual final energy use for HVAC in an office building
- Energy-Efficient Passive House using thermal mass to achieve high thermal comfort

The REHVA European HVAC Journal

Volume: 49 Issue: 1 January 2012
www.rehva.eu

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

Electronic version of content is available at www.rehva.eu -> The REHVA European HVAC Journal

ADVERTISEMENTS
Ms Cynthia Despradel
cd@rehva.eu

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

PUBLISHER
Teknik Yayıncılık Tanıtım A.Ş.
Balmumcu, Barbaros Bulvarı,
Bahar Sok, Karanfil Ap.
Beşiktaş İstanbul Türkiye
Tel: 90-212-2758359
Fax: 90-212-2749273
www. teknikyayincilik.com

Contents

EDITORIAL

ARTICLES

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

CASE STUDIES

PRODUCTS & SYSTEMS

EU POLICY

REHVA WORLD

PUBLICATIONS

Advertisers

In the next issue of REHVA Journal (February 2012)

Theme: **Energy efficient HVAC Equipment and EU regulations**.
Articles due: **16 January 2012**.
Guest editor: **Mr Jorma Railio**. E-mail: **jorma.railio@gmail.com.**

Energy efficiency and healthy indoor environment

Olli Seppänen
Editor-in-chief

The indoor air quality (IAQ) in buildings directly impacts occupant health, comfort and work performance. Well-established, serious health problems resulting from poor IAQ include Legionnaires' Disease, lung cancer from radon exposure, airborne infection such as pulmonary tuberculosis (TB) and severe acute respiratory syndrome (SARS), and carbon monoxide (CO) poisoning. Building occupants frequently report discomfort and building-related health symptoms, and sometimes develop building-related illnesses. Excessive dampness or moisture in buildings is responsible for a range of problems including mould, dust mites and bacteria; and exposure to damp environments is associated with respiratory problems including asthma attacks. In its recent report The European Federation of Allergy and Airways Diseases Patients' Associations (EFA) confirmed the worrying estimation that 1 in 2 Europeans may suffer from an allergy by 2015, many of them related to indoor air quality.

A recent research project EnVIE supported by EU DG RESEACH estimated that EU countries loose about 2 million adjusted life years annually due to exposure to various pollutants in the indoor air. Many of these negative health effects could be avoided by paying proper attention to the technology for good indoor environment and energy efficiency.

It is extremely important that the pursuit of improved building energy efficiency of building does not worsen the indoor air quality but, vice versa, simultaneously improves it. If the focus on EU regulations is only on energy efficiency the member states and citizens may ignore the indoor air quality and pay for their mistakes later by incurring various health problems and related costs.

Europe should learn from the lessons of the first energy crisis in the 1970´s, when, due to improper energy saving measures, buildings were made too tight ignoring ventilation and indoor air quality issues. Moisture and mould problems increased the prevalence of respiratory illnesses. The sick building syndrome was created due to unprofessional energy saving techniques. It is important that when the energy efficiency of a building is improved, that attention is also paid to the indoor air quality. Actually, without simultaneously specifying the indoor environment, the energy declaration does not make any sense – the most effective way to save energy in buildings is to shut down all heating and lighting but what is the use is that kind building? We need energy efficient buildings which support health and better working conditions and therefore productivity. Energy efficiency means that energy is used efficiently to maintain and maximise a good, healthy indoor environment.

Energy efficiency and a good, healthy indoor environment are not necessarily conflicting objectives. Several technologies are available to achieve both goals simultaneously. These technologies include: heat recovery from the ventilation air, ventilation control by demand (by actual air quality), filtering and cleaning of air, low emission usage, clean building materials, moisture proof constructions etc. Many of these technologies are described in the European standards such as EN. But the problem is that the standards are voluntary consensus documents and are not mandatory in the member states. The results of an ongoing project "HealthVent" supported by DG SANCO show that regulations in EU countries are very heterogeneous and none of member states have binding comprehensive regulations on indoor air quality for non-industrial buildings. The overall aim of the HealthVent project is to develop health-based ventilation guidelines for protecting people in places like homes, schools, kindergartens, and offices against health problems caused by poor indoor air quality, and at the same time ensuring that energy is utilized efficiently. Articles on Ventilation systems in Europe, Ventilation rates and IAQ in national regulations and European ventilation standards are based on the REHVA work in this project.


Your Solution Partner for
HVAC & R Products
Blast Freezers
Dry Coolers
LT/HT Coolers
Air Cooled Condensers
Wet / Dry Coolers with
Ecomesh Spray System
Starbox
Codensing Units
OEM Finned
Pack Heat Exchangers
and Steam Coils
EUROVENT
CERTIFIED PERFORMANCE
ID NO:COILS-02-04-
001/002/003/004
F2522-3/8"
F3833-5/8"
F4035-1/2"
F4035-5/8"
Air Heating and
Cooling Coils Using Water,
Software COILS 5.5 FRT1
Air Coolers
30th year
TÜV CERT
ISO 9001:2000
Reg.No: 44 100 083512-E6
TSEK
CE
FRITERM®
TERMİK CİHAZLAR SANAYİ VE TİCARET A.Ş.
member of
ISKID
AIR CONDITIONING & REFRIGERATION MANUFACTURERS' ASSOCIATION
rehva
Federation of european heating and airconditioning associations
Supporting Member
EUROVENT
member of
ISKAV
Heating, Cooling, Air Condition Research and Education Foundation
Founder member
Head office / Factory
Organize Deri Sanayi Bölgesi 18. Yol 34957 Tuzla İstanbul/Turkey
Tel: +90 216 394 12 82 (pbx) Fax: +90 216 394 12 87
e-mail: info@friterm.com web: http://www.friterm.com

Assessing electrical energy use in HVAC systems

Ian Knight
Welsh School of Architecture, Cardiff University
Knight@cardiff.ac.uk

The iSERV project aims to collect sub-hourly HVAC system energy use data from around 1 600 HVAC systems in the EU Member States, analyse and compare this information through the development of benchmarks. iSERV is designed to show the ability for automatic HVAC system monitoring to reduce energy use in practice and compare this to the costs and savings of regular inspection.

Introduction

According to the EC's Joint Research Centre (2009), Heating, Ventilation and AC systems in the 27 European Union Member States were estimated to account for approximately 313 TWh of electricity use in 2007, about 11% of the total 2 800 TWh of electricity consumed in Europe that year (**Table 1**).

Table 1.
EC Joint Research Centre, Institute for Energy, 2009.

Equipment	Electrical consumption as % of total EU use in 2007
Air conditioning units and chillers	0.75
Fans in ventilation systems	3.34
Pumps	1.81
Space and Hot Water Heating	5.23

HVAC systems must therefore be a key contributor towards energy savings if the EU is to reach its target of reducing energy use by 20% by 2020.

The old adage 'you can't manage what you can't measure' is very apt for HVAC systems as there is a real absence of publicly available information derived from large scale datasets on the detail of energy consumption of HVAC systems in buildings.

This article explores an approach towards achieving a better understanding across the EU Member States of these important elements of European energy consumption.

A lack of information on which to base policy decisions and future legislation regarding achieving energy efficiency in HVAC systems is part of the reason behind the funding of an Intelligent Energy Europe (IEE) project on the Inspection of HVAC Systems through continuous monitoring and benchmarking (iSERVcmb). This project is addressing the problem of practically improving the energy performance of HVAC systems in EU buildings by producing benchmarks from sub-hourly in-use data obtained from HVAC systems around the EU. With a budget of €3.3M, iSERV is the largest project ever funded by the European Commission's EACI agency, with its predecessor project, HARMONAC, being the second largest.

The iSERVcmb benchmarks for energy performance by HVAC system components for specified end use activities will assist approximately 1 600 HVAC systems across 16+ EU Member states in understanding and reducing their energy consumption. It will do this through:

- Defining the HVAC system components, plus the spaces and activities it serves,
- Collecting and analysing sub-hourly data from these systems,
- Producing energy use benchmarks based on the HVAC components and the activities served,
- Providing reports back to the building owner that show how they are performing against their bespoke benchmarks, along with potential conservation actions they might take.

One of the bases for the iSERVcmb project is the findings from the IEE HARMONAC project that concluded at the end of 2010.

Figure 1, taken from HARMONAC, vividly illustrates the possible potential range of electrical energy consumption per m² in HVAC systems. This is derived from data taken across the EU for 42 HVAC systems energy use in real buildings. The figure also presents the total annual electrical energy use per m² of the building in which the HVAC system operated.

One of the observations to be made about **Figure 1** is that some major elements of HVAC system consump-

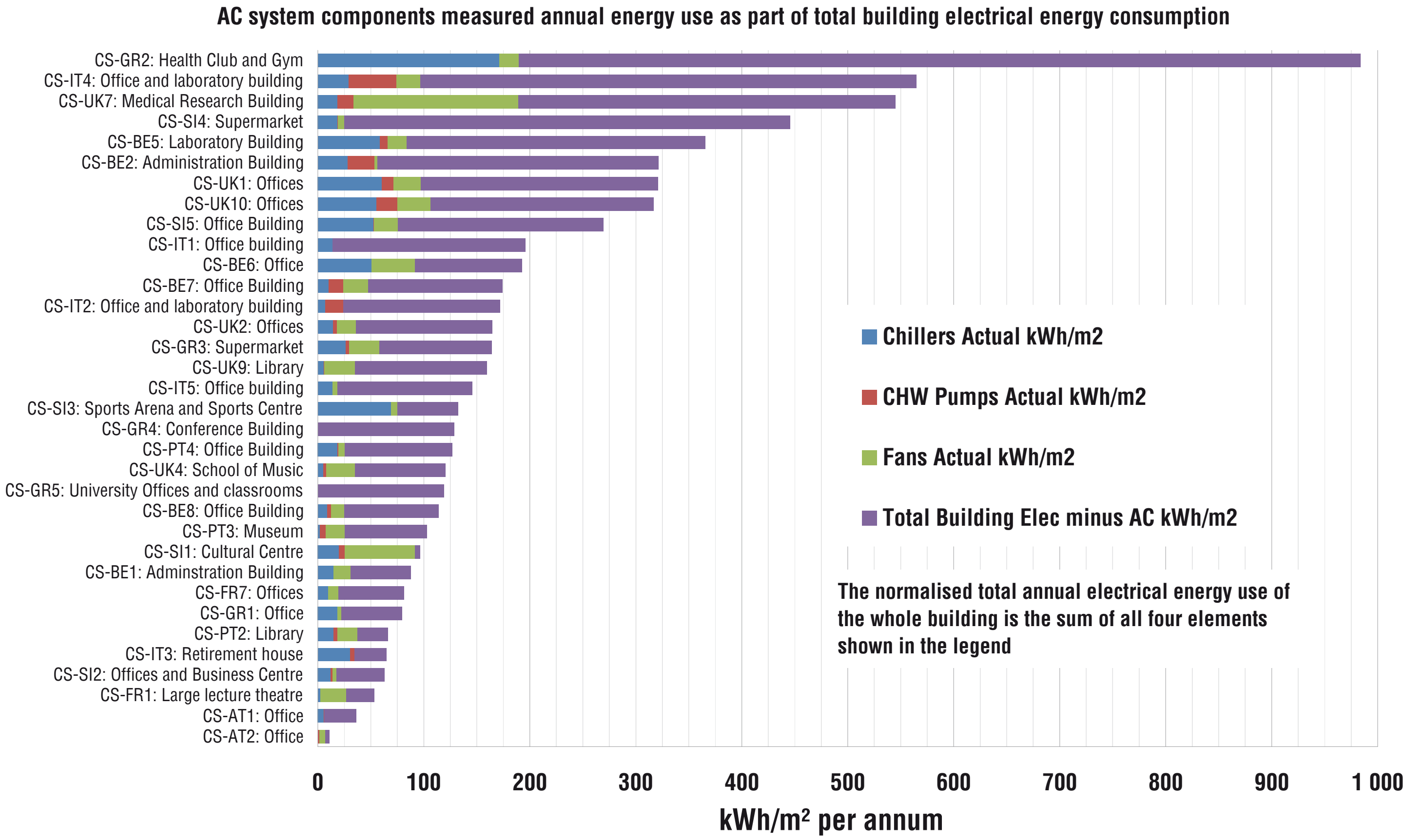


Figure 1. Overall annual energy use and total energy use in 33 HARMONAC buildings.

tion are missing for a few of the buildings e.g. the data may have Chiller electrical consumption and the main AHU's, but not Chilled Water pumps or Humidifier use. In addition, nearly all the systems monitored have some elements of electrical consumption unmetered e.g. electrical energy use in terminal fancoils or electrical terminal reheat systems. The point being made is that the energy use of HVAC systems is likely to be nearly always under-reported with current metering installations for buildings and HVAC systems.

Figure 2 shows how this metering problem manifests itself for One Wood Street in London, a modern (completed May 2008) prestige office block which is 'fully' metered to UK building regulation standards. It can be seen that, despite an apparently comprehensive metering strategy, nearly one third of the annual electrical energy use (labelled 'Balance') is unaccounted for. This building was one of the UK Case Studies in HARMONAC and was well documented, but still no-one was sure where this unaccounted energy was going. The author believes at least some of this unaccounted consumption is occurring in the HVAC system – potentially in the tertiary chilled water pumps for the chilled beams, and in the numerous fancoils in the core of the building. So, whilst HVAC systems apparently consume around one third

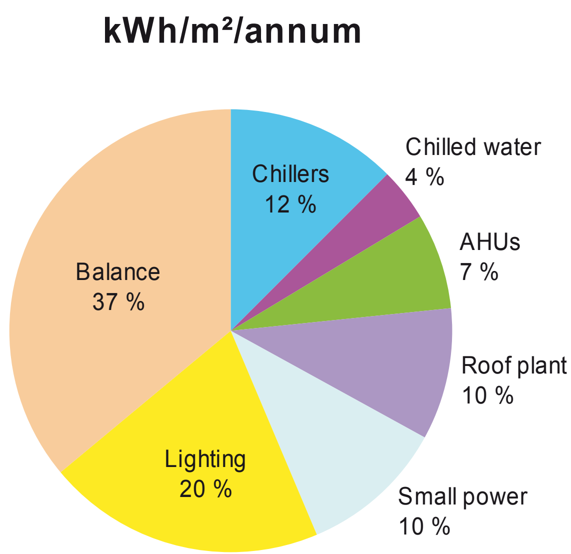


Figure 2. Annual electrical energy use in One Wood Street building, London. The Balance term denotes undefined electricity use in the building.

of the annual electrical energy use in this building, it is entirely possible that their actual electrical consumption might be closer to one half of all electrical energy use in the building.

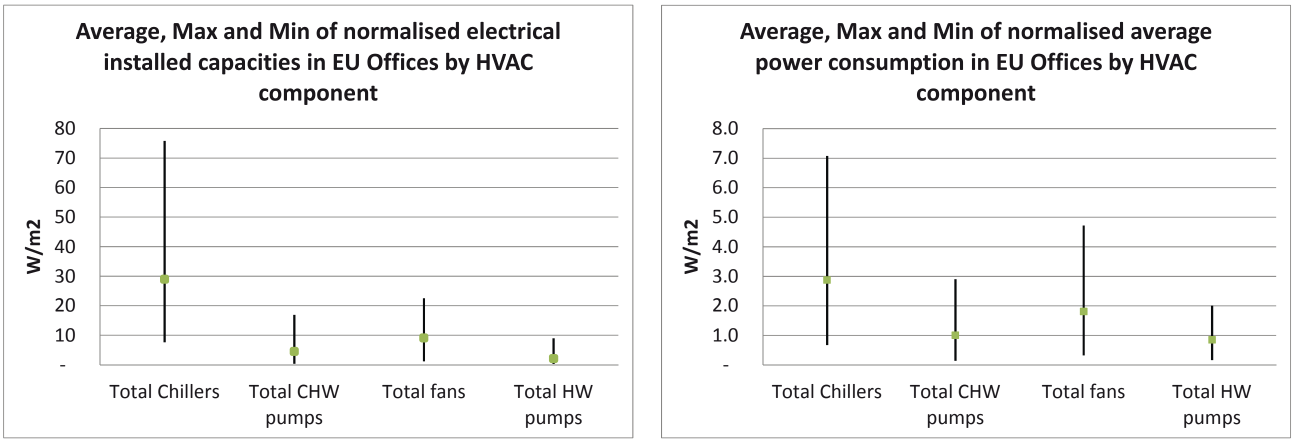


Figure 3. Average, Maximum and Minimum Installed and Annual Average Measured Power Demands normalized for floor area for Chillers, Chilled Water Pumps, Air Handling Units and Hot Water Pumps installed in EU Offices.

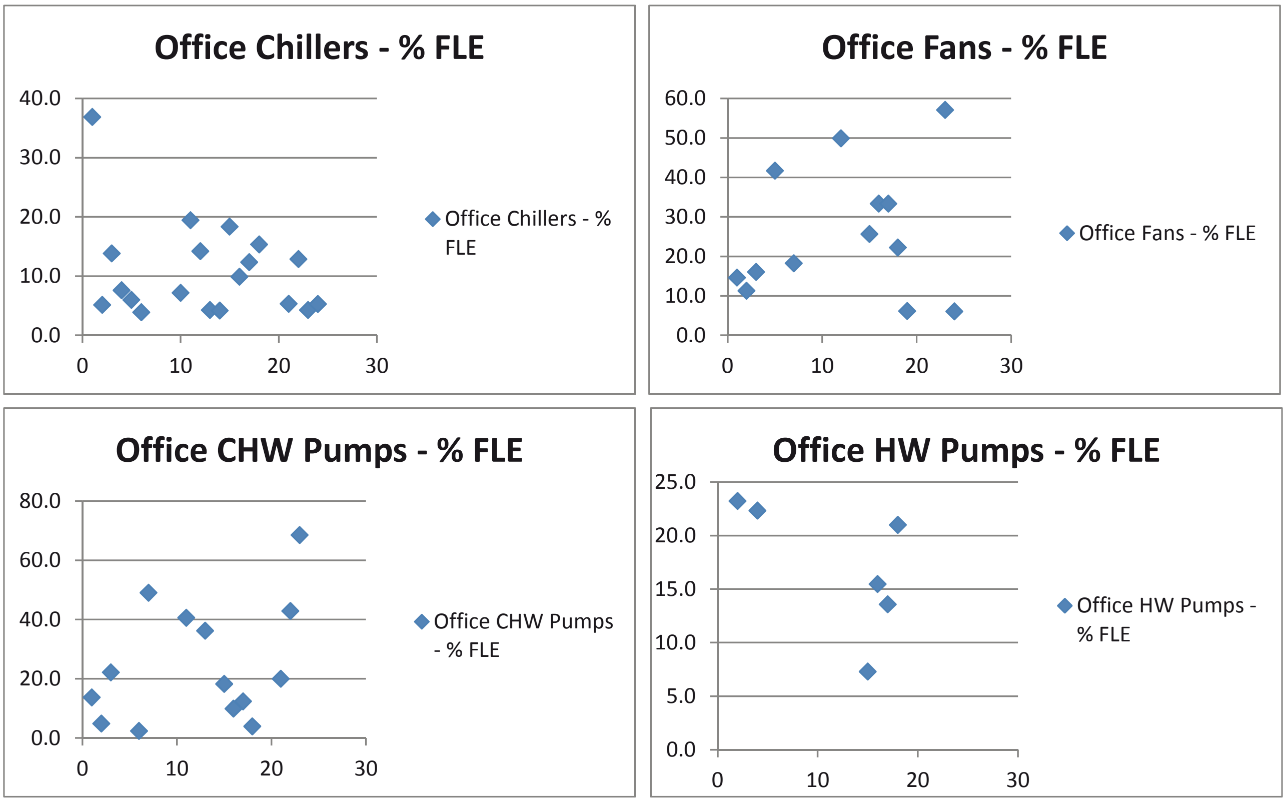


Figure 4. Measured average annual power demand by HVAC component as a percentage of the Full Load Equivalent for HARMONAC Case Study systems.

The next figure presented from HARMONAC is shown in **Figure 3**. This shows the ranges of installed electrical capacities in EU Offices by HVAC system component against the annual average measured power demand for those same HVAC system components taken from systems around Europe. The sample size for the components ranges from 14 to 23 systems.

It can be seen that the measured average power demand per unit area over the course of a year by the HVAC components follows the order of installed capacities by component, i.e. Chillers have the highest installed capacities and consume the most energy over the year, etc. In total the average power demand/m² of an HARMONAC Office HVAC system is around 6.5 W/m² or 56 kWh/m² per annum.

In terms of % of Full Load Equivalent (FLE) however, the order changes when we look at the ratio of the average annual power demand to the average installed loads. FLE is calculated as the power demand of the component assuming it runs continuously i.e. 8 760 hours per year. **Figure 4** presents the data by HVAC component type for each of the HARMONAC Case Study systems.

Taking the averages from the data used to produce **Figure 4**, the Chilled Water Pumps and Air Handling Units have the highest annual average power demand to % FLE ratio with an average power demand of 25% of their installed electrical capacity over the year across the sample. They are followed by Hot Water Pumps which consume about 17% of FLE (though based on a much smaller sample size), with Chillers consuming the least at around 11% FLE.

However, the range of % FLE's vary significantly for each HVAC component so, while we are able to look at an average for each component to obtain a first feel for the impact of installed load on likely annual use, it will not be until we obtain a much larger sample set from iSERVcmb that we will be able to present any statistically significant averages.

Future data on HVAC energy use

One of the main reasons for wanting to know about the energy use of HVAC systems in practice is to enable better prediction of what an HVAC system should consume in practice – this is important for both the operation and design of HVAC systems to achieve real-life low energy consumption.

The review of the HARMONAC data shows that iSERVcmb therefore has to obtain data on end use activities, HVAC components and operation hours when setting up a procedure that will allow a reasonable estimate for consumption in HVAC systems. The approach is similar to that used in the German VDI 3807 Guidelines and also the UK SBEM Methodology, with the intention being that data produced by iSERVcmb should be of value in informing these and similar methodologies.

Using an underpinning rationale that any procedure should be able to be related back to the actual HVAC equipment physically installed in a building, iSERVcmb requires data to be collected on installed HVAC equipment, including nominal power ratings. This will, over the course of the project, allow actual energy consumption data for various HVAC system components installed in real buildings, serving described end use activities, to be compared with their nominal power ratings and other characteristics. This data can then be used to benchmark best, average and worst energy consumptions for various end use activities served by HVAC system components.

From this data we should be able to predict with more certainty where HVAC energy use is likely to be occurring in systems serving stated activities in real buildings, and therefore where we should concentrate efforts on reducing this use.

Having a clear and supportable basis for obtaining these estimates also offers benefits in other areas, such as estimating energy use for Inspection purposes.

One aspiration for the iSERVcmb approach is that it can act as a complement to physical Inspections by helping target Inspections towards those systems most likely to receive real energy saving benefits as indicated by their current level of consumption for the activities they are serving. It should be noted that for the estimated benchmarks to continue to have relevance the iSERVcmb database must continue to obtain data, so that as improvements are made in HVAC component and system efficiencies the benchmarks evolve to reflect what is currently possible.

Collecting energy data for HVAC systems

As a first step towards collecting the data it requires for establishing targets and benchmarks for HVAC systems, iSERVcmb has established a spreadsheet for collating information about HVAC systems, activities and areas served in buildings. This can be downloaded from the iSERVcmb website www.iservcmb.info by anyone wishing to collate information on their HVAC systems in one place. This should be of great assistance in reducing the time and effort needed for both the owner and Inspector during an Inspection, as well as reducing errors and misunderstandings which can undermine the value of an Inspection. The spreadsheet requests the information shown in **Table 2**.

> *"The Excel spreadsheet developed by the iSERV project is a unique tool to structure and organise the information of HVAC systems... It aligns perfectly with the need to improve the value of HVAC system inspections by having collected and gathered pertinent information prior to the inspection…"*
>
> **Olli Seppänen, REHVA General Secretary**

Table 2. Data requested by the iSERV HVAC template data sheet.

Building	Utility Meter	HVAC sensor	HVAC system	HVAC component	Schedules of Setpoint&Occupation	Space
Building Name	Name	Name	Name	Name	Name	Name
Description	Description	Description	Description	Description	Description	Description
Organisation Name	Meter Type	Sensor Type	Main HVAC system	Component type	Time Control Method	Floor Area (m²)
Site Name	Unit Type	Unit Type	HVAC type	Component sub-type	Date Range: Applies From	Sector
Sector	Multiplier	Duct/Pipe Area (m²)	System Classification	Serves which HVAC system(s)	Date Range: Applies To	Activity
Address	Space Where Located	Unique Sensor ID	System Sub-Classification	Space Where Located	RH Range: Upper Limit	Served By HVAC(s)
Town	Unique Meter ID	Data Starts From	Data Starts From	Nominal Electrical Power Input (KW) OR/AND Meter Name	RH Range:Lower Limit	Utility Meter(s)
Postcode	Data Starts From	End Month	End Month		Heating Setpoint / Date & Time	Schedule of Setpoints, RH and Occupancy
Country	End Month		Sensor Name	Sensor Name	Cooling Setpoint / Date & Time	Sensor Name
Control of HVAC Temperature	Parent Meter Name		Meter Name	Data Starts From	Relative Humidity / Date & Time	Data Starts From
Construct Month			Control of Flow Temperature	End Month	Occupancy / Date & Time	End Month
Data Starts From				Parent Component		Control of HVAC Temperature
End Month				Nominal Heat Rejection Capacity (KW)		HVAC Component Physically located here
Property Reference Code				Coefficient of Performance (COP)		Utility Meters Physically located here
GPS - latitude				Energy Efficiency Rating (EER)		Space Notes
GPS - longitude				Seasonal Energy Efficiency Rating (SEER)		
Gross Internal Area (m²)				European Seasonal Energy Efficiency Rating		
Conditioned GIA (m²)				Manufacturer		
Schedule				Range		
Main HVAC				Model		
Building Notes				Serial Number		
				Year of Manufacture		
				Nominal Cooling Capacity (KW)		
				Nominal Heating Capacity (KW)		
				Nominal Heating Power Input (KW)		
				Maintenance contract		
				Maintenance trigger		
				Date of last maintenance visit		
				Date of next maintenance visit		

Cells in light red show data that is chosen from embedded lists

Cells in orange show data that is chosen from data entered elsewhere in the spreadsheet

Cells highlighted in grey colour acquire their content automatically from other cells.

Cells in green show data that can be sourced from the Eurovent Certification HVAC Database

Cells highlighted in blue colour show optional data, but which is still very useful to owner and iSERV

It can be seen that there are significant numbers of cells which are either selected from predetermined lists, previously entered data or which are 'optional'. The optional cells do however contain important information for the wider analysis of the data for both the HVAC system owners' reports, Inspection purposes and the iSERVcmb project. End users are therefore recommended to also complete this information where possible and where appropriate.

The spreadsheet also provides a mechanism to connect all this information together, as both an EPBD Inspection and any future analysis requires knowledge of how the HVAC components, HVAC systems, Building spaces, Utility meters, HVAC sensors and Space activities are connected.

> *"…CIBSE is participating in iSERV as the project offers practical help to those who operate and manage HVAC systems to reduce energy consumption, carbon emissions and, most importantly to many building operators, cost. The iSERV data entry spreadsheet is an invaluable tool for gaining an overall understanding of the HVAC system described and for collating information essential for Inspections"*
>
> **Hywel Davies, Technical Director, CIBSE**

Conclusions

The energy used in HVAC systems is a major proportion of the total energy use in Europe.

Within HARMONAC the electrical consumption of an Office HVAC system could vary from 18 kWh/m²/a to 106 kWh/m²/a, with an average of 55 kWh/m²/a. This data is only for systems where complete data was available for all major components. It is thought that two of the HVAC systems would have achieved consumptions of between 10 – 14 kWh/m²/a had they been fully monitored. Therefore the annual energy consumption achieved by HVAC systems per m² in Office buildings across Europe can be seen to vary by up to a factor of 10 times.

The data presented in this article also shows that the normalised ranges of consumption by HVAC **components** for 'Offices' can also vary by up to 10 times from one HVAC system to another. However, HARMONAC was unable to explore any more deeply the reasons for these differences existing in practice.

To make any major inroads into reducing this energy use it is important that we not only understand the ranges for actual energy consumption in HVAC systems serving various end-use activities, but that we also understand the causes of variations in HVAC system energy consumption for meeting the requirements of the same end-use activities.

This information will then allow more confidence in investment in improving the energy efficiency of poorer performing systems, as well as provide an understanding of how legislation should be framed to encourage better performing systems to be adopted.

iSERVcmb is a pan-European project which will collate into one place much of the data needed to underpin the achievement of the 10 – 50% savings HARMONAC indicated were possible in EU Air Conditioning systems. The approach will be fully detailed and the outputs derived will be discussed with all the main actors as the project evolves.

The outputs and findings from iSERVcmb will be reported in future REHVA Journal articles, the REHVA Annual Conference in Timisoara, Romania in April 2012, and future iSERVcmb workshops around the EU. Should you wish to know more, or to become involved in the project, please contact the project Coordinator via the website www.iservcmb.info.

Acknowledgements

The author wishes to thank all the contributors to the HARMONAC and iSERV projects who have helped produce the information which has enabled this article to be produced, as well as the European Commission for funding both projects. 3E

Supported by INTELLIGENT ENERGY EUROPE

Optimal thermal environment improves performance of office work

Li Lan
Institute of Refrigeration & Cryogenics, Shanghai Jiao Tong University, Shanghai 200240, China
International Centre for Indoor Environment and Energy, DTU Civil Engineering, Technical University of Denmark, Building 402, DK-2800 Kongens Lyngby, Denmark

Pawel Wargocki
International Centre for Indoor Environment and Energy, DTU Civil Engineering, Technical University of Denmark, Building 402, DK-2800 Kongens Lyngby, Denmark

Zhiwei Lian
Institute of Refrigeration & Cryogenics, Shanghai Jiao Tong University, Shanghai 200240, China

Introduction

The salaries of office workers are many times higher than the cost of operating a building in developed countries (Woods, 1989; Seppänen, 1999). Consequently, even small improvements in human performance and productivity following improvements of indoor environmental quality (IEQ) can result in a substantial economic benefit. Based on very conservative assumptions, Fisk and Rosenfeld (1997) estimated that improving indoor environment in US office buildings would result in a direct increase in productivity of 0.5% to 5%, worth US$12 billion to US$125 billion annually. It should be recognized that this estimate includes the effects of thermal environment and lighting quality affecting vision, and is only partially affected by indoor air pollution, or the distraction caused by odours and scents and their effects on productivity. The more recent estimates suggest slightly lower yet still considerable annual economic benefit of $17 to $26 billion as a result of improving IEQ (Fisk et al., 2011).

Even though the potential productivity benefits are quite substantial, they are not generally considered in conventional economic cost-benefit calculations pertaining to building design and operation. This is despite the fact that building services engineers are gradually interested in improving indoor environments and quantifying the subsequent effects of these improvements on productivity (Wargocki and Seppänen, 2006). Among many factors the reliable relationships between IEQ and productivity are needed so this may happen. An attempt to create such relationships was made by Seppänen and Fisk (2006) (see also REHVA Guidebook by Wargocki and Seppänen (2006)). Besides the relationships between air quality, ventilation and performance and ventilation rate and absence rates, the function estimating the effect of temperature on performance of office work was developed. Also others attempted to create similar relationship (Berglund et al.,1990; Roelofsen, 2001; Jensen et al., 2009; Lan et al., 2011b).

The objective of this paper is to compare quantitative relationships between thermal environment (temperature and thermal sensation) and human performance. The effects of indoor temperature on human performance are then discussed taking into account seasonal differences (winter vs. summer), as well as the selection of different categories of indoor environment used for design, as prescribed by the European Standard EN15251 (2007).

The relationship between thermal environment and work performance

Air temperature is the commonly used indicator of thermal environment in IEQ and productivity research. One of the very first attempts to create the relationship between temperature and performance was made by Wyon (1986), and was based mainly on his experimental studies; the relationship differentiated between effects in summer and in winter (depending on clothing), as well as between effects for different type of work. The relationship showed that both elevated and too low temperatures have negative effects on performance of office work. Analogous observations were made by other authors who developed similar relationship. For example, Berglund et al. (1990) predicted performance decrement over a range of elevated indoor temperatures (see **Figures 2 and 3**) based on the performance measurement of wireless operators and Gagge's two-layer model. The temperatures used in their experiments spanned however from about 30°C to 40°C; they were thus unusually high compared to temperatures "normally" occurring indoors. The results published by 24 different studies were used by Seppänen et al. (2006) to create the relationship between temperatures and performance (**Figures 2 and 3**); the studies were performed under laboratory conditions and in the field and dealt with performance of office work (21 studies) and schoolwork (3 studies).

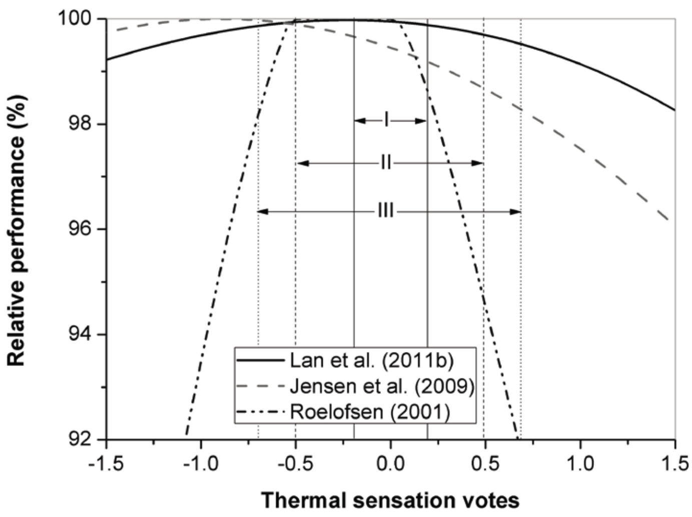


Figure 1. The relationships between thermal sensation and relative performance with superimposed categories of indoor environment according to standard EN15251 (2007); TSV is coded as follows: -3=cold, -2=cool, -1=slightly cool, 0=neutral, 1=slightly warm, 2=warm, 3=hot.

Although the relationships described above linked temperature to performance, it is interesting to discuss whether the effects of thermal environment on performance should only be defined using temperature and whether other metrics such as thermal discomfort should be used as well. This question is particularly valid considering that Wyon et al. (1975)

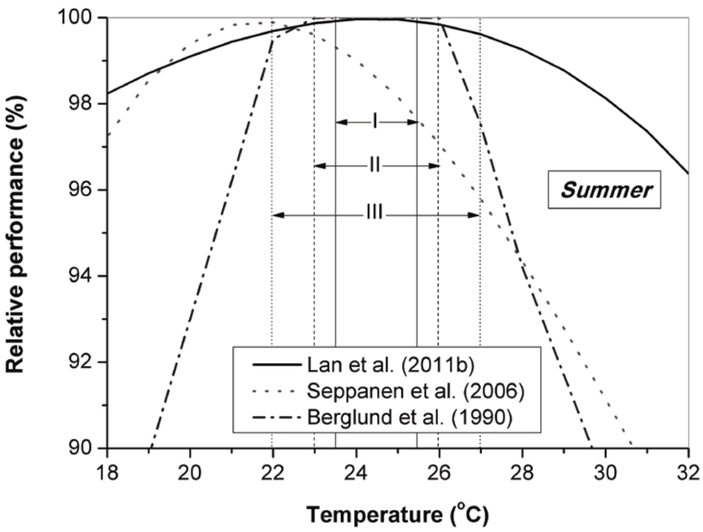


Figure 2. The relationships between air temperature and performance with superimposed categories of indoor environment for summer conditions according to standard EN15251 (2007).

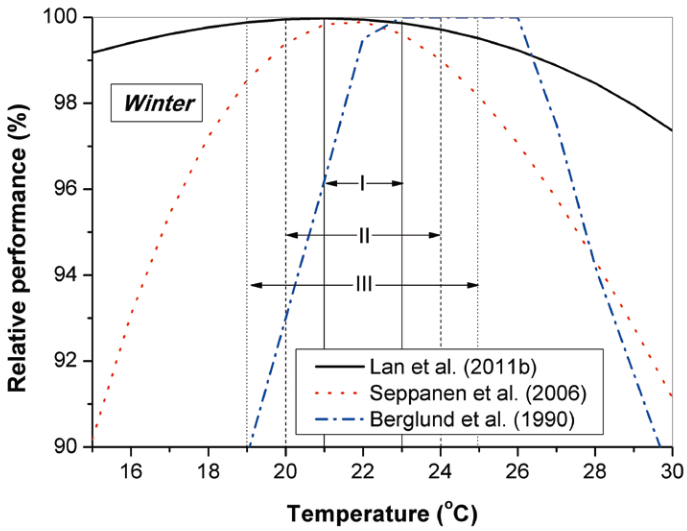


Figure 3. The relationships between air temperature and performance with superimposed categories of indoor environment for winter conditions according to standard EN15251 (2007).

showed that subjects could achieve similar performance results under two different temperatures of around 23.2°C (at 0.6 clo) and 18.7°C (at 1.15 clo); at both temperatures they achieved subjectively assessed thermal neutrality by slightly adjusting the air temperature. This question is also valid considering that thermal discomfort is not only influenced by the temperature but is a result of combination of six parameters including metabolic heat production (physical activity), clothing, temperature, mean radiant temperature, air velocity and air humidity; different combinations of these parameters may result in the same thermal sensation or Predicted Mean Vote (PMV) as defined by Fanger (1970). Consequently these two indices along with the temperature can be used to describe how the thermal environment affects performance. This approach was adopted by Roelofsen (2001) who related the loss of performance with PMV (**Figure 1**) using the data of Berglund et al. (1990) and Loveday et al. (1995). Kosonen and Tan (2004) also used PMV to illustrate how the productivity loss can be minimized through improved thermal comfort design criteria; however, only the effects of feeling too warm on productivity were reported and no relationship between PMV and productivity was created. Jensen et al. (2009) derived on the other hand the relationship between thermal sensation votes and performance (**Figure 1**); they adopted the Bayesian model taking into account probabilistic distribution of different factors influencing thermal sensation and used the data on performance of addition task (a component skill used to simulate office work) from several laboratory and field experiments when creating their relationship. Recently yet another quantitative relationship also between thermal sensation votes and work performance was derived by Lan et al. (2011b) (**Figure 1**); they used the data on performance of neurobehavioral tests and simulated office work from their own three independent laboratory studies in which thermal sensation of subjects was recorded (Lan et al.,2009; Lan and Lian, 2009; Lan et al., 2011a).

Figure 1 compares the three different relationships between thermal sensation and work performance developed by Roelofsen (2001), Jensen et al. (2009) and Lan et al. (2011b). It shows that there exists thermal sensation for optimal performance: feeling too cold or too warm will negatively affect the performance, though the effects are not symmetrical around thermal neutrality and they are somewhat skewed towards slightly cool sensation. The model of Roelofsen (2001) indicates the greatest impact of thermal discomfort on performance and probably carries the highest level of uncertainty. The relationship of Jensen et al. (2009) is similar to Lan et al. (2011b) on the cool side, though it is much different from the model of Lan et al. (2011b) on the warm side of the thermal sensation scale. The lowest impact on performance is observed for the relationship of Lan et al. (2011b) which only included laboratory data.

Using the relationships presented in **Figure 1**, **Table 1** summarizes the potential effects of thermal environment on performance for different categories of indoor environment as specified in the standard EN15251 (2007). The relationship established by Lan et al. (2011b) indicates that within category I (with high level of expectation) one may expect the performance to decrease as much as 0.12% if different thermal conditions are selected while if category III (with acceptable, moderate level of expectation) is selected

Table 1. The potential maximum reduction in performance for different categories of indoor environment as defined by standard EN 15251 (2007).

Category according to EN15251	Predicted mean vote (PMV)	Maximum performance decrement compared to optimum performance of 100% (%)		
		Lan et al. (2011b)	Jensen et al. (2009)	Roelofsen (2001)
I	-0.2<PMV<0.2	0.12	0.82	1.44
II	-0.5<PMV<0.5	0.31	1.34	5.48
III	-0.7<PMV<0.7	0.50	1.75	8.42
IV	PMV<-0.7;PMV>0.7	>0.5	>1.75	>8.42

Table 2. The potential maximum reduction in performance for different categories of indoor environment as defined by standard EN15251 (2007) in winter and in summer.

Category according to EN 15251	Operative temperature (°C)		Maximum performance decrement compared to optimum performance of 100% (%)					
			Lan et al. (2011b)		Seppänen et al. (2006)		Berglund et al. (1990)	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
I	23.5~25.5	21~23	0.08	0.14	2.36	0.39	0.00	3.80
II	23.0~26.0	20~24	0.15	0.28	2.93	0.98	0.00	7.00
III	22.0~27.0	19~25	0.39	0.49	4.21	1.84	2.50	10.2
IV	<22; >27	<19; >25	>0.39	>0.49	>4.21	>1.84	>2.50	>10.2

the performance can be reduced by up to 0.5% from the optimal performance of 100%. Consequently changing from category III to category I one may expect improvement of performance by at least 0.38%. Similarly, the relationship of Roelofsen's (2001) predicts that changing the category III to category I may increase the performance by at least 6.98%. For the thermal conditions outside the criteria defined by categories I to III (category IV) one may expect that performance can be reduced by at least 0.5% compared with the optimum, and probably even more. This is also illustrated in **Figure 1** that shows the ranges of thermal sensation votes for different categories of indoor environment as specified by standard EN15251 (2007). All relationships show that designing for a lower environmental category will result in reduced performance.

Season-specific analysis

The relationship between thermal sensation and performance developed by Lan et al. (2011b) was used to create the relationship between temperature and performance for summer (**Figure 2**) and for winter (**Figure 3**) to examine the effect of season on the predicted effects of temperature on performance. The relationship of Lan et al. (2011b) was used for this purpose as it shows the most conservative estimates of the effects of thermal environment on performance among the relationships presented in **Figure 1**, although other relationships can be used as well; thus the effects presented below are the minimum effects. When creating **Figures 2 and 3** the mean radiant temperature was assumed to be equal to air temperature (i.e., operative temperature equals the air temperature), the activity level to be 1.2 met, air velocity to be 0.15 m/s and the relative humidity to be 50%; the clo value was assumed to be 1.0 clo for winter, and 0.5 clo for summer; other set of assumptions can of course be made if one wants to run similar sensitivity analyses in the future. The relationships between temperature and performance which are independent of seasonal changes and which were developed by Berglund et al. (1990) and Seppänen et al. (2006) were superimposed on **Figures 2 and 3** for comparison.

Using the relationships presented in **Figures 2 and 3**, **Table 2** summarizes the potential effects of temperature on performance in winter and in summer for different categories of indoor environment as specified in standard EN15251 (2007). It shows there are significant difference in the estimated effects on performance between winter and summer if the relationships of Seppänen et al. (2006) and Berglund et. (1990) are used, but quite comparable effects on performance between the two seasons are observed in case of the relationship of Lan et al. (2011b). The latter relationship shows also the most conservative effects on performance among all three relationships; the performance is expected to decrease from the optimal performance of 100%cbetween 0.08% and 0.39% in summer, and between 0.14% and 0.49% in winter. Consequently changing indoor environmental category from III to I one may expect the performance of office work to be improved by at least 0.31% to 0.35%; this effect is, as expected, comparable with the estimates shown in **Table 1**. For temperatures outside category I to III (category IV) one

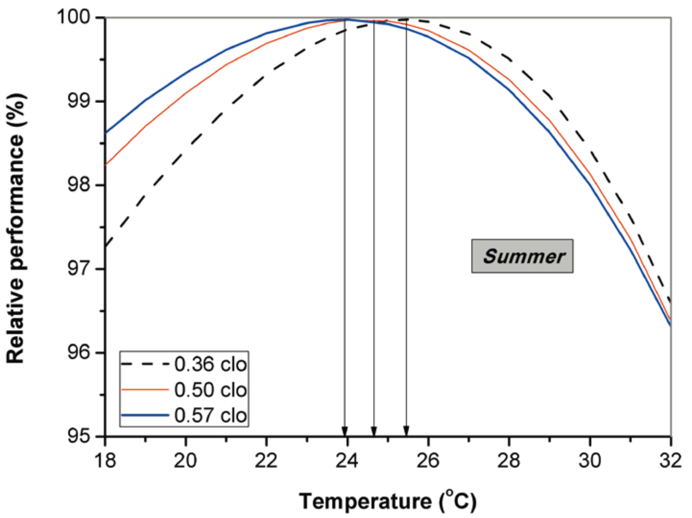


Figure 4. The relationship between indoor temperature and human performance at different clothing insulation levels for summer conditions.

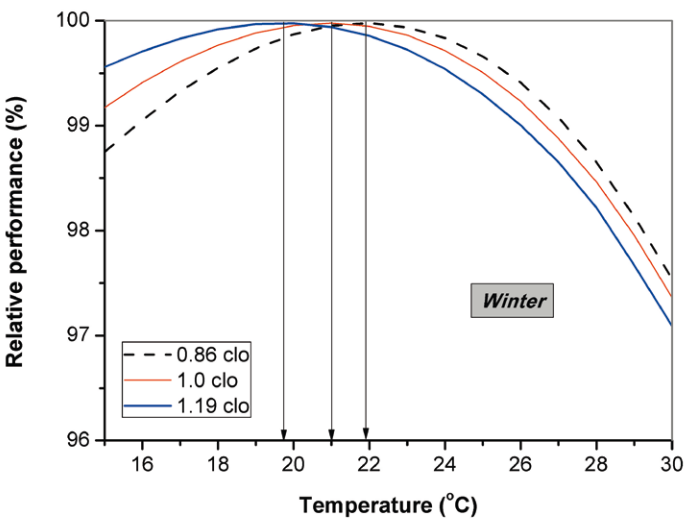


Figure 5. The relationship between indoor temperature and human performance at different clothing insulation levels for winter conditions.

may expect that performance can be reduced by at least 0.39%. This can also be seen in **Figures 2 and 3** which show also the temperature requirements for different categories of indoor environment as specified by standard EN15251 (2007).

It should be noted that **Figure 3** shows that the temperature for optimum performance in winter is similar between the relationship developed by Lan et al. (2011b) and the relationship of Seppänen et al. (2006). This may suggest that the latter relationship is better suited for winter not for summer conditions, although the data used for developing this relationship stem from experiments performed both in winter and in summer, in different climatic regions and from laboratory and field studies (see Seppänen et al. (2006) for details).

Figures 4 and 5 show the impact of changes in clothing insulation during summer and winter on the air temperature for optimum performance; they are based on the relationship of Lan et al. (2011b) shown in **Figure 3**. The insulation of each set of ensemble is calculated according to the description of ASHRAE Handbook (2005). All ensembles include shoes and briefs or panties. In summer, the indoor air temperature for optimum performance can be increased from about 23.9°C to 25.4°C when people wear walking shorts and short-sleeved shirt corresponding to 0.36 clo instead of trousers and short-sleeved shirt corresponding to 0.57 clo. The indoor air temperature for optimum performance can be decreased from about 21.9°C to 19.7°C in winter when trousers, long-sleeved shirt, thick long-sleeved sweater and thick sleeveless vest are chosen corresponding to 1.19 clo instead of trousers, long-sleeved shirt and thin long-sleeved sweater corresponding to 0.86 clo.

Implications

Many countries now mandate that thermostats should be set higher during warm weather to conserve the energy used for cooling buildings. For example, a campaign named Cool Biz has been carried out by the Japanese government recommending raising the set points during summer to 28°C and wearing lighter clothing (Akiyama et al., 2011). **Figure 4** shows that increasing air temperature to 28°C and above, even with very light clothing, may reduce performance by minimum of 0.5% if the most conservative relationship of Lan et al. (2011b) is selected. The increased temperatures will also increase Sick Building Syndrome (SBS) symptoms as indicated by Mendell et al. (2002). They found that higher summer temperatures even in mid to high levels within the comfort zone are associated with more SBS symptoms. Also Krogstadt et al. (1991) and Fang et al. (2004) showed that high temperatures will increase SBS. The increased temperatures can also result in negative physiological responses (e.g., eye problems, change in respiratory patterns and oxygen exchange) (Lan et al., 2011a), which may consequently affect health conditions and performance, although at present it is not clear whether these effects are just because of elevated temperature, or are due to thermal discomfort or both. Since elevated temperatures in summer may have negative consequences for building users, it may be recommended that air temperature during summer should be set within the lower half of the summer thermal comfort range, mainly to improve performance of office work but also to avoid the negative health effects discussed above. This does not have to cost energy if only methods allowing avoiding thermal discomfort due to warmth with low energy use are advanced. One of the methods worth considering can for example be using the personalized ventilation for cooling by intensifying the convective heat transfer (Melikov and Knudsen, 2007).

Many countries now also mandate that thermostats should be set lower during cold weather to conserve the energy used for heating buildings. Similar to Cool Biz, the Warm Biz campaign request home owners and office building users to set thermostats to maximum 20°C during the heating season. **Figure 3** shows that keeping temperatures in winter at 20°C would basically have minimal effect (about 0.05% decrement) on performance. At the same time the intensity and frequency of SBS symptoms will be reduced as indicated by many previous studies (Reinikainen and Jaakkola, 2001; Mendell and Mirer, 2009; Lan et al., 2010; 2011a). Actually Fisk et al. (2011) estimated that eliminating temperatures above 23°C in winter would result in annual economic benefits of $3.4 billion of which $2.1 billion is attributable to improved performance and $1.1 billion to reduced prevalence of SBS symptoms. As shown in **Figure 4**, the temperature for optimum performance in winter could be decreased efficiently by increasing clothing insulation level. Thus maintaining the buildings in winter at the cooler end of the recommended comfort range may not affect performance but it may also substantially reduce many acute symptoms, all achieved together with saving a good deal of energy.

Limitations

The relationships shown in **Figures 1 to 5** are applicable for buildings with mechanical heating and cooling. Specifically **Figures 2 and 3** provide different cooling/heating set points when applying the Fanger's PMV model (1970). For the buildings without mechanical cooling, the indoor temperature (being the temperature at which people neither want more cooling or more heating) is a function of outdoor temperature, as prescribed by the adaptive comfort model (de Dear and Brager, 1998; EN15251, 2007). According to the adaptive model it is possible to reach thermal neutrality across the range of outdoor temperatures due to adaptive actions such as windows opening, adjustment of clothing and behavioural changes. It is difficult to estimate the effects on performance in buildings without mechanical cooling, although laboratory experiments suggest no negative effects of drifting temperatures (occurring in such buildings) on performance of simulated office work (Kolarik et al., 2009). More data on the effects on performance would still be needed from the buildings in which thermal conditions are specified using adaptive model. Nevertheless it should be noted that thermal conditions providing thermal neutrality, as e.g. defined by the adaptive model, may not give rise to maximum performance. This has already been demonstrated by Pepler and Warner (1968) and is also well illustrated by the relationships presented in **Figure 1** which indicates that slightly cool environment promotes performance.

Conclusions

Inadequate thermal conditions expressed by both elevated or too low temperatures, by too warm or too cool environment have significant negative effects on human performance.

Studies indicate that comfortable cool environment is beneficial for performance of office work. Avoiding elevated temperatures in winter and in summer can bring measurable benefits.

Designing thermal environment for the lower category of indoor environment as specified in standard EN15251 (2007) will cause reduced performance of office work. The potential savings on the first costs and running costs by designing for the lower category of indoor environment can consequently be counteracted by reduced performance of office workers. Designing for the highest category would thus be desirable.

Acknowledgement

This work was supported by the International Centre for Indoor Environment and Energy, Technical University of Denmark, and the National Natural Science Foundation of China (No.51108260).

References

See the complete list of references of the article in the html-version at www.rehva.eu -> REHVA European HVAC Journal

Ventilation system types in some EU countries

Andrei Litiu
Junior project engineer in the REHVA office
al@rehva.eu

Introduction

Ventilation system is a combination of appliances designed to supply interior spaces with outdoor air and to extract polluted indoor air. The system can consist of mechanical components (e.g. combination of air handling unit, ducts and terminal units). Ventilation system can also refer to natural ventilation systems making use of temperature differences and wind with facade grills in combination with mechanical exhaust (e.g. in corridors, toilets etc.). Both mechanical and natural ventilation can be combined with operable windows. A combination of mechanical and non-mechanical components is possible (hybrid systems).

Across EU countries, ventilation does not follow the same practices. This discrepancy can be due to the climate and building tradition. For the future development of energy efficient ventilation for good indoor environment it is important to know the ventilation systems in current building stock in Europe. In this summary commonly used ventilation systems in Europe in dwellings, schools, kindergartens and office buildings. The ventilation systems are either natural or mechanical ventilation. These main categories are further subdivided into several subsystems (**Figure 1**).

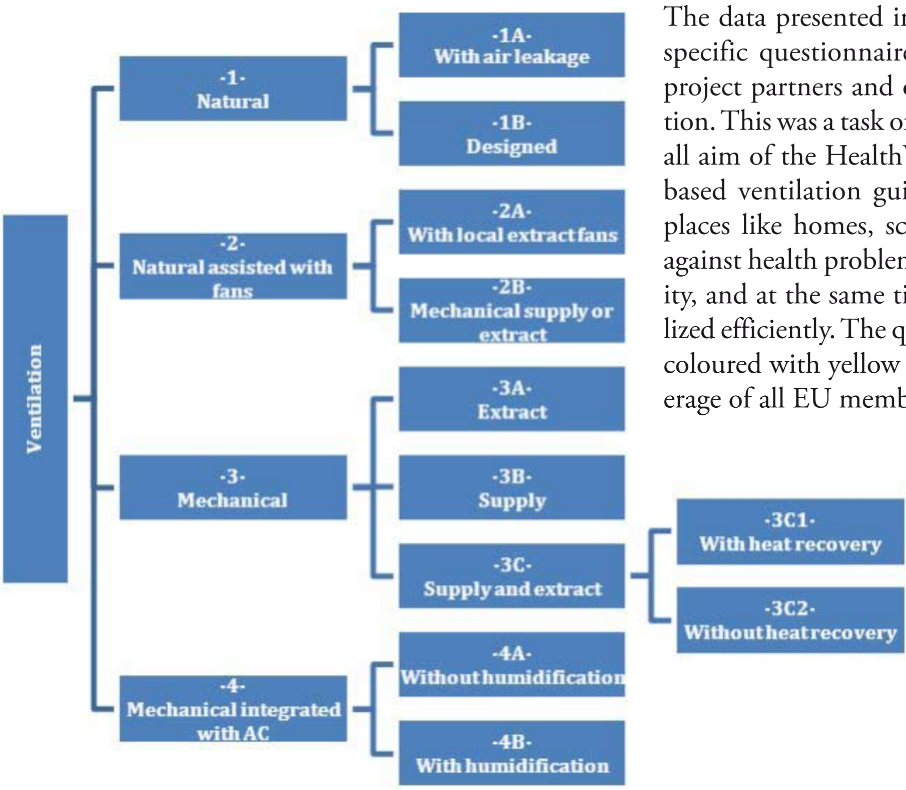


Figure 1. Classification of ventilation systems in this article.

Data collection

The data presented in this article was collected with a specific questionnaire in the HealtVent project from project partners and other national experts on ventilation. This was a task of REHVA in the project. The overall aim of the HealthVent project is to develop health-based ventilation guidelines for protecting people in places like homes, schools, kindergartens, and offices against health problems caused by poor indoor air quality, and at the same time will ensure that energy is utilized efficiently. The questionnaire covered the countries coloured with yellow in the **Figure 2**, giving good coverage of all EU member states.

The responses were based either on national regulations, national knowledge in construction practises, national related studies or national statistics. With only a few respondents from each country may be a source of error. However, as the data was collected just to provide an overview of the European situation, minor errors are not significant.

For each of 15 systems in **Figure 1** colour was designated (**Table 1**). The results are presented in the diagrams (**figures 3-13**). The colours were chosen based on accurate visual distinction and on system and adjacent subsystems identification (i.e. different shades of the same colour).

Figure 2. The countries for which are included in the survey coloured with yellow.

Ventilation systems in buildings stock

The responses from the participating countries showed that national official statistics of ventilation systems is not available from any country. The results shown below are based on the estimations delivered by experts from participating countries. Some subjective judgement has been use in grouping the some ventilation system types in the results. Collected information was also incomplete, particularly regarding the ventilation systems in the building stock. The estimation of ventilation system in the building stock can be give only in residential buildings, schools and kindergartens, and only for a few countries (**figures 3, 4, 5 and 6**).

For houses the distribution of ventilation systems, presented in **Figure 3**, clearly shows that natural ventilation and fan assisted natural ventilation account for more than 50% of existing systems. The values vary

Table 1. Colour code for the ventilation systems in the figures below.

	1A	Natural ventilation with air leakage
	1B	Designed natural ventilation
	1A, 1B	Natural ventilation
	2A	Natural ventilation with local extract fans
	2B	Hybrid ventilation (1A or 1B + intermittent 3A or 3B)
	2A, 2B	Natural assisted with fans
	1A, 1B, 2A, 2B	Natural ventilation with or without assisting fans
	3A	Mechanical extract ventilation
	3B	Mechanical supply ventilation
	3A, 3B	Mechanical ventilation
	3C1	Mechanical extract and supply ventilation with heat recovery
	3C2	Mechanical extract and supply ventilation without heat recovery
	3C1, 3C2	Mechanical with or without heat recovery
	4A	Ventilation integrated with AC without humidification
	4B	Ventilation integrated with AC with humidification

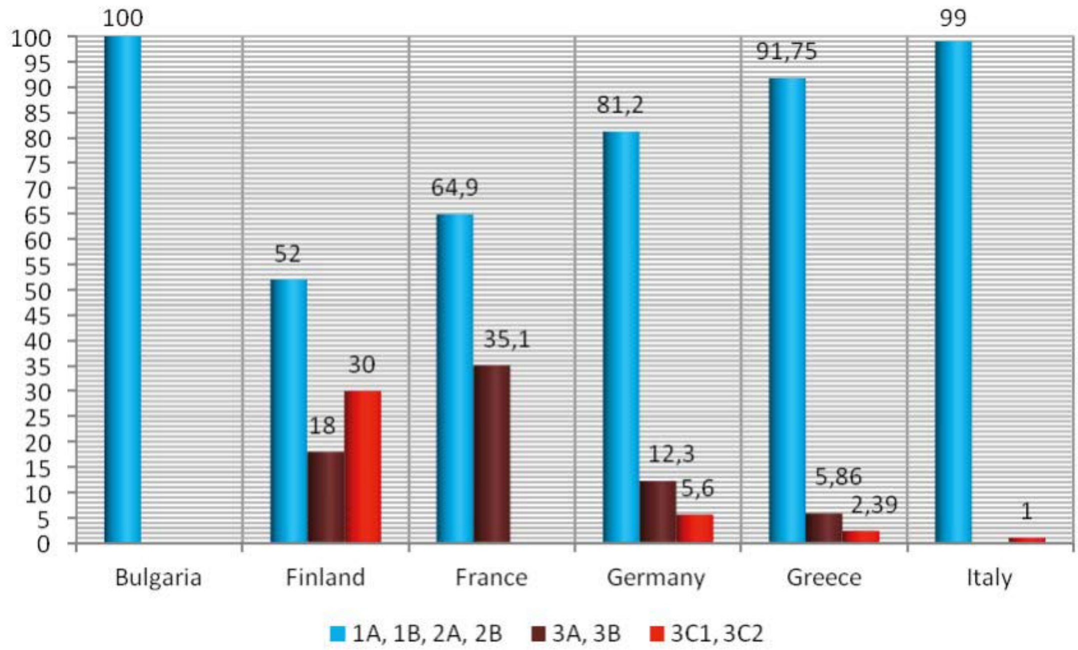


Figure 3. Distribution of ventilation systems in percentage from total number of houses in existing building stock.

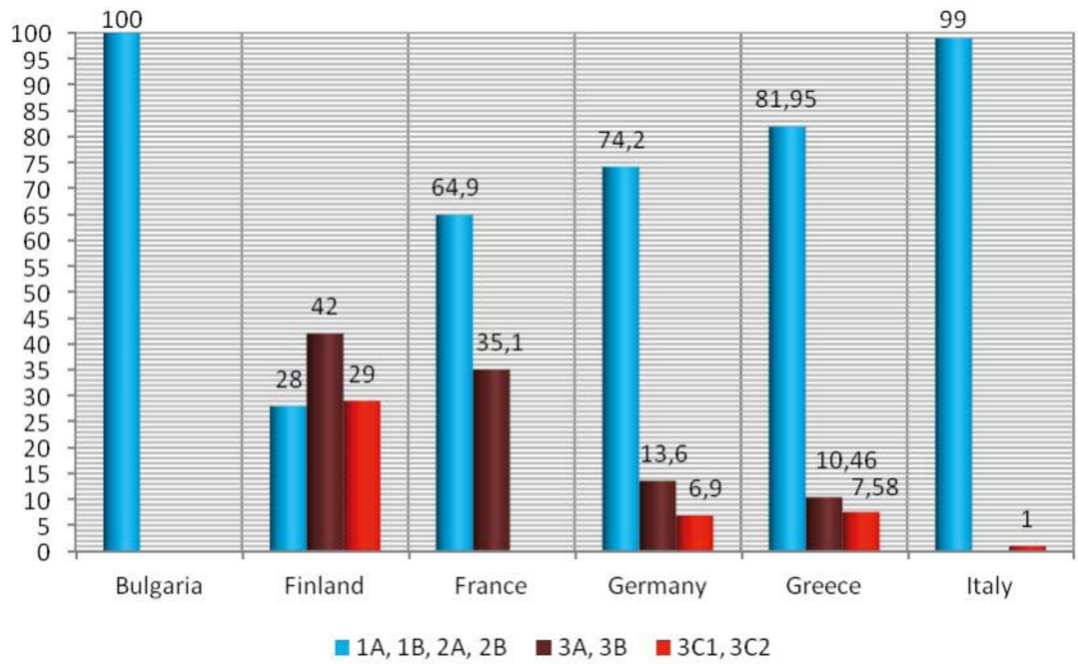


Figure 4. Distribution of ventilation systems in percentage from total number of apartment buildings in existing building stock.

from Bulgaria with 100% natural to Finland with 52% natural and 48% mechanical.

For apartment buildings, presented in **Figure 4**, the situation is almost the same with slight differences for Greece and Germany but with obvious domination of mechanical ventilation in Finland.

It is interesting to observe that France has only extract or supply mechanical ventilation whereas Greece and Germany have one third of the mechanical ventilation systems with extract and supply (with or without heat recovery) and Finland has more than half of the houses and almost half of the apartments equipped with supply and extract mechanical ventilation.

Evolution of residential ventilation systems in some countries

Types of the ventilation systems used in a specific country differ with construction year due to changes in regulations and construction practise. In the responses to the questionnaire each country selected its range of construction year. The breakdown of the ventilation systems based on the selected construction year of buildings are presented in percentage from specific building constructed during the time period indicated above each pie chart.

The European residential building stock (in m²) accounts for 75% of the whole building stock, from which 64% is taken by houses. The **figures 7-13** show the distribution of ventilation systems in the building constructed during each indicated time period.

Looking at the development of ventilation systems is evident that in all countries the use of natural ventilation systems is decreasing in favour of mechanical ventilation systems. The evolution is different in all counties but the trend is the similar

- before 1980 all countries used mainly natural ventilation;
- Finland was within the first countries to make a change i.e. before 1959, by introducing mechanical supply and/or extract ventilation systems; gradually the situation evolved reaching the point that all after 2004 constructed buildings have only mechanical ventilation systems;
- in the United Kingdom the changes took place between 1980 and 2010, during which the constructed buildings assured ventilation mostly through more and more fan assisted natural ventilation but also mechanical supply and/or extract ventilation; only lately, i.e. 2011 mechanical ventilation systems account for half of systems in constructed houses;

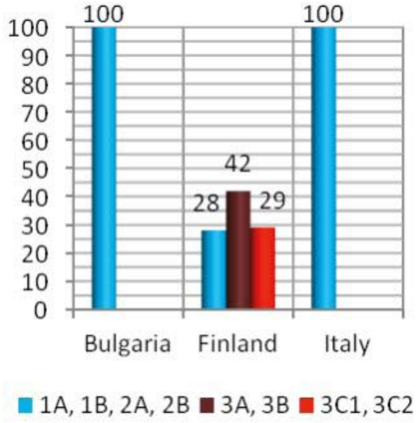


Figure 5. Distribution of ventilation systems in percentage from total number of school buildings in existing building stock.

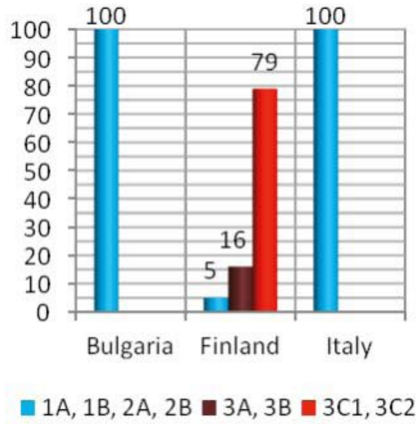


Figure 6. Distribution of ventilation systems in percentage from total number of kindergartens buildings in existing building stock.

- for Greece 1978 was the turning point after which more fan assisted natural ventilation and mechanical extract and/or supply systems were used; the situation has been slowly evolving but still natural ventilation accounts for half of the currently constructed houses;

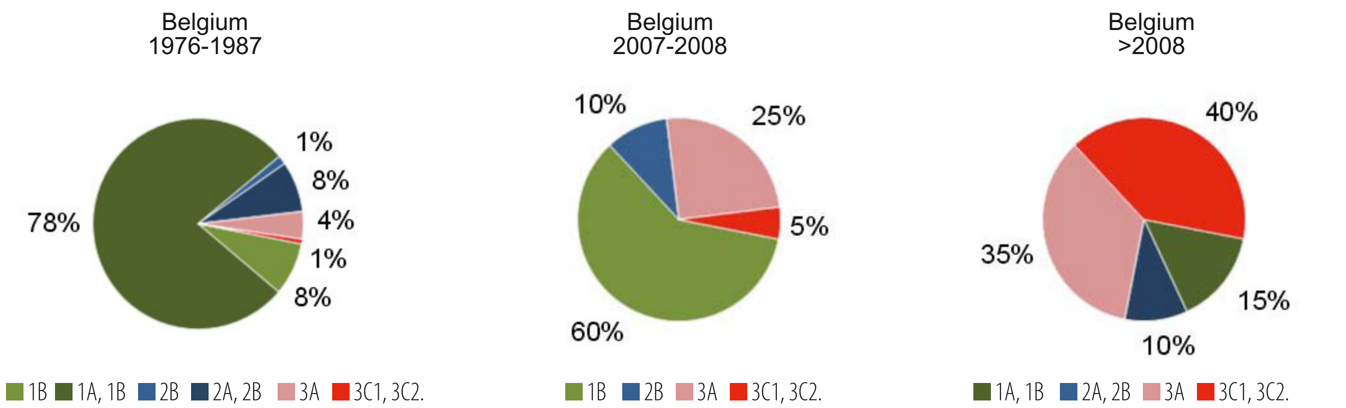


Figure 7. Distribution of ventilation systems in houses by construction year in Belgium: before 2007, 2007-2008 and after 2008.

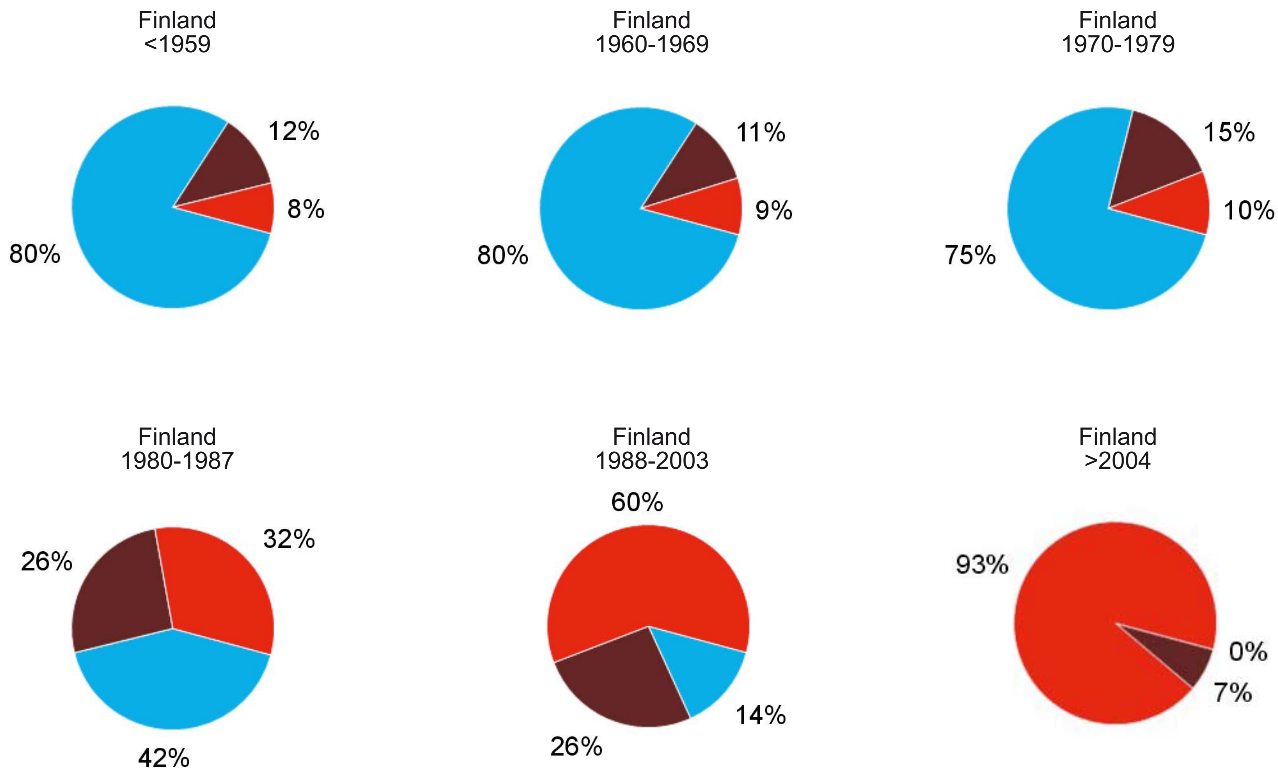


Figure 8. Distribution of ventilation systems in houses by construction year in Finland: before 1959, 1960- 1969, 1970-1979, 1980-1987, 1988- 2003 and after 2004. ■ 1A, 1B, 2A, 2B ■ 3A, 3B ■ 3C1, 3C2.

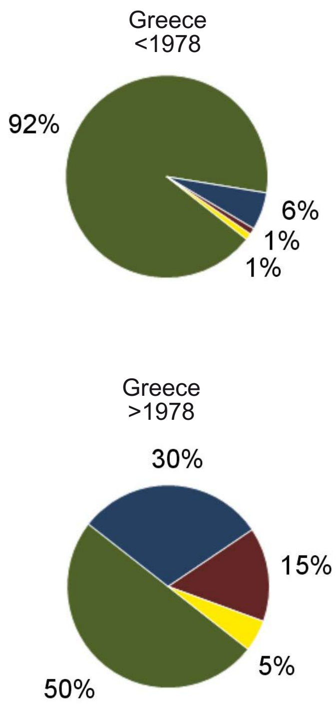


Figure 9. Distribution of ventilation systems in houses by construction year in Greece: before 1978 and after 1978. ■ 1A, 1B ■ 2A, 2B ■ 3A, 3B ■ 3C1.

- in Belgium only lately, i.e. after 2008, more mechanical ventilation systems were installed than natural ;
- Portugal, although has favoured fan assisted natural ventilation over natural ventilation, introduced mechanical ventilation systems as hybrid ventilation;
- Romania adopted new regulation in 2010, after which 20% of constructed houses have mechanical ventilation systems; still until 2008 more than 99% of buildings had natural ventilation systems;
- the data from Norway, provides only evidence of the decrease of natural ventilation share in favour of other ventilation systems.

As a conclusion, the distribution of ventilation systems has had a similar evolution from natural ventilation systems towards mechanical ventilation systems. The evolution occurred sooner for some countries than others but it is clear that lately mechanical ventilation practises are forced by emerging regulations regarding energy efficiency and performance. But still, as most houses from the building stock are old houses the overall distribution of ventilation systems allocates the greatest share to natural ventilation systems.

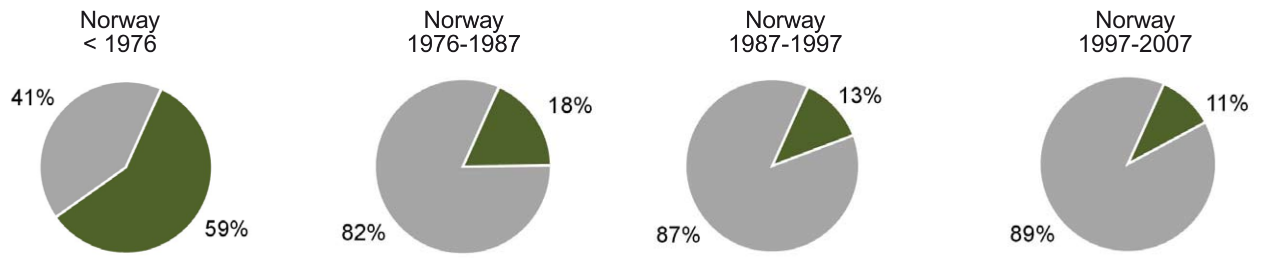


Figure 10. Distribution of ventilation systems in houses by construction year in Norway: before 1976, 1976 – 1987, 1987 - 1997, and 1997-2007. ■ 1A, 1B ■ OTHER.

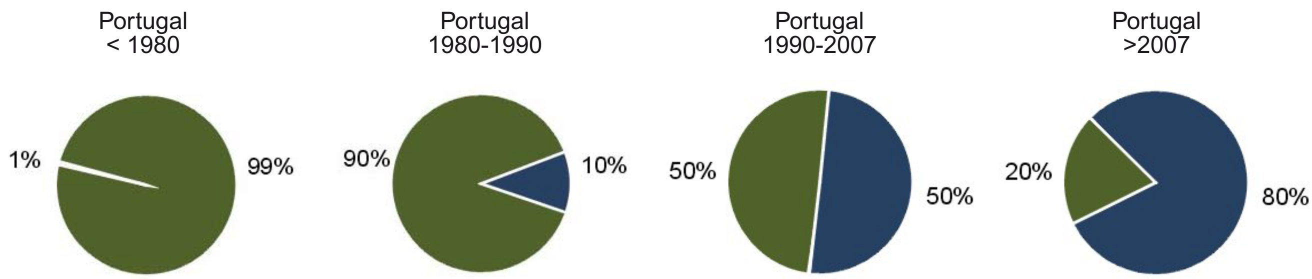


Figure 11. Distribution of ventilation systems in houses by construction year in Portugal: before 1980, 1980- 1990, 1990-2007, and after 2007. ■ 1A, 1B ■ 2A, 2B.

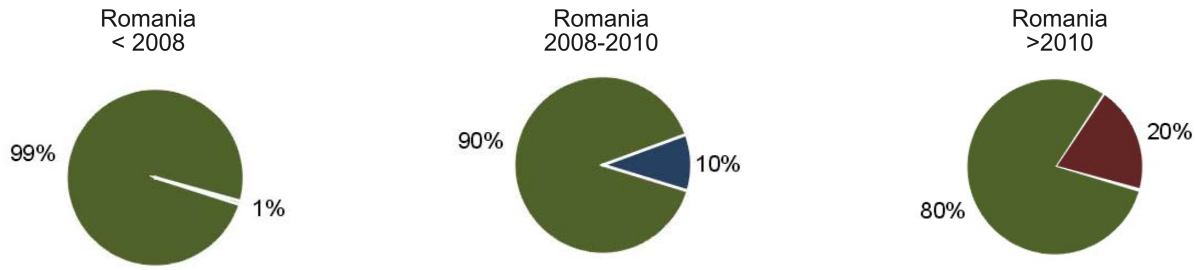


Figure 12. Distribution of ventilation systems in houses by construction year in Romania: before 2008, 2008-2010 and after 2010. ■ 1A, 1B ■ 2A, 2B ■ 3A, 3B.

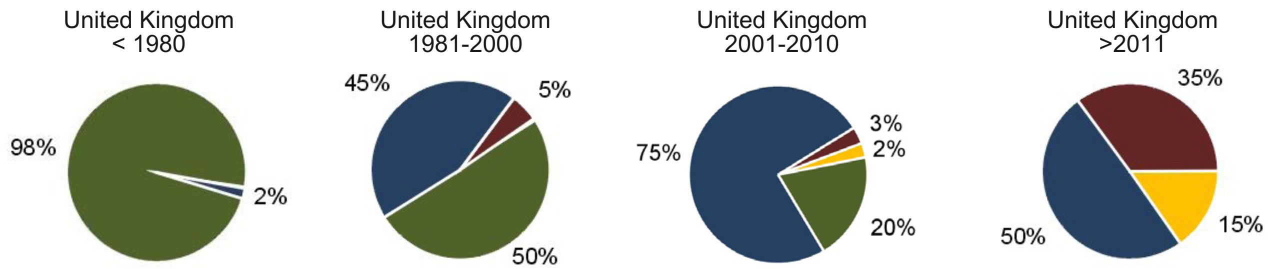


Figure 13. Distribution of ventilation systems in houses by construction year in United Kingdom: before 1980, 1981-2000, 2001-2010 and after 2010. ■ 1A, 1B ■ 2A, 2B ■ 3A, 3B ■ 3C2.

Acknowledgements

The HealthVent project was sponsored by the Executive Agency for Health and Consumers (EAHC) through the grant agreement n° 2009 12 08. The EAHC implements the EU Health Programme, the Consumer Programme and the Better Training for Safer Food initiative. REHVA thanks the project partners and other national experts for submitting the data on ventilation systems. 3E

This article is based on the paper Brelih, Nejc, Seppänen Olli. "Ventilation rates and IAQ in european standards and national regulations" presented at the AIVC conference Oct 12-13, 2011, Brussels, Belgium.

Ventilation rates and IAQ in national regulations

Nejc Brelih
Junior project engineer in the REHVA office
nb@rehva.eu

REHVA – Federation of European Heating, Ventilation and Air Conditioning Associations
Washington Street 40, 1050 Brussels, Belgium

Summary

This paper presents some results from the HealthVent project supported by the European Commission DG Sanco. One of the objectives of the project has been to review and critically evaluate the existing requirements on ventilation and IAQ defined in national building codes and European standards. This paper presents a summary of the values given in European ventilation regulations, and results of a comparison. The up-to-date data in national legislation and codes were collected from 16 European countries with questionnaires, which were sent to project partners and trusted experts on ventilation. The requirements on ventilation rates were found to be given in different units, therefore test cases of real-life design situations were introduced to compare the data on a basis of a common unit. The results show that the ventilation rates given in the regulations are inconsistent and very heterogeneous. The ventilation rates in test cases range from 0.23 to 1.21 h^{-1} in dwellings and from 4.2 to 41.7 l/s for local exhaust rates. The ventilation rates per person in test cases of classroom, playroom, and office range from 4 to 25 l/s. Big differences were also found in pollutant levels. Limit CO levels range from 3.0 to 12.5 mg/m³ and formaldehyde levels from 10 to 100 µg/m³. In conclusion, the evaluation of the data showed that values in the European local regulations, standards, and those practised locally, are very inconsistent. Moreover, several values in regulations were found to be looser than the recommended values published in European standards and WHO guidelines, thus allowing lower ventilation rates and higher pollutant levels than recommended. Results indicate that there is a considerable need on the European level to harmonize the ventilation and IAQ regulations and adjust them to the values provided in standards and guidelines.

Introduction

Considering the amount of time people spent inside and the concentrations of indoor pollutants, the buildings are the most important factor in air pollution exposure and associated health effects. Ventilation is used to bring outdoor air to the occupied indoor zone and to remove or dilute indoor-generated pollutants. Ventilation rate, as the flow of outdoor air to a space, is one of the most important factors affecting indoor air quality.

In this article some of the results from the work performed in the HealthVent project[2], supported by the European Commission. The objective of the HealthVent project is to develop health-based ventilation guidelines for the EU. Members of the project group are experts from different disciplines from 9 European countries. One of the objectives of the project was to review and critically evaluate the existing requirements on ventilation and IAQ defined in building codes and European standards. The project's focus was set on ventilation rates, pollutants, noise, temperature and relative air movement in dwellings, offices, schools and kindergartens.

Methods

The work focused on national regulations and practice in European countries. The data was collected with a special questionnaire, which was sent to project partners and trusted experts on ventilation in several European countries. The questionnaire comprised of 10 questions

2 HealthVent project website: www.healthvent.eu

and sub-questions. The respondents were asked to provide values of ventilation rates, pollutant limits, noise levels, etc., which can be found in the national regulations. In case if no such values existed in the regulations, they were asked to provide values which are most widely used in practice (from standards, guidelines, etc.). In the responses they had to mark if the provided value is mandatory or voluntary to use. Respondents in 16 countries supplied the requested data (**Table 1**).

The returned questionnaires revealed that the ventilation rate criteria are given using various units depending on a country, which do not allow direct comparisons. Criteria are expressed as flow rate per number of persons, flow rate per floor area, flow rate per number of rooms, fixed flow rate per room type, number of air changes per hour, or combination of different units. In order to compare ventilation rates criteria, we developed several test cases, which represent real-world situations.

Test cases were developed for two different dwellings, a kitchen, a toilet, a bathroom, a school classroom, a kindergarten playroom, and an office. The details of the test dwellings are shown in **Table 2 and 3**. Using this data we compared the ventilation rates in dwellings on the base of air changes per hour, ventilation of kitchens, bathroom, and toilet as ventilation rate per room, and ventilation of classroom, playroom, and office as air flow rate per person.

Table 1. Countries included in the summary and abbreviations used in charts below.

BG	Bulgaria	**LT**	Lithuania
CZ	Czech Republic	**NL**	Netherlands
DE	Germany	**NO**	Norway
FI	Finland	**PL**	Poland
FR	France	**PT**	Portugal
GR	Greece	**RO**	Romania
HU	Hungary	**SI**	Slovenia
IT	Italy	**UK**	United Kingdom

Comparison of ventilation rates

The results show that values are very inconsistent among European countries. **Figures 1 and 2** show ventilation rates[3], which were calculated using the input data from **Tables 2 and 3**. The lowest ventilation rate in dwellings is 0.23 h^{-1} and the highest 1.21 h^{-1}. Large differences can also be seen in the cases of local exhaust rates, where the highest rates can be up to five times higher than the lowest rates. The ratio is therefore similar to the one of air changes in dwellings, where it is almost 1 to 6. Observing ventilation rates in the cases of classroom and playroom, one can distinguish two groups of countries with similar values. The first group has ventilation rates of around 10 l/s per person. It is formed by the following countries: Finland, Germany, Hungary,

3 Ventilation rate is the flow of outdoor air to a space

Table 2. Properties of the test dwellings.

Properties	Dwelling case 1	Dwelling case 2
floor area	50 m^2	90 m^2
ceiling height	2.5 m	2.5 m
main rooms	2: 1 living, 1 sleeping	4: 1 living, 1 sleeping, 2 children
kitchen	1 x 10 m^2 with window and electric stove	1 x 15 m^2 with window and electric stove
toilet	1 x 2 m^2	1 x 2 m^2
bathroom	1 x 5 m^2	1 x 5 m^2
persons	2	4

Table 3. Properties of the test rooms.

Properties	Kitchen	Toilet	Bathroom	Classroom	Playroom	Office
area	10 m^2	2 m^2	5 m^2	50 m^2	50 m^2	12 m^2
ceiling height	2.5 m	2.5 m	2.5 m	2.8 m	2.8 m	2.8 m
persons	1	1	1	25	25	1

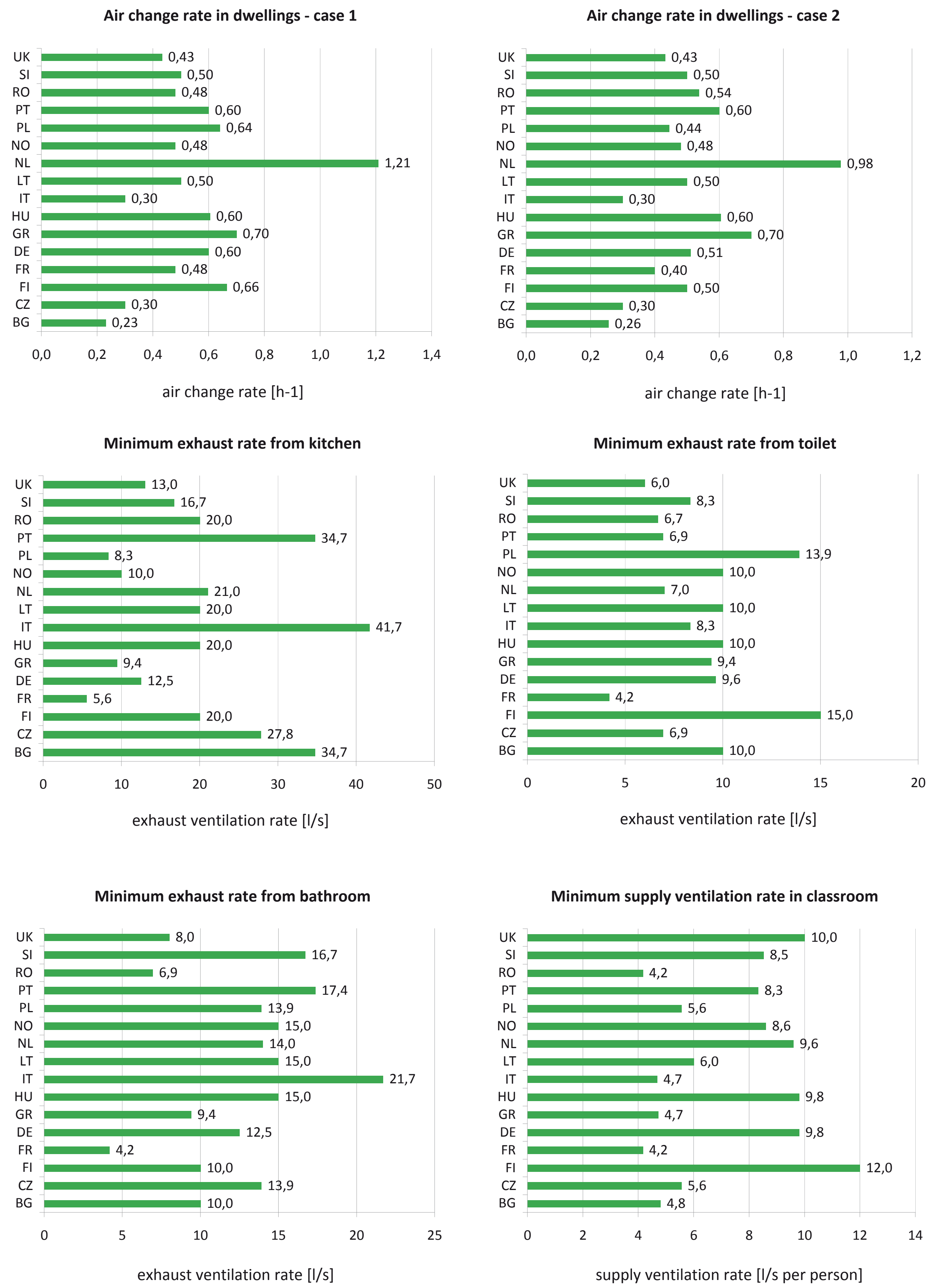


Figure 1. Comparison of ventilation rates in the test cases of dwellings, kitchen, toilet, bathroom and classroom.

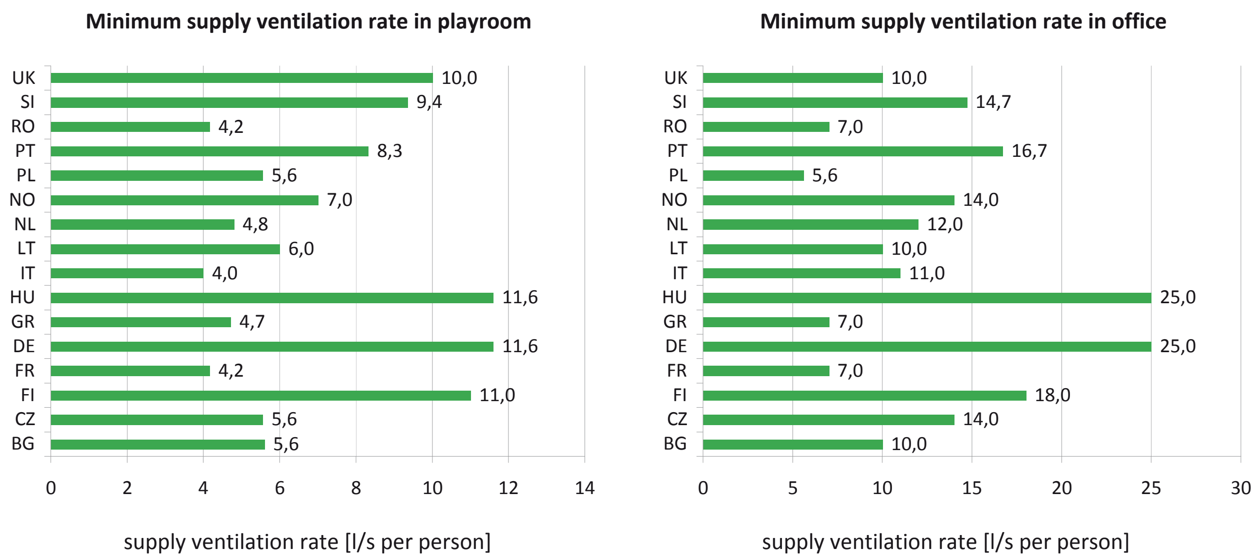


Figure 2. Comparison of ventilation rates in the test cases of kindergarten playroom and office

the Netherlands, Norway, Slovenia and UK. The second group has rates of around 4 l/s per person and is formed by the following countries: Bulgaria, Czech Republic, France, Greece, Italy, Lithuania, Poland and Romania. Both Nordic countries are in the group with higher ventilation rates, which is predominantly formed by the countries from the North and West of Europe. No countries from the Southern Europe are in that group. The ventilation rates in offices cannot be so obviously divided into two groups, because rates are much more scattered. Two ventilation rates that stand out are from Germany and Hungary, which are calculated according to EN 15251. The region-based conclusions are therefore not possible in the office case.

Indoor pollutants

The required limit levels of selected pollutants are shown in **Table 4**. The table also includes the WHO suggested values to serve as a comparison [2, 3]. The comparison of all values is difficult, because the limits are given as a maximum or average concentration in a given time. Only 6 out of 16 countries have requirements on limit indoor pollutant levels in non-industrial buildings. Limit levels of only two pollutants are found in the regulations of all the 6 countries: carbon monoxide (CO) and formaldehyde (HCOH). The range of CO limit levels is wide, from 3 to 12.5 mg/m³. The WHO recommended limit is 7 mg/m³, therefore the limit of 4 countries exceeds that value. Formaldehyde limit values range from 10 to 100 µg/m³ and all values are equal to or below the WHO recommended value of 100 µg/m³. Limit values of other pollutants are not included in the regulations of all countries and their ranges are also wide.

Discussion

The data was collected from 16 countries from all parts of Europe, thus giving a good coverage of regions with different building practice and climate. Although the respondents are experts on ventilation, a certain measure of uncertainty exists regarding the accuracy of the data in the received questionnaires. Due to limited resources, all data could not be verified. The data presented in this article are informative and should not be used for the design of ventilation.

Different boundary conditions, which are used to calculate the ventilation rates, show that countries have taken different approaches to define ventilation in the regulations. Approximately one third of countries have requirements for the ventilation of dwellings, which result in air change rate lower than 0.5 h^{-1}.That is in contrast with the health-based recommendations of minimum air change rate of 0.5 h^{-1} [5]. The ventilation rates in classrooms, playrooms and offices are also in contrast with health-based recommendations, because the resulting ventilation rates are often below 10 l/s per person. In the extensive review of studies that investigated the association of ventilation rates with human responses, Seppänen et al. [5] and Sundell et al. [6].

Table 4. Indoor pollutant limit levels.

	WHO	FI	LT	NO	PT	RO	SI
Ammonia[μg/m³]	-	20	40	-	-	-	50
Asbestos	-	0 fb/cm	0.1 mg/m³	0.1 fb/cm	-	-	-
CO[mg/m³]	7#2	8	3	10#5	12.5	6#3	10
CO_2[ppm]	-	1200	-	1000	1000	-	1670
Formaldehyde[μg/m³]	100	50	10	100#3	100	35#3	100
NO_2[μg/m³]	40	-	40	100#4	-	-	
Ozone[mg/m³]	0.1#5	-	0.03	-	0.2	-	0.1
PM_{10}[μg/m³]	20	50	50	-	150	-	100
Radon[Bq/m³]	-	200#1	-	100	400	140#6	400
Styrene[μg/m³]	-	1	2	-	-	-	-

#1 annual average, #2 daily maximum, #3 30 min average, #4 1 h average, #5 8 h average, #6 instant max, fb – fibre

The limit levels of pollutants are often higher than those recommended by the WHO, and missing in the regulations of several countries. The ranges of values are wide, which indicates that the countries do not use common theoretical background to determine the limit values. Minimum requirements for pollutant levels in non-industrial buildings should be included into the regulations of all European countries.

Conclusion

A review of the European regulations for ventilation rates and indoor air quality showed that the values in regulations are inconsistent and vary greatly according to country. Almost all of the regulated parameters included in the review are already defined in European Standards, which were accepted in the CEN voting process by national bodies. Nevertheless, the values found in the standards and those in the regulations are not harmonized. The inconsistency on the national level between the EN standards and regulations, as well as on the European level from country to country, causes problems to designers and industry, and increases the construction cost. Besides that, the current practice is in contrast with the efforts of unification and standardization of the European common market. Clearly, a common European guideline is needed, which would serve as a basis for national European regulations. The guideline should include ventilation rates, technical properties, and other parameters related to the performance of ventilation.

Acknowledgements

The HealthVent project was sponsored by the Executive Agency for Health and Consumers (EAHC) through the grant agreement n° 2009 12 08. The EAHC implements the EU Health Programme, the Consumer Programme and the Better Training for Safer Food initiative. REHVA thanks the project partners and other national experts for submitting the data on national regulations.

References

[1] WHO Regional Office for Europe Copenhagen, "The Right to Healthy Indoor Air. Report on a WHO Meeting," Bilthoven, 2000.

[2] WHO, "Air quality guidelines. Global update 2005. Particulate matter, ozone, nitrogen dioxide and sulphur dioxide," WHO Regional Office for Europe, Copenhagen, 2006. [Online]. http://www.euro.who.int/__data/assets/pdf_file/0005/78638/E90038.pdf

[3] WHO Regional Office for Europe. (2010) WHO guidelines for indoor air quality: selected pollutants. [Online]. http://www.euro.who.int/__data/assets/pdf_file/0009/128169/e94535.pdf

[4] European Committee for Standardization, „EN 15251: 2007. Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics," CEN, 2007.

[5] O. Seppänen, W. J. Fisk, and M. J. Mendell, „Association of Ventilation Rates and CO2 Concentrations with Health and Other Responses in Commercial and Institutional Buildings," Indoor Air, vol. 9, no. 4, pp. 226-252, December 1999.

[6] J. Sundell et al., „Ventilation rates and health: multidisciplinary review of the scientific literature," Indoor Air, vol. 21, no. 3, pp. 191-204, June 2011.

Electricity use in two low energy office buildings in Norway

Natasa Djuric
SINTEF Energy Research, Department of Energy Processes, NO-7465 Trondheim, Norway, natasa.djuric@sintef.no

Vojislav Novakovic
Norwegian University of Science and Technology (NTNU), Department of Energy and Process Engineering, NO-7491 Trondheim, Norway, vojislav.novakovic@ntnu.no

Frode Frydenlund
SINTEF Energy Research, Department of Energy Processes, NO-7465 Trondheim, Norway, frode.frydenlund@sintef.no

Introduction

In order to perform a proper building energy labeling, it is important to document and measure building energy use. Documentation, measurements, and quality control of building energy performance would increase in importance as new concepts are implemented and further step towards zero emission building are taken. Lifetime commissioning (LTC) has been recognized as a quality control tool for building energy performance through the entire system lifetime [1-3]. The relationship between the standards developed under the European *Energy Performance of Buildings Directive* (EPBD) umbrella and LTC is explained in [4].

Measurement and monitoring of the building energy performance can be challenging and expensive depending on the monitoring platform, the monitoring platform ownership, the age of the building, when the building monitoring platform was installed, etc. Due to the above mentioned importance of the energy measurement, the research work on building performance energy monitoring has initiated different activities, Annex 47, Cost-effective Commissioning for Existing and Low Energy Buildings [5] and Annex 53, Total Energy Use in Buildings: Analysis and Evaluation Methods [6].

The aim of this article is to show the total electricity use in two low energy office buildings in Norway. A few years of energy monitoring data are presented. The research work on these low energy buildings has been reported to Annex 53.

Building descriptions

Detailed data have been collected for two low energy office buildings in Norway through the research project Lifetime commissioning for energy efficient operation of buildings [7]. The detailed building data were collected by using LTC procedures, which are explained in [4]. These two analyzed buildings are located in Trondheim and Stavanger. Both buildings are role model buildings for the Norwegian Energy Efficiency Agency [8].

The first building is a low energy office building in Trondheim, Norway, with a heated area of 16 200 m². The design outdoor temperature is -19°C, while the average annual outdoor temperature is 6°C. The building has been in use since September 2009. Since then the number of occupants has been increasing. Eight variable air volume (VAV) systems were installed in the building with a maximum air volume from 12 500 m³/h to 22 000 m³/h. Specific air flow rate was 8.9 m³/h/m². A brief overview of the installed VAV systems is given in **Table 1**. The overview gives the performance of the installed ventilation systems, which includes air flow rate, fan power, and specific fan power of the entire ventilation system (SPF_e).

All the ventilation systems in **Table 1** were VAV systems with modern Static Pressure Reset Demand Control Ventilation (SPR-DCV) that is frequently called *optimized* VAV [9]. In the low energy office building in Trondheim heating was provided by radiators, while cooling of the IT rooms was provided by fan-coils. The heating energy for ventilation, space heating, and domestic hot water was supplied by district heating and heat pumps. There were two heat pumps installed. The first heat pump was a reversible heat pump providing part of the heating energy for ventilation in the winter period, while in the summer period the evaporator of the heat pump provided cooling for ventilation.

Table 1. VAV systems in the office building in Trondheim.

System ID	Air flow rate		Fan power		SFP_e (kW/(m³/s))
	Supply fan (m³/h)	Exhaust fan (m³/h)	Supply fan (kW)	Exhaust fan (kW)	
36.01	22 000	22 000	7.47	6.89	2.17
36.02	22 000	22 000	7.47	6.89	2.17
36.03	20 000	20 000	6.30	5.83	2.01
36.04	20 000	20 000	6.30	5.83	2.01
36.05	15 000	15 000	4.68	4.28	1.97
36.06	18 000	18 000	6.50	5.88	2.30
36.07	14 500	14 500	5.07	4.53	2.21
36.08	12 500	12 500	3.97	3.52	1.99

Table 2. Ventilation systems in the office building in Stavanger.

Ventilation system	Air flow rate		Fan power		SFP_e (kW/(m³/s))
	Supply fan (m³/h)	Exhaust fan (m³/h)	Supply fan (kW)	Exhaust fan (kW)	
360.010	90 000	90 000	38.8	41.6	4.64
360.011	75 000	75 000	32.6	32.7	4.69
360.012	90 000	90 000	38.8	41.6	4.64

This heat pump is a water/air heat pump and it supplies eight heating/cooling coils in the air handling units given in **Table 1**. Depending on the evaporation and condensation temperatures, maximum heating capacity of the condenser can be 550 kW, and maximum compressor power 150 kW. This heat pump has three compressors, which are step-wise controlled. The second heat pump was a cooling plant which provided cooling for IT rooms, while the condenser heat was utilized to support heating. This cooling plant has a maximum heating capacity of the condenser of 260 kW, maximum compressor power of 60 kW, and maximum evaporator load of approximately 200 kW depending on the evaporation and condensation temperatures. Detailed information of the first case building can be found in [10].

The second case building is located in Stavanger, Norway, where the design outdoor temperature is -9°C, while the average annual outdoor temperature is 7.5°C. This building has been in use since June 2008 and is rented as an office building. The heated area of the building is 19 623 m² and it was designed for 1 200 occupants. Currently, there are about 1 000 occupants. The ventilation system consists of three variable air ventilation systems, where the maximum air volume is 90 000 m³/h for two ventilation systems and 75 000 m³/h for the third system. A brief overview of the installed ventilation system is given in **Table 2**. Specific air flow rate was 12.9 m³/h/m².

The three VAV systems operate with constant air pressure. The higher SFP_e in **Table 2** could be explained by an additional pressure drop in double façade. In the second case building, the fresh air was supplied to offices and then extracted via a central atrium. The extracted air was used for heat recovery in ventilation and finally extracted through double façade. Heating is provided by radiators and ceiling panels, while cooling is provided by fan-coils. Heating energy for ventilation, space heating, and domestic hot water is supplied by district heating and supported by condenser heat. Cooling energy is supplied by two cooling plants. Heat realized from the cooling plant condensers is used as additional energy for heating. This way, the cooling devices are at the same time heat pumps. The installed heat pumps are frequency controlled. The installed cooling capacity of one heat pump is 200 – 600 kW and the compressor power 50 – 130 kW, while the cooling capacity of the second heat pump is 420 – 1200 kW and the compressor power 120 – 300 kW. Detailed information of the second case building can be found in [11].

Hourly electricity use

The first case building is equipped with a high number of energy meters, which include measurement of electricity for light, appliances, ventilation, etc. The second case building has a lower number of energy meters, but a higher data quality of the energy measurements. Before the hourly profiles of electricity use are presented, the issues in measurements and data logging are explained.

Issues in energy measurement

The first case building located in Trondheim is equipped with 74 energy meters, where 66 meters are for electricity and eight meters are for heating and cooling measurements. The technical platform for the energy measurement was separated from the building energy management system (BEMS). Therefore, there is no history of the energy measurements in the BEMS of the first case building. These energy measurements were transferred to an energy savings company database. The use of two different technical platforms for building management and energy monitoring, where energy consumption had not been logged in the BEMS, could be an issue. This issue can be explained with poor functional integration, because the labeling of the system and components in the energy service company was slightly different than in BEMS and it might be that what was shown as the compressor electricity use was that of another equipment. Specifically, it can be difficult to estimate energy use of equipment that has its own control unit. Such equipment can be heat pumps, cooling plants, and air handling units. Even thought equipment manufacturers guarantee good data transfer from the equipment control unit to the BEMS, there can be many problems in the data transfer. Challenges in heat pump performance estimation are reported in [12], while other issues and data reliability are explained in [13].

Electricity use

The hourly profile of the electricity use in the office building in Stavanger for one week in September 2009 is shown in **Figure 1**. In Figure 1, electricity use profiles are summed up. The electricity use was independent of the outdoor temperature, but instead determined by the building users. In average over the year, hourly electricity profiles were varying from 180 kW during non-occupied periods to 550 kW during occupied periods. By comparing hourly electricity use profiles over several years, it was found that the hourly electricity profiles were quite similar as in **Figure 1**.

In **Figure 1** it is possible to notice that both fans and cooling plant contribution to the total electricity use was low. Actually, electricity use was dominated by the use of appliances such as PCs. The reason for the low energy use of the cooling plant was that the heat pumps were oversized (for the current purpose) as explained in [14]. Most of the year, one heat pump was working and the second heat was shut down. For example, in 2009 both heat pumps were in use only 116 hours. In August 2011, most of the PCs in the building were replaced by laptops and the operation time of the ventilation system was decreased by one hour. These measures resulted in decreasing the hourly electricity profiles to approximately 160 kW during non-occupied periods and to 460 kW during occupied periods. Results of these measures on the total electricity use will be shown in the next Section.

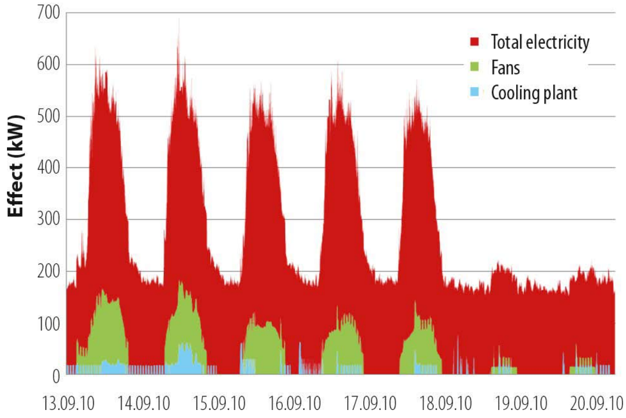


Figure 1. Hourly profiles of electricity use in the office building in Stavanger.

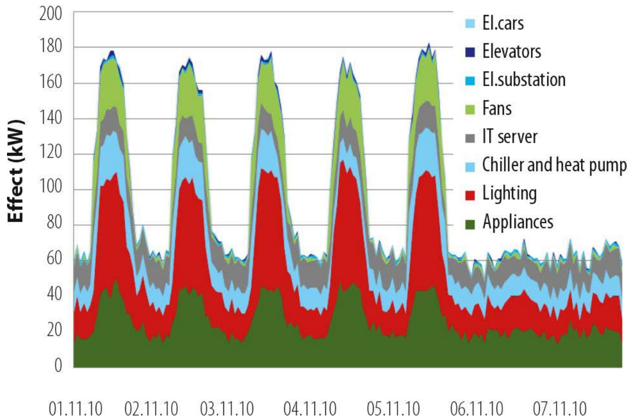


Figure 2. Hourly profiles of electricity use in the office building in Trondheim.

The hourly profile of the electricity use in the office building in Trondheim for one week in November 2010 is shown in **Figure 2**. The electricity use in **Figure 2** was summed up by the purpose of the electricity use.

In **Figure 2** *El. substation* implied electricity for circulation pumps and additional devices necessary for the substation operation. In the case of the office building in Trondheim, electricity use was also independent of the outdoor temperature, but instead determined by the building users. In average over the year, hourly electricity profiles were varying from 70 kW during non-occupied periods to 200 kW during occupied periods. The electricity consumption of the fans was determined by the building users as it is possible to notice in **Figure 2**. The VAV systems were controlled by presence sensors, meaning the fans were operating only when there were users in the building. The electricity consumption of the heat pump and chiller was quite constant as shown in **Figure 2**. The reason for this was that the heat pump

Table 3. Specific electricity use in the office building in Trondheim.

Purpose	Appliances	Light	Cooling plants	IT server	Fans	Substation	Elevators	El.cars
Specific use (kWh/year/m^2)	15.1	14.3	8.4	6.4	6.0	1.0	0.3	0.1

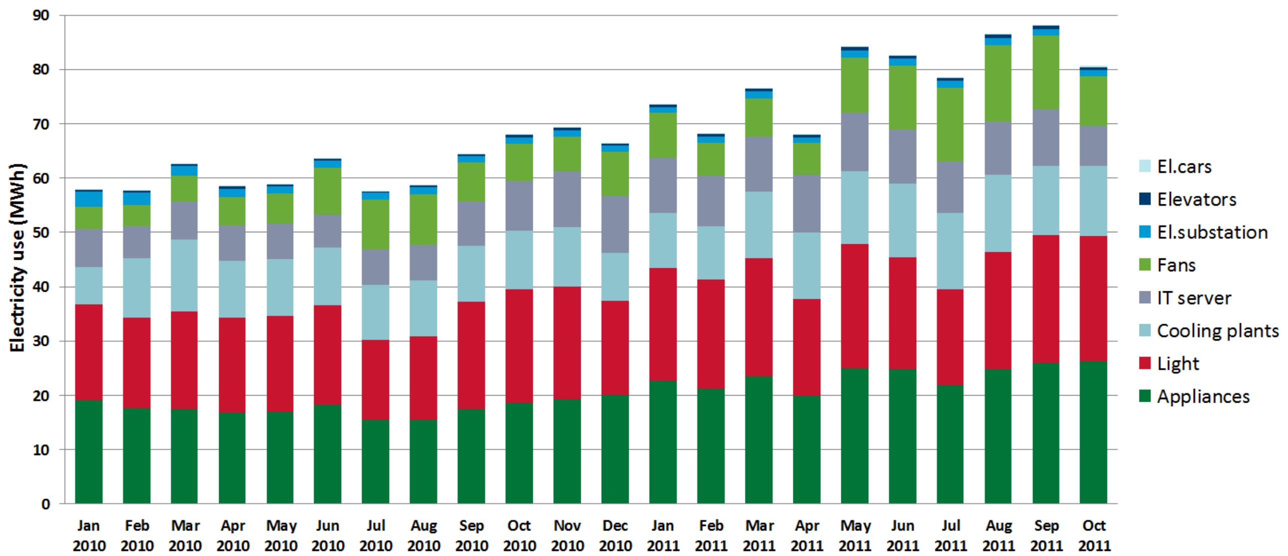


Figure 3. Total electricity use for the office building in Trondheim.

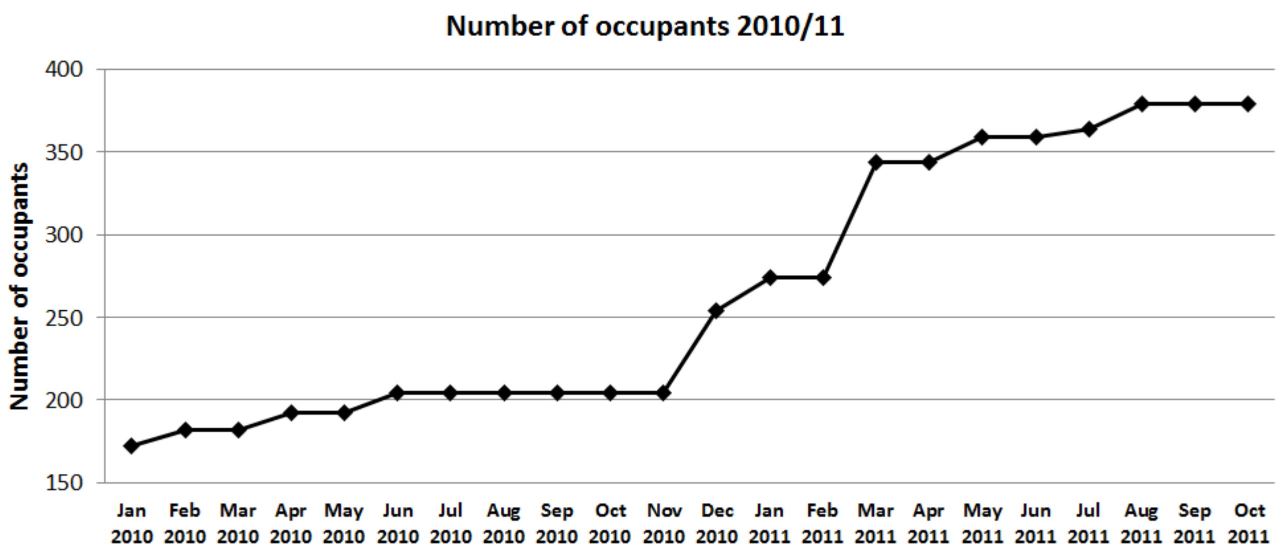


Figure 4. Number of occupants in the office building in Trondheim.

and chiller were oversized and the compressors were in operation all the time at the lowest step and thereby using constant power. In **Figure 2**, it is possible to notice that appliances, lighting, chiller, heat pump, and IT server contributed mostly to the hourly profiles during non-occupied periods as well as during occupied periods.

Total electricity use

The total electricity use for the office buildings in Trondheim and Stavanger are shown in **Figure 3** and **Figure 5**, respectively. Recall that the number of occupants increased in the office building in Trondheim, as shown in **Figure 4**.

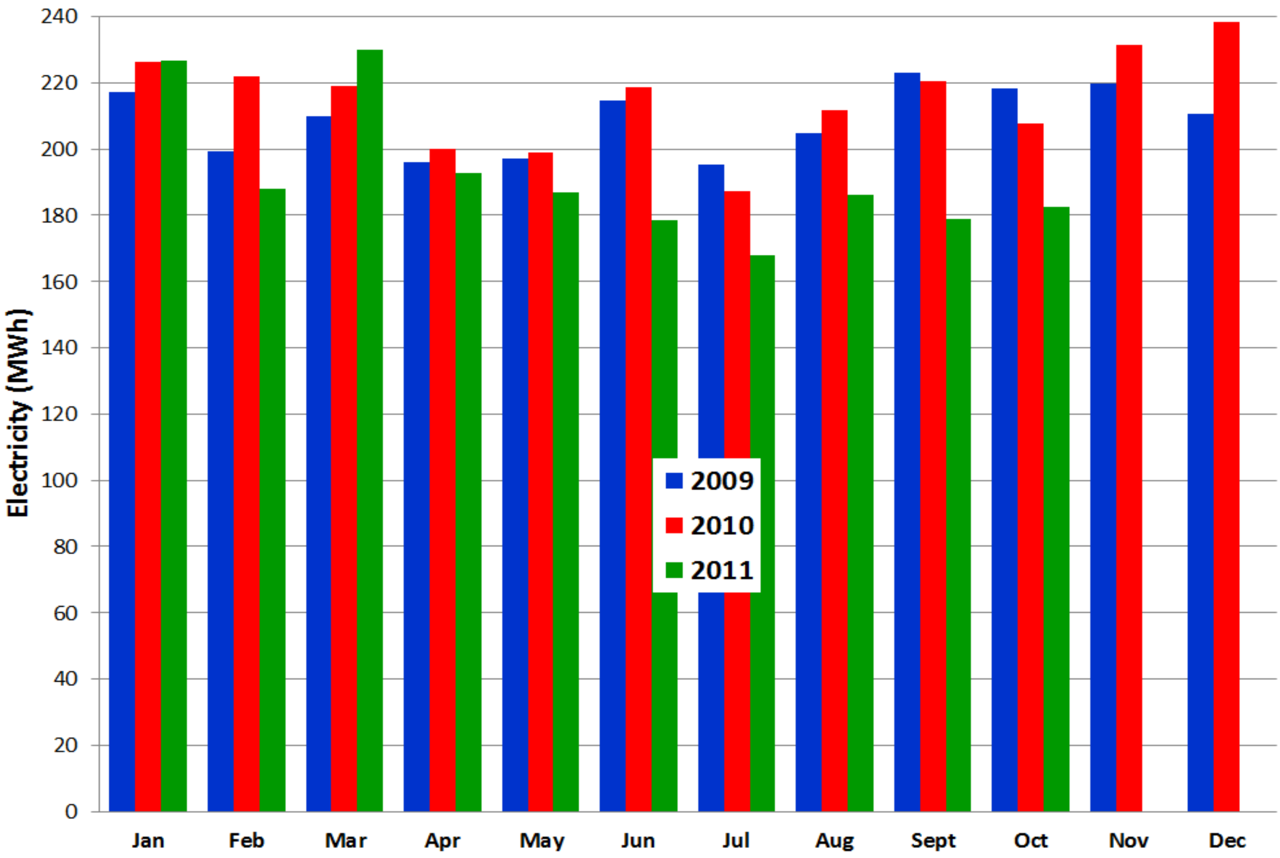


Figure 5. Total electricity use for the office building in Stavanger.

By comparing the results in **Figure 3** and **Figure 4** it is possible to notice that the total electricity use increased with an increase in the number of occupants. Further, in **Figure 3**, it is noticeable that appliances, light, cooling plants, and electricity for the IT server contributed the most to the total electricity use. This could also be assumed based on the hourly profiles in **Figure 2**, because appliances, light, cooling plants, and IT server were dominating in the hourly profiles. Finally, specific electricity use for the office building in Trondheim per m² is given in **Table 3**. The results in Table 3 are sorted based on the highest specific use.

The total electricity use over three years for the office building in Stavanger is shown in **Figure 5**. Two energy saving measures were implemented in this building since August 2011, as mentioned before. These measures decreased the hourly electricity profiles and resulted in a 30 MWh decrease in the total monthly electricity use.

Conclusions

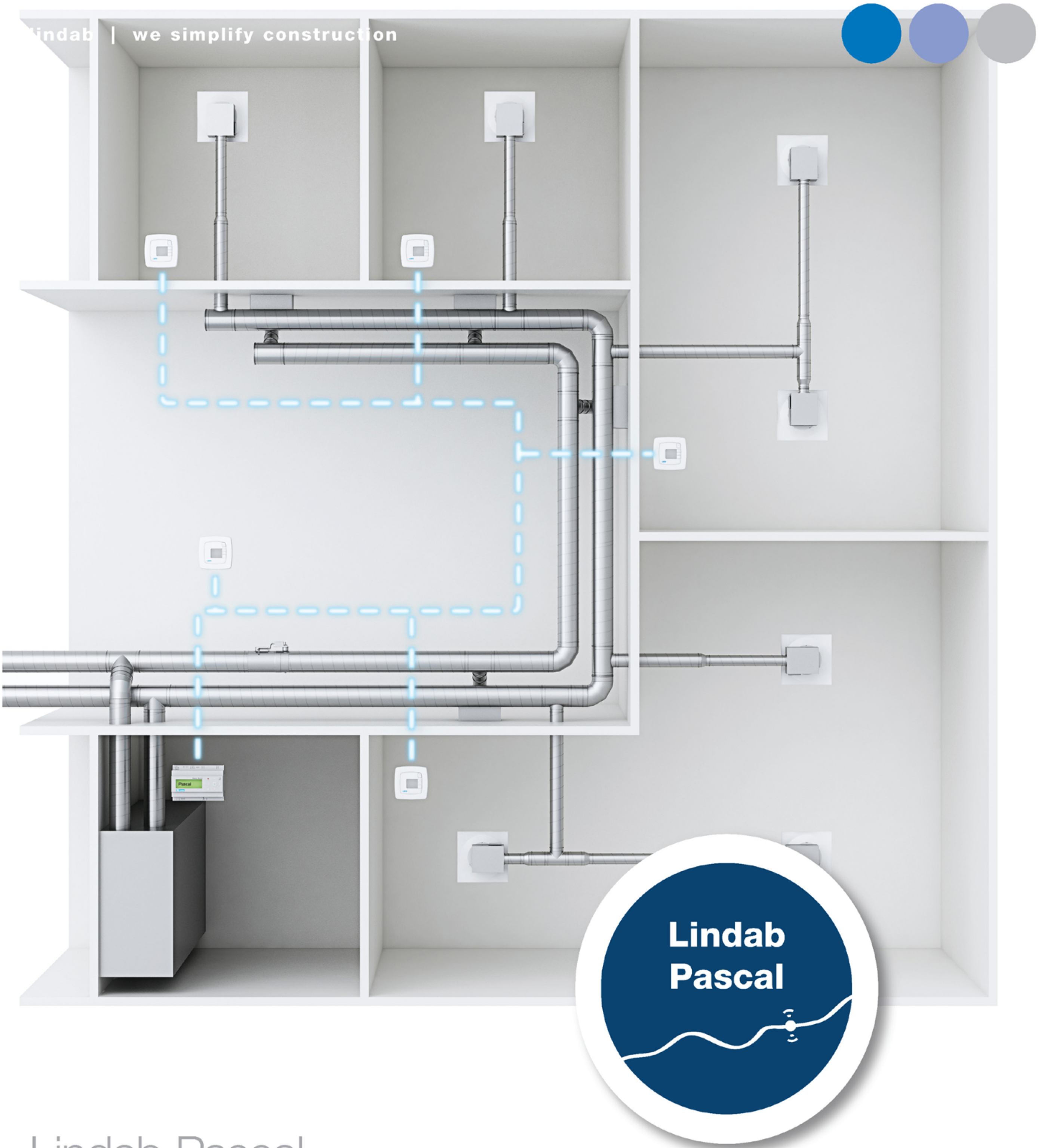
The article presented electricity use in two low energy office buildings in Norway. Appliances, light, cooling plants, and IT server seemed to dominate to the total electricity use of the low energy buildings. The reasons for the relatively high electricity use of the cooling plant were oversizing plant and the choice of plant unsuitable for its current purpose. Results for the office building in Trondheim showed that the *optimized* VAV system resulted in an electricity use for the fans of 6 kWh/year/m². Results on the electricity use in the office building in Stavanger showed that simple energy efficiency measures gave a definite decrease in the total electricity use. The results of our research on LTC showed the importance of proper energy measurements to enable proper decision making, energy labeling, and proof of concepts.

Acknowledgements

This work was financially supported by the Research Council of Norway and the other members of the project: Life-Time Commissioning for Energy Efficient Operation of Buildings (project number 178450/s30). The authors are thankful to Lars O. Nord, NTNU, for English proofreading.

References

See the complete list of references of the article in the html-version at www.rehva.eu -> REHVA European HVAC Journal



Lindab Pascal

Simplified VAV solution with full potential...

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

Lindab - We simplify construction...

Lindab®

www.lindab.com

Energy efficient and low CO_2 office building

Pellervo Matilainen
Design Manager M&E
Skanska
Pellervo.Matilainen@skanska.fi

Miimu Airaksinen
Research Professor
VTT, Finland
miimu.airaksinen@vtt.fi

Reduction of energy use reduces both the primary energy use and $CO_{2\,eq}$ emissions.

Current office buildings are becoming more and more energy efficient. In particular the importance of heating is decreasing, but the share of electricity use is increasing. When the CO_2 equivalent emissions are considered, the emissions from embodied energy make up an important share of the total, indicating that the building materials have a high importance which is often ignored when only the energy efficiency of running the building is considered. This paper studies a new office building in design phase. The results showed that the reduction of energy use reduces both the primary energy use and $CO_{2\,eq}$ emissions. Especially the reduction of electricity use has a high importance for both primary energy use and CO_2 emissions when fossil fuels are used. The lowest $CO_{2\,eq}$ emissions were achieved when bio-based, renewable energies or nuclear power was used to supply energy for the office building. Evidently then the share of $CO_{2\,eq}$ emissions from the embodied energy of building materials and products became the dominant source of $CO_{2\,eq}$ emissions.

Introduction

The ambition in sustainable development of the built environment is to reduce the harmful impact of the nature of materials and building energy use [1]. Often the building energy use and the minimization of its $CO_{2\,eq}$ emissions are considered to be the desired goal. However, as the energy use decreases the importance of $CO_{2\,eq}$ emissions originating from building materials and products increases. Thus, what kind of materials and building products are used becomes more important [3]. In addition, the minimization of $CO_{2\,eq}$ emissions is perhaps not the only desired target, but we need to consider also the minimization of primary energy use, since it highlights rather well the use of natural resources.

The aim of the study is to

1) Find out the different available options in the design phase in order to minimize the energy consumption;
2) Consider how the $CO_{2\,eq}$ emissions from the embodied energy from building materials and $CO_{2\,eq}$ emissions from energy use in the building should be treated;
3) Consider how we should weight the primary energy use and the $CO_{2\,eq}$ emissions of different design options. In this study is a real office building was studied.

Methods

The studied building is an office building located in Helsinki developed by Skanska Commercial Development Finland. The building was under design phase and the aim was to study different alternatives in order to choose the most energy and environmental efficient way to erect the building. The gross floor area of the nine storey building is 26 000 m². The geometry of the building is quadratic. The studied properties are shown in **Table 1**.

The buildings were modelled in a dynamic IDA simulation environment [2]. The building model was the architect's real 3D model but the building spaces were simplified to 43 different zone models each representing typical uses of the space type, such as office rooms, meeting rooms, cafeteria, etc.

Embodied Carbon in Materials

The embodied CO_2 includes energy consumption of building materials and products, the use of raw materials and greenhouse gases. The most important greenhouse gases are fossil fuel derived CO_2, CH_4 and N_2O.

Table 1. Studied design alternatives. The control systems include ventilation and lightning.

Feature	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Building envelope excl. windows	Building Code 2010	Building Code 2010	Building Code 2010	Building Code 2010	Building Code 2010	Passive house
Windows (W/m²K)	1.0	1.0	1.0	1.0	0.7	0.7
Ventilation heat recovery	70%	70%	80%	80%	90%	90%
LED lighting	in garage	in garage	in garage	in garage	in all spaces	in all spaces
Systems control level	building	room	room	building	room	room

In the 2010 Building Code the U-values for external walls is 0.17 W/m²K, base floors 0.16 W/m²K, roofs 0.09 W/m²K and doors 1.0 W/m²K. The ventilation heat recovery requirement in the 2010 Building Code is 45%, which was not used in calculations, since that was not an option in the design phase. In the so called passive house level the U-values for external walls is 0.08 W/m²K, base floors 0.15 W/m²K, roofs 0.08 W/m²K and doors 0.7 W/m²K.

Table 2. Primary energy factors and CO_2 equivalent emissions used.

	Primary Energy Factor	CO_2 equivalent*
District heating average	1.87	0.22
District heating bio	0.4	0.12
Electricity average	1.87	0.38
Electricity from district heating average	1.87	0.38
Peak electricity from nuclear power	2.8	0
Peak electricity from coal	2.0	0.928
District cooling	0.25	0.12
Green electricity	0.2	0

* Unit: kg CO_2/kWh.

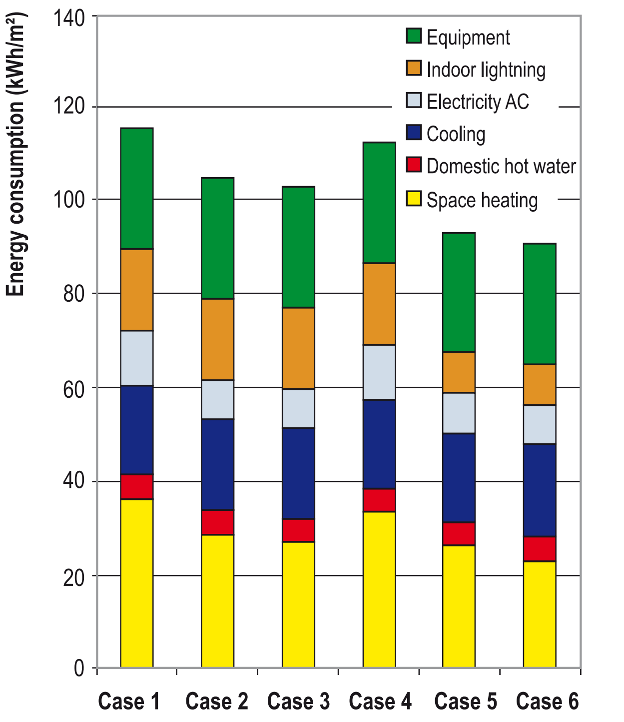


Figure 1. Yearly energy consumption in different cases. Electricity AC represents for electricity for air conditioning systems.

In the calculations the greenhouse gases are transformed to $CO_{2\,eq}$ by using IPCC's characteristic factors.

Energy Sources and their CO_2 Equivalent Emissions and Primary Energy

The studied alternatives for energy and their CO_2 emissions are shown in **Table 2**.

The service life for building was assumed to be 50 years. The embodied CO_2 emissions from building materials and process were estimated according to design drawings.

Results

The energy consumption was highest in the case 1 and lowest in the case 6. But the energy consumption in case 4 was also really high, being nearly the same as in the case 1 and showing that the building level control is inefficient with respect to energy saving. In particular the heating energy consumption is the highest when the control is at the building level. The energy consumption was 20% lower in case 6 compared to case 1. The only difference between cases 3 and 4 was the temperature control. In case 3 the control was at the room level, while in the case 4 the control was at the building level. That resulted in a 7% difference in total energy consumption and a 20% difference in space heating, in addition the difference in cooling was also 20% between those two cases (**Figure 1**). Since in office buildings the electricity use has higher importance than heating, case 6 does not have that much difference in consumption, even though the insulation values are much better (equal to passive house). The major difference between cases 3 and 5 was the LED lightning, in case 5 all lightning was done by LEDs, which clearly resulted in a lower energy consumption.

The Finnish Building code is very advanced with respect to reducing heat losses from buildings; e.g., the U-values and ventilation heat recovery, as well as air tightness of the building envelope, are required to be rather good. This can be clearly seen from the energy consumptions (**Figure 1**). The CO_2 equivalent emissions of heating are also rather low due to the low energy consumption when average Finnish district heating, cooling and electricity are used as energy sources (**Figure 2**). In **Figure 2** heating includes both space heating and domestic hot water.

Due to the low heating energy consumption the embodied CO_2 emissions and electricity are dominant components in the CO_2 emissions. That is actually rather surprising, since case 1 is the typical building code level in new office buildings, and only ventilation heat recovery is clearly better than the average in new buildings. In this study the embodied CO_2 includes energy consumption of building materials and products, and the use of raw materials and greenhouse gases.

Evidently, if all the electricity used is generated from renewable energy sources and for district heating and cooling bio-fuels are used, the embodied CO_2 emissions have the highest share and the over all CO_2 equivalent emissions decrease dramatically (**Figure 3**). However, the problem with renewable electricity is that the power plants produce renewable energy on a yearly basis. Thus, sometimes the electricity might originate from fossil fuels for a short period of a time if not enough electricity from renewable sources is available. The electricity produced by fossil fuels is substituted by renewable energy on a yearly basis to get the balance. Usually this means excess energy, e.g., from wind power.

Figure 4 shows the primary energy consumption as a function of the relation between embodied and energy-derived $CO_{2\,eq}$ emissions. The $CO_{2\,eq}$ embodied corresponds to the $CO_{2\,eq}$ emissions from materials during their lifetime and $CO_{2\,eq}$ energy corresponds the $CO_{2\,eq}$ emissions from energy use in the building (heating, cooling and electricity). When all different options for heating, cooling and electricity sources were compared it can be clearly seen that the nuclear-based energy alternatives all ended up with rather high primary energy consumption and since the building energy use is carbon neutral, the embodied CO_2 emissions become dominant (**Figure 4**).

If low primary energy is the target, then bio-based district heating systems seems to be effective as well as the use of electricity from renewable energy sources. Ground heat or the average local heating performed rather similarly in respect to primary energy use. This is because the ground heating systems use electricity but

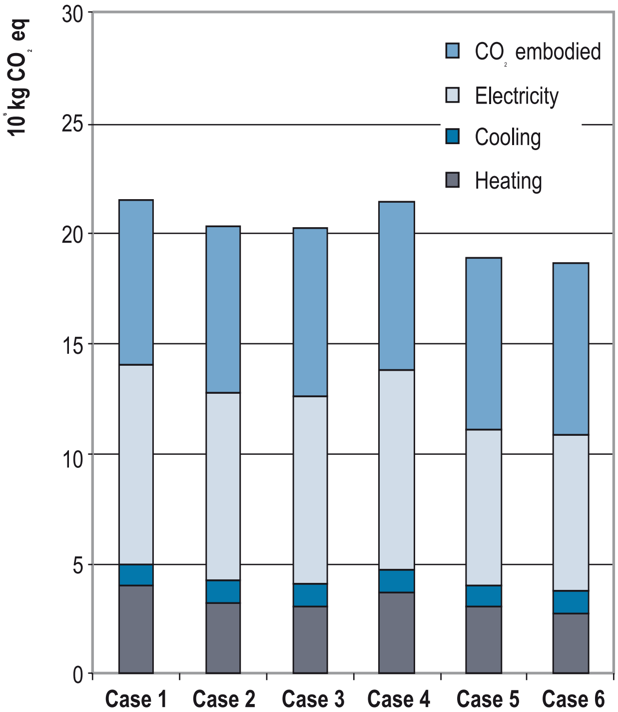


Figure 2. The share of each energy consumption and embodied CO_2 in different cases when average district heating, cooling and electricity are used. The heating includes both space heating and domestic hot water heating.

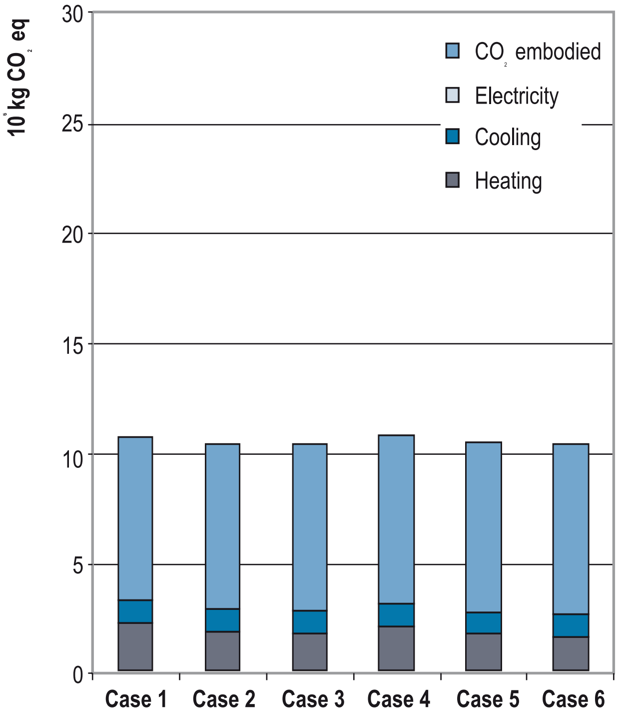


Figure 3. The share of each energy consumption and embodied CO_2 equivalent in different cases when district heating, cooling from bio-fuels is used and electricity is from renewable energy sources.

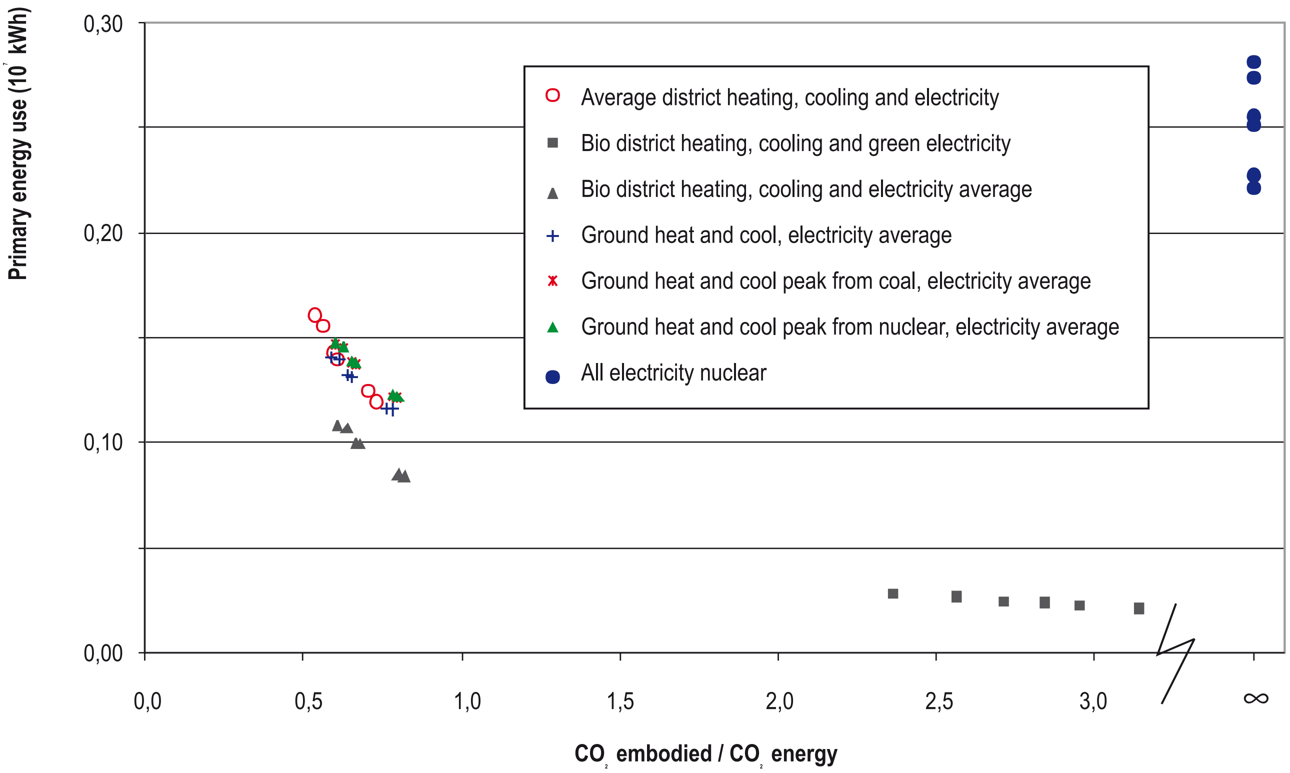


Figure 4. Primary energy consumption as a function of the relation between embodied and energy derivated CO_2 equivalent emissions.

they can utilize the "free" thermal energy obtained from the ground. It can be seen that the local variations do have an effect on both primary energy use and $CO_{2\ eq}$ emission; in some parts the average Finnish values do have a good correlation to local energy production, but in some places the local production is closer to biomass-based production and in other locations closer to peak conditions. The lowest primary energy use is in alternatives based on bio local heating, cooling and green electricity. The lowest relation between $CO_{2\ eq}$ embodied and $CO_{2\ eq}$ energy in addition to low primary energy use was with the cases based on bio local heating, cooling and average electricity. When average electricity or nuclear energy based electricity was used, there was a clear trend in that energy saving gave the highest primary energy use savings.

Discussion and Conclusions

The reduction of energy use reduces both the primary energy use and CO_2 emissions. The reduction of electricity use has a high importance for both primary energy use and CO_2 emissions when fossil fuels are used. Often energy originated from fossil fuels is also used as a complimentary source of energy, thus the importance of reducing energy use and especially electricity originated from fossil sources has a high priority.

The lowest $CO_{2\ eq}$ equivalent emissions were achieved when bio-based, renewable energies or nuclear power was used to supply energy for the office building. Evidently then the share of $CO_{2\ eq}$ emissions from embodied energy from building materials and products became the dominant source for CO_2. The lowest primary energy was achieved when bio-based local heating or renewable energies were used in addition to local cooling. Obviously the highest primary energy was when nuclear power was used. When the primary energy use and $CO_{2\ eq}$ are minimized the $CO_{2\ eq}$ originated from materials become rather dominant. In this study the $CO_{2\ eq}$ emissions originated from building materials and products is between 2.4 to 3.1 higher compared to $CO_{2\ eq}$ emissions originated from building energy use during running time.

References

[1] Citherlet, S.; Clarke, J.A.; Hand, J. Integration in building physics simulation. Energy Build. 2001, 33, 451–461.

[2] IDA Simulation Environment. Available online: www.equa.se

[3] Jonsson, A. Tools and methods for environmental assessment of building products—methodological analysis of six selected approaches. Build. Environ. 2000, 35, 223–238.

[4] Airaksinen M., Matilainen P., 2011, A Carbon Footprint of an Office Building Energies, Energies, 4(8), 1197-1210

How to reach less than 15 kWh/m² annual final energy use for HVAC in an office building

J-C Léonard
EDF R&D – Energy in Buildings and Territories Department.
Site des Renardières. Avenue des Renardières – Ecuelles.
77818 Moret sur Loing CEDEX – France.
jean-christophe.leonard@edf.fr

P Pedrocchi
Image et Calcul. 11 rue Alfred de Vigny
25000 Besançon.
pp@image-calcul.fr

The activity of the HDL Company, located in Besançon (France), is to renovate buildings. HDL wanted to show its expertise in energy efficiency in the most credible possible way: by applying it to its new headquarters. In 2008, HDL refurbished an old school (2 036 m²) to establish its new offices. HDL wanted an exemplary operation: reach less than 15 kWh (final energy)/m².year for HVAC consumptions. EDF offered them support by measuring the site energy performance. In this article, we describe the technical characteristics of the building and the HVAC systems in place. Then, for each end-use, we present two years of energy and performance measurements: ground source heat pumps, distribution pumps, ventilation, lighting and others uses. We show the improvements made during these two first years of operation. Finally, to generalize this field case to other refurbishment operations, we propose eleven rules to be applied to achieve this level of consumption. So far and according to our information, this renovation operation remains the most efficient one in France.

Figure 1. HDL's Headquarters.

Building

Habitat Développement Local (HDL) has acquired the former school Jean-Jaurès (2 036 m²) in Besançon (**Figure 1**) and completed a partial expansion to install offices and

Figure 2. Chilled beam during installation.

Figure 3. AHU with rotary exchanger.

create a central building housing the various departmental structures of Habitat. The activity of the company includes renovating and leasing out buildings. Concerned by sustainable development, HDL wanted to show its clients how to master energy efficiency in the most credible possible way: leading by example.

The consultants Image & Calcul, based in Besançon, were entrusted with the task of rehabilitating the site with an ambitious goal: to keep consumption under 50 kWhEp/m^2.year (Ep: primary energy) for the Heating, Ventilation and Air Conditioning (HVAC) in a region known for its harsh winters (temperature of –13°C) and its hot summers. A high level of energy efficiency was required in terms of energy efficiency.

Minimizing all requirements: heating, cooling and lighting

Losses under base conditions are 65 kW, or 32 W/m^2. Reinforced insulation in opaque walls –part of the insulation is made from the outside– results in U coefficients around 0.25 W/m^2.K. In addition to 20 cm of mineral wool, roof insulation is completed with 8 cm of wood wool (U: 0.14 W/m^2.K). Here the goal is to reinforce thermal inertia in the roof for comfort in summer. Indeed, in addition to its low thermal conductivity, wood wool benefits from high mass density and thermal capacity. In summer, the heat coming from the roof is therefore delayed by 5 to 7 hours, after employees have left the offices.

Windows are aluminum with argon-filled double glazing (Uw: 2 W/m^2.K). The surface area is limited, covering 28% of the façade on average. This type of glazing is a good compromise between a low solar factor (38%) to limit solar contribution and high light transmission (70%) to promote natural lighting. The upper part of the interior office walls have translucent panels that allow light to pass through to the central walkways. To minimize energy consumption due to lighting, motion detectors were installed in all walkways and service areas. They also control HVAC in meeting rooms.

Installing high efficiency equipment

Distribution terminals are chilled beam modules (**Figure 2**). These are cassettes without fans that require neither filters nor condensation trays. Maintenance is therefore quite simple. These cassettes are operating at high temperature in summer (17°C) and low temperature in winter (35°C). Pretreated air in the central unit is brought into the beams via buses that pass the air over the batteries by induction.

Losses related to air renewal are minimized: Air Handle Unit (AHU) is equipped with a high efficiency rotary heat exchanger with 80% efficiency (**Figure 3**). The two fans are equipped with variable speed drive. Hygroscopic coating on the recuperator humidifies new air in the winter and dries it in the summer.

Figure 4. Water/water heat pumps.

Figure 5. Geothermal probes.

Hot and cold water are produced by two glycol/water heat pumps (**Figure 4**). The heating power of each is 32.6 kW, cooling power is 25.4 kW for absorbed power of 7.2 kW (COP of 4.5 at 0°C/35°C). A 9 kW electric heater is installed on the loop in order to prevent imperfection in implementation of insulation in the rehabilitation. Heat pumps are connected to a field of ten vertical geothermal probes, each penetrating to a depth of 100 meters (**Figure 5**). The size of the field was based on 50 W/ml. In winter, water coming from the probes travels to the heat pump evaporators. In summer, priority is given to the geo-cooling mode: water from the probes supplies the cooling battery of the AHU and the comfort modules, via a heat exchanger. In this case, the building is cooled without electric compression.

In case of heat wave, the heat pump supports the geo-cooling mode. The schematic diagram allows possible heat evacuation from the heat pump condenser to the vertical probes. Most of the circulation pumps are equipped with variable speed drive.

Finally, in addition to motion detectors, T5 type lighting is used. The cost of HVAC part, with the vertical geothermal probes, was 194 €HT/m².

Remarkable result

Final consumptions for all uses reach 50.1 kWh/m².year. HVAC consumptions represented less than a third with 14.5 kWh/m².year (or 37.5 kWhEp). HDL has improved the set goal (50 kWhEp/m².year) despite a harsh winter. Other uses represent two thirds of consumption, or 36 kWh/m².year, ten of which are related to lighting (**Figure 6**).

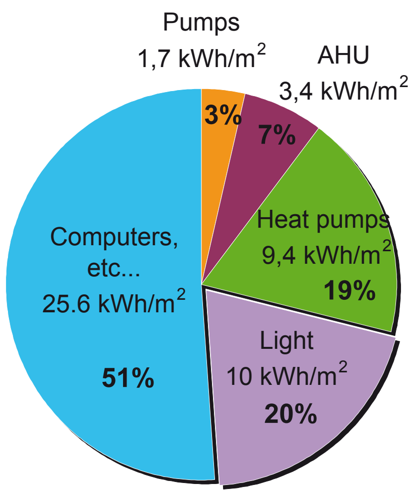


Figure 6. Distribution of annual consumption by use.

Heat pumps are operating under excellent conditions: their average annual COP machine is 4.2 and close to 4 when including consumption of the pump that irrigates the geothermal probes. Despite the cold weather during the winter of 2009–2010, electric output was never required. Geo-cooling was able to provide necessary cooling (**Figure 7**).

Table 1 shows the changes of consumption rate between the first and the second year of operation. The improvements come from better settings, especially concerning programming intermittency, detection of air flow leaks in ventilation pipes, cleaning clogged pump filters, lowering condenser temperature, etc.

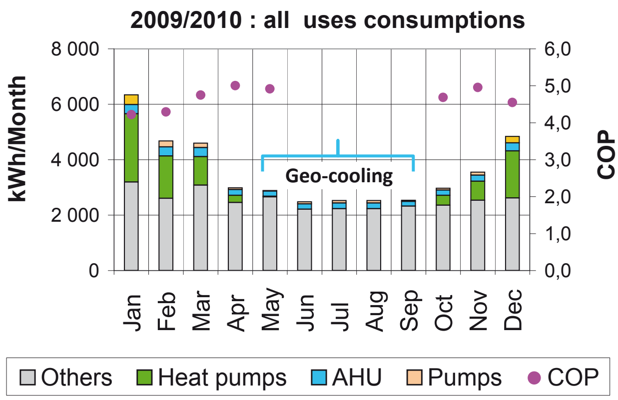


Figure 7. Monthly changes by uses and COP of the heat-pump.

"Class A" in terms of greenhouse gas emissions

When including lighting consumption, this site reaches a class B energy label, and class A in terms of greenhouse gas emissions. A gas boiler and air/water cooling unit solution (performance estimated at 95%) would have been positioned in class B also, but in class B concerning greenhouse gases emissions. The vertical geothermal solution reduces CO_2 emissions by two-thirds.

Competitive operating budget

Geothermic solutions have a clear advantage over fossil fuels in terms of operating costs: MWh of heat from the heat pumps is around 28 € Tax Free/MWh (set premium included, the site has a "yellow tariff" for electricity). With a gas boiler, it would have been close to 45 € Tax Free/MWh. Under these conditions, the costs of the energy station are particularly low, reaching 5.6 €/m², all uses included. The HVAC annual cost represents 1.9 €/m² with 1.3 for the heat pumps. It's remarkable. This operation shows that geothermic solutions are an excellent source of eco-efficient energy.

It has allowed HDL, with the involvement of all players, to achieve its ambitious target. Two bars that are difficult to achieve, in primary energy, were passed: 40 kWhEp/m².year for HVAC and 130 for all uses. In comparison to the various studies carried out by EDF R&D and current literature on the subject, in our opinion, this renovation project has the best performance in the country in terms of energy eco-efficiency.

Conclusions

HDL wanted an exemplary refurbishment for its headquarters in terms of energy efficiency. This operation shows that we can, at reasonable costs (HVAC = 194 €/m²) reach less than 15 kWh/m².year for HVAC and less than 25 including lighting. To achieve these levels of consumption on others operations, it will, whenever possible, be necessary to apply the eleven following principles:

- Insulate the walls at 0.25 W/m².K;
- Insulate the roof at 0.15 W/m².K;
- Install windows with Ug of 1.1 W/m².K, preference for PVC;
- Limited the glazed surface to 30% of the vertical walls;
- Systematize for lighting, the installation of T5 tubes with presence detection;
- Install a double flow AHU with rotary exchanger;
- Choose auxiliaries (pumps and fans) with variable electronic speed;
- Install - the cornerstone of all - thermodynamic machine with a COP close to 4 (water table or vertical probes according constraints on site).

If these technical points are followed with these organizational measures:

- Regular controls on site during refurbishment phase;
- Scrupulous (even zealous…) commissioning;
- Energy monitoring at the first start in winter,
- then, the renovation will, certainly, be a success.

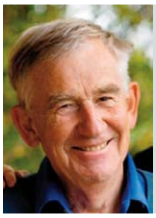
Table 1. Comparison of consumption between the first and second year of operation.

Consumptions by use	First year "First commissioning"	Second year "Refinement settings"
Pumps	2,5	**1,7**
AHU	4,8	**3,4**
Heat pumps	12,5	**9,4**
HVAC	19,8	**14,5**
Others	37,8	**35,6**
Total	57,6	**50,1**
Heating needs	52	**43**
Cooling needs	3	**6**
COP*	3,8	**4,15**
Degrees days (Average thirty 2555)	2594	2486

kWh/m2.year

* : including the pump that irriguates the probes

Energy-Efficient Passive House using thermal mass to achieve high thermal comfort



Loa Andersson
Managing Director
RLI Byggdata AB
rli@termodeck.com

Alexander Engström
Technical Director
RLI Byggdata AB
alex@termodeck.com

Gösta Lindström
Technical Manager
Dr. Sc.Civil Engineering
AB Strängbetong
Gosta.Lindstrom@strangbetong.se

Introduction

A five-storey apartment building in South-Western Sweden shows that by active usage of thermal mass a low energy consumption and high thermal comfort is achieved at a normal building cost.

Description of the project

The project called "Lärkträdet" is situated in the Swedish town Vara, around 100 km North-east of Gothenburg. The building was designed as a passive house (according to Passive House codes by Swedish Energy Agency) and planned for elderly persons (all people are above 75 years old) and was taken into operation in June 2010. The total area (Atemp)[2] is 1 242 m² of which 830 m² is living floor space. The basement consists of storage areas, one common area, heating and electrical equipment room (heat pump, etc) and four floors with apartments. On each floor there are four flats, two with a size of 50 m² and two with a size of 54 m². On the roof there is a terrace, solar panel installations and the mechanical plant room. See **Figure 1** and **Figure 2**.

Figure 1. External view from South-East.

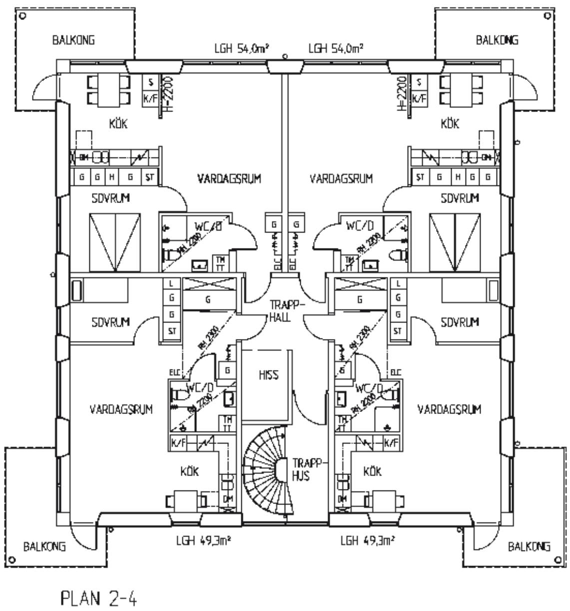


Figure 2. Floor plan.

Structural system

The building envelope consists of well-insulated and load-bearing pre-fabricated sandwich wall elements (150 mm concrete, 250 mm EPS, 70 mm concrete) supporting the floors of 200 mm deep hollow core concrete slab elements. The insulation thickness is the same practically everywhere as the slabs are supported on the inner

2 The area in m² is based on Atemp which is the total floor area measured inside the external wall heated to more than 10°C.

part of the concrete wall. Therefore, the cold bridges are very low. Other passive houses have normally an insulation thickness above 400 mm. See **Figure 3**.

The wall and slab are then cast together. This construction forms a very airtight building without having to use any tape for sealing of membrane joints. The ground floor slab consists of 250 mm concrete on top of 300 mm EPS insulation, The roof has an average insulation of 400 mm EPS. To verify the air tightness the Royal Institute of Technology pressure tested the whole building in May 2010. The result at a pressure of 50 Pa, was 0.27 l/s per m² of building envelope area.

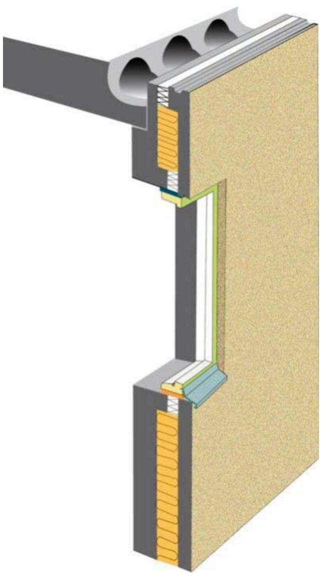


Figure 3. Facade element from Strängbetong.

HVAC system

The HVAC system consists of mechanical supply and exhaust air with a thermal wheel heat recovery unit. The building is using the TermoDeck system for ventilation, heating and cooling, where the supply air is passing through a labyrinth inside the hollow core slab before entering the room. See **Figure 4**. The AHU is placed on the roof. The supply air leaves the AHU at a temperature between 13 and 27°C depending on the outdoor temperature. There is a separate supply air duct from the

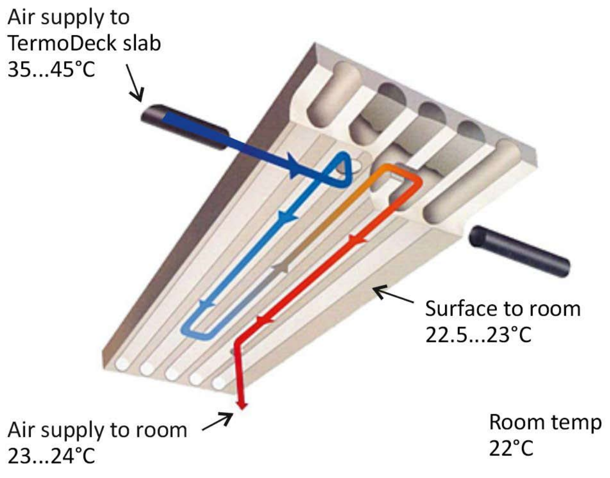


Figure 4. TermoDeck slab in heating mode.

AHU to each apartment which has a heating coil in the supply air duct placed above the false ceiling in the bathroom or entrance. There is also a short bulkhead in the bedroom. The rest of the supply air route sits inside the slab. The supply air temperature can be heated to maximum 49°C. The supply air flow to the apartments varies between 0.40…0.50 l/s, m² residential floor area.

The heating coil is regulated by a thermostat inside the apartment which allows the tenant to adjust the indoor temperature between 20 and 23°C. There are three supply air diffusers in each apartment, two in the living room and one in the bedroom. See **Figure 5**.

Figure 5. View from living room.

The exhaust air is removed from the bathroom. In the kitchen there is a separate exhaust from the cooker hood not connected to the AHU used when cooking food.

Each bathroom is equipped with an electric towel rail (connected to household electricity).

Heating and hot water system

Heating is generated from a ground source heat pump (8.4 kW electrical power with an estimated yearly COP of 2.7), designed to cover at least 90% of the energy consumption) which is complemented by an electric heating coil (9 kW) to be used as back-up and during the coldest period. The building has no radiators and the apartments are heated by hot air which can be supplied at a temperature up to 49°C.

16 solar panels with a total area of 37 m² facing West and South are installed to provide hot water. Around 50% of the hot water is designed to be generated from the solar panels.

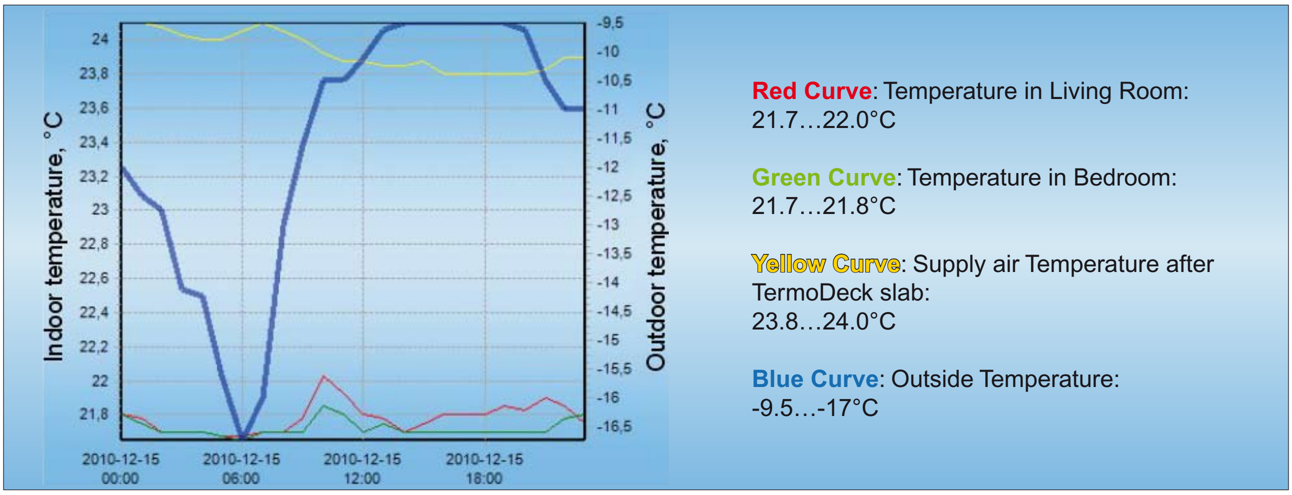


Figure 6. Temperatures in Apartment 3C facing North-East with supply temperature 42…48°C after the heating coil (into the slab). Scale for indoor temperatures on left and outdoor temperature on right.

Passive houses and thermal mass

Passive houses are built to reduce energy usage as they are well insulated, low infiltration rates and energy efficient HVAC-systems. However, they rarely have high thermal mass which in combination with high passive energy gains mainly from solar heat can lead to overheating and poor thermal comfort. Further, previous research shows that there are many advantages with heavy constructions such as lower indoor temperatures during the summer months and lower energy and peak power requirements.

In order not to exceed the mandatory requirement for passive houses of 10 W/m² of heating demand the window area cannot be too big and the insulation in walls (normally >400 mm), roof (normally >500 mm) and ground (normally >300 mm) must be quite thick. The wall thickness required depends to a large extent of the level of cold bridges.

How thermal mass is influencing the indoor thermal climate

As the TermoDeck system is used for ventilation, heating and cooling, the supply air (after its passage through the hollow core slab) is never above 24…25°C when entering the room even when the supply air to the hollow core slab is 49°C. See **Figure 6**. The risk of overheating the bed rooms is thus eliminated and a better and more even indoor climate is achieved as the heat is distributed more uniformly from ceiling and floor to the whole apartment. Warm surface areas also assure a high thermal comfort.

Overheating is also reduced as cool night air temperatures down to 13°C can be supplied which dissipates the heat accumulated during day time and cools down the slab making it possible to absorb heat the next day. Due to an incorrect adjustment in the air handling unit the minimum supply air temperature was set to 18°C. See **Figure 7**.

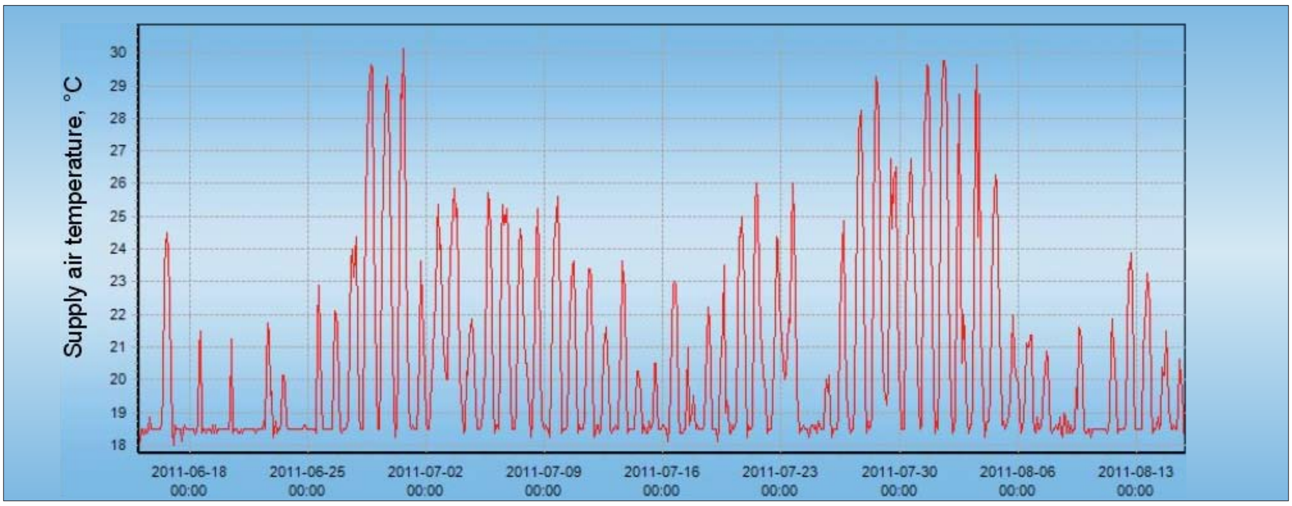


Figure 7. Supply air temperature.

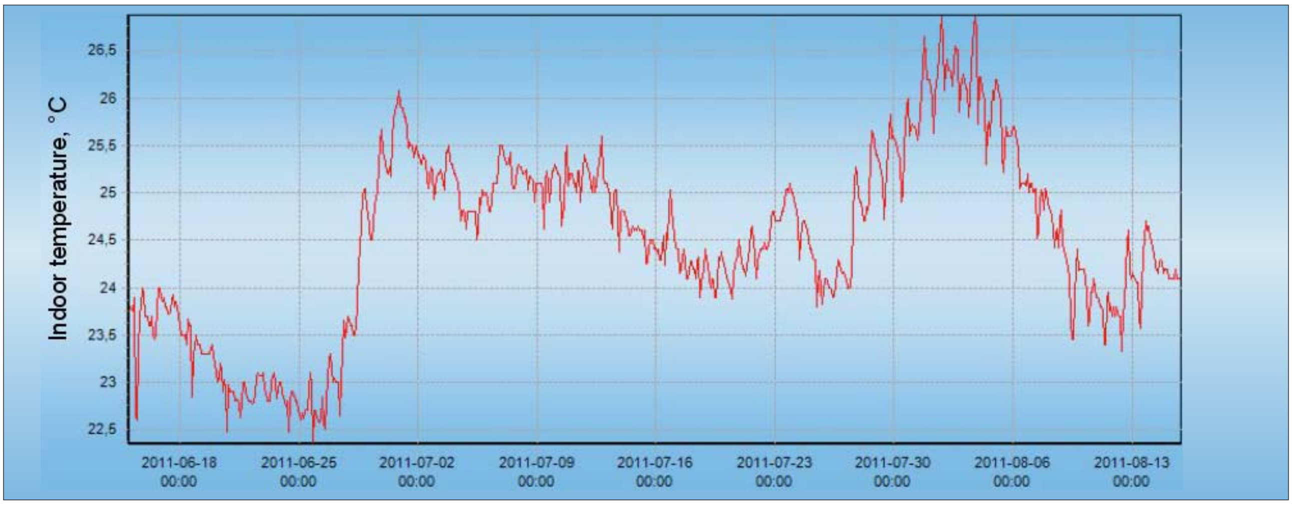


Figure 8. Indoor temperatures in Apartment 2A. Situated on the 1st floor. South-West orientation.

This was supposed to have changed during 2011 but the problem still exists. Despite this, the indoor temperature in a South-West apartment on the 1st floor has not exceeded 26°C for more than 90 hours during the year (well below the advice of 440 hours for Passive House codes). See **Figure 8**. The maximum temperature has never exceeded 27°C. The indoor temperatures in apartments facing NW and NE have never exceeded 26°C. The outdoor temperature was peaking at around 30°C during this period (the average outdoor temperature during July was 2°C higher than normal). During the hottest times, cold has been heat recovered from the exhaust air. In order to achieve these relatively low temperatures, the mid-pane blinds have probably been drawn and the tenants have probably opened the windows. When the AHU is adjusted correctly, the maximum indoor temperature is estimated to exceed 26°C for around 30…40 hours.

By using a well insulated and air tight building together with a high degree of available thermal mass (due to exposed concrete slabs and walls) the building's time constant is high (above 350 hours). The dimensioning outdoor temperature can therefore be reduced from -18°C down to -10°C according to the specifications for passive houses in Sweden

Comparison between heavy and light-weight building

A master's thesis – carried out at Mälardalens Högskola, Sweden - examined Lärkträdet. First, a theoretical model of Lärkträdet was created in the simulation software IDA Indoor Climate and Energy to conduct a preliminary mapping of its energy use. Then, the building frame was changed from its heavy original in concrete (not using TermoDeck) to a lighter version based on a wooden stud construction in order to compare how the building's indoor climate and its energy and power requirement would differ if the building was built using a lighter frame.

With a minimum temperature of 22°C in the whole building the energy consumption for heating was 7.4% higher for the wooden stud construction compare to the heavy construction according to the simulation.

In comparison with the wooden stud construction, the greatest advantage of the concrete construction was found to be its considerable better indoor climate. In the wooden stud construction the operative indoor temperature was outside of acceptable boundaries for a studied apartment unit in the building for almost four times as many hours (673 vs. 175) as in the concrete construction. The operative indoor temperature is also much more stable in the heavy building. An apartment with windows in South and West was studied. For example, in the light-weight building the indoor temperature is above 26°C even in March. (**Figure 9**).

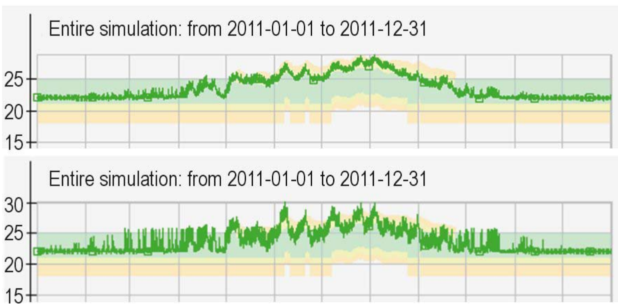


Figure 9. Simulated indoor temperature in the original concrete construction is more stable and comfortable (top) than in the building with light-weight wooden stud construction (below).

Energy consumption

Total purchased electrical energy was designed to be 30.5 kWh/m^2 (Atemp), year. For the first year, the measured value was 37.9 kWh/m^2, year. This value is continuously decreasing and for the period Dec 2010 to Nov 2011 the value is 33.1 kWh/m^2, year. (Each period is twelve months). The purchased electrical consumption between June and November 2011 has decreased by 25…40% on a monthly basis compared to the same period 2010. Normal year correction for heating has not been done. When item 4 is taken into account (2…3 kWh/m^2 reduction), the building has dried out and items 2, 6 and 7 (see under next heading) have been sorted out the total purchased electrical energy is expected to be around 28 kWh/m^2 for a normal year. See next heading and **Table 1** and **Figure 10**.

Differences between designed and real data

The input data used during the design of the project was compared to the real measured data. All simulations have been carried out with the software IDA Indoor Climate and Energy.

1. The efficiency of the heat exchanger was calculated to be 80% in the design. When measured it seems to be around 73%. Simulated yearly increased **heating** consumption: **2.5 kWh/m^2** (Atemp). (Not expected to be reduced).
2. The room thermostats were originally installed from the manufacturer on a range from 17...27°C leading to high indoor temperatures (above 23°C) during winter. This was changed to maximum 23°C in June 2011. However, indoor temperatures have still been above 24°C in October 2011 so the thermostats don't seem to work properly (as the heating coil is still on). Indoor design temperature was 21°C.Simulated yearly increased **heating** consumption: **2...3 kWh/m^2**.

Table 1. Electrical Energy Consumption divided on different energy meters (kWh/m^2, year) on 2010-2011.

	July-June	Nov-Oct	Dec-Nov	Expected
Ground Source Heat Pump	17.9	16.8	16.1	13.5
Electric Coil for Water tank	5.6	3.3	2.8	1.9
Fans	5.6	5.6	5.6	5.6
Property Electricity[2] (excl. fans)	8.8	8.7	8.6	7.0
Total Purchased Electrical Energy[3]	37.9	34.4	33.1	28.0

2 Property electricity is the electricity paid for by the landlord (for lifts, common areas, lights in stair ways and outdoor, etc).

3 Purchased electrical energy includes all energy used by the property except the household electricity that is paid for by the tenants (lights, electrical appliances, etc).

3. Internal heat gains are less than the specifications for passive houses used for the simulation. The household electricity has been measured for each apartment. There are 16...17 persons living in the building. Simulated yearly increased **heating** consumption: **3.5 kWh/m^2**. (Not expected to be reduced)
4. Actual mean outdoor temperature during the first heating season is 3°C less than the weather year used for the simulation. Simulated yearly increased **heating** consumption: **5...6 kWh/m^2**. (This will vary from year to year). Compared to a normal year the consumption would decrease by **2...3 kWh/m^2**.
5. The SFP of the fans is measured to 2.0 kW/m^3,s. It was designed to be 1.6 kW/m^3,s. Calculated yearly increased **electrical** consumption: **1.0 kWh/m^2**. (Not expected to be reduced).
6. An electric coil placed outside the heat pump used to heat up the hot water in the hot water tank was used excessively. When the hot water circulation was stopped (after 7 months) the electrical consumption was heavily reduced from 900 down to 300 kWh per month. Estimated yearly increased **electrical** consumption: **3.7 kWh/m^2.**

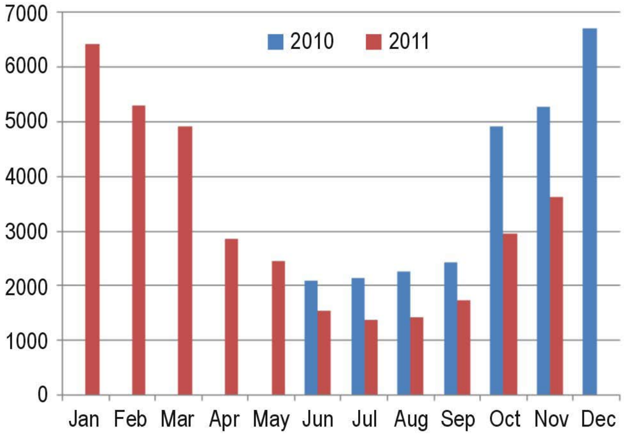


Figure 10. Purchased Electrical Energy Consumption during 2010 and 2011 (kWh).

Temperature Design Data:

* Design Winter Outdoor temperature: -18°C
* Design Summer Outdoor temperature: 27°C
* Designed Mean Annual Outdoor temperature: 7.0°C
* Actual Mean Annual Outdoor temperature (Oct 2010 – Sep 2011): 6.0°C
* Designed Mean Outdoor temperature during heating season (Oct – Mar): 1.5°C
* Actual Mean Outdoor temperature during heating season (Oct 2010 – Mar 2011): -1.5°C
* Indoor design temperature: 21°C.

7. A leaking pump in the basement has led the pump to work for several hours each day. This is reported to have been solved on Nov 10 2011.Estimated yearly increased **electrical** consumption: **1.7 kWh/m².**

Construction costs

The total construction cost for Lärkträdet is around 19 350 SEK per m² of residential floor area excl. VAT. It is difficult to compare against other conventional buildings as the cost depends on several aspects such as type of contracting form, size of project, areas included in the price (parking places, common areas, etc), choice of standard in bathrooms and kitchens. However, the cost increase does not seem to be higher than maximum 5% compared to conventional building costs (using water radiators and less insulation).

Conclusions

- The measurements from Lärkträdet shows that the indoor temperature is very similar in different rooms within the apartments all year around.
- The active usage of thermal mass leads to:
  - An even temperature throughout the apartment without risk of overheating
  - Very stable indoor temperatures also during hot and cold periods
  - Few hours with high temperatures during summer months
- The passive house requirements can be achieved with 25.0 mm insulation in the walls if cold bridges are kept low.
- Low energy multi-family residential buildings don't have to cost much more than conventional designs.

Project data

Name: **Block name "Lärkträdet"**

Location: **Allegatan 24, 534 32 Vara, Sweden**

Function of the building: **Apartment building**

Developer and Owner: **Vara Bostäder AB**

Architect: **Vara Byggkonsult AB**

Contractors:

Main contractor: **Tommy Byggare AB**

Sub-contractor: **AB Strängbetong** (as for the building frame and envelope including TermoDeck.

Total Area: **1 242m²** (830 m² of residential floor area divided on 16 apartments).

Building envelope area: **1 339 m²**

Windows from the wall area: **16%**

U-values of construction components

Building Components	U-values
Facade Wall (including cold bridges)	0.21 W/m², K
Basement Wall	0.18 W/m², K
Ground	0.12 W/m², K
Window incl. frame	0.90 W/m², K
Roof	0.087 W/m², K
Infiltration	0.27 l/s, m² of Building Envelope Area at 50 Pa
Average U-value ((incl. cold bridges)	0.27 W/m², K

Passive houses in Sweden

Requirements of Passive Houses according to codes by Swedish Energy Agency:

- U-value of windows should be at least 0.9 W/m², K
- Air leakage rates of 0.30 l/s per m² façade at 50 Pa
- Heating demand at dimensioning outdoor temperature (DUT) shall be max 10 W/m² (for Southern Sweden).

Advice:

- The maximum yearly energy consumption is 60 kWh/m². (This figure is reduced to 30 kWh/m² if electricity is used for producing heating and hot water – such as using heat pumps, etc. This figure includes everything except household electricity used by the tenants).
- Heat Exchanger Efficiency (including losses in shafts, due to unbalanced air flows, etc) of at least 70%.
- Indoor temperature from April to September shall not exceed 26°C more than maximum 10% of the time (=440 hours).
- The ventilation system should have an SFP-value of maximum 1.5 kW/(m³/s).
- Property electricity shall be maximum 10 kWh/m².
  (The m² area is the total area= Atemp)

Lindab Pascal

- a new simplified VAV solution with full potential

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

Lindab Pascal lower your energy use. Never before have energy use and indoor climate been this high on the agenda. The fact that energy use in the building sector accounts for more than 40% of Europe's CO_2 consumption and that studies of modern office buildings shows that employees are only in their offices in 70% of their daily working hours gives every office building an increase demand for a flexible indoor climate solution. Lindab Pascal has a demand control function that via a presence sensor can detect if there is any presence in the rooms and go to a low non-occupancy airflow level to optimize the energy consumption.

Lindab Pascal is a solution that makes it more simple to fulfil the needs for a well functioning VAV system. The solution is basically based on volume flow regulation which makes it a variable pressure system. Unlike constant pressure systems in the market today the duct layout is of less importance and the need for regulation equipment is less. With a variable pressure system it is possible to obtain correct airflows in all parts of the system and in all operating conditions. In the heart of the Pascal solution you will find the MBBV box. The MBBV box regulates each diffuser in the system to correct airflow. The unique linear cone damper technology of MBBV, which makes it possible to handle up to 200 Pa with low sound level, combined with an integrated actuator with precise flow measurement, eliminates the need for any other regulation equipment between the fan and the MBBV box. All components used in the solution are with standard settings from factory and can easily be adjusted and commissioned after installation. With only a few standard components, no special requirements for duct layout and a flexible system set up, Pascal makes designing, installation and commissioning so much easier.

The demand for VAV systems in modern construction is increasing and with good reason. VAV systems in general save a lot of the energy used for transportation and cooling of air. With the Pascal solution it is possible to lower the energy consumption even more. Instead of a traditional pressure regulation of the fan, the Pascal solution has a fan optimizer function that controls the fan speed of both supply and exhaust fan. The system makes sure that at least one damper in the system is 85% open, which ensures that enough air is available in all parts of the system, but at the same time ensures that the fan does not provide more pressure than necessary. For optimal fan control Pascal reads all damper positions at room level.

Visit Lindab.com

Lindab Pascal simplifies construction...

Contacts:
Anders G. Madsen
Lindab Comfort
Email: anders.madsen@lindab.com
Tel. +45 73 23 26 80

News from the European Commission

European Regulations

Regulation supplementing EPBD Directive 2010/31/EU on a cost optimal framework methodology for energy performance requirements in buildings

The Inter service consultation submission consists of two documents:

- The Draft supplementing Directive 2010/31/EU which establish a comparative methodology framework for calculating cost optimal levels of minimum energy performance requirements for buildings and building elements.
- Directive 2010/31/EU now stipulates that Member States shall ensure that minimum energy performance requirements are set with a view to achieving cost-optimal levels for buildings, building units and building elements using a comparative methodology framework established by the Commission, completed with the relevant national parameters.
- The Guideline provides relevant additional information to the Member States and reflects accepted principles for the cost.

Find documents on REHVA website under EPBD section cost efficiency paragraph:
http://www.rehva.eu/en/epbd#cost-eff

ErP Group Analysis: Lot 6 – Air conditioning and ventilation systems

The draft air conditioning reports task 4 and 5 of Lot 6 and of the Executive summary regarding the air conditioning part have been published. The European Commission will provide detailed comments to the contractor on the draft task 4 and 5 air-conditioner reports following the second stakeholder meeting on 30 September 2011. Regarding the draft reports tasks 1 to 5 for air conditioning and for ventilation comments are expected until 31 October 2011.

Eco-design of energy related products directive (ErP)

The Amended Ecodesign Working Plan will provide the European Commission and the stakeholders of the Consultation Forum with background information and analysis in order to establish the (second) Working Plan. The Working Plan sets out an indicative list of product groups which are considered priorities for the adoption of implementing measures under the Ecodesign Directive.

Download the full document on:
http://www.ecodesign-wp2.eu/index.html

Criteria proposal for Eco-label and GPP, Summary of the 1st AHWG Meeting – July 2011

The main purpose of this meeting was a discussion on the proposed criteria areas and not on the precise values or formulations of the criteria. The discussions at the 1st AHWG and the resulting feedback will form the input into development of the draft final criteria proposal for Eco-label and GPP. This draft final will be discussed in the 2nd AHWG Meeting that is planned in November this year in Brussels.

More detail on REHVA website

News News News News News News News N

European Commission supported projects

iSERV

This project aim to collect sub-hourly HVAC system energy use data from around 1 600 HVAC systems in the EU Member States and analyse this information.

iSERV project benefits are mainly:

- feedback on energy use patterns and comparisons with similar systems
- establish a detailed understanding of the energy consumption of HVAC systems
- how to improve in-use energy efficiency of HVAC systems
- identify performing systems to avoid their inspections

REHVA will play an active role to get participants enrolment in this project and disseminate the results of the study. Should you be interested in a direct participation, please do contact the project via the iSERV website http://www.iservcmb.info/ - or contact the project Coordinator, Dr Ian Knight, at knight@cf.ac.uk. See all details in the announcement on the Build Up portal: http://www.buildup.eu/news/15861

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

BUILD UP +

The Commission has decided to continue developing and updating the BUILD UP portal for building energy efficiency related information at least to the end of 2013. REHVA is one of the organisations updating the information at the portal. If you have interesting cases, publications or events go www.buildup.eu and upload your information.

Current status of the portal:

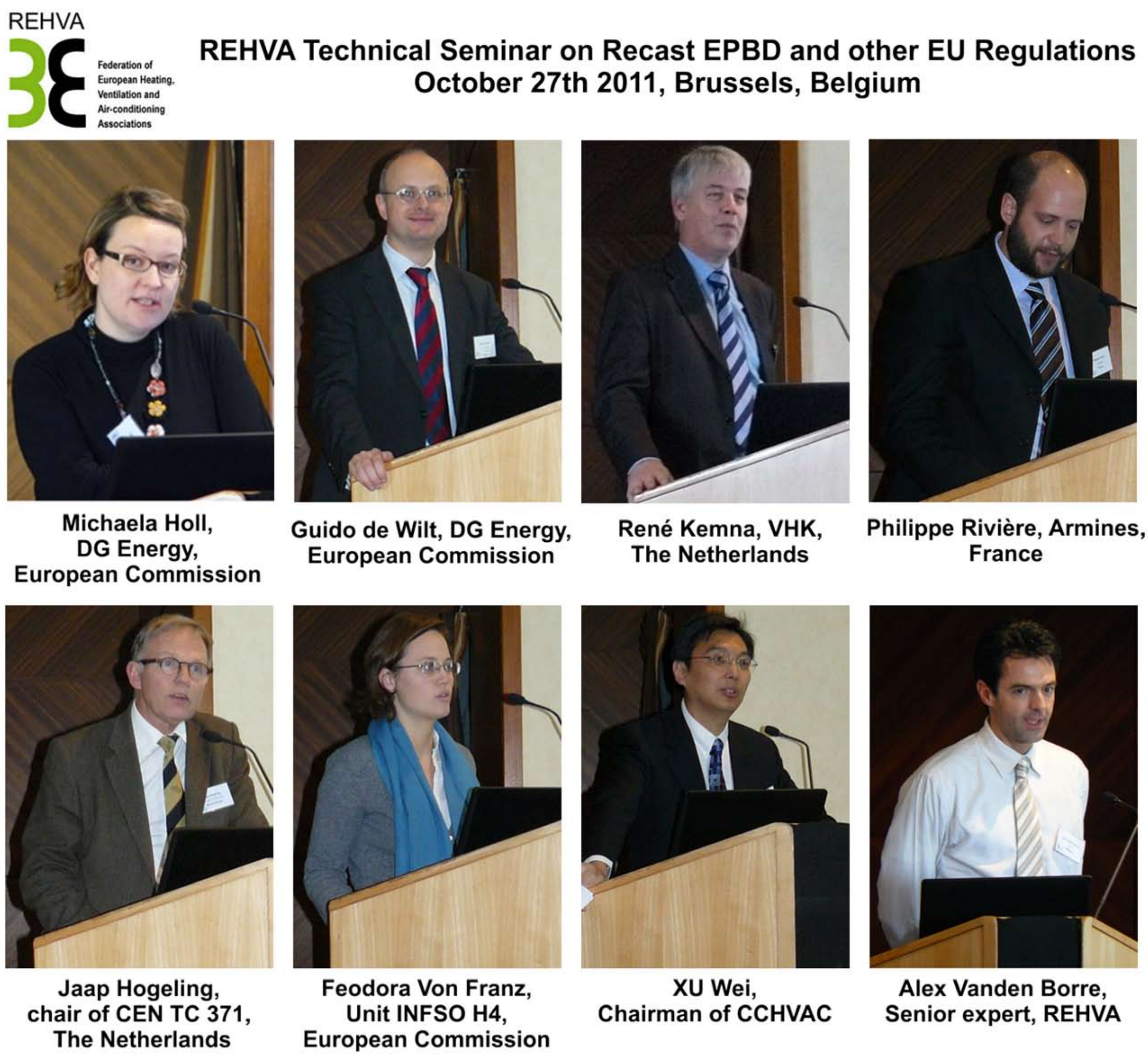
- Over 600 visitors a day
- English is the main language but material in all 23 EU languages is accepted (headlines in 22 languages)
- Search by language, theme, topic, keyword, date, country, etc.
- Status in July 2011: 2 047 publications, 182 cases, 155 tools, 59 upcoming events

Full presentations available at: http://www.rehva.eu/en/technical-information

REHVA Seminar on EU regulations related to energy efficiency of buildings

Summary by Alex Vanden Borre, Project Engineer, REHVA

The REHVA annual technical seminar took place in "The Hotel" in Brussels on the 27th October 2011. The seminar covered the "hot topics" related to energy efficiency from Commission legislation to the European standardization. The audience was delighted with the presentations.

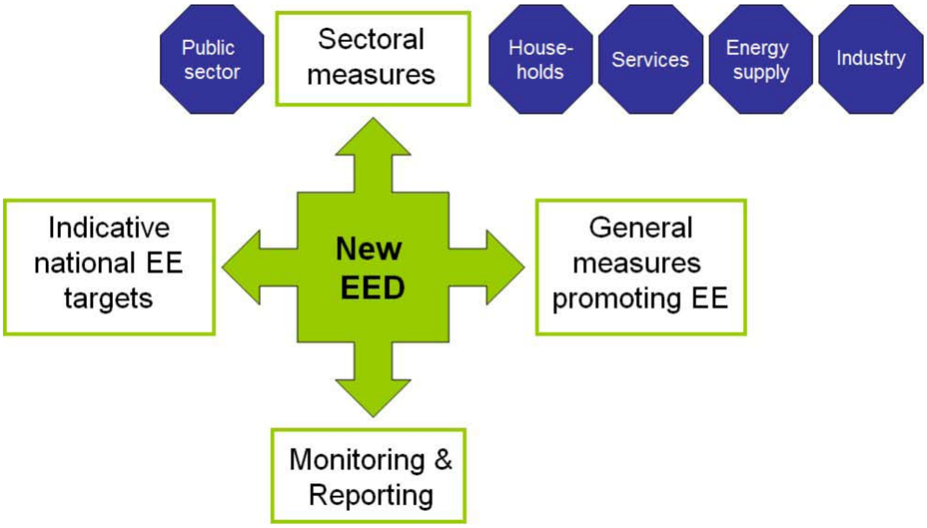


The prominent speaker in the REHVA annual technical seminar in Brussels explained to the audience important European and international activities related to energy efficiency of buildings.

Recent policy developments on energy efficiency in buildings

Michaela Holl, the European Commission, DG Energy

The proposal for a new **Energy Efficiency Directive (EED)** was adopted on 22nd June 2011. It will replace both the ESD (energy end-use efficiency and energy services) and the CHP (combined heat and power) Directives. Currently, it is in the hands of the Council and the European Parliament. The agreement is foreseen to be concluded during the Danish Presidency in the first half of 2012. In this version, no specific chapter on buildings is developed yet. The key concept of this policy is to set clear obligations to achieve targets: Member States have to make sure to reduce 1.5% annual energy sales through energy efficiency measures; annual renovation works must cover at least 3% of the total floor area of the buildings in the public sector (which is doubling the current rate in Europe); energy management needs strengthening with energy metering for consumers; etc.



A NEW IMPETUS IS NEEDED to promote energy efficiency: COMMISSION has PUT FORWARD A proposal for NEW ENERGY EFFICIENCY DIRECTIVE.

The public sector needs more stringent Energy Efficiency criteria to public spending in buildings. New legislative initiative will come on energy performance contracting including in the building sector. More highlights are made on training needs for the workforce.

The **Energy Roadmap for 2050** is expected to be adopted by mid-December 2011. The building sector has a crucial role as emissions potential reduction could be of 90% by 2050. The objective is to explore all options for decarbonising the EU's energy system with a target of 85% reduction compared to 1990 levels also exploring all energy efficient technologies, RES and increasing the cross border interconnections with more "intelligent" electricity grids.

The recast **EPBD** is currently under implementation in the member states (deadline July 2012). Member states have to report to the Commission by June 30th 2012 on financial and other supporting measures (same time as National Energy Efficiency Action Plans). CEN has received a new mandate from the Commission to revise 31 EPBD related CEN standards.

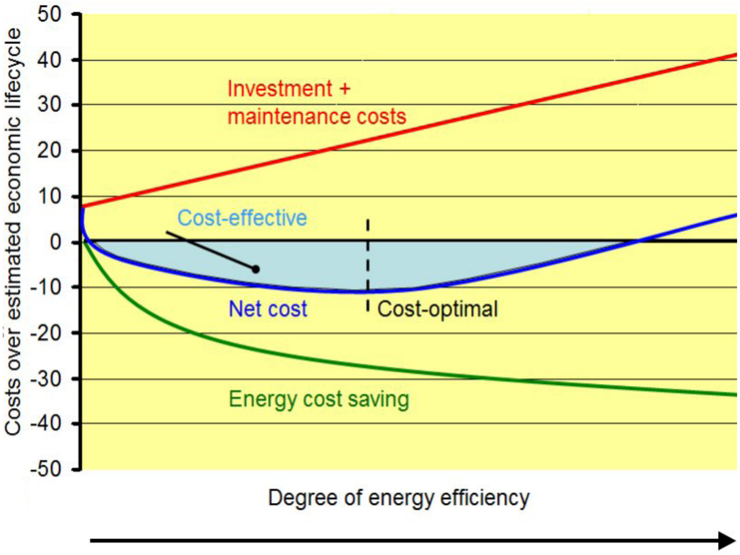
A **voluntary EU-wide certification** scheme based on recast EPBD article 11 for non-residential buildings is under development. Its adoption is planned for mid-2012. The idea of the 'Best in class' label is to compare the building with a highly efficient building, starting with national calculation methods to further develop a common EU calculation method based on CEN.

The Commission has announced its intention to **finance Energy Efficiency** in buildings up to 17 billion Euros or 20% of Structural Funds for 2014-2021.

The EU's cost optimal methodology framework

Michaela Holl, the European Commission, DG Energy

EPBD recast instructs Member States on how to set energy performance requirements achieving **cost optimal levels**. The Cost optimal level is the energy performance that leads to the lowest cost during the estimated economic lifecycle. 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, not by the market! An equivalent level of ambition is targeted in all MS but no harmonisation of requirements is needed. The cost optimality is also expected to become the reference point for EU funding (EEE-F, ERDF).



The Commission request member states to specify their regulations to be cost optimal. The Cost optimal level is the energy performance that leads to the lowest cost during the estimated economic lifecycle.

The EPBD establishes nearly zero energy target with nearly zero energy buildings defined as "buildings with a very high energy performance (…) and a very significant share of RES". But MS may not be obliged to set net cost effective requirements over the estimated economic lifecycle. The method still needs to ensure the phase-in of the NZEB and its technologies, it needs to adjust boundary definition in CEN standard so that active RES can be accounted and priority needs to be set on energy efficiency.

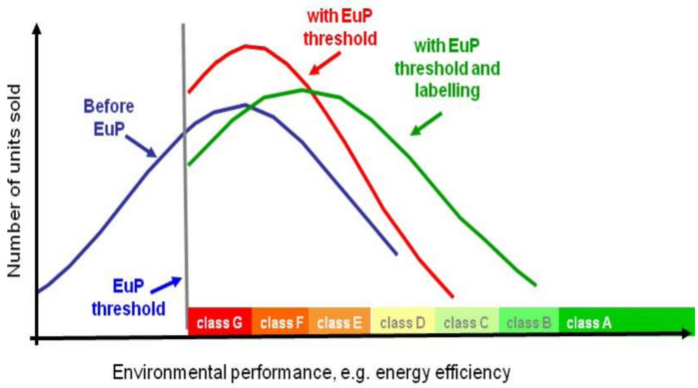
The **Commission determines** starting year, cost categories, calculation period, need for sensitivity analysis for energy prices and discount rate, defines term reference building and sets rules for selecting measures/packages. The **MS determine** primary energy factors, estimated economic lifecycle, cost input data, discount rate, establish reference buildings and select measures/packages, climate data, and decide on whether to include disposal costs/earnings from RES.

The cost optimal methodology is defined in 6 steps. The Commission's Joint Research Centre of Ispra performed tests and main lessons are that the proposed approach and guidance given can work, but cost optimal methodology has to be an iterative process to reach qualitative data with need to revisit input data, reference buildings and definition of measures.

Ecodesign and Labelling

Guido de Wilt, DG Energy, Unit C3, Energy efficiency & Intelligent Energy Europe

The **Ecodesign Directive (Ecodesign of energy related products – EuP and ErP)** - focus on the energy efficiency of products (supply side) - and the **Energy Labelling Directive** – focus on standard energy consumption of product (demand side) - are both addressing the use phase of products which has the larger impact on the environment as life cycle analysis shown.

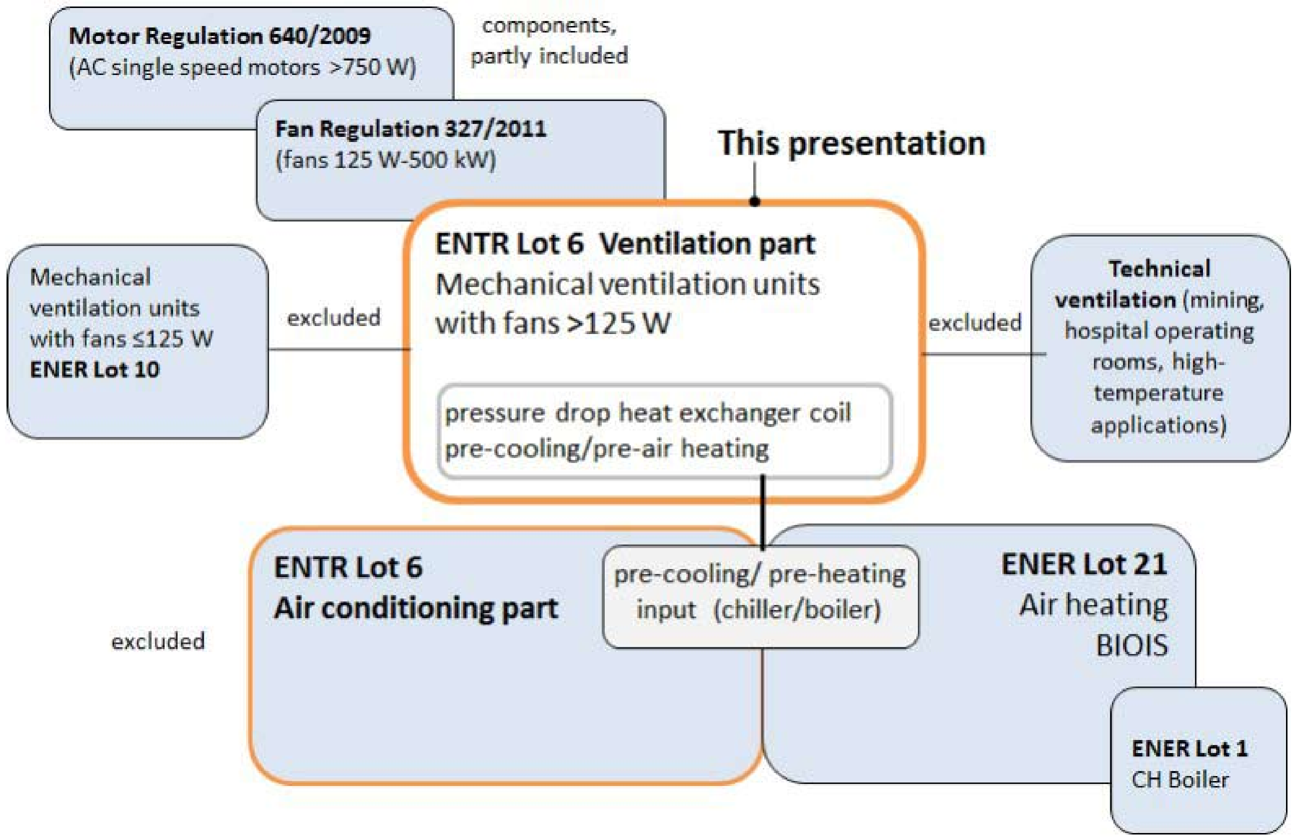


Product which do not meet the minimum criteria of environmental criteria cannot be marketed in Europe. The energy classes specified in EuP or ErP based regulations will improve the environmental performance further. The best products may get also the Environmental label.

The Commission is currently developing a proposal on Energy Efficiency regarding **systems** including energy audits and energy management systems.

Feedback on status of following **Ecodesign lots** (product groups) were given : Lot 1 Boilers; Lot 2 Water Heaters; Lot 10 air-conditioning; Lot 11 fans; Lot 15 Solid fuel small combustion installations; Lot 20 Local room heaters; Lot 21 Central heating products using hot air to distribute heat. Details are available in the presentation material you can find on: http://www.rehva.eu/en/rehva-seminar-buildings-related-eu-regulations-and-projects-brussels-27-10-2011

A deep analysis of the **Ventilation products regulations** based on Ecodesign directive on-going study Lot 6 (Tasks 1-5) for fans >125 W was presented by René Kemna of VHK. Focus is on standards, economic and market figures, usage and key messages, life cycle assessment and the Best Available Technologies (BAT).



Environmental criteria and regulations for HVAC products are drafted in several working groups (LOT). Mr Kemna focused in his presentation on ventilation products.

The preparatory study, analysing whether and which Ecodesign requirements should be set for **large air-conditioning and ventilation products** (ENTR LOT 6) was presented by Philippe Rivière of Armines (philippe.riviere@mines-paristech.fr). The study covers air conditioners >12 kW and condensing units, chillers for air conditioning applications, terminal units and heat rejection units. Stakeholders are encouraged to register at the website of the study: www.ecohvac.eu and contact the contractor on their own initiative. The final report is foreseen for March 2012.

CEN-EPBD standards

Jaap Hogeling - Chair CEN TC 371 Program Committee on EPBD

Jaap Hogeling presented the status of the second generation **CEN-EPBD standards** supporting the implementation of the EPBD Recast. Currently, the CEN-EPBD standards are used in all EU Member States as basis for their building codes and used in many EU MS in a "practical way". Based on the feedback of users, Member States and analysis in the CENSE project, it is reported that there is room for improvement with more modular and unambiguous structure, clearer common method versus the national choices, calculations checks with software and also more attention for retrofit, NZE buildings and sustainable energy production.

China Building Energy Efficiency Policies and Codes & Standards System

XU WEI, Director of Institute of Building Environment and Energy Efficiency, China Academy of Building Research Chairman, China Committee of Heating Ventilation and Air Conditioning.

Professor XU WEI presented the Chinese situation on building energy efficiency. This brought another perspective to the audience considering the huge challenges China has to face in the fast growing context also setting the building energy efficiency improvement on the top priority.

The summary intends to give a quick overview of some presentations. You can find all detailed presentations material of the 27th October seminar on: http://www.rehva.eu/en/technical-information

European ventilation standards

Nejc Brelih
Junior project engineer in the REHVA office
nb@rehva.eu

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

Washington Street 40, 1050 Brussels, Belgium

Introduction

European Standards on ventilation are published by the European Committee for Standardization (CEN). Standards are shaped by consensus among enterprises, public authorities, consumers, and trade unions, through a consultation process organised by independent, recognised standardisation bodies at national, European and international level. They are sets of voluntary technical and quality criteria for products, services and production processes, also called technical specification. Standards are voluntary to follow, except if they are referred or used as a part of national legislation. Before a final draft version is adopted as EN standard, it is submitted to 30 CEN Members for a weighted Formal Vote. After its adoption, each of the 30 National Standards Bodies publishes the new EN as an identical national standard and withdraws any national standards that conflict with it. Hence, one EN becomes a national standard in the 30 member countries of CEN.

Standards and technical reports related to IAQ

The ventilation related work in the CEN is coordinated in technical committee CEN TC 156 – Ventilation for buildings, which currently consists of 11 workgroups that cover different interest fields of ventilation. At the time of writing of this article, there were currently 65 European Standards published by the CEN TC 156. The purpose of this article is to filter these 65 articles and extract those, which are directly related to indoor air quality (**Table 1**). Being directly related to indoor air quality means that in some point they are directly addressing measures which can help to improve indoor air quality. The standards deal either residential buildings or non-residential or both. The list of standards in **Table 1** includes standards that mostly deal with functional properties of ventilation systems or equipment. Other standards produced by the CEN TC 156, which do not appear on the list of IAQ related standards, mostly includes standards that deal with mechanical properties and testing of ventilation systems and equipment.

Among the above list of standards, only a few directly address the indoor air quality issues, while others address it indirectly. Only standard EN 15251 and report CEN/TR 14788 are directly dedicated to indoor air quality while the others tackle only some specific IAQ related considerations like air flow rate, requirements on prevention of uncontrolled humidity in systems, etc. List below provides insights into the contents of standards that are the most directly related to IAQ.

CEN/CR 1752:1998. Ventilation for buildings – Design Criteria for the indoor environment

This Technical Report specifies the requirements for, and methods of expressing the quality of the indoor environment for the design, commissioning, operation and control of ventilation and air-conditioning systems. This report does not have a status of a standard but has relevant information on indoor air quality and climate. It covers indoor environments where the major concern is the human occupation, but excludes dwellings. It does not cover buildings where industrial processes or similar operations requiring special conditions are undertaken. The practical procedures, including selection of parameters to be measured during commissioning, control and operation, are also not covered.

EN 15251:2007. Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics

This European Standard specifies the indoor environmental parameters which have an impact on the energy performance of buildings. - The standard specifies how to establish indoor environmental input parameters for

Table 1. Directly indoor air quality related standards.

Standard reference	Title
CR 1752:1998	Ventilation for buildings - Design criteria for the indoor environment
EN 15251: 2007	Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics
EN 13779:2007	Ventilation for non-residential buildings - Performance requirements for ventilation and room-conditioning systems
CEN/TR 14788:2006	Ventilation for buildings - Design and dimensioning of residential ventilation systems
EN 12097:2006	Ventilation for Buildings - Ductwork - Requirements for ductwork components to facilitate maintenance of ductwork systems
EN 13053:2006	Ventilation for buildings - Air handling units - Ratings and performance for components and sections
EN 15239:2007	Ventilation for buildings - Energy performance of buildings - Guidelines for inspection of ventilation systems
EN 15240:2007	Ventilation for buildings - Energy performance of buildings - Guidelines for inspection of air conditioning systems
EN 15665:2009	Ventilation for buildings - Determining performance criteria for design of residential ventilation systems
prEN 15780:2008	Ventilation for buildings - Ductwork - Cleanliness of ventilation systems
FprEN 779:2011	Particulate air filters for general ventilation - Determination of the filtration performance

building system design and energy performance calculations. The values of indoor environmental parameters in this standard are based on CR 1752 and other earlier published standards. It specifies methods for long term evaluation of the indoor environment obtained as a result of calculations or measurements. It specifies criteria for measurements which can be used if required to measure compliance by inspection. It identifies parameters to be used by monitoring and displaying the indoor environment in existing buildings. This standard is applicable mainly in non-industrial buildings where the criteria for indoor environment are set by human occupancy and where the production or process does not have a major impact on indoor environment.

EN 13779:2007. Ventilation for non-residential buildings — Performance requirements for ventilation and room-conditioning systems

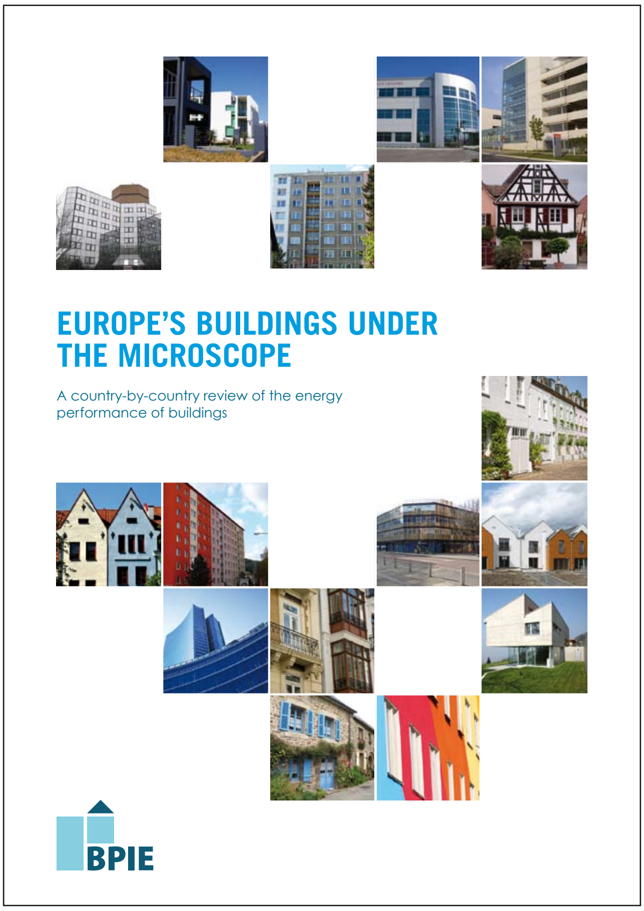
This European Standard applies to the design and implementation of ventilation and room conditioning systems for non-residential buildings subject to human occupancy, excluding applications like industrial processes. It focuses on the definitions of the various parameters that are relevant for such systems. The guidance for design given in this standard and its annexes are mainly applicable to mechanical supply and exhaust ventilation systems, and the mechanical part of hybrid ventilation systems. Applications for residential ventilation are not dealt with in this standard. Performance of ventilation systems in residential buildings are dealt with in CEN/TR 14788. The classification uses different categories. For some values, examples are given and, for requirements, typical ranges with default values are presented. The default values given in this standard are not normative as such, and should be used where no other values are specified. Classification should always be appropriate to the type of building and its intended use, and the basis of the classification should be explained if the examples given in the standard are not to be used.

CEN/TR 14788:2006. Ventilation for buildings – Design and dimensioning of residential ventilation systems

This Technical Report specifies recommendations for the performance and design of ventilation systems which serve single family, multi-family and apartment type dwellings during both summer and winter. It is of particular interest to architects, designers, builders and those involved with implementing national, regional and local regulations and standards. Four basic ventilation strategies are covered: natural ventilation; fan assisted supply air ventilation; fan assisted exhaust air ventilation; fan assisted balanced air ventilation. Combinations of these systems are not excluded and a ventilation system may serve only one dwelling (individual system) or more than one dwelling (central system). The ventilation aspects of combined systems (ventilation with heating and/or cooling) are covered. The ventilation of garages, common spaces, roof voids, sub-floor voids, wall cavities and other spaces in the structure, under, over or around the living space are not covered. 3E

BPIE puts European Buildings under the Microscope

The Buildings Performance Institute Europe, launched in November two new reports that tap fully into European buildings legislation.



European Buildings under the Microscope – a country by country review of the energy performance of buildings

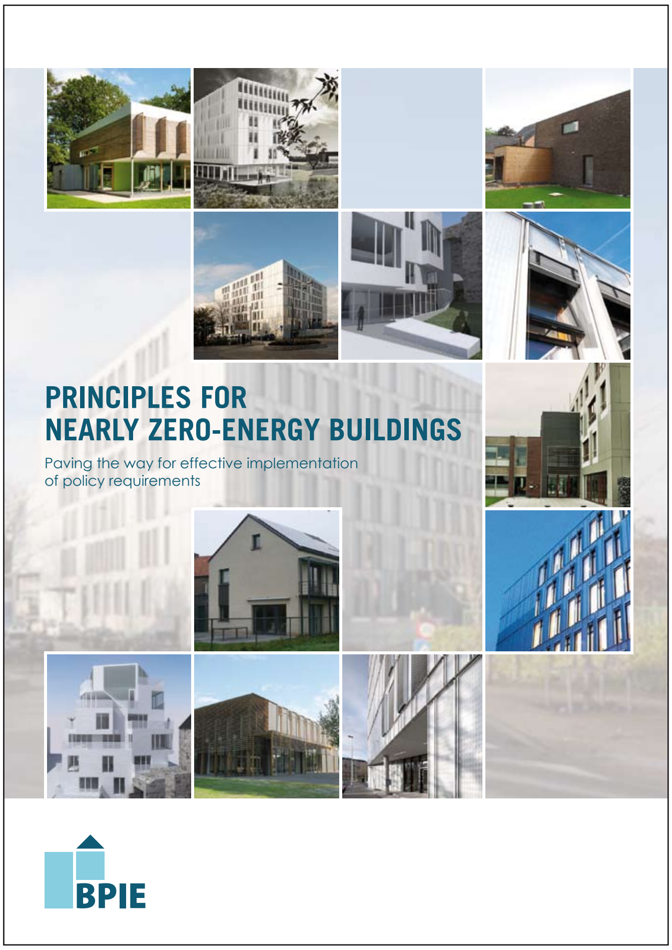
Utilizing the full potential for energy savings within the European building sector can bring significant benefits: boost the ailing European economy and increase our energy security. As the rate of new constructions is quite low, around 1%, the biggest challenge in exploiting this energy saving potential is the systematic renovation of the existing building stock.

A key obstacle to this challenge is clearly our limited knowledge and understanding of existing buildings. In a huge data collection effort, BPIE compiled and analyzed data from all 27 EU Member States as well as Norway and Switzerland to provide a vital and up-to-date picture of the European building stock and its energy and CO_2 savings potential. The data was used to model a variety of scenarios for the systematic renovation of European buildings. The objective is to put European policy making on a more solid basis by providing the statistics for a fact-based discussion on how to leverage the energy saving potential of EU buildings while maximizing environmental, economic, and social benefits.

The report is of particular importance to the individual Member States as they draw up their plans for implementing the elements of the recast EPBD and improving the energy efficiency of their building stock. It will also guide policy makers at EU level in terms of understanding the current situation and real potential of reaching the desired EU targets. Finally, the report is a tool needed by the industry and other relevant bodies to raise the importance of energy efficient renovations and ultimately assist in pushing for higher renovation rates.

The study was launched on October 11 in the context of the *Renovate Europe Day*, an industry-led initiative calling for a higher percentage of deep renovations up until 2050 (www.renovate-europe.eu). The report provides the analytical basis for a five-year campaign, ("Renovate Europe"), which was kick-started that day and is to be continued at Member State level.

Principles for nearly Zero-Energy Buildings



The EU has set ambitious targets to ensure that from 2020 all new buildings consume very little energy and it has created the term "nearly Zero-Energy Building" or nZEB. But acknowledging the variations in building culture and climate throughout Europe, European building legislation (EPBD) does not prescribe a uniform approach to nZEBs.

By the end of next year, Member States must provide a definition for nearly Zero-Energy Buildings adapted to their national conditions and submit plans for increasing the number of nZEBs including specific targets per building category.

Concepts and concrete examples for low-energy or climate-neutral buildings already exist in many European countries and come from different sources. But the views on how such buildings should be defined, and the means and techniques to achieve almost 'zero' energy consumption levels show considerable differences. As a logical consequence, there is an urgent need for a common understanding of the principles for nZEBs.

To support the effective implementation of European buildings regulation, BPIE has therefore developed a tangible approach towards a sustainable definition for nearly Zero-Energy Buildings. The report contains an analysis of existing concepts related to low-energy buildings, outlines the key challenges and potential solutions for an nZEB definition, identifies a set of principles for nZEBs and finally applies these principles to reference buildings to assess the effects.

The objective is to guide policy makers as well as the key stakeholders, such as the building industry and building professionals, who will be involved in making low-energy buildings become a reality across Europe in less than a decade.

Download the full reports from http://www.REHVA.eu/en/news, Building Performance Institute Europe reports or from www.BPIE.eu

About BPIE

The Buildings Performance Institute Europe (www.bpie.eu), a Brussels based not-for-profit organisation focusing on increasing the energy performance of European buildings It is dedicated to improving the energy performance of buildings across Europe, and thereby helping to reduce CO_2 emissions from the energy used by buildings.

BPIE acts both as an international centre of expertise on all aspects of energy efficiency and energy performance in European buildings, and as the European centre for a Global Buildings Performance Network www.globalbuildings.org created by ClimateWorks.

The main focus lays on policy analysis, policy implementation and dissemination of knowledge through studies, policy briefs and best practices.

VDI - GUIDELINES PUBLISHED SEPTEMBER – OCTOBER 2011

September:

VDI 2089/3. "Building services in swimming baths; Open-air pools"

This guideline applies to heating, ventilating, air-conditioning and sanitary installations for all sections of outdoor swimming pools. It applies to outdoor swimming pools of all types excluding but swimming pools for family use only.

In developing the recommendations regarding the technical facilities, the user behaviour specific to outdoor swimming pools was taken into account. Outdoor swimming pools are, as a rule, predominantly used on sunny days, by guest in bathing garments. This has been taken into account in formulating the requirements for technical equipment and water temperatures. The use of regenerative energies and energy-saving techniques for pool and shower water has been given particular attention.

VDI 3809/1. "Acceptance of building installations; Heating"

This guideline applies to heating installations, distinguishing as subsections heat supply, heat distribution and heat generation. In order to ensure the overall function of an installation the ready-to-use installation must be subjected to a detailed test. The guideline provides general testing criteria in tabular form (checklists) for technical acceptance (including partial acceptance). The testing applies to all facilities serving for heat transmission (in the room and on heat exchangers), heat distribution, heat generation, building automation, fuel supply and storage, exhaust-gas handling and disposal.

VDI 6003. "Potable-water-heating systems; Comfort criteria and performance levels for planning, evaluation and use" (*Draft Guideline*)

The guideline provides information about the expert planning, evaluation and implementation of water heating systems that are built in sanitary facilities of residential properties and similar buildings.

This VDI draft guideline revision contains but the changes with respect to the currently valid guideline VDI 6003:2004-10, but not its full text. This draft revision is only valid when used together with the VDI 6003:2004-10.

October:

VDI 2067/10. "Barrier Economic efficiency of building installations; Energy demand for heating, cooling, humidification and dehumidification" *(Draft Guideline)*

This guideline describes the calculation of the energy demand of buildings and rooms whose conditions should be met and which therefore must be supplied with or dissipated of energy and materials. The material demands will be treated similarly to energy demands. The guideline takes into account both radiation, transmission and ventilation processes. Influences of energy transfers to the room, technical equipment, energy supply and conversion are not subject of the guideline. The calculation basis is a defined set of weather data.

VDI 3805/1. "Product data exchange in the Building Services; Fundamentals"

The guideline VDI 3805 Part 1 describes fundamental rules for the exchange of product data in the computer-aided process of planning technical building services. It furthermore specifies the general product data model, the associated data record structure and the description of geometry data, technical data and, if applicable, any media data. The guideline compiles extensions and corrections to the series of guidelines VDI 3805, which have become necessary and have proven useful in the course of application of VDI 3805. It applies primarily to the products and components of heating, ventilation, air-conditioning and sanitary systems. However, other products can also be represented using the series of guidelines VDI 3805.

VDI 3805/25. "Product data exchange in the Building Services; Chilled ceiling elements)" *(Draft Guideline)*

The objective of the guideline is to provide a set of rules for the exchange of product data in computer-aided planning processes for the building services product range of chilled ceiling elements and their accessories on the basis of the guideline VDI 3805 Part 1.

VDI 3808. "Assessment of energy efficiency of buildings and building services; Application of existing techniques"

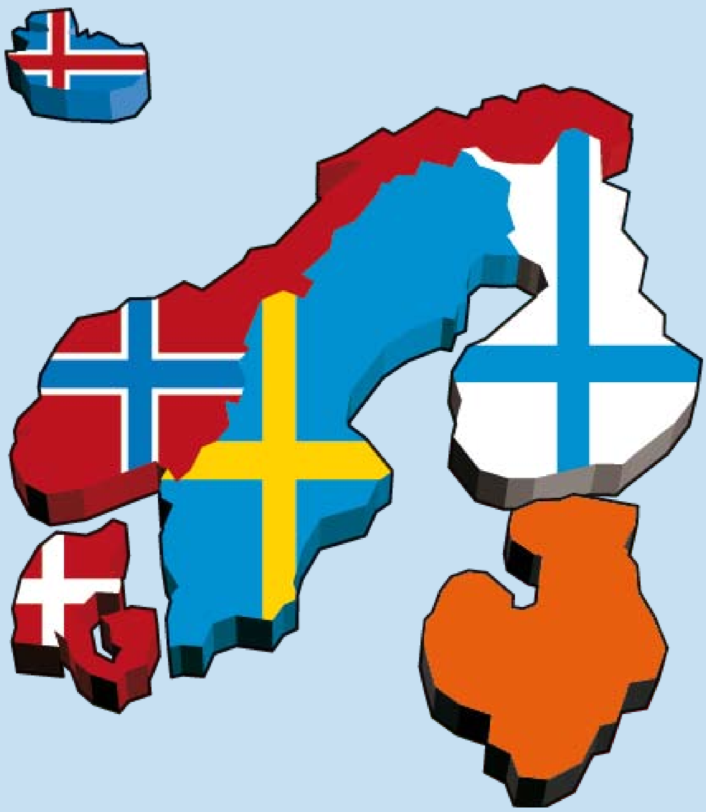
The guideline gives an overview on the various methods for assessing the energetic efficiency of buildings and building services. The guideline aims to assist the user of such methods in assessing the suitability or mandatory application of the methods.

SCANVAC NEWSLETTER

SCANVAC - SCANDINAVIAN FEDERATION OF HEATING, VENTILATION AND SANITARY ENGINEERING ASSOCIATIONS IN DENMARK, FINLAND, ICELAND, NORWAY AND SWEDEN

"Scanvac Newsletter 2/2011 - Online at www.scanvac.net!"

- Coming events
- Doctoral Theses
- Awards



- Articles

• **Finnish Building Services Industries Association – Lobbying for a Better Life**

• **SKOL associated with the Federation of Finnish Technology Industries**

• **Energy Efficient and Low Co2 Office Building**

• **Energy Performance of Buildings Directive (EPBD) – influences on building design in Finland**

• **Swedish Energy Agency wants to build 500 near-zero-energy buildings**

• **New bachelor degree programme produces sustainable building engineers**

...and more

EVENTS 2012

12-13 January	ACRECONF India	New Delhi, India	www.acreconf.org
21 - 25 January	ASHRAE Winter Meeting	Chicago, USA	www.ashrae.org
9 February	II Conference and Exhibition "Energy Audit and Energoservice. Problems and Solutions"	Moscow, Russia	www.abok.ru
23 - 25 February	XIII Conference and Exhibition "Software for heating, ventilation, air conditioning, water and heat supply. Projection, calculations, equipment selection, automation systems,"	Moscow, Russia	www.abok.ru
13 March	Round table "Normative and methodological support in the design and construction. ABOK Standards System TM" in the framework of the "Climate World"	Moscow, Russia	www.abok.ru
28 March	REHVA and AICARR seminar at MCE, HVAC in Zero Energy Buildings	Fiera Milano, Italy	www.rehva.eu
16 April	REHVA Seminar in Light and Building	Frankfurt, Germany	www.rehva.eu
17 - 20 April	REHVA Annual Conference and Meeting	Timisoara, Romania	www.rehva-am2012.ro
17 - 19 April	XVI European AVOK-EHI Symposium "Modern energy-efficient equipment for heating, water and air-conditioning of buildings"	Moscow, Russia	www.abok.ru
18 - 21 April	International construction forum Interstroyexpo 2012	St. Petersburg, Russia	www.abok.ru
26 - 27 April	Focus on Renewable District Heating and Cooling	Copenhagen, Danmark	www.euroheat.org
30 April - 2 May	X. International HVAC+R Technology Symposium	Istanbul, Turkey	www.ttmd.org.tr/2012sempozyum
24 - 25 May	Romanian international conference on energy performance of buildings "European Solutions and Policies for Sustainable Urban Development: Theory and Practice"	Bucarest, Romania	www.aiiro.ro
24 - 25 May	Conference on "Creating a climate for the desired objects of cultural heritage: monuments, museums, buildings for religious purposes"	Moscow, Russia	www.abok.ru
18 - 22 June	EU Sustainable Energy Week 2012 in Brussels	Brussels, Belgium	www.eusew.eu
25 - 27 June	10th IIF/IIR Gustav Lorentzen Conference on Natural Refrigerants	Delft, The Netherlands	www.gl2012.nl
8 - 12 July	Healthy Buildings	Brisbane, Australia	www.hb2012.org
17 - 19 September	Ventilation 2012	Paris, France	www.inrs-ventilation2012.fr
10 – 11 October	33rd AIVC Conference and 2nd TightVent Conference	Brussels, Belgium	www.aivc.org
17 – 19 October	47th Conference of plants – "Plants for the Early Third Millennium"	Sinaia, Romania	www.aiiro.ro
12 - 14 November	7th International HVAC Cold Climate Conference	Calgary, Alberta, Canada	http://ashraem.confex.com/ashraem/icc12/cfp.cgi
5 - 7 December	43th International congress of Heating, Air Conditioning and Refrigeration	Belgrade, Serbia	www.kgh-kongres.org/

FAIRS 2012

23-25 January	AHR Expo	Chicago, USA	www.ahrexpo.com
7-9 February	Chillventa Russija	Moscow, Russia	www.chillventa-rossija.com/en/
7-10 February	Interclima + elec	Paris, France	www.interclimaelec.com
7-10 February	Aqua-Therm	Moscow, Russia	www.aquatherm-moscow.ru
23-25 February,	ACREX 2012	Bangalore, India	www.acrex.org.in/
29 February - 3 March	SINERCLIMA 2012	Batalha, Portugal	www.eventseye.com
20 - 22 March	ecobuild 2012	London, United Kingdom	www.www.ecobuild.co.uk
20 - 23 March	NORDBYGG 2012	Stockholm, Sweden	www.nordbygg.se
27 - 30 March	MCE - Mostra Convegno Expocomfort 2012	Fiera Milano, Italy	www.mcexpocomfort.it
15 - 20 April	Light + Building	Frankfurt, Germany	www.light-building.messefrankfurt.com
17 - 19 April	XVI European AVOK-EHI Symposium "Modern energy-efficient equipment for heating, water and air-conditioning of buildings"	Moscow, Russia	www.abok.ru
2 - 5 May	ISK - SODEX 2012	Istanbul, Turkey	www.hmsf.com
10 - 12 May	RENEXPO® CENTRAL EUROPE, 6. International Energy Trade Fair	Budapest, Hungary	www.renexpo.hu
9 – 11 October	Chillventa 2012	Nuremberg, Germany	www.chillventa.de/en/
9 – 11 October	Finnbuild 2012	Helsinki, Finland	http://web.finnexpo.fi/Sites1/FinnBuild/en/Kavijat/Pages/default.aspx
17 - 18 October	CEP® Clean Energy & Passive House Expo	Budapest, Hungary	www.cep-expo.hu

REHVA SUPPORTERS

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.

carmicubertis / communication design

38^ Mostra Convegno Expocomfort

27-30 March 2012

fieramilano

MCE 2012

human comfort solutions

Heating, cooling, water, energy.
Four sectors, one single great event.

From March 27 to 30, 2012 the world leading exhibition in the HVAC, plumbing and sanitary fitting sectors will bring to Milan a complete showcase of the most advanced technologies for comfort, efficiency and energy saving.

Air conditioning, Ventilation / Refrigeration / Heat pumps / Insulation / Heating / Renewable Energy / Implements and tools / HVAC components / Plumbing technology / Water treatment / Home and building automation / Taps / Coatings / Bathroom ceramics / Radiators / Bathroom accessories

www.mcexpocomfort.it

mce mostra convegno expocomfort®

EXPOBAGNO

NEXT ENERGY

organised by

Reed Exhibitions®

supported by

Ministero dello Sviluppo Economico

RegioneLombardia

Provincia di Milano

Milano Comune di Milano Attività Produttive

in cooperation with

FIERA MILANO

CARR AICARR Cultura e Tecnica per Energia Uomo e Ambiente

ANGAISA

ANIMA Federazione delle Associazioni Nazionali dell'Industria Meccanica Varia ed Affine

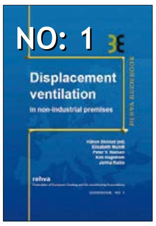
ASSISTAL

REHVA

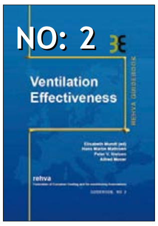
Federation of European Heating, Ventilation and Air-conditioning Associations

REHVA GUIDEBOOKS

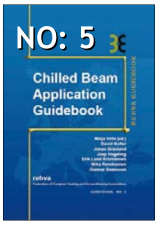
REHVA Guidebooks are written by teams of international experts



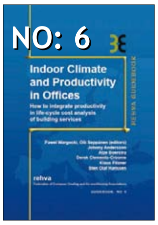
Displacement Ventilation Guidebook serves as a comprehensive and easy-to-understand design manual. It explains the benefits and limitations of displacement in commercial ventilation and outlines where ventilation should be applied. Various case studies are included. The benefits of displacement ventilation 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.



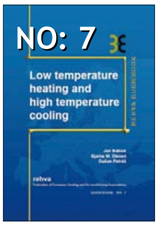
Improving the ventilation effectiveness allows the indoor air quality to be significantly enhanced without the need for higher air changes in the building, thereby avoiding the higher costs and energy consumption associated with increasing the ventilation rates. This Guidebook provides easy-to-understand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



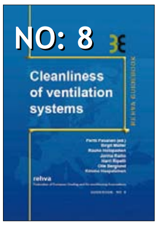
Chilled beam systems are primarily used for cooling and ventilation in spaces, which appreciate good indoor environmental quality and individual space control. Active chilled beams are connected to the ventilation ductwork, high temperature cold water, and when desired, low temperature hot water system.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

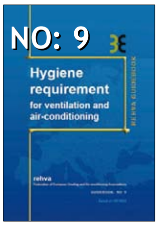


This Guidebook describes the systems that use water as heat-carrier and when the heat exchange within the conditioned space is more than 50% radiant. Embedded systems insulated from the main building structure (floor, wall and ceiling) are used in all types of buildings and work with heat carriers at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

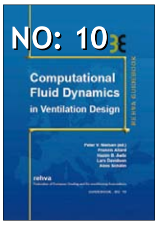


Cleanliness of ventilation systems Guidebook aims to show that indoor environmental conditions substantially influence health and productivity. This Guidebook presents criteria and methods on how to design, install and maintain clean air handling systems for better indoor air quality.

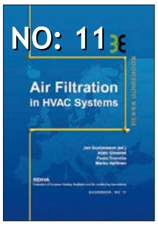
New REHVA eGuidebooks available at www.beuth.de!



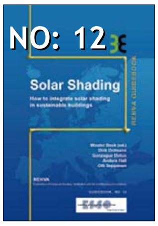
Hygiene requirement is intended to provide a holistic formulation of hygiene-related constructional, technical and organisational requirements to be observed in the planning, manufacture, execution, operation and maintenance of ventilating and air-conditioning systems. These requirements for ventilating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



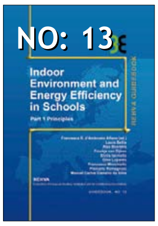
CFD-calculations have been rapidly developed to a powerful tool for the analysis of air pollution distribution in various spaces. However, the user of CFD-calculation should be aware of the basic principles of calculations and specifically the boundary conditions. Computational Fluid Dynamics (CFD) –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



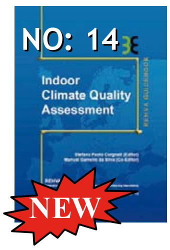
Air filtration Guidebook will help the designer and user to understand the background and criteria for air filtration, how to select air filters and avoid problems associated with hygienic and other conditions at operation of air filters. The selection of air filters is based on external conditions such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



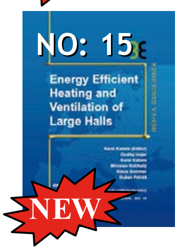
Solar Shading Guidebook gives a solid background on the physics of solar radiation and its behaviour in window with solar shading systems. Major focus of the Guidebook is on the effect of solar shading in the use of energy for cooling, heating and lighting. The book gives also practical guidance for 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.