Rehva Guidebooks:

No 1  Displacement Ventilation in non-industrial premises
No 2  Ventilation Effectiveness
No 3  Electrostatic Precipitators for industrial applications
No 4  Ventilation and Smoking
No 5  Chilled Beam Cooling

Rehva Reports:

No 1  Rehva Workshops at Clima 2005 - Lausanne
Rehva Workshops
at Clima 2005

Lausanne, Switzerland
10 – 12 October 2005

Olli Seppänen
Håkon Skistad
(Editors)
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REHVA is close to 50 year old organisation of European professionals in the field of building services (heating, ventilating and air-conditioning). REHVA represents more than 100,000 experts from 30 European countries.

REHVA’s main activity is to develop and disseminate economical, energy efficient and healthy technology for mechanical services of buildings.

Clima 2000 world congresses are official conferences of REHVA; the previous conferences were hosted by REHVA national association in Italy, Hungary, Denmark, Yugoslavia, UK, and Belgium. The 8th conference in 2005 was organised by the Swiss association, SWKI. The board of directors would like to present its gratitude to Swiss organisers of the conference for the excellent arrangements.

As a part of the conference REHVA organised 15 workshops. The objective of the workshops was to provide an opportunity for two-way communication between the expert speakers and their audiences on the selected subjects. The workshops offered a platform for the skilled professional participants to enhance and update their technical knowledge, share their experiences and views, and reflect about the advancement of energy efficient HVAC technologies for buildings, including indoor environment and intelligent management techniques. The red thread throughout the workshops was the required efforts towards the successful implementation of the Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings.

Each workshop was organised and chaired by a recognised European expert. The workshops were closely connected to the topics of permanent REHVA Task Forces, which will further use the workshop material to develop European guidelines for improving energy efficiency of buildings. Each workshop produced a summary of the results which are presented in this report – the original Power Point presentations presented in the workshops are available at the REHVA website www.rehva.com.

On behalf of REHVA I would like to express REHVA’s sincere gratitude to the workshop organisers and speakers for their invaluable work and excellent summaries of the workshops. The workshop summary was edited by Håkon Skistad to whom REHVA remains in great debt of gratitude.

The REHVA technical Workshops were supported by the Intelligent Energy Europe Agency at European Commission. REHVA is thankful for this support and hopes to be in the service of the commission also in the future.

Olli Seppänen
Professor
President of Rehva
Member countries of Rehva

Austria
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Bosnia and Herzegovina
Bulgaria
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Czech Republic
Denmark
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Spain
Sweden
Switzerland
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United Kingdom

REHVA WORKSHOPS AT CLIMA 2005, LAUSANNE

This book gives a summary of the workshops that were held at the conference Clima 2005 in Lausanne, on 9th – 12th October 2005.

The main issue of the conference Clima 2005 was “HIGH TECH, LOW ENERGY”. This also was the target of the Workshops, aiming at the successful implementation of the Directive 2002/91/EC.

Looking back in time, the aims of the Heating, Ventilating and Air Conditioning business (HVAC) have changed. Originally, when Rehva was founded, the aim was to create a good indoor environment for people in buildings. As time went by, environmental protection came into focus, requiring less contaminant emissions to air and water. Today, the main focus of HVAC professionals is energy efficiency and energy saving in our field, more concisely expressed as energy performance in buildings. However, none of the previous aims have been put aside, which means that the targets for the members of Rehva is the combined requirement of:

- A healthy and productive indoor environment
- Minimising the emissions to air and water in the environment
- Optimising the energy performance of buildings.

The list of titles of the Rehva Workshops below illustrates that all these aims are on the agenda.

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Håkon Skistad
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<th>Chairs</th>
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<td>How to maintain the clean and hygienic air handling systems</td>
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</tr>
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List of organisers
These experts have organised the workshops including the programs, final invitations and conclusions. These experts are representing the corresponding national associations of Rehva.

Francis Allard, France
Atze Boerstra, The Netherlands
Ben Bronsema, The Netherlands
Derek Clements-Croome, UK
Andy Drysdale, Denmark
Rauno Holopainen, Finland
Jaap Hogeling, The Netherlands
Maria Kolokotroni, UK
Denia Kolokotsa, Greece
Martin Liddament, UK
Bjarne Olesen, Denmark
Helmut Muller, Germany
Peter Novak, Slovenia
Pertti Pasanen, Finland
Jorma Railio, Finland
Dusan Petras, Slovakia
Livio de Santoli, Italy
Jörg Schlenger, Germany
Håkon Skistad, Norway
Jorma Säteri, Finland
Olli Seppänen, Finland
Pierre-Jean Vialle, France
Maija Virta, Finland
Pawel Wargocki, Denmark


1. Background

As Bakke stated in 1999: "The school is a central arena for creation of future social health, function knowledge, performance and wellbeing for our children today and the working force for tomorrow". Which implicates that the indoor environmental quality in our schools worldwide should be such that it supports performance and wellbeing of children and teachers (not interfere with it).

Significant know-how and expertise is available for creating a healthy indoor environment in buildings without unnecessary energy use. Much of the engineering efforts today are aimed at office and industrial buildings, hospitals etcetera. The indoor environment in school buildings can be considered a backward area, however. See for example figure 1 describing the outcome of a field study in 11 primary schools in Eindhoven, the Netherlands (Dijken et al, 2005): maximum CO₂ levels of 3000 or 4000 ppm in schools are no exception!

The proceedings of the recent Indoor Air and Healthy Buildings Conferences show this is not only the case in Western Europe. Numerous school buildings all over the world suffer from an inadequate or even bad indoor environment.

Many people think a bad indoor environment in schools is just natural, but they seldom realise what this means for the wellbeing of their children and the ‘productivity’ of the school system. Isn’t it strange that we expose our precious but vulnerable children to an indoor environment we try to avoid in work places for adults?

The available floor area per person in classrooms, around 1.5 - 2.0 m², is much less than that in e.g. office rooms, where 8.0 - 10.0 m² per person is normal. This implies a much larger ventilation demand in schools to remove odours, VOC’s and, still more important, airborne infectious agents like viruses, bacteria, parasites and fungi. Nevertheless the installation budgets for new office buildings often are a factor of 2-3 higher than those for new schools!

The situation described above was the reason for REHVA to organise a kick off meeting for a new REHVA taskforce (nr. 4) on ‘Indoor Climate in schools’. The kick-off meeting was held on June 12, 2004 and was chaired by Mr. Ben Bronsema. The kick-off meeting was attended by participants from the Netherlands, Finland, France, Belgium and United Kingdom.

The Clima 2005 workshop (of what this report is a summary) was the second activity of the school taskforce.
Figure 1: Average, maximum and minimum \(\text{CO}_2\) concentrations in 11 Dutch Primary schools (source: Dijken et al, 2005)

School guideline activities in the Netherlands

In 2004 a TVVL working group published a draft research report (in Dutch) on “Indoor Environment in Schools”. The Working Group is partly sponsored by TVVL, a part of the work being done by TVVL members on a voluntary basis.

In the report both general information on indoor climate in schools and it’s effect on children and students is given and information on how to design good ventilation, heating and cooling systems for class rooms.

On the basis of this report ISSO will produce a (more elaborated) publication on this issue, probably 2nd half of 2006, aimed at practitioners, and drawn up according to the Dutch quality standard for Climate Control MKK. Funding for this work is still partly missing.

REHVA dissemination activities around schools and indoor climate might to a certain extent be combined with TVVL activities in the Netherlands.

For more information on the TVVL guideline contact Ben Bronsema via: b.bronsema@bk.tudelft.nl. For more information on the coming ISSO publication on schools, contact Jaap Hogeling via: j.hogeling@isso.nl.
1.2 Aim and scope
The ‘Indoor Climate and ventilation of schools’ workshop at Clima 2005 (attended by about 30 people) had several objectives:

- To inventory the status quo in schools (as far as Indoor Climate and energy performance is concerned);
- To discuss the end-effects of inadequate Indoor Air Quality and thermal climate in schools (learning performance, sick leave etcetera);
- To inform on current activities (in and outside Europe) on Indoor Climate and Energy in schools;
- To share knowledge on the design of (better) ventilation, heating and cooling systems for schools;
- To discuss the necessity to draw up a REHVA Guidebook on Indoor Climate and Energy in schools.

The target group of the REHVA school workshop at Clima 2005 were HVAC, IEQ and energy consultants, equipment manufacturers and providers of building maintenance and operation services.

1.3 Indoor climate in Finnish schools
In Finland there are about 5,000 schools where there study and work altogether about 750,000 pupils of comprehensive and secondary pupils and teachers.

A study has been done to assess actual ventilation rates, indoor air quality and also the quality of repairing process in the Finnish schools. Ventilation and indoor air quality of elementary and secondary schools were studied by distributing questionnaires to 1264 school-principals.

In 20 schools measurements were done on ventilation rate, CO₂ and particle concentrations, and temperature and humidity in the classrooms were carried out in 20 schools.

Almost half of studied school buildings (48%) had mechanical supply and exhaust ventilation system. Only 10% had natural ventilation and 26% had natural supply with mechanical exhaust.

The study showed that most frequent indoor air quality problems were:
- draught in winter time (42% of the schools)
- inadequate fresh air supply (40% of the schools)
- stuffy air (31% of schools)
- visible mould or smell of mould (26% of schools)

In general, the complaints about poor indoor air quality were more common in the schools with natural ventilation system than with mechanical ventilation systems, being least frequent with mechanical supply and exhaust (Figure 2).

Ten schools were chosen for the measurements and the total number of the classrooms measured was 56. The average classroom size was 60 m² and average value of pupils was 23. Different ventilation systems are compared in Figure 3. Mean values of exhaust airflows and CO₂ concentrations are shown.
Figure 2. Prevalence of weekly complaints in Finnish schools, for 3 ventilation system categories

Figure 3. Mean values of exhaust airflows and CO₂ concentrations with different ventilation systems (Finnish guideline values are 6 l/s, person or 3 l/sm²).

The overall conclusion was that indoor air quality problems seem to be common in both primary and secondary schools.
The type of ventilation system proved to have significant influence on the quality of indoor air and the incidence of complaints and health symptoms. The solutions of natural ventilation and mechanical exhaust ventilation that were used in practice, suited poorly to the school buildings. In both systems the intake air caused draught. Furthermore, insufficient ventilation rates were a problem in natural ventilation systems. Mechanical supply and exhaust ventilation showed remarkably better performance by higher ventilation rates and lower CO₂ concentrations. Also, the occurrence of draught was approximately fifty percent lower in schools with mechanical ventilation systems. However, also in mechanically ventilated buildings there were indoor air quality problems indicating faults in control and maintenance, and in some cases low design quality.

1.4 Effects of IEQ on the performance of schoolwork by children

Recent experiments have shown that poor indoor environmental quality (IEQ) in office buildings can reduce the performance of office work by adults (Wyon and Wargocki, 2006). It is thus reasonable to suspect that poor IEQ can also negatively affect the performance of schoolwork by children. While it is well documented that IEQ in schools is both inadequate and frequently much worse than in office buildings (Angell and Daisey, 1997), there is little direct evidence that classroom performance is being negatively affected (Mendell and Heath, 2005). New studies carried out at the International Centre for Indoor Environment and Energy, Technical University of Denmark investigated whether IEQ can affect the performance of schoolwork by children. They were supported partially by American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) through contract 1257-RP and partially by the Danish Technical Research Council (STVF). The preliminary results of the these studies are reported in the following.

Three independent field intervention experiments investigated the effects of increased outdoor air supply rates and reduced air temperatures in classrooms on the performance of schoolwork. They were carried out in an elementary school in Denmark in classrooms with about 100 10- to 12-year-old pupils. The experiment investigating the effect of reduced temperatures was carried out in late summer using two parallel classes of 10-year-old children (Wargocki et al., 2005a). The air temperatures were reduced from 23.6°C to 20°C in a 2x2 crossover design balanced for order of presentation, each condition being maintained for a full week. The temperature was reduced using wall-mounted split air conditioning unit. The experiments investigating the effects of increased outdoor air supply rates were carried out in late summer and in winter in four identical classrooms of 10- and 12-year-old children (Wargocki et al., 2005a,b). The outdoor air supply rate was increased from about 5 to 9.5 L/s per person in summer, and from about 4 to 8.5 L/s per person in winter, in each case in a cross-over design balanced for order of presentation. Each experiment was carried out in two parallel classrooms at a time and each condition lasted for a week. The outdoor air supply rate was increased using the existing mechanical ventilation system. In all three experiments the performance of schoolwork was measured using parallel versions of performance tasks representing up to eight different aspects of schoolwork, from reading to mathematics. The tasks were selected so that they could have been a natural part of an ordinary school day. The tasks were administered by the children’s usual teachers. They included: addition of numbers; multiplication of numbers; subtraction of numbers; checking columns of numbers against each other; sentence comprehension; proof-reading of text in which
deliberate errors had been inserted; acoustic proof-reading, i.e. listening to a recorded voice and checking a transcript in which deliberate errors had been inserted; and reading a text in which choice points had been inserted to determine whether the children understood the text (reading and comprehension). In addition the teachers carried out check-list observation of the children’s behaviour. Parents and teachers recorded their observations of children’s health and mood in logbooks, and the children themselves marked visual-analogue scales each week to indicate the intensity of various symptoms of ill health. During experiments, the teachers and pupils were allowed to open the windows as usual, and no changes to the lesson plan or normal school activities at school were made, so as to ensure that the teaching environment and daily routines remained as normal as possible. Both teachers and pupils were blind to interventions.

Reduced temperature significantly (P<0.05) increased the rate at which pupils subtracted numbers and performed a reading and comprehension task and the rate at which pupils categorised logical statements as true or false. It tended (P<0.10) to reduce errors when they proof-read what purported to be a transcript, in which discrepancies had been inserted, while listening to a recorded voice reading the original text aloud and to increase the rate at which numbers were compared. In no test (except for acoustic proof reading) was the proportion of errors affected. Increased outdoor air supply rate significantly (P<0.05) improved the performance of the following individual tasks by from 3% to 35%: addition, multiplication, number checking and subtraction in summer, and reading and comprehension, sentence comprehension, subtraction and multiplication in winter. In all the tasks mentioned, there was a statistically significant improvement in the work rate, while the error rate remained constant. For none of the tasks was a statistically significant reduction in performance associated with the increased outdoor air supply rate or the reduced temperature.

Using the performance of individual tasks that were affected by an increased outdoor air supply rate, the average performance of schoolwork was computed and a regression equation against the outdoor air supply rates measured in the classrooms was derived (figure 4). The regression indicates that doubling the outdoor air supply rate would improve the average performance of schoolwork by about 15%. It may be seen that there is extremely good quantitative agreement between the results of the two independent experiments, which were performed at different times of year, in different classrooms and with children at two different ages.

In conclusion, the present results indicate that improving classroom conditions can considerably improve the performance of school work by children. Since the performance of schoolwork affects learning, they also imply that improving classroom conditions can have lifelong consequences both for pupils and for society.

1.5 Energy efficient ventilation systems for school refurbishment in Switzerland

In Switzerland a study has been conducted on Indoor Climate and energy performance in 20 school buildings, with construction dates ranging from 1890 to 1987 (Flourentzou et al, 2004). Of the buildings studied, 19 had natural ventilation in the class rooms, and 50% had mechanical ventilation for the gym.
A special tool was developed (named ‘EPIQR diagnosis instrument’) to assess the school’s quality. This tool was used to map e.g.:

- Physical state of the buildings;
- Actual energy use (translated in an ABCDEFG energy label rating);
- Indoor environmental quality, and:
- Refurbishment costs.

The energy analysis learnt the following:

- mean energy consumption in the schools was 480 MJ/m² per year;
- maximum energy use was 800 MJ/m² per year, minimum use was 330 MJ/m² per year;
- older schools (100 years old or more, often partly refurbished in the 70s) often had lower energy use than newer (10-20 year old) schools;
- poor energy performance of school buildings in Switzerland can not (only) be attributed to use of natural ventilation (without heat recovery systems).

Other conclusions from the study are:

- there are many IEQ complaints in Swiss schools;
- one of the more common complaints dealt with ‘limited control of IEQ’;
- natural and mechanically ventilated classrooms have often similar IAQ problems;
- no building owner was willing to give up there natural ventilation systems (often only consisting of operable windows without mechanical exhaust) for a mechanical ventilation system (mechanical supply and exhaust in each class room);
- design of good, draft free, natural ventilation for class rooms is tricky; the overall conclusion was that designers still need to learn a lot about how to design better natural / hybrid ventilation systems.
1.6 Innovative Finnish solutions for school ventilation

In Finland, during the last years, several innovative school ventilation projects have been initiated. The Poikkilaakso School in Helsinki (2001) for example (see figure 5), is an experimental school building where some elements typical for hybrid systems are combined with mechanical ventilation. The ventilation system is fully mechanical low-pressure system, having central air-handling unit including filtering, heat recovery, etc. The building serves as an airflow route and there are no suspended ceilings or visible ducts inside. Air handling unit on the top of the roof is connected to large supply air duct on the roof (see figure 6), from which two vertical ducts lead to each classroom having displacement diffusers. Central spaces of the building are ventilated with transfer air from classrooms (no ducts). Extract is from the central hall. Demand controlled ventilation is based on CO₂ and occupancy sensors in the classrooms. There are supply airflow dampers for each classroom; and speed controlled fan keeps constant 50 Pa pressure in the main supply duct on the roof. Dimensioning ventilation rates were 3 L/s,m² in classrooms, 5 L/s,m² in lunchroom and 2 L/s,m² in offices. According to the measurements in 2001-2002, very low noise levels (20-30 dB(A)) and good IAQ (CO₂ <1000 ppm) were achieved. Displacement ventilation air distribution was found somewhat problematic, because in the classrooms desks were placed directly near the diffusers. Draft close to diffusers and no temperature or CO₂ gradient above 0.6m were measured. Lower supply air temperatures for cooling purposes were not possible use due to draft. The user feedback was very positive as school stuff pointed it out that there is a “feeling of natural ventilation” in the building with no suspended ceilings and no visible ducts. And this was achieved with fully mechanical, low-pressure heat recovery ventilation... As a conclusion, this successful demonstration project encourages for the use of low pressure and smart ducting design utilising building spaces as air flow routes.

1.7 Workshop results and recommendations

The second half of the workshop was used for discussion. The discussion was centred around 10 statements on typical issues related to indoor climate in schools.

The workshop attendants first discussed how wide and serious the problem is. Available school studies are mainly from Nordic countries, the UK, France, Switzerland, the Netherlands and the US, there is no data for example from tropical climates. Representatives from some countries (Norway, Finland) pointed out that about 50% and some countries that about 80% (Denmark, Netherlands) of schools have inadequate thermal comfort (TC) and indoor air quality (IAQ). The phrase “inadequate” was discussed as some parties found it having too strict meaning and the statement was amended to be more careful saying that ‘TC and IAQ are inadequate or need major improvement’.

The following issue discussed was the underlying cause of the non optimal situation in schools. Is low IEQ quality caused by low budgets? Or is low quality caused by poor engineering? Or is it all a matter of lack of know-how amongst the professionals involved in school (ventilation) design? This are all possible explanations, but it was pointed about that there can be many potential reasons that differ from country to country. As one workshop participant stated: ‘The most important is to find correct measures to fix the current situation, taking into account regional differences’.

12
Furthermore the effects of inadequate climate were briefly discussed. There was a consensus that there is solid scientific evidence from numerous studies showing that inadequate indoor climate leads to discomfort and SBS symptoms which are emphasised by outdoor pollution in many locations close to traffic or industry. Also we concluded that there is some evidence that poor indoor climate may possibly lead to long term health effects (both in pupils and teachers). There are also studies showing that inadequate indoor climate in schools is especially unacceptable for hypersensitive children (today about 20% of children) and may provoke asthma and allergy.

Figure 5: Poikkilaakso School in Helsinki

Very motivating evidence for authorities are the results from recent studies showing that inadequate indoor climate in schools leads to impaired learning performance of pupils. Numerous office studies have shown a link between increased sick leave and poor IAQ. Unfortunately we agreed that there are no sickleave studies available yet (not for children, nor for teachers).
Another question discussed was: What is (generally speaking) the number 1 cause for poor indoor climate in schools? There was a general consensus that in many cases the main cause for indoor climate problems in schools is an inadequate or missing ventilation system.

Which lead to a discussion about natural vs. mechanical ventilation of class rooms? It was stated that there are many ventilation system types and technical solutions capable to provide good IAQ and TC; feasible solutions are often climate dependent. In some specific cases such as a cold climate or high outdoor pollution, mechanical systems seem to be the only alternative. In many other cases hybrid or even natural ventilation system may provide acceptable or even good IAQ, however there is a lack of well-documented, successful demonstration projects. Many studies have addressed minor or major problems of such systems especially in Nordic countries. On the other hand, other studies (e.g. in the Netherlands) showed that also mechanical ventilation systems give problems in practice.

In general the participants concluded that more important than system type (natural vs. mechanical) is that ventilation system are well designed, easy to operate and easy to maintain.

This ventilation system discussion lead to a secondary discussion about how much fresh air supply is enough for children (less than adults as is often the case in national building regulations? or the same amount as for adults or even more anticipating for the vulnerability of young children?).

Last but not least it was discussed what actions are needed within REHVA to improve the Indoor Climate in schools. The group agreed that a 2 way approach is needed:

1. Development of ‘motivational’ guidance (answering the ‘why? question’). Explaining to especially school building decision makers why it is important to invest in good indoor climate in schools (learning performance argument, school infection risk argument, etcetera).

2. Development of engineering guidance (answering the ‘how? question’). Explaining to HVAC engineers and others involved in school (and school building service systems) design how to design a high quality mechanical or natural ventilation class room system, that guarantees good indoor climate, low energy use and easy operation and maintenance.

The following concrete steps are suggested towards the REHVA board:

- **Action 1.** Development of a 4 or 8 page leaflet addressing the why question. To be published both on the REHVA website and in print.
- **Action 2.** The writing of a general REHVA guideline on indoor climate in schools (that includes a why? chapter based on the action 1 leaflet). Built up like the Dutch TVVL school guideline with it’s class A / B / C system solutions for class A / B / C building budgets. Preferably sponsored by the EU.
- **Action 3.** Translation of REHVA guideline to member state languages with additional local information / local alterations where necessary. Organised and paid for by national member countries.
- **Action 4.** The organisation of national ‘Indoor climate system solutions to school indoor climate problems’ courses targeted for HVAC professionals / members of national HVAC associations (in local language). Standard workshop material developed by REHVA and partly paid for by EU.

1.8 References


Håkon Skistad¹, Ben Bronsema², Chair persons
Jaap Hogeling³, Atze Boestra⁴

¹ SINTEF Energiforsking AS, Trondheim, Norway
² Delft University of Technology, the Netherlands
³ ISSO, the Netherlands
⁴ Boerstra Binnenmilieu Advies, the Netherlands

2.1 Background
Rehva has decided to publish a guidebook on how to reduce the exposure to environmental tobacco smoke (ETS) in premises where smoking is allowed. This book was presented at Rehva’s general assembly in Lausanne, October 2005. Neither the book nor the workshop has been supported by the tobacco industry.

2.2 Aim and scope
The aim of this workshop was to present Rehva Guidebook no 4 “Ventilation and Smoking”, and to discuss the topics presented in the book.

The aim of the book is to present ways of ventilation premises where smoking is allowed so that guests’ and employee’s exposure to ETS is reduced by describing methods for efficient ventilation. The aim is not to promote tobacco smoking.

2.3 Workshop programme
1. Presentation of the REHVA Guidebook 4 “Ventilation and Smoking” (Ben Bronsema)
2. The history and team behind the book (Ben Bronsema)
3. Contents of the book (Håkon Skistad)
4. The health aspects – Is there an acceptable exposure limit for ETS? (Atze Boerstra)
5. “Smoke free Architecture”- The TU Delft experiments (Ben Bronsema)
6. Air cleaning – a viable means of reducing ETS? (Håkon Skistad)
7. Can we rely on ventilation or air cleaners to reduce exposure to ETS (Håkon Skistad)
8. Discussion

2.4 The history behind the book
The work with the book started as an investigation for the Norwegian Hospitality Association. The aim of the investigation was to find measures to protect employees and non-smoking guests against environmental tobacco smoke (ETS). The Norwegian handbook 1999 was never published, because smoking was banned before the book was completed. The work with the international guidebook started 2001 as Cost G3 activity, and was continued in Rehva Task Force 12 during 2002. The book was finally published in September 2005.
2.5 Authors and contributors

More than 30 experts from Europe have been engaged in the writing of the book. The persons involved have been:

- Ben Bronsema (NL) (Chair Rehva)
- Jacob Bekker (NL)
- Peter van den Engel (NL)
- Wil de Gids (NL)
- Jaap Hogeling (NL)
- Piet Bouma (NL)
- Artze Boestra (NL)
- Bart Cremers (NL)
- Elles de Groot (NL)
- Cees Knijn (NL)
- Håkon Skistad (Chair Cost G3)
- Monica Berner (N)
- Valentina Raisa (I)
- Olli Seppänen (FIN)
- Jorma Railio (FIN)
- Seppo Enbom (FIN)
- Kim Hagström (FIN) - Halton
- Beat Kegel (CH)
- Thomas Rueegg (CH)
- Lars Olander (S)
- Peter Bjersten (S)

Reviewers of the book have been:

- Yasushi Kondo (JAP)
- Hideki Kubota (JAP)
- Hans Martin Mathisen (N)

2.6 The contents of the book

The book contains the following chapters:

1. Ventilation and smoking in a nutshell
2. Terminology, symbols and units
3. Introduction
4. Reading indications
5. National laws and regulations
6. Ventilation for the control of ETS
7. Passive smoking and health
8. Management and interior design of the premises
9. Principles of room air distribution
10. Zoning strategies
11. Zoning and temperature control
12. Ventilation system arrangements outside the room
13. Air cleaners
14. Smoking stations and smoking rooms
15. Design check list
16. Case studies
17. References

Appendix A - Amount of some harmful chemical components found in tobacco smoke

Appendix B – testing of air cleaners
2.7 The health aspects—Is there an acceptable exposure limit for ETS?

Atze Boerstra raised the question of “How much ETS is enough?”

- What to design for?
- What are allowable levels of Environmental Tobacco smoke (in the non-smoking area)?
- In terms of olfactory discomfort, irritation and long term health effects?
- Or should it be zero?
- What indicators of ETS exposure to use?
- How about working with performance criteria, in the context of smoking and ventilation?

He addressed the composition of tobacco smoke, the health effects of passive smoking and gave some numerical estimates for Europe, based on data from the Dutch Health Council:

- 500+ ETS related sudden infant death syndrome cases
- 10,000+ ETS related lung cancer deaths
- 60,000+ ETS related deaths from cardio vascular diseases
- 500,000+ children ETS related asthma, bronchitis
- 16-19% higher change on health complaints if exposed to ETS at work

Possible indicators of ETS:
- Nicotine
- Fine dust (PM10 / PM2,5)
- 3-ethenylpyridine

Although there are no generally accepted limits to ETS, Boerstra suggested the following as “practicable, reasonable” values. (ALARA vs zero tolerance discussions)

<table>
<thead>
<tr>
<th>Target levels for concentration in non-smokers area / room</th>
<th>Smoke free building</th>
<th>Smoke free rooms / corridors next to enclosed smoking room (hard walls + doors)</th>
<th>Smoke free areas next to smoking areas (air curtains, over/under pressure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicotine</td>
<td>&lt; 0,05 µg/m³</td>
<td>&lt; 1,0 µg/m³</td>
<td>&lt; 10 µg/m³</td>
</tr>
<tr>
<td>Fine dust (PM 2,5)</td>
<td>&lt; Co + 5 µg/m³</td>
<td>&lt; Co + 10 µg/m³</td>
<td>&lt; Co + 40 µg/m³</td>
</tr>
</tbody>
</table>

An alternative approach could be to require that the contaminant concentration in the non-smoking zones should not be more than a certain fraction of that in the smoking zone:

<table>
<thead>
<tr>
<th>Target levels relative concentration in non-smokers area / room (Cnon-sm. / Csmoking)</th>
<th>Smoke free building</th>
<th>Smoke free rooms / corridors next to enclosed smoking room (hard walls + doors)</th>
<th>Smoke free areas next to smoking areas (air curtains, over/under pressure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicotine</td>
<td>-</td>
<td>5%</td>
<td>20%</td>
</tr>
<tr>
<td>Fine dust (PM 2,5)</td>
<td>-</td>
<td>5%</td>
<td>20%</td>
</tr>
</tbody>
</table>
2.8 Smoke free Architecture - Smoke separation without walls
Ben Bronsema reported from field tests at the Technical University in Delft about confining a smoking zone with air curtains.

His conclusions were:
- An effective separation between the zones can be obtained without physical walls.
- Use an air curtain with low discharge velocity, which implies larger air volume flows.
- Take the supply air to the air curtain from inside the smoking zone.
- The extract volume flow inside the smoking zone must be equal or larger than the entrained airflow into the outside of the air curtains.
- In this particular case the supply air flow to the air curtains was of the same magnitude as the entrained air on the outside of the air curtains.

The study included both physical tests, CFD modelling and analytical calculations.

2.9 Air cleaners
Håkon Skistad gave a presentation of what air cleaners can do, and what they can not do, in relation to tobacco smoke. Conclusions:
- Air cleaners remove particulate matter from the air, thereby
  - Reducing nuisance
  - Reducing cleaning work in the room and in the ventilation system
  - Reducing ventilation flow and energy use
- Most air cleaners do not remove gaseous contaminants
  - So they do not protect people against ETS (or the protection is very limited)
- If your goal is to remove visible smoke
  - Then air cleaners help
- If your ambition is to take care of peoples’ health
  - Then you need fresh air!
- Perhaps the best solution is a combination!?

Can we rely on ventilation or air cleaners to reduce exposure to ETS
Many people, and politicians, would say a definite NO to this rhetoric question. And with good reason – too many ventilation installations do not work as they should, or is not able to fulfil the ventilation task that is needed.

However, when the ventilation system is designed and installed properly and maintain properly, then ventilation can reduce the concentrations of ETS in the rooms significantly.
2.10 Discussions

- The reason behind the ban on smoking:
  A political desire to make the smokers stop smoking. The arguments of protecting employees and non-smokers are secondary reasons. (Australian participant)

- Standards for ETS in indoor air? Responsibility of the designer/the responsible?
  Comment: There are no generally accepted standards for the maximum concentration of ETS in the room air. The responsibility of the designer has so far not been challenged. (US participant)

- Detection of ETS: Suggested use of submicron particle counting. New, cheaper technology is available (Dutch participant)
  Comment: Skistad: In Norwegian investigations, it was found that other sources of particulate emissions (cleaning, changing table cloths etc) contributed significantly to particle contents in the air when the smoking intensity was low (particle between 0,3 µm and 2 µm). Dutch participant: For submicron particles, tobacco smoke is the dominating source of particles. Submicron particle counting technology is now available at a cheap price (Phillips).

- The book recommends supplying the air in the non-smoking zone, and extracting air in the smoking zone. Does this imply that we expose the smokers to the contaminants from the non-smokers in addition to the smokers own emissions? (Slovenian participant)
  Comment: The contaminant emission from non-smokers is so much less than the contamination from the smokers that it does not make any discernible difference in the smoking zones. Feedback from practice is that smokers notice an improved air quality in the smoking zone, due to the improved ventilation efficiency.

2.11 Results

Tobacco smoking is a pollutant that creates problems not only to the smokers themselves, but also to people around the smokers. Tobacco smoking also makes the room surfaces and furniture require more cleaning.

The best solution to these problems is no doubt that people stop smoking.

However, as long as smoking goes on, ventilation can reduce the exposure to ETS in buildings. The following conclusions were made with respect to ventilation and smoking:

1. It is possible to make ventilation system that reduces the concentration of ETS in non-smoking zones to around 1 µg/m³.
2. If there is no accepted limit concentration to ETS, we miss the main criterion for designing ventilation system.
3. We can rely on ventilation to reduce the exposure to ETS, but it requires that the ventilation is correctly planned, installed and maintained.
4. The general trend seems to be that smoking is banned in more and more countries.
5. Until tobacco smoking is eliminated on earth, there is a market for the book.

2.12 References

3 NEW GUIDELINES FOR MAINTENANCE OF CLEAN AND HYGIENIC VENTILATION SYSTEM

Pertti Pasanen¹, Chairman
Rauno Holopainen², Secretary

¹University of Kuopio, Finland
²Helsinki University of Technology, Finland

3.1 Background
Hygiene or cleaning of ventilation systems is regulated with official regulations or voluntary guidelines only in few countries. Most of these documents are based on the fire safety reasons, and thus there is a lack of commonly accepted, hygiene based, guidance for cleaning or maintaining ventilation systems which aims to improve indoor air quality. The cleanliness of ventilation systems is also important for energy performance. Only if the system is clean enough, the target level of indoor environment can be achieved with minimum required energy input.

3.2 Aim and scope
The aim of the workshop was to introduce the REHVA guidebook draft “Clean ventilation systems” for general discussion with questions by which the different parties from different countries were promoted for discussion. The discussion was aimed to find out consensus and acceptance for practices to maintain clean ventilation systems in European countries.

3.3 Cleanliness in ventilation systems

3.3.1 Cleanliness criteria for ventilation systems
The purpose of ventilation system is to provide healthy, fresh and clean air into the building. However, the ventilation system may become a major source of odours in the building. With a proper action it is possible to eliminate nearly completely the odour emissions from the new and also in the older system ventilation system. For the new systems the hygienic aspects is easier to take account than in renovation of the used systems. The key issue is to design and build the ventilation system in a way that it can be kept clean enough during the whole lifetime of the installation. Some of the design features and maintaining of cleanliness, as well as hygiene requirements and recommendations for the system and its components, are presented in European standards (ENV 12097, EN 13779, EN 13053) and also in national guidelines (SNBH 1994, FISIAQ 2001, HVCA 1998, VDI 6022 Parts 1 and 3).

New installations shall be built by using components which are clean from dust, debris and oil residues which may cause odours or promote fungal growth. The installation work shall not produce filings inside the ductwork. In practice, this means that the duct and components need to be cut with shears instead of abrasive cutting machines. Especially the following contaminants should be avoided

- residues of lubricant oils from the manufacture
- dust accumulated during manufacture or from installation work
• deposited micro-organisms, particularly when toxin producing species are present

In existing systems the main focus shall be addressed to maintenance of the system and its components. Only few guidelines define the criteria for cleanliness. Most of the national ones include definition to inspect and clean the systems or components with a certain period. Maintenance instructions are given for filters, coil units, humidifiers and cooling towers.

3.3.2 Installation
Dust and other impurities of new ventilation system originate from manufacturing processes, transportation, storage and construction. In newly installed air systems, the amount of dust on the inner surfaces may be high if the ducts and components are not protected against impurities properly. In this case, system has to be cleaned after installation. The protection against dust during the construction process and using ducts and components without residual oil are the ways to decrease dust accumulation on the air duct surfaces. Cutting methods which do not produce a lot of steel filings are recommended. Training and directions of clean installation methods are needed for all the employees at the construction site.

3.3.3 Inspection training
In some countries, codes, guidelines or standards for the training of the maintenance personnel exist. The training of the personnel is a very important part of the proper maintenance and the cleanliness of ventilation systems.

3.3.4 Verification of cleanliness of ventilation systems
Different methods to evaluate cleanliness of ventilation systems are applied. The simplest and least time-consuming methods are based on subjective visual observation of the cleanliness of ventilation system combined with use of some special instrumentation. The use of visual scales makes the method more objective and reliable. Very often the inspector needs to decide if the system has to be cleaned or not. However, in some cases more objective method is needed to help the decision. In that case, the advanced techniques are able to give relatively accurate results that are comparable to given limit values.

3.3.5 Report and documentation
The inspection and cleaning results of ventilation system shall be reported (HVCA 1998, NADCA 2001) and recorded (Holopainen et al. 2002b) on the maintenance manual of the building for next periodic inspection. In general, the report shall review the purpose of the inspection, describe what was found during the examination of the facility and recommendations about what needs to be done to improve the cleanliness of the system (NADCA 2003).

3.4 Cleaning of ventilation system
Several cleaning methods have been used to clean air ducts. The cleaning methods are chosen to achieve acceptable cleaning results without causing damage to the surface of ventilation system (NADCA 1995, HVCA 1998). The pre-standard (ENV 12097) requires the specification of the cleaning methods for periodical duct cleaning.
The duct cleaning methods are considered to be dry or wet methods (ENV 12097, HVCA 1998). Common dry cleaning methods are compressed air cleaning, hand vacuuming and mechanical brushing (NADCA 1995, ENV 12097, HVCA 1998, NADCA 2001).

In the case that ventilation system is ordered to clean a cleaning plan of the system shall be prepared. It consists of the following information (NADCA 1995, HVCA 1998, NADCA 2001, Holopainen et al. 2003b):

- the ventilation system(s) to be cleaned
- cleaning method(s)
- vacuum collector device(s) (airflow rate or pressure drop)
- efficiency of filter(s) in depressurizing fan unit
- location of exhaust air will be supplied
- health and safety requirements
- verification of cleaning result

Cleaning plan shall be done on the basis of the visual inspection which helps to find out optimum method(s) and equipment to be used in the work. The plan should also define the responsibilities of each organisation and their designated persons involved in the project.

3.5 Results of the conversations

Experienced specialists from eight different countries were gathered to discuss about the draft of guidebook. The conversation was outlined by introduction presentation to the guidebook draft which was followed by short reviews to the national regulations and guidelines about the cleanliness and hygiene of ventilations systems. These presentations were from Finland, Germany and The Netherlands. The main focuses in the presentations are listed below.

The Finnish approach consist official regulations for cleaning the exhaust air ducts to promote fire safety. According the statute the exhaust air ducts, which may contain combustible material like grease, solvents or flammable powder have to be cleaned yearly. And exhaust air ducts of the systems serving day-care centres, schools, hospitals, hotels, prisons etc. have to cleaned once in every five years. The official regulation renders the cleaning of the ventilation systems in commercial or residential buildings to done voluntarily. The Finnish building code for Indoor Climate and Ventilation, D2 states out that, the ventilation systems shall be easily cleanable and the systems shall be clean during the commissioning of the systems.

Voluntary guideline (FiSIAQ) consists two categories to cleanliness. The higher class P1 demands that maximum dust accumulation level shall not exceed value 1 g/m² in the supply air ducts and correspondingly in class P2 the amount of shall not exceed 2.5 g/m². The trigger values when the systems shall be cleaned are 2.5 and 5 g/m², respectively. Following documents are available:

- The regulation of cleaning of air handling systems, Ministry of the Interior (802/2001) (Law)
• Regulations and Guidelines 2003, Indoor Climate and Ventilation of Buildings, D2, Ministry of the Environment (The National Building Code of Finland)
• Classification of Indoor Climate, Construction, and Building Materials 2000, FiSIAQ (Guideline)

In Germany, the guideline VDI 6022 is under revision and the new version will be published in spring 2006. The prevailing guideline consists of three separate parts and the new one will be written in one volume with appendixes. The guidebook consist hygiene requirements for physical, biological and microbiological contaminants. Document gives instructions for proper design of the components, cleanliness and quality demands for manufacture and services. Commissioning of new system is also included in the guideline as well as the methodology for good operation and maintenance practices. Special industrial branches such as food, wood-processing, textile, automotive, printing offices are included. In the document the visual observation and measuring methods are described in the appendix. The VDI 6022 set demands for the personnel who should be trained according to a certain training program.

The basic idea in guideline is that the ventilation systems shall not deteriorate indoor air quality. Outdoor air is used as a reference air. This means that the quality of indoor air shall not be worse than the quality of outdoor air, and in the systems that use recirculated air, the quality of the reference air shall be determined. For the cleanliness of ductwork use of good particle filters is recommended.

Currently, in The Netherlands there is a growing discussion to prepare national guidelines for duct cleaning. Industrial and cleaning companies are involved in the discussion which is lead by the local chapter of ISIAQ. ISIAQ-nl has initiated work and sat a workgroup to get the new guideline. A Dutch organisation, Dutch Association Cleaners of Ventilation systems, is preparing a ‘performance labelling’ system to defines criteria, demands and measure methods for cleaning ventilation systems. This is a new approach to market good management practices of buildings to get high indoor air quality. The labelling system includes an action level as a trigger level and a target level which is aimed to fulfil. Pathogens, dust accumulation and amount of grease in the ducts are the followed parameters.

The discussion promoted by the introduction presentations revealed that there are no conflicts between the REHVA guidebook manuscript and the national guidelines. According to the audience, the guidebook is welcomed to harmonise the national guidelines. It seems that there are special needs also for national guidelines but the guideline published by a strong organisation like REHVA will help national organisations to prepare their own guidelines within a common framework. Thus, the international guidebook was considered as an important publication. Some special questions were asked; what is the relationship between amount of dust and debris in the duct and health outcomes? And how dirtiness is rated to energy consumption? If these questions are not answered how could we know the necessity of cleaning of ventilation system? The authors were asked to look the answers for these questions.
The verification of cleanliness was one of the topics for the discussions. The audience agreed that verification of the cleanliness is very important. Visual inspection was considered as the first method and very often gives a sufficient picture about "clean enough" or "clearly unclean". Other methods like use of comp and the filter methods will be needed if the result of visual inspection is uncertain or argued. As the guidebook is aimed to help in practical work, it shall give recommendations about the evaluation methods. The filter method was accepted for verification method if the visual inspection aided with comp does not give a reasonable result about the cleanliness of ventilation systems. It was emphasised that objective determination of the cleanliness is difficult because the dust is not equally dispersed in the system. Thus the sampling and selection of the measuring points has to be carried out carefully.

A procedure to evaluate and maintain the cleanliness in ventilation system.

Introduction to standards related to guidebook gave some main differences with standards and guidelines. The standards define some minimum values e.g. prEN 12097 gives minimum values for the sizes of cleaning openings and distances between the openings. In generally, the standards are more "normative" and their approval and revision always requires a wide European consensus. This is one reason that standards should usually be kept short and precise, and written at a quite general
level. The guidebooks can give detailed instructions for good practices and they can be revised without long lasting consensus statements. The guidebooks are not normative. Short allegorical questions may be asked; the standards tells ‘what to do’ and the guidebook tells ‘how to do’.

REVHA organization is preparing new guidebooks aimed for good practices in cleaning work. There are two volumes of the guidebook, the first is titled ‘EVHA (2005a) Guide to Cleaning and Hygienic Management of Ventilation Systems. “dry dust”’ and to other is titled ‘EVHA (2005b) Guide to Cleaning and Risk Management of Grease Extract Systems’. Both the guidebooks gives additional value in the same field than the REHVA guidebook. There are some chapters with similar topic and but most of the items are different. The EVHA guidebooks fulfil the REHVA guidebook and vice versa. The editors in chief are aware both of the works which helps to focus the books so that the win-win principal is utilized.

The audience in the workshop initialized also the discussion of the review process. Almost all participated specialists informed themselves being interested to review the guidebook.

3.6 Further work and recommendations
The next step for the REHVA guidebook manuscript is to make it ready and readable. This means e.g. revision of the style in different chapters and revision of the English language.

Design and installation of the ventilation system are in key role when systems with high hygienic standards are built. Of course, the availability of clean components is important.

For good performance of the whole life span of the system the maintenance aspects (including cleanliness) should be taken account.

To get wide acceptance for the guidebook a good review process is needed. This was considered as an important phase before final printing of the book. Almost all participants informed that they can read the manuscripts as reviewers. The Workshop fulfilled well its purposes and it seems that the new printed guidebook can be published during the next year.
3.7 References


4 IMPROVING THE RELIABILITY AND VALUE OF BUILDING SERVICES

Clements-Croome
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Godfaurd John\(^2\), Shaomin Wu\(^2\), Bob Albany\(^3\), Vic Fairey\(^4\)

\(^1\)School of Construction Management and Engineering, The University of Reading, UK; Chairman of Whole Life Performance Task Group, Chartered Institution of Building Services Engineers (CIBSE)
\(^2\)School of Construction Management and Engineering, the University of Reading, UK
\(^3\)Emcor Group, UK
\(^4\)Dytecna Limited, UK

4.1 Background
Building services are a major consideration in the sustainability agenda. They define the internal environment that significantly affects well-being and work performance (Clements-Croome 2000). Insufficient attention is given combines value, which is their quality and whole life cost. Building services engineers are not often involved in early design decisions. The services contractors are mostly subcontractors. Capital cost still dominates the decision making in the construction industry leading to a loss in quality and value. Current building procedures and processes tend to be based upon initial cost and do not always address the overall performance of the building. There is a need to improve the current processes by introducing Whole Life Performance (WLP) and Reliability Design for the WLP to encourage the construction sector to move away from the traditional approaches. WLP procedures and Reliability Design improve design, construction, installation and operation of building systems as well as the choice selection of equipment including components, subsystems and systems for building services.

4.2 Aim and scope
As the business environment becomes increasingly more competitive, it is essential that all available resources are used optimally and effectively. The need to place reliability and the WLP at the forefront of design for building systems is becoming increasingly important, as operational failures, inadequate maintenance policies and logistic support issues, directly and/or indirectly, affect the WLP and adversely affect business. Reliability analysis and its implementation, will lead to an improved whole life performance of the building systems, and hence their WLP.

The aim of the workshop is to encourage the use of proven whole life performance procedures, strategies and techniques available as well as reliability design methodologies, to improve the procurement, design and operation of building systems for the benefits of building services users, and to demonstrate how increased value for money (i.e., quality and whole life costs) enhances the business asset by having a built facility which is healthy for people to work in and is sustainable in terms of energy, water, waste and pollution. The scope includes the Whole Life Process, noting the importance of the initial definition of services requirements from which all else
evolves. This is linked to a Through Life Business Model that reflects business requirements of an organisation.

4.3 Understanding whole life performance for building services

4.3.1 A Strategic Approach for Whole Life Performance

In the USA the defence and aerospace industries have teamed up to form the Product Life Cycle Support (PLCS) Inc. to research and promote the opportunity to work in harmony in terms of improving plant availability, increasing value, reducing costs and wastes as well as improving accessibility and quality of product and product information. For designers, it will mean more reliable systems; for the clients - better value for money.

Many facilities management (FM) companies, suppliers and manufacturers in the building systems industry do not share information on the maintenance and performance of the components or systems in this industry. This is often misunderstood by many as giving away their trade secrets. If the building industry is to achieve continuous improvement, there is a need to dispel this misconception by learning from other industries and developing a trust culture.

The whole life value of an item or system not only includes the embedded energy in all its components, the manufacturing costs, design, procurement, installation, replacement and disposal, but also factors such as quality, durability, functionality and environmental impact. All these factors influence the whole life performance of a component, hence system, to a greater or lesser extent. It is important to understand patterns of failure. An integrated approach is essential. This means the involvement of the facilities manager at inception, with continued team membership through to operation of the facility. This is also true of contractors and manufacturers. It is vital for the client and design team to establish a coherent mission and values strategy at the start (Latham, 1992; Egan, 1998). There is also a need to be aware and understand the interfaces that exist between the building services installations and the fabric; those between the design and construction aspects and the replacement and maintenance requirements. Clients need to be aware of the importance of selection and configuration of systems and the performance impact that they have.

4.3.2 The Through Life Business Model

The Through Life Business Model is intended to allow users to identify all costs associated with a project from initial inception to final disposal and make due assessment of the implications of each of the cost phase. It includes comprehensive, reliable and accurate information across the wide spectrum of the building’s economically viable life. Traditionally, the costs of design and construction have been the only sources of data that could be predicted with confidence and have been used for the option comparisons required during the design process. This has inevitably led to situations where the lowest first cost has driven the project with the result that subsequent operation and maintenance have been unnecessarily expensive and difficult. The Through Life Cost Model is a systematic approach in balancing capital with revenue costs to achieve an optimum solution over the whole life of a building. It recognises that quality affects occupants work performance (John, 2005).
4.3.3 Methodology for Analyses: Availability, Reliability, Maintainability, Safety

Within the construction industry, it is not customary to evaluate the performance of building services systems in terms of their ability to perform. Our Clients require the industry to provide the required environment or services to facilitate their business. How do we demonstrate that the request has been provided? For many years the defence, aeronautical, transport, offshore and nuclear industries both here in Europe and in the USA have methods to ensure that products and system perform as and when required. Of the various methods that have developed within those industries, some can be applied to the building services industry. These methods enable practitioners to demonstrate to their Clients that the required level of service can be achieved with the systems provided. With respect to the data that is currently available to the building services industry, we consider that the following methods of system analysis are appropriate (Loy, 2004). Using these analytical techniques building services practitioners will be able to demonstrate that the systems that they have developed will provide the required level of service and that the safety issues relating to the systems have also been considered and addressed. Consequently business value will increase (Wu and Clements-Croome, 2004, 2005).

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Method of Analysis</th>
</tr>
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<tbody>
<tr>
<td>To review the system structure and reliability</td>
<td>Reliability Block Diagrams</td>
</tr>
<tr>
<td>To review the robustness of the system</td>
<td>Failure Modes &amp; Effects Analysis</td>
</tr>
<tr>
<td>To review the effects of the system interfaces</td>
<td>Interface Hazard Analysis</td>
</tr>
<tr>
<td>To review the system safety aspects in terms of construction, operation, maintenance, environment and disposal</td>
<td>Operating &amp; Support Hazard Analysis</td>
</tr>
<tr>
<td>To review the effects that the maintenance task have on the system level of serviceability</td>
<td>Scheduled &amp; Corrective Maintenance Analysis</td>
</tr>
</tbody>
</table>

4.3.4 Through Life Support of Building Systems

Through life support starts at design, and not when the building is handed over and the owner takes control. The need to define the operation, maintenance, replacement and support strategy as part of the design and how this in turn needs good quality information from manufactures and FM experts. Various approaches to procurement will be discussed. The need to optimise energy use, and to co-ordinate building fabric design decisions with the building services, will be emphasised (Clements-Croome, 2000; 2004).

4.3.5 Data Classification

Without reliable data the WLP process is without foundation. There is a lack of data on matters such as reliability, availability, integration and whole life support. There is also a lack of data in post occupancy evaluation. Facilities management and post occupancy evaluation play a major role in achieving occupant’s satisfaction and
feedback data. Similarly without a credible industry standard means of recording, storing and retrieving this information any data used has limited credibility. Unfortunately with WLP in its infancy within the construction industry there is no coherent data management system (acquisition, storage and use). Those industries where the WLP process has been established the longest, such as the process and defence industries, have made the greatest inroads into the management of WLP data. Changes to the methods of procurement within the construction industry, such as the Private Finance Initiative, have begun to act as a catalyst to a change the perception of WLP. Inevitably the long recognised absence of reliable WLP data will now move up to the top of the list of topics to be progressed.

4.3.6 Risk and Financial Impact
Risk management is an essential part of a Best Practice process for delivering a project using a whole life approach. Risk is inherent in every part of a project, from brief to operation and finally disposal. Risk can be effectively managed to minimise the probability of impact to the client and the delivery team. Processes can be adapted or developed to identify, analyse, control and mitigate risk to reduce unpredictability and to increase the prospects of project success (El-Haram, 2001; Clements-Croome, 2004).

4.4 Activity programme
The task force is currently focusing on the following research:

- Developing a Through Life Business Model to foster team and process integration
- Developing Support Structure for system design
- Developing Availability/Reliability Models for improving whole life performance
- Developing Warranty Policies and Maintenance Policies for optimising whole life cost

A Technical Memorandum is under-progress. This Memorandum introduces methodologies for the whole life performance procedures. It is written by experienced engineers and researchers including manufacturing engineers, consultants, contractors, and academic researchers. Its electronic version will be published soon, and its hardcopy version will be considered for publication afterwards. The current chapters of the Technical Memorandum are shown in the table that follow.

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Topic</th>
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<tbody>
<tr>
<td>1</td>
<td>Introduction of Whole Life Performance</td>
</tr>
<tr>
<td>2</td>
<td>The Through Life Business Model (TLBM)</td>
</tr>
<tr>
<td>3</td>
<td>Reliability, Availability, Maintainability and Safety of Systems</td>
</tr>
<tr>
<td>4</td>
<td>Through Life Support of Building Systems</td>
</tr>
<tr>
<td>5</td>
<td>Data Classification</td>
</tr>
<tr>
<td>6</td>
<td>Risk and Financial Impact</td>
</tr>
<tr>
<td>7</td>
<td>Worked Example</td>
</tr>
</tbody>
</table>
4.5 **Challenges**

A couple of challenges arose out of the discussion from the workshop which are relevant to the construction industry. The following are the main challenges with respect building services:

- Educating and training of technicians from different backgrounds and levels for ensuring whole life performance optimisation;
- Effective communication throughout the building supply-demand chain;
- A change in culture throughout the construction industry to reflect whole life value and sustainability ideals.

4.6 **Summary**

Task Force 10 has introduced methodologies for tackling the following:

- Optimising availability and whole life performance to meet the user’s requirements.
- Developing life cost ratios to inform the importance of life cycle value.
- Setting/measuring performance standards.
- Integrating project team, processes, and systems.
- Data management using various sources including owners; embedded sensors; and facilities managers.
- Structured selection of components, sub-systems and systems configurations.

The use of the methodologies will produce a high quality, low risk solution for the selection of building services systems. There will also be better cooperation across the construction supply chain when these methods are introduced. Businesses will realise a reduction in their whole life cost. The major impact will be in higher work performance levels thus contributing to an improved business performance as well as healthier and sustainable environments.

4.7 **References**

- BS 5760 (1986), Reliability of Systems, Equipment and Components.


Shaomin Wu, Derek Clements-Croome (2005) Optimal maintenance policies under different operational schedules, IEEE Transactions on Reliability, Vol 54(2) pp 338-346


5 EVALUATION OF COST EFFECTIVENESS OF INDOOR CLIMATE

Olli Seppänen¹, Pawel Wargocki², Chairpersons
Johnny Andersson³, Atze Boerstra⁴, Invited Speakers

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5.1 Background
Increased evidence shows that indoor environmental conditions substantially influence health and productivity. Building professionals are interested in improving indoor environments and quantifying the effects. Potential health and productivity benefits are not yet generally considered in conventional economic calculations pertaining to building design and operation. Only initial cost, and energy and maintenance costs are typically considered. Calculations have also shown that many measures to improve indoor air environment are cost-effective when the health and productivity benefits resulting from an improved indoor climate are included into the calculations. There is an obvious need to develop tools and models so that economic outcomes of health and productivity can be integrated in cost benefit calculations with initial, energy and maintenance costs. The topic of this workshop was to discuss a methodology that can be used to evaluate the value of the indoor environment.

5.2 Aim and scope
The focus of the workshop was on the effects of indoor air quality and climate (thermal environment, air quality, ventilation) on sick leave and performance. The workshop had two main objectives:

• to present the results of the REHVA Task Force which has been developing a method describing how the value of indoor environment can be included in investment calculations of buildings;
• to discuss the further work of REHVA in the area of indoor environment and productivity especially as regards the research needs, practical applications, etc.

The target group of this workshop were consultants, building owners, employers, equipment manufacturers, providers of building maintenance and operation services.

5.3 State of the art review

5.3.1 Components of productivity
Productivity is a complex concept which is defined in different ways in various disciplines but should not be confused with individual performance (Pritchard, 1992). In principle, productivity is an index ratio of output relative to input. It can thus be improved by reducing input (costs) and/or improving output. Productivity is often understood as the ability of people to enhance their work output through increase in the quantity and/or quality of the product or service they deliver (Leaman and Bordass
2000). Any environmental condition that decreases individual performance (either quantity or quality), increases absenteeism, or reduces turnover, is more expensive (or costly) for organisations than the capital and operating costs of better indoor environments (Woods, 1989). Consequently, a poor indoor environment decreases organisational productivity both by reducing revenue and by increasing costs.

To visualise the relative correlation of the various costs and earning factors, a simple equation can be established that includes the most significant costs and benefits related to building operation and management. In this connection, it is crucial to apply annual costs and not narrowly consider initial outlays. For example, the following simplified correlation of annual expenses and revenues can be established (Skåret 1992, Hanssen 1997):

\[ B \cdot a + E + M + C + S = P - G \]

where:

- \( B \) = investment capital costs related to building, furnishings, equipment and installations;
- \( a \) = annuity factor (amortisation factor);
- \( E \) = annual energy costs;
- \( M \) = annual operating and maintenance costs;
- \( C \) = annual cleaning costs;
- \( S \) = annual salaries including all related costs;
- \( P \) = annual production revenue (products/fees, etc.); and
- \( G \) = annual profit.

To assess IEQ in terms of employee performance and productivity, it is necessary to consider a variety of measures that might be used as indicators of an effect on company productivity. The following measures were recommended at an ASHRAE Workshop in Baltimore in September 1992 (Wyon, 1993): (a) absence from work, from workstation; unavailable on telephone; (b) health costs, including sick leave, accidents, injuries; (c) observed downtime, interruptions; (d) controlled independent judgments of work quality, mood, etc.; (e) self-assessments of productivity; (f) component skills, task measures, speed, slips, accuracy; (g) output form pre-existing work-groups; (h) total unit cost per product or service; (h) output change in response to graded reward; (i) voluntary overtime or extra work; (j) cycle time from initiation to completion of discrete process; (k) multiple measures at all organizational levels; (l) individual measures of performance, health and well being at work; (m) time course of measures and rates of change. Absence from work represents a 100% loss of productivity, but also deteriorated IEQ may reduce performance at work in a substantial way. This, in turn, may result in a considerable loss of productivity and business outcome.

5.3.2 Review of the research on the effects of IEQ on performance of office work

Temperature

Room temperature affects the productivity of office workers through the operation of several mechanisms (Wyon and Wargocki, 2006a). Thermal discomfort distracts attention and generates complaints that increase maintenance costs. Warmth lowers arousal, exacerbates SBS symptoms and has a negative effect on mental work. Cold conditions lower finger temperatures and so have a negative effect on manual dexterity. Rapid temperature swings have the same effects on office work as slightly raised room temperatures, while slow temperature swings just cause discomfort.
Vertical thermal gradients reduce perceived air quality or lead to a reduction in room temperature that then causes complaints of cold at floor level. Individual control of the thermal microclimate reduces most of these problems.

Indoor air quality and ventilation

In a series of experiments carried out recently it was shown that commonly occurring indoor sources of pollution may cause a reduction in the performance of office tasks (Wyon and Wargocki 2006b). In a series of laboratory simulation experiments with exposures of up to 5 hours the performance of simulated office work was increased by removing common indoor sources of air pollution (floor-coverings and personal computers), or by increasing the rate at which clean outdoor air was supplied per person (3-30 L/s/p). The resulting pollutant levels affected the headache and difficulty in thinking clearly and the perception of indoor air quality. These findings were validated in two 8-week field intervention experiments, which were carried out in call-centres in northern Europe and in the hot humid Tropics. The results of field experiments show that indoor air quality had a larger effect on the actual performance of office work in the field than would be predicted from the laboratory experiments.

5.3.3 Summary of relations between IEQ and performance

Based on the results of the studies investigating the effects of temperature and indoor air quality on performance of office work, the following quantitative relationships were suggested to estimate the effects of temperature, indoor air quality and ventilation on performance and sick leave:

- the relationship between performance of office work and ventilation rate (Seppänen et al., 2005a);
- the relationship between performance of office work and temperature (Seppänen et al., 2005b);
- the relationship between performance of office work and perceived air quality (Wargocki et al., 2000);
- the relationship between sick-leave and ventilation rate (Fisk et al., 2003).

The relationship between performance of office work and ventilation rate (Fig. 1) was analyzed statistically based on studies that quantified office work performance by measuring the reaction time, performance of simulated office work (typing, addition, proof-reading) and performance of actual work in offices (talk-time in call-centre). Each data point was weighted by the number of subjects and the different metrics (e.g., speed of simulated work) were assigned weighing factors according to the relevance of the metric for overall office work performance. The analyses suggest that work performance will on average increase by approximately 1.5% for each doubling of outdoor air supply rate.

The relationship between temperature and work performance (Fig. 2) was statistically analyzed based on the data from 24 studies in a similar way as it was done in case of the relationship between ventilation and work performance described above. Individual data points were weighted for the number of subjects and for the relevance of the work outcome metric to real work. The analysis suggests a reduction of performance by about 1% for every 1°C change (reduction/increase) of temperature from 22°C.
Figure 1. Change in performance per 10 L/s per person increase of outdoor air supply rate

Figure 2. Change in performance per 1°C increase in indoor temperature

The relationship between perceived air quality and performance of office work (Fig. 3) was created based on experiments with subjects performing simulated office work. The air quality was modified by changing the outdoor air supply rate or reducing the pollution load on the air. The analysis suggests about 1% increase in performance for 10% reduction of % dissatisfied with air quality.

The relationship between sick-leave and ventilation (Fig. 4) was estimated based on studies using sick-leave or short-term illness as outcomes. The analysis suggests a 10% reduction in illness or sick leave for doubling of outdoor air supply rate.
In addition to the above quantitative relationships, an attempt to create a qualitative relationship between self-estimated performance and prevalence of SBS symptoms was presented. This relationship suggests 1% increase of self-estimated performance for 7.4% decrease in prevalence of symptoms (Niemelä et al., 2005).

![Figure 3. Relative performance of office work as a function of perceived indoor air quality](image)

**Figure 3.** Relative performance of office work as a function of perceived indoor air quality

![Figure 4. Relative sick-leave as a function of ventilation](image)

**Figure 4.** Relative sick-leave as a function of ventilation

### 5.3.4 Typical annual costs of an office building

When comparing costs for office buildings on a European level there are large differences making a comparison difficult and perhaps meaningless. There are e.g., different climates; different building types and materials used; different energy costs
for electricity, heating and cooling; different wages for maintenance and cleaning personnel, and different ways of calculating workplace areas. In order to make comparisons possible costs, areas and rates of consumption, etc. must be well defined. On the other hand, when weighing these costs against the benefits of increased productivity expressed as wage cost per working hour saved, the national cost levels will influence both scales of the balance. The operating cost level of an office is influenced by the age and size of the building, the quality level of the premises, and above all, of the location of the building, whether in an attractive downtown area or in a less central location.

The total annual operating cost for a square meter of office space – whether hired (and thus eventually included in the rent) or own – cover several different items:

- Consumptions – heating, cooling, and electricity – depending mostly on the location, the size and age of the building, the ambient climatic conditions and the required indoor thermal climate and air quality.
- Cleaning costs – cleaning of the premises is – and should be – a substantial part of the total cost for the office space. A reduced level of cleaning standard will most probably result in reduced well-being and could in the extreme lead to the risk of SBS.
- Maintenance – both running and preventive – of the building and its installations is necessary for keeping thermal climate and air quality at an acceptable level.

Facilities Management, FM, is thus of vital importance and should be effective in order to provide a good working environment for the office personnel. FM may include a large number of different needs to be satisfied.

The needs vary between different stakeholders: business managers who want to gain higher efficiency and productivity from the facility; employees who want to have functional and appealing workplaces; Building owners who want a better return on their real estate investment; and service suppliers – either in-house or outsourced, e.g. maintenance and cleaning personnel – who want to have easily maintainable spaces with good accessibility.

In the following example typical operating costs, for different types and sizes of offices and office buildings of different age and standard in Sweden are presented. All costs are from Sweden and are given in €/m². The values are based on statistics and could be regarded as benchmark values. A further step would be to add annual capital costs for properly chosen air handling installations etc. at different quality levels regarding indoor air quality and thermal climate.

The following different types of offices are considered:

- Office type 1: Total rented area: 500 m² in a larger building. Number of office workers: 20. Traditional area with single offices, i.e. the area per worker is high: 25 m² per worker.
- Office type 2: Total rented area: 1350 m². Number of office workers: 75. This office type comprises 50% traditional area with single offices and 50% with landscape. Area: 18 m² per worker.
- Office type 3: Total rented area: 4900 m². Number of office workers: 350. This office type comprises 15% traditional area with single offices and 85% with landscape. High area efficiency; area: 14 m² per worker.
The following different building types are considered:

- **Building type 1**: Modern building, built or renovated 1990 or later. 80% landscape offices resulting in high space efficiency. High demands on energy efficiency and environment. Thermal climate: TQ1 – highest requirements. Comfort cooling in all rooms. High quality maintenance.
- **Building type 3**: Older office building from the 1980’s or earlier. 100% single offices resulting in low space efficiency. No expressed demands on energy efficiency and environment. No comfort cooling. Normal quality maintenance.

Typical Swedish annual costs for heating, cooling and electricity for these building types were taken as follows:
- Heating: 0.0676 €/kWh;
- Electricity and cooling: 0.1 €/kWh.

Annual energy use and costs are shown in Table 1 and total annual operating costs for the different buildings are given in Table 2. The results suggest that energy costs for raising the quality level of thermal climate and indoor air quality seem to be small in comparison with the possible gains from higher productivity, reduced sick leave, and better comfort and well-being.

**Table 1. Annual energy use and costs.**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating [kWh/m²]</td>
<td>45-55</td>
<td>100-120</td>
<td>150-170</td>
<td></td>
</tr>
<tr>
<td>Annual cost [€/m²]</td>
<td>3.0 – 3.7</td>
<td>6.8 – 8.1</td>
<td>10.1 – 11.5</td>
<td></td>
</tr>
<tr>
<td>Cooling [kWh/m²]</td>
<td>15-25</td>
<td>12-20</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Annual cost [€/m²]</td>
<td>1.5 – 2.5</td>
<td>1.2 – 2.0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Electricity [kWh/m²]</td>
<td>30-40</td>
<td>25-35</td>
<td>15-25</td>
<td></td>
</tr>
<tr>
<td>Annual cost [€/m²]</td>
<td>3.0 – 4.0</td>
<td>2.5 – 3.5</td>
<td>1.5 – 2.5</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Total annual operating costs for the different buildings.**

<table>
<thead>
<tr>
<th>Total rental cost§)</th>
<th>Building type 1</th>
<th>Building type 2</th>
<th>Building type 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>€/workplace</td>
<td>€/m²</td>
<td>€/workplace</td>
<td>€/m²</td>
</tr>
<tr>
<td>Office type 1</td>
<td>2400</td>
<td>100</td>
<td>4800</td>
</tr>
<tr>
<td>Office type 2</td>
<td>1700</td>
<td>100</td>
<td>3400</td>
</tr>
<tr>
<td>Office type 3</td>
<td>1300</td>
<td>100</td>
<td>2700</td>
</tr>
</tbody>
</table>

§): the sums include electricity, cleaning and maintenance
5.3.5 Calculation principle on how to evaluate the value of indoor environment

Several examples can be given on how to evaluate the value of indoor environment. The following example (updated from Seppänen and Vuolle 2000) illustrates how the effect of room temperature on performance is integrated in the evaluations of the cost effectiveness of various alternatives of air conditioning. The evaluation is based on computer simulations of thermal conditions and energy consumption in the Finish climate (Helsinki). A typical Finnish office building was selected for the analysis. It is a concrete structure with narrow bays and private offices located in the exterior zone of building (no open plan offices). A small office was selected in the detailed analysis. The basic case (#1) used as a reference has moderate solar protection of windows (light blinds between the panes), and heavy construction to decrease the daily high temperatures with the thermal capacity. The options to reduce high temperatures in the room are: (#2) mechanical cooling with cooling capacity of 20 W/m² floor in the air handling unit; (#3) increased operation time of ventilation from 10 to 24 h per day in summer (typically the ventilation is running only during the office hours plus a couple of additional hours); (#4) increased outdoor air flow rate from 2 to 4 L/s per m² floor (usually the outdoor air temperature is lower than indoor air temperature in Finnish climate), and increased operation time from 10 to 24 h per day in summer; and (#5) cases #2 to 4# combined. The investment cost of mechanical cooling was assumed to be ca. € 24,000 and for increased ventilation rate € 25,000. They are based on a large Finnish database on refurbishment costs. The first costs have been calculated assuming 50 similar rooms to be remedied under the same contract. The first cost has been converted to annual cost using the annuity factor of 0.1098, which corresponds the life cycle of 15 years and interest rate of 7 %. The effect of the remedial measures on room temperature, productivity and energy consumption was calculated with a modular computer program IDA Indoor Climate and Energy (Vuolle and Sahlin, 2000).

The energy consumption was calculated using Helsinki reference year weather data. The energy costs used in the calculations reflect the average energy cost in Helsinki.
for heating 0.04 €/kWh and 0.1 €/kWh for electricity. Heat recovery from ventilation air with a temperature efficiency of 50% was used in calculations. The loss of productivity was estimated using the relationship shown in Figure 2. The results of the calculations are shown in Figure 5. The cost items include the value of lost working hours, increase in energy cost, and annual cost of the remedial measure. The results clearly indicate how large benefits of improved productivity can be obtained when the temperature is controlled. These benefits largely exceed costs needed to control the temperature.

5.3.6 The productivity arguments in practice – how to convince the client

A thorough indoor climate investigation often ends with the conclusion that serious and expensive improvements are needed to improve the situation and diminish the amount of indoor climate complaints. Facility managers often are reluctant to invest in their building, so in practice a successful IEQ consultancy project involves not just a technical discussion but also lots of motivational input from the investigator. Let’s imagine that a facility manager is confronted with the following statement: ‘We investigated your building and our conclusion is that your have a serious IEQ problem. Do you want to spend € 300/m² to improve IEQ?’ The first reaction will probably be negative if the cost is only taken into account. This is especially the case when the facility manager has expected rather cheap solutions. The alternative is to describe to him the value of the investments using another type of statement: ‘You have a serious IEQ problem. Do you want to improve employee productivity by more than 10%, decrease sickness leave by a few % and achieve a return on investment of more than 10?’ The experience suggests that this approach is much more effective and more often results in real IEQ improvements in the building.

To illustrate the above alternative approaches, a case study has recently been carried out in a Dutch office building where people complained of IEQ related symptoms. The work in the building involved not only regular office work but also laboratory tests and technical work comprising adjustments on machinery. Investigation included collection of symptoms and perceptions of employees using questionnaires, measurements of numerous IEQ parameters, as well as building and HVAC system inspections. The conclusion was that the quality of indoor air, thermal climate and acoustic and visual work environment in the building was ‘below average’ and significantly worse than in a normal Dutch (office) building. Based on an analysis of the questionnaire outcomes and the measurements, as well as the quantitative relationships between IEQ and performance an estimate was made of the yearly productivity loss in the building assuming additive effects on productivity of different IEQ factors although the combined effect of IEQ parameters on performance is still unknown. The estimate was based on IEQ score of the building and compared with the building with good IEQ (IEQ score of 7) and the average Dutch building (IEQ score of 6). It was also assumed that the average net salary cost per person (after tax) was € 40,000 and the gross output per person (contribution per person to the company’s turn-over) was € 100,000. Thus a productivity effect of 1% for one person would results in an annual benefit of € 1,000. The results of the estimations are shown in Table 3.
Table 3. Estimated annual benefit of improved productivity in the Dutch case building

<table>
<thead>
<tr>
<th></th>
<th>Building with good indoor air quality (IEQ score = 7)</th>
<th>Average Dutch office building (IEQ score = 6)</th>
<th>Building in which the case study was carried out (IEQ score = 5.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated increase in productivity</td>
<td>0%</td>
<td>2.5% to 7.5% (average 5%)</td>
<td>4% to 12% (average 8%)</td>
</tr>
<tr>
<td>Number of employees</td>
<td>350</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>Annual benefit of improved productivity</td>
<td>€ 0 mil.</td>
<td>€ 0.9 to €2.6 mil.</td>
<td>€ 1.4 to €4.3 mil.</td>
</tr>
</tbody>
</table>

The results presented in the table suggest that postponing improvements of IEQ in the case building can cost annually up to € 4.3 million a year. The following renovation plan was suggested:

- **Introduction of a new ‘functional concept’** that would further separate (physically but also in terms of air pressure differences) the office, laboratory and technical activities.
- **Moderate renovation of the facade** (improvement of air tightness, replacement of glazing, extra sun shielding).
- **Intensive upgrade of central HVAC units**, the introduction of new supply grilles and cleaning of ducts.
- **Introduction of new lighting fixtures**.
- **Improvement of cleaning procedures and introduction of a clean desk discipline**.

The overall cost for the renovation of the case building resulting in an IEQ score of 7 was estimated to be € 5 million (€ 600-700/m²). Thus the pay back time was estimated to 2 years and the return on investment (assuming a life span of 15 years in the improved situation) to around 7.

5.4 Results and recommendations

About 50 people participated in the discussion during the workshop. The discussion focused on specific questions related to methodology used in the studies investigating the effects of IEQ on productivity and to the methods used to establish quantitative relationships between IEQ and productivity. It was pointed out that there is a need for data on the effect of multifactorial exposures on performance, as well as of the impact of ventilation effectiveness, cleaning and maintenance of HVAC systems and buildings with natural ventilation on performance. There is also a need for a link between SBS symptoms and objectively-measured work performance. So far such a link has been attempted for self-estimated performance.

The general conclusion was that the data on the effects of IEQ on productivity collected so far indicate fantastic return on investments. An improvement of IEQ is a win-win-win situation: building owner benefits from higher return on investment through increased lease, employer benefits from improved productivity and an employee benefits from better IEQ and reduction of building related health symptoms. Even though much better dialogue between building owners and tenants is still required.

It has been emphasized that motivation for people who are responsible for IEQ in buildings is crucial. Motivation should be provided by underlining the value of a
building that is able to create a healthy, comfortable and productive environment and incorporating it in the sustainability concept. This can only be attained by providing strong evidence linking IEQ with health and productivity and comparing energy and building costs with human costs. The examples of building costs for Swedish conditions seems to be similar for other countries (e.g. The Netherlands) and it would be useful to have benchmark costs from different countries.

There was also a clear support for quick publication of a REHVA guideline presenting the quantitative relationships which can be used to estimate the value of the indoor environment.

5.5 References


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²ISSO, Dutch Building Services Research Institute, Netherlands

6.1  Aim and scope

The European Energy Performance of Buildings Directive (EPBD) was published in January 2003 and obliges the EU Member States to implement a series of measures. A recent statistical analysis of the needs for information realised within EEPB project demonstrated that the information about EPBD status is poor in the whole Europe. This workshop has been designed in order to give the participants a clear overview of the overall status of the work and the progress to be expected in the near future.

6.2  Status of EPBD Implementation

Peter Wouters, BBRI, Belgium

The European Energy Performance of Buildings Directive (EPBD) was published in January 2003 and obliges the EU Member States to implement a series of measures. The EPBD imposes each MS to implement the following requirements:

1. the general framework for a methodology of calculation of the integrated energy performance of buildings;
2. the application of minimum requirements on the energy performance of new buildings;
3. the application of minimum requirements on the energy performance of large existing buildings that are subject to major renovation;
4. energy certification of buildings; and
5. regular inspection of boilers and of air-conditioning systems in buildings and in addition an assessment of the heating installation in which the boilers are more than 15 years old.

In terms of requirements to the Member States (MS), it is important to situate the EPBD in relation to following directives:

- The EPBD imposes MS to implement a set of requirements as listed above but without mandatory requirements in terms of minimum energy efficiency (i.e. some countries can impose very severe requirements and a strict implementation scheme whereas others might have very light requirements without control on site)
- The proposal for a directive on energy services and end use energy will specify minimum energy saving targets at MS level, i.e. 1% per year for the period 2007 – 2012. One of the discussion items is the question whether these targets are mandatory are only recommendations.
In order to increase the probability of a successful implementation of the EPBD, a series of EC support measures are foreseen:

- A mandate for CEN to prepare a series of standards (see summary by J. Hogeling)
- A series of SAVE projects have been adopted, these projects have started in the beginning of 2005. The SAVE 2005 call (deadline January 31 2006) foresees also the support of EPBD related proposals.
- The EPBD Concerted Action (www.epbd_ca.org) brings representatives from 24 MS together and aims to stimulate information exchange between MS. It is expected that this will give a substantial support to MS, reduce redundancy in the national efforts and will facilitate a certain degree of harmonisation
- The EPBD Buildings Platform is expected to start in the beginning of 2006 and should improve communication about various EPBD issues and help MS in the national implementation.

6.3 En standards prepared by CEN under EU mandate

Jaap Hogeling, ISSO, the Netherlands

6.3.1 Introduction

For the implementation of the Energy Performance of Buildings directive, major efforts have been done in European Standardisation during the year 2004. Five CEN Technical Committees have been involved in developing about 40 standards, under a Mandate from the Commission to CEN.

Most of the work has been carried out in a very short time, some drafts being developed from scratch to a draft European Standard in less than eight months, with a speed really exceptional in CEN. The CEN Enquiry stage is now running and is expected to be finished by the end of this year 2005. CEN Enquiry for the first completed draft was launched in the end of March 2005. The EN or EN-ISO Standards should be available, after finalization taking into account the comments received, and after the CEN Final Vote, probably in early 2007.

The real influence of the standards has been under discussion on national level and on European level. The Directive leaves the Member States a lot of freedom in implementation. Of course there is a clear justification in national implementation: there are different climates, building types and also the available energy sources differ from country to country, and also economical and cultural differences prevent a strict European regulation.

The EU Mandate for CEN aims on a harmonised European framework to support the implementation of the EPBD. Not only the legal minimum but also to adopt the principles in real practice? Instead of nearly 30 countries struggling with the same technical questions separately, a harmonised CEN approach is chosen to prevent different national approaches which could form obstacles for trade and communication within the open EU market. These were basic questions which resulted in some 40 Work Items in five CEN Technical Committees.

6.3.2 The CEN program

For the standards and WI's as prepared by CEN see attached list. These standards are developed under the responsibility of the following CEN Technical Committees (TC's):
TC 89 THERMAL PERFORMANCE OF BUILDINGS AND BUILDING COMPONENTS
TC 156 VENTILATION FOR BUILDINGS
TC 169 LIGHT AND LIGHTING
TC 228 HEATING SYSTEMS IN BUILDINGS
TC 247 BUILDING AUTOMATION, CONTROLS AND BUILDING MANAGEMENT
This work of CEN was coordinated by the CEN-BT-WG173 on the EPBD

By the end of 2004, the work resulted in "TC drafts", all technically completed but several drafts required editorial work and then have been delivered to CEN for further progressing to CEN Enquiry. The almost 2000 pages of text had been developed in an exceptionally tight time schedule. Enquiry started by 1 April 2005.

6.3.3 The interrelation
The interrelation between the EPBD standards and the EPBD is shown in figure 1. (The prEN’s related to the WI’s can be found in the attached table.) This figure with other schemes can be found in the CEN Technical Report (the so called Umbrella Document) to be published to support the use and understanding of the EPBD standards. This draft CR as already available and will be published officially after the end of the Enquiry period.

6.4 The prEN’s published and challenges
As most of the prENs are now published the first reactions have been received. These first reactions give the following picture:

- Limit the number of pages >> Will be possible by deleting some informative annexes and merging standards.
- Try to merge some of the standards >> this will be considered.
- Improve the harmonisation of definitions and input/output data >> this will be done, a supporting XML file attached to the CR will be finalised during the coming months.
- Manage the complexity: keep it simple and allow for advanced solutions >> this seems possible by using as much as possible performance descriptions.
- Harmonise in such way that it will be easy to report on indoor conditions in relation with the EP-certificate (art.7) and inspections reports (art.8 & 9). >> This seems possible by fitting the relevant standards (prEN15251 & 13779 etc.) in this respect.
6.5 CEN standards for expressing energy performance of buildings
Claude Alain Roulet, EPFL, Switzerland

6.5.1 Introduction
Expression of the energy performance of buildings is needed:
- to enable the establishment of regulations regarding energy performance of buildings;
- to provide a means for defining energy ratings for buildings and deliver certificates;
- to encourage governments, building designers, owners, operators and users to improve the energy performance of buildings.

Energy certification of buildings requires a method that is applicable to both new and existing buildings, and which treats them in an equivalent way. Therefore, a methodology to obtain equivalent results from different sets of data is proposed in a standard. A methodology to assess missing data and to calculate a "standard" energy use for space heating and cooling, ventilation, domestic hot water and lighting is also provided.

To take account of the building size, the energy rating is divided by a representative dimension, such as the conditioned floor area. It is then compared with a required limit, which may depend on building use, climate, energyware, building size or shape and occupancy parameters such as required ventilation rate and illuminance levels.

The standard also proposes a seven level scale for sorting buildings into classes. The
thresholds of the classes are defined at the national or regional level, based on the existing building stock and on the regulations.

6.5.2 Energy rating
PrEN 15203 defines the uses of energy to be taken into account and provides methods to assess energy performance ratings for new and existing buildings. It also provides a methodology to improve confidence in the building calculation model by comparison with actual energy consumption and to assess the energy effectiveness of possible improvements.

Basically two types of ratings are proposed: a rating obtained by calculating the energy performance of a given building from data obtained from drawings and other standards, and an operational rating obtained from the measurement of energy consumption. An asset rating is proposed for labelling. It is a calculated rating in standard conditions for occupancy, climate and use.

In both cases, the results should be expressed in terms of primary energy or CO2 production. There is indeed no physical meaning to add together kWh of delivered electricity, wood, coal, gas or oil. Therefore, ratings are expressed either in terms of primary energy use or CO2 production. Cost may also be a possibility.

Input parameters
Inputs for calculated ratings
- Annual energy use for heating and cooling, calculated according to prEN 13790. This standard needs itself, among others, the calculation of the energy performance of heating and cooling systems according to prEN 15316 (appropriate part)
- Annual energy use for hot water, calculated according to prEN 15316-3-1;
- Annual energy use for lighting, calculated according to prEN 15193-1;
- Annual energy use for ventilation, calculated according to prEN 15241;
- Conversion factors from delivered energy to primary energy and CO2 production, according to prEN 15315.

Inputs for operational rating and calculation model validation:
Metered energy use for all energywares.

Additional inputs, normally provided on a national level:
- Gross calorific value of energywares;
- Standard data related to occupancy (temperature, humidity, airflow rate, internal gains, hot water use, and standard energy use for appliances other than heating, cooling, ventilation, hot water and lighting);
- Standard climatic data.

Main outputs
The asset rating, a standard energy use that does not depend on occupant behaviour, actual weather and other actual (environment or input) conditions.
The operational rating, based on the delivered energy.
The energy effectiveness of possible improvements.

6.5.3 Expressing the energy performance
The ratings form prEN 15203 are used in prEN 15217, together with building dimensions and possibly other parameters such as climate, use, etc., to express the energy performance of a building.

PrEN 217 defines:

1. Global indicators to express the energy performance of whole buildings, including heating, cooling, ventilation, domestic hot water and lighting systems. This includes the different possible indicators as well as a method to normalize them.
2. Ways to express energy requirements for the design of new buildings or renovation of existing buildings.
3. Procedures to define reference values and benchmarks
4. Ways to design energy certification schemes. This last part is mainly a guideline enabling the member states to select the approach best suited to their needs.

Figure 3: Proposal for sorting buildings given in prEN 15217. For each building type, the thresholds between classes are based on the average rating of the existing building stock, \( R_s \), and on the national limit for new buildings, \( R_r \).

6.5.4 Perspectives
The drafts passed the public enquiry and are now under revision to take account of the many received comments. A clear comment from several CEN members is that at least prEN 15203 and 15315, and possibly also prEN 15127 should be merged into...
one single standard. The elaboration of these European standards benefits from the contributions of many experts from several countries, and, therefore, should present more advantages and fewer defaults than any local document. They could be of great help to governments in charge of applying the building energy performance directive.

6.6 Rehva contribution to accompanying EC projects
Francis Allard, REHVA, Univ. La Rochelle, France

In 2004, REHVA has been involved in three different European projects in the frame of IEE Intelligent energy for Europe program of the European Union. These three projects are in fact accompanying actions to EPBD implementation. Their global goal is to facilitate and disseminate the knowledge about energy performance in techniques related to buildings. We will describe briefly these three actions; each of them will also be presented in separated workshop during CLIMA 2005.

6.6.1 EULEB: European High Quality and Low Energy Buildings

- **Participants:**
  6 participants are involved in the project:
  1. UDO Department for Environmental Architecture University of Dortmund, German (coordinator)
  2. LMU Low Energy Architecture Research Unit, London Metropolitan University, UK
  3. ABITA Centro Interuniversitario A.B.I.T.A – Universita di Firenze, Italy
  4. ULR LEBTAP – University of La Rochelle, France
  5. UPC Universitat Politècnica de Catalunynia, Spain
  6. REHVA

The main objective is to select and document European high quality and low energy architecture examples to support the EPBD.

- **Main tasks:**
The main tasks of the project are organised in 9 Work packages
  - WP1: identification of buildings:
    3 types of buildings: - Local government office buildings
    - Educational buildings
    - Leisure facilities (ex: cultural, museum, sports,..)
  - WP2: collection of data
  - WP3: Visualization of data
  - WP4-5-6-7: CD construction and translation
  - WP 8-9: dissemination

- **Status:**
Until now, about 100 buildings have been identified with the following criteria:
  - Good Design, preferably award winning buildings
  - Low Energy Consumption
  - Availability of monitored energy consumption or easily measurable
  - Availability of financial data relating to energy saving features (RUE and RES)
The final selection of buildings is in progress and the evaluation procedure is to be tested.

**REHVA’s contribution:**
In this project, REHVA is leader of WP 7: translations, it is also in charge of the evaluation procedure and the final dissemination through workshops, seminars, journal and website. EULEB has been presented in WORKSHOP 11 Wednesday Oct. 11 9 to 11 AM.

### 6.6.2 VENT. DIS. COURSE: Development of Distance Learning Vocational Training Material for the Promotion of Best Practice Ventilation Energy Performance in Buildings

**Participants:**
9 participants are involved in the project:
1. Brunel University, UK (coordinator)
2. University of Athens, Greece
3. ENTPE, France
4. REHVA
5. BSRIA, UK
6. VEETECH Ltd, UK
7. FINVAC, Finland,
8. AICVF, France
9. HABE, Greece

The main objective is to accelerate the implementation of ventilation within EPBD for a best practice of an energy efficient and healthy ventilation

**Main tasks:**
The main tasks of the project are organised in 6 Work Packages
- WP1: review and evaluation of existing distant learning methods
- WP2: collection of all necessary information
- WP3: Development of distance learning material
- WP4: Training methodology
- WP5: Testing of the training package
- WP6: Dissemination

**Status:**
- The state of the art of existing distant learning in ventilation is being processed
- The specific definition of each training material has been defined.
- Each partner is now preparing training material

**REHVA’s contribution:**
- Leader of dissemination activities (WP 7)
- Leader of testing activities (WP 5)
- In charge of mechanical ventilation training material and translation in one language

This project has been presented in Workshop 13: Wednesday Oct-12, 9 to 11h,
6.6.3 EEBD: Electronic Energy Buildings Directive

- **Participants:**
  10 participants are involved in the project:
  - 1 Technological Educational Institute of Crete, Greece (coordinator)
  - 2 University of Athens, Greece
  - 3 BYTE SA, Greece
  - 4 ULR LEBTAP – University of La Rochelle, France
  - 5 REHVA
  - 6 Regional Energy Agency of Crete, Greece
  - 7 Black Sea Regional Energy Agency, Bulgaria
  - 8 BUSRHAE, Bulgaria
  - 9 AEE INTEC, Austria
  - 10 BRE, UK

The main objective of the project is the development of a web-based information platform for experts for the take off of EBPD.

- **Main tasks:**
The main tasks of the project are organised in 6 Work Packages
  - WP1: Overview of the vocational training needs
  - WP 2 and 3: Development of the tool
  - WP 4: Evaluation and testing of EEBD Tool
  - WP 5 and 6: Dissemination activities

- **Status:**
  - The questionnaire has been elaborated and distributed
  - About 400 questionnaires have already been treated:

The training need is very high all over Europe

- Evaluation of existing training material is in progress
- Formulation of the tool is in progress

- **REHVA’s contribution:**
  - Leader of dissemination activities (WP 5)
  - Testing and evaluation of EEBD tool (W 4)

This project has been presented in Workshop 12 Tuesday Oct-11, 15 to 17 h.

6.7 Discussions and main issues

During the discussion the main question raised where focused on three main topics:
1. What is the real schedule of implementation and what are the procedures?
2. How can we define the primary energy demand in a uniform way?
3. What about tools (softwares, manual methods, technical solutions)?

a) **What is the real schedule and what are the procedures?**
In the first round of questions and discussions, it has been seen that the knowledge is quite poor about the practical implementation. What are the qualifications required for
the inspectors? How to hire thousands of inspectors in each country? The feeling is that nothing will occur in January 2006, each country will have to elaborate is own answer.

b) How to define the primary energy demand?
The questions here are more about the method and the data to be used. The energy panel is very different from one country to another.

6.8 ANNEX: References List of EPBD STANDARDS

List of Mandated Work Items and standards related to the EPBD (2005-10-20), the list of the prEN’s under the EPBD Mandate as they have been published for public enquiry.

As far as known the end of enquiry date is given. Official reactions on the prEN should be sent to the National Standard Body (Member Body; MB) in the CEN member states. All the official comments will be processed by the MB’s and sent to CEN in Brussels. CEN will analyse the voting results and send it to the responsible CEN/TC secretariat. After this the CEN Working Group responsible for that prEN will start the analysis and the preparation of the final version of the standard to be voted for Formal Vote within one year. During this revision process comments given to related standards have to be taken in account as well.

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<td>EN13792</td>
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Maija Virta¹, Chairperson
Mika Ruponen¹ and Risto Kosonen¹, Secretaries

¹Halton Oy, Finland

7.1 Background
The building industry continues to see a growing interest in creating solutions that consider the priorities of indoor environment quality (IEQ) and energy conservation. Additionally, there is obvious link with indoor climate and productivity. It is also important to note that the systems should be built and used as designed and all set performance metrics should be continually evaluated at different stage of the building development and management process. Otherwise, the IEQ and energy consumption targets are not simultaneously attainable.

A building project begins with a consideration of various performance objectives of interest to building stakeholders. While primary attention is generally given to space requirements and construction costs, a wide spectrum of objectives may be at least informally considered at this stage, including: energy-efficiency, life-cycle economics, occupant comfort and productivity as well as building functionality and adaptability.

Correctly designed, air distribution systems can offer high standards of comfort and air quality. It may be however, that they do this at the expense of high running costs (energy and maintenance). Alternative approaches that minimize the quantity of air handled and also have the ability to provide a high quality environment are available and increasing in popularity.

However there is not enough independent information available from modern air distribution systems. This is why Rehva has recently published a new chilled beam application guidebook. This guidebook is aimed at consulting engineers and contractors, who want to design and execute good chilled beam systems and also facility owners, who want to develop life cycle cost efficient buildings and comfortable occupied spaces for people.

This book provides tools and guidance to achieve good indoor climate in the space using chilled beam technology, to select chilled beams and other required components and to design the air and water distribution system. It also presents some case studies, where chilled beams are used.
7.2  Aim and scope
The aim of this workshop was to discuss end users’ needs as well as highlight the practical problems in today’s air distribution systems and presents new, more energy efficient system to ventilate and cool spaces.

7.3  Occupant satisfaction in existing buildings
Indoor environment is important for us because we spend about 90 % of our time indoors. In public media quality of outdoor air is discussed a lot, but indoor air is hardly ever mentioned. Indoor environment quality is directly linked with employee productivity. Occupant centred development of indoor environment quality improves satisfaction and productivity fast. Indoor air is also one of the biggest health risks.

Occupants know their surroundings and occupant satisfaction is the most important quality measure. To be able to found out occupant satisfaction and possible problem areas in a building, you need to survey it. For example occupants could fill in a survey through Internet, and results are analysed and reported. After that the further actions and first improvements of indoor environment can be recommended in areas, where dissatisfaction or productivity loss is significant. Typical result after the survey shows, that even if the building is designed to meet the highest level of indoor environmental quality with occupant satisfaction over 85 %, the real satisfaction is much lower around 60 – 80 %. In cases where occupant satisfaction is measured, both occupants and facility owners benefit from the result.

Figure 1. A case study of a measured occupant satisfaction in a Finnish office building. Thermal comfort is the biggest factor causing dissatisfaction. 26 % of 247 respondents reported dissatisfaction to thermal comfort.

7.4  Chilled beam cooling
The chilled beam system is one of the newest HVAC systems in commercial buildings in North and Central Europe. The design methodology and selection principles of a chilled beam system has been developed and documented to take into account the different design practices and climate conditions in Europe. The hot and humid
climate conditions, where chilled beam system could be a new, energy efficient room air-conditioning system, has also been taken into account.

The chilled beam system promotes excellent thermal comfort and the energy and space saving advantages, which the use of water as a cooling medium provides. The system operation is simple and trouble-free, with limited maintenance requirements. Chilled beam system design complements the flexible use of available space, whilst the high temperature cooling and low temperature heating maximize the opportunity for free cooling and heating.

The chilled beam systems are primarily used for cooling and ventilation in spaces, where requirement for good quality environmental conditions and individual space control is needed and where the internal moisture loads are moderate. Systems can also be used for heating in some applications.

Due to dry coil operation, the beam system should be used in spaces where the internal moisture loads are moderate, the primary air is dehumidified and infiltration through the structures is in control. Especially in hot and humid conditions the special attention should be paid to the building construction design as well as to the design, operation and maintenance of ventilation and air-conditioning system.

Different HVAC systems have different or complementary applications and the final choice between the different systems is depending on the building’s design and function as well as the desired quality level of indoor climate conditions and life cycle cost comparisons.

Figure 2. Typical installations of chilled beams in office environment.

7.5 Operation principle of chilled beam system
Chilled beam systems are primarily used for cooling and ventilating spaces, where good indoor environmental quality and individual space control are appreciated. Chilled beam systems are dedicated outdoor air systems to be applied primarily in spaces where internal humidity loads are moderate. They can also be used for heating.

Active chilled beams are connected to both the ventilation supply air ductwork, and the chilled water system. When desired, hot water can be used in this system for
heating. The main air-handling unit supplies primary air into the various rooms through the chilled beam. 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 (14-18°C) or warm (30-45°C) water is cycled through the heat exchanger. Recirculated room air and the primary air are mixed prior to diffusion in the space. Room temperature is controlled by the water flow rate through the heat exchanger.

Passive chilled beams comprise a heat exchanger for cooling, and when desired for heating. The operation is based on natural convection. The primary air is supplied to the space using separate diffusers either in the ceiling or wall, or alternatively through the raised floor.

![Figure 3. Operation principle of passive and active chilled beam. (Passive on left, active on right.)](image)

### 7.6 Energy efficiency of chilled beam system

Use of chilled ceilings and beams has a positive effect on the energy consumption of buildings. Since water is the primary energy carrier, the system is more energy efficient than an all air system.

Additionally it is possible to further improve the overall efficiency by using higher cooling water temperatures and lower heating water temperatures than are used in air based or fan coil systems. Even sustainable energy sources (waste heat, ground heat etc.) and free cooling can be utilized in order to improve the energy performance of the building.

### 7.7 Results

During the workshop two major areas was raised in discussion: technical demands of modern ventilation systems and right performance metrics.

#### 7.7.1 Technical demands of modern ventilation systems

North and Central European industry has lots of know-how of modern ventilation systems such as chilled beam system, displacement ventilation system and also high induction air diffusion. However many of these systems are still relatively unknown in many parts of the world and there is not enough practical knowledge of systems. This makes industry afraid to utilise these technologies and benefits of better indoor environment and lower energy conservation are not realised.
Displacement ventilation has been an interesting topic in research around the world during the last ten years, but there is hardly any scientific or seminar papers from chilled beam system. There were several technical areas, which should be better studied either in field case studies or in more scientific research.

Industry still feels some confusion what is a right design cooling capacity in practical cases. There are many markets where the design capacity of office cooling system is still over 150 W/floor-m² due to insufficient solar shading in building and over design of system. The best designers are able to simulate the thermal mass of a building in order to reduce peak capacity in design down to 50 – 70 W/floor-m². Unfortunately there are still lots of over designed buildings, where system is not running in the optimal area, and there are also problems with control system to operate in partial loads.

As the chilled beam system is so new in many markets, most of the questions were very practical: what is a difference between old induction unit and active chilled beam, how passive and active chilled beams operate with radiant ceiling, etc.

As passive chilled beam system needs a separate ventilation system, there was lots of discussion how to ventilate the space most efficiently and is it also possible to combine benefits of displacement ventilation and passive beams together. In this area there is not enough studies made to be able to give an extensive answer. The convective flow from a passive chilled beam mixes air at least in the high level, but is the air quality evidently better in occupied zone?

The other unknown area is how the control system operates together with terminal unit. There are lots of practical know how, but no documented studies from interaction of them and what are the right controller set values for each system.

Chilled beam system is not yet used in hot and humid climate. However it could offer a very interesting new solution to save energy and improve indoor environment.

The leakage of building, ductwork, raised floor or suspended ceiling is influencing the operation of these modern ventilation systems in practice. The new European standards based on EBPD directive sets stricter demands for tightness, which increases the possibility to use these systems.

Draught in the occupied spaces is one of the most common complaints in today’s office environments. This is why good air distribution in the space is one of the most critical design criteria, when designing good indoor environment. However there is not enough research and practical information available, e.g. how the thermal plumes in the space influences the throw pattern of a terminal unit and what kind of influence that has to the comfort. Also the draught criteria in standards are not fully understood by designers and facility owners and this is why sometimes the target design values are unrealistic or process ends in over design.

### 7.7.2 Right performance metrics

In too many buildings the end users are dissatisfied with thermal comfort and indoor air quality. In some of the studied cases the calculated satisfaction based on field
measurement should be around 90% but when asked from occupiers the result is around 70%. The difference may become from unrealistic target setting, from bad execution during construction process or from insufficient maintenance. It would be important to get building owners and facility management people to better understand they buildings and systems and look more after them.

Another interesting topic was what is a right measure to follow system operation and user satisfaction. The room air temperature measurement on the wall is the common practice to control system and conditions in the space. In practise this leads too often only to optimise the room air temperature and not the true user satisfaction or energy usage of system. This is why other measures and measurement methods need to be developed, like energy consumption of building, Occupant Satisfaction Survey (once or continuously) or field evaluation of indoor conditions.

In US today the major drivers when selecting components or design systems are ADPI and LEED points but they are not used in Europe.

7.8 Recommendations
There is a need to further develop building process and tools that makes possible to set realistic performance metrics and evaluate targets. The novel process needs new business contract models, supporting tools and customer service concepts, but also modern, more intelligent air distribution systems and components.

This may also mean new ways of using existing or even completely new kind of air distribution systems, where focus will be not only on keeping the room air temperature in required level, but being able to control the thermal conditions (temperature, velocity, air quality, humidity, etc.) in the space based on the user request in an energy efficient manner. More scientific and practical studies are needed from these systems.

At the moment the industry is lacking both knowledge of modern air distribution systems and time to study and develop them further. The REHVA chilled beam and displacement guidebook need to be translated and distributed around the world to increase the awareness.

In order to make sure that people are aware of their indoor environment the energy labelling need to be complemented with indoor environment labelling.

7.9 References
Livio deSantoli¹, Peter Novak²,

¹ University La Sapienza, Rome, Italy
² SITHOK, Ljubljana, Slovenia

8.1 Background
This workshop is the follow up and continuation of the workshop on the same topic at Indoor Air 2005 conference.

- The Museum environment, overview (Morten Ryhl-SVENDSEN, The Royal Danish Academy of Fine Arts, Copenhagen)
- Risk management approach in conservation environment (Livio DeSANTOLI, University La Sapienza, Roma)
- Preventive conservation in museums (Brad PREZANT USA) William Esposito, ASHRAE)
- HVAC in Museums, overview (William Environmental monitoring for conservation, overview (Marco PERINO, Politecnico di Torino)
- International Standard for indoor environment in museums (Francesca Romana D'AMBROSIO, Università di Salerno)

8.2 The museum environment - an overview

Morten Ryhl-Svendsen, Conservator MSc School of conservation, red Royal Danish Academy of fine Arts. Paper presented at Rome, 7 May 2005 “The museum environment"

8.2.1 Introduction
Within the work of preserving cultural heritage objects for as long as possible, the impact of the surrounding environment is a crucial factor. The goal is to avoid or at least retard what sometimes is called "time's effect", but what really is the influence of climate and other factors on the rate of materials decay. As in other aspects of life, to prevent is better than cure; it is better to avoid damage in the first place than to have to repair damage. Within cultural heritage conservation, this field of slowing down "time's effect" is called preventive conservation.

8.2.2 Preventive conservation framework
One useful approach to preventive conservation was put forward by Michalski and co-workers at the Canadian Conservation Institute (Michalski 1994). It operates within a framework of nine agents of deterioration, each which can be met by a response of five stages of control.

The nine agents of deterioration:
- Direct physical force
• Thieves, vandals, displacers
• Fire
• Water
• Pests, microbiology
• Contaminants
• Radiation
• Incorrect temperature
• Incorrect relative humidity

The five stages of control:
• Avoid
• Block
• Detect
• Respond
• Treat

The agents of deterioration speak for themselves. On the five stages of control the intention is that they should be applied in succession as listed, that is first try to Avoid the source of deterioration, if this is not possible, then try to Block between source and artefact, e.g. by use of barrier foil, climate zone, air filter etc. Detect mean to monitor or inspect for the effect of the Avoid or Block actions; do they work? If not, then Respond by improve the actions. Only if actions fail and artifacts are damaged, it is necessary to Treat by performing active conservation with possible risk of damaging or losing the artifact. Avoid would have been better...

In the following I will concentrate of the deterioration agents, which makes the main components of the physical and chemical indoor environment: temperature, relative humidity, and contaminants (air pollution). Besides this, light and radiation will briefly be discussed.

8.2.3 Climate: the effect of temperature

Some physical properties of materials are affected by temperature. It affects flexibility of some materials, so that they become stiff and inflexible if the temperature drops. Some materials will become brittle below a certain temperature; this is called the “glass transition temperature”. This is the case of many polymer materials, e.g. different kinds of glue, or plastics. If the temperature rises, materials will become softer, and some materials will be damaged in temperatures not unusual in a normal indoor environment. This could e.g. be an object made from wax, or some plastics - see Figure 1.

Temperature also affects the rate of chemical reactions, and as such will higher temperature speed up deterioration processes. This covers a whole range of different types of reactions, for example oxidation, or hydrolysis. Finally temperature is controlling the rate of biological attacks, as there are limits, beyond which microorganisms (or larger pests) will not live. On the other hand, in warm environments fungi and similar organisms will flourish fast. Indirectly temperature is also important as it influences the relative humidity of air. If a parcel of air is cooled down, the relative humidity of this air will increase.
Figure 1. The effect of heat. A vinyl record is buckled after exposure to heat from a lamp. It is now impossible play.

8.2.4 Climate; the effect of relative humidity

Materials which contain moisture will react with the relative humidity of air toward establishing equilibrium between the relative humidity of the material and the air. In other words, such hygroscopic materials (among many other things: wood, paper, and textile) will either give off or absorb water vapour. In an environment with many, large and sudden changes in the relative humidity of the air, such materials may experience a large physical stress and dimensional changes because of this water vapour activity. In the case of a multi-layered material, e.g. veneered wood, or a painted surface, this may lead to cracks or breakage in the material - see Figure 2.

As with temperature, for most materials there will be a level of relative humidity which is too low, or too high. A low relative humidity will dry out materials; again this may lead to cracks, or to stiffness and less flexibility. A high relative humidity will advocate fungal growth, and the basis for life of insects. Some chemical reactions need moisture, why a high relative humidity will increase the rate of deterioration. Corrosion will not happen in a dry environment. Hydrolysis of organic materials as for example seen in the deterioration of photographic film material on plastic is also retarded by a low relative humidity. At high relative humidity there is a risk of direct condensation on cooler surfaces, such as pictures hung on a cold wall.
8.2.5 Classes of materials and their response to climate

Different objects react differently to the climate. There are a few alley materials which are more or less unaffected by any almost climate, noble metal such as gold objects being one of them.

- Dry environments: There are groups of materials, which are preserved better within some common climate boundaries. This is for example the case of corroded iron objects, or ceramics containing water soluble salts. These objects should be stored in a dry environment in order to stop deterioration; typically below 30% RH.

- Low temperatures: As the RH influences the rate of hydrolysis and other chemical processes, a moderate to dry atmosphere (30-50%) is also typically recommended for chemically unstable archival materials. These include photographic and moving image film on cellulose acetate or nitrate base. In order to slow down this process even further, cool or cold storage (while keeping the RH moderate to low) is at the same time recommended for these materials (see e.g. Reilly 1993).

- Moderate humidity: Most hygroscopic materials will be preserved at a moderate relative humidity, about 50% RH or so. However, this is not a strict rule, as the optimal environment for each single object relates closely to the previous climate story of that object. Objects stored for a long time in a more humid, or a drier environment, will only slowly adapt to climate changes. This

Figure 2. Ted effect of incorrect relative humidity. A wooden board in a cupboard door with crack due to low winter relative humidity. From a Danish church.
includes materials such as wood, or ivory. Besides the level of temperature and RH, the degree of the climates fluctuations has a high impact on such materials.

8.2.6 Recommendations on climate
Thomson 1986 gave a comprehensive introduction to climate and materials in museums. Camuffo 1998 reviewed the fundamental physical aspects of material interaction with temperature and RH. Correct and incorrect levels of RH were discussed by Michalski 1993, and by Erhardt & Mecklenburg 1994. Michalski 2002 reviewed the effect of temperature on materials. Lately, Padfield 2004 discussed the attainable climate levels in museum stores versus its conversationally quality, taking the limitations of air conditioning into account.

Only few standards exist on cultural heritage collection climate. These are mainly aimed toward collections which are uniform in materials, such as archives. A British standard and one international standard exist on library collections (BS 5454 and ISO 11799). For photographic materials a couple of standards on storage exist (ISO 18911 and ISO 18920). Recently a guideline for climate in archival institutions was published by the Canadian Conservation Institute (Michalski 2000).

For mixed collections no international standards exist today, but ASHRAE has published a guideline (ASHRAE 2003). However, work is at the moment ongoing toward the creation of European norms on conservation, including the environment. This work is initiated within CEN under the Technical Committee 346. It will still take some years before these standards are to be published, in 2008 or 2009 at the earliest.

8.2.7 Contaminants
Contaminants in air, or air pollutants, are emitted from many sources, both natural and manmade. Although only present in trace amounts (ppb range) these compounds will be able to cause material damage. With regard to material deterioration, key pollutants and examples on their sources and effects are listed in Table 1. Please note that the list is by no means complete.

The way most air pollutants attack materials is by being converted into acid (e.g. nitrogen dioxide is oxidised into nitric acid) the acid being the aggressive compound. Other compounds attack materials directly by oxidation, e.g. ozone. On Figure 3 an example of metal corrosion due to acetic acid is shown.
The rate of chemical deterioration is dependent of temperature, the relative humidity, and the available amount of pollutant compound. With regard to moisture, some reactions are strongly dependent on water, and will not happen at all below a certain relative humidity.

The main effect of particles on objects is soiling, which especially is a problem with fine particles. Due to their small size they will deposit almost everywhere, and be very difficult to remove. The coarse particles, or dust, may in an indirect way cause wear of the artefacts surfaces. When artefacts become dusty, they are likely to be cleaned often due to aesthetic reasons. With more cleaning, the wear of the artefacts surface is
increased. On dust and particles, good references are, for example, Yoon & Brimblecombe 2001, or Nazaroff et al 1993.

Table 1. Key Pollutants

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Source</th>
<th>Effect on materials (examples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxides of nitrogen, especially NO₂</td>
<td>Mainly outdoor; combustion (traffic)</td>
<td>Fading of dyes. Degradation of paper.</td>
</tr>
<tr>
<td>Ozone</td>
<td>Outdoor photo-chemical reactions. Limited indoor sources, e.g. electric office equipment</td>
<td>Fading of dyes. Cracking of rubber.</td>
</tr>
<tr>
<td>Oxides of sulphur, especially SO₂</td>
<td>Outdoor; combustion of fossil fuel, natural sources e.g. volcanoes.</td>
<td>“Red rot” on leather. Corrosion of metal. Degradation of paper.</td>
</tr>
<tr>
<td>Reduced sulphur gases, especially H₂S, COS</td>
<td>Outdoor natural sources; indoor sources e.g. material emission.</td>
<td>Tarnishing of silver. Corrosion of other materials.</td>
</tr>
<tr>
<td>Carboxylic acids, especially HCOOH and CH₃COOH</td>
<td>Indoor; emission from materials, e.g. wood.</td>
<td>Corrosion of lead.</td>
</tr>
<tr>
<td>Fine Particles</td>
<td>Both outdoor and indoor sources, but composition may vary.</td>
<td>Soiling. Initiates corrosion.</td>
</tr>
</tbody>
</table>

8.2.8 Recommendations on air quality

Thresholds or limits for contaminants are much discussed. Baer & Banks 1985, and Brimblecombe 1990, gave general reviews of the composition of the museum atmosphere and its effect on materials. Recently, three publications on air quality in museums provided additional information and guidance on pollution species, sources, effects, mitigation and control (Blades et al 2000; Hatfield 2002; Tétreault 2003). No standards deals specifically with air quality and heritage collections, however, recommendation on the required purity of air is included in the library and archive standards mentioned above, as well as in the ASHRAE 2003 guideline.

8.2.9 Light and radiation

Light is energy, and will therefore react with the materials that absorb it. The red and infrared spectra of light will radiate heat to surfaces, and will raise the temperature of the material. In special situations, such as in showcases, the case may act as a greenhouse and accumulate heat inside. Especially if the light source is placed inside the showcase the temperature may be quite high, with all the disadvantages of temperature as discussed earlier in this paper.

But more directly, light will react photo-chemically with a large range of materials and cause fading of colours and other damaging processes. Damage from light accumulates, so that doubles the light intensity gives double the damage. The most damaging part of the light spectra is the violet, and outside the visible spectra, the ultraviolet (UV), as these radiation types are high in energy compared to the rest of the light spectra.
Figure 3. The effect of air pollution. Lead bullet (17th century) with white corrosion, due to fumes emitted from construction materials in a display case. Acetic acid vapours given off by wood will, together with the CO$_2$ of the air, transform the lead into basic lead carbonate.

Light is necessary for people in order to see things, thus a natural part of an exhibition environment. However, only the visual spectrum is necessary. The UV-content should be removed, either by choosing UV-low or free light sources, or by blocking the UV-content by the use of filters in front of lamps or on windows. The UV content of museum light should always be below 75 micro-Watt/lumen; however, the lower the better.

In exhibition galleries, light should ideally only be lit when people are present. The light dosage can be lowered considerable by using motion detectors or similar installations, which turn the light on and off. Outside opening hours the exhibition areas should always be dark except for cleaning and other work.

In storage light should only be lit when people are present in the room. When empty, the room should be dark, with the windows blinded.

Light is normally expressed in terms of intensity, with the unit lux. And normally the recommendations for light levels in museums are given in lux-levels for different classes of materials, see Table 2.

<table>
<thead>
<tr>
<th>Class of material</th>
<th>Recommendation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very sensitive</td>
<td>50 lux</td>
<td>Textile, early photographs, watercolours, low quality paper</td>
</tr>
<tr>
<td>Moderate sensitive</td>
<td>150-200 lux</td>
<td>Oil paint, wood, plastics, high call indents</td>
</tr>
<tr>
<td>Little or non-sensitive</td>
<td>500 lux (or higher)</td>
<td>Stone, metal, glass</td>
</tr>
</tbody>
</table>
In reality it is dosage which matter. A low light intensity over many years is just as damaging as a shorter period of a higher intensity. So if possible, the light exposure as such (lux hours) for each exhibited object should be controlled, rather than the intensity alone. The following dosage recommendations were given by Colby 1992, for art on paper (Table 3):

<table>
<thead>
<tr>
<th>Class of material</th>
<th>Recommendation per year</th>
<th>Causes a just noticeable fading after:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very sensitive</td>
<td>12,000 lux hours (equals 4 weeks by 42 hours at 75 lux)</td>
<td>100 years (1.2 Mlux hours)</td>
</tr>
<tr>
<td>Moderate sensitive</td>
<td>42,000 lux hours (equals 10 weeks by 42 hours at 100 lux)</td>
<td>250 years (10 Mlux hours)</td>
</tr>
<tr>
<td>Little or non-sensitive</td>
<td>84,000 lux hours (equals 20 weeks by 42 hours at 100 lux)</td>
<td>3500 years (300 Mlux hours)</td>
</tr>
</tbody>
</table>

Thomson, 1986, describes the issue of light and radiation in museums in great detail. Besides this, additional information can be found in, among others; Derbyshire & Ashley-smith 1999, Ashley-smith et al 2002, or Michalski 1990.

**8.2.10 References**


8.3 Standards for levels of pollutants in Museums

*Acceptable Risk Concentration*: concentration below which the risk for damage is minimal. The risk is based on accumulated experimental data (NOAEL).

Background Level: level based on average levels from unpolluted outdoor environment (clean troposphere). This simple approach was used in conservation for the last 20 years (Thomson 1986). It has been observed that objects stored far from industrial or urban environment remain in much better conditions over many decades or centuries than those exposed to polluted urban environment.

*Dosage*: maximum cumulative flux (concentration x time) allowed for a pollutant (Brimblecombe 1998).

No-Observed Adverse Effect Level (NOAEL): level at which damage is not observed for a specific setup (analytical method, exposure time, temperature and presence of other reactants or catalysts). The information found can be very limited depending of the experimental setup and can bring premature conclusion on the concentration dependency of the object. The proper usage of the term would include specifications of all parameters necessary to make the value meaningful. For example, a useful syntax for NOAEL would include: NOAEL = Concentration (temperature, relative humidity, time, property measured).

*Threshold*: level at which reaction cannot happen in any time. It relies on reaction kinetics and thermodynamics.

Table 1 presents the preliminary specifications format (Tetreault, 1998).

The preliminary proposition on class of control is based on three levels ABC where A being the “minimal risk” pollutant concentration for a period of 100 years for the most sensitive object; B and C are for a period of 10 years and 1 year respectively. As seen with lead, the most sensitive to acetic acid vapour, the maximum level of acetic acid for general museums of each class of control could be 2.2, 22 and 220 µg/m³ for the class of control A, B and C.

This long term project will help to update or refine the existing specifications for pollutants in museum, libraries and archives. These specifications are primary tools in the prevention of damage caused by pollutants. The list of pollutants to control will be revised and the approach of concentration dependency will be seriously considered to establish the maximum pollutant concentration for different class of control. Resources will be required to investigated object-pollutant interactions to establish the most accurate dosages. Simple analytical methods have to be optimised for the range of pollutant levels covered in the different class of control.

To assist in setting reasonable preservation targets, Table 2 (Tetreault, 1998) provides targets that are attainable in various locations and under various conditions. This table is particularly useful when it is not possible to accurately measure pollutant levels, which often is the case. One of the greatest challenges in controlling pollutants is the high cost of pollutant concentration analyses; a complete program of analyses is often unaffordable for small or medium-sized institutions. Most of the published data dealing with pollutant levels in museums and archives were obtained with the help of government subsidies or with the collaboration of a conservation institute or a university with a scientific interest in the subject.
8.3.1 References

<table>
<thead>
<tr>
<th>Key airborne pollutants</th>
<th>Maximum average concentration for indicated preservation targets (^a), µg/m(^3) (ppb)</th>
<th>Reference average concentration range, µg/m(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 year</td>
<td>10 years</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>1000 (400)</td>
<td>100</td>
</tr>
<tr>
<td>Hydrogen sulphide</td>
<td>1 (0.71)</td>
<td>0.1</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>10 (5.2)</td>
<td>1</td>
</tr>
<tr>
<td>Ozone</td>
<td>10 (5.0)</td>
<td>1</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>10 (3.8)</td>
<td>1</td>
</tr>
<tr>
<td>Fine particles (PM(_{2.5}))</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Water vapour</td>
<td>keep below 60% RH (^d)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Concentration for indicated preservation targets.
\(^b\) Concentration for 100 years preservation target.
\(^d\) Water vapour should be kept below 60% relative humidity.
Notes:
a: Preservation target is the length of time (in years) for which the objects can be exposed to the indicated level of pollutants with minimal risk of deterioration. These targets are based on the LOAED of most objects and assume that average RH is kept between 50 and 60%, temperature ranges between 20 and 30°C, and the collection is kept clean (if not, the maximum levels of key airborne pollutants for each class of targets may need to be readjusted). These values are not applicable to hypersensitive materials.
b: Because most objects have high LOAED for acetic acid, concentrations below 100 µg/m³ are not mandatory.
c: Acetic acid levels can be as high as 10 000 µg/m³ in enclosures made with inappropriate materials, such as fresh acid-cured silicone.
d: For permanent collections where the RH has not been between 50 and 60%, maintain the historical conditions.

Table 2 Preservation targets versus air quality control.

<table>
<thead>
<tr>
<th>Air quality control in building</th>
<th>Potential preservation targets (in years)(^a)</th>
<th>In enclosures with EM(^b)</th>
<th>In enclosures without EM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural ventilation or HVAC system with moderate-efficiency particle filter, no gas filter</td>
<td>In a room</td>
<td>Without ES(^c)</td>
<td>With ES</td>
</tr>
<tr>
<td></td>
<td>1 – 10</td>
<td>≤ 1</td>
<td>10 – 100</td>
</tr>
<tr>
<td>HVAC system with gas and good-efficiency particle filters(^d), building membranes that are good gas barriers, and basic control of visitor flow</td>
<td>10 – 100</td>
<td>≤ 10</td>
<td>10 – 100</td>
</tr>
<tr>
<td>HVAC system with gas and high-efficiency particle filters(^d), building membranes that are good to very good gas barriers, and limited access</td>
<td>≥ 100</td>
<td>≤ 10</td>
<td>10 – 100</td>
</tr>
</tbody>
</table>

Notes:
a: Adverse effects of water vapour and hypersensitive materials are excluded.
b: Emissive materials (products and objects).
c: Efficient sorbent (enclosures are assumed to have an air exchange rate of once per day).
d: Assumes periodic replacement of filters.
9 NEW EUROPEAN STANDARDS FOR INSPECTION OF AIR CONDITIONING SYSTEMS FOR ENERGY EFFICIENCY

Railio, Vialle
Jorma Railio¹, Pierre-Jean Vialle², Chairmen/Rapporteurs
¹FAMBSI, Finland, ²CETIAT, France

Participants: 17 persons from 13 countries: Argentina, Australia, Belgium, China, Estonia, Finland, France, Hungary, Japan, Latvia, Sweden, Switzerland, USA (in addition, experts from Slovenia and United Kingdom had expressed interest in the possible new REHVA Task Force, but were not able to participate)

9.1 Background
Article 9 of the Energy Performance of Buildings Directive (EPBD) [1] requires measures to establish a regular inspection of air-conditioning systems of an effective rated output of more than 12 kW. According to Article 10, these inspections shall be carried out by independent experts.

9.2 Aim and scope
The Workshop presents Draft European Standards on Inspection of air conditioning and ventilation systems. The implementation of these standards will be discussed, including possible REHVA work for further guidelines to support the implementation in real practice.

9.3 State of the art
Under a Mandate issued by the Commission CEN has prepared standards to support the implementation of the EPBD. The mandate includes 31 Work Items, two of which have resulted into Draft European Standards within the scope of this Workshop:


These two drafts have recently been subject to CEN Enquiry, which closed 28 September 2005. The results from the Enquiry will be studied in the relevant Working Groups under CEN/TC 156. In order to prepare Final Drafts by the target date defined in the Mandate, August 2006, two meetings have been scheduled: 1 December 2005 and early April 2006. The earliest time to have the Standards published will be spring 2007.

Standards will describe a common European methodology for inspection of air-conditioning and ventilation systems. Need for more detailed guidance how to apply this methodology in different types of buildings, new and existing ones, has already been identified. Activities to this direction are already going on, for example in the EU supported AUDITAC project [4]. Co-ordination between different activities is also needed.
9.4 Expected results
Before the Workshop, the expected results were described as follows:
- A framework for recommended activities to support the inspection practices
- This framework will identify measures that should be taken on different levels: regulatory actions, continuation of the standardisation work, and the practical guidance needed.
- The role of REHVA in this framework and a proposal for activities e.g. Task Forces

9.5 Presentations and discussions
The workshop was introduced by Jorma Railio, presenting the two chairmen, Pierre-Jean Vialle and himself, and the purpose of the workshop: presentation of the projects of standards on inspection of air conditioning and ventilation systems and discussion on the possible future actions for REHVA to support the implementation of these standards.

In a first presentation, J. Railio reminds the context of the Energy Performance Directive of Buildings (EPBD) and its implication on new European Standards development. The inspection of air conditioning systems is mandated by the directive in article 9, justifying the development of a specific standard. Every building with a total effective rated output superior to 12 kW for the air conditioning systems shall be regularly inspected. The inspection of ventilation systems is not directly required in EPBD. Ventilation is only mentioned as one possible element in combination with the air conditioning system, but as it has an influence on energy consumption it has been decided by the CEN to also develop a specific standard. On the other hand, several articles in the Directive give indirect justification for inspection of ventilation systems, as efforts for good energy performance should not result in inadequate ventilation.

The public enquiry for these two standardisation projects is now ended. The deadline for their publication is planned for the beginning of the year 2007.

The structure of the two standards is similar. They both include paragraphs dealing with the justification of the inspection, the methodology to apply, the advice on possible improvements and the frequency of inspection. Few elements are available at this date concerning the results of the public enquiry, but the first information obtained point out that there is a demand to simplify the standards and also possibly merge the two texts in order to have only one standard covering the two types of inspection. More generally speaking the feedback points out a lack of information about what is going on in these activities.

Starting from this point supplementary action in order to monitor the process in CEN and also help the implementation of standards seem to be necessary. These actions could be partly taken in charge by REHVA in collaboration with others existing projects as AUDITAC, and with involvement of members of the relevant CEN groups, CEN/TC 156/ WG 10 (Inspection of air-conditioning systems) and CEN/TC 156/WG 11 (Inspection of ventilation systems).

Following this presentation a discussion takes place with the participants of the workshop. Different remarks are made:
Before inspecting ventilation systems, it should be necessary to inform building owners about ventilation;

- The knowledge about the legislation, standards and practical procedures has so far reached very few people. Practical questions like "Who is responsible for the inspections – who will pay the inspections" are to be expected?

- What kind of report will be delivered after the inspection? By whom, to whom?

Pierre-Jean Vialle then presented in more details the objectives and the contents of the project of standard concerning the inspection of the ventilation systems. The conclusions from the second presentation are the following:

- Ventilation of buildings is necessary to maintain indoor air quality
- Ventilation is, and will be even more in future, an important source of energy consumption in buildings
- Importance of the inspection process to maintain/improve the performances and the efficiency of the systems
- Strong need of legal requirements exists to support these actions

The discussion after this presentation took up the question of how much time the inspection will take. A full inspection and audit of the ventilation and/or air conditioning systems will take several days in a typical building. Therefore it is necessary to consider carefully what will be included in the mandatory inspection, and what shall be left on voluntary basis. Extensive inspections are often justified by health and productivity benefits, but the number of qualified inspectors is limited at least for some years from now. Voluntary additions to the obligatory inspections should be encouraged.

In inspection of ventilation systems there are many technical issues, where need for improvement appears repeatedly: heat recovery units, airtightness of ductwork and air handling units, and filters. Long experiences exist in Sweden in obligatory regular ventilation inspection, and these are also made available for CEN/TC 156/WG 11 in preparation of prEN 15239. These experiences also point out the importance of up-to-date documentation of the systems, and proper advice to the end users.

Then a third presentation concerning the main objectives and the organisation of the AUDITAC project is made by Mr Vincent Lemort from the team of Professor Jean Lebrun. The contribution of this team to the project will especially concern the set up of simulations tools allowing to calculate the building loads. The AUDITAC team consists of research teams from 7 countries (Austria, Belgium, France, Italy, Portugal, Slovenia and United Kingdom), and experts from EUROVENT.

AUDITAC concentrates on air conditioning systems, excluding "ventilation only" applications.

A reaction to this presentation to be noted concerns the simulation of the functioning of heat pumps in heating mode, as this mode is frequently used in Scandinavian countries.
A proposal was made by Johnny Andersson (Sweden) to review the projects of standards and also AUDITAC reports before publication, in order to have the possibility to bring corrections if necessary.

In the ventilation inspection, also the quality of the building envelope should also be at least noted. In many cases, improvement of ventilation is not sufficient if the quality of the construction elements is poor (poor thermal insulation, infiltration, moisture problems), but ventilation still blamed for problems in the internal environment.

Finally, a general discussion took place in order to define the possible future actions for REHVA. As the deadline for AUDITAC project is the end of year 2006 and the expected publication date of the standards are in 2007, it is decided to report the actions at this period in order to have enough available elements.

The workshop did not take any position on the question: shall prEN 15240 and prEN 15239 be merged? But the need for stronger link to other standards like prEN 13779 [5] and prEn 15251 [6]. A workshop is planned to be held at CLIMA 2007 to decide the actions to come.

9.6 Results – conclusions
A clear majority, 15 participants out of 17, expressed their interest in a new REHVA Task Force within the subject. No objections were expressed.

It was, however, pointed out that the new active phase aiming at writing one or several REHVA Guidebooks should wait until the work in CEN/TC 156/WG 11 and 10 is approaching Formal Vote, and AUDITAC project is reaching its final stages. In other words, the active phase in REHVA could be planned not earlier than autumn 2006. The framework of activities for the new Task Force was described at the end of the Workshop as follows:

- Review existing material from CEN and AUDITAC
- Make a plan for supporting material like guidebooks later on (end 2006 ->)
- Workshop at CLIMA 2007 for further work in REHVA.
- Work in the meantime by e-mail, the mailing list to include the participants of this Workshop, members of CEN/TC 156/WG 11+10 and members of the AUDITAC Team.

9.7 References
[6] prEN 15251 Criteria for the Indoor Environment including thermal, indoor air quality (ventilation) and light
10.1 Topic  
Theory and applications of low temperature water based radiant heating systems and high temperature cooling systems to improve the overall energy efficiency and promote the use of renewable energy sources.

10.2 The objective  
The workshop will introduce the contents of the draft Guidebook on the applications of this technology, design principles, dimensioning and control. The objective of the workshop is to discuss the contents of the draft for final modifications and invite feedback of the subjects to be included in the Guide Book.

10.3 Target group  
Consultants, contractors and equipment manufacturers.

10.4 The scope  
The workshop gives an opportunity to the theoretical aspects such as thermal environment, design and calculation, control algorithms as well as practical approaches and limitations (materials, constructions, heat transfer surfaces, controls). The results of the discussions will be used in the final draft version of the guide book.

10.5 Programme for the workshop

1. Introduction and opening of the workshop  
   Denmark  
   B Olesen,  

2. Proposed contents of the guidebook  
   Slovenia  
   D Peteras,  

3. Presentation of the details in the draft guide book  
   Denmark  
   B Olesen,  

4. Application of LTH/HTC in buildings  
   P Novak, Slovakia  

5. Discussion  

6. Summary and closure  
   Denmark  
   B Olesen,  

The summary and results of the discussion are included in the list of content presented below.
10.6 The guidebook

10.6.1 General
In general there were support for the content of the guide book. A few people had access to a copy of the first draft. Based on the discussion the new sections and additional paragraphs will be included as shown below.

10.6.2 Scope
Comment in the discussions:
The scope will include also suspended radiant ceiling panels for heating and cooling; but electrical heating systems are not included.

10.6.3 Planned contents of the guidebook

1. Terms, definitions and symbols
Shall follow existing terms and definition used in relevant CEN and ISO standards.

2. Basic principles of radiant surface heating and cooling
2.1 Heat transfer
2.2 Thermal balance of a room with radiant surface heating and cooling
2.4 Principles of radiant heat exchange
    2.4.1 Emissivity factor
        Comment in the discussions:
        - Reflective ceiling plates (so called mirror) to reflect coldness/warmth to the occupied zone
        Application – ice rinks
    2.4.2 View angle factor

3. Indoor environmental conditions

3.1 Thermal Environment
    3.1.1. Operative Temperature
    3.1.2. Surface Temperature
    3.1.3. Vertical Air Temperature Difference
    3.1.4. Radiant Temperature Asymmetry
    3.1.5. Draft – Air velocity
3.2 Indoor Air Quality
    3.2.1 Air temperature and Humidity, Cool and Dry Air
        Comment in the discussions:
        - deal more with ventilation, as the systems are usually coupled (associated) together – question how far?? Should this section be here. Important for the control section and also important for the condensation avoidance

3.3 Noise – acoustic comfort
4. Types of systems
   Heat exchange coefficient between surface and space

4.1 Radiant heating and cooling panels
   4.1.1 System description
      Comment in the discussions:
      Include also systems that do not cover the whole ceiling, but are used
      as a supplement to embedded system to allow for faster changes in
      load and supplementary heating and cooling
   4.1.2 Heating and cooling capacity
   4.1.3 System testing

4.2 Pipes isolated from main building structure
   4.2.1 System description
   4.2.2 System with pipes embedded in the screed or concrete
   4.2.3 System with pipes embedded outside of the screed (e.g. in the thermal
      insulated layer)
   4.2.4 System with pipes embedded in the screed
   4.2.5 System with pipes embedded in the a wooden construction
      Comment in the discussions:
      - Systems with embedded capillary pipes should be explained more in
        detail
   4.2.6 Heating and cooling capacity
      A. Standard method (EN1264)
      B. Other methods
   4.2.7 System testing

4.3 Thermo Active Building Systems (TABS)
   4.3.1 System description
   4.3.2 System with pipes embedded in the massive concrete slabs (plane section
      systems)
   4.3.3 Capillary pipes embedded in a layer at the inner surface
   4.3.4 Heating and cooling capacity
   4.3.5 Dynamic capacity calculations
   4.3.6 System testing
      Comment in the discussions: Add a paragraph
      4.4 Phase change materials
      This new section shall deal with the application of phase change materials
      together with the systems described in the guide book.

5. Control and operation
   Comment in the discussions:
   - participation of Siemens CH, who is running a research project with
     EMPA and others about TABS controls (results in 2007)

5.1 General description, Classification (EN12828)
5.2 Radiant Heating System Controls
   Floor mass
   Time delay
   The duty cycle
   Self-regulating effect
5.3 Radiant Cooling System Controls
5.4 TABS controls

*Comment in the discussions:*
Important to stress the self-regulating effect
- Time response – e.g. comparison of TABS vs. other systems
- Optimization of the operation in first years. Important information for the design of the control system

5.5 Operation regarding the economic aspects

*Comment in the discussions:*
- How to calculate energy costs – heating/cooling, portion upwards/downwards. You do not want to pay for your neighbours energy use etc.

6. Energy sources

*Comment in the discussions:*
Include a paragraph explaining why the systems promote the use of renewable energy. Introduce the concept of low-exergy

6.1. Heating (Heat source)
6.2. Cooling (Cooling energy source)
6.3. Heat Pumps

7. Installation

*Comment in the discussions:*
A new section must be made dealing with installation methods for the different type of systems (insulation, pipes, pipe holders or form plates, screed or concrete). Important to emphasis pressure control during installation, precautions against freezing water by winter installations. Mention also here pre-fabricated possibilities

8. Safety

Classification

8.1 Durability of the system
Durability of plastic pipes PE-Xa (Life Cycle???)
- Plastic pipes, Classification
- Water Pipes Leakage
- Ventilation Ductwork/pipe system Leakage

8.2. Indoor environment impact
- Hand Burning
- Physical Injury

9. Application of the system in buildings

*Comment in the discussions:*
Under applications a general paragraph should give some guidance on where to and where not to use the system described in this guide book.
Also in this part or under the individual type of buildings the possible use when retrofitting buildings should be described.
As example
- TABS is not suitable for family houses as the only system, as the user may want to change the temperature level in sleeping rooms during the day, when the room is not used for heating
- using of additional system for individual control

9.1 Residential buildings
   Single family houses, Apartments
9.2 Offices
   M+W Zander Office Building/ TABS is used
9.3 Educational facilities
   Sports Academy Oberhaching, Munich, Germany
9.4 Sports facilities
   Swimming pools, Boerdeland hall in Magdeburg, Germany/ Sprung floor heating, Ice ice-hockey arena/ Low temperature ice cooling - Low temperature heating (tempering), Lawn heating / keeping clear from snow & ice
9.5 Industrial buildings
   Industrial and Storage spaces
9.6 Museums
9.7 Other public buildings
   International Airports Bangkok

10. Design tools
    - Available design tools and software, dynamic simulations. Could be a separate section or included in the sections above

11. Conclusion

12. Appendix
11 DATABASE FOR EUROPEAN HIGH QUALITY LOW ENERGY BUILDINGS

Helmut Mueller ¹, Francis Allard ², Joerg Schlenger ¹, Chairmen/Chairpersons

¹University of Dortmund, Germany
²University of La Rochelle, France

11.1 Background

Within the EULEB-Project, funded by the European Commission, a database will be created, providing information on European high quality buildings with low energy consumption. By providing information on these public buildings in use, provisos against low energy architecture and technology shall be eliminated. The conference participants will be the future target groups of the database (Architects, Engineers, Investors, etc.).

11.2 Aim and scope

The Workshop was intended to inform the future users of the database about the work progress and to get feedback on the CD contents. The selected buildings (Office buildings, Educational buildings and Leisure facilities) and their climatic context should be presented.

11.3 Review of workshop

11.3.1 Introduction and opening

An overview was given by Helmut Müller (University of Dortmund), introducing the involved partners and describing the main objectives and the target groups of the project.

Figure 1: Project Partners

<table>
<thead>
<tr>
<th></th>
<th>Universität Dortmund, Lehrstuhl für Klimagerechte Architektur</th>
<th>Université de La Rochelle, LEPTAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>London Metropolitan University, LEARN</td>
<td>Universitat Politècnica de Catalunya</td>
<td></td>
</tr>
<tr>
<td>Università degli Studi di Firenze, ABITA</td>
<td>Federation of European heating and air-conditioning associations</td>
<td></td>
</tr>
</tbody>
</table>
11.3.2 Presentation of selected buildings

Within the project, 50 buildings from all over Europe have been identified and evaluated regarding their suitability for the project. Out of these 50 buildings, 25 have been selected using a simple evaluation system. This system included different criteria such as quality of architecture, energy consumption, use of renewable energies, advanced technologies or intelligent low-tech-solutions as well as the availability of monitored data. Each of these project-relevant criteria was given different emphasis and was rated based on the information available at this stage of the project.

**EULEB - First evaluation of buildings**

**Building information:**
- **Short Name:** Examp
- **Name:** Example building
- **Country:** no man’s land
- **Climatic zone:** Alwaysnice
- **Occupancy:** Educational

<table>
<thead>
<tr>
<th>No.</th>
<th>Criterion</th>
<th>rating</th>
<th>weighting</th>
<th>weighted rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>Good Design, preferably award winning buildings</td>
<td>5</td>
<td>20%</td>
<td>1,0</td>
</tr>
<tr>
<td>2)</td>
<td>Low Energy Consumption (heating, ventilating, cooling, lighting)</td>
<td>8</td>
<td>20%</td>
<td>1,6</td>
</tr>
<tr>
<td>3)</td>
<td>Advanced technologies for building and services</td>
<td>2</td>
<td>15%</td>
<td>0,3</td>
</tr>
<tr>
<td>4)</td>
<td>Renewable energy utilisation and integration (solar thermal, PV, biomass, geothermal etc)</td>
<td>9</td>
<td>15%</td>
<td>1,4</td>
</tr>
<tr>
<td>5)</td>
<td>High comfort solutions (thermal, ventilation and lighting)</td>
<td>1</td>
<td>10%</td>
<td>0,1</td>
</tr>
<tr>
<td>6)</td>
<td>Availability of monitored energy consumption or easily measurable</td>
<td>8</td>
<td>10%</td>
<td>0,8</td>
</tr>
<tr>
<td>7)</td>
<td>Availability of financial data relating to energy saving features (RUE and RES)</td>
<td>4</td>
<td>10%</td>
<td>0,4</td>
</tr>
</tbody>
</table>

| Overall rating                                                                 | 100%   | 5,6      |

This evaluation system leads to comparable evaluation of the suitability of buildings for the EULEB-project. Within the different climatic zones in Europe (south, middle, north), the buildings with the highest overall-ratings should be selected for further treatment. Therefore, the different climates, building technologies and cultural aspects of the European Countries have to be taken into account for the assessment of the several criteria.

**Figure 2a:** EULEB-Evaluation sheet.

Some of the selected buildings have been presented briefly by Jörg Schlenger (University of Dortmund), Mike Wilson (London Metropolitan University), Cristian Ghiaus (University of La Rochelle) and Marco Sala (University of Florence). The presentations included a short overview on the special features leading to the selection of the buildings.
11.3.3 Methodology for data collection and analysis

The project team is searching for ways of comparing the energy consumption of the different buildings. As the buildings are located all over Europe (from Finland to Greece), different climatic conditions result in very different consumption for heating, cooling, ventilation and lighting. Cristian Ghiaus (University of La Rochelle) presented a new way of estimation and comparing of the energy consumption of buildings using “free running temperature”.

![Figure 2b: Local distribution of selected buildings](image)

![Figure 3: HVAC operating zones: 1) heating, 2) ventilation 3) free-cooling, 4) mechanical cooling.](image)
This system gives the possibility to easily analyse and compare the energy consumption and comfort of one building in different climates, based on measured or statistical climatic data.

### 11.3.4 Climatic zones of Europe

A second way of comparison of building performance related to different climatic conditions was analysed and presented by Jörg Schlenger (University of Dortmund).

**Figure 4: Classification of selected buildings according to ASHRAE, CDD base 10°C / 18°C**
A way of climatic classification related to energy consumption of buildings was developed by Briggs / Lucas / Taylor and was published in ASHRAE 4610/4611 (2003). This system is based on the well-known classification by KOEPPEN (1846-1940), but also includes the calculation of heating and cooling degree days (HDD/CDD). The system was developed for the USA using cluster analysis of about 5000 locations, resulting in four major climatic zones and several subdivisions. The ASHRAE-System seems to be suitable for the use in Europe some criteria are adapted to European climate. The main problem is that the CDDs in ASHRAE are calculated to the base of 10 °C. This does not seem to be appropriate for Europe as the indoor design and typical operating temperatures in Europe and the USA differ a lot. When calculating the CDD for example to a base temperature of 18 °C, the results would become more realistic for the European building market, but this would require a new cluster analysis to adapt the subdivisions of the classification system.

11.3.5 Structured discussion
During the presentations many questions of the audience already were discussed. The following session of questions and discussion brought the chance to go more into detail with certain issues.

A great interest in the project was experienced, going very often into details of certain technologies applied in the presented buildings to achieve the aims of both low energy consumption and high indoor quality. Some special issues discussed were new insulation materials, integration of renewable energies in building surfaces and energy supply systems using renewable energies.

11.3.6 Closing and future actions
As the project is still in an early stage, the future actions will now be the collection of precise data for each of the 25 buildings, the data analysis and the visualisation of the results.

Mike Wilson (London Metropolitan University) gave an additional overview on a new European MSc-Course on Integration of Renewable Energies in Buildings (IREB)” which was established by some of the EULEB partners in another project, co-funded by the European Commission. This international course will help to build more capacities in the European building market, bringing forward the establishment of high quality low energy buildings in Europe.

Further information can be found on the project-website www.EULEB.info .

11.4 Results
The workshop showed a wide interest in the upcoming database for high quality low energy buildings. Detailed questions on advanced technologies or solutions applied in the presented buildings proved the demand of such information material and the high potential, which can be tapped in the European building marked.

The numerous questions and discussions on the pros and cons of certain aspects and technologies demonstrated the importance of proving the efficiency of innovative concepts using monitored data from existing buildings.
The today’s early stage of the EULEB project, where the building data are currently collected, gave an idea of what can be expected in the future. It will be interesting to repeat this workshop after a one year period, when the building analysis and comparison is finished and more detailed results are available.

11.5 Acknowledgement
This project is partially supported by The European Commission.

\[Figure 5: Support by the European Commission\]

The sole responsibility for the content of this paper lies with the authors. It does not represent the opinion of the Community. The European Commission is not responsible for any use that may be made of the information contained therein.

11.5.1 References

Denia Kolokotsa¹, Francis Allard²

¹Technical Institute of Technology of Crete, Greece
²LEPTAB, Université de La Rochelle, France

12.1 Background
The EU promotes energy savings in buildings by putting into force the DIRECTIVE 2002/91/EC, whereas all Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive at the latest on 4 January 2006” (Article 15). The proposed measures are summarized to:

- A methodology for integrated energy performance standards.
- Application of such standards on new and renovated buildings.
- To establish certification schemes in M.S. for all buildings.
- Inspection of boilers/heating and cooling installations.

The scope of EEBD project is the development of a dynamic vocational training tool in order to assist engineers to comply with the Directive’s demands.

12.2 Aim and scope
In the framework of the EEBD project a REHVA Workshop is organised in the frame of the CLIMA2005 conference in Lausanne (9-12 October 2005). In this specific Workshop the objectives of the project, the vocational training needs for the Energy Performance Buildings Directive and the dynamic specifications of the vocational training tool are presented and described. This Workshop provided the opportunity to exchange ideas and get some input from the end users concerning the syllabus and specifications of the tool.

12.3 The necessity of a dynamic vocational training tool for the up take of the EPDB, the EEBD project
(D. Kolokotsa)
The necessity of an EPBD vocational training tool is forced by the following:

The EPBD should be implemented by the combined forces of different target groups. The various MS have different priorities based to regional/local characteristics (heating, cooling, ventilation, etc.).

A high number of information, tools, and calculation models are available.

The anticipated expectations from a vocational training tool:

- **Global approach:**
  - General information and training
  - Links with CEN standards
- **Local approach:**
  - National changes in building codes and construction practice
What are the accepted methods to calculate the energy consumption?
What is the role of CEN standards in relation to the national building codes?
How is the energy consumption calculated and certificate given?
How are the parameters of indoor climate considered and expressed in the certificate?
From where can I find information on the possible measures for energy improvement applicable to my conditions/building?
How are the inspections performed in my country - guidelines?
Who does the inspections?
Where can I find a reliable certified inspector?
How can I become a certified inspector?
What happens to other MS?

The objectives of the EEBD project are:
- Major objective: Take-off of the EPBD through the development of a web-based dynamic vocational training tool.
- Specific objectives:
  - Examination of vocational training needs related to EPBD.
  - Collection and filtering of available material.
  - Development of the training modules.
  - Development of the dynamic part specifications (interactions with the trainees).
  - Evaluation of the tool.
  - Dissemination of the tool.

The deliverables of the EEBD project are:
1. Report on Vocational Training needs for the various EU regions.
2. Report on trainee’s profile.
3. Inventory of the vocational material.
4. Vocational training syllabus for the four EU regions.
5. Static part of the training tool.
6. Specifications of the dynamic part of the tool.
7. The dynamic tool in a Web site in three languages (English, French and German).
8. Report on the testing activities.
11. Video recording of the Virtual Classrooms.
12. Electronic brochures and on-line help desk for the EEBD tool.
13. Hardcopy brochures for the EEBD tool.
14. Proceedings of the two Workshops.

12.4 Review of the vocational training needs in EU
(F. Allard)
A questionnaire has been elaborated and widely distributed in Europe with the following objectives:
1. Identification of potential participants and end users
2. Identification of training and information needs and requests from end user
3. Formulation of the training tool specifications according to identified needs
4. Inventory of existing educational material for its integration in the tool
The questionnaires answers allow a lot of analysis, the following approach is proposed:

- Which categories of end user have responded? (And feel concerned?)
- How much end users are informed about the Directive?
- Who knows what?
- Did they take into account Energy performance before?
- Who is concerned?
- Will they be interested to apply this Directive?
- How many are interested to receive further information and how? Who?

For this first statistical analysis, we considered 382 responses. We present a little statistical analysis already carried out about this first sample of data: we organized it in three items:

- definition of end user profile
- definition of training needs
- interest for following the development and results of EEPBD

### 12.4.1 Definition of end user profile

![Employer category [%]](image)

*Fig 1: Employer categories*

domain: only 14% are not fitting. Within the answers, we have a large majority of designers (51%). However, all professional expertise areas are well represented with a majority for HVAC sector (46%) and energy consultant (37%)
Employers’ categories and expertise areas are finally well chosen; only 10% are not fitting any employer category proposed. The same result is obtained for expertise areas.

### 12.4.2 Definition of training needs

Fig. 3 shows that the directive principles are globally known, 87% have already heard tell of this directive, so 13% have been informed by the way of this questionnaire. However, the effects of the Directive are not so well known.

Some differences do exist between end-user profiles. People less informed are from:
- Design (65%), Administration/Government (64%), Manufacturing (66%), contractor/installer (66%), Building owner or manager (69%)
- Mainly in Architecture field (lower level of 60%)
- A low information level in Greece (44%)

Fig 4: Information needs about the Directive.

A low proportion of people have already attended a meeting or seminar about this Directive, globally 26% of questioned people, 21% among Designers employees, 18% among architects or building designers and 23% among Electricians (only 8% in Greece and 15% in France). Similar results (26%) and repartitions are observed about known training program or seminar.

Fig 5: Interest in future work done by EEPBD
12.4.3 Interest for following the development and results of EEPBD
A high fraction considers the EEBD project useful (93%) and is interested into having future information (93%).

![Graph showing percentage of people consenting to receive information in English.](image)

*Fig 6: % of answer accepting English language for training.*

Finally, specific information appears to be necessary in language used as for specific professional profiles. Figure 6 shows clearly that only 33% of the end users consent to receive information in English.

12.4.4 Questionnaire follows up:
The online questionnaire will be accessible until the end of 2005. We need more confident results by the involvement of more end users. Furthermore this end user participation can initiate a valuable feedback habit for training content. Questionnaires have highlighted a huge curiosity about the Directive modalities, differences and consequences throughout Europe. There is a demand for general information on European countries, specific laws and habits (questionnaires results can be a part of this point) and some anxiety about the Directive consequences for ones activity domain.

12.5 EEBD dynamic-interactive Tool
The dynamic tool includes 3 sub systems.

1. asynchronous courses
2. asynchronous collaboration
3. Live meetings

12.5.1 Asynchronous courses
The courses are placed in servers which run a Learning Management System (LMS). LMS is a scalable platform for managing classroom-based and e-learning activities, resources, curricula, and catalogues across an enterprise. LMS supports industry
standards for course development and delivery and provides a simple authoring tool for creation of online courseware.

LMS provides the features and functions to support enterprise-wide training management and delivery.

LMS supports the following tasks:
- Register users.
- Manage enrolment.
- Create courses that conform to industry standards.
- Present the Course Catalogue.
- Provide easy navigation to courseware.
- Provide easy navigation within the course.
- Enforce course prerequisites.
- Track student progress within a curriculum.
- Track student’s completion of learning objectives.
- Display data on courses, enrolment, progress, and grades.
- Compile reports.
- Manage delivery resources.
- Manage security of data.
- Distribute self-paced courseware.

LMS provides features and functions for several types of users. Each user sees the interface that is appropriate to the user role they have been assigned. For example, the instructor has access to the functional modules that are needed to teach a course and view student rosters and progress data.

12.5.2 Asynchronous collaboration

With asynchronous collaboration module, users can instantly create secure work spaces on the Web, providing them with a "Place" to coordinate, collaborate and communicate on any project or ad hoc initiative. Key capabilities include:

- **Coordination:** People, tasks, plans, and resources.
- **Collaboration:** Ideas and discussion, issues, shared documents, files and general due diligence.
- **Communication:** Actions and decisions, key findings and lessons and knowledge capture.

12.5.3 Live meetings

The live meetings module is based on three on demand concepts:

- **Presence awareness:** See, in advance, whether a person(s) or application(s) is available to collaborate, share information and/or take an action.
- **Instant messaging:** Be able to converse virtually through the exchange text-, audio- and/or video-based information in real time.
- **Web conferencing:** Share information, an application or an entire desktop or engage in team white boarding.

At the stage of the project, the tool is being implemented, the static part has already been discussed between the participants and the dynamic part is under construction.
12.6 Discussion and recommendations
The discussion and recommendations made at the end of the workshop have been focusing on three main topics:

- The coherence of the project with other European or national actions,
- The quality insurance of the data,
- The availability of the tool, its limits and possible extensions

12.6.1 Coherence with other European or national actions
During the discussion it appeared that a closer link with European EPBD platform or other related projects could be very useful in order to avoid any duplication of work and to give the end users access to first quality information.
At national level it will be also useful to maintain contact to institutional bodies in charge of EPBD implementation.
These two points will be taken into account by the EEBD projects participants in the future and if some links are missing now they will be set up in the future.

12.6.2 Quality insurance of the data
In such a tool, the quality of the data which will be used is essential. That is why we organised a work flow in order to feed it. The data which will be used will be official data from EC or for CEN for the standards, concerning regional or national data, we will refer to national regulations and as far as it will be possible, we will propose a link to existing site with original sources. Considering tools or methods, we will refer only to existing standards or references. In the first development, the data will be controlled directly by experts.
Then, some limited or controlled access on some domain of the tool will guarantee the quality of additional data.

12.6.3 Availability of the tool, its limits and possible extensions
The tool will be free of access in the present form. In the future it could be further developed within the frame of a collaboration between industrial partners, association or/and public entities. At the end of the project the tool will be delivered in three languages: English, French and German. However, extensions to other languages are already foreseen and guidelines for extension will also be delivered at the end of the project.
Maria Kolokotroni¹, Martin Liddament²,

¹Brunel University, UK
²Veetech Ltd, UK

13.1 Background
The workshop introduced the project Vent DisCourse funded under the Intelligent Energy European programme. The main objective of the project is to accelerate implementation of a core area (ventilation) within the Energy Performance of Buildings Directive (EPBD) at European and national levels and thus improve energy efficiency in buildings by directly transferring existing knowledge to appropriate actors in a suitable format. This will be achieved by developing and promoting training material (paper based and electronic textbooks) in distance-learning format for building professionals to facilitate the implementation of best practice ventilation energy performance (both for indoor environmental quality and thermal comfort) in large new and retrofitted buildings of various types. In addition, the training methodology to include the operational schedule of the material in its various facets and requirements for certification will be defined during the project. More information about the project and results as they become available can be found in http://dea.brunel.ac.uk/ventdiscourse.

13.2 Aim and scope
The objective of this workshop was to discuss the contents of the proposed training material.

13.3 Background to the Vent discourse project
Vent DisCourse addresses non-technical educational and cultural barriers to the implementation of RES in the area of building ventilation. Efficient ventilation can increase comfort and quality of life in buildings in addition to a reduction of energy intensity and energy consumption.

The European Energy Performance of Building Directive (EPBD) must be implemented in national regulations by 2006. Several countries have already developed calculation procedures to evaluate the integral Energy Performance of Buildings. However, there is very little information on energy sub-systems of buildings, such as ventilation.

Ventilation is the process of supplying clean air to the occupants of a building and removing carbon dioxide, indoor pollutants and excessive humidity (and heat in naturally ventilated buildings) to maintain a comfortable and healthy environment. Compensating for ventilation heat losses in winter, and heat gains in summer, plus the energy required to drive the ventilation process represents around one third of the total energy requirements of a building.
It is estimated, that energy use by ventilation losses and fans accounts for almost 10% of total energy use in EU. When using natural and hybrid ventilation systems, the expected energy saving on long term within EU is approximately 64 PJ/year for residential buildings alone, giving a reduction of 3.6 Mton CO₂-eq./year [1] Practical savings of 25Mton oCO₂-eq/year has been proposed by application of natural ventilation for non-domestic buildings [2]. There is practical and proven potential in improving mechanical ventilation systems to be more energy efficient [3].

This project targets the demand side where users of energy play an important role. However, the degree energy use can be determined to a large extent during the design (or major refurbishment) of a building. To this end, the market actors are not the actual users but the designers and operators of buildings. These actors are usually reluctant (mainly due to financial and job demand reasons) to devote large percentage of their professional time to undertake additional training. However, they could always find small chunks of time that could use to refresh their knowledge, especially if such knowledge will have a direct benefit to carrying out their job (in this case familiarity with one area of EPBD). For this, distance learning methods, used extensively by educational establishments, could be used as opposed to whole day(s) CPD seminars. Distance learning methods could range from carefully structured textbooks to 2-3 pages dedicated CPD pages that could appear on professional journals.

The project will build upon completed building ventilation related projects carried out within the framework of SAVE (eg TUNE UP!, AIRWAYS), ALTENER (eg SOLVENT, IRTUS) and RTD projects (NATVENT – natural non-domestic ventilation, TIP VENT- mechanical ventilation, SAVEDUCT – mechanical ventilation leakage, URBVENT – urban ventilation, RESHYVENT – residential ventilation). It will consider the results of international projects such as HybVENT [4]. It will also build upon national projects and dissemination results. For example in the UK, Action Energy has produced a number of brochures on ventilation [5] and numerous related building case-studies (good practice and new practice case-studies [6]).

The project addresses core areas of the EPBD [7] as the need for ventilation (with associated needs for heating and cooling) is referred to in the definitions of Article 2. Referring to the annex for the calculation of energy performance in buildings, the proposed action addresses directly ventilation (d) and natural ventilation (h) for all building types (apart from single family houses). It also influences all aspects to be considered in the calculation of energy performance and in particular thermal characteristics – air-tightness (a), air-conditioning installation (c), position and orientations – outdoor climate (f), passive solar systems and solar protection (g) and indoor climatic conditions (i).

13.4 **Applicable distance learning methods**

The first work carried out within the project was to review and evaluate educational distance learning methods for target audience and their application to building ventilation training material. A report was produced with the scope to evaluate how the objectives of European and national energy related ventilation policies and programmes can be embodied within distance learning training. The objective is to identify the market needs and two categories of potential trainees for which to develop vocational training material for the participating countries: France, Greece, Finland
and the UK. The report was prepared on the bases of the national reports of the participating countries and completed by the task leader (University of Athens).

The report shows that:

1. Currently the UK market is characterised by a number of courses on ventilation and building services addressed at engineers who are already in the industry. Additionally the UK market is well prepared for the EPBD implementation. Engineers are aware of the coming regulations and seminars addressed at architects, building services engineers, contractors and developers are already taking place in order to meet the new legislation and the role of ventilation and its energy impact on buildings.

2. In the other participant countries, courses on ventilation are generic and very limited. Additionally, there is a lack of knowledge on the relation between ventilation systems and energy performance of buildings although the coming legislation of the building energy performance.

3. Distance learning training on building ventilation is well developed in the UK. In the other participant countries, engineers are provided with training on building services but this is not in distance learning mode of study. In Greece and Finland distance education is encouraged and under development while in France is not yet existent.

4. Currently, paper based material; web-based material and CPD articles are the three applicable distance learning vocational training methods for engineers. Specifically, building designers (architects) and building services engineers form the two categories of potential trainees for which vocational training material will be developed further in this project.

5. The three distance learning methodologies, paper based material, web-based material and CPD short articles could form appropriate training and provide engineers with courses on ventilation and its energy impact within the frames of the new legislation of the energy performance of buildings.

6. It seems that the paper-based material is the preferred distant learning method among students and engineers already occupied in the industry who wish to continue with further training. Internet based material is also desirable but this should be complementary to the paper based material. CPD short articles form also an appropriate way of education as they analyse contemporary issues, i.e. new legislations, in short and comprehensive way.

7. In all the EU member counties, the EU Building Directive should be implemented from January 2006. This will have an impact on the market and industry of the countries; legislation should be updated in order to meet the new building regulations. Engineers could be provided with information and further training on the new legislation, appropriate design and training on ventilation technologies via distance learning vocational training material in order to meet the new requirements.

The report includes information and statistical data on the professions in the engineering area. We can conclude that in all countries professional institutions for the heating, ventilation and air-conditioning of buildings provide engineers with technical manuals, guides and information on current legislation.
13.5 Proposed Educational Material and its Structure

The following material is proposed:

- **Foundation module: Principles of energy efficient building ventilation and the EPBD**
- **Module 1: Natural and hybrid ventilation**
- **Module 2: Energy efficient mechanical ventilation**
- **Module 3: Ventilation for Urban Buildings**
- **Module 4: Assessment of Building Ventilation**
- **Common Resource Module**

The structure of printed material has been proposed as follows:

1. Each package should be divided into sections that the students can absorb in one session (for example 2-3 hours of study). Therefore each section (eg chapter) should be approximately 10-12 pages long to include the following elements:
   1. Section objectives – so those students are aware of the goals to be achieved by studying this specific section.
   2. Introduction to the section
   3. 4-5 sub-sections each with some illustrations in the form of pictures or graphs and with a number (typically 2) personal feedback questions.
   4. The Personal feedback questions should be designed to revise the material learnt in the sub-section and the students should attempt themselves. Solutions to the personal feedback questions should be provided separately so that the students can instantly check their workings.
   5. More complicated sub-section which contain key or difficult to understand principles should included worked examples so that the students have a similar solutions before they attempt the corresponding personal feedback question.
   6. Each section should include a summary at the end to highlight the key elements learnt while studying it. This might include the main definitions and equations.
   7. Each training package should conclude with a form of assessment. The form and timing of the assessment should be provided to the students from the very beginning together with the training material. Such an assessment could be:
      - Assignments: These are pieces of work based on the material provided which students should attempt and trainers would mark. Each assignment should include a brief with a detailed description of the work to be carried out and also specific instructions on the form of the report (eg number of pages, structure, marking scheme).
      - Unseen exam questions: This could comprise of 4-5 questions with a choice for the students (eg to answer 3-4) or of a larger number of multiple-choice questions. The duration of the examination should be known in advance and usually limited to 2-3 hours.

For distance learning training, it is desirable that at least some of the assessment is carried by assignment so that the students could get feedback, before a final assessment by an exam. Each training package could be assessed solely by assignments or a combination of assignment and exams.

**Contents of Educational Material**

The contents of the proposed educational material were presented as follows:
Foundation module: Principles of energy efficient building ventilation and the EPBD

<table>
<thead>
<tr>
<th>Requirements of Indoor Air Quality and Climate</th>
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<tr>
<td>Criteria for Ventilation Rates</td>
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<tr>
<td>General Principles of Ventilation</td>
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<tr>
<td>Psychrometrics</td>
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<tr>
<td>Energy Use of Ventilation</td>
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<tr>
<td>Principles of Energy Efficient Ventilation</td>
</tr>
</tbody>
</table>

Module 1: Natural and hybrid ventilation

| Introduction and background                  |
| Summary of applications                      |
| Natural ventilation mechanisms and approaches |
| Hybrid ventilation mechanisms and approaches  |
| Incorporating controls                       |
| Other items                                  |
| Integrated design principles                 |
| Advanced calculation guidelines              |

Module 2: Energy efficient mechanical ventilation:

<table>
<thead>
<tr>
<th>Effect of Ventilation on Indoor Generated Pollutants</th>
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<tr>
<td>Residential Ventilation Systems</td>
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<tr>
<td>Ventilation systems for Commercial and Public Buildings</td>
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<tr>
<td>Duct Systems and Pressure Losses</td>
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<tr>
<td>Fans</td>
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<tr>
<td>Air Handling Units</td>
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<tr>
<td>Filters and Air Cleaning</td>
</tr>
<tr>
<td>Heat Recovery</td>
</tr>
<tr>
<td>Control of Air Conditioning and Ventilation</td>
</tr>
<tr>
<td>Room Air Distribution and Ventilation Efficiency</td>
</tr>
<tr>
<td>Noise Control</td>
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<td>Design and Installation</td>
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</tbody>
</table>

Module 3: Ventilation for Urban Buildings

<table>
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<tr>
<th>Urban built environment and the role of ventilation</th>
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<tbody>
<tr>
<td>Choice of ventilation according to climate and local environment</td>
</tr>
<tr>
<td>Characteristics of the urban environment</td>
</tr>
<tr>
<td>Urban Pollution</td>
</tr>
<tr>
<td>Indoor air quality and ventilation in the urban environment</td>
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<tr>
<td>Ventilation strategies for different types of buildings</td>
</tr>
<tr>
<td>Ventilation rates for different types of urban buildings</td>
</tr>
<tr>
<td>Design calculations for the optimal design of openings and calculation for wind speed in urban areas</td>
</tr>
<tr>
<td>Case studies</td>
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</tbody>
</table>

Module 4: Assessment of Building Ventilation:

| Introduction to assessment techniques              |
| Measuring ventilation and comfort parameters       |
Commissioning and Balancing of ventilation systems
Commissioning of controls and sensors
Measurement of air tightness
Performance evaluation of real buildings
Evaluating energy, environmental and financial costs (Life-cycle)
Operation and maintenance
Fire safety
Mechanical

**Common Resource Module**

<table>
<thead>
<tr>
<th>Computerised Tools</th>
</tr>
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<tbody>
<tr>
<td>Case-studies</td>
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<tr>
<td>Legislation</td>
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The contents were discussed in detail during the workshop and some useful suggestions were made and these will be considered in further developing the material.

**13.6 Conclusions**

In general the professional knowledge in ventilation design should be improved, as its significance in creating healthy, sustainable buildings and energy use of buildings is so significant. The web based teaching was considered an excellent way to teach engineering students, and also to practicing engineers in the principles of energy efficient ventilation. The REHVA members association have expressed already their interest in using the material for the training courses in their own countries. The material should be prepared so that it is easy to translate into various languages (figures, length of text etc)

It was also concluded that the material should be structured so that part of the lectures are independent, and can be studies independently from the others. The additional reading suggestions are given in the lectures and also recommendation for the basic knowledge before entering to the modules. General and supporting modules should serve all other modules.

**13.7 References**

3. TipVent, 5th Framework Project
5. Energy-efficient mechanical ventilation systems (GPG257), Comfort without air-conditioning in refurbished office - an assessment of possibilities (NPCS118), Mixed-mode buildings and systems - an overview (GIR056), Natural ventilation in non-domestic buildings – a guide for designers; developers and owners (GPG237)
14.1 Background
In industrial applications, minor attention has previously been paid to energy efficiency of ventilation. Heating and ventilation has been made using as much energy as was needed. No matter how we did it, the energy used for heating and ventilation was negligible compared to the total energy consumption of the plant – typically only 1 - 5%. However, this "1%" corresponds to a large amount of energy when compared to other energy uses in the community. (Example from an aluminium electrolysis plant: 1% of the total energy use corresponds to the overall energy use of 500 – 1000 one-family houses). Thus, energy issues in ventilation of industrial plants must be paid attention to.

14.2 Aim and scope
The Workshop focused on ventilation of industrial and similar premises, i.e. buildings were ventilation rate is determined mainly by other criteria than human occupancy and emissions from building materials and furnishings.

REHVA objectives for this Workshop were defined as follows:
- Publishing guidebooks, thereby developing common European Good Practice
- Arranging seminars, thereby creating a forum for the exchange of experience and development of knowledge
- Arranging Professional Development Courses on a European level

14.3 State of the art
Scientific knowledge on ventilation in industrial premises has been developed for many years. W. Baturin [4] is counted as one of the pioneers since the 1940’s. However, design and dimensioning of systems and equipment has typically been based on rules of thumb, the validity and limitations of which was unknown to both the designer and his client..

The end user's focus on ventilation has changed over the years. The needs of the process have always been, and still are, in focus. During the 1970’s, worker protection came more into focus. In the 1980’s emissions to air and water was emphasized. And now, energy efficiency is one of the major issues.

The need for a scientific approach became obvious as new demands appeared one after another. Resulting from a number of national activities within the field of industrial ventilation, an international network of experts was established to collect
experiences from all over the world, into a documentation of the scientific fundamentals into one international Industrial Ventilation Design Guidebook [1]: (abbreviated here as DGB).

The benefits of advanced Industrial Air Technology are described in the DGB as follows:

- Improved health of workers and reduced absenteeism as a result of better IAQ.
- Improved indoor air quality gives improved work satisfaction, higher productivity and reduced production failures.
- Reduction in maintenance costs for the building fabrics, machinery and products.
- Reduction in energy consumption can be achieved with improved usage patterns and reduced air flow rates.
- Increased awareness allows improved selection of new energy-efficient systems in ventilation design, with same results as in the previous point.
- Improved systems and equipment result in cleaner surroundings and thus improve also the image of the company.
- Environmental pollution is reduced by lower energy usage and lower emissions to the surroundings.
- High level industrial air technology systems and equipment improve the life cycle economy.

After a couple of preparatory meetings, the COST G3 – Industrial Ventilation action started in 1996, with participants from 15 member countries of COST (Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and United Kingdom), and four organisations outside COST (ABOK/ Russia, ASHRAE/ USA, SHASE/ Japan, University of Toronto/ Canada). In 2001, two European organisations, REHVA and EUROVENT joined the COST G3 action.

The DGB was published in spring 2001, with 1500 pages describing the fundamental knowledge of Industrial Ventilation.

In parallel with writing the fundamentals, plans for specific guidebooks for practitioners developed. These were divided into two groups: "Systems and Equipment" and "Applications". Right before CLIMA 2005, the first two books were published, resulting from joint activities between COST G3 and REHVA:

- Ventilation and smoking [2]
- Electrostatic precipitators [3] (system & equipment type of booklet)

In preparation or earlier stages are currently a few "application" booklets:

- Electrical equipment rooms (draft versions have been published in Finland [4])
- Wood dust exposure
- Displacement Ventilation in industrial applications

In 2004, a decision was made in REHVA to establish a working group for Industrial Ventilation.
14.4 What makes industrial ventilation different from common HVAC?
This topic was introduced by Håkon Skistad. Traditionally non-industrial ventilation has been just to provide a certain air flow or air change rate, often relying on infiltration or uncontrolled natural ventilation. Industrial applications, on the contrary, require a more scientific approach. The steps in the design being:
1. Possibilities for source elimination – search for less emitting processes
2. Encapsulating the process
3. How to carry the pollutants away with minimum penetration to the occupied zone
4. Dilution of the pollutants which still penetrate to the occupied zone
5. Cleaning the gaseous pollutants to minimise negative effects to the outdoor environment

Today, energy has become a key issue. In industrial applications, energy for HVAC has been considered as a minor issue. However, a single industrial plant may need as much energy for HVAC as some 500-1000 one-family houses. This should be considered in connection with the Energy Performance of Buildings directive EPBD.

So, what makes industrial ventilation different from common HVAC? The scientific approach is different, and has to be a scientific approach instead of trial and error. And the size is usually large, so the designer's fault will become large and expensive. But the industrial work environment keeps changing and is in several applications not so different from non-industrial ones. It can be asked: can the "industrial" and "non-industrial" disciplines merge in the future? This should be possible, but maybe a long time is needed. The relationship between the EPBD and industrial ventilation was discussed. In a number of member states industrial buildings seem to be excluded, but no participant was able to give an exact borderline. It looks that energy considerations are growing in importance and there is still a lot to do also in utilisation of waste energy from processes in district heating, and other similar solutions, looking at energy from a broader scope.

14.5 Experiences from different countries
Experiences and activities from different countries were then presented by:

1. Raimo Niemelä, Finland. One of these activities is going on jointly with INRS, France, and explained further by Jean-Raymond Fontaine
   - The Finnish activities develop further some of the new systematic approaches described in the DGB:
     - Design Methodology
     - Room air conditioning strategies. This is still a developing issue and could be worked on in REHVA
     - Target level assessment
   In addition, developments in CFD and visualisation techniques have brought new tools for scientific approaches. The "Virtual Space 4D" project is still going on, and at the time of CLIMA 2007 results will be available.

2. Håkon Skistad, Norway. This survey introduced developments in industrial ventilation applications between 1969 and 2005, with a number of practical examples how to deal with different production processes in large halls. It presented an overview of technical solutions and design tools (including developments in
modelling techniques) of four decades. The presentation supported the views already presented earlier under the "state-of-art".

In the discussion that followed, all participants presented some views from their national or personal point of view. Just to mention a few points:

- Dissemination of knowledge, including practical examples, from one country to another, and also to countries who have been involved less or not at all in the existing network. One Finnish ongoing supporting action may, within the near future, provide a common framework of introducing examples of good practical solutions in an international database.
- Growing importance of energy performance has increased and will still increase the need for more sophisticated and more accurate tools
- Consulting engineers' limited time during and after the design process; design tools have to be practical but with a solid scientific basis behind
- Practitioners also have limited possibilities for international activities, but can be involved through national mirror groups.
- Like "Ventilation and smoking", the "Industrial ventilation" approach can be used in many other applications outside basic industrial processes: commercial kitchens, operation theatres etc. Special applications such as cleaning of ductwork (from the labour protection point of view) can be included, too.

14.6 Results

The REHVA objectives set before this Workshop were not objected, but how to proceed from now on still need some consideration. The COST G3 network of experts is still available, and participants of this Workshop are also available for this network. Stronger involvement of consulting engineers and other practitioners is needed, but national mirror groups can give more possibilities for practitioners than direct participation in European or international groups.

14.7 Conclusions – the main steps from Lausanne to Helsinki

- Finalise two or three application booklets by REHVA – at least the "Electrical Equipment Rooms" (updating and reviewing needed)
- Establish, in addition to the existing network of experts plus participants of this Workshop, also national networks of experts, or national mirror groups (such groups exist already at least in Finland, France, Norway and Italy).
- Present the status of activities in VENT2006 (May 2006, Chicago – one special Roundtable Session is being planned there)
- Prepare a follow-up workshop and/or special session for CLIMA 2007 (preferably also meetings within specific subjects)

14.8 References


Jorma Säteri\textsuperscript{1} and Andy Drysdale\textsuperscript{2}, Chairmen

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\textsuperscript{2} Danish Technological Institute, Denmark

\section*{15.1 Background}

The importance of indoor air quality (IAQ) in buildings is indisputable and numerous studies have documented that IAQ significantly impacts occupants’ comfort, health and productivity. Potential savings and productivity gains from providing users with a “good” IAQ are enormous. The key parameters for current evaluation of IAQ in buildings are temperature, relative humidity and CO\textsubscript{2} concentration. Measurement and control of these parameters is crucial to meet the requirements for a healthy, comfortable and productive IAQ but traditional building HVAC control strategies are often insufficient. More promising strategies are emerging, but their potential will first be fully utilised when reliable, accurate and inexpensive sensors to measure key IAQ parameters become widely available and are combined with methods of using these measurements in the HVAC control strategies.

An initiative carried out with funding from the Nordic Innovation Centre has enabled a consortium of eight Nordic partners to successfully work together in an effort to increase focus on IAQ. The project is called “\textbf{Multisensors and Other New Technology for Improved indoor Environment in buildings\textsubscript{2}}, or MONTIE”. Each partner in the project has their own competencies and specialist know-how and the goal of MONTIE is to establish a strong knowledge base and discussion forum to address the current – and future uses - of advanced multisensors to provide key information about IAQ of relevance to health, comfort and conservation of resources. This will be combined with information about other technological advances to support the development of improved HVAC systems. Special focus will be placed on converting expert academic knowledge into practical applications and use.

Project activities are centred on a comprehensive information plan to spread knowledge about the importance of IAQ together with the advantages resulting from the use of microsensors and other technological advances to provide relevant and accurate measurements of relevant parameters. Increased information and awareness will provide the foundations for initiating coherent efforts to increase the level of knowledge about IAQ, and to spread this knowledge widely in order to increase and initiate new development activities. The goal is to initiate and boost the number of IAQ development activities and to increase business and commercial export opportunities. More information about the MONTIE initiative is available at www.teknologisk.dk/montie.

\section*{15.2 Aim and scope}

The aim of the workshop is to summarise state-of-the-art technology on sensors and their application for the objective measurement and demand based control of indoor
air quality. Furthermore the goal is to use the workshop as a forum to initiate discussions about the future needs for development work and information dissemination. After a short introduction and presentation of the MONTIE initiative the workshop included the following presentations given by experts within their fields:

- **Benefits of demand controlled indoor environment**  
  **- Comfort, productivity and energy efficiency**  
  Jørn Toftum, Technical University of Denmark / International Centre for Indoor Environment and Energy

- **Technological advances within the field of micro multisensors**  
  **- A Nordic perspective**  
  Peter Østbø, SINTEF, Bertil Hök, Hök Instrument and Per Gløersen, SensoNor

- **Integration of micro multisensors into HVAC installations**  
  **- What do we have and what do we need to control the future indoor climate**  
  Peter Gravesen and Jens Møller Jensen, Danfoss

15.3 State of the art review

15.3.1 Indoor environment

Numerous studies have documented that the indoor environment in buildings significantly impacts occupants’ comfort, health and productivity. For office workers in the United States, studies estimate potential annual savings and productivity gains of 10 - 30 billion USD from reduced Sick Building Syndrome symptoms (SBS) and 20 - 160 billion USD from direct improvements in worker performance that are unrelated to health (Fisk 2000). Additional savings may be gained from reduced respiratory disease and reduced allergies and asthma. In addition, (Milton et al. 2000) indicated that lower levels of outdoor air supply in office buildings were associated with increased sick leave. Thus, the economic consequences to society of effects on health and productivity due to inadequate indoor environments are considerable.

Appropriate measurement and control of significant indoor environment factors are crucial for building technical installations to meet the requirements to a healthy, comfortable and productive indoor environment. The aspects of the indoor environment that are influenced by the ventilation and climatic systems and their control comprise the thermal environment, the air quality and to some extent the acoustic environment.

Several models allow for the prediction of thermal sensation and comfort (Fanger 1973; Gagge et al. 1986), and experimental studies have been carried out that successfully controlled the thermal indoor environment based on the integrated measurement and estimation of these parameters (Goto et al. 2000; Kakegawa et al. 2000).

Recent research has documented that the air temperature and humidity not only have a strong impact on human heat loss, but also on the perceived air quality (Fang et al. 1998; Toftum et al. 1998). In addition, elevated temperatures may exacerbate SBS
symptom intensity (Mendell 1999). Thus appropriate measurement and control of the parameters that determine the thermal environment are important not only for thermal comfort, but also for other aspects of the indoor environment.

For some types of mental work (e.g. complex or creative mental work) optimum thermal comfort and productivity may coincide, whereas for other types of mental work slight warm or cold discomfort may increase arousal and thus productivity (Fisk 2000). Given that the optimum temperature differs between tasks and also varies among individuals, delegation of individual control of temperature may be a practical means to decrease thermal discomfort, reduce SBS and increase productivity.

Indoor air is a complex mixture of numerous compounds in very small concentrations. The concentration of the pollutants depends on indoor sources, ventilation and cleanliness of the outdoor air. CO2 is often used as an indicator of the pollution generated by humans. At the low concentrations typically occurring indoors, CO2 is harmless and not perceived by occupants, but it is a good indicator of other human bioeffluents being perceived as a nuisance. In rooms with a high occupancy, which may change in a short time, CO2 monitoring is a well-established practice for controlling the supply of outdoor air. Demand controlled ventilation is based on the actual need of ventilation, and, compared with a constant airflow system, saves energy without degrading the indoor air quality. However, to fully utilize the advantages of demand controlled ventilation in commercial buildings, there is a need for reliable, stable and inexpensive air quality sensors.

Volatile organic compounds (VOC) may originate from building materials, furniture, occupant activities or intake air and are a likely cause of health effects and comfort problems in non-industrial indoor environments (Andersson et al. 1997). A large number of individual VOCs in low concentrations have been detected in indoor environments, but the knowledge concerning the health effects of individual VOCs is often sparse or inconclusive (WHO 1989). Identification of compounds has been restricted to a rather narrow "chemical window" and currently it is speculated, which "stealth chemicals" that have not yet been identified may cause symptoms among occupants of many buildings.

The total VOC (TVOC) has been suggested as a measure of the concentration of indoor air pollution. However, the TVOC concept has been questioned for a number of reasons including the fact that simple addition of the quantities of individual VOCs may not be relevant from a health point of view (Andersson et al. 1997). Although the performance of artificial noses to assess perceived indoor air quality has been studied in non-industrial environments, reliable sensors and algorithms for processing measurement data are not available yet (Posselt et al. 1999).

Indoor exposure to ultrafine particles (< 1 um) and the subsequent health effects is currently an area of special concern, since ultrafine particles may deposit deep in the lung (alveoli). Numerous epidemiological studies have reported significant associations between outdoor airborne particle concentrations and excess morbidity and mortality. At present, only limited information is available on indoor exposure to particulate matter and the resulting effects on comfort, health and productivity.
A multitude of physical and chemical factors affect human perception of, and response to, the indoor environment. The leading parameters are the air temperature, the air velocity and the air humidity. The potential of demand-controlled ventilation to improve the indoor environment and reduce energy consumption in common office buildings depends on the development of reliable and inexpensive air quality sensors. A future aim is to identify the compounds in the air that cause complaints, symptoms and reduced productivity. With such knowledge, improved air quality sensors that enable the evaluation of perceived air quality, individual VOCs, mixed gases and airborne particles can be developed for the creation of healthy, comfortable and productive indoor environments.

15.3.2 Individual sensors

The physical parameters necessary to measure in conjunction with indoor environment are temperature, relative humidity and CO2 concentration. In addition it would be useful to be able to measure local pressure variations and if possible to measure draught (local undesired air flow)

Commercially available CO2 sensors are mostly based on the infrared absorption band at a wavelength of approximately 4.3 µm. A typical sensor includes a blackbody radiator heated to approximately 700°C, chopper, tuned filter, and pyroelectric detector. Various schemes for differential operation to minimise the effect of common mode errors are being used. A relatively long optical path, 100-300 mm, is required due to the weak absorption at small CO2 concentrations. Using multiple reflections to fold the optical path, the sensor design can be made somewhat more compact. The demands on mechanical precision to align the optical elements and secure high reflectivity of surfaces are high. The IR source is subject to ageing with the consequence that the devices require repeated re-calibrations. Power consumption is also inherently high due to the need for high temperature operation. No micro-system implementation of a complete CO2 sensor based on IR absorption has been reported to date. Typical accuracy of state-of-the-art CO2 sensors is ±50-100 ppm within the measurement range of 0-2000 ppm, response time 1-2 minutes, and power consumption 2-5W.

Capacitive or resistive humidity sensing elements are available from a large number of suppliers at a price range of € 5-20. Typical accuracy is ±3% within the range 10 to 90% RH. In most cases, polymers or ceramics having relatively strong water adsorption are being used as sensing material. The phenomena involved are not truly irreversible, and subject to ageing and other undesired properties. Consequently, the accuracy and long-term characteristics of state-of-the-art humidity sensors are far from ideal. It is believed that measurement of a physical property within the gas itself (average molecular mass) will not suffer from these limitations. Pressure and temperature sensor elements with adequate performance are available from many suppliers. However the integration of temperature and pressure elements into one micro-system with extremely low power consumption represents a significant engineering challenge. Most sensors on the market provide analogue output signals, 0-10 V and/or 4-20 mA. Strong efforts to launch e.g LON Works (system interface and communication protocol launched by Echelon, Inc.) as a basis for network solutions have not resulted in widespread acceptance. However, the issue of a related standard (ISO164845) may promote this solution. Very few industrial references can be found on wireless solutions.
15.3.3 Multi-sensors

Existing technology for measuring indoor environment parameters is based on a wide range of traditionally constructed sensors measuring individual physical parameters usually connected by cables or wires. Often traditional installation control strategies are based on temperature control alone, whereas there are a number of arguments pointing to the fact that control strategies should be adapted to human presence in a more intelligent way. A multi-sensor (or sensors) incorporated into the control system, as part of an ambient intelligence network will be able to address this problem by providing key information about a range of useful indoor environment parameters. The few multi-sensors that are currently available are based on traditional technology. Similarly, there is some experience available of individual wireless sensors.

Thus there is considerable scope for a wireless multi-sensor that is inexpensive, easy to install, flexible, user-friendly, maintenance-free, and reliable with long battery life. By using MEMS technology (Micro Electro Mechanical Systems) it is possible to perform several environment parameter measurements with small and compact multi-sensors with low power consumption and wireless communication to the surrounding control systems.

Such multi-sensors based on MEMS technology will contribute to considerably improved indoor environment measurement and control possibilities with an intelligent interaction with the building's control systems and with the immediate surroundings.

The feasibility of MEMS was studied in a project called “MASCOT” (Micro Acoustic Sensor Systems for CO₂ Tracking), in which implementation of an acoustic CO₂ sensor was demonstrated. While the technology platform has thus been established, important performance improvements are still required. The present MASCOT demonstrator does not fully meet the performance required for use in IAQ solutions (the signal resolution needs to be improved by a factor of 5-10). Furthermore, the sensor was designed without attention to power consumption. To achieve the required low power operating characteristics, major modifications of both activating and detecting elements will be necessary.

15.4 Discussions

15.4.1 Demand controlled ventilation

- Experience from France show up to 90% savings in large meeting rooms, which people found hard to believe. A recent study shows 20…30% savings in offices.
- Occupancy sensors are widely used in France, experience shows that good savings are achieved also this way.
- Participant from Switzerland pointed out long-time experience and good result gained by using traditional IR and photo acoustic sensors. Chairs described the Nordic perspective and the need to find low cost sensors.
- Participants from Singapore also pointed out good energy efficiency experience with a “demand ventilation” and “demand cooling” system that responds dynamically to the varying needs in the occupied zones of a building.
15.4.2 Possibilities of low-cost multi micro-sensors

- Low cost would enable several sensors even in one room, which would reduce current difficulties in the selection sensor location.
- Diagnostics of system function and performance was considered an important field of application of micro-sensors. Measurements from micro-sensors would give added value information about air quality in and around the expensive filters often used in the building and automotive sectors.
- The quality of supply air could be controlled (e.g. shutting down ventilation during high outdoor pollution), if low-cost particle/gas sensors were available.
- Commissioning of buildings would be easier with high amount of sensors in the building.
- In Japan, wireless sensor systems are being used for commissioning. After completing the necessary measurements the extra sensors installed for commissioning can be moved to another building.
- Important and reliable information about the IAQ and energy performance of buildings would be gained by combining sensor networks with real-time building simulation. This information could be used as basis for IAQ and energy supply agreements and productivity / energy saving investments.

15.4.3 State-of-the-art of multi micro-sensors

- The 3 x 3 mm² CO₂/RH micro-acoustic sensor (MASCOT) presented by Per Gloersen, Bertil Hök and Peter Østbø provoked lively discussion.
- Some participants considered the resolution of the prototype sensor, 200 ppm CO₂, insufficient. In their opinion, the resolution should be in the order of 20 ppm. Speakers pointed out that there is room and possibilities for improvement in the prototype.
- The sensor responds to CO₂ and RH, which enables compensation for humidity.
- The response time was estimated to be 2…3 seconds
- There is no experience from long-term drift, but speakers estimated it to be low. They did not consider that critical as drift can be zeroed using history data. For current sensor solutions the acceptable long-term drift is 20-30 ppm over several years, which has been reached by several suppliers.
- It was feared that sensors might lose their sensitivity over time. This needs to be addressed in future research.
- There was interest in future research on calibration issues – how to ensure that gas sensors are still measuring correctly and have not been “poisoned” during operation by other gases
- There is ongoing sensor development of micro-sensors also in Japan.
- The issue of monitoring other gases (NOₓ, ozone etc), nanoparticles and micro-organisms (pollen etc) was raised, along with the reliability problems with state-of-the-art catalytic sensors.
- Power consumption of the sensor element is the critical issue in making wireless sensors; low power transmitters will become available soon.

15.5 Recommendations

The development work on multi-sensors was deemed necessary. It is obvious that there is worldwide interest and future market for this work. Inexpensive sensors will enable better indoor environmental conditions and more efficient use of energy. Better
indoor environment conditions will improve the comfort and productivity in buildings.

Further applied research and development work is imperative in order to proceed with the multi-sensor concept. In addition, an exhaustive and widespread dissemination process will also be needed, such that knowledge and know-how of IAQ and related disciplines will be strengthened. Relevant activities could include seminars and conferences, where samples, prototypes etc. are expected to be available, and international conferences, with participation of leading international speakers. The Clima 2007 Conference could be a suitable platform for presenting the results to the HVAC community.

15.5.1 References


MASCOT – An IST project “Micro Acoustic Sensor Systems for Co2 Tracking”, IST-2001-32411, completed February 2004


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