Indoor climate in low energy buildings – main topic in Healthy Buildings Conference

The Healthy Buildings 2012 conference 8–12 July 2012 in Brisbane, Australia (www.hb2012.org) attracted 680 participants from 43 countries, with the largest delegations (apart from the host country – Australia), from China, Korea, Japan and USA. Professor Jarek Kurnitksi, a member of REHVA Board of Directors attended the conference and highlights some of the results of the Conference focusing on Indoor Air Quality and Climate in low energy buildings.

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Healthy Buildings and Indoor Air are the flagship conferences of the International Society of Indoor Air Quality and Climate – ISIAQ. The first Indoor Air conference was held in Copenhagen in 1978 and first Healthy Buildings in Stockholm in 1988. Since then, the Indoor Air conference has been held eleven times and the Healthy Buildings conference eight times.

The next Indoor Air conference will be held in Hong Kong in 2014 while the next Healthy Buildings conference will follow the ISIAQ's new conference series format. Beginning of 2015, the Healthy Building conferences will be held in each of the three major regions – Europe, the Americas, and Asia-Pacific. The Healthy Buildings Regional/Topical Conferences will be held in the odd-numbered years between the international Indoor Air conferences. The ISIAQ Board of Directors has published the call of letter of interest to invite potential hosts one of the Healthy Buildings 2015 regional conferences (see at www.isiaq.org).

Too warm in new low-energy houses

It is known that low energy houses and apartments may be easily overheated if not carefully designed. This is now quite comprehensively studied in Denmark, from where **Henrik N. Knudsen**, **Ole M. Jensen** and **Lars Kristensen** reported the results of occupant satisfaction survey from low energy houses built between 2007 and 2010. These houses followed primary energy requirement of 52.5 kWh/m²/year + 1 650 kWh/year divided by the (gross) heated floor area corresponding to current Danish Building Regulations 2010. This includes energy for hot water, electricity for building operation (multiplied by a factor 2.5 to convert to primary energy), local renewable energy production and a possible penalty for overheating. For a "standard family" living in a detached house of 150 m², this gives a maximum primary energy use for space heating of 44 kWh/m².

Occupants were generally satisfied with their new houses, but were most dissatisfied with the thermal conditions. A majority (68%) specified that they experienced too warm during summer. This was the most prevalent complaint, and in agreement with physical measurements. During winter the occupants were also most dissatisfied with thermal conditions as 27% of respondents experienced too cold, and 25% found that the temperature varied too much. Additionally, there were a series of problems with the technical installations and their use was difficult. The energy use was higher than expected.

PHOTOS: KIRSTEN SANDER / DET GROENNE HUS.

Dr **Henrik N. Knudsen** from Danish Building Research Institute at Aalborg University presented a occupant satisfaction survey from new low energy houses.

The study concluded with a series of recommendations to increase occupant satisfaction in low energy houses:

- Avoid uncomfortably high temperatures during summer with external solar shading, consider the size of the windows facing towards the sun and make effective use of natural ventilation possible.
- Develop more robust and easy-to use technical installations enabling occupants to control the indoor climate and energy consumption as intended in their new relatively technically advanced house, e.g. by a single user-friendly user interface that can communicate with all relevant technical installations.
- Ensure that occupants can use their house as intended by technical installations being fully operational from day one.
- Communicate about the energy consumption so that occupants get realistic expectations according to their family situation and behavior.

EPBD has led to more similar national requirements for ventilation and summer temperature

Energy performance of buildings directive given in 2002 has launched a fast development in many European countries with effects on summer thermal comfort, the control of which is required in the directive, as well as ventilation rates. Summer temperature limits are implemented to national regulations in most of countries, Professor **Jarek Kurnitski** reported. From studied countries only in UK the requirements were not included into the regulation.

The question of adequate ventilation is more complicated. Nordic countries with long history of ventilation requirements have binding requirements of outdoor airflow rates in the building codes. In some countries, energy performance requirements have made ventilation requirements mandatory, but there still some countries do not have mandatory ventilation requirements, that is the situation in Germany. In this case, the ventilation may be too low, because improved energy performance will require more airtight buildings and as consequence infiltration air change will be decreased.

Summer thermal comfort

- EN 15251 type of summer temperature requirements are implemented in most countries studied
- In Denmark, in the current BR2010, there is cooling energy penalty for non-residental buildings, if the building will be overheated, but the binding requirement for temperatures will apply from 2015

Country	Regulation	Binding requirements for summer thermal comfort
Finland	D3 2012	27 °C (25 °C in non-residential) cannot exceeded between June 1st and August 31st no more than 150 degree hours, simulated with TRY
Denmark	BR2010	for class 2015 and 2020 (voluntary since 2015), 26°C must not exceeded by more than 100 hours and 27°C for more than 25 hours compared to TRY
Estonia	2007 VVm 258	27 °C (25 °C in non-residential) cannot exceeded between June 1st and August 31st no more than 150 (100 in non-residential) degree hours, simulated with TRY
Germany	EnEV 2009	between 25 and 27 °C depending on the climate region , and may not be exceeded more than 10% of the time of presence
UK		Not included in the regulation, recommendations in CIBSE Guide A (2006)

Results: Binding ventilation requirements

- Binding values of whole dwelling ventilation rate and outdoor airflow rates are shown
- Exhaust flow rates shown are sometimes binding, sometimes "strongly recommended" depending on country and interpretation of codes

	Ventilation requirements and recommendations						
	Finland	Denmark	Estonia	Sweden	Norway	Germany	UK
Regulation (year, section)	D2 2012	BR2010	2007 258[c]	2012 BR19	2010	EnEV 2009	2010 F
Whole dwelling ventilation rate, l/(s m^2)	0.35	0.35[b]	0.42	0.35	0.35	not incl.[d]	0.3 +[e]
Outdoor air flow rate in bedrooms and living rooms, l/(s m^2)	6 l/s pers.[a]	0.35	1.0[f]				
Exhaust flow rates, l/s							
Kitchen hood	25	20	20	25	30		13
Bathroom	15	15	15	15	15		8
Toilet	10	10	10	10	10		6

[a] or 0,5 l/ (s m^2) if the number of persons is not known
[b] original value 0.3 l / s per. m^2 gross area corresponding to 0.35 l / s per. m^2 net area
[c] EN 15251 values in the energy performance act nr 258 make EN 15251 category II values mandatory
[d] ventilation rates are not included in the regulation, recommendations in DIN EN 15251
[e] +9 l/s+n*4l/s, where n is the number of bedrooms
[f] not required any more as binding value since 9.1.2013

Professor **Jarek Kurnitski** from Tallinn University of Technology showed that summer thermal comfort and ventilation requirements are getting more uniform in national building regualtions.

Overheating criteria for schools in UK

School buildings, with their associated nature of activities and occupancy profiles, represent a particular challenge to designers with respect to summertime overheating, especially in a context of climate change. The risk of overheating increases as current building regulations push towards highly insulated and air tight building envelopes. There have already been reported incidences of newly built classrooms being too warm, with some reaching temperatures of 33°C.

Within the UK context, a set of environmental design guidelines – Building Bulletin 101 'Ventilation in School Buildings' (BB101, 2006) – have been published to provide a series of performance criteria related to ventilation, indoor air quality and overheating in school environments. With the intention of providing better classroom indoor climates, **Marilyn Pisani, Esfand Burman and Dejan Mumovic** proposed a new set of revised environmental performance criteria with the aim of replacing the current BB101 guidelines and partly following the adaptive thermal comfort model defined by BS EN 15251.

The revised BB101 criteria include:

1. Maximum 80 hours T_{op} > 28°C (T_{op} = operative temperature)
2. Maximum 200 hours T_{op} > 25°C
3. Maximum 150 hours $T_{op} > T_{max}$ (T_{max} = maximum operative temperature defined by EN 15251)
4. Number of hours $\Delta(T_{op} - T_{ext})$ > 3°C, when T_{ext} is > 22°C = 0 (T_{ext} = external temperature)
5. Maximum T_{op}=32°C
6. Either criterion 1 & 2 or 3 must be chosen to comply with. All four criteria must be met.

New German Rule on Workplace Temperature Requirements

The German Ordinance on Workplaces calls for a healthy room temperature range. This requirement is specified in a revised version of the German rule for Workplaces ASR A3.5 'Room Temperature'. The former version of this rule laid down that the indoor air temperature shall not exceed 26°C that has led to many court cases with strict interpretation. As the former rule was originally not intended for a hot summer periods the aim of revision was to explain how to deal with a high room temperature during a hot summer period in Germany, **Runa T. Hellwig and Kersten Bux** from Augsburg University and German Federal Institute for Occupational Safety and Health reported.

Contrary to the former rule the new rule contains a three step model. This model applies for inside work places with low internal heat load and for light or medium physical work load, as office type of work. The new rule specifies the procedure while the outside temperature rises above 26°C. Depending on the indoor air temperature the following procedure must be applied:

- Air temperature at a workplace between 26°C and 30°C: If there is an adequate solar shading system already in operation the employer should apply the effective measures listed below.
- Air temperature at a workplace between 30°C and 35°C: The employer shall apply the effective measures listed below.
- Air temperature at workplace above 35°C: The workplace is not suitable for work without measures being taken which are appropriate for working in heat during the excess temperatures.

The effective measures while indoor air temperature exceeds 26°C are according to rule for Workplaces ASR A3.5, 2010:	
i)	effective control of solar shading devices (e.g. keeping blinds closed outside working time)
ii)	effective control of ventilation (e.g. night cooling by ventilation)
iii)	reducing the internal heat load (e.g. running electrical equipment only when necessary)
iv)	early morning ventilation
v)	applying flexible working hours
vi)	casual dress code
vii)	providing soft drinks (e.g. mineral water)

HealthVent project aims at health-based ventilation guidelines for Europe

Health-based ventilation guidelines are needed to assist EU in optimizing and revising policies relevant for healthy indoor air dealing with source control, urban ambient air quality and low energy buildings. It is important to protect EU citizens against health risks due to poor ventilation, but at the same time there is no need to over ventilate buildings with investments and energy penalties at ventilation rates that are not supported by tangible benefits for health, productivity and welfare.

The project identified six complementary approaches that shall be considered when developing the guidelines for health-based ventilation:

1. emissions from humans – activity based ventilation using CO_2 and humidity as markers of exposure
2. results from published epidemiological studies showing the relationship between ventilation and health in non-industrial indoor environments
3. outdoor air pollution – mainly particulate matter (PM2.5, PM10), pollens and ozone
4. the toxicological data on pollutants such as WHO guidelines and labeling systems
5. existing field and laboratory data with reported emission rates of pollutants relating the concentrations of pollutants and ventilation rates
6. problems related to ventilation detected in practice

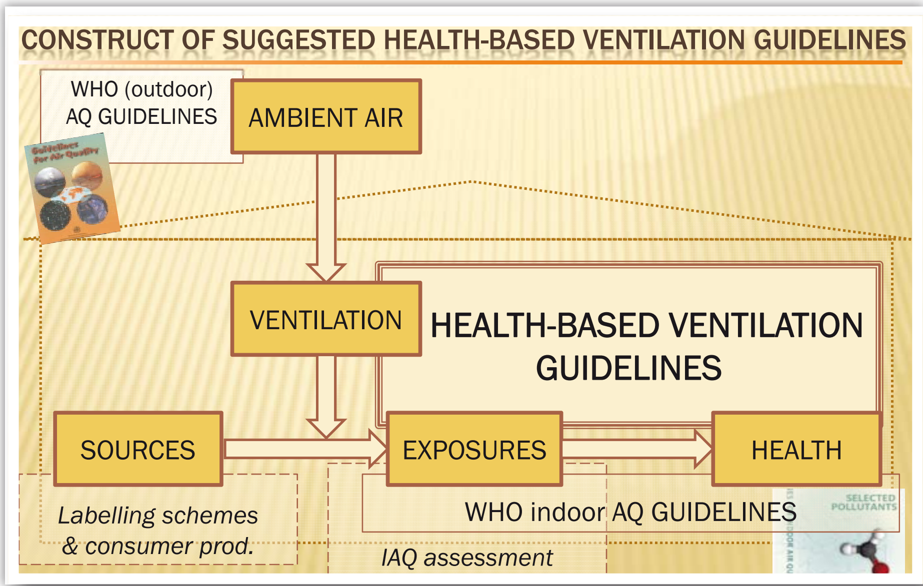
Approaches 1 to 5 will lead to the creation of guidelines prescribing ventilation rates (quantitative guideline): ventilation rates at which ventilation should be supplied to reduce health risks of the population exposed. The approach 6 will contribute to the development of descriptive guideline prescribing technical means and solutions to avoid and mitigate the problems related with ventilation systems: practical aspects of ventilation – compliance, proper design, maintenance and operation.

Professor **Pawel Wargocki**, coordinator of the HealthVent reported that current ventilation standards (e.g., EN15251, ASHRAE 62) are constructed on ventilation requirements related to sensory comfort. Different classes of sensory comfort are defined and requirements are specified for different building users (visitors and occupants). Ventilation requirements are modified based on the strength of pollution sources (classes of building materials). There are inadequate requirements for air used for ventilation and for compliance with the requirements in the standard.

For formulation of health-based ventilation guidelines it was stressed that ventilation is related to exposures having consequences for health. Ventilation is not solving all problems, but the source control must be implemented as a primary measure to control exposures, both as regards outdoor air (to be cleaned with relevant filtering) and indoor air (emissions from building to be controlled). Ventilation is then an ultimate measure to reduce exposures when all other possible measures to reduce health risks have been implemented. Ventilation guidelines need to be harmonized with all other documents regulating different sources of pollution indoors and outdoors and determining indoor air quality with respect to their potential health consequences. It is also important that ventilation system is kept clean; ventilation should not become a source of pollution.

To be used in the design of buildings, health-based ventilation guidelines can be divided into two main pillars:

- Prescriptive (quantitative) guidelines: ventilation rates at which ventilation should be supplied to reduce health risks of the population exposed
- Descriptive (qualitative) guidelines: practical aspects of ventilation – compliance, proper design, maintenance and operation



Professor **Pawel Wargocki** from Technical University of Denmark, DTU presented the approach used in HealthVent project to develop health-based ventilation guidelines. New principle is based on health effects due to the exposure to (inhaling) harmful pollutants. Exposure depends on outdoor (ambient) air quality, indoor sources and ventilation.

Minimum ventilation rate based on health effects is 7–10 L/s and 15 L/s per person based on productivity

Ventilation rates based on the results from epidemiological studies showing the relationship between ventilation and health were discussed in the presentation given by Dr. **Stylianos Kephalopoulos** from European Commission Joint Research Centre Ispra on behalf of Prof. **Paolo Carrer** from University of Milan and others.

The review of literature suggests that the minimum rates at which no effects are observed on the acute health outcomes in the reported epidemiological studies are in the range from 7 to 10 L/s per depending on building type (homes, offices and schools); no negative effects on performance and productivity in offices were seen at ventilation rates not lower than 15 L/s per person.

These rates are indicative and will guide researchers in HealthVent project to determine which rates should be used as a minimum requirements needed to control exposures in order to minimise risk for health. These rates are expected to be published in late 2012 or early 2013 when the project will be completed.

To determine necessary ventilation rates it is proposed to use 3-step process:

- **Step 1**. Basic minimum ventilation requirement when outdoor and indoor sources meet WHO outdoor air quality guidelines, (based on metabolic emissions)
- **Step 2**. Regular minimum ventilation requirement when Step 1 not met (based on data from epidemiological studies to control exposures)
- **Step 3**. Special minimum ventilation requirements for people with special needs, to achieve comfort, productivity, etc. based on data from epidemiological studies

Following the CEN standards would improve the ventilation system related problems

Descriptive guidelines prescribing technical means and solutions were discussed in the paper by Professor **Olli Seppänen** from REHVA. He concluded that European Standards, if properly applied, should already ensure no problems with ventilation systems (good practice). They already cover a significant part of the elements which are included in the descriptive guidelines presented in his paper, there he specified 21 measures in three groups:

- **Group A** showing measures leading to avoidance of specific sources of pollution related to ventilation system.
- **Group B** showing measures leading to reduction of exposure to pollutants with ventilation.
- **Group C** showing measures leading to proper operation and maintenance, and compliance with regulations, of ventilation systems.

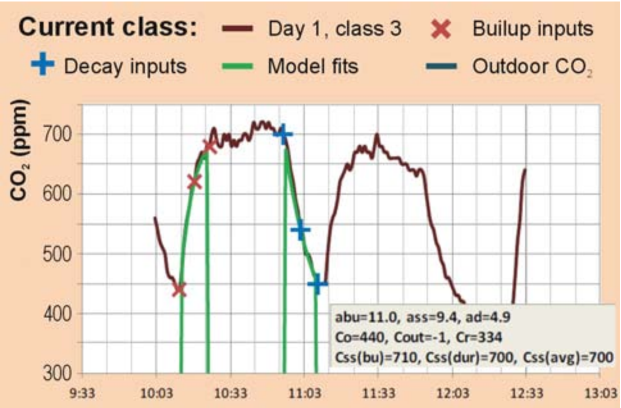
These standards are however not often followed in practice as they are not mandatory unless referred in the national or EU regulations. National building regulations regarding ventilation, on the other hand, include only few of the elements of the descriptive guideline outlined above. The descriptive guidelines described in his paper, if adopted, would minimize health risks from unnecessary exposures associated with improperly operated and maintained ventilation systems. Harmonized regulations would benefit industry by i.e. reducing the construction cost of ventilation systems.

Window opening depends more on classroom temperature than air quality

Pawel Wargocki and Nuno da Silva from DTU reported another interesting application of CO_2 sensors in classrooms. Many existing schools are naturally ventilated and ventilation rates may be inadequate if window airing is not used with regular intervals. There is evidence that classroom temperature is the driving factor for window opening, not the poor ventilation. If temperature stays within comfort limits, windows will not be typically opened and indoor air quality may become very poor with consequent effects on learning performance and health outcomes. In their study CO_2 sensors that provide a green/yellow/red visual indication were installed in pairs of naturally ventilated classrooms during normal school operation showing when the windows in the classroom should be opened. Providing such CO_2 feedback reduced CO_2 levels. More windows were opened in this condition, and this increased energy use for heating and reduced the cooling requirement. Split-cooling reduced the frequency of window opening when no CO_2 feedback was present, suggesting that classroom temperature is the driving factor for this behavioral response; at the same time installing split-cooling reduced air quality in the classroom. Children liked CO_2 feedback and their perceptions and symptoms were somewhat improved with CO_2 feedback.

Ventilation in schools and dwellings

Several studies reported interesting results on school and dwelling ventilation. Dr. **Otto Hänninen** reported the method of evaluation of ventilation rates in European schools from CO_2 measurements as part of a proposed WHO school survey. It is suggested that from 100 to 300 schools per country CO_2 measurements will be conducted in three classrooms and at one outdoor site using automated data loggers during one school week. Such large study will need a robust and reliable method for air change evaluation from CO_2 data typically not in steady state (concentration is building up during the measurement). The paper focused on the testing of the use and accuracy of the build-up method.



An example of ventilation analysis for a class. Red markers = build-up phase; blue markers = decay phase; green lines = ventilation model fit. Decay estimate (4.9 h^{-1}) is lower than build-up (11 h^{-1}) as the demand control adjusts the ventilation according to the CO_2–level monitored in the ventilation system.

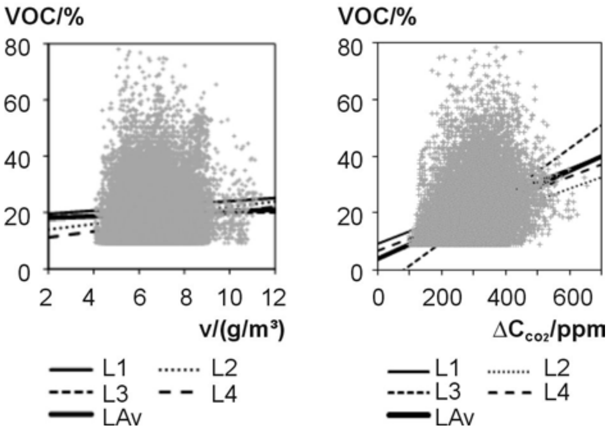
Dr. **Otto Hänninen** from National Institute for Health and Welfare (THL), Finland tested the determination of ventilation rate from build-up and decay phase.

Air change estimation with conventional mass balance equation needs the knowledge of final steady state concentration. As this might not be known, Hänninen derived in another paper an equation which allows to derive air change rate from two concentration readings during the build-up process. This new calculation equation makes measurement and calculation process more flexible.

It was concluded that the build-up curvature is typically more affected by incomplete mixing than the decay curvature due to the presence of occupants. Nevertheless, the build-up method is the only option that can be universally applied for estimating ventilation rates the pupils actually are exposed to during the classes. The steady state method is not applicable in cases when the ventilation is lower than 4-5 air exchanges per hour and the decay method is applicable only for breaks and other situations when the class is unoccupied. Because estimated from build-up curves, the air change estimates become independent of calibration errors of the CO_2 monitoring devices.

CO_2 sensors are superior to mixed gas sensor for demand controlled ventilation in dwellings

As CO_2 sensors are quite expensive for residential applications, there is a need for alternative sensors in demand controlled residential ventilation systems**. Dennis Johansson, Hans Bagge and Lotti Lindstrii** from Lund University tested commercial mixed gas sensors in order to get indication on changes of relative humidity and occupancy in dwellings. The mixed gas sensor tested showed very limited correlation with these parameters and the output varied extensively, see the Figure below. It was concluded that further analysis and laboratory work is needed to judge whether the application of measuring ventilation demand with such a sensor is relevant.



Professor **Dennis Johansson** from Lund University presented the response of a mixed gas sensor. The measured mixed gas sensor output is shown as a function of indoor vapour content for all measured points in all 4 buildings in the left, and as a function of difference in CO_2 concentration between indoor and outdoor in the right.

Reliable data is needed of the emission of building materials

- harmonising testing of construction product emissions in relation to CE marking

In the ventilation standards (EN 15251, ASHRAE 62.1 and 62.2) ventilation need is calculated as sum of two components, ventilation rate for occupancy L/s per person and ventilation rate for emissions from building materials, L/s per floor area. This stresses the importance of known emissions from construction products as they can constitute a significant source of indoor pollution. EN 15251 distinguishes between non low-polluting, low-polluting and very low-polluting classes. Low-polluting will reduce building material ventilation rate component by factor 2 and very low-polluting by factor 4. Evidently and urgently EU will need harmonised product labelling criteria to be used as a part of ventilation rate design specification. If material emissions are not known the designer has to specify high over ventilating ventilation rates according to non low-polluting class, otherwise adequate indoor air quality cannot be assured.

The European Commission has been progressing in the development of a harmonisation framework in Europe concerning the emission testing and health based evaluation of indoor products emissions. When implemented this will allow industries in providing low emitting products throughout the European Market at reasonable costs and also will enable building designers and consumers making informed choices among the variety of building and other indoor related products available on the market.

European Commission's is coordinating harmonization efforts of construction product emissions evaluation in order to incorporate this into CE marking system. The aim is that in future any indoor construction product with CE marking shall comply with requirements for material emissions. In the harmonisation process the consensus is already reached for the measurement methods based on ISO standards, and the parameters to be tested are divided into core and the transitional criteria as shown in Table below.

	Current criteria	**Core and transitional criteria** → Step I (1 to 2 years)	**Harmonised criteria** → Step II (*ca. 5 years*)
AFSSET (France)	- R-value (based on LCI) - Carcinogens - TVOC	*Core* criteria: - R-value - Carcinogens - TVOC	*Harmonised* criteria
	- Sum of "not-yet-assessed" VOC	Transitional criteria: - Sum of "not-yet-assessed" VOC	
AgBB (Germany)	- R-value (based on LCI) - Carcinogens - TVOC	*Core* criteria: - R-value - Carcinogens - TVOC	*Harmonised* criteria
	- Sum of "not-yet-assessed" VOC - TSVOC - Sensory evaluation	*Transitional* criteria: - Sum of "not-yet-assessed" VOC - TSVOC - Sensory evaluation	
DICL (Denmark)	- Irritation - Formaldehyde and other aldehydes - Carcinogens	*Core* criteria: - R-value - Carcinogens - TVOC	*Harmonised* criteria
	- Sensory evaluation	*Transitional* criteria: - Sensory evaluation	
M1 (Finland)	- TVOC - Formaldehyde - Ammonia - Carcinogens	*Core* criteria: - R-value - Carcinogens - TVOC	*Harmonised* criteria
	- Sensory evaluation	*Transitional* criteria: - Sensory evaluation	

Dr. **Stylianos Kephalopoulos** from European Commission Joint Research Centre Ispra presented common core and transitional criteria versus harmonised criteria for existing labelling schemes. (LCI = Lowest Concentration of Interest)

The importance of sensory evaluation in transitional criteria was reported by Dr. **Jorma Säteri** from Metropolia Applied University: more than 1200 M1 classified product data from Finland showed sometimes no correlation between TVOC and sensory evaluation (some products had and some did not have the correlation).

The purpose of the European Construction Products Regulation (CPR) is not to influence the level of protection but to harmonise the technical description of products, for facilitating cross-border trade. CE marking could (wherever relevant) be accompanied by performance classes that cover all national regulations in Europe. Then each EU Member State can specify which performance classes a product shall fulfil for being accepted on that national market. The intention is that this CE marking will substitute any national law.

Outstanding issues still to be resolved concern the establishment of harmonised criteria for:

- the definition of emission performance classes of building products in the context of CE marking
- a common approach and an upper limit for TVOC
- the evaluation of substances not having LCI values ("not-yet-assessed" substances)

It was estimated that it will take about five years to reach fully defined harmonised criteria incorporated into CE marking system.

Comfort and productivity in offices

Productivity in office type of work and learning performance in schools has been studied for many years. REHVA has published Guidebook No 6 on Indoor climate and productivity in offices already in 2006. The topic is still popular and a number of articles were presented on this topic.

However, mostly these studies have repeated previous research in new locations and with some new features. Somehow the latest studies presented in Brisbane were less conclusive and did not have that rigour as the old studies being used in the preparation of REHVA guidebook. These types of studies require very careful planning and execution. All aspects need to be controlled including potential learning effects as well as proper selection of experimental conditions.

Present studies seem to miss these aspects or at least the proper discussion of these aspects when discussing the results. Older studies may be judged as with higher scientific quality. Almost no new meaningful data relevant in design of buildings was presented during the conference in this field.