FINAL PROGRAMME

with PRESENTATIONS

39th AIVC Conference

Smart ventilation for buildings

18 - 19 September 2018

7th TightVent Conference

5th venticool Conference

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BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM

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18-19 September 2018

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ROOM A / ANTIPOLIS AUDITORIUM

09:00 -10:30 Opening - Plenary session

Chairpersons: ***Peter Wouters, François Durier***

Welcome on behalf of AIVC, venticool, TightVent
Peter Wouters, *Manager, INIVE EEIG, Belgium*

Welcome on behalf of CETIAT/ADEME
François Durier, *CETIAT, France* & Pierre Deroubaix, *ADEME, France*

Will the "smart" movement lead to an improved indoor environmental quality?
Bjarne Olesen (Invited speaker), *ASHRAE President–DTU, Denmark*

Advances in European residential ventilation systems in Nearly Zero Energy Buildings
Jarek Kurnitski (Invited speaker), *REHVA Vice-president–Chair of the Technology and Research Committee, Estonia*

EU support for innovation and market uptake in smart buildings
Philippe Moseley (Invited speaker), *EASME, Belgium*

French energy and indoor air quality policies for buildings and ventilation
Emmanuel Acchiardi, (Invited speaker), *MTES & MCT, France*

Industry views with respect to smart ventilation as an enabler of indoor air quality
Yves Lambert (Invited speaker), *EVIA, Belgium*

10:30-11:00 Coffee break

ROOM A / ANTIPOLIS AUDITORIUM

11:00- 12:30 Parallel Session 1A - Long & Short Oral Presentation
Session: Analysing airtightness measurements

Chairpersons: ***François Rémi Carrié, Paula Wahlgren***

Quality framework for airtightness testing in the Flemish Region of Belgium – feedback after three years of experience (Long Oral Presentation)
Maarten De Strycker, *Belgium*

French database of building airtightness, statistical analyses of about 215,000 measurements: impacts of buildings characteristics and seasonal variations (Long Oral Presentation)
Bassam Moujalled, *France*

Preliminary analysis results of Spanish residential air leakage database (Long Oral Presentation)
Irene Poza-Casado, *Spain*

Assessment of durability of airtightness by means of repeated testing of 4 passive houses (Long Oral Presentation)
Jiri Novak, *Czech Republic*

Onsite evaluation of building airtightness durability: Long- term and mid-term field measurement study of 61 French low energy single family dwellings (Long Oral Presentation)
Bassam Moujalled, *France*

In-situ and laboratory airtightness tests of structural insulated panels (SIPs) assemblies (Short Oral Presentation)
Vitor Cardoso, *Portugal*

ROOM B / ELLA FITZGERALD

11:00- 12:30 Parallel Session 1B - Topical Session: Commissioning of ventilation systems - Improving quality of installed ventilation systems

*Chairpersons: **Gaëlle Guyot, Laure Mouradian***

Several measurement campaigns in Europe highlighted that the quality of installed ventilation systems is often far from the performance expected at design stage (Boersta, 2012; Caillou, 2012: Jobert, 2012). However, with the generalization of low energy buildings with air-tighter envelopes, ventilation performance becomes a crucial issue to avoid health problems and building damages. In this regard, several projects and initiatives have been conducted in France these past few years to improve the quality of installed ventilation systems, using the commissioning as a driver for change. Area of works proposed in this session are: the commissioning as a key point in the development of quality management schemes, the improvement of the reliability of ventilation performance assessment protocols, in-situ ventilation performance assessment methods for hybrid and natural ventilation, and change management towards a better quality of installed ventilation systems with active participation of stakeholders.

Development and test of quality management approach for ventilation and indoor air quality in single-family buildings
Sandrine Charrier (Invited speaker), *France*

Applications of the Promevent protocol for ventilation systems inspection in French regulation and certification programs
Adeline Bailly Mélois (Invited speaker) & Laure Mouradian, *France*

Presentation of a national consultative body on ventilation issues: actors, working groups and projects overview
Andrés Litvak & Romuald Jobert (Invited speakers), *France*

Assessing the performance of hybrid and natural ventilation systems: a review of existing methods (Short Oral Presentation)
Gabriel Remion, *France*

ROOM C / MILES DAVIS

11:00- 12:30 Parallel Session 1C- Long & Short Oral Presentation Session: Indoor Air Quality & Ventilation in non-residential buildings

*Chairpersons: **William Bahnfleth, Pierre Deroubaix***

Thermal Comfort and indoor air quality in Drøbak Montessori School - A case study of Norway's first plus-energy school (Long Oral Presentation)
Maria Myrup, *Norway*

Ventilation Performance of Natural Ventilation Building with Solar Chimney (Long Oral Presentation)
Haruna Yamasawa, *Japan*

Ventilation Performance of Office Building with Natural Ventilation Shaft (Short Oral Presentation)
Toshihiko Sajima, *Japan*

Indoor air quality measurements in 35 schools of South - Western Europe (Short Oral Presentation)
Patrice Blondeau, *France*

ROOM C / MILES DAVIS

A study of running set-points and user IEQ satisfaction perspectives in the Norwegian commercial building stock (Short Oral Presentation)
Niels Lassen, *Norway*

Indoor Environment in Sickroom with Ceiling Induction Diffusers and Measuring Method of Ventilation Effectiveness Using Tracer Gas (Short Oral Presentation)
Peihuan Liu, *Japan*

Development of a zonal model to assess indoor climate and damage risks to art works in church buildings (Short Oral Presentation)
Arnold Janssens, *Belgium*

Effects of meteorological factors on CO2 concentrations (Short Oral Presentation)
Maria Marrero, *Spain*

12:30- 13:30 Coffee break

ROOM A / ANTIPOLIS AUDITORIUM

13:30- 15:00 Parallel Session 2A – Topical Session: Smart ventilation control strategies

Chairpersons: ***Max Sherman, François Durier***

Smart ventilation of buildings is a process to continually adjust the ventilation system in time, and optionally by location, to provide the desired IAQ benefits while minimizing energy consumption, utility bills and other non-IAQ costs (such as thermal discomfort or noise). The energy and IAQ performance of smart ventilation relies on a relevant control, based on information received from sensors and provided to actuators, operating with relevant and efficient control algorithms. The control strategy becomes therefore a key element of smart ventilation, building energy performance and IAQ. The objective of this session is to present and illustrate the definition of smart ventilation prepared by AIVC; show examples of the energy savings and IAQ performance of smart ventilation; discuss the various aspects of smart ventilation control strategies from the inputs of a panel of experts.

What is smart ventilation - presentation of the AIVC definition
François Durier, *France*

A review of smart ventilation energy and IAQ performance in residential buildings (Long Oral Presentation)
Gaelle Guyot, *France*

Smart ventilation control strategies - Panelists' point of view
Wouter Borsboom, *Netherlands,* Iain Walker, *USA,* Pawel Wargocki, *Denmark*

Discussion with the audience
Max Sherman (Moderator), *USA*

ROOM B / ELLA FITZGERALD

13:30- 15:00 Parallel Session 2B - Topical Session: Ductwork airtightness: Ongoing works in some European countries

Chairpersons: ***Valérie Leprince, Lars-Åke Mattsson***

On one hand, there is a number of studies that demonstrate significant energy use impacts of ductwork leakages, showing that the total energy use related to ventilation could be reduced by over 30 to 50 % by achieving an airtight ventilation system. On the other hand, a recent study has been performed among the TightVent Airtightness Association Committee (TAAC) to compare ductwork airtightness requirements in Europe. It has shown that ductwork airtightness does not seem to be taken into account (neither in regulation nor in energy performance programmes) in most European countries. Conversely to building airtightness the awareness regarding ductwork airtightness has not grown in most Europeans Countries. Therefore, progress is still needed to better understand the impact of ductwork airtightness on energy use (fan, cooling and heating) and indoor air quality. The objective of this session is to present ongoing work in some European countries which have begun to define requirements either in regulation or in labels regarding ductwork airtightness.

Introduction: Why shall we care about ductwork airtightness?
Valérie Leprince, *France*

Duct leakage testing in Portugal, a consulting engineer's view and experience
Carlos Lisboa (Invited speaker), *Portugal*

Ductwork airtightness in UK: requirements and assessment of the installed performance
Marcus Lightfoot (Invited speaker), *Netherlands*

Statistical analysis of about 1,300 ductwork airtightness measurements in new French buildings: impacts of the type of ducts and ventilation systems (Long Oral Presentation)
Bassam Moujalled, *France*

Ventilation ductwork systems certification for a better air tightness (Long Oral Presentation)
Marie-Clemence Briffaud, *France*

The new air tightness class in ductwork - Aeroseal technology to seal leakages in new/retrofit ductwork and duct components - the foundation for highest energy efficiency in ventilation systems"
Jorg Mez (Invited speaker), *Germany*

ROOM C / MILES DAVIS

13:30- 15:00 Parallel Session 2C - Long Oral Presentation Session: Ventilative Cooling

Chairpersons: ***Hilde Breesch, Peter Holzer***

Key findings of four years of research on Ventilative Cooling and how it is done
Philipp Stern, *Austria*

Status and recommendations for better implementation of ventilative cooling into Danish standards, building legislation and energy compliance tool
Christoffer Plesner, *Denmark*

The influence of thermal mass on the predicted climate cooling potential in low energy buildings
Paul O' Sullivan, *Ireland*

ROOM C / MILES DAVIS

Validation of Dynamic Model BSim to Predict the Performance of Ventilative Cooling in a Single Sided Ventilated Room
Michal Pomianowski, *Denmark*

Ventilative cooling in a school building: evaluation of the measured performances
Hilde Breesch, *Belgium*

Freevent: ventilative cooling and summer comfort in 9 buildings in France
Andrés Litvak, *France*

15:00- 15:15 **Room change**

ROOM A / ANTIPOLIS AUDITORIUM

15:15- 16:30 **Parallel Session 3A – Topical Session: Demand controlled ventilation in French buildings – 35 years of wide scale experience**

Chairpersons: ***Fabrice Lamarre, Laure Mouradian***

Demand controlled ventilation systems are representing a large majority of installations in France. They are commonly used for more than 35 years. The strong development of these systems can be explained by the French regulatory framework for air renewal. These demand controlled systems have been developed in order to optimise the energy consumption and at the same time to ensure indoor air quality and building durability. In residential buildings, demand control is based mainly on humidity whereas in commercial buildings it is based on occupancy and/or CO2 levels. Research is still in progress to guarantee that the indoor air quality is ensured at design stage and maintained during the building life. The objectives of this session are to: show an overview of the available demand controlled ventilation systems installed in France in residential and commercial buildings; explain the assessment procedure, used to deliver technical agreements; share French experience of such systems, based on on-site measurements for assessing long-term durability in dwellings.

Introduction to demand controlled ventilation in France
Fabrice Lamarre & Laure Mouradian, *(France)*

From Technical Appraisal of Demand-Controlled Ventilation Systems to Indoor Air Quality Assessment Using the Thermo-Hygro-Aeraulic code MATHIS
François Demouge (Invited Speaker), *France*

Feedback on installation, maintenance and aging of mechanical humidity-controlled exhaust units (Long Oral Presentation)
Stephane Berthin, *France*

Long-term durability of humidity-based demand-controlled ventilation: results of a 10 years monitoring in residential buildings (Long Oral Presentation)
Elsa Jardinier, *France*

Occupancy controlled ventilation in refurbished office building, combining presence and CO2 detection
Jean-Michel Navarro (Invited Speaker), *France*

ROOM B / ELLA FITZGERALD

15:15- 16:30 Parallel Session 3B-Topical Session: Integrating uncertainties due to wind and stack effect in declared airtightness results

Chairpersons: ***Valérie Leprince, Christophe Delmotte***

Building airtightness tests have become very common in several countries, either to comply with minimum requirements of regulations or programmes, or to justify input values in calculation methods. This raises increasing concerns for the reliability of those tests. There are four key sources of uncertainty in airtightness testing: measurement devices (accuracy and precision); calculation assumptions (e.g. reference pressure, regression analysis method); external conditions (wind and stack effect impact); and tester's behaviour. While competent tester schemes and independent checking procedures show potential to contain errors due to the tester's behaviour, there have been extensive yet sterile debates about how the building pressurisation test standard ISO 9972 should address other sources of uncertainties. As a result, no change has been made on these aspects on the new version of the standard which was published in September 2015.

With the present standard, the zero-flow pressure shall not exceed 5 Pa for the test to be valid. Consequently, in moderately windy conditions, it may be impossible to perform a pressurisation test in accordance with the standard, even using precautions with a careful uncertainty analysis.

This is the second topical session on this subject after the first one at AIVC 2017. The objective of this new session is to give a review of the work performed on this subject and to discuss recent work to quantify or contain the uncertainty.

Introduction: Output of the AIVC working group
Valérie Leprince, *France*

Wind speed in building airtightness test protocols: a review
Adeline Mélois (Invited Speaker), *France*

Experimental study of enclosure airtightness of an outdoor chamber using the pulse technique and blower door method under various leakage and wind conditions (Long Oral Presentation)
Xiaofeng Zheng, *United Kingdom*

Experimental Investigation of the Impact of Environmental Conditions on the Measurement of Building Infiltration, and its correlation with Airtightness (Long Oral Presentation)
Alan Vega Pasos, *United Kingdom*

Uncertainties in airtightness measurements: regression methods and pressure sequences (Long Oral Presentation)
Martin Prignon, *Belgium*

Numerical and experimental identification of factors influencing the pressure homogeneity during an airtightness test in a large building (Short Oral Presentation)
Loubna Qabbal, *France*

ROOM C / MILES DAVIS

15:15- 16:30 **Parallel Session 3C - Topical Session: Rationale behind ventilation requirements and regulations**

Chairpersons: ***Wouter Borsboom, Willem de Gids***

Internationally there are many different requirements and regulations for ventilation. Sometimes the variation is more than a factor of five. There are strong drivers to reduce energy consumption for HVAC, and therefore the spread in requirements and regulation is worthwhile to study. To reduce ventilation flows there is a necessity to understand the reasons behind. Demand control to reduce this flows is in many countries growing but the control parameters are quite different, for instance humidity versus CO2 control. If you don't know the reasons for ventilation, you cannot decide when and to what level you can reduce the ventilation flows. Latest studies on contaminants related to health are probably important for demand controlled ventilation. The objective of this session is to: show the differences in ventilation requirements; present the rationale behind the regulation given by the different countries; analyse the reasons for the differences in background and philosophies; present latest research in relation to most important contaminants; discuss the strategies on demand controlled ventilation

Ventilation requirements for different rooms as a result on the inquiries in 20 countries
Willem de Gids, *Netherlands*

IAQ in working environments in Belgium: alternative approaches to CO2 requirement (Long Oral Presentation)
Samuel Caillou, *Belgium*

How should we characterize emissions, transport, and the resulting exposure to SVOCs in the indoor environment? (Long Oral Presentation)
John Little, *USA*

Diagnostic barriers to using PM2.5 concentrations as metrics of indoor air quality (Long Oral Presentation)
Benjamin Jones, *United Kingdom*

Rationale behind ventilation standards and regulations given by 20 countries
Wouter Borsboom, *Netherlands*

16:30- 17:00 **Coffee break**

ROOM A / ANTIPOLIS AUDITORIUM

17:00- 18:00 **Parallel Session 4A - Long & Short Oral Presentation Session: Reducing noise and improving thermal comfort of ventilation**

Chairpersons: ***Wouter Borsboom, Sonia Garcia Ortega***

Noise Radiated by Circular Ventilation Ducts (Long Oral Presentation)
François Bessac, *France*

Improvement of the acoustical performance of mechanical ventilation systems in dwellings: a case study (Long Oral Presentation)
Samuel Caillou, *Belgium*

Influence of office layout and ceiling height on vertical temperature gradient in office rooms with displacement ventilation (Long Oral Presentation)
Natalia Lastovets, *Finland*

Ductwork design flaws and poor airtightness: a case study about a ventilation system reconditioning in an underground shelter (Short Oral Presentation)
Fabrice Richieri, *France*

Ductwork noise calculations: main outputs of AcouReVe project (Short Oral Presentation)
François Bessac, *France*

ROOM B / ELLA FITZGERALD

17:00- 18:00 Parallel Session 4B - Long & Short Oral Presentation Session: Modeling & energy performance of ventilation system

Chairpersons: ***Willem de Gids, Wendy Miller***

Including air-exchange performance in building regulation (Long Oral Presentation)
Harm Valk, *Netherlands*

Performance of a dual core energy recovery ventilation system for use in Arctic housing (Long Oral Presentation)
Boualem Ouazia, *Canada*

Experimental analysis of PCM heat exchanger in ventilated window system (Short Oral Presentation)
Yue Hu, *Denmark*

Development of Psychrometric diagram for the energy efficiency of Air Handling Units (Short Oral Presentation)
Kiyan Vadoudi, *France*

Cooling and Heating performance of Ceiling Radiant Textile Air Conditioning System with PAC (Short Oral Presentation)
Mari Kuranaga, *Japan*

Optimal control strategy of air-conditioning systems of buildings requiring strict humidity control (Short Oral Presentation)
Chaoqun Zhuang, *Hong Kong*

Validation of a Digital Twin with Measurement Data (Short Oral Presentation)
Johannes Brozovsky, *Germany*

CFD analysis of the optimal installation location of adsorption material in two ventilation conditions in residential buildings: natural convection and mechanical ventilation (Short Oral Presentation)
Haneul Choi, *South Korea*

ROOM C / MILES DAVIS

17:00- 18:00 Parallel Session 4C- Short Oral Presentation Session: Control of indoor pollutants

Chairpersons: ***Andy Persily, William Bahnfleth***

Indoor particle concentration related to occupant behavior of Korean residential buildings
Hyungkeun Kim**,** *South Korea*

Ventilation improvement for make-up air supply system cooking - generated indoor particles
Kyungmo Kang, *South Korea*

The impact on indoor air of bio-based insulation materials: effect of humidity and potential mould growth
Ana Maria Tobon Monroy, *France*

The Assessment of Particulate Matter (PM2.5) Removal Efficiency o n Air Cleaner Products through Full Scale Test in Korea
Kichul Kim, *South Korea*

The assessment of surface condensation risk in dwellings.
The influence of climate in Spain
Pilar Linares, *Spain*

A Stochastic Approach to Estimate Uncertainty in Pollutant Concentrations in an Archetypal Chilean House
Constanza Molina, *United Kingdom*

Thamesmead Condensation, Damp and Mould Strategy.
The use of smart thermostats to assess ventilation interventions with demand controlled ventilation.
Peter Rickaby, *United Kingdom*

Accuracy Improvement for Estimating Indoor Carbon Dioxide Concentration Produced by Occupants
Masaki Tajima, *Japan*

Impact of construction stages on Indoor Air Quality
Charline Dematteo, *France*

Olfactory adaptation model based on change of odor threshold using impulse response function
Toshio Yamanaka, *Japan*

18:30- 20:30 Poster presentations – Industry stands – Cocktail reception

ROOM A / ANTIPOLIS AUDITORIUM

08:30– 10:00 Parallel Session 5A- Topical Session: Assessing performance of ventilation systems

Chairpersons: ***Max Sherman, Pawel Wargocki***

The old paradigm of a ventilation system providing constant airflow was relatively easy to assess. One could check a single flow rate, one could simulate energy impacts. Indoor air quality impacts were assumed. That paradigm is changing as we consider smarter ventilation systems, and multiple objectives for our ventilation system; performance means much more than simple airflow. The way we assess ventilation systems must evolve at the same time. This session has presentations look at different themes for assessing performance and looks at approaches used in a variety of countries. After the presentations there will be discussions about the approaches followed by some voting to see the opinion of the audience.

A review of performance-based approaches to residential smart ventilation (Long Oral Presentation)
Gaëlle Guyot, *France*

Rethinking Occupancy-based ventilation controls (Long Oral Presentation)
Ian Walker, *United States*

Demand controlled ventilation: relevance of humidity based detection systems for the control of ventilation in the spaces occupied by persons (Long Oral Presentation)
Sébastien Pecceu, *Belgium*

A review of the performance indicators of night-time ventilation (Short Oral Presentation)
Rui Guo, *Denmark*

Assessing the energy use and IAQ of various HVAC systems during the early design stage (Short Oral Presentation)
Marwan Abugabbara, *Sweden*

ROOM B / ELLA FITZGERALD

08:30– 10:00 Parallel Session 5B- Long & Short Oral Presentation Session: Demand controlled ventilation

Chairpersons: ***Arnold Janssens, Kari Thunshelle***

Measured and Simulated Energy Savings and Comfort Improvement of a Smart Residential Ventilation Control Strategy: Preliminary Results for North America and Europe (Long Oral Presentation)
Danny Parker, *United States*

Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates (Long Oral Presentation)
Markus Gwerder, *Switzerland*

Simulation of control strategies for ventilation systems in commercial buildings (Long Oral Presentation)
Bart Merema, *Belgium*

Smart monitoring of ventilation system performance with IEQ sensor networks (Long Oral Presentation)
Atze Boerstra, *The Netherlands*

ROOM B / ELLA FITZGERALD

Short-term mechanical ventilation of air-conditioned residential buildings: case study and general design framework (Short Oral Presentation)
Zhengtao Ai, *Denmark*

Hybrid ventilation systems enslaved by IAQ sensors (Short Oral Presentation)
Alexandre Lucet, *France*

Resilient demand control ventilation system for dwellings (Short Oral Presentation)
Xavier Faure, *France*

Numerical Assessment of the Influence of Heat Loads on the Performance of Temperature-Controlled Airflow in an Operating Room (Short Oral Presentation)
Cong Wang, *Sweden*

ROOM C / MILES DAVIS

08:30–10:00 Parallel Session 5C - Long & Short Oral Presentation Session: Improving the efficiency of ventilative cooling

Chairpersons: ***Manfred Plagmann, Pilar Linares Alemparte***

Ventilative cooling and improved indoor air quality through the application of engineered Earth Tube systems, in a Canadian climate (Long Oral Presentation)
Trevor Butler, *Canada*

Free cooling of low energy buildings with ground source heat pump system and bidirectional ventilation (Long Oral Presentation)
Huijuan Chen, *Sweden*

Energy analysis for balanced ventilation units from field studies (Long Oral Presentation)
Bart Cremers, *Netherlands*

Characterising window opening behaviour of occupants using machine learning models (Short Oral Presentation)
Junseok Park, *South Korea*

Experimental and numerical study of a building retrofitting solution combining Phase Change Material wallboards and night ventilation (Short Oral Presentation)
Timea Bejat, *France*

Potential of mechanical ventilation for reducing overheating risks in retrofitted Danish apartment buildings from the period 1850-1890 – A simulation-based study (Short Oral Presentation)
Daria Zukowska, *Denmark*

10:00-10:30 Coffee break

ROOM A / ANTIPOLIS AUDITORIUM

10:30-11:30 **Parallel Session 6A-Topical Session: Development of Indoor Air Quality Metric**

Chairpersons: ***Pawel Wargocki, Max Sherman***

We all know IAQ is important, but traditionally the determination of it has been either through surrogates (like ventilation) and the use of engineering judgment. For most physical factors of concern, we prefer to have objective, quantifiable factors to optimize. A measurable and quantifiable factor is called a "metric" and developing a good one for IAQ is a key step forward in building physics. In this session we shall look at five different approaches at metrics for indoor air quality from ones that are relatively well know such as carbon dioxide concentrations, to others that are just being proposed.

Development of an Indoor Carbon Dioxide Metric (Long Oral Presentation)
Andrew Persily, *USA*

Economics of Indoor Air Quality (Long Oral Presentation)
Max Sherman, *USA*

A use case of data analysis for assessing Indoor Air Quality indicators (Short Oral Presentation)
Xavier Boulanger, *France*

Subjective Evaluation for Perceived Air Pollution Caused by Human Bioeffluents (Short Oral Presentation)
Lisa Yoshimoto, *Japan*

ROOM B / ELLA FITZGERALD

10:30-11:30 **Parallel Session 6B- Topical Session:
Performance of heat recovery ventilation systems in practice**

Chairpersons: ***Arnold Janssens, Jelle Laverge***

In new houses in Europe the share of mechanical ventilation with heat recovery is increasing as a result of more severe energy performance requirements and of energy labelling for residential ventilation units. The presentations in this session provide information about the performance of heat recovery ventilation systems in practice, in terms of energy performance and indoor air quality.

Improving the usability and performance of heat recovery ventilation systems in practice (Long Oral Presentation)
Wouter Borsboom, *Netherlands*

Energy performance of demand controlled mechanical extract ventilation systems vs mechanical ventilation systems with heat recovery in operational conditions : Results of 12 months in situ-measurements at Kortrijk ECO-Life community (Long Oral Presentation)
Jelle Laverge, *Belgium*

Temperature, draft and ventilation efficiency of room based decentralised heat recovery ventilation systems (Long Oral Presentation)
Jelle Laverge, *Belgium*

ROOM C / MILES DAVIS

10:30-11:30 **Parallel Session 6C-Topical Session: Presentation and Discussion of the recently adopted IEA EBC Annex 80 on Resilient Cooling**

Chairpersons: ***Peter Holzer, Hilde Breesch***

The inexorable increase in energy consumption for the cooling of buildings, and the increase in overheating of buildings has become one of the major topics for sustainable development in the building sector. To tackle these challenges a new Annex has been approved by the IEA EBC Executive Committee in June 2018 and which is currently in its Preparation Phase. The Annex 80 will assess and further develop Resilient Cooling for Residential and Small Commercial Buildings across all participating countries enabling multilateral transfer of knowledge. The Annex is open for the participation of scientific institutions as well industrial partners. The next preparation meeting will be held on 20th September 2018 in Juan-les-Pins at the Palais des Congrès.

11:30- 11:45 **Room change**

ROOM A / ANTIPOLIS AUDITORIUM

11:45- 12:45 **Parallel Session 7A – Topical Session:**
Indoor Environmental Quality Global Alliance (IEQ-GA)

Chairpersons: ***Max Sherman, Donald Weekes***

The AIVC is one of the founding members of the new Indoor Environmental Quality Global Alliance (IEG-GA). The Alliance is expected to be an independent international NGO whose members are public or non-profit entities that are involved with advancing knowledge on common indoor environmental quality issues. In its formative phases, the Alliance is being hosted by ASHRAE.
The current Alliance president is Don Weekes. The current ASHRAE representative to the Alliance is Bill Bahnfleth and the current AIVC representative is Peter Wouters. These members of the Alliance Board will summarize the activities and aspirations of the Alliance and be available for an interactive discussion with the audience.

Indoor Environmental Quality – Global Alliance: History
William P. Bahnfleth, *USA*

Indoor Environmental Quality – Global Alliance & the AIVC
Peter Wouters, *Belgium*

Indoor Environmental Quality – Global Alliance: The Next Decade
Donald Weekes, *Canada*

ROOM B / ELLA FITZGERALD

11:45- 12:45 Parallel Session 7B - Topical Session: Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications. The new IEA-EBC Annex 78

Chairpersons: ***Bjarne Olesen, Pawel Wargocki***

Ventilation accounts for approximately 20% of the global energy use for providing an acceptable indoor environment. The requirements for ventilation in the most standards and guidelines assume acceptable quality of (clean) outdoor air. In many locations in the world, the outdoor air quality is so bad that it is better to avoid supplying outdoor air to the buildings. In such cases, the alternative to use ventilation is to substitute supply of outdoor air with air cleaning so that the indoor air can be kept at high quality. Even when outdoor air is of a good quality, the use of air cleaning substituting ventilation air could reduce the rate of outdoor air supplied indoors and thereby energy for heating/cooling the ventilation air and for transporting the air (fan energy) can be saved. Since it is expected that air cleaning may in parallel improve the indoor air quality (perceived air quality and health) and reduce energy use for ventilation, it should be considered as a very interesting technology that can be used in the future. There is however a need for better evaluation of its potential to improve indoor air quality (and substitute ventilation rates) and the energy implication of using gas phase air cleaning. There is also a need to develop standard test methods of the performance of air cleaning devices.

Background and Objective of IEA-EBC Annex 78
Bjarne Olesen, *Denmark*

Measurements of perceived indoor air quality
Pawel Wargocki, *Denmark*

Discussion

ROOM C / MILES DAVIS

11:45- 12:45 Parallel Session 7C - Topical Session: Measurement accuracy of air flow and pressure difference

Chairpersons: ***Isabelle Caré***

The construction, function and maintenance of ventilation installations are of great importance for the perception of the interior climate of a building by those who work or live there and for its annual running costs. To check that the installation is functioning as intended, it is essential to use measurement methods, which are reliable and have known measurement uncertainties. Several project research have shown the issues related to the measurement of air flow at air terminal devices because of the induced disturbance of the flow pattern. Standards have been written in the past years, to describe measurement methods approved for on-site measurements. However, difficulties to reach the required measurement uncertainty still exist as the measuring instruments are probably not well characterized. The objective of this session is to: present and illustrate the issues related to flow measurement at air terminal devices; discuss the various aspects of air flow measurement from the inputs of experts.

Introduction - Presentation of the objectives of the session
Isabelle Care, *France*

A review of European standards related to measurement at air terminal devices
Carl Welinder (Invited Speaker), *Sweden*

Measurement issues of air flow at air terminal devices and perspectives
Samuel Caillou (Invited Speaker), *Belgium*

Discussion with the audience

12:45-13:30 Lunch Break

ROOM A / ANTIPOLIS AUDITORIUM

13:30-15:00 **Session 8A - Topical Session: Sensors for smart ventilation**

Chairpersons: ***Francois Durier, Iain Walker***

Smart ventilation of buildings means continual adjustment of ventilation rates in response to parameters such as: occupancy, outdoor conditions, electricity grid needs, indoor contaminants, operation of other systems. Smart ventilation can provide information to building owners, occupants, and managers on operational energy consumption and indoor air quality. Many smart ventilation strategies require sensors to measure air conditions inside (and sometimes outside) a dwelling. Recent developments in low-cost sensors have opened up the opportunity to sense indoor contaminants and use these measurements to control ventilation, filtration and air cleaning systems. Using low-cost computers together with low-cost sensors and implementing wireless sensor networks in buildings are also interesting perspectives to be investigated. The objective of this session is to: to show an overview of the available low cost sensors for indoor air measurements (particulates, VOCs, CO2) and results of their evaluation; assess their applicability to ventilation system control; show examples of the implementation of low-cost sensors in low cost computers or wireless sensor networks.

Use of low-IAQ sensors
Laure Mouradian (Invited Speaker), *France*

Are low-cost sensors good enough for IAQ controls? (Long Oral Presentation)
Ian Walker, *USA*

Indoor air quality investigation in a ventilated demonstrator building via a smart sensor (Long Oral Presentation)
Loubna Qabbal, *France*

A cost-effective and versatile sensor data platform for monitoring and analysis of building services (Long Oral Presentation)
Christian Hviid, *Denmark*

Discussion with the audience

ROOM B / ELLA FITZGERALD

13:30-15:00 **Parallel Session 8B - Long & Short Oral Presentation Session: New methodologies and improvements for airtightness & air flow rates measurements**

Chairpersons: ***Paula Wahlgren, François Rémi Carrié***

Individual unit and guard-zone air tightness tests of apartment buildings (Long Oral Presentation)
Angela Rohr, *Germany*

An extended pressure range comparison of the blower door and novel pulse methods for measuring the airtightness of two outdoor chambers with different levels of air tightness (Long Oral Presentation)
Christopher Wood, *United Kingdom*

Non-intrusive experimental assessment of air renovations in buildings and comparison to tracer gas measurements (Long Oral Presentation)
Maria Jose Jimenez Taboada, *Spain*

Airflow measurements at supply air terminal devices on residential balanced ventilation systems (Short Oral Presentation)
Valérie Leprince, *France*

ROOM B / ELLA FITZGERALD

The future of passive techniques for air change rate measurement (Short Oral Presentation)
Sarah Lima Paralovo, *Belgium*

Airtightness measurement of large buildings by using multi-zonal techniques: a case study (Short Oral Presentation)
Sylvain Berthault, *France*

A new method to measure building airtightness (Short Oral Presentation)
Timothy Lanooy, *Netherlands*

Comparison of experimental methodologies to estimate the air infiltration rate in a residential case study for calibration purposes (Short Oral Presentation)
Paolo Taddeo, *Spain*

Experimental study on the measurement of Building Infiltration and Air Leakage rates (at 4 and 50 Pa) by means of Tracer Gas methods, Blower Door and the novel Pulse technique in a Detached UK Home (Short Oral Presentation)
Alan Vega Pasos, *United Kingdom*

ROOM C / MILES DAVIS

13:30-15:00 **Parallel Session 8C - Long & Short Oral Presentation Session: Evaluation of the effectiveness of the ventilation system**

Chairpersons: ***Samuel Caillou, Pierre Deroubaix***

An experimental investigation into the ventilation effectiveness of diffuse ceiling ventilation (Long Oral Presentation)
Chen Zhang, *Denmark*

A holistic evaluation method for decentralized ventilation systems (Long Oral Presentation)
Sven Auerswald, *Germany*

Influence of multizone airleakage on IAQ performance in residential buildings (Long Oral Presentation)
Gaëlle Guyot, *France*

Residential balanced ventilation and its tested impacts on indoor pressure and air quality (Long Oral Presentation)
Boualem Ouazia, *Canada*

Isolation Rooms - CFD Simulations of Airborne Contamination Through Doors During Passage (Short Oral Presentation)
Trond Thorgeir Harsem, *Norway*

ROOM C / MILES DAVIS

Thermal comfort, IAQ and Energy use in Bedrooms (Short Oral Presentation)
Regina Bokel, *Netherlands*

15:00-15:15 **Room change**

ROOM A / ANTIPOLIS AUDITORIUM

15:15-16:15 **Parallel Session 9A – Topical Session: Air Quality in Domestic Kitchens**

Chairpersons: ***Benjamin Jones, Max Sherman***

Cooking has been identified as a key pollutant source in houses. Occupants are at risk of exposure to elevated pollutant concentrations emitted by cooking if they are not controlled. Ideally pollutants should be removed at their source before they are allowed to mix in the air. A common method of removal is the cooker/range hood whose performance, indicated by a capture efficiency, is not yet regulated by a standard or norm. Accordingly, this session will consider measurements of harmful pollutants made in kitchens, the effectiveness of mitigation measures, such as cooker/range hoods, and the ventilation rates and cooker/range hood capture efficiencies required to control pollutant concentrations. The objectives of this session are to: Consider measurements of pollutants made in domestic kitchens; evaluate cooker/range hoods and other methods of exposure mitigation; identify appropriate health-based regulations.

An intervention study of PM2.5 concentrations measured in domestic kitchens (Long Oral Presentation)
Catherine O'Leary, *United Kingdom*

Measured pollutant removal performance of island overhead kitchen exhaust (Long Oral Presentation)
Ian Walker, *USA*

Assessment of range hoods based on exposure (Long Oral Presentation)
Wouter Borsboom, *Netherlands*

Estimated distributions of PM2.5 concentrations in the kitchens of the English housing stock for infiltration and mechanical ventilation scenarios (Short Oral Presentation)
Catherine O'Leary, *United Kingdom*

ROOM B / ELLA FITZGERALD

15:15-16:15 Parallel Session 9B – Topical Session: BIM and Construction 4.0 opportunities in relation to ventilation and airtightness

Chairpersons: ***Philippe Moseley, Peter Wouters***

The market uptake of BIM (Building Information Modelling) is rapidly growing in nearly all countries and one can assume that this trend will continue and even accelerate in the coming years. In practice, there was until recently little to no attention for BIM in relation to ventilation related aspects. This session will give an overview of BIM activities at European level and 2 practical applications of BIM.

Overview of what the EU is doing in relation to BIM
Philippe Moseley (Invited Speaker), *Belgium*

BIM-integrated Design tool for in-line recommended ventilation rates with Demand Controlled Ventilation strategy (Long Oral Presentation)
Kari Thunshelle, *Norway*

Ventilation Planning for Mid-sized Japanese Commercial Kitchens and Calculation Method of Ventilation Rate Using Building Information Modeling (Short Oral Presentation)
Osamu Nagase, *Japan*

ROOM C / MILES DAVIS

15:15-16:15 Parallel Session 9C – Topical Session: French initiatives: An update on the French indoor air quality observatory recent results: focus on ventilation and perspectives

Chairpersons: ***Corinne Mandin, John Little***

The French indoor air quality observatory (OQAI) was set up by the French authorities in 2001 with the objective to collect data on indoor pollutants in various indoor environments to be used for public policies. Funded exclusively by public funding, the OQAI is coordinated by the scientific and technical center for building (CSTB) and involved an extensive network of partners across France in charge of the field campaigns and the laboratory analyses. To date, nationwide surveys were carried out in dwellings (2003-2005), schools (2013-2017), and office buildings (2013-2017). The next survey to be started early 2019 will focus on age care facilities. A specific attention is given to ventilation in all of these surveys. An air stuffiness index has been developed to facilitate the communication around air exchange in buildings. Lastly, the OQAI has been coordinating since 2012 a permanent data collection on indoor air quality and ventilation in energy-efficient buildings. The aim of the session is to share with the participants the last OQAI results, with a dedicated focus on ventilation. The objectives of this session are: to present the last results of the OQAI surveys with a focus on ventilation; to put these results into perspective in a European context; to discuss about needs for the future surveys and gaps to be filled

OQAI last results:
- Indoor air quality and ventilation in energy-efficient dwellings
- Indoor air quality and ventilation in schools: first results of the nationwide survey
- Indoor air quality in office buildings: first results of the nationwide survey

Corinne Mandin, *France*

Ventilation, energy transition, indoor air quality and health, REHVA-EU perspective
Atze Boerstra (Invited Speaker), *The Netherlands*

Discussion with the audience

16:15-16:45 Coffee break

16:45-18:15 Closing session

Chairpersons: ***Andy Persily, Peter Wouters***

Best paper & poster award
Max Sherman, *USA*

Summing up of the "Ventilative cooling – Resilient cooling" track
Peter Holzer, *Institute of Building Research & Innovation, Austria*

Summing up of the "Smart ventilation, IAQ & Health" track
Benjamin Jones, *University of Nottingham, United Kingdom*

Summing up of the "Airtightness" track
Arnold Janssens, *University of Ghent, Belgium*

French R&D activities in relation to conference topics by ADEME
Nicolas Doré (Invited Speaker), *ADEME, France*

Modern History of Indoor Air Quality (1973-Present)
Donald Weekes (Invited Speaker), *President, IEQ-GA, Canada*

Announcement of 2019 conference
Arnold Janssens, *University of Ghent, Belgium* & Samuel Caillou, *BBRI, Belgium*

18:15 End of conference

20:00 Conference Dinner

(Admission to the Conference Dinner is by voucher only)

General Information

Secretariat Hours

Secretariat will be open during the following dates and times:

- Monday 17 September, 2018 / 17.30 – 19.00
- Tuesday 18 September, 2018 / 08.00 – 18.30
- Wednesday 19 September, 2018 / 08.00 – 18.00

Poster display information:

- Posters should be set up on Tuesday 18 September, 2018 from 08.30 – 10.30
- Dismantling of posters should be finished by Wednesday 19 September, 2018 at 17.00

Secretariat and Organizers have no liability for posters left behind.

Poster dimensions

(A0) size, 120CM Height X 80CM Width

Poster presentation session

Authors are expected to be in front of their poster in order to reply to any questions as per schedule below:

Tuesday 18 September, at 18:30 – 20:30

- 18:30 - 19:15: poster boards with odd numbers
- 19:15 - 20:00: poster boards with even numbers

Long & Short Oral Presentations information:

- Long Oral Presentations (indicated within the programme) are expected to last 12 minutes; another 3 minutes are foreseen for questions and answers (15 minutes in total).
- Short Oral Presentations (indicated within the programme) are expected to last 3 minutes; another 2 minutes are foreseen for questions and answers (5 minutes in total).

Notes

ADEME

Agence de l'Environnement et de la Maîtrise de l'Energie

French Environment & Energy Management Agency

Climate change - ecological, energy transition

ADEME is active in the implementation of public policy in the areas of the environment, energy and sustainable development. ADEME provides expertise and advisory services to businesses, local authorities and communities, government bodies and the public at large, to enable them to establish and consolidate their environmental action. As part of this work the agency helps finance projects, from research to implementation, in its areas of action.

Four vocations:

- developing knowledge: ADEME organizes and contributes to the financing of research and innovation and to establishing and coordinating observation systems to better understand how industries are changing;
- convincing and mobilising: Because public information and awareness are essential to the success of environmental policies, ADEME implements communication campaigns to change mindsets, behaviours and purchasing and investment practices;
- advising: ADEME acts in an advisory capacity to direct the decisions of actors in society and the economy, establishing tools and methods that suit their needs. Direct dissemination via expert advisers is a major way in which it provides its expertise;
- assisting with implementation: ADEME provides graduated financial support and promotes the implementation of regional and national references.

Organisation

With its head office in Angers, ADEME has over 1,000 employees split between:

- 3 central departments sites in Angers, Paris and Valbonne;
- 17 regional divisions, 13 in metropolitan France and 4 in overseas France, which linked 26 implantations across the country;
- 3 representative bodies in overseas territories;
- 1 office in Brussels.

Synergy between head office and regional divisions

With staff based in 26 implantations and 3 representative bodies in overseas territories, ADEME focuses it actions on individuals, public authorities and businesses as part of a local service. Some 400 agents (almost half of its staff) based in 26 regional divisions (including overseas) and 3 representative bodies in overseas territories (French Polynesia, New Caledonia and Saint-Pierre and Miquelon) work in the field on behalf of ADEME to promote sustainable development, the fight to mitigate climate change, energy management, renewable energies and, more generally, energy and ecological transition. ADEME's regional teams implement two major energy and ecological transition policies on behalf of the French State in the areas of support for renewable heat (Heat Fund) and waste prevention and management (Waste Fund).

Areas of interventions

Waste, land and polluted soils, climate and energy, air and noise, cross-functional action (sustainable production and consumption, sustainable cities and territories)

Peter Wouters

Manager INIVE EEIG

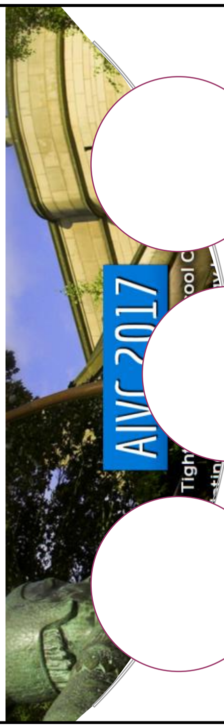
AIVC – TightVent - venticool

AIVC | TightVent Europe — BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM | venticool — the international platform for ventilative cooling

INIVE

International Network for Information on Ventilation and Energy Performance

GRUPOTERMOTECNIA · CETIAT · bbri.be · SINTEF · eERG end-use Efficiency Research Group · TNO innovation for life · Fraunhofer IBP · CSTB le futur en construction



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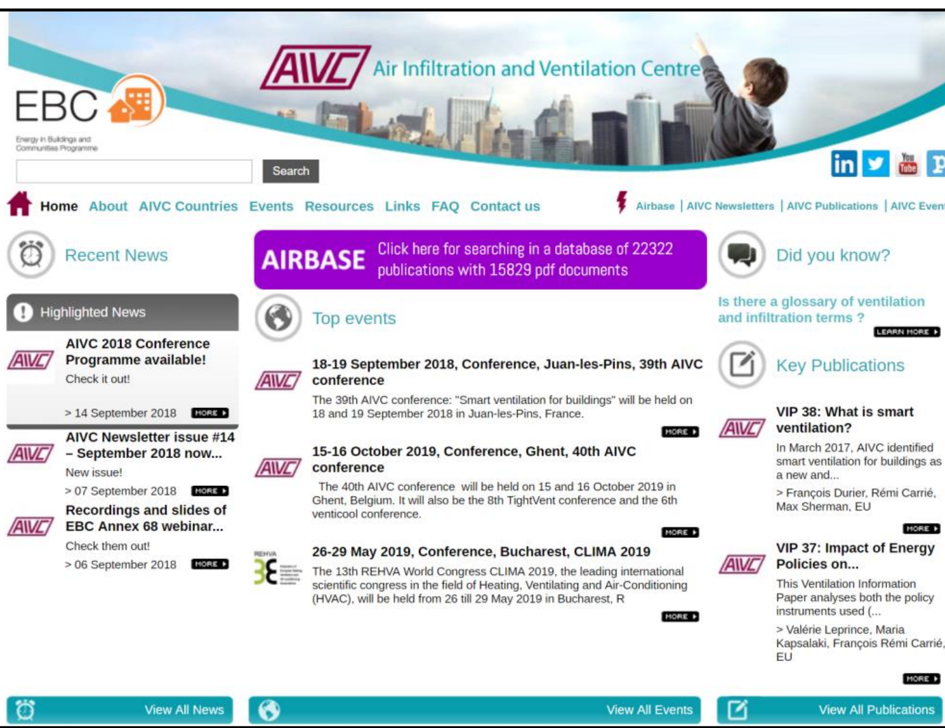
About TightVent and airtightness

About venticool and ventilative cooling



AIVC member countries

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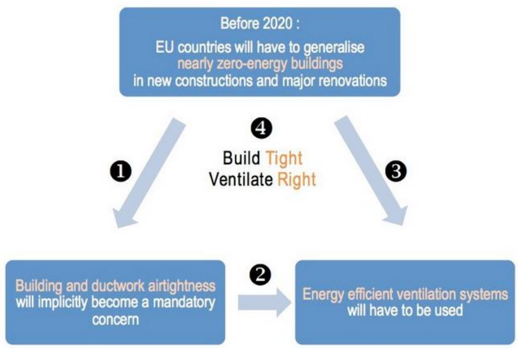
About TightVent



Reasons behind TightVent Europe

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Recent News

- BSRIA Topic Guide – Airtightness
- 12-14 September 2016, Conference, Alexandria, VA –37th AIVC – ASHRAE-IAQ joint Conference
- 2nd QUALICHeCK Conference | EPBD Review – Elements for better compliance and quality of works
- New guide released: "How to build a Passivhaus- Rules of thumb"
- Air Leakage Guide. Meeting the air leakage requirements of the 2012 International Energy Conservation Code (IECC)

Categories

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TightVent Europe

BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM

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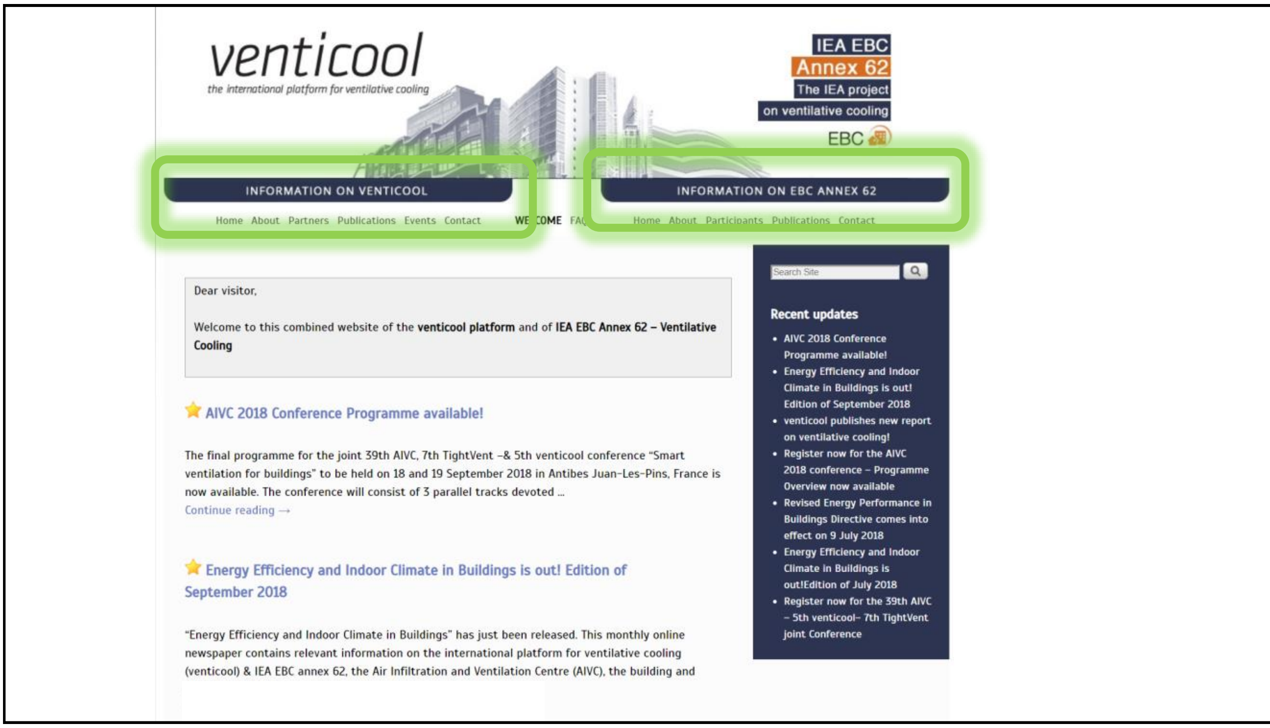
TightVent Airtightness Associations Committee – TAAC

- The participants (TAAC members and guests) are from Belgium, Canada, Croatia, Czech Republic, Denmark, Estonia, France, Germany, Hungary, Ireland, Latvia, Norway, Poland, Spain, Sweden, UK and the US.
- The scope includes various aspects:
  - airtightness requirements in the countries involved
  - competent tester schemes in the countries involved
  - applicable standards and guidelines for testing
  - collection of relevant guidance and training documents

About the AIVC

About TightVent and airtightness

About venticool and ventilative cooling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Welcome to this combined website of the venticool platform and of IEA EBC Annex 62 – Ventilative Cooling
AIVC 2018 Conference Programme available!
The final programme for the joint 39th AIVC, 7th TightVent –& 5th venticool conference "Smart ventilation for buildings" to be held on 18 and 19 September 2018 in Antibes Juan-Les-Pins, France is now available. The conference will consist of 3 parallel tracks devoted ...
Continue reading →
Energy Efficiency and Indoor Climate in Buildings is out! Edition of September 2018
"Energy Efficiency and Indoor Climate in Buildings" has just been released. This monthly online newspaper contains relevant information on the international platform for ventilative cooling (venticool) & IEA EBC annex 62, the Air Infiltration and Ventilation Centre (AIVC), the building and
Recent updates
AIVC 2018 Conference Programme available!
Energy Efficiency and Indoor Climate in Buildings is out! Edition of September 2018
venticool publishes new report on ventilative cooling!
Register now for the AIVC 2018 conference – Programme Overview now available
Revised Energy Performance in Buildings Directive comes into effect on 9 July 2018
Energy Efficiency and Indoor Climate in Buildings is out!Edition of July 2018
Register now for the 39th AIVC – 5th venticool– 7th TightVent joint Conference


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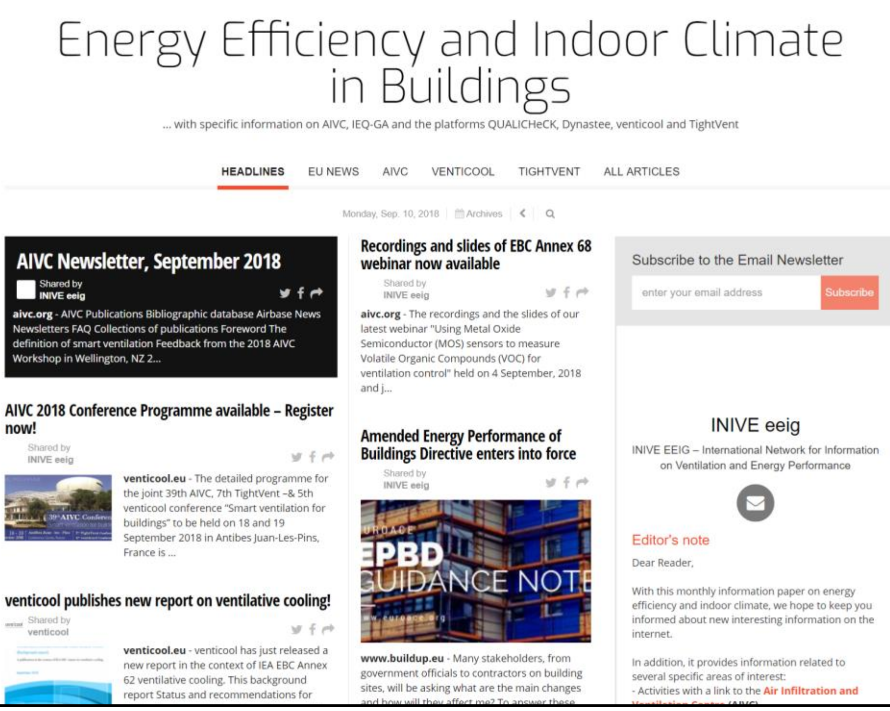

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AIVC

TightVent Europe
BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM

venticool
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CETIAT
ensemble, innover et valider

Welcome on behalf of
CETIAT and ADEME

François Durier and Pierre Deroubaix

ADEME
Agence de l'Environnement
et de la Maîtrise de l'Energie

ADEME
Agence de l'Environnement
et de la Maîtrise de l'Energie

French Environment and Energy Management Agency

CETIAT
ensemble, innover et valider

French Technical Centre of HVAC system manufacturers

Welcome (back) to France!

27-29 September 2007, Conference, Crete - 28th AIVC Conference
Chania, Crete, Greece 27/09/2007

20-22 November 2006, Conference, Lyon - 27th AIVC Conference
Lyon, France 20/11/2006

21-23 September 2005, Conference, Brussels - 26th AIVC Conference
Brussels, Belgium 21/09/2005

15-17 September 2004, Conference, Prague - 25th AIVC Conference
Prague, Czech Republic 15/09/2004

12-14 October 2003, Conference, Washington D.C. - 24th AIVC Conference
Washington D.C., United States of America 12/10/2003

23-26 October 2002, Conference, Lyon - 23rd AIVC Conference
Lyon, France 23/10/2002

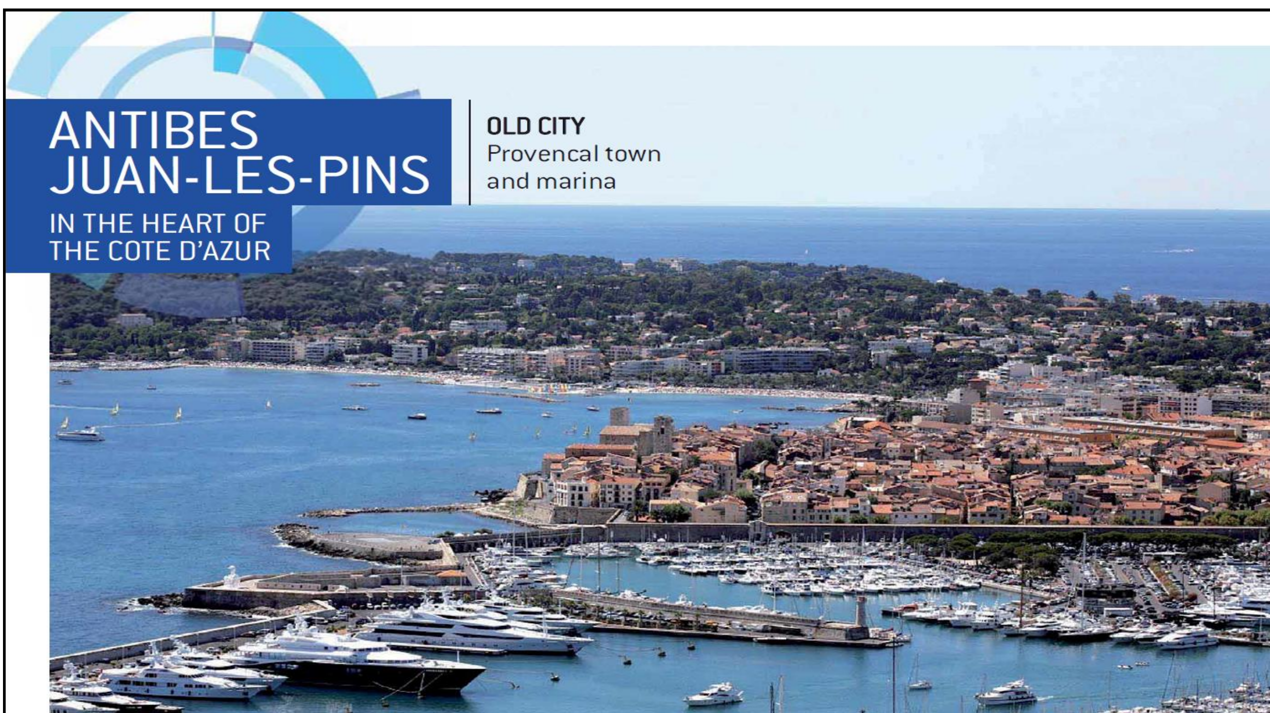
27-30 September 1994, Conference, Buxton - 15th AIVC
Buxton, United Kingdom 27/09/1994

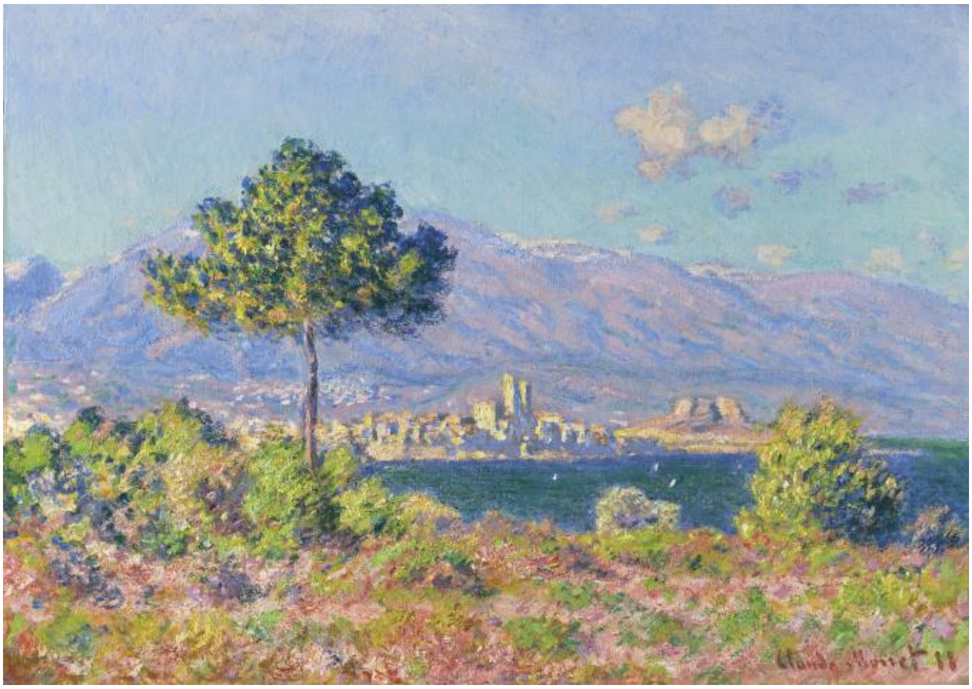
21-23 September 1993, Conference, Copenhagen - 14th
Copenhagen, Denmark 21/09/1993

14-18 September 1992, Conference, Nice - 13th AIVC Conference
Nice, France 14/09/1992

24-27 September 1991, Conference, Ottawa -12th AIVC Conference
Ottawa, Canada 24/09/1991

18-21 September 1990, Conference, Belgirate - 11th AIVC Conference
Belgirate, Italy 18/09/1990





Antibes,
vue du plateau
Notre-Dame

Claude Monet
1888

Pêche de nuit
à Antibes

Pablo Picasso
1939

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- Meeting rooms: Auditorium, Ella Fitzgerald/B, Miles Davis/C



Some practical information

- Meeting rooms: Auditorium, Ella Fitzgerald/B, Miles Davis/C
- Lunch, coffee breaks, exhibition on Level 2
- Tuesday 18:30-20:30: poster session with beverages
- Wednesday: summing up of the conference (closing session)
- Wednesday 20:00: Conference Dinner (by voucher only)
- Speakers: please provide file at welcome desk as soon as possible

We wish you
a fruitful and
interesting Conference!

International Centre for Indoor Environment and Energy

Will the "smart" movement lead to an improved indoor environmental quality?

Professor Bjarne W. Olesen, Ph.D.

www.ie.dtu.dk

Technical University of Denmark

DTU

SMART

- Smart Grid
- Smart Cities
- Smart Communities
- Smart Buildings
  - Smart ready buildings
  - Resilient buildings
  - Smart ventilation
  - Smart control

Improved IEQ?

- NO
- MAYBE?
- YES

Smart Grids

- Electricity grid
- Natural gas grid
- District Heating
- District cooling
- Sewage system
- Fresh air grid?????

Building Our New Energy Future

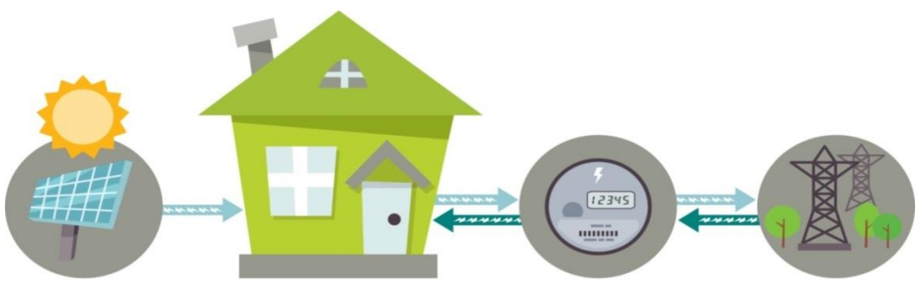
Shaping Tomorrow's
Built Environment Today

Sheila Hayter
ASHRAE President 2018-2019

Step 2: Get Engaged

- Smart Grid Community
- Cyber Security Community
- Wellness Community

BUILDING OUR NEW ENERGY FUTURE



BECOME AWARE

Data transfer between buildings and grid

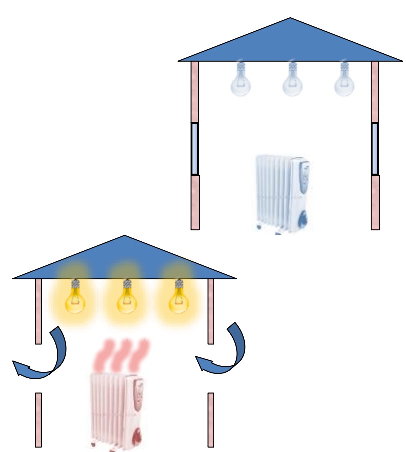
- Two-way energy flow
- Data from the grid to the building/occupants
  - Information on when to use el-energy
    - Washing
    - Charging (cars, batteries and others)
  - Information on indoor environment and energy use
    - When to use solar blinds
    - Open-close windows
- Data from the building/occupants
  - Information from system sensors
  - Information from room sensors (temperature, humidity, ventilation, IAQ, daylight etc.)
- Cyber security

Grid-Buildings-Occupants

- The grid sells energy to ”buildings”
- The grid should **sell comfort** to people
- Too high and too low ventilation **you pay more**
- Room Temperatures outside the comfort range **you pay more**
  - Heating season
    - Too low room temperature-building damage, health
    - Too high room temperature-energy costs
  - Cooling season
    - Too low room temperature-energy costs
    - Too high room temperatures-decreased IAQ
- Feed-back from the grid to the occupants

Occupant behaviour and energy use

- Simulation study:
  - Occupant behaviour can affect energy use by more than 300 %
- Literature survey
  - In identical dwellings, the highest energy use is typically 2-3 times as high as the lowest
  - Differences as high as 600 % has been observed



Development towards Near Zero Energy Buildings

- Not possible to reach goals through 'traditional' technologies
  - Envelope **insulation**
  - Building **airtightness**
  - Ventilation **heat recovery**

Robust technologies
- No user interactions
- Works with and without people in the building

- Other measures are needed
  - Demand <u>controlled</u> **ventilation**
  - Solar **shading** to <u>control</u> overheating and daylight
  - **Lighting** <u>control</u>
  - **Window** opening

Sensitive technologies
- User interactions required
- Difficult to understand consequences

Types of behaviour with impact on indoor environment and/or energy use

Adjust <u>to</u> the environment	Adjust the environment	Activities with other aims than adjusting (to) the environment
• clothing • activity level • posture • hot/cold drinks • etc.	• thermostat adjustments • window openings • electrical lights • solar shading • etc.	• cooking • electrical loads • Showering • etc.

Behaviour changes as a tool of improved indoor environmental quality and energy conservation?

- Is it possible to achieve energy savings and better indoor environment by facilitation of behaviour changes?
- Can direct and current information about consequences of actions facilitate behaviour changes?
- Will information about actual price of heating and advice about behaviour facilitate changes in habits?

SUPPORT FOR SETTING UP A SMART READINESS INDICATOR FOR BUILDINGS AND RELATED IMPACT ASSESSMENT

FINAL REPORT

vito ECOFYS Waide Strategic Efficiency OFFIS

https://smartreadinessindicator.eu/files/sri_1st_technical_study_-_final_report.pdf

ECOFYS Waide Strategic Efficiency OFFIS vito

VITO: Stijn Verbeke, Yixiao Ma, Paul Van Tichelen, Sarah Bogaert, Virginia Gómez Oñate
Waide Strategic Efficiency: Paul Waide
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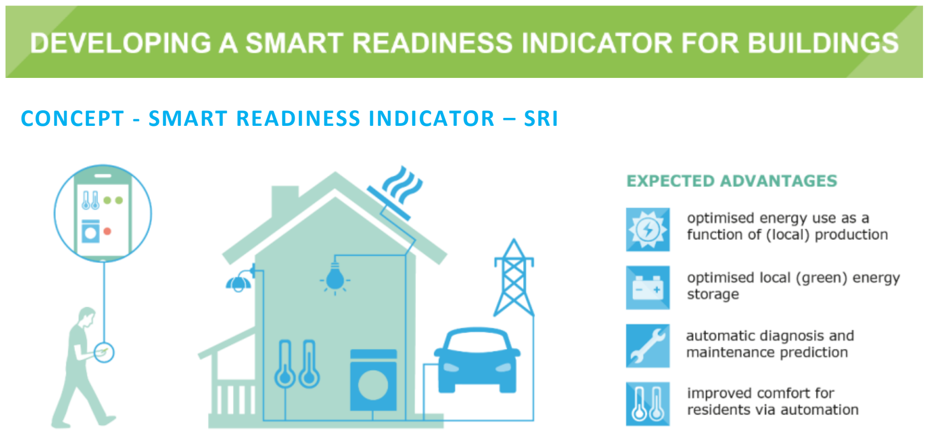


Figure 1 – Expected advantages of smart technologies in buildings

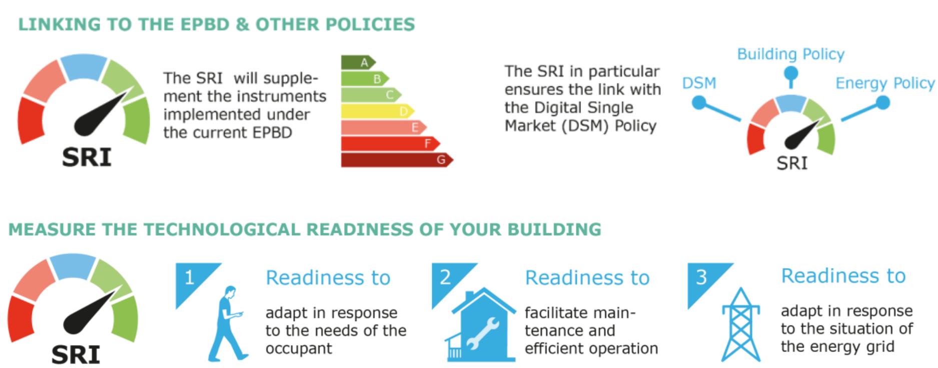
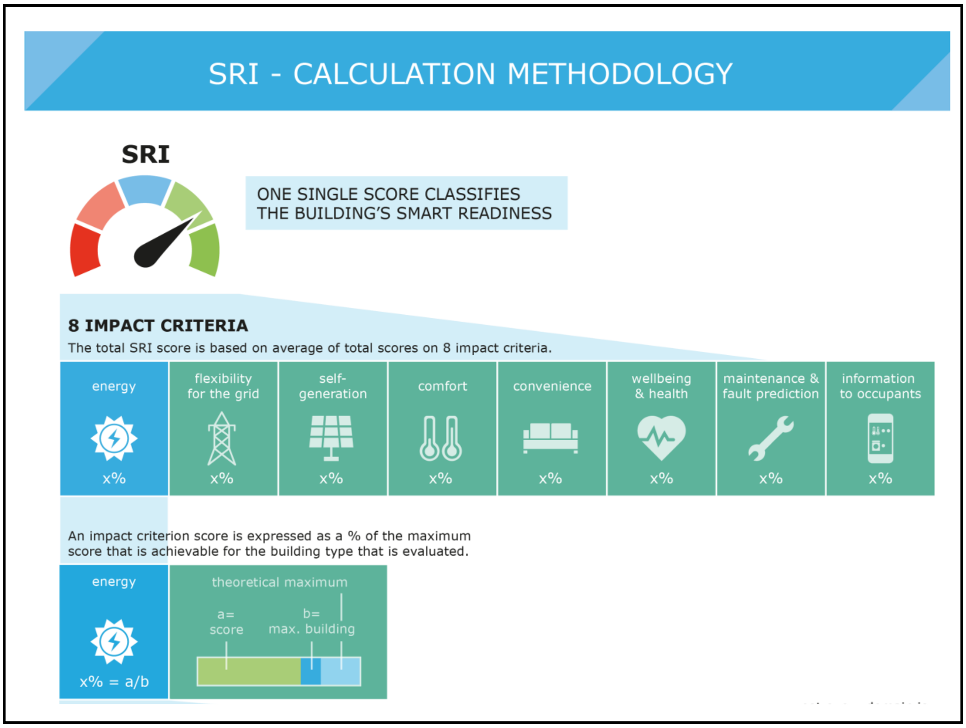
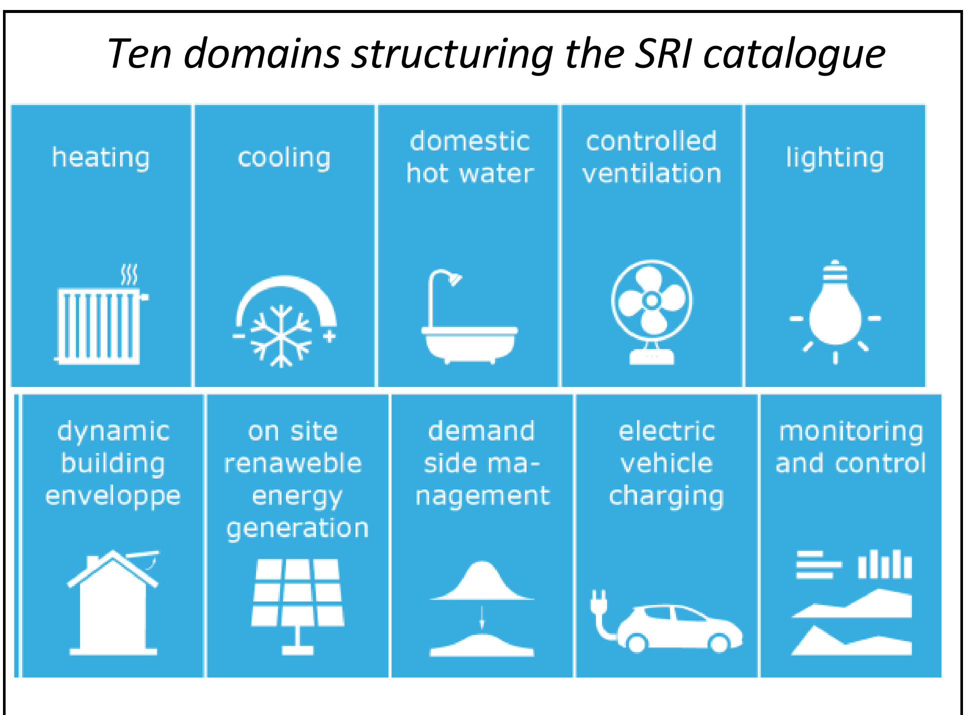


Figure 3 – Three key functionalities of smart readiness in buildings


SRI - CALCULATION METHODOLOGY
SRI
ONE SINGLE SCORE CLASSIFIES
THE BUILDING'S SMART READINESS
8 IMPACT CRITERIA
The total SRI score is based on average of total scores on 8 impact criteria.
energy
x%
flexibility for the grid
x%
self-generation
x%
comfort
x%
convenience
x%
wellbeing & health
x%
maintenance & fault prediction
x%
information to occupants
x%
An impact criterion score is expressed as a % of the maximum score that is achievable for the building type that is evaluated.
energy
x% = a/b
theoretical maximum
a= score
b= max. building


Ten domains structuring the SRI catalogue
heating
cooling
domestic hot water
controlled ventilation
lighting
dynamic building enveloppe
on site renaweble energy generation
demand side ma-nagement
electric vehicle charging
monitoring and control

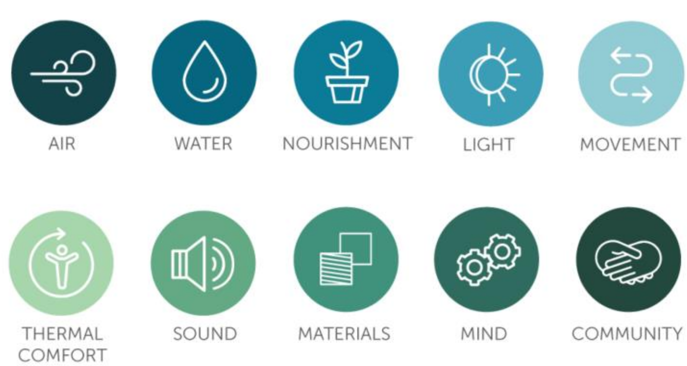
Wellness Community

GET ENGAGED

POINTS-BASED SCORING

100 POINTS AVAILABLE (+10 POINTS IN INNOVATIONS), MORE WAYS TO GET THERE

TEN CONCEPTS



WELL BEING STANDARD

- This is not a standard like ASHRAE, ISO or CEN standards
- This is a method to evaluate ”Well Being” in a building established by the Well-Being Institute.
- The founders and concept is similar to the LEED program

WELL BEING STANDARD

Letter of Assurance MEP

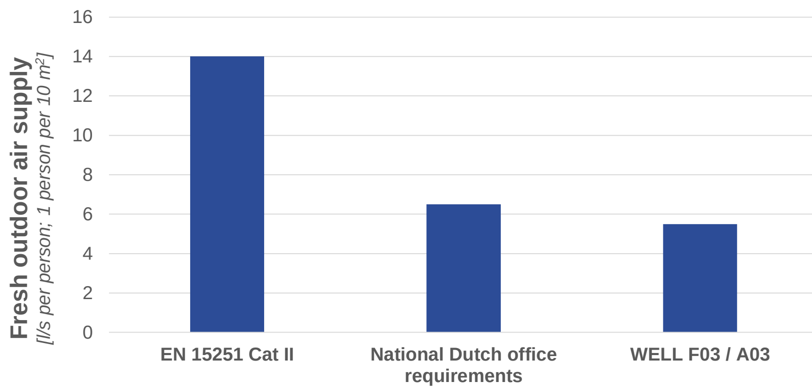
PART 4

Ventilation Rates for Residences

The following requirements are met:

- Ventilation rates are designed to comply with all requirements set in ASHRAE 62.2-2013 (or more recent version) for dwelling units.
- Ventilation rates are designed to comply with all requirements set in ASHRAE 62.1-2013 for common areas and other spaces apart from dwelling units.

Low ventilation rate requirements (!)



WELL BEING STANDARD
Increased Ventilation

Letter of Assurance MEP

PART 1 Increased Outdoor Air Supply

One of the following is required in all regularly occupied spaces:

- Exceed outdoor air supply rates met in ASHRAE 62.1 (62.2) by 30%.
- Follow CIBSE AM10, Section 4, Design Calculations, to predict that room-by-room airflows will provide effective natural ventilation.

WELL BEING STANDARD

Letter of Assurance MEP

PART 2 Demand Controlled Ventilation

For all spaces 46.5 m² [500 ft²] or larger with an actual or expected occupant density greater than 25 people per 93 m² [1,000 ft²], one of the following requirements is met:

A demand controlled ventilation system regulates the ventilation rate of outdoor air to keep carbon dioxide levels in the space below 800 ppm (measured at 1.2-1.8 m [4-6 ft] above the floor).

Projects that have met the Operable windows feature demonstrate that natural ventilation is sufficient to keep carbon dioxide levels below 800 ppm (measured at 1.2-1.8 m [4-6 ft] above the floor) at maximum intended occupancies.

Smart Ventilation by AIVC

- *Smart ventilation is a process to **continually adjust the ventilation** system in time, and optionally by location, to provide the **desired IAQ** benefits while **minimizing energy ~~consumption~~ use,** utility bills and other non-IAQ costs (such as thermal discomfort or noise).*
- *A smart ventilation system **adjusts ventilation rates** in time or by location in a building to be responsive to one or more of the following:*
  - *occupancy,*
  - *outdoor thermal and air quality conditions,*
  - ***Indoor climate conditions***
  - *electricity grid needs,*
  - *direct sensing of contaminants,*
  - *operation of other air moving and air cleaning systems.*
- *In addition, smart ventilation systems can provide information to:*
  - *building owners,*
  - *occupants,*
  - *managers on operational energy ~~consumption~~ **use** and indoor ~~air quality~~ **climate***
  - *signal when systems need maintenance or repair.*

Smart Ventilation by AIVC

- *Being responsive to occupancy means that a smart ventilation system can adjust ventilation depending on demand such as reducing ventilation if the building is unoccupied.*
- *Smart ventilation can time-shift ventilation to periods when*
  - *a) indoor-outdoor temperature differences are smaller (and away from peak outdoor temperatures and humidity),*
  - *b) when indoor-outdoor temperatures are appropriate for ventilative cooling,*
  - *c) when outdoor air quality is acceptable.*
- *Being responsive to electricity grid needs means providing flexibility to electricity demand (including direct signals from utilities) and integration with electric grid control strategies.*

From Individuel Buildings
to
Smart Communities and Smart Cities

Will the "smart" movement lead to an improved indoor environmental quality?

- NO
- MAYBE?
- YES

Advances in European residential ventilation systems in Nearly Zero Energy Buildings

Jarek Kurnitski

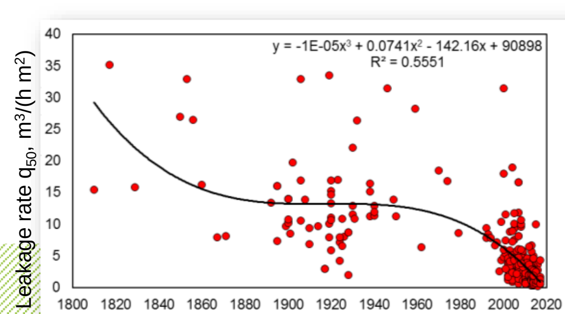
Tallinn University of Technology, Aalto University

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

Background

- Energy performance of buildings has been continuously improved in Europe
- Transition to nearly zero energy buildings (NZEB) next step in 2019-2021 + more deep renovation planned
- Well insulated and airtight NZEB provide challenges or opportunities – depending on point of view – for ventilation systems

Example of building leakage rate development in Estonia (Kalamees 2018)



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Ventilation in 2nd recast of the EPBD

DIRECTIVE (EU) 2018/844

Indoor Environmental Quality (IEQ) requirements in EU:

- Currently there are no binding ventilation and IEQ requirements at EU level
- From a regulatory point of view this remains under the competencies and responsibilities of the EU Member States

JRC assessment (2016) of the implementation status of the EPBD by the EU MS in terms of ventilation and indoor air quality criteria:

- Many inadequate ventilation problems reported from renovation
- New evidence that mechanical HR ventilation systems lead to an overall improvement of the IAQ and reduction of reported comfort and health related problems if properly designed and operated

Example of ventilation requirements (BPIE 2015)

- Ventilation is included in all surveyed EU MS building regulations but **minimum requirements are set only for half of the countries** while for the other half there are only recommended minimum ventilation rates
  - ⇒ Generally no consensus in national regulation and guidelines

Country and Standard Reference	Whole Building Ventilation Rates	Living Room	Bedroom	Kitchen	Bathroom + WC	WC only
Brussels (NBN D 50-001)	3.6 m³/(h·m²) floor surface area	Minimum 75 m³/h (limited to 150 m³/h	Minimum 25m³/h (limited to 72m³/h)	Open kitchen Minimum 75 m³/h (exhaust)	Minimum 50 m³/hour (limited to 75 m³/h	Minimum 25 m³/h
Denmark (BR10)	Min. 0.3 l/s·m² (supply)	Min. 0.3 l/(s·m²) (supply)		20 l/s (exhaust)	15 l/s (exhaust)	10 l/s (exhaust)
France (Arrêté 24.03.82)	10-135 m³/h (depending on room number and ventilation system)			Continuous: 20 – 45 m³/h		Minimum 15 m³/h
Germany (DIN 1946-6)	15-285 m³/h (details see chapter)			45m³/h (nominal exhaust flow)	45 m³/h (nominal exhaust flow)	25 m³/h (nominal exhaust flow)
Italy (Legislative Decree 192/2005, UNI EN 15251)	Naturally ventilated: 0.3 – 0.6 vol/h	0.011 m³/s per person for an occupancy level of 0.04 persons/m²			4 vol/h	
Poland (Art 149 (1) – Journal of Laws 2002 No. 75, item. 690, as amended and PN-B-03430:1983/ Az3:2000)	20 m³/h for each permanent occupant should be calculated according to the Polish standard but not less than 20 m³/h	20 -30 m³/h for each permanent occupant (for public buildings) For flats, it is a summary of flow from all rooms		30 m³/h to 70 m³/h without windows	50 m³/h	30 m³/h
Sweden (BFS2014:13 – BBR21)	Supply: min 0.35 l/(s·m²) floor area					
UK (Approved Document F)	13-29 l/s (depending on bedrooms)			13-60 l/s (extract)	8-15 l/s (extract)	6 l/s (extract)
EN 15251	0.35 – 0.49 l/(s·m²)	0.6 – 1.4 l/(s·m²)		14-28 l/s	10-20 l/s	7-14 l/s

Requirement **Recommendation** **European standard**

EPBD ANNEX 1: ventilation, IAQ and comfort levels

5

- In EPBD Annex 1, new requirements are set:
  - "The energy needs for space heating, space cooling, domestic hot water, lighting, **ventilation** and other technical building systems shall be calculated in order **to optimise health, indoor air quality and comfort levels defined by Member States** at national or regional level"
- → clear mandate to MS to establish minimum ventilation and other IEQ requirements for new buildings and major renovations to implement the directive
- Mandate to The Commission to conduct before 2020 a feasibility study on stand-alone ventilation systems inspection, clarifying the possibilities/timeline to introduce this

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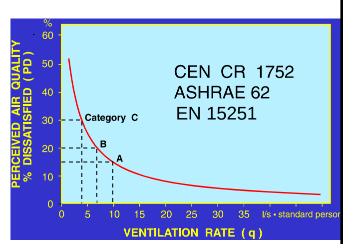
Existing evidence on ventilation need

6

- Body odor/bioeffluents/perceived air quality 4, 7 and 10 L/s pers (CR 1752:1998)
- 0.5 ach in Nordic countries associated with house dust mites (Wargocki et al. 2002)
- No effects on asthma and allergy when ≥ 0.37 ach (7 L/s pers) or $CO_2 \leq 900$ ppm above outdoors (Bornehag et al. 2005)



- Mechanical ventilation system reduced allergic symptoms and asthma and RH (Kovesi et al. 2009, Xu et al. 2010, Wright et al. 2009)
- Reduction of ventilation rate from 0.5-0.8 ach to 0.4-0.5 ach did not have negative effect on SBS symptoms, but air was perceived as stuffy/poor (Engvall et al. 2005)
- CO_2 1600 ppm (total) no effects on acute health symptoms and mental performance (experiments to isolate bioeffluents, Zhang et al. 2018)

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From evidence to ventilation design

- Health based ventilation rate 4 L/s pers recommended for the condition in which the only source of pollution are human occupation emitting bio-effluents (Carrer et al. 2018, HealthVent project)
- 6-7 L/s pers (summary by Carrer et al. 2015) should apply in occupied rooms (bedrooms, living rooms), but the same amount of extract air is needed from wet rooms and kitchen (source control)
- Default occupancy and transfer air assumptions to be applied to end up with room based supply and extract airflow rates
- Selection of air flow rates in dwellings has recently been updated in European and ISO standards (EN 15251, prEN 16798-1, ISO 17772-1:2017)
- Further developed in REHVA GB 25 to be suitable for practical design

Air flow rate sizing in REHVA GB 25

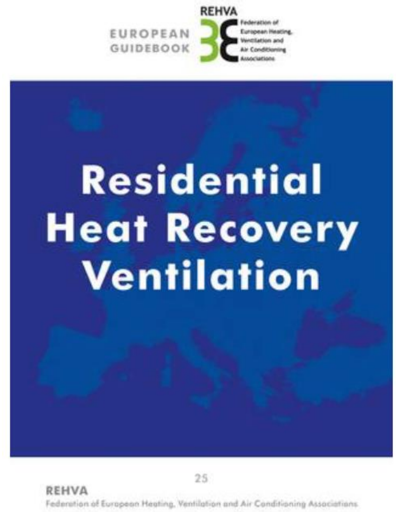
- Based on 7 L/s pers, common occupancy density and rooms default assumptions
- Transfer air from bedrooms accounted

	Supply airflowrate L/s	Extract airflowrate L/s	Air velocity[1] m/s
Living rooms[2] >15 m^2	8+0.27 L/(s m^2)		0.10
Bedrooms >15 m^2	14		0.10
Living rooms and bedrooms 11-15 m^2	12		0.10
Bedrooms <11 m^2, 3rd and the following bedrooms in large apartments	8		0.10
WC		10	
Bathroom		15	
Bathroom in one room apartement		10	
Utility room		8	
Wardrobe and storage room		6	
Kitchen[3]		8	
Kitchen[3], one room apartement		6	
Kitchen, cooker hood in operation		25	
Average airflowrate of a whole residence L/(s m^2)	0.42		
Staircase of an apartement building, ACH	0.5		

[1]Maximum air velocity values apply at design airflow rate and supply air temperature in heating season conditions, in boost mode higher velocities may be accepted, see section 2.2.
[2]Transfer air from bedrooms may be reduced, 12 L/s is the minimum value
[3]Airflow rate in the kitchen when cooker hood is not in operation

REHVA GB 25 (2018) Challenge of silent, clean and draft-free energy efficient ventilation

- Ventilation need – selection of airflow rates
- Ventilation system sizing – pressure drop and noise calculations
- Selection of ventilation units
- Ventilation system layouts:
  - New buildings
  - Renovation
- Commissioning and balancing
- Maintenance



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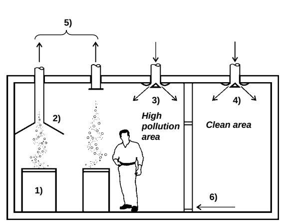
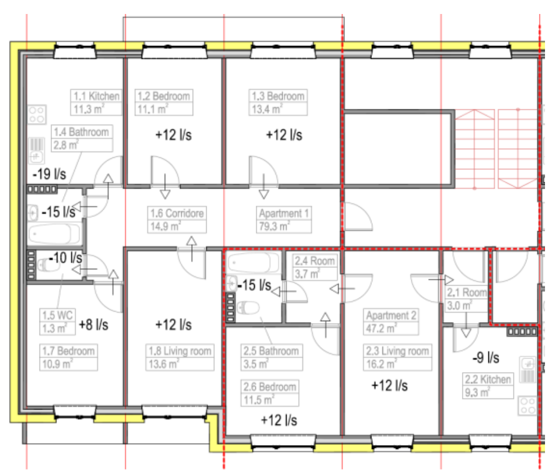
Example: how to determine airflow rates and transfer air paths?

- The procedure for airflow sizing
- 1 L/s = 3.6 m^3/h





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Example: one bedroom apartment

- Airflow rate calculation in one bedroom apartment. The determining airflow rate is marked with bold

Room	Area, m^2	Airflow rate, L/s (m^3/h)		
		Supply	Extract	General air change
2.1 Room	3.0	-	-	
2.2 Kitchen	9.3	-	8 (28.8)	
2.3 Living room	16.2	12 (43.2)	-	
2.4 Room	3.7	-	-	
2.5 Bathroom	3.5	-	15 (54.0)	
2.6 Bedroom	11.5	12 (43.2)	-	
Entire apartment	47.2	-	-	47.2·0.42=20 (72.0)
Total		**24 (86.4)**	23 (82.8)	20 (72.0)

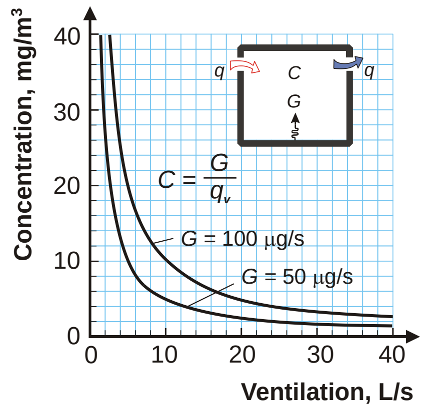
- Total supply and extract airflow rates are almost equal and one extract airflow rate has be increased by 1 L/s to balance the ventilation
- The total design airflow rate of 24 L/s corresponds to 0.73 ach

Demand controlled or constant ventilation?

- Demand controlled ventilation (DCV) in offices can often save 40% of energy (e.g. 33–41% reported in Ahmed et al. 2015)
- Occupancy difference: 0.4 L/s m^2 in homes vs. 2 L/s m^2 in offices - by factor 5 difference in ventilation
- REHVA GB 25 recommends continuous operation for residential ventilation as a robust and reliable solution but many technical solutions are available for demand-controlled ventilation
- DCV needs to be controlled in addition to bioeffluents and humidity generation also by other emission sources (VOC etc.) which do exist all the time
  - when these sources are taken into account much longer ventilation operation is needed compared to simple CO_2 control.
  - Walker and Brennan (2008) have shown that only the saving in between 0-8% can be achieved depending on occupancy pattern and climate.

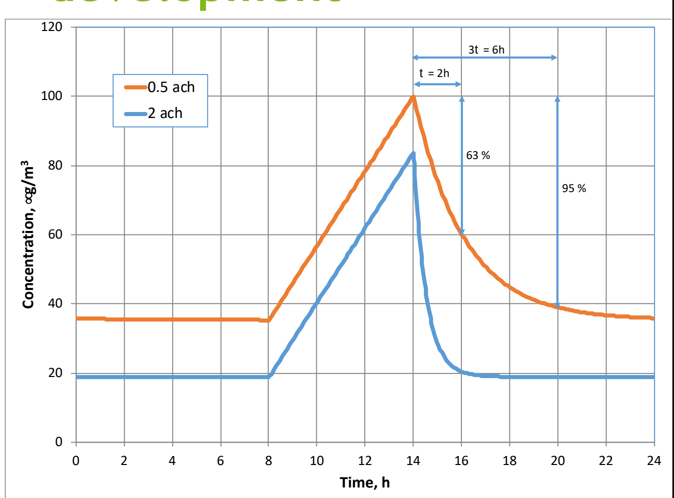
Effect of ventilation rate on pollutant concentration

- The pollutant concentration is proportional to pollution generation and inversely proportional to ventilation rate



Example of concentration development

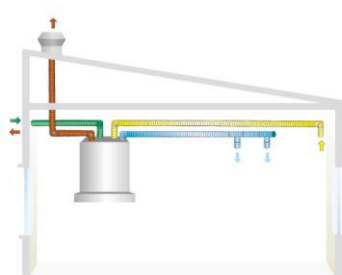
- Ventilation switched off for 6 hours
- In the case of 0.5 ach it takes 2h to decrease by 63% (1 time constant) and 6 h by 95% (3 time constants)
- In DCV operation airflows are to be boosted to keep acceptable IAQ



Ventilation system options

- HR-ventilation units typically installed in bathrooms, on the top of cooker hoods or in the service spaces or attic – ductwork needed
- Ventilation systems may be:
  - centralized
  - decentralized (single apartment ventilation unit)
  - room ventilation units (monoblock)
- Room ventilation units are not capable to extract air from wet rooms and kitchen, i.e. half of ventilation is missing – not easy to use in dwellings

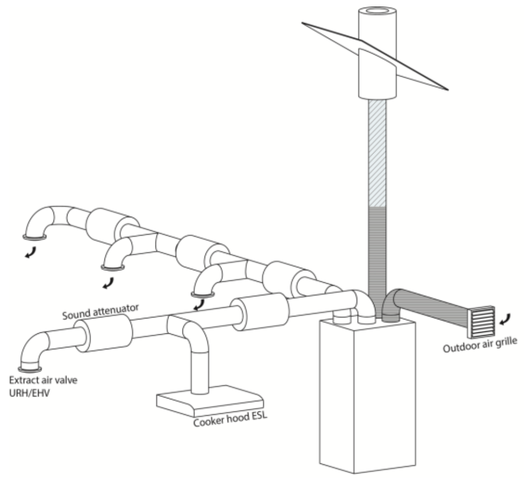
Single dwelling ventilation unit integrated with the cooker hood



- Brown arrow on the wall (optional) indicates that in some cases exhaust through the wall is possible where, particuarly in that case, distances to windows and minimum velocity as well as compliance with local requirements is to be checked

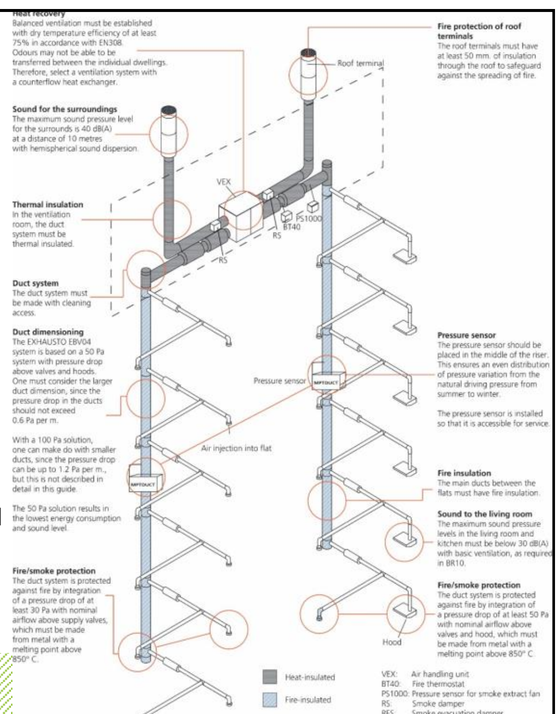
Typical single dwelling ventilation unit

- Plate heat exchanger: cooker hood extract is taken through the heat exchanger
- Rotary heat exchanger: these units incorporate an extra duct connection for the cooker hood by-pass (i.e. connected after the heat exchanger)
- Outdoor air is taken directly from the facade, but exhaust is ducted to the roof

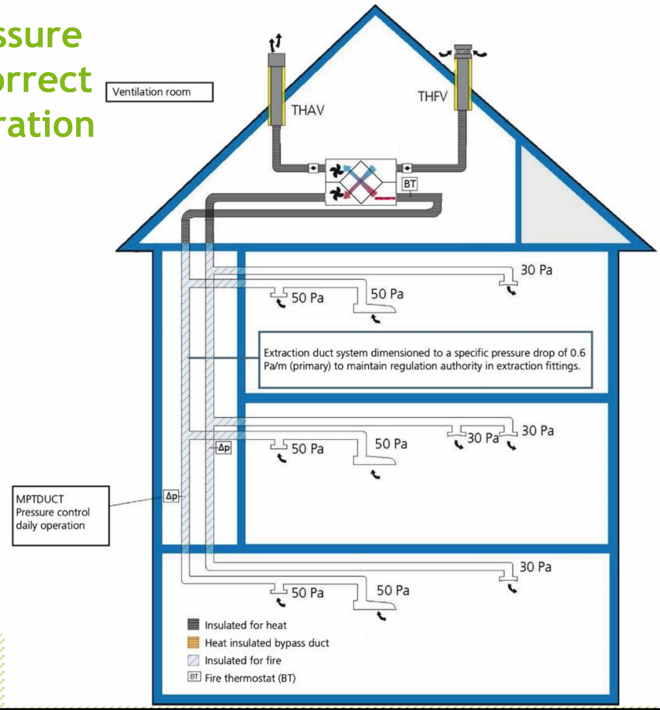


Centralized system

- Plate heat exchangers are always used to avoid odour transfer in the heat recovery section
- Air handling unit serves cooker hoods and constant pressure is maintained halfway between that of the supply and extract air main ducts
- Opening the cooker hoods will increase extract airflow rate in the dwellings and the system increases the fan speed in order to keep constant static pressure in the main ducts



Typical pressure drops for correct system operation



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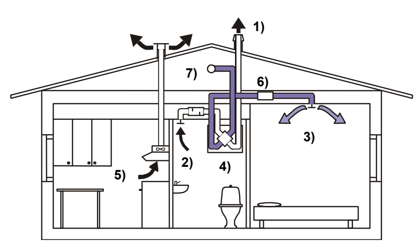
Cooker hoods in modern buildings

- Stand alone cooker hoods can generate more than 100 Pa negative pressure in new airtight dwellings – it is preferable to connect the cooker hood to the ventilation unit in order to allow balanced operation
- If not compensated, then the maximum negative pressure during cooker hood operation should not exceed 30 Pa



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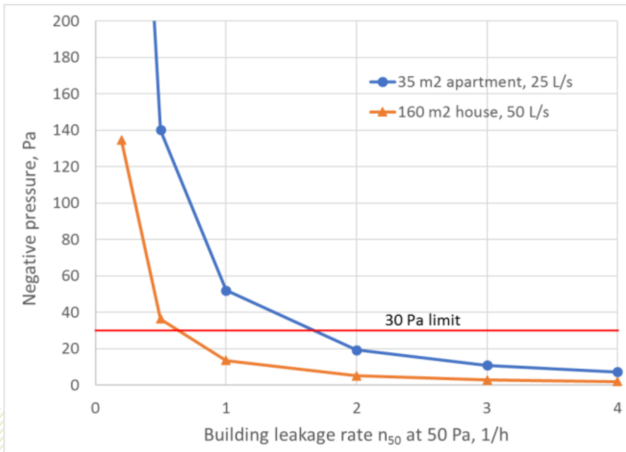
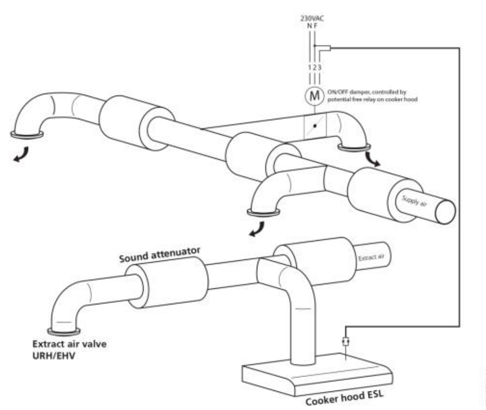
Airflow balance in airtight buildings

- Nearly zero energy buildings NZEB = airtight buildings with n_{50} < 1 1/h
- Special solutions needed for cooker hood and fireplace compensation



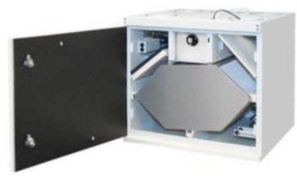
Cooker hood operation

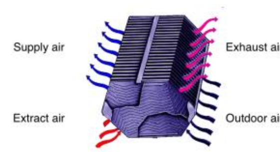


- In centralized system on/off damper and an additional supply air diffuser controlled with voltage signal
- General ventilation (min 8 L/s constant airflow) and boost (min 25 L/s) when the damper is opened

Which heat exchanger? Counterflow plate

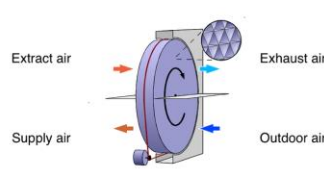
- The supply air and extract air have completely separate air passages therefore any possible odours in the extract air do not transfer to the supply air
- Plate heat exchangers (of metal) do not transfer humidity and are more sensitive to frosting
- Under specific temperature and humidity conditions condensation can occur in the heat exchanger on the exhaust side and it has to be safely drained outside ventilation unit





Which heat exchanger? Rotary

- Rotary heat exchangers (non-hygroscopic and hygroscopic) transfer humidity due to condensation and are less sensitive to frosting
- Humidity transfer is a positive feature in a cold climate as it can help avoid excessively low relative humidity in the winter
- While rotary heat exchangers are recommended for a cold climate, in very small apartments with high occupant density, where humidity removal becomes important, non-hygroscopic heat exchangers are recommended



Filters – ISO $PM_{2.5}$

- Minimum particle removal efficiencies ($e_{min}PM$) in ISO filter classes are shown in the Table below
- Particle removal efficiency shows the percentage of particle mass in the air removed by the filter. Removal efficiencies are defined for smaller and larger particle size ranges, i.e. up to 1 µm (ultrafine), up to 2.5 µm (fine particulate matter, the most important size range) and up to 10 µm (very large particles/coarse dust)

ISO 16890 Filter Classes	$e_{min}PM_1$	$e_{min}PM_{2.5}$	$e_{min}PM_{10}$	Reporting Value
ISO Coarse			<50%	Arrestance
ISO PM_{10}			>50%	ePM_{10}
ISO $PM_{2.5}$		>50%		$ePM_{2.5}$
ISO PM_1	>50%			ePM_1

Conclusions

- There is no conflict between good indoor climate and energy efficiency targets in airtight buildings if heat recovery ventilation is used:
  - major ventilation solution in Central and North Europe – simply impossible to build NZEB without heat recovery
  - in warmer climates co-benefits such as filtration of pollen and particulate matter (carcinogenic according to IARC 2014) as well as sound insulation not yet widely accepted and understood (JRC 2016)
- NZEB requirements provide new opportunities for dedicated ventilation systems as well as for research and harmonisation in order to ensure robust and reliable operation of ventilation satisfying high level health and comfort requirements of occupants

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EU support for Smart Buildings under Horizon 2020

Philippe Moseley
Project Advisor
EASME Unit B1 Horizon 2020 Energy

39th AIVC Conference
Smart ventilation for buildings
Juan-les-Pins, 19 September2018

Research question

"How is Europe's Horizon 2020 framework programme supporting research, innovation and market uptake of smart buildings?"

buildings

Title / Keyword | Journal: Buildings
Author / Affiliation | Article Type: all
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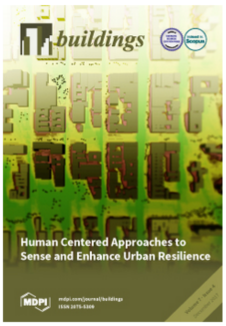
Volume 7, Issue 4



Buildings **2017**, *7*(4), 105; https://doi.org/10.3390/buildings7040105

Open Access | Article

EU Support for Innovation and Market Uptake in Smart Buildings under the Horizon 2020 Framework Programme

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Received: 22 September 2017 / Revised: 17 October 2017 / Accepted: 7 November 2017 / Published: 10 November 2017

(This article belongs to the Special Issue Selected Papers from Sustainable Places 2017 (SP2017) Conference)

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European Commission

Methodology

Revised EPBD: Smart Readiness Indicator for buildings

Ability of a building to:

(1) interact with its users

(2) manage itself efficiently

(3) interact with the wider energy environment

European Commission

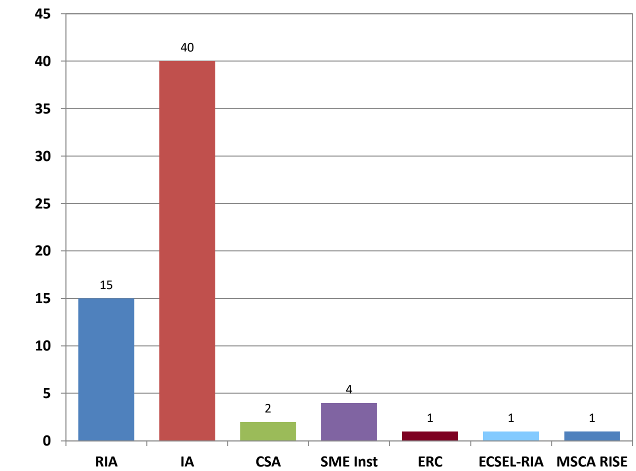
Methodology

Building's ability to interact with users				
Full automation	User interface	Control of entire building	Control of individual appliances	Implicit Demand Response

Building's ability to manage itself						
On-site storage	Heating and cooling	Lighting	Domestic Hot Water	Domestic appliances	Self-learning / AI	Optimization

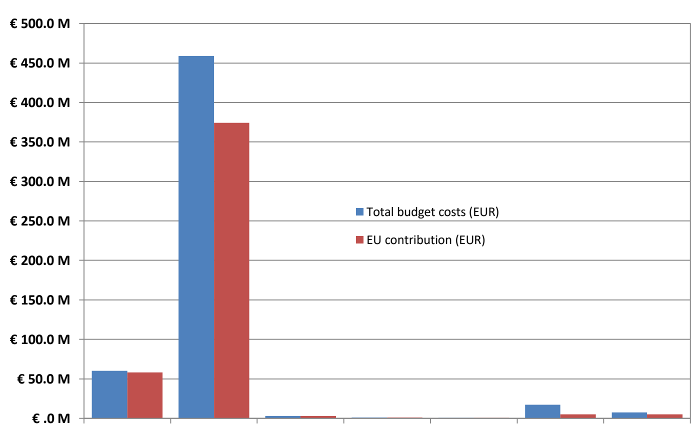
Building's ability to interact with the energy environment			
Interoperability & communication	Electromobility & smart charging	Data privacy & protection	Explicit Demand Response

Number of projects by funding scheme



RIA = Research & Innovation Action
IA = Innovation Action
CSA = Coordination & Support Action
SME Inst = SME Instrument Phase 2
ERC = European Research Council proof of concept
ECSEL-RIA = Electronic Components and Systems for European Leadership Joint Undertaking
MSCA RISE = Marie Skłodowska Curie Action Research & Innovation Staff Exchange

Budget/EU contribution by funding scheme



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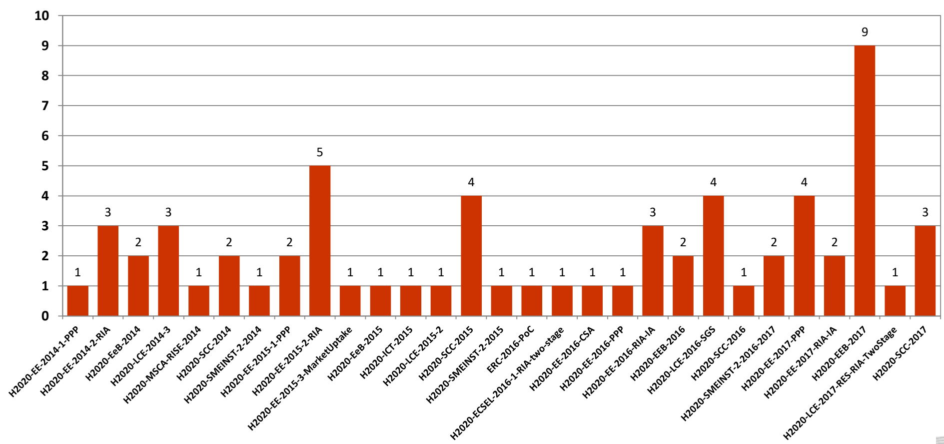
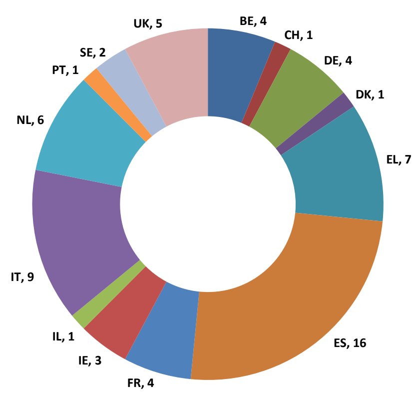
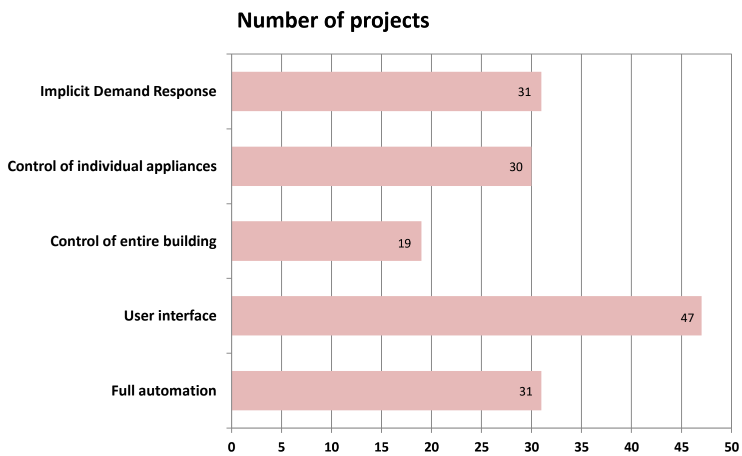
Number of projects by Call



Number of projects per coordinator's country

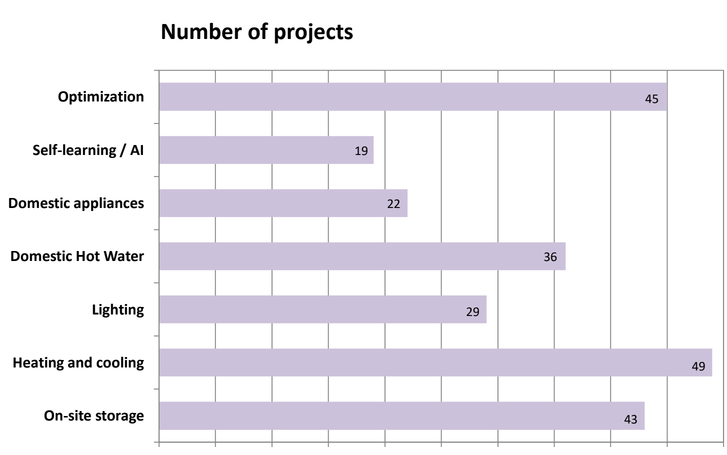


Building's ability to interact with users



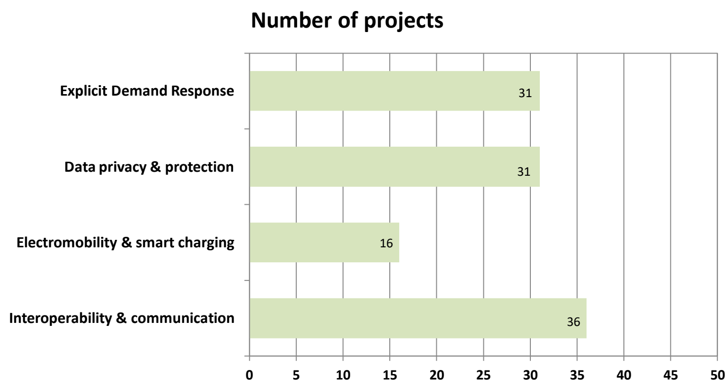
European Commission

Building's ability to manage itself



European Commission

Building's ability to interact with the wider energy environment



European Commission

Key findings

- As of June 2018, Horizon 2020 has supported 64 actions relating to energy-smart buildings
- The rate of funding for smart buildings is accelerating
- Total costs of these 64 actions = 547.9m EUR, of which 446.7m EUR EU contribution
- No single project is comprehensively investigating every aspect of smart buildings, but several come close
- There is no automated way to collect this kind of data – manual searches are necessary.

European Commission

Funding from Horizon 2020 for smart buildings

Horizon 2020 call: Energy efficiency (EE)

- EE-1-2018-2019-2020: Decarbonisation of the EU building stock
- EE-4-2019-2020: Upgrading smartness of existing buildings through innovations for legacy equipment
- EE-5-2018-2019-2020: Next-generation of Energy Performance Assessment and Certification
- EE-13-2018-2019-2020: Enabling next-generation of Smart Energy Services valorising energy efficiency and flexibility

2018 Call closed: proposals to be assessed

European Commission

Horizon 2020 Participant Portal

http://ec.europa.eu/research/participants/portal/desktop/en/home.html

European Commission

39th AIVC Conference
Smart ventilation for buildings

EASME

Executive Agency for Small and Medium-sized Enterprises

THANK YOU
FOR YOUR ATTENTION

Philippe MOSELEY
Unit B.1 Horizon 2020 Energy
https://ec.europa.eu/easme/en/energy

Follow EASME on Twitter @H2020EE @philippemoseley

European Commission

AIVC

EVIA European Ventilation Industry Association

Industry views
with respect to smart ventilation
as an enabler of
Indoor Air Quality

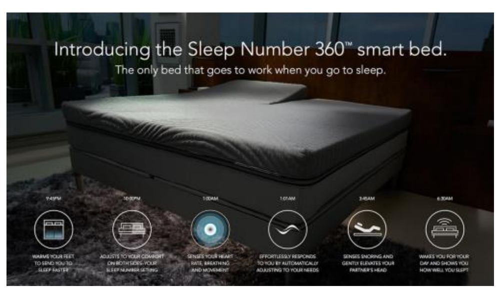
EVIA Members

Companies

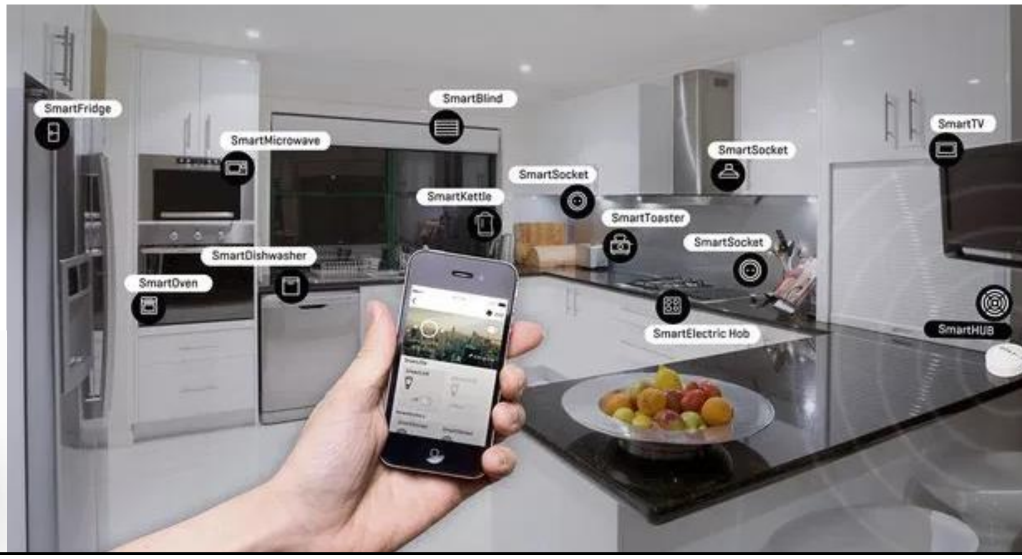
Associations

"WE ARE LIVING IN THE AGE OF THE IPHONE, YET THE ARCHITECTURE AND CONSTRUCTION INDUSTRIES ARE STILL IN THE WALKMAN PHASE"
QUOTE UNSTUDIO - BEN VAN BERKEL

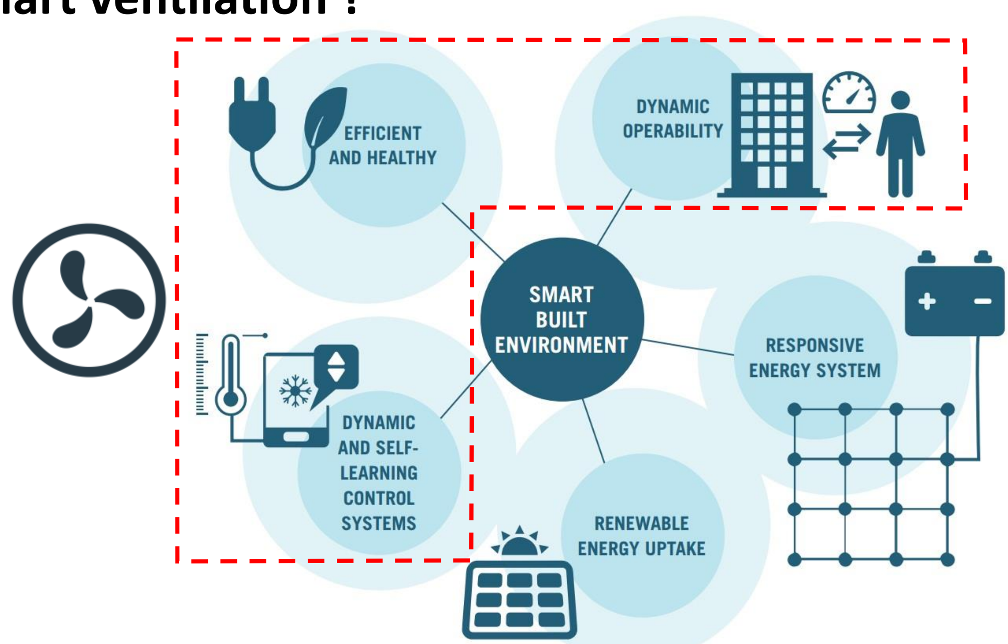
Smart items in our daily life ?



Smart home ?



Smart ventilation ?



Economic reality

Smart ventilation in SRI

Focus on ENERGY

Smart Readiness Indicator - SRI

Measure the technological readiness of your building

1 Readiness to adapt in response to the needs of the occupant

2 Readiness to facilitate maintenance and efficient operation

3 Readiness to adapt in response to the situation of the energy grid

= Boundary condition

European Commission

Smart ventilation in Ecodesign Lot 33?

FOR PRODUCTS IN SCOPE

Ventilation not included

European Commission

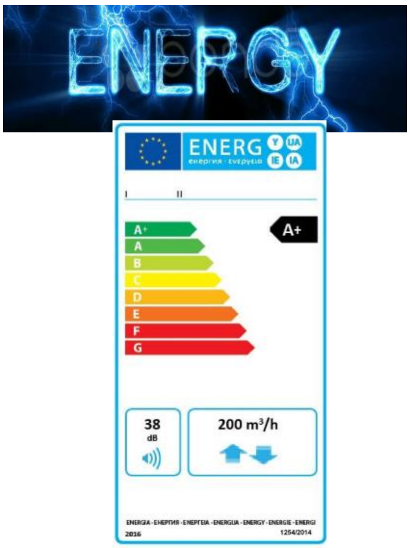
ENERGY LABELLING REGULATION

SMART

Icon on label if complies with technical requirement
Amendment to existing regulation

	Energy label
washers	
Washing machines	
Tumble dryers	
Electric storage water heaters	
HVAC cooling	
HVAC heating	
Refrigerating appliances	
Home batteries	
Electric vehicle chargers	
Commercial	
HVAC cooling	
HVAC heating	
Refrigeration	
Commercial & households	
Electric radiators	
Electric boilers (space/water)	

Smart ventilation in Ecodesign Lot 6 ?

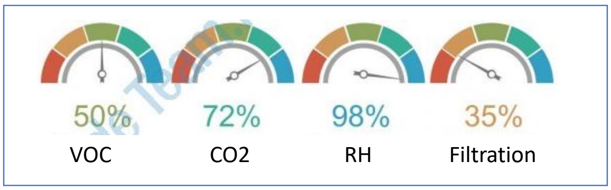


European Commission

We believe

Smart Ventilation
IAQ

EVIA IAQ label



IAQ label main targets

- Raise awareness of the impact of smart ventilation systems on IAQ
  - Help to move the market to efficient solutions (sensors, filtration, etc …)
  - Assert the main purpose of ventilation system -> improving IAQ
- Complement energy aspects (energy labelling)
  - Introduce efficiency of ventilation system on IAQ in parallel to their energy efficiency.
- Propose a European common method for all type of mechanical ventilation systems existing in Europe
- Label has to be clear and simple to understand by the general public

Scientific partners

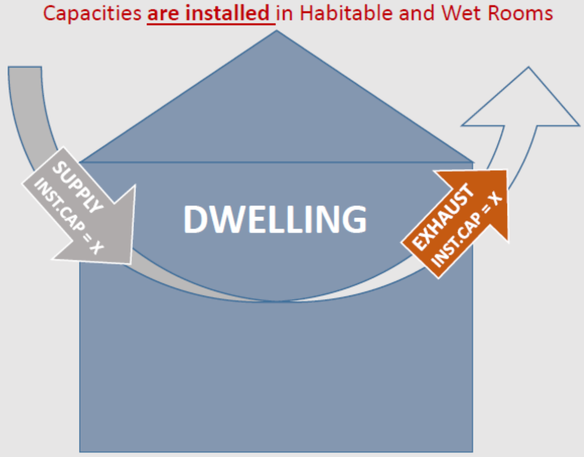
taskforce

Van Holsteijn en Kemna BV (VHK)
Elektronicaweg 14
2628 XG Delft
The Netherlands
www.vhk.nl

Department of Architecture and Urban Planning
Jozef Plateaustraat 22
9000 Gent
Belgium
www.ugent.be

instead of .....

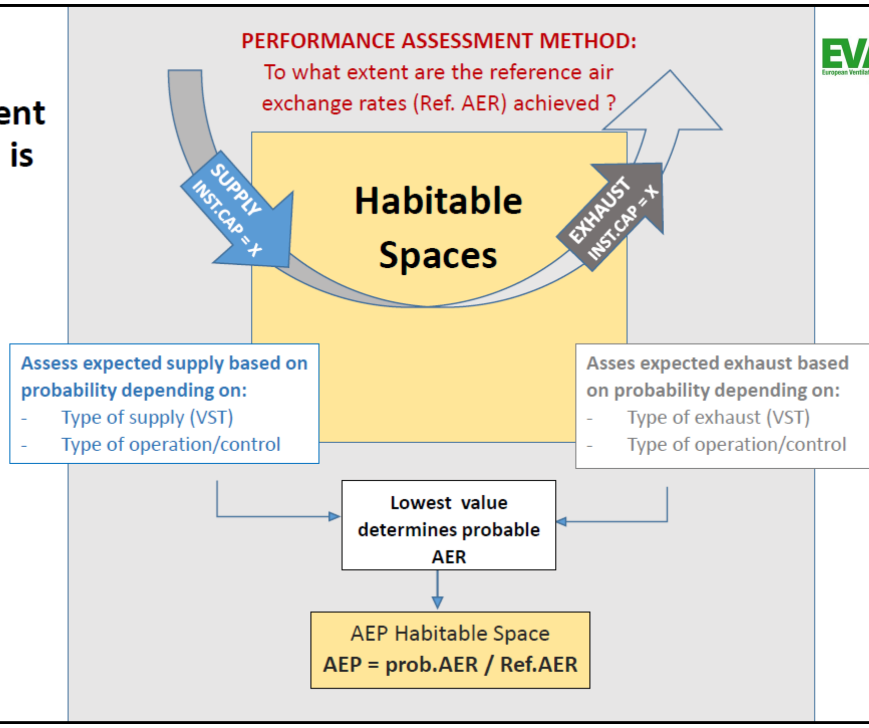
PRESCRIPTIVE METHOD:
Code compliant Air Exchange Provisions and Capacities **are installed** in Habitable and Wet Rooms



AN ADEQUATE AIR EXCHANGE PERFORMANCE IS ASSUMED

Evidence is found in measuring the AER over the building

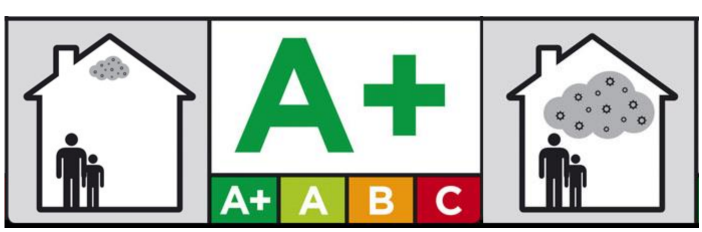
…..an additional performance assessment method on room level is proposed……



Proposal voluntary IAQ label

Ventilation performance system *X*

@ installed capacity of 1.0 [l/s/m^2] for habitable spaces



But it does not stop there…

Ventilation system

- Demand controlled
- IAQ sensor based
- Data online

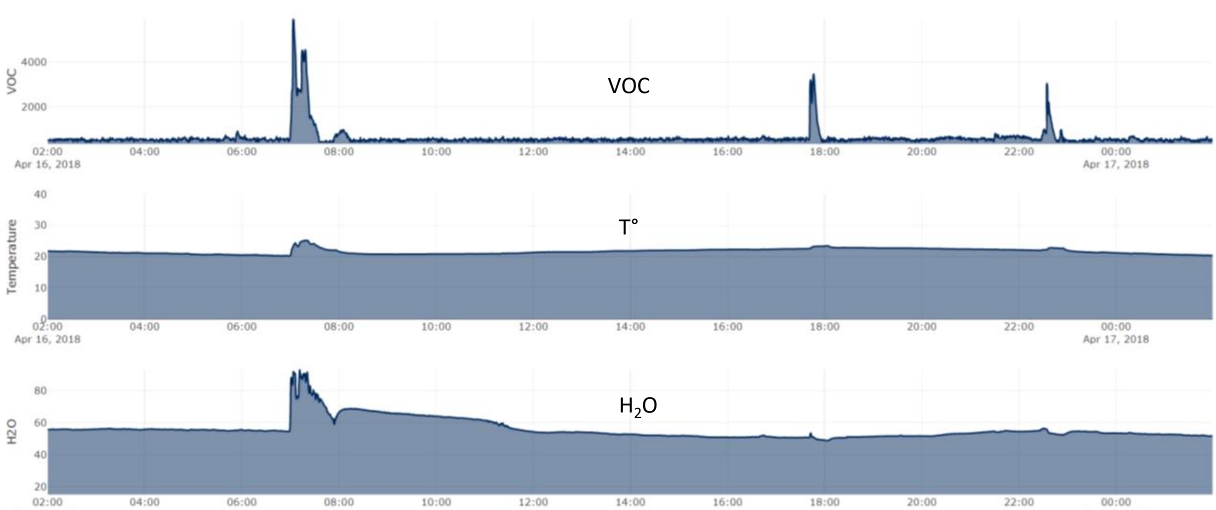
Installer

- Status
- Maintenance

User

- Feedback on IAQ
- Increase awareness

To measure is to know




EVIA
European Ventilation Industry Association
Dare to Dream
?
Indoor Air Quality


(R)evolution is coming…
EVIA
European Ventilation Industry Association
HELP WANTED
POLICY
GUIDELINES
PRACTISES
STANDARDS
RULES
REGULATIONS
COMPLIANCE

Quality framework for airtightness testing in the Flemish Region of Belgium
-
feedback after three years of experience

M. De Strycker, L. Van Gelder, V. Leprince

AIVC 2018

BELGIAN CONSTRUCTION CERTIFICATION ASSOCIATION vzw / asbl

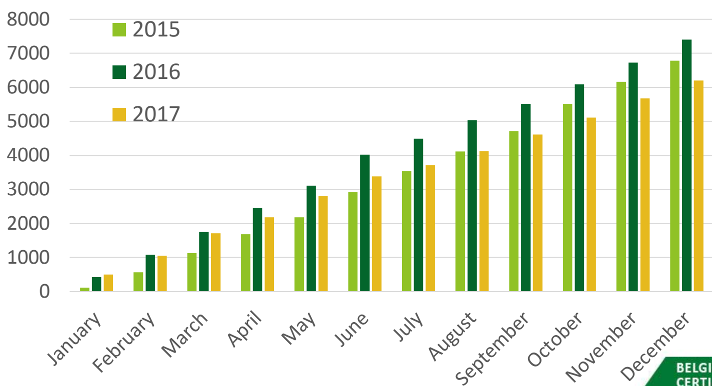
Context

- Airtightness test implicit mandatory in Flanders
  - No explicit requirement, but overall evaluation of building envelope
  - 90% of new dwellings tested
- Requirements for tests (1/1/15)
  - Conform STS-P 71-3, additional clarifications to NBN EN 13829:2011
  - By qualified tester
  - Test results registered in database
  - Guarded by a quality framework
- Requirements for the organiser of a quality framework (15/12/17): impartial, accreditation according to ISO 17065, annually 10% of measurements inspected on-site and desktop and minimum 90% of active testers

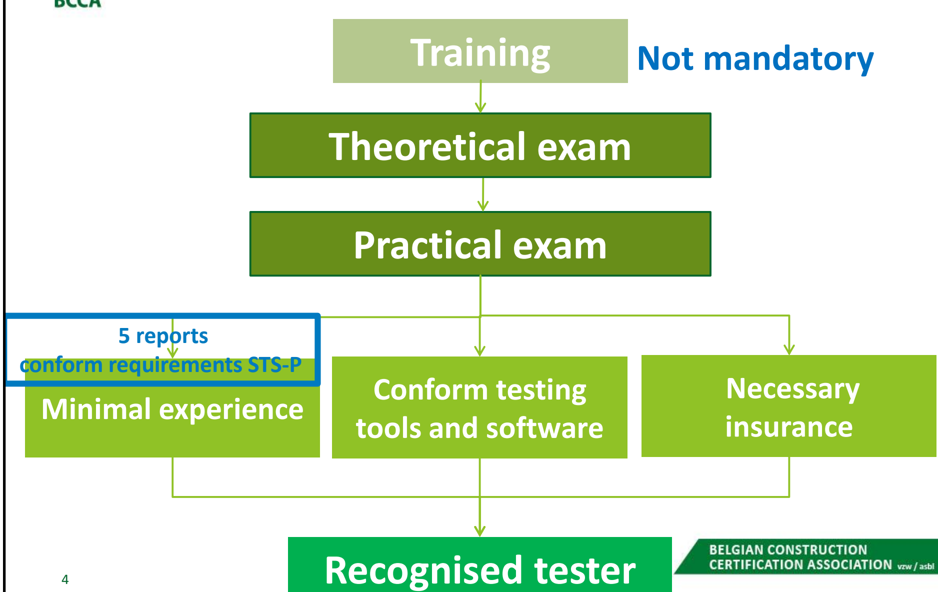
BELGIAN CONSTRUCTION CERTIFICATION ASSOCIATION vzw / asbl

Numbers

- Since 1/1/2015 operational
- February 2018: 189 qualified testers in 142 recognised companies
- More than 7000 tests/year registered



Process of qualification



BCCA

Process of conformity declaration

Opening dossier
- Address, building type, name of tester
- Planning (day before measurement)

Measurement
- SMS start of measurement
- Building preparation, measurement
- SMS with leakage rate

Report
- Details of measurement
- Result

Conformity declaration
- Responsibility of tester
- Hand over to client

BCCA

Process of inspection

During measurement
- Qualified tester?
- Calibration of devices?
- Building preparation
- …

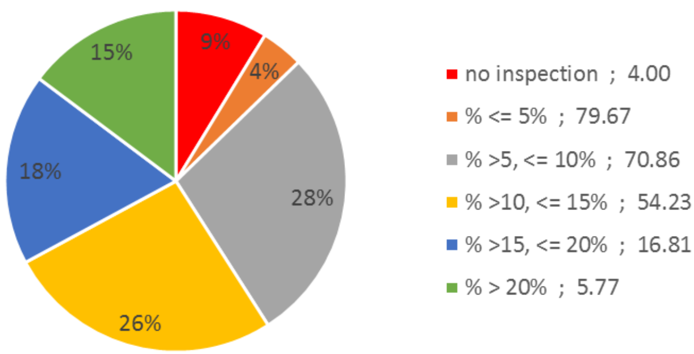
After measurement
- All previous topics
  + Reliability of result

On report
- Calculation parameters
- Result
- Administrative aspectss
- …

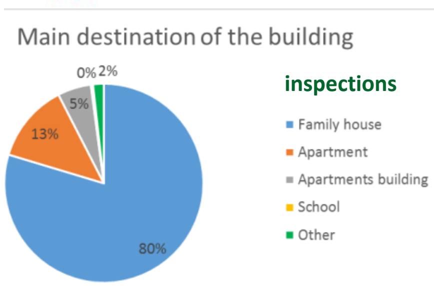
→ **Sanctions**

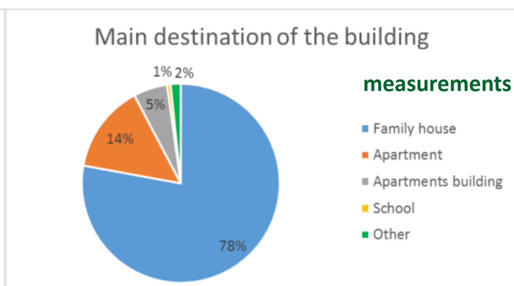
Results: inspection rate of companies

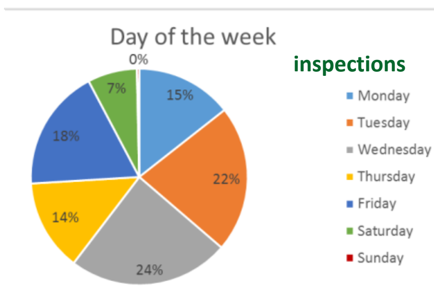
On site inspections

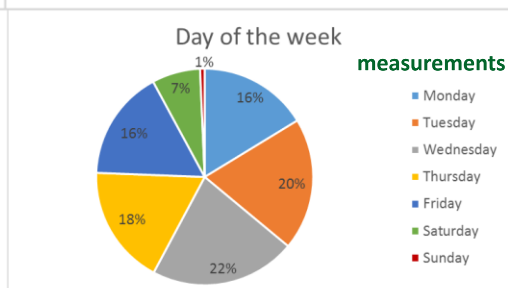


Results: repartition of inspections

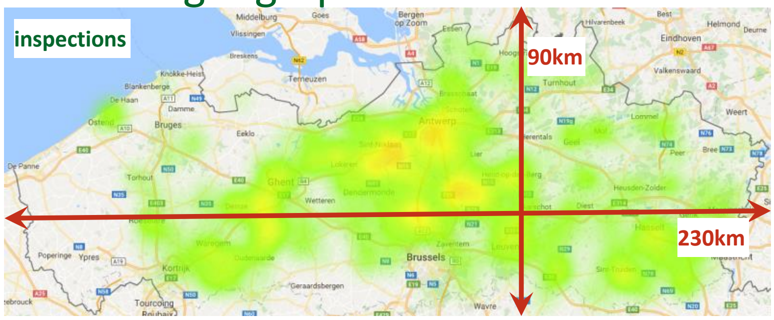


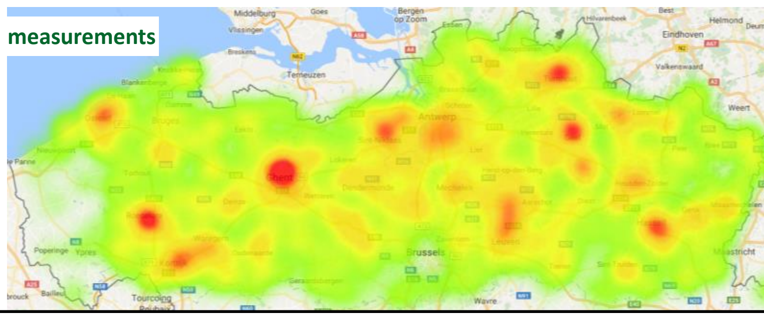




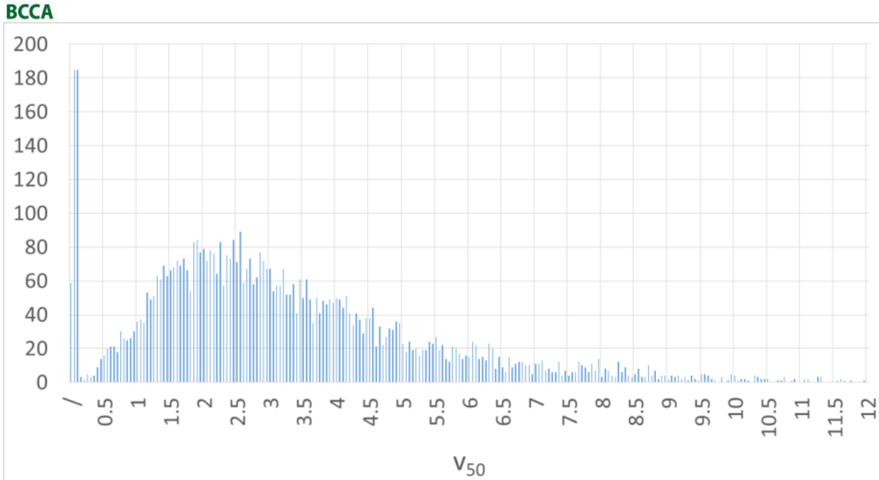


Results: geographical distribution





Results



Results

- Examples of non-conformities (on site,only majors – 2017)
  - The required meteorological conditions were not respected: the natural pressure difference as reported by the measurer was too high (4)
  - There is a difference between the indicated/sealed/closed openings with STS-P 71-3 with an expected impact greater than or equal to 5%. (4)
  - The calibration of the thermometer is more than six months overdue (2)
  - The coefficient of determination r^2 is less than or equal to 0.95 (1)
  - Deviation from the procedure with suspected major impact on the measurement result by breaking down the inspection (1)
- Major non-conformities are treated by an independent commission
- Resulting in the following sanctions
  - 46 increased monitoring frequency
  - 7 new measurements
  - 2 temporarily qualification withdrawals (due to non-valid calibration)

Conclusion

- Possible to develop quality framework at limited cost for testers
- Inspection is effective and efficient
- Desktop and on site inspections are both necessary and complementary
- Database allows for further analysis of results (e.g. average v_{50}=3.36m³/h/m²)

- Similar framework has been setup for residential ventilation systems

Contact

Comments or questions?

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www.ikventileerverstandig.be

www.bcca.be

Details of inspection after measurement

- STOP sms with leakage rate is sent
- Within 5 minutes inspector contacts measurer that inspection will be performed
- Within 15 minutes after contact inspector arrives on site
- Measurer is asked to cruise at 50Pa (over- or underpressure, whichever setup was the last)
- Result is compared with result in sms

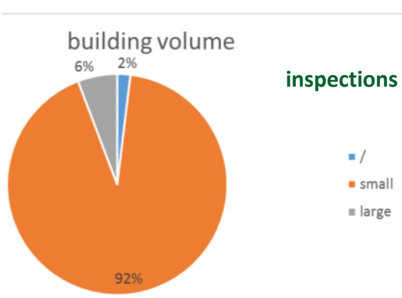
- Average time between stop sms and end of inspection <25min

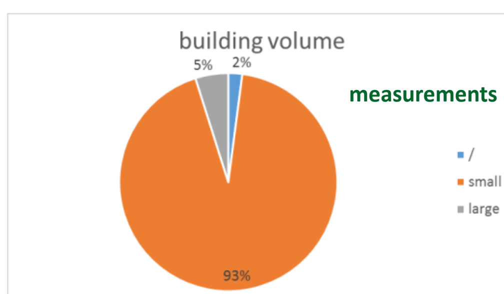
Cost

- Company fee (only first year): 400 EUR
- Training (optional, 1 day)
  participation theoretical exam included: 285 EUR
- Theoretical exam: 150 EUR
- Practical exam (half day, one on one): 490 EUR
- Price per measurement: 40 EUR
- Larger buildings progressively increasing up to

BELGIAN CONSTRUCTION CERTIFICATION ASSOCIATION vzw / asbl

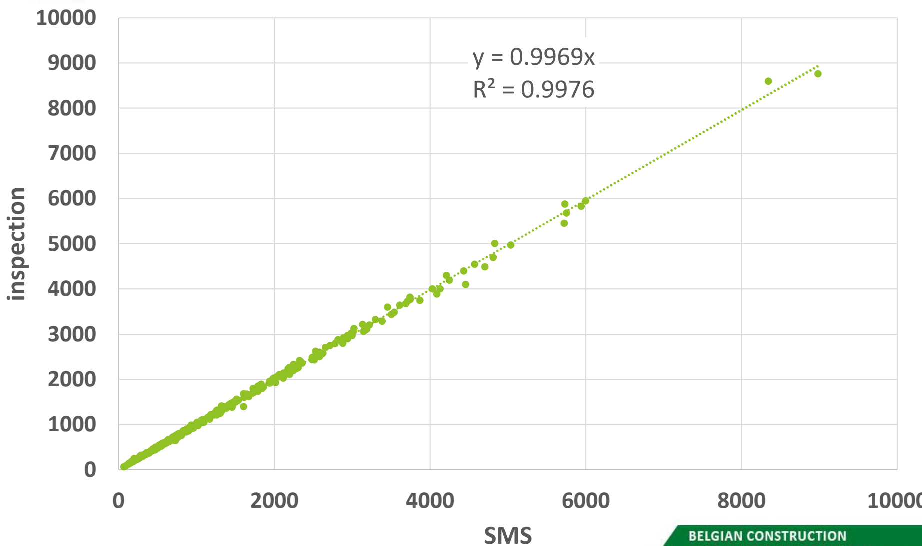
Results: repartition of inspections





BELGIAN CONSTRUCTION CERTIFICATION ASSOCIATION vzw / asbl

Effective?


y = 0.9969x
R² = 0.9976
inspection
SMS
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
0
2000
4000
6000
8000
10000

French database of building airtightness, statistical analyses of about 215,000 measurements

Impacts of buildings characteristics and seasonal variations

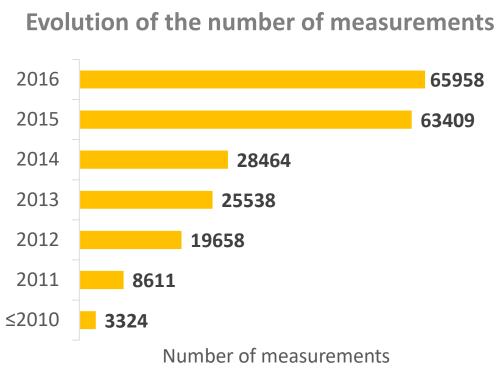
Bassam Moujalled*, Valérie Leprince, Adeline Mélois
*bassam.moujalled@cerema.fr

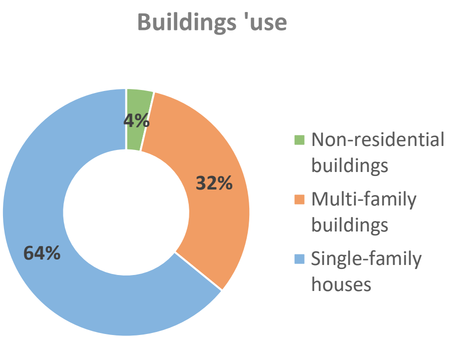
Introduction

French context of building airtightness

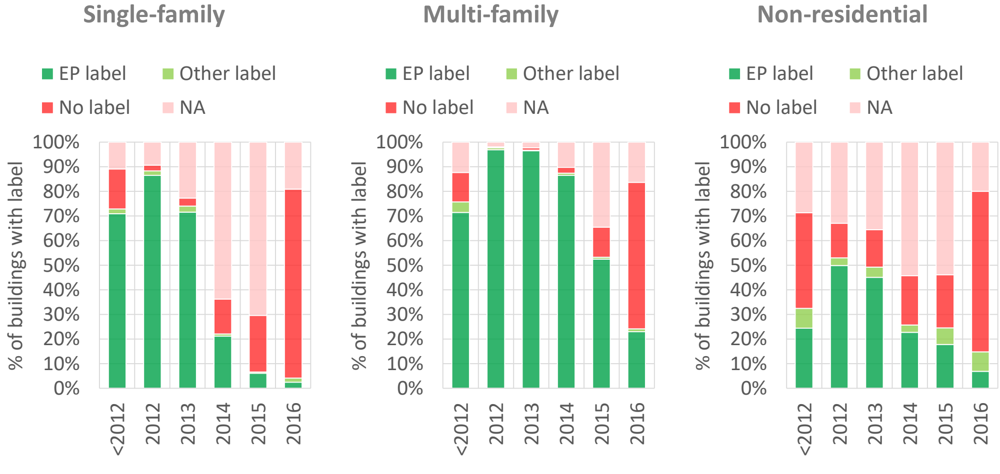
- Created in 2007, the French database is fed annually by the register tables of certified tester
  - ✓ *871 certified testers in 2018*
- Since 2013, a **mandatory requirement** of the French EP-regulation which requires a limit airtightness level for new residential buildings.
  - ✓ *To be justified either by an airtightness test performed by a qualified tester, or by the application of a certified quality management approach on building airtightness*
- About **215,000 measurements** have been recorded in the database till the end of 2016

Database overview
Distribution of the measurements



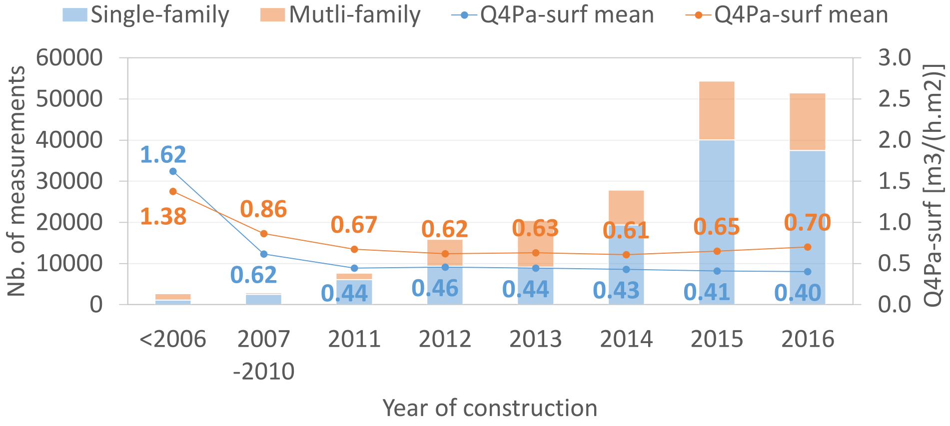


Database overview
Share of buildings with EP-label



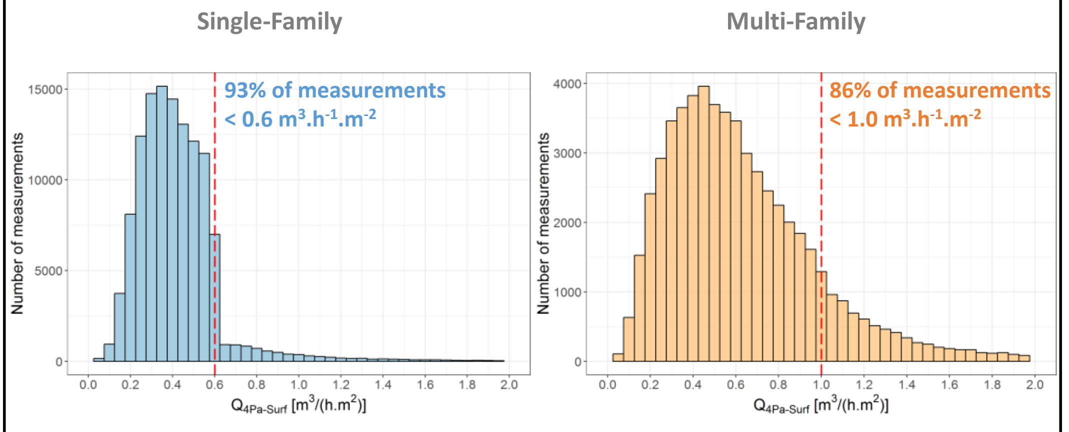
Evolution of building airtightness

Residential buildings

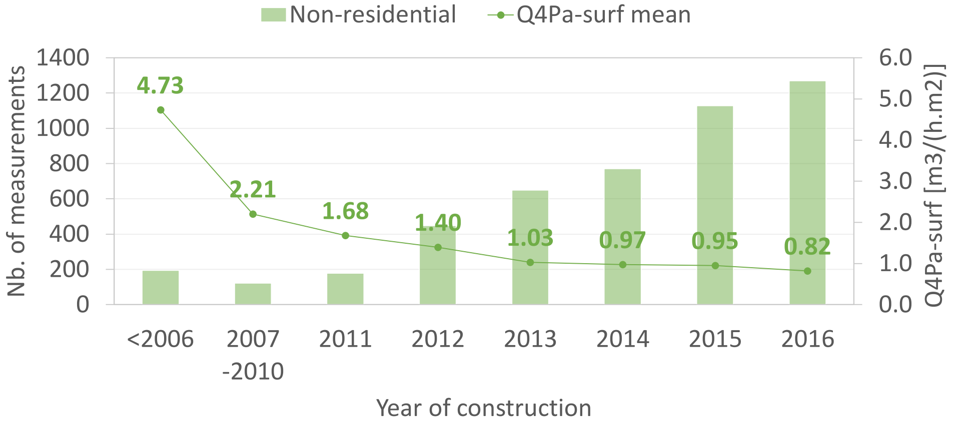


Evolution of building airtightness

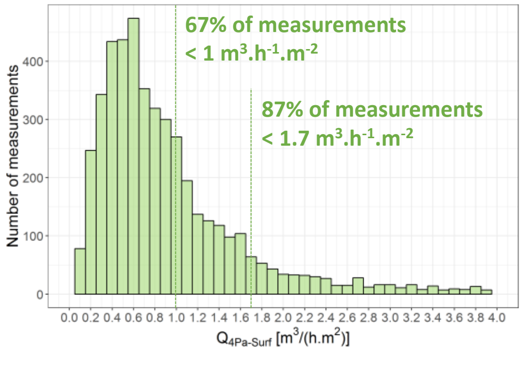
Residential buildings

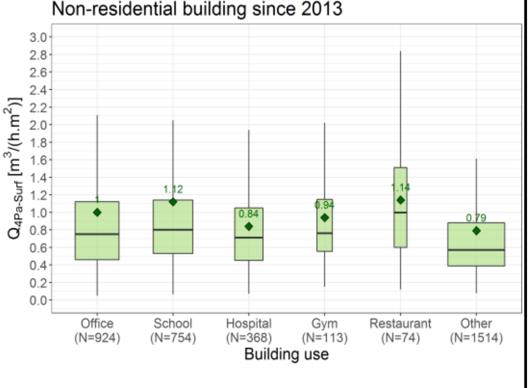


Evolution of building airtightness
Non-*Residential buildings*



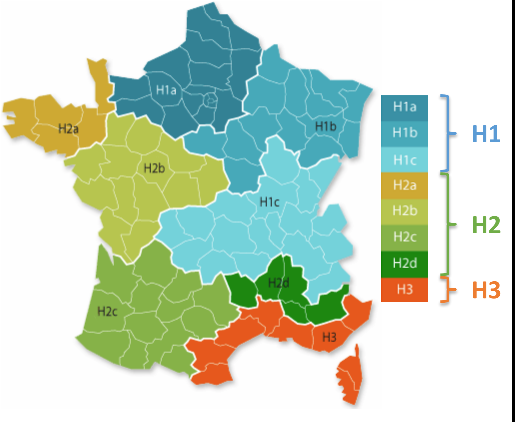
Evolution of building airtightness
Non-*Residential buildings*



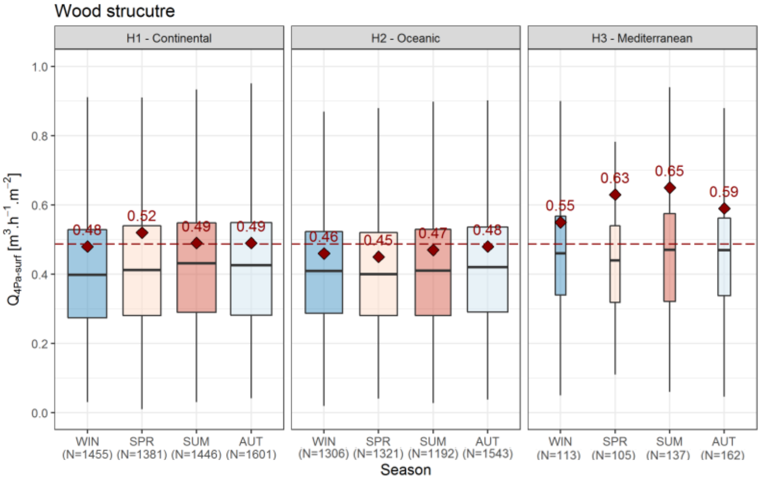


Impact of seasonal variations

- **Treatment of airtightness**
  - Wood structure *(vapour barrier)*
  - Heavy structure with interior insulation *(plasterboards and mastics at the inside facing of the walls)*
  - Heavy structure with exterior insulation *(like interior insulation or by coating on the masonry)*
- **Climatic zones**

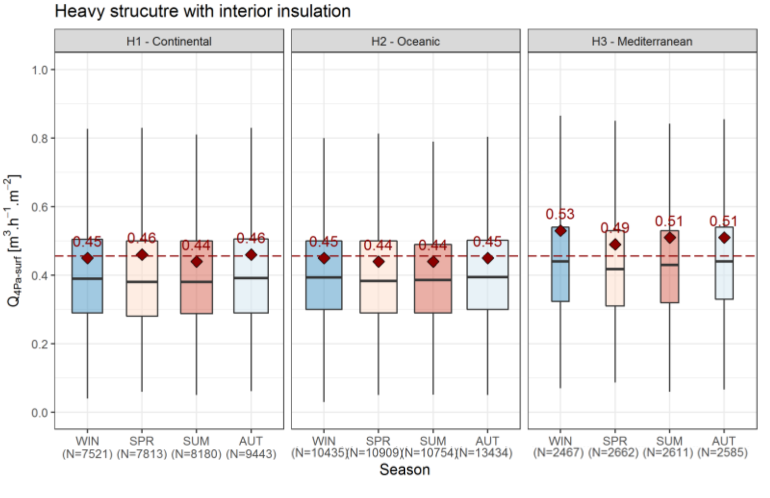


Impact of seasonal variations
Wood structure



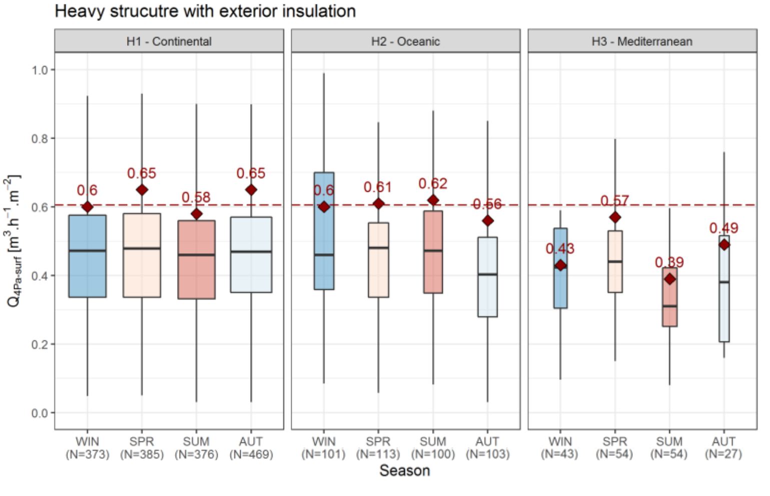
Impact of seasonal variations

Heavy structure with interior insulation



Impact of seasonal variations

Heavy structure with exterior insulation



Conclusions

- **215,000 building airtightness measurements in the database**
  - ✓ Mostly residential buildings
  - ✓ **Measurements from 2015 can be considered as representative of new French residential buildings**
- **New residential buildings:**
  - ✓ **Single-family** : the air permeability slightly decreases from year to year with a mean value around 0.4 $m^3.h^{-1}.m^{-2}$ in 2016
  - ✓ **Multi-family** : the yearly mean air permeability fluctuates between 0.60 and 0.65 $m^3.h^{-1}.m^{-2}$

Conclusions

- **New non-residential buildings:**
  - ✓ Mainly office buildings and schools
  - ✓ **Air permeability of the different uses is globally equivalent,** with the exception of restaurants with higher air permeability
  - ✓ **Air permeability of office buildings is globally equivalent for different volume ranges**
- **Seasonal variations:**
  - ✓ **Impact only observed in the case of wood constructions**, with slightly higher values during summer in the south of France in particular

Thanks…

www.cerema.fr

Universidad de Valladolid

Preliminary analysis results of Spanish residential air leakage database

Irene Poza-Casado, Alberto Meiss, Miguel Ángel Padilla-Marcos and Jesús Feijó-Muñoz

39th AIVC – 7th TightVent & 5th venticool Conference, 2018. Antibes Juan-Les-Pins, France

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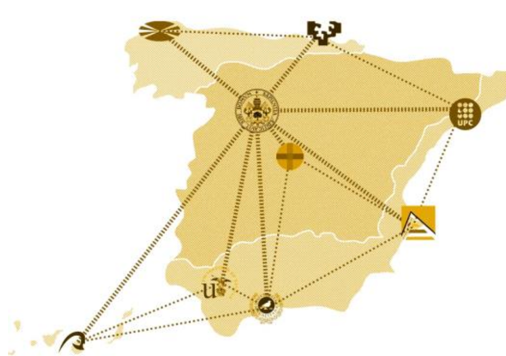
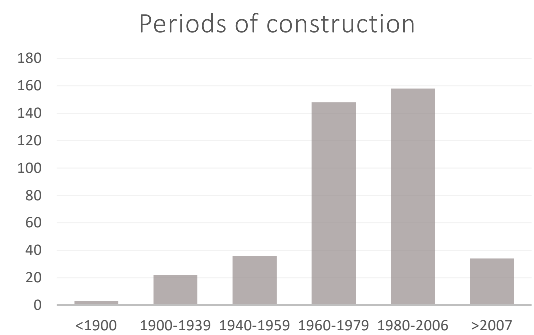
Universidad del País Vasco Euskal Herriko Unibertsitatea
UNIVERSIDADE DA CORUÑA
Universitat d'Alacant Universidad de Alicante
CEU Universidad San Pablo
UNIVERSITAT POLITÈCNICA DE CATALUNYA
UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA
UNIVERSIDAD DE MÁLAGA

1 Introduction

- In Mediterranean countries, climate benevolence and the tradition of ventilating naturally have led to very few studies focusing on this area.
- The Spanish building code **does not establish any limitation** regarding airtightness and requires controlled ventilation systems, calculated based on ideally airtight envelopes.
- Infiltrations are responsible for **10.5% to 25.4% of the energy demand** in winter for dwellings built after 2006.
- ***INFILES Project*** aims to characterize the envelope of the current residential building stock.
- The creation of a **national air leakage database** will allow to determine factors that have a major impact on airtightness and the energy impact, and to define some guidelines to improve it.

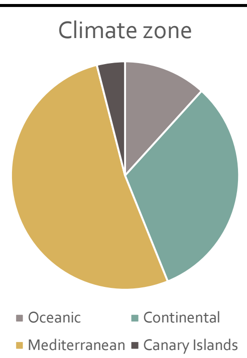


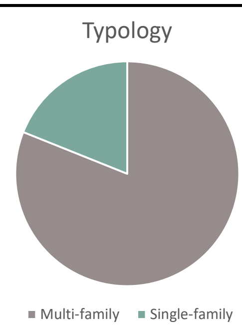
2 Sample

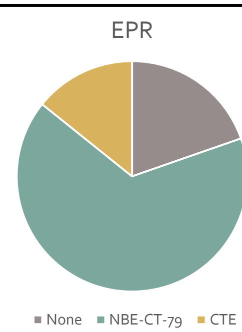


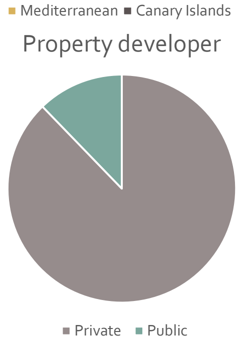
Universidad de Valladolid

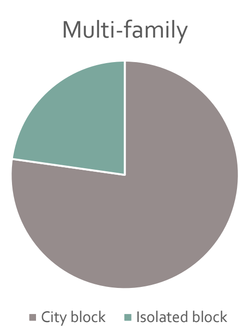
Preliminary analysis results of Spanish residential air leakage database. Irene Poza-Casado, Alberto Meiss, Miguel Ángel Padilla-Marcos and Jesús Feijó-Muñoz

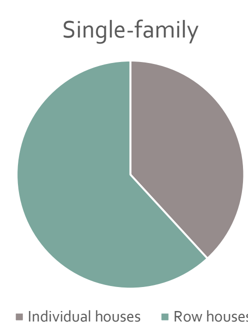






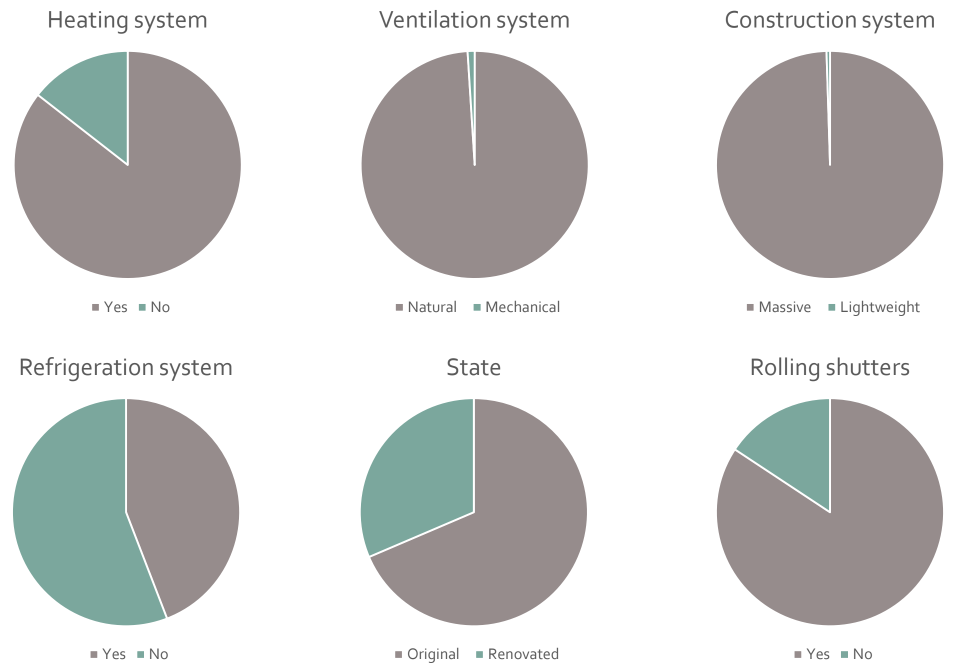




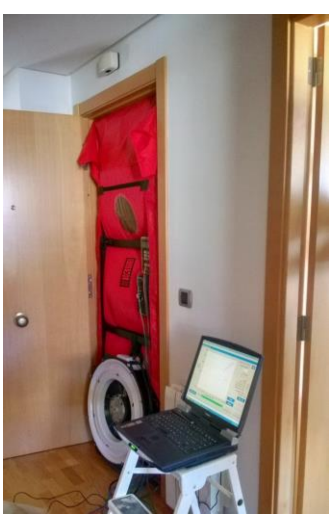


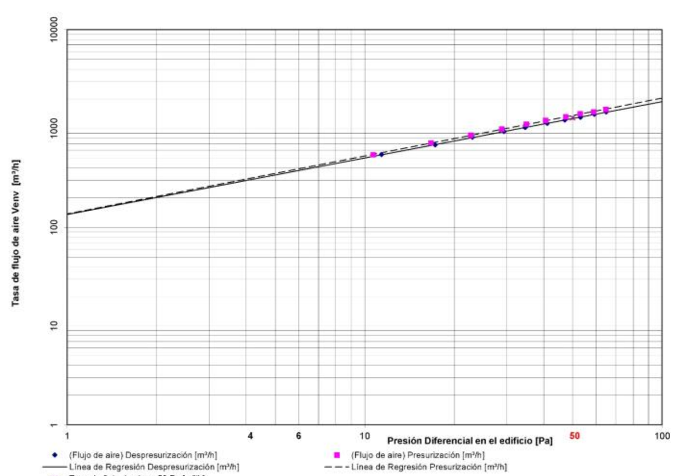
Universidad de Valladolid

Preliminary analysis results of Spanish residential air leakage database. Irene Poza-Casado, Alberto Meiss, Miguel Ángel Padilla-Marcos and Jesús Feijó-Muñoz



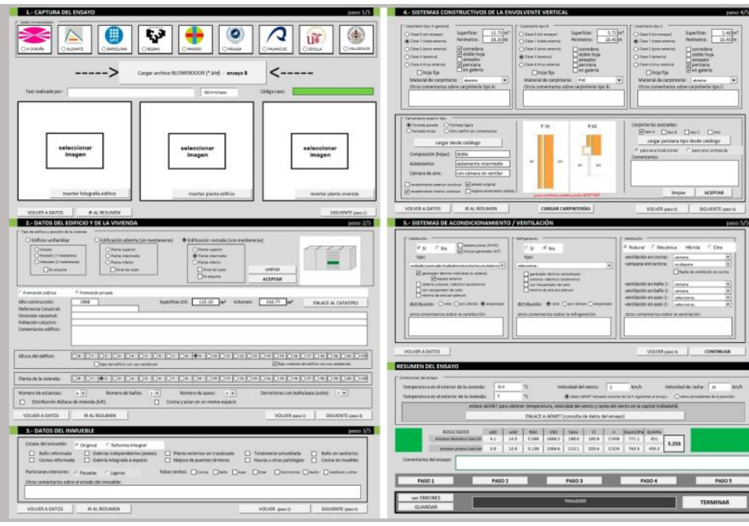
3 Testing method





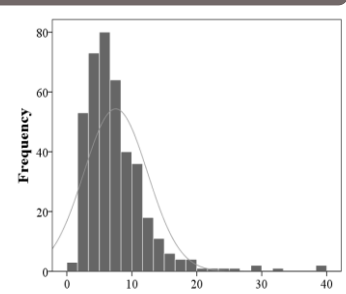
Infil-App

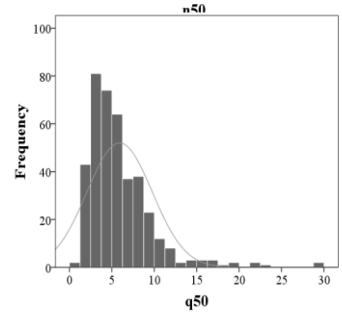
- A software tool and a protocol were developed in order to retain the information in a uniform and systematic way.
- A wide characterization of more than 140 parameters are stored.



4 Results

		N	Mean	Median	S.d.	Min.	Max.
V_{50}	(m^3/h)	401	1710.57	1312.45	1285.5	226.9	9099.33
n_{50}	(h^{-1})	401	7.52	6.39	4.91	1.19	39.42
q_{50}	($m^3/h{\cdot}m^2$)	401	5.91	5.00	3.85	0.96	29.92
w_{50}	($m^3/h{\cdot}m^2$)	401	19.33	16.49	12.81	3.09	100.79
n	(-)	401	0.60	0.6	0.81	0.51	0.98





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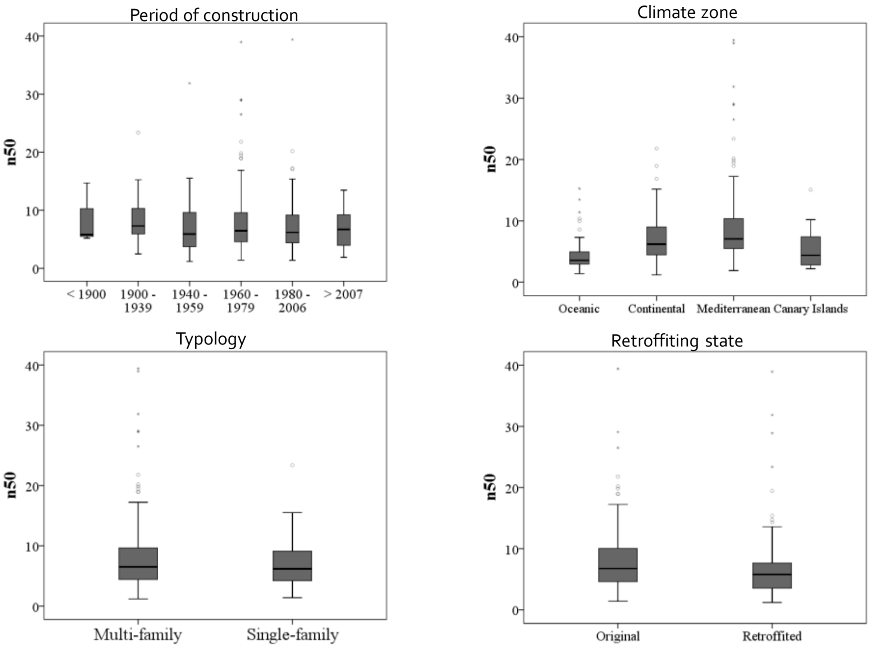

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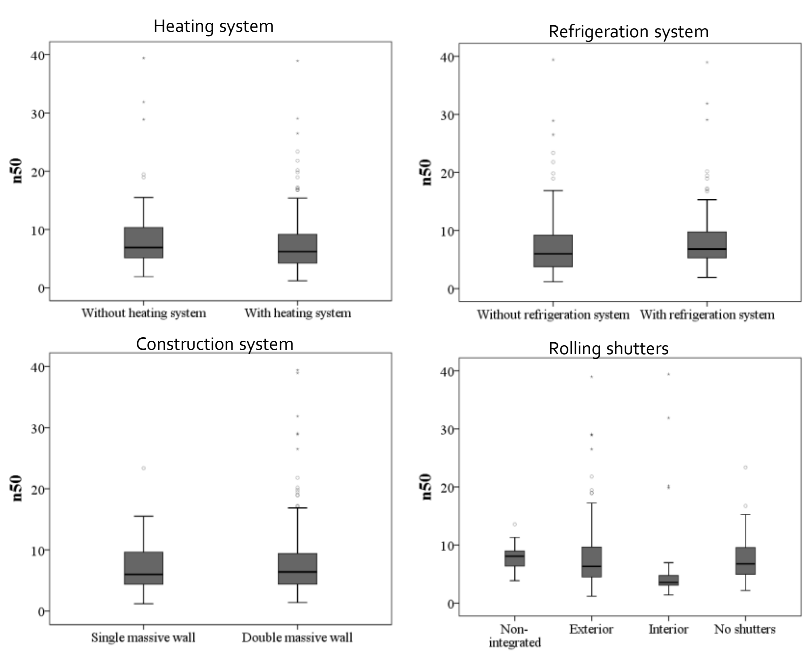

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Preliminary analysis results of Spanish residential air leakage database. Irene Poza-Casado, Alberto Meiss, Miguel Ángel Padilla-Marcos and Jesús Feijó-Muñoz

5 Conclusions

- More tan 400 cases constitute the Spanish residential air leakage database.
- The mean air change rate of the whole database is **7.52 h-1** and the mean air permeability rate at **50 Pa is 5.91 m³/h·m²**.
- **Climate zone, retrofitting, refrigerating system** and the position of the **shutters** were found to be in relation with the air change rate of the dwellings tested.
- No significance was found related to the period of construction, typology, heating system or construction technology.
- A great **potential for energy savings** through the improvement of construction elements can be deduced from the results.
- A larger sample should be considered in order to draw more accurate results.
- Further conclusions will be derived from a deeper analysis of the data and the increase of the number of cases tested.

References

AENOR. EN 13829:2000. Thermal performance of buildings. Determination of air permeability of buildings. Fan pressurization method. (ISO 9972:1996, modified) (2000).

Chan, W. R., Joh, J., & Sherman, M. H. (2013). Analysis of air leakage measurements of US houses. *Energy and Buildings*, *66*, 616–625. https://doi.org/10.1016/j.enbuild.2013.07.047

Feijó-Muñoz, J., Poza-Casado, I., González-Lezcano, R. A., Pardal, C., Echarri, V., Assiego de Larriva, R., … Meiss, A. (2018). Methodology for the Study of the Envelope Airtightness of Residential Buildings in Spain: A Case Study. *Energies 2018, Vol. 11, Page 704*, *11*(4), 704. https://doi.org/10.3390/EN11040704

Fernández-agüera, J., Sendra, J. J., Suárez, R., & Oteiza, I. (2015). Airtightness and indoor air quality in subsidised housing in Spain. In *36th AIVC Conference ' Effective ventilation in high performance buildings'*. Madrid, Spain. Retrieved from http://www.aivc.org/resource/airtightness-and-indoor-air-quality-subsidised-housing-spain

Jiménez Tiberio, A., & Branchi, P. (2013). A study of air leakage in resitential buildings. In *2013 International Conference on New Concepts in Smart Cities: Fostering Public and Private Alliances (SmartMILE)* (pp. 1–4). Gijón. https://doi.org/10.1109/SmartMILE.2013.6708180

Leprince, V., Carrié, F. R., & Kapsalaki, M. (2017). Building and ductwork airtightness requirements in Europe – Comparison of 10 European countries. In *38th AIVC Conference. Ventilating healthy Low-energy buildings* (pp. 192–201). Nottingham, UK.

Leprince, V., Kapsalaki, M., & Carrié, F. R. (2017). Impact of Energy Policies on Building and Ductwork Airtightness. *Ventilation Information Paper, AIVC*, (37), 1–14.

Meiss, A., & Feijó-Muñoz, J. (2014). The energy impact of infiltration: a study on buildings located in north central Spain. *Energy Efficiency*, *8*(1), 51–64. https://doi.org/10.1007/s12053-014-9270-x

Ministerio de Fomento del Gobierno de España. Norma Básica de Edificación NBE-CT-79. Condiciones térmicas en los edificios (in Spanish) (1979). Spain. Retrieved from https://boe.es/boe/dias/1979/10/22/pdfs/A24524-24550.pdf

Ministerio de Fomento del Gobierno de España. Código técnico de la Edificación (CTE). Documento básico HS 3: Calidad del aire interior (in Spanish) (2006). Retrieved from http://www.codigotecnico.org/images/stories/pdf/salubridad/DBHS.pdf

Montoya, M. I., Pastor, E., & Planas, E. (2011). Air infiltration in Catalan dwellings and sealed rooms: An experimental study. *Building and Environment*, *46*(10), 2003–2011. https://doi.org/10.1016/j.buildenv.2011.04.009

Thank you!

Acknowledgements

This study has been possible thanks to the research project ***INFILES: Repercusión energética de la permeabilidad al aire de los edificios residenciales en España: estudio y caracterización de sus infiltraciones***, funded by the Spanish Ministry of Economy and Competitiveness (ref. BIA2015-64321-R). The attendance to this conference has been possible thanks to the program *Movilidad de Doctorandos UVa 2018*.

Assessment of durability of airtightness by means of repeated testing of 4 passive houses

Jiří Novák

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Czech Technical University in Prague

Method




- 4 passive houses
- known construction method and air barrier system
- can the system maintain its performance over time?

⬇

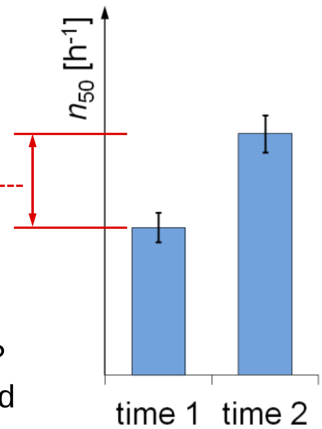
- repeated airtightness testing (EN 13829 / EN ISO 9972)
- 1st test after completion of the building
- repeated testing over a period of 11 years
- comparison of test results

Common issues of the method

- effect of ageing?

X

- modifications of the building?
- different building preparation?
- different testing procedure and equipment?
- different climatic conditions? (seasonal variations)



Particular points of the study

Tetsing

- the same technician (knows the buildings)
- the same equipment (a blower door, pressure sensors calibrated yearly, the fan not re-calibrated)
- the same testing procedure
- well documented building preparation (nearly identical for all the tests, differencies are traceble)
- nearly all the tests carried out in the same period of year

↓

- some of the common issues overcome (minimised)
- uncertainty minimised
- differencies between test results reflect mailny the ageing of material and interventions of users

Particular points of the study

Buildings

- well documented design
- nearly identical dimensions
- the same construction method
- the same air barrier system
- very similar quality of workmanship (serial production, the same contractor, built within the same period of time)
- different building use (single-family house, „show house“, training centre)

⬇

- allows for assessment of different users behaviour on the airtightness durability
- differencies between the buildings reflect mailny the influence of users

Buildings tested

- pilot project
- development of 13 passive houses (the same location)
- buildings completed in 2007
- standardised design (the same construction and dimensions)
- serial production (the same quality of workmanship)
- emphasis on airtightness

Buildings tested

- timber structure
- air barrier layer – PE foil sheets sealed with butyl tapes
- ballanced mechanical ventilation with heat recovery

Building A

Building use

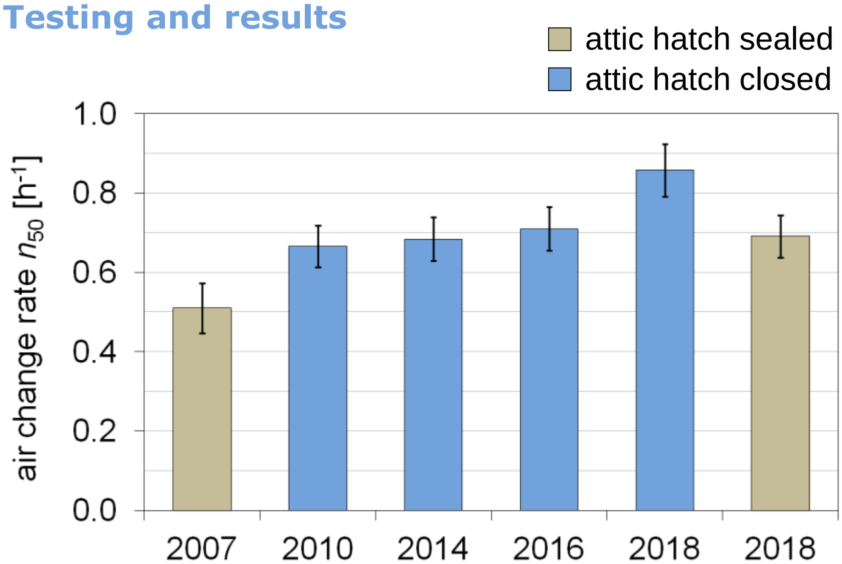
- single-family house
- inhabited since 2007
- the owner – aware of airtightness

Service life

- no substantial interventions to the air barrier system
- defect or degradation of the attic hatch

Building A

Testing and results



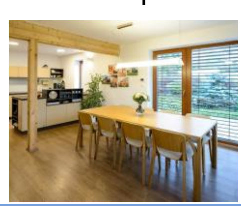
Building B

Building use

- “show house” of the construction company
- not inhabited
- excursions, visits

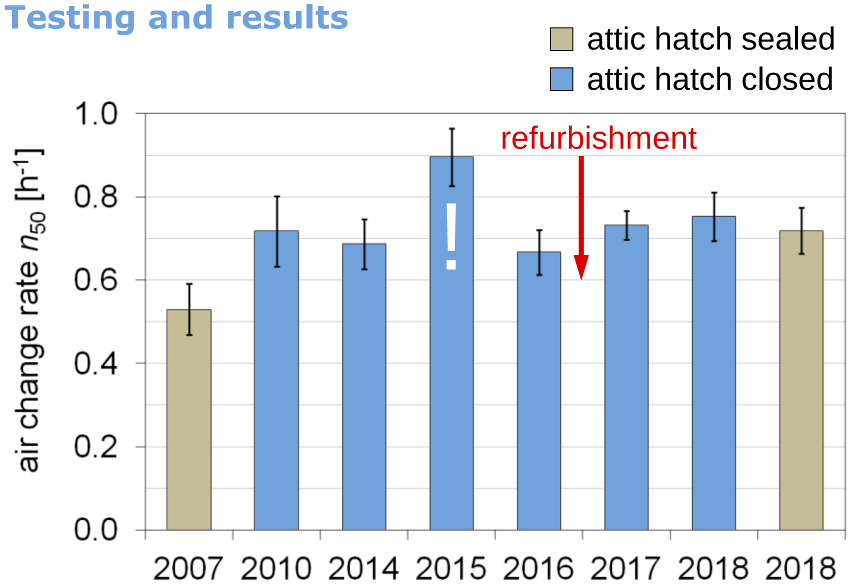
Service life

- no inhabitants – minimal interventions to the air barrier system
- round-robin tests of the A.BD.CZ – since 2010 (mech. load)
- partial refurbishment and equipment in 2016 (airtightness addressed, quality of workmanship controlled)



Building B

Testing and results



Building C

Building use

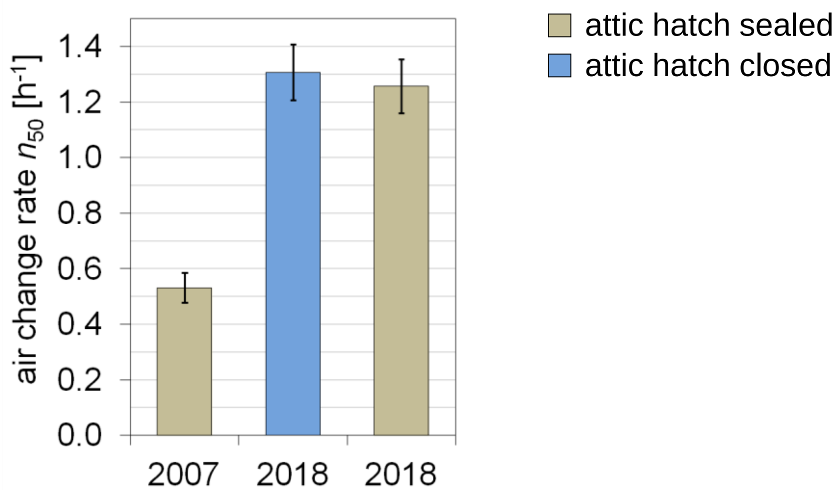
- training centre
- not inhabited
- conferences, workshops + accomodation

Service life

- installation of furniture in 2007 – no further information
- no inhabitants – minimal interventions to the air barrier system
- failure of sewage water pipework – between 2007 and 2018...
- improperly repaired – air barrier not sealed

Building C

Testing and results



Building D

Building use

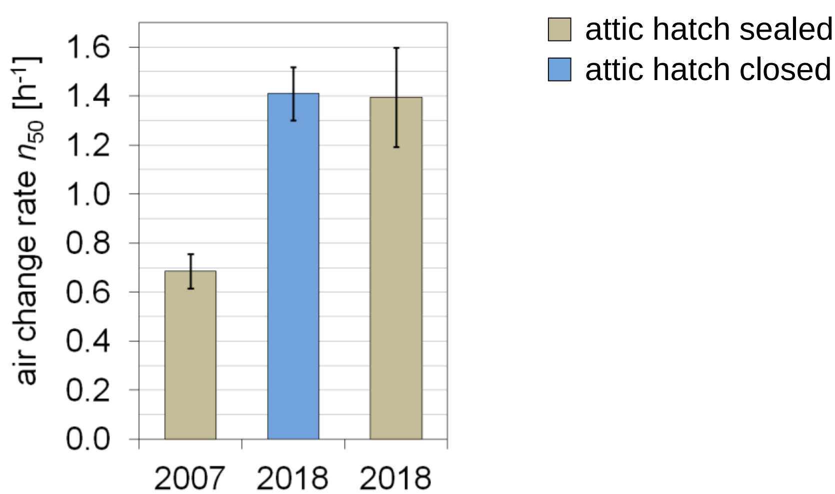
- single-family house
- inhabited since 2006
- 2 owners – not aware of airtightness

Service life

- installation of furniture in 2007 – no further information
- deep refurbishment before the 2nd owner moved in
- airtightness not addressed

Building D

Testing and results



Discussion

Buildings C and D

- the airtightness has deteriorated over the 11 years
- the n_{50} has increased of approx. 106 and 146 %
- despite a good quality of design and execution of the air barrier system

- consequence of later interventions to the air barrier system with no concern about airtightness

Discussion

Buildings A and B

- the airtightness has deteriorated over the 11 years
- the n_{50} has increased of approx. 36 %
- probably mostly consequence of ageing of products
- the n_{50} seems to increase mostly in the first years
- reasons remain unclear (probably not linked with rheology)
- airtightness has not changed since 2010
  → good long term performance can be achieved
- hygrothermal loads due to the presence of inhabitants seems not to be significant (ventilation system installed!)
- refurbishment of building B
  → interventions to the air barrier systems not necessarily deteriorates the airtightness if the work is executed properly

Conclusions

Prerequisites and threats for airtightness durability

	building			
	A	B	C	D
careful design of the air barrier system (ABS)	OK	OK	OK	OK
appropriate products for the ABS	OK	OK	OK	OK
careful and supervised execution of the ABS	OK	OK	OK	OK
control of the hygrothermal loads	OK	OK	OK	?
conscious users behaviour	OK	OK	?	?
competent interventions to the ABS	OK	OK	NO	NO
long therm performance achieved?	**OK**	**OK**	**NO**	**NO**

Thank you for your attention

Questions?

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Onsite evaluation of building airtightness durability

Long- term and mid-term field measurement study of 61 French low energy single family dwellings

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*bassam.moujalled@cerema.fr

Introduction

- The French ongoing research project **DURABILITAIR**
  - ✓ *to improve our knowledge on the variation of buildings airtightness through **onsite measurement campaigns** and accelerated ageing in laboratory controlled conditions*
- Literature review (task 1) showed an important evolution over time of the air permeability in real buildings, especially in the 3 first years
- The second task of the project deals with the quantification and qualification of the durability of building airtightness of single detached houses through **field measurement** at:
  - ✓ *mid-term scale (MT)*
  - ✓ *long-term scale (LT)*

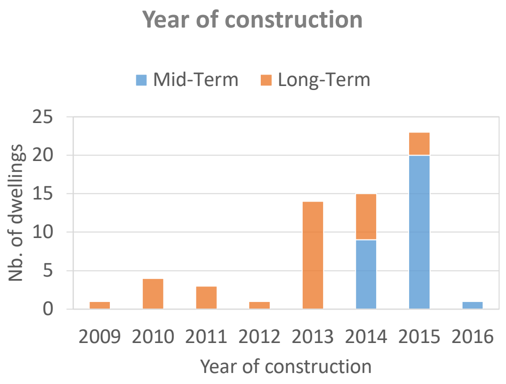
Methodology

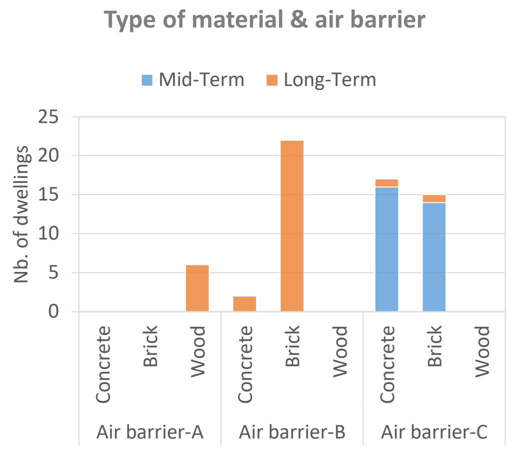
- MT and LT measurement campaigns based on two samples of single-detached low-energy dwellings:
  - ✓ *All dwellings measured upon completion and treatment of airtightness well known*
- MT measurement campaign (1-3 years):
  - ✓ *Sample of 30 new single-detached dwellings*
  - ✓ *The airtightness of each dwelling to be measured once per year over the 3-year period*
  - ✓ *Five dwellings to be measured twice per year (impact of seasonal variations)*
  - ✓ *For six dwellings, the airtightness of an installed window to be measured once per year over the 3-year period*

Methodology

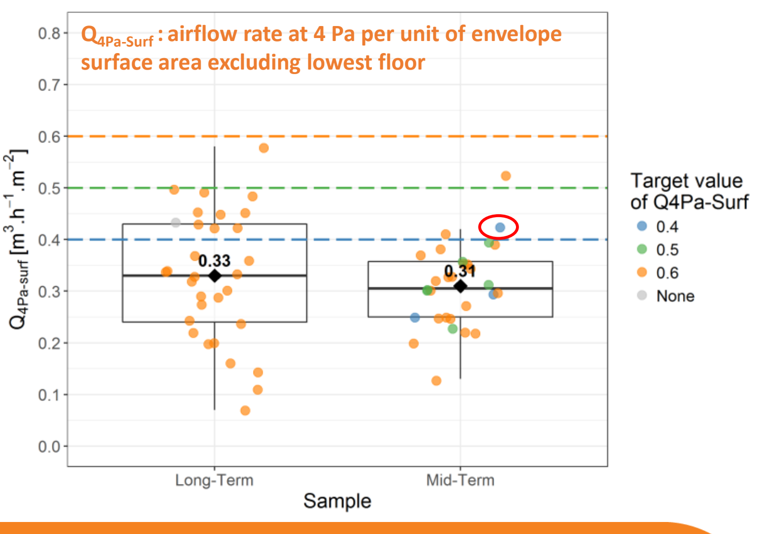
- LT measurement campaign (5-10 years):
  - ✓ *Sample of 32 single-detached dwellings constructed during the last 10 years*
  - ✓ *The airtightness of each dwelling measured once*
- Measurement protocol based on ISO 9972 and its French implementation guide, with additional requirements:
  - ✓ *Measurements to be performed under the same conditions as the measurement upon completion both in pressurization and depressurization*
  - ✓ *Detailed qualitative leakage detection to be performed*
  - ✓ *Questionnaires for occupants to be filled at each measurement regarding the action of the occupants on building envelope*

Results
Characteristics of buildings



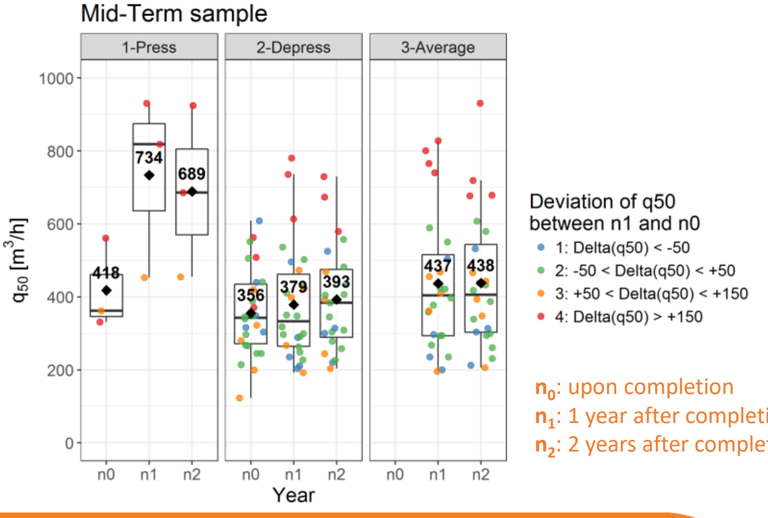


Results
Characteristics of buildings



Results of MT measurements

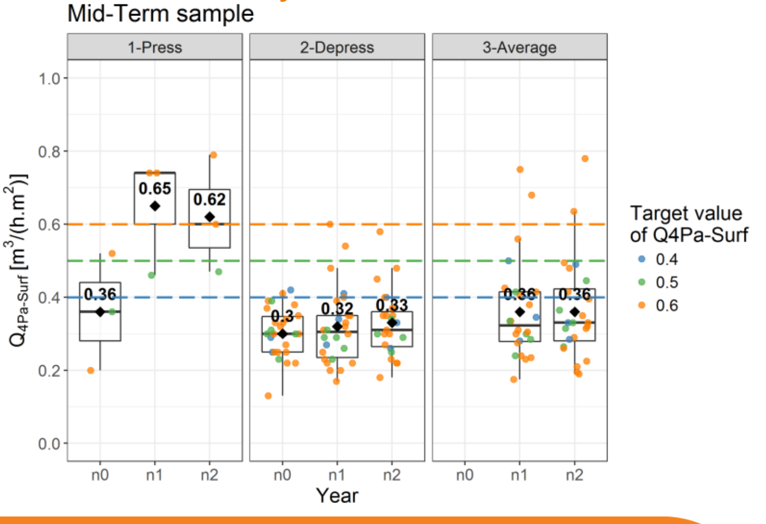
Evolution of q_{50}



n_0: upon completion
n_1: 1 year after completion
n_2: 2 years after completion

Results of MT measurements

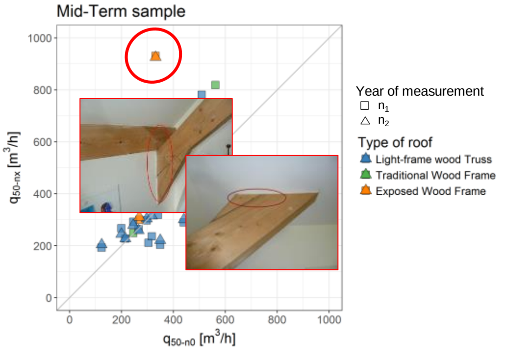
Evolution of $Q_{4Pa-Surf}$ vs. target value



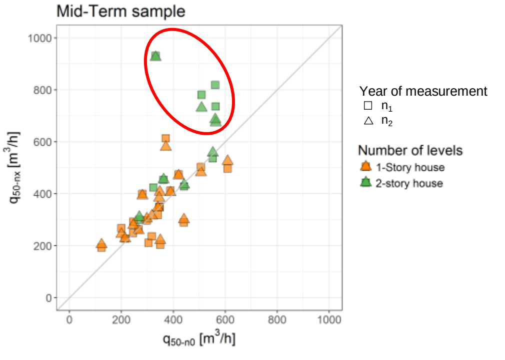
Results of MT measurements

Impact of roof type and levels number

Type of roof

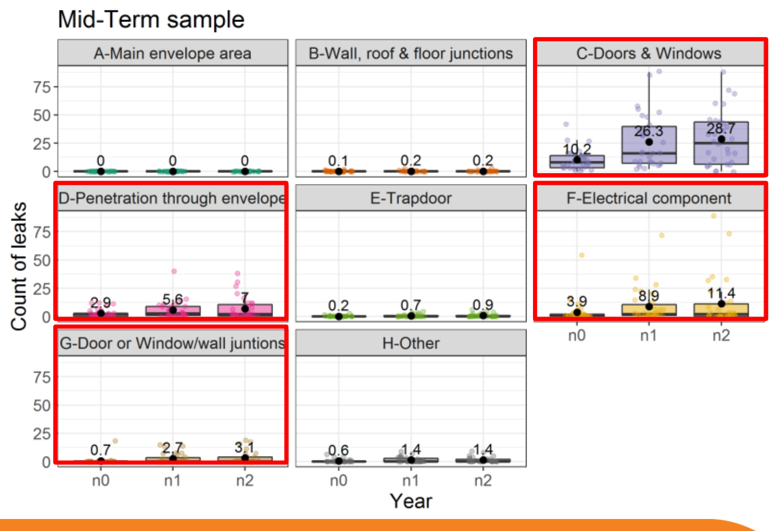


Number of levels



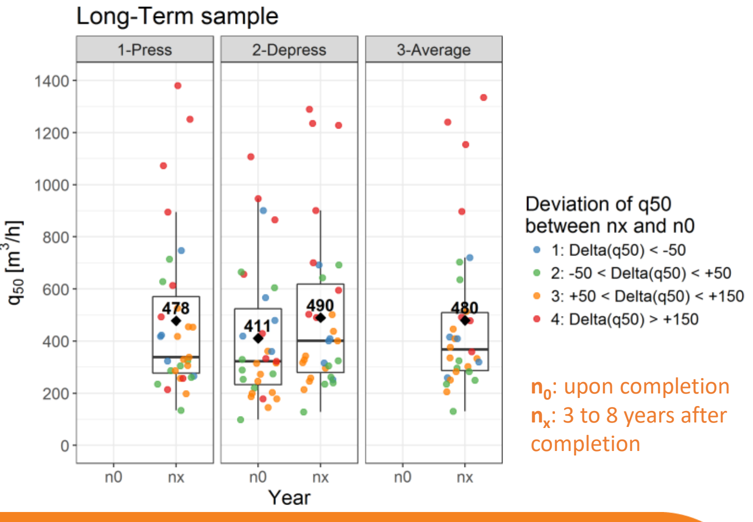
Results of MT measurements

Evolution of leaks



Results of LT measurements

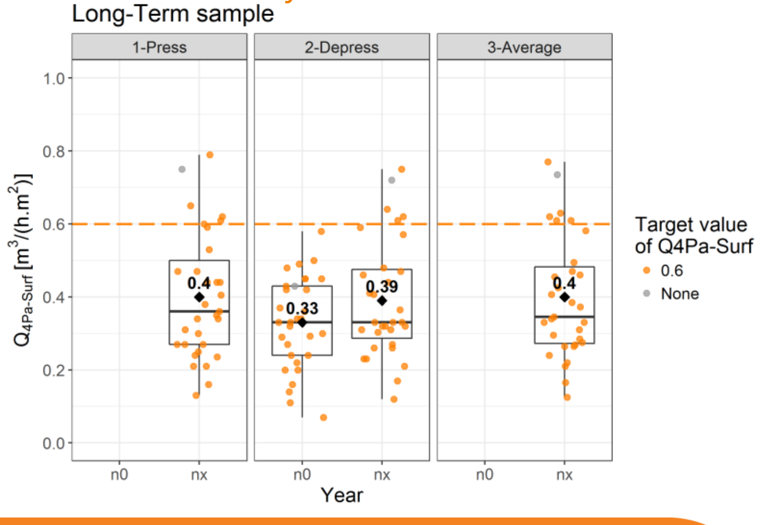
Evolution of q_{50}



n_0: upon completion
n_x: 3 to 8 years after completion

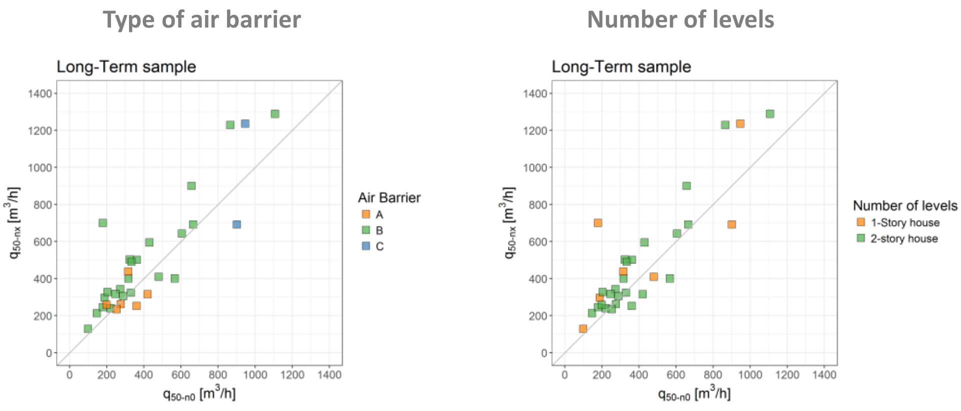
Results of LT measurements

Evolution of $Q_{4Pa\text{-}Surf}$ vs. target value



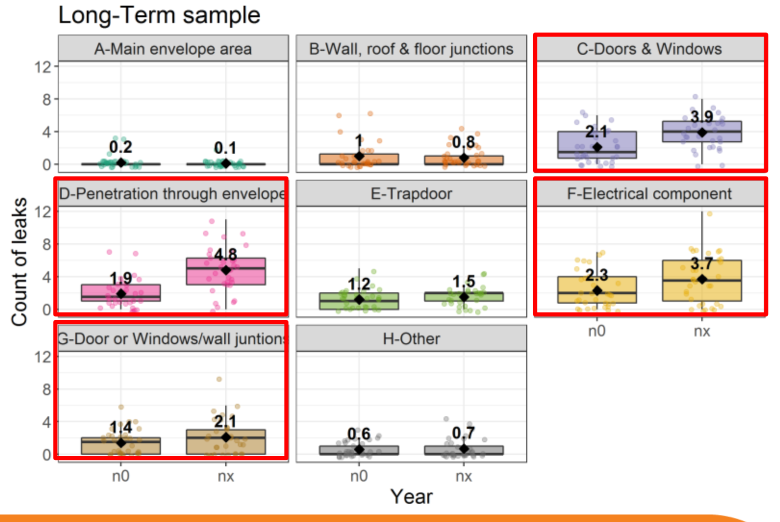
Results of LT measurements

Impact of roof type and levels number



Results of LT measurements

Evolution of leaks



Conclusions

- **Mid-term sample (1-3 years):**
  - ✓ Slight increase of q_{50} with an average increase of +16% and a median value of +6%
  - ✓ Strong increase of q_{50} in the case of a 2 -story house with an exposed wood frame roof
- **Long-term sample (3-8 years):**
  - ✓ More important increase of q_{50} than MT sample with an average and a median value around 28%
  - ✓ The increase in building air permeability is less important than in the previous studies

Conclusions

- **Significant increase of the number of leakages for:**
  - ✓ doors and windows
  - ✓ electrical components
  - ✓ penetrations through envelope
  - ✓ junctions between walls and doors/windows
- **The measurement campaigns and data analysis will continue in 2019** *(seasonal variation, the durability of airtightness of installed windows, correlation between the leakages and the air leakage rate)*

Thanks…

Projet DURABILIT'AIR

Lauréat de l'Appel à Projets de Recherche 2015 « vers des Bâtiments Responsables à l'Horizon 2020 »

avec le financement de

Vitor E.M. Cardoso,
Nuno M.M. Ramos,
Ricardo M.S.F. Almeida,
Pedro F. Pereira,
Manuela Almeida and
Rui Sousa

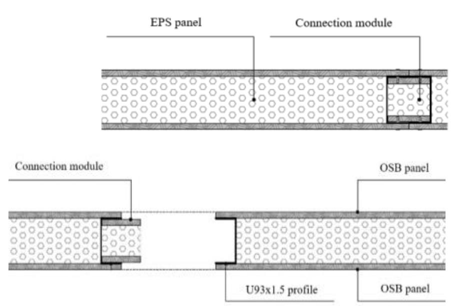
In-situ and laboratory airtightness tests of structural insulated panels assemblies

OBJECTIVES

- **Assessment of the airtightness offset between the finished wind barrier construction stage and the commissioning stage**
- **Comparison of the airtightness performance in laboratory and field application of the SIPs envelope solution**

Essential requirements of ETAGs on SIPs highlight as the main issues in air permeability assessment :

- energy economy
- cold draughts
- water vapour condensation



Laboratory specimens and tests

Wall assembly: 360x300 cm^2

Window: 55x70 cm^2

Joint sealing: continuous mastic strand

Interior surface: unfinished

Exterior surface: finished

Standard: EN 12114-2000

Temperature: 15-16 ºC

Relative humidity: 55-60 %

Equipment: Integrated electromechanical system

In situ case study and tests

Typology: Single floor SIPs dwelling

Slab: reinforced concrete

Walls and roof: SIPs

Exterior openings: side hung aluminium frames

Mechanical exhausts: kitchen and bathrooms

Natural grilles: living room and laundry

Standard: EN13829-2000

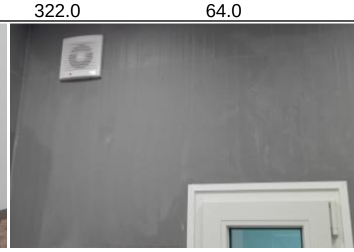
Equipment: Retrotec1000 model

Construction stage: method B

- Envelope assembled and exterior coating applied
- Interior plasterboard connections not sealed

Commissioning stage: methods A and B

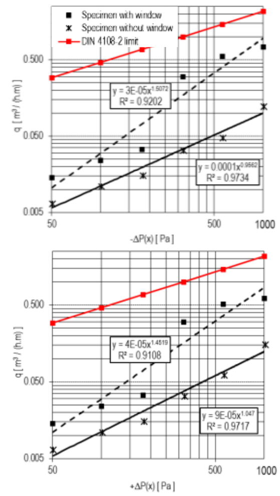
Floor area [m^2]	*Volume [m^3]*	*Envelope area [m^2]*	*SIPs – windows joints length [m]*	*Internal SIPs joints length [m]*
103.0	319.3	322.0	64.0	329.5



Results and Discussion

- Wall assembly: joints contribution of 0.0048 m3/(h.m) at 50 Pa
- With added window: joints contribution of 0.0113 m3/(h.m) at 50 Pa
  - Mainly justified by window permeability
  - Good performance according to DIN4108-2

In situ building stage	n_{50} *[h^{-1}]*	q_{50} *[m^3/(h.m^2)]*
Construction - method B	2.49	2.47
Commissioning - method A	1.98	1.96
Commissioning - method B	1.55	1.54



- In situ case study is far less airtight than the laboratory results suggest
- 37.8% reduction from construction to commissioning stage (method B)
- Interior finishing works improved the envelope airtightness
- Purpose openings contribute with only 21% of the total air change rate

Conclusions

- The SIPs envelope system complies with the requirements of DIN 4108-2 standard.
- <u>In Portugal SIPs can be an alternative to the traditional heavy construction solutions</u>
- Overall airtightness performance is highly influenced by workmanship and unforeseen air paths
- Airtightness laboratory results should not be the only method to evaluate real case performance
- <u>Airtightness laboratory results should be perceived as an optimum benchmark for the comparison and selection between building envelope solutions</u>

39th AIVC - 7th TightVent & 5th venticool Conference

Smart ventilation for buildings

18-19th, September 2018, Antibes Juan-Les-Pins

Development and test of quality management approach for ventilation and indoor air quality in single-family buildings

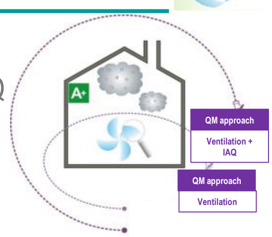
Sandrine Charrier, Gaëlle Guyot, Romuald Jobert, François-Rémi Carrié and Claire-Sophie Coeudevez

Sandrine Charrier
DGAC/SNIA
Ex- Cerema - Centre-Est

Topical Session: Commissioning of ventilation systems
Improving quality and installed ventilation systems

Structuration of quality management (QM) approaches

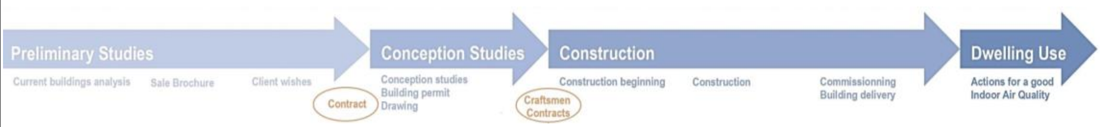
- 2 QM approaches:
  - one dedicated to ventilation and one to ventilation and IAQ



- Structuration of QM approaches
  - Who?

QM approach headmaster | Engineering department salesperson | Engineering departments | Final user Client | Site supervisor | Craftsmen | Independant Assessor

  - When?



Structuration of QM approaches

- Structuration of QM approaches
  - **What?** Main steps of a QM approach application

Preliminary Studies — Current buildings analysis, Sale Brochure, Client wishes, Contract

Conception Studies — Conception studies, Building permit, Drawing, Craftsmen Contracts

Construction — Construction beginning, Construction, Commissionning, Building delivery

Dwelling Use — Actions for a good Indoor Air Quality

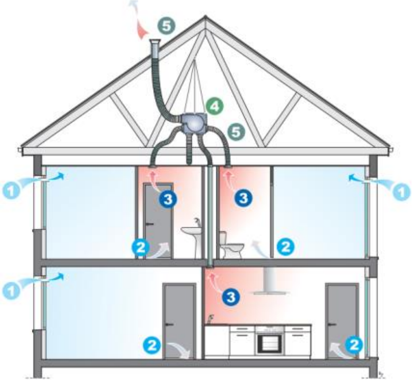
☆ Current performances analysis
☆ QM approach objectives
☆ Buildings involved in QM approaches
☆ Conception and construction tools (drawing details, …)
☆ Training (engineering departments, site supervisors, craftsmen)
☆ Actors involvement
☆ Site supervision
☆ Correction of non-compliant points
☆ Measures
☆ Final user awareness

QM approach board, correction of non-compliant points and improvements

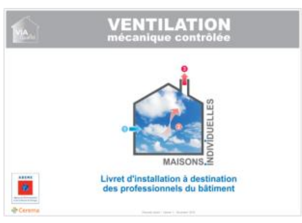
3 tools implemented

- **Tool 1: Guide for single-family house builder**
  - The result of the whole VIA Qualité project

- **Tool 2: Guide for installers, technical drawings**

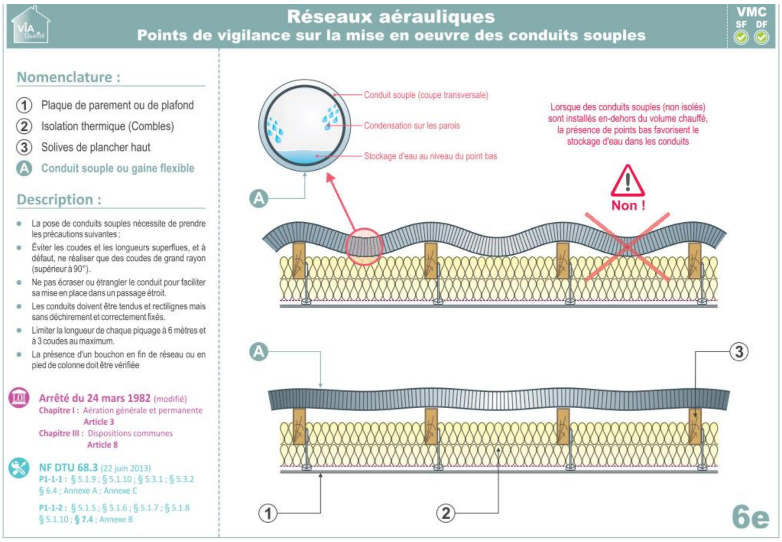


1 Air inlet
2 Air transfer
3 Air exhaust
4 Ventilation unit
5 Ductwork



3 tools implemented

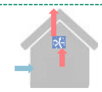
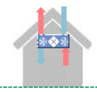
- Tool 2: Guide for installers, technical drawings



3 tools implemented

- Tool 3: Guide for final users

Implementation on 8 single-family buildings

- **Sample selection**
  - 2 single-family houses builders
  - Both have a certified QM approach on building airtightness
  - **For each builder**, **4 dwellings**:
    - 3 with simple exhaust humidity demand-controlled ventilation  * 6
    - 1 with balanced ventilation  * 2

    and

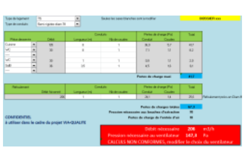
    - 3 apply the ventilation QM approach  * 6
    - 1 applies the ventilation and IAQ QM approach  * 2

Implementation on 8 single-family buildings

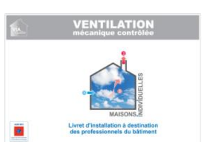
- **The way builders implemented QM approaches**

Conception
- Site analysis tool

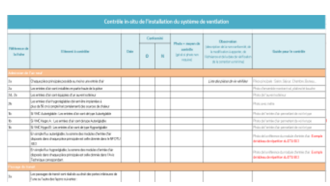
- Simplified pressure drop calculation



Training
- Engineering departments and site supervisors
- Craftsmen



Site supervision board



Final users information

Results

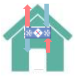
Ventilation system measures

Table: Comparison of the 8 dwellings results with the 21 houses first campaign results

	7 dwellings with QM approach	21 dwellings without QM approach
Minimum exhaust airflow	No over-ventilated dwelling 2 regulatory airflows 5 under-ventilated dwellings	3 over-ventilated dwelling 4 regulatory airflows 14 under-ventilated dwellings
Mean value of non-compliant points	3.7	3.6
Defaults points	Fan : 35% Air exhaust : 23% Ducts : 19% System configuration : 12% Air transfer : 8% Air inlet : 4%	Fan : 24% Air exhaust : 31% Ducts : 15% System configuration : 15% Air transfer : 5% Air inlet : 11%
% duct airtightness class ≤ A	72%	50%
Duct airtightness class	1 class B (15%) 4 class A (57%) 2 out of class A (28%)	2 class B (8%) 10 class A (42%) 12 out of class A (50%)

IAQ measures

- 1 dwelling with good results
- 1 dwelling with bad results



Feedbacks

Sample	- Too small (4 dwellings/builder)
Timing	-- Difficulty to match project timing with dwellings one
Keys steps	+++
Involvement, motivation	+++ / -
Training	+++
Conception	+++ Pressure drop calculation Modification French technical standards
Site supervision	+++ / -
Feedbacks	+++ / -

Conclusion

- **Time difficulties**
- **But, QM approaches enabled to:**
  - **Identify key steps and highlight key rules**
  - **Implement and test key tools** (3 guides, a simplified pressure drop calculation tool and a site supervision document)
- **Positive feedbacks**
  - **Training**
  - **Tools implemented with and for builders**
- **The project enabled to help the beginning of the transformation of French professionnals on the subjects of ventilation and IAQ**

39th AIVC - 7th TightVent & 5th venticool Conference

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Thank you for your attention

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Other VIA Qualité publications:

- *Jobert R, Guyot G (2013) Detailed analysis of regulatory compliance controls of 1287 dwellings ventilation systems, 34th AIVC Conference, Athens, Greece, 2013, 10 p.*
- *Guyot G, Bailly A, Bernard A-M, Perez G, Coeudevez C-S, Déoux S, Berlin S, Parent E, Huet A, Berthault S, Jobert R, Labaume D, Ferrier G, Justet S (2015). Ventilation performance and indoor air pollutants diagnosis in 21 French low energy homes, 36th AIVC Conference, Madrid, 2015, 9p.*

Applications of the Promevent protocol for ventilation systems inspection in French regulation and certification programs

Adeline Mélois and Laure Mouradian

PROMEVENT project: 2014-2017

- 8 French partners:

Cerema, CETIAT, ALLIE'AIR, CETII, PBC Pierre Barles Consultant, effinergie, ICEE, PLEIAQ

- Funding received by:

ADEME – Agence de l'Environnement et de la Maîtrise de l'Energie

Ministère de l'Environnement, de l'Énergie et de la Mer – Ministère du Logement et de l'Habitat Durable

PROMEVENT project: 2014-2017

- **Objective: improve the quality of ventilation systems controls**
- **Method: analysis and test of protocols regarding:**
  - visual checks
  - pressure differences and airflow at air vents
  - ductwork airleakage
- **Scope:**
  - Dwellings: single-family houses & multi-family dwellings
  - balanced ventilation & single humidity demand-controlled ventilation

REQUIREMENTS OF THE PROMEVENT PROTOCOL

Define checks and measurements to perform

Pre-check

<u>Study of several documents:</u>
- control **completeness**
- collect **needed data**
- identify **where to perform** checks and measurement (sampling rules)
- list **missing data**
- identify when **no complying** with relevant regulations or standards.

REQUIREMENTS OF THE PROMEVENT PROTOCOL

Define checks and measurements to perform

Pre-check

Output data from pre-check

On-site follow-up of pre-check
(Collect of missing information)

Functional checks

Check whether, for the ventilation system:

- all components installed and in good condition
- system installed correctly in accordance with design specifications, relevant regulations and standards
- system free from loose objects and clean
- adequate access for operation and maintenance
- all controls readily accessible
- all components present and installed as required in the design specifications:
  - externally mounted air transfer devices
  - internally mounted air transfer devices
  - ducted air terminal devices (inside)
  - ductwork
  - air handling unit including heat recovery system and filters
  - air intake and discharge openings

REQUIREMENTS OF THE PROMEVENT PROTOCOL

Define checks and measurements to perform

Pre-check

Output data from pre-check

On-site follow-up of pre-check
(Collect of missing information)

Functional checks

and/or

Functional measurements at ATDs

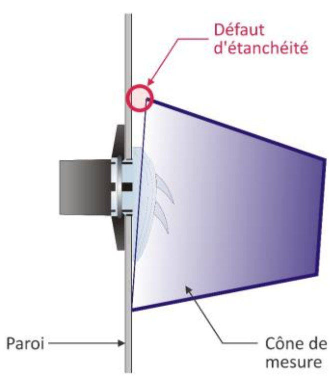
- measurement conditions (closed windows and doors, the settings at ventilation unit and at the ATDs)
- measurement principle (types of measuring instrument, minimum duration of the measurement, the position of the instrument)
- relevant corrections to apply
- uncertainty for airflow measurements:
  - MPE ≤ 10%
    total maximum uncertainty = 15%
  - OR total uncertainty precisely evaluated and under 15%
- uncertainty for pressure measurements:
  - MPE ≤ 3%/0.5 Pa
    total maximum uncertainty = 10%/5 Pa
  - OR total uncertainty precisely evaluated and under 10%/5 Pa

ENTS OF THE PROMEVENT PROTOCOL

	Extraction		Soufflage		
One-point thermal anemometer + hood	✓	✓	✗	✗	✗
Checkered thermal anemometer + hood	✓	✓	✓	✓	✗
Pitot tube + powered flow hood	✓	✓	✓	✓	✓
Propeller anemometer + hood	✓	✓	✓	✓	✗
Propeller anemometer + hood with extension	✓	✓	✓	✓	✓

REQUIREMENTS OF THE PROMEVENT PROTOCOL

- **Recommandations from on-site and laboratory campaings**



errors on the measured airflow up to 30%.

errors on the measured airflow up to 50%.

REQUIREMENTS OF THE PROMEVENT PROTOCOL

Define checks and measurements to perform

Pre-check

Output data from pre-check

On-site follow-up of pre-check
(Collect of missing information)

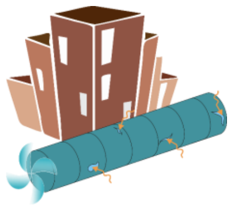
Functional checks

and/or

Functional measurements at ATDs

and/or

Special measurement ductwork airtighness



Supplements to the French national standard FD E51-767

- Defines new **sampling rules**
- Specifies how to **prepare ATDs**
- Specifies how to **prepare unit connections**
- Defines a **penalty coefficient** to correct measurement results
- Defines a fixed **leakage airflow rate of ventilation unit** (single-family house) to deduced

REQUIREMENTS OF THE PROMEVENT PROTOCOL

Define checks and measurements to perform

Pre-check

Output data from pre-check

On-site follow-up of pre-check
(Collect of missing information)

Functional checks

and/or

Functional measurements at ATDs

and/or

Special measurement ductwork airtighness

Report drawing up

REQUIREMENTS OF THE PROMEVENT PROTOCOL

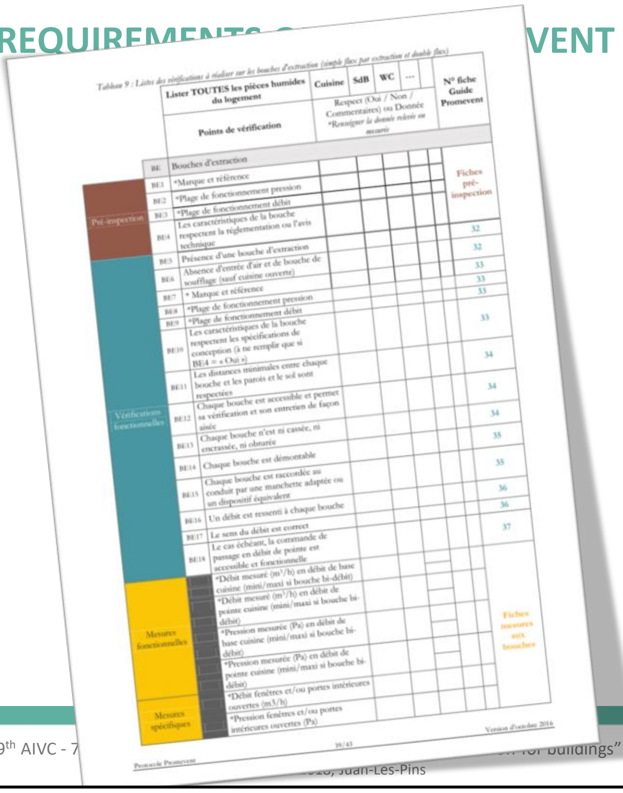


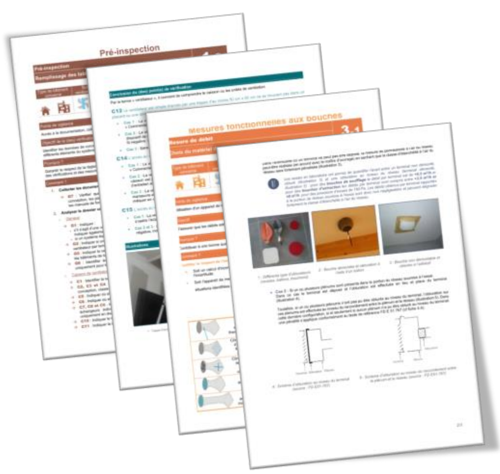
Tableau 9 : Listes des vérifications à réaliser sur les bouches d'extraction (simple flux par extraction et double flux)

		Lister TOUTES les pièces humides du logement / Points de vérification	Cuisine	SdB	WC	…	N° fiche Guide Promevent
			Respect (Oui / Non / Commentaires) ou Donnée *Renseigner la donnée relevée ou mesurée				
	BE	Bouches d'extraction					
Pré-inspection	BE1	*Marque et référence					Fiches pré-inspection
Pré-inspection	BE2	*Plage de fonctionnement pression					
Pré-inspection	BE3	*Plage de fonctionnement débit					
Pré-inspection	BE4	Les caractéristiques de la bouche respectent la réglementation ou l'avis technique					32
Vérifications fonctionnelles	BE5	Présence d'une bouche d'extraction					32
Vérifications fonctionnelles	BE6	Absence d'entrée d'air et de bouche de soufflage (sauf cuisine ouverte)					33
Vérifications fonctionnelles	BE7	* Marque et référence					33
Vérifications fonctionnelles	BE8	*Plage de fonctionnement pression					33
Vérifications fonctionnelles	BE9	*Plage de fonctionnement débit					33
Vérifications fonctionnelles	BE10	Les caractéristiques de la bouche respectent les spécifications de conception (à ne remplir que si BE4 = « Oui »)					34
Vérifications fonctionnelles	BE11	Les distances minimales entre chaque bouche et les parois et le sol sont respectées					34
Vérifications fonctionnelles	BE12	Chaque bouche est accessible et permet sa vérification et son entretien de façon aisée					34
Vérifications fonctionnelles	BE13	Chaque bouche n'est ni cassée, ni encrassée, ni obturée					35
Vérifications fonctionnelles	BE14	Chaque bouche est démontable					35
Vérifications fonctionnelles	BE15	Chaque bouche est raccordée au conduit par une manchette adaptée ou un dispositif équivalent					36
Vérifications fonctionnelles	BE16	Un débit est ressenti à chaque bouche					36
Vérifications fonctionnelles	BE17	Le sens du débit est correct					37
Vérifications fonctionnelles	BE18	Le cas échéant, la commande de passage en débit de pointe est accessible et fonctionnelle					
Mesures fonctionnelles		*Débit mesuré (m³/h) en débit de base cuisine (mini/maxi si bouche bi-débit)					Fiches mesures aux bouches
Mesures fonctionnelles		*Débit mesuré (m³/h) en débit de pointe cuisine (mini/maxi si bouche bi-débit)					
Mesures fonctionnelles		*Pression mesurée (Pa) en débit de base cuisine (mini/maxi si bouche bi-débit)					
Mesures fonctionnelles		*Pression mesurée (Pa) en débit de pointe cuisine (mini/maxi si bouche bi-débit)					
Mesures fonctionnelles		*Débit fenêtres et/ou portes intérieures ouvertes (m3/h)					
Mesures spécifiques		*Pression fenêtres et/ou portes intérieures ouvertes (Pa)					

Protocole Promevent 39/43 Version d'octobre 2016

www.promevent.fr

PROMEVENT Practical Guide



www.promevent.fr

- 2 cards on pre-check
- 40 cards on functional checks
- 4 cards on functional measurement
- 7 cards on ductwork airtightness measurement

Application in French regulation and Certification programs

- **Largely accepted and becoming the national reference**
  - Various partners
  - Public funding
  - Consultation of various professionals during the project

- **2 regulatory applications:**
  - “bonus of constructability” (2016)
  - “public buildings showing exemplary energy and environmental”(2016).

Application in French regulation and Certification programs

- **Certification programs and others programs:**
  - Effinergie labels: application of Promevent protocol by an independent and state-approved measurer
  - Reference document of the French national indoor air quality observatory (OQAI) refers to the Promevent method
  - Certification organism CERQUAL Qualitel Certification has included the Promevent protocol in its reference document.

effinergie
Observatoire de la qualité de l'air intérieur
CERQUAL QUALITEL CERTIFICATION

Application in French regulation and Certification programs

- **Complementary step for application:**

Define how to analyze results of a diagnostic for conformity

- Functional Check:
  - Regulatory enforcement verification point
  - Check point for the application of good practices
  - Acceptable tolerance
- Functional measurements:
  - Define reference values Min/Max
  - Tolerances application

Support for training and standardization

- **Training:**
  - included in the Praxibat training course
  - Will be presented in a MOOC dedicated to indoor air quality and buildings ventilation

PRAXIBAT
La formation par la pratique

- **Standard**
  - used during the reviewing of the European standard prEN 14134 *Ventilation for buildings - Performance testing and installation checks of residential ventilation systems*

PromevenTertiaire 2018-2021

- **Protocol for ventilation systems inspection in non-residential buildings**
  - 3 years projects : 9 French partners
  - Funding from :

PromevenTertiaire

- **On Site Campaign**
  - Office, school and/or hotels new buildings
  - 3 buildings to test protocol application robustness
  - 4 different measuring teams
- **Laboratory tests**
  - Calibration
  - Uncertainties evaluation
- **Impact of observed dysfunctions**
- **Final result: Protocols + Guidebook**

Complementary projects to promevent

- **Vnat project,**
  - Protocol for inspection of hybrid ventilation systems in dwellings
- **Assessment of natural and hybrid ventilation systems performance for low energy buildings**
  - PhD work of G. Remion

Thanks

adeline.melois@cerema.fr

Cerema

AIVC TightVent Europe venticool

Presentation of a national consultative body on ventilation issues: actors, working groups and projects overview

Gaëlle Guyot, Andrés Litvak,
Romuald Jobert, and Laurent Deleersnyder

Cerema, France

Fédérer les acteurs de la ventilation

CLUB Ventilation

Outline

1. **Background in France**
2. **Construction of a national consultative body on ventilation issues**
3. **A massive online open course**
4. **A website as a ressource centre**
5. **Conclusion**

1. Background in France – *EP and airing regulations*

- **The EP regulation (RT2012) generalizes low energy dwellings (~50 $kWh_{ep}/m^2/y$)**
  - Envelope airtightness requirement for single-family dwellings:
    - $q_{a4} \leq 0.6\ m^3/h/m^2 \cong n_{50} \leq 2.3\ h^{-1}$
    - Justification : measurement or quality management approach
- **Dwellings ventilation is concerned by another 30 year-old regulation (1982-1983)**
  - Compulsory general layouts of ventilation installation (doors undercut, …)
  - Exhaust airflows in each humid room
    - Depending on the number of humid and main rooms of the dwelling
    - => 6 – 9 L/s/pers in a 4 bedroom-dwelling
    - Can be reduced in case of DCV systems
  - No compulsory procedure at commissioning

1. Background in France – *State of the art*

- **Most of the new dwellings: Humidity-based DCV**
  - Rewarded in the EP calculation
- **An agreement procedure for each DCV system**
  - A multizone modelling using conventional entry data (weather, dwellings, occupancy, …)
  - Per room, over the heating period :
    - CO_2 cumulative exposure indicator E_{2000} < 400.000 ppm.h
    - Number of hours $T_{RH>75\%}$ < 600 h in kitchen, 1000 h in bathrooms, 100 h in other rooms
- **The manufacturer describes for each system and for each size of dwelling, the configuration (type and number of exhaust devices + trickle ventilators) to be used**

1. Background in France – *On site ventilation performance*

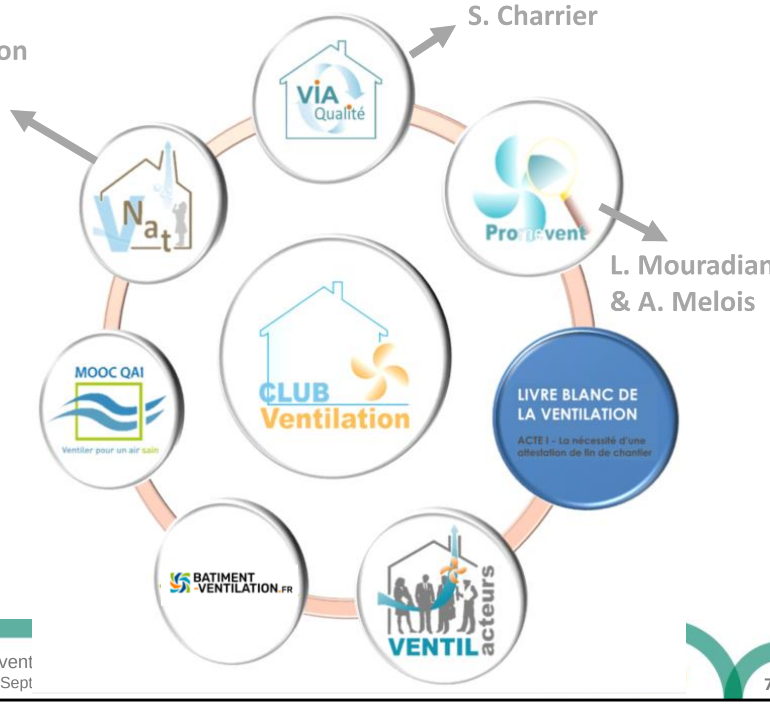
- **In France, since more than 20 years, 50% of buildings have non-compliant ventilation systems**
  - **Including 40% of controlled buildings with insufficient air change rates (ORTEC, 2009)**
- **Statistics on 1287 French new dwellings (Jobert, 2012) :**
  - **68% of single family dwellings of the sample have non-compliant ventilation systems**
- **Not better on low-energy houses**
  - A campaign on 21 low-energy houses (Guyot et al, 2015)
  - No house comply fully with the 2 regulations, 3.6 dysfunctions per house !
  - Shared responsibilities :
    - 43 % due to a poor design
    - 55 % due to a poor onsite installation
    - 2% due to a inappropriate using / maintenance by final user
- **=> Organisational issues due to multiple interactions between professionals during the construction phase**

2. Construction of a national consultative body on ventilation issues

- **2015 : the French ministry in charge of construction decided to invite all major actors of the ventilation field to join the"Club Ventilation"**
- **45 participants:**
  - building manufacturers, building managers, craftsmen, building companies,
  - label and certification and ventilation manufacturers representatives,
  - but also specialists of the ventilation field including training organisations, public agencies, engineering consultants.
- **Aims:**
  - To coordinate and propose projects and studies, their results, and new proposals;
  - To propose reference texts and follow normative evolutions;
  - To support and train professionals;
  - To bring together actors;
  - To bring about a change in ventilation systems design, mounting, use and maintenance.
- **Plenary meetings: 4 to 5 times a year + working groups**

2. Construction of a national consultative body on ventilation issues

- Connected key achievements



2. Construction of a national consultative body on ventilation issues

- The Ventil'acteurs project

- Aim
  - mobilize all the actors from building's sector in order to propose an action plan to eradicate each of the dysfunctions

- Mean:
  - collect advice and recommendations from all professional of the field trough a survey :
  - https://docs.google.com/forms/d/e/1FAIpQLSdoO_308O_DvbINgsCh-FI708Cfp14HRFfpKT6S4zFKcTIXaQ/formResponse

⇒ **A shared overview of pitfalls and difficulties with areas of improvement.**

⇒ **Then, propose an action plan to provide more reliable and performing ventilation installations in residential buildings.**

Ventilation des logements - Enquête sur la qualité des installations de VMC* dans les logements neufs

* Ventilation Mécanique Contrôlée

Agir pour la qualité des installations de ventilation

Point de départ de la réflexion collective du projet VENTIL' acteurs sur l'analyse des dysfonctionnements généralement constatés dans les installations de ventilation des bâtiments du secteur résidentiel

Le présent questionnaire est destiné à dresser un premier état des lieux et à prioriser les axes de travail

D'avance merci pour votre concours !

Pourquoi le projet VENTIL' acteurs ?

Si les systèmes de ventilation mécanique actuels sont théoriquement capables de contrôler les débits d'air neuf nécessaires au confort hygiénique et hygrothermique des occupants, il apparaît dans de nombreux retours terrain que la qualité des installations n'est pas toujours au rendez-vous dans les différents processus de conception, de mise en oeuvre, d'utilisation et de maintenance des systèmes de ventilation utilisés dans les bâtiments résidentiels.

Pourtant, la qualité de ces installations constitue un élément essentiel pour aboutir à un air intérieur de qualité. Elle pèse aussi considérablement sur la performance énergétique des logements.

Fort de ce constat, l'ADEME et la Direction de l'Habitat, de l'Urbanisme et du Paysage (DHUP) ont confié au Cerema, l'animation d'une réflexion avec l'ensemble des acteurs de cette filière pour identifier les causes profondes de ces dysfonctionnements et imaginer des pistes de progrès, organisationnels et technologiques.

Ce questionnaire constitue le point de départ de la réflexion collective du projet VENTIL' acteurs sur l'analyse des dysfonctionnements généralement constatés sur les installations de ventilation des bâtiments du secteur résidentiel.
Vos réponses, que nous espérons nombreuses, permettront de dresser un premier état des lieux de cette situation afin de prioriser les axes de travail à mettre en place.

D'avance, nous vous remercions pour votre participation !

SUIVANT

Page 1 sur 10

N'envoyez jamais de mots de passe via Google Forms.

2. Construction of a national consultative body on ventilation issues

- **The "Livre blanc – Acte I" proposes:**
  - A compulsory certificate at the end of the construction work for any new building or major refurbishment with new ventilation installation
  - Certificating that airing regulation has been taken into account
    - Based on visual checks and airflows measurements on a sample
    - According to a technical baseline as the Promevent protocol (residential)
    - Accepting cost + existing protocol : January 2019 fro residential sector ?

2. Construction of a national consultative body on ventilation issues

- **The "Livre blanc – Acte I" includes Appendices**

A. State of the art of ventilation installations and indoor pollution

B. Socio-economic impacts of the proposed measure

C. Survey about recognized tools, publications and technical guidelines about ventilation installations

3. A Massive Open Online Course on IAQ & Ventilation

- A MOOC, entitled "Ventilation: the keys to control indoor air quality", open to all actors of the building sector (including occupants)

- the MOOC is sequenced into 5 sections (corresponding to 5 weeks, each of them being divided into 3 modules), according to the following program:
  A. IAQ and regulations in the building sector
  B. Ventilation and regulations in French buildings
  C. Design of a ventilation system in Residential
  D. To control a ventilation system and analyze the IAQ
  E. Implementation of actions promoting a good IAQ

A MOOC is a course of study made available over the Internet without charge. It is a free Web-based distance learning program designed for the participation of large numbers of geographically dispersed students.

MOOC QAI
Ventiler pour un Air Sain

Created by Cerema, Atipee

Financed by PACTE, ADEME

3. A Massive Open Online Course on IAQ & Ventilation

- **The educational objectives of the MOOC consist in better knowing:**
  - the sources of indoor pollutants, ventilation systems and air treatment
  - the health and economic issues related to a good IAQ
  - the regulations on IAQ and ventilation in buildings
  - the design and implementation rules of a ventilation system in residential buildings
  - the pathologies associated with the incorrect implementation of ventilation systems and to understand their impacts
  - the keys to healthy ventilation and IAQ
  - the principles of measurement audits, analysis methods, protocols of measurement and sampling procedures
  - the ways to improve IAQ
  - IAQ management methods (commissioning)

Created by Cerema, Atipee

Financed by PACTE, ADEME

3. A Massive Open Online Course on IAQ & Ventilation

- The MOOC will be hosted by the end of 2018, on the platform FUN of ADEME dedicated to Sustainable Buildings (https://www.mooc-batiment-durable.fr/).
- Launched by ADEME and Plan Bâtiment Durable from Ministry of Ecology and Solidarity Transition, the platform has two objectives:
  - the growing competence of the professionals of the building industry and real estate on the themes of the energy transition and sustainable building in general (construction and renovation),
  - the dissemination to the general public, to a knowledge of the issues related to green building, in particular, the energy renovation of housing.

MOOC QAI
Ventiler pour un Air Sain

Created by Cerema tipee

Financed by PACTE ADEME

4. A website as a ressource center : batiment-ventilation.fr

- The need for a reference resource centre internet platform was raised by the Club Ventilation
- The overall objective of the project is to provide a set of online resources (regulatory information, baseline studies, feedback,...) to the attention of all the professionals of the construction on the subject of ventilation, both for new construction and for refurbishment.
- An inventory of existing resources will be done throughout a database. The Club Ventilation will be consulted.
- The website will be online in early 2019

BATIMENT-VENTILATION.FR

Financed by PACTE République Française

Created by Cerema CETIAT

4. A website as a ressource center : batiment-ventilation.fr

- **Type of Ressources :**
  Online articles / Factsheets / SERIOUS GAME / MOOC / FAQ
- **Contents of the site :**
  - A comprehensive and up-to-date information concerning the current regulations.
  - A comprehensive and accessible presentation to all audiences target of the technical principles of ventilation;
  - A bibliography extended studies and guidebooks on the topic of ventilation;
  - A frequently asked questions (FAQ);
  - A reformatting of existing content to make them suitable for a website.
  - Interactive content ("serious games") to promote the site;
  - Regular news.

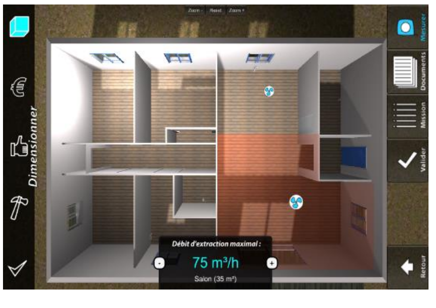
BATIMENT -VENTILATION.FR

Financed by

Created by

4. A website as a ressource center : batiment-ventilation.fr

- **SERIOUS GAME : *« ventilgame »***



- A serious game is a game designed for a primary purpose other than pure entertainment.
- The idea shares aspects with educational simulation generally, including flight simulation and medical simulation, but explicitly emphasizes the added pedagogical value of fun and competition.

VENTILGAME is intended to be a tool for promoting Ventilation Resource Centre. It has the ambition of e–informing actors of the building sector on the physical quantities essential to the design and implementation of ventilation systems, according to regulatory frames, in a fun and dynamic approach, through virtual 3D dwellings simulation

BATIMENT -VENTILATION.FR

Financed by

Created by

Thanks

gaelle.guyot@cerema.fr
andres.litvak@cerema.fr

Assessing the performance of natural ventilation systems : a review of existing method

Gabriel Remion, Bassam Moujalled, Mohamed El Mankibi, Romuald Jobert, Laurent Deleersnyder

Introduction

- **State of the art of the VNAT project about measurement of natural airflow**

  ↓

  Developping a protocole allowing to assess the performance of hybrid ventilation

- **Why measuring hybrid ventilation's airflows is a difficult task?**

Hybrid ventilation

Natural mode ↔ Mechanical mode

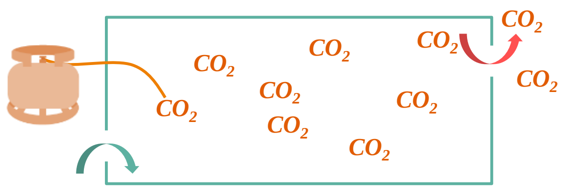
3 operating modes :
- *Natural assisted*
- *Mechanical assisted*
- *Alternated*

Natural mode:
- Unstable flow path
- Variable airflows

Mechanical mode:
- Low pressure

Measuring natural airflow

- **Tracer gas methods**



- Emisson rate & concentration -> Airflow
- \+ Does not interfere with the flow path

- **4 means of injecting the gas**
  - Constant injection ; Constant concentration ; Concentration decay ; Pulse method

- **Problems depending on methods**

Assume steady airflow

Interzonal flows

High amount of TG

Sophisticated materials

Assume homogeneity of the gas

Dosing homogenous of the TG

Conclusion

- **No ideal measurement method**
- **One measurement is insufficient**

Extrapolation

Wind
T°C

Measurement → Modelling

Validation

Perspectives of the VNAT project

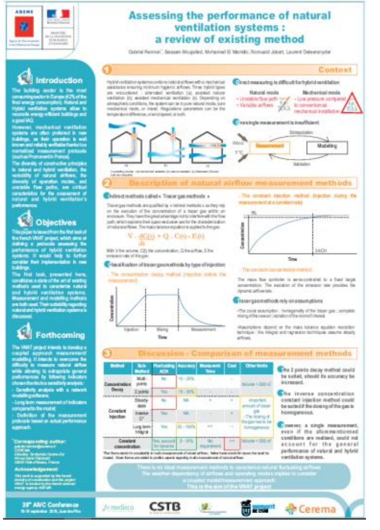
- **Developping a coupled « measurement/modelling » approach**
  - Long term in-situ measurement of indicators compared to the model
  - Definition of the measurement protocole based on a performantial approach

Cerema

AIVC TightVent Europe venticool

Thanks

gabriel.remion@cerema.fr


Assessing the performance of natural ventilation systems : a review of existing method

Introduction

Objectives

Forthcoming

Context

Description of natural airflow measurement methods

Discussion - Comparison of measurement methods

Thermal comfort and indoor quality in Drøbak Montessori School – A case study of Norway's first plus-energy school

Maria Myrup[1], Tor Helge Dokka[1], Ivar Ørnes[1], Saqib Javed[2]

[1]Skanska Norway, [2]Lund University

Photo: Robin Hayes

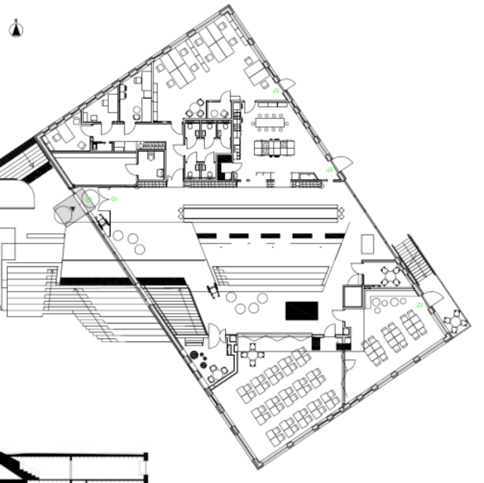
SKANSKA

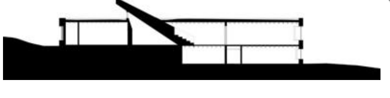
Drøbak Montessori lower secondary school

The vision of the school:

To become Norway's most environmentally friendly school

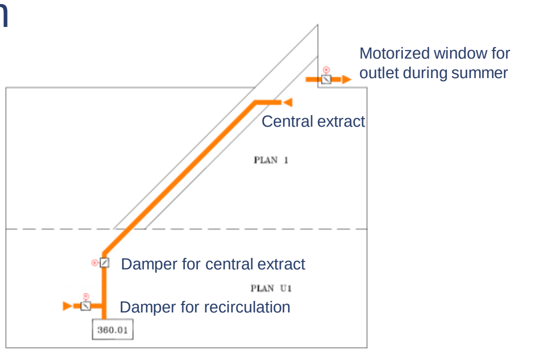
- Norway's first plus-energy school
- First school to fulfill the Norwegian Powerhouse concept
  - Produce more renewable energy during the lifetime of the building than used for materials, production, operation, renovation and demolition
- Architect: Snøhetta
- Heated area: 870 m²
- 60 students from 8th to 10th grade
  - Wish to include 7th grade and become 80 students
- Opened on the 9th of March 2018

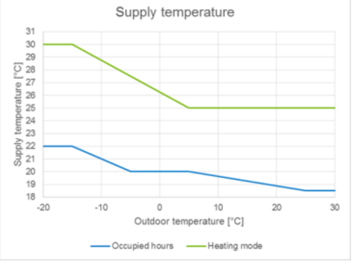


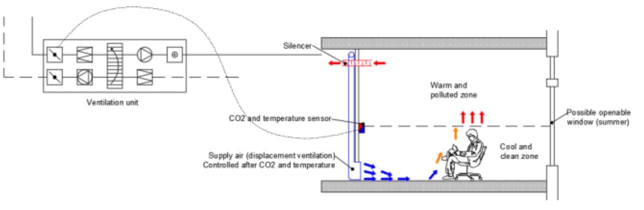


Heating and ventilation system

- Displacement ventilation
  - Fully mechanical – winter
  - Hybrid – summer
- Heating and cooling covered only by the ventilation system
- Low supply temperature during daytime
- Higher supply temperature during night (heating mode)

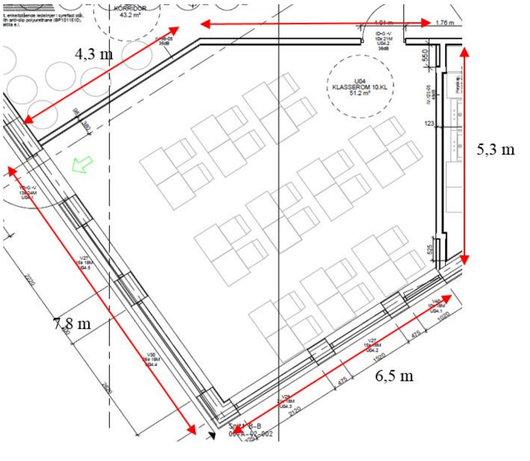






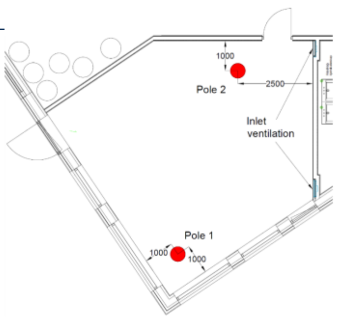
Validation of the heating system – Field test

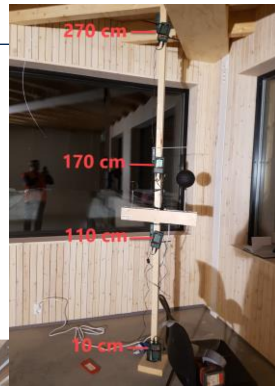
- Class room in the lower floor of 51,2 m²
  - Exposed concrete on the floor
  - Acoustic dampers in the ceiling
- Ventilation:
  - 7.30 AM to 4 PM: “Normal mode”
    - Airflow depending on CO2 and temperature
  - 4 PM to 7.30 AM: “Heating mode” / “Cooling mode”
    - Airflow depending on the temperature of the room
    - Heating starts at 19 °C
  - Supply temperature depending on outdoor temperature



Field test

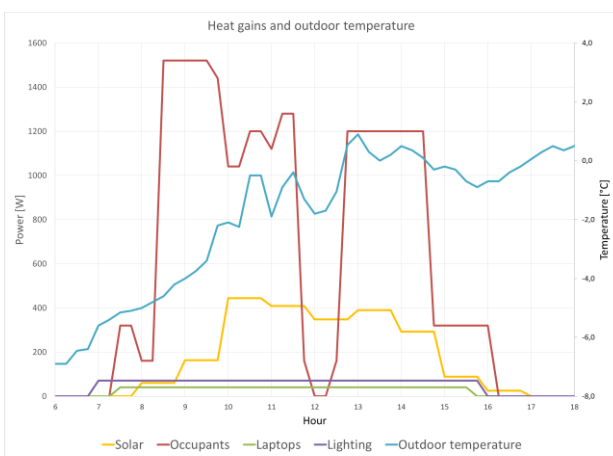
- Conducted on February 8th 2018
  - Midnight to 3 PM
- Measurements of:
  - Dry bulb temperature
  - Operative temperature
  - Air velocities
  - CO_2-concentration
- Two measurement poles – 4 heights
- Focus on temperature and CO_2
- Occupied with students and teachers





Field test

- Supply temperature:
  - Night: 27,1-28,1 °C
  - Occupied hours: 16-18 °C
- Airflow:
  - Night: approx. 547 m3/h
  - Occupied hours: approx. 520 m3/h
- Between 13-19 people
  - Break from 11.30 to 2.30
- Outdoor conditions:
  - Cloudy day
    - Solar gain based on nearby measurement and roughly estimated
  - Temperature between -7 and +3 °C



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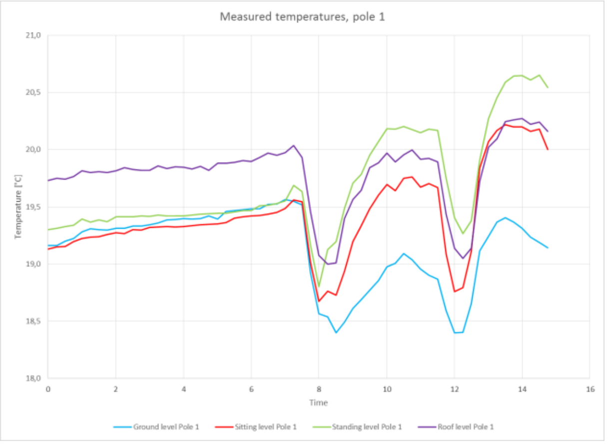
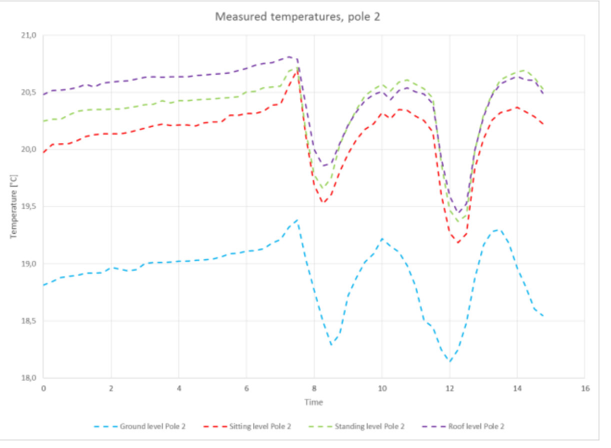
Field test - results





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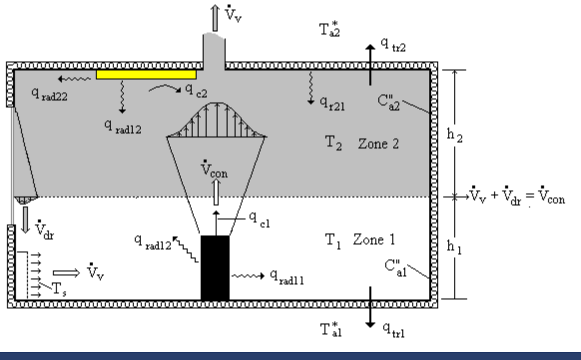
Two zone models

- Two-zone-model for temperature and contaminant stratification
- Thermal zone model based on a six node-two mass model
- Two linear differential equations – solved analytical
  - Mass temperature, surface temperature, room temperature
- Calculation of temperature gradients, operative temperature in the two zones etc.

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & a_{24} & a_{25} & 0 \\ a_{31} & 0 & a_{33} & a_{34} & 0 & 0 \\ 0 & a_{42} & a_{43} & a_{44} & 0 & a_{46} \\ 0 & a_{52} & 0 & 0 & a_{55} & 0 \\ 0 & 0 & 0 & a_{64} & 0 & a_{66} \end{bmatrix} \bullet \begin{bmatrix} T_1 \\ T_{S1} \\ T_2 \\ T_{S2} \\ T_{a1} \\ T_{a2} \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ b_5 \\ b_6 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ \frac{dT_{a1}}{dt} \\ \frac{dT_{a2}}{dt} \end{bmatrix}$$



$$C_1(t) = d_1 \exp(\lambda_1 t) + d_2 \exp(\lambda_2 t) + C_{1\infty}$$

$$C_2(t) = d_1 k_1 \exp(\lambda_1 t) + d_2 k_2 \exp(\lambda_2 t) + C_{2\infty}$$

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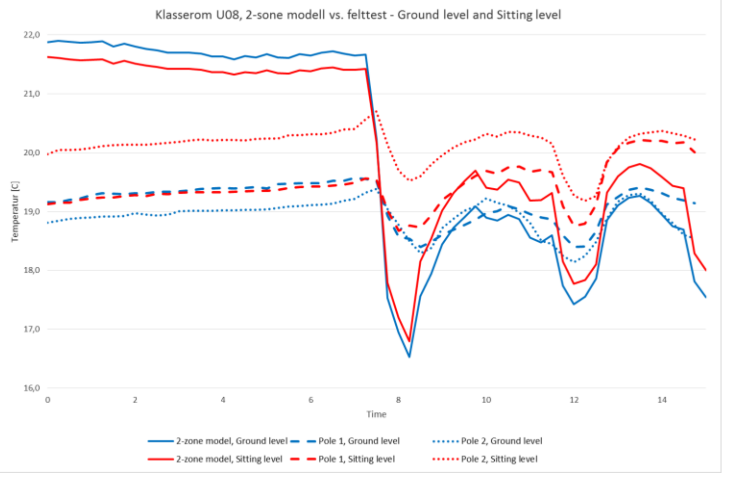
Comparison with a two-zone-model, temperature

- Good compliance during operating hours
- Two-zone-model overpredict temperature during night in the lower part of the room
  - Model developed for supplying cooled air
  - Heat sink through floor
- Faster "drop" – rises faster
  - Thermal mass underestimated



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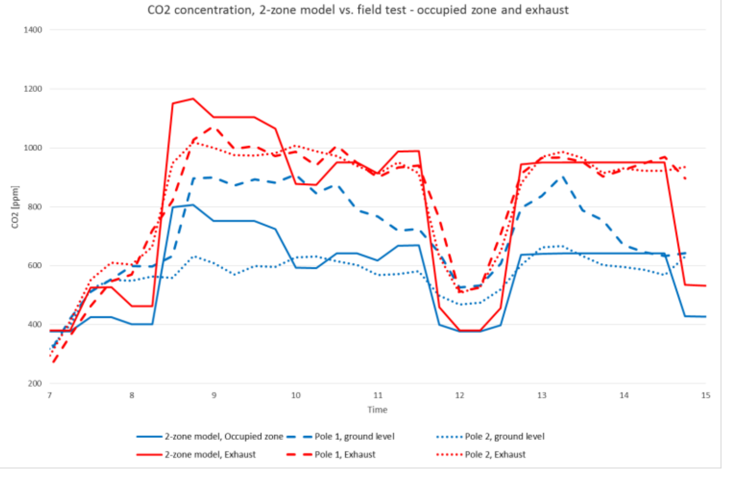
Comparison with a two-zone-model, CO_2

- Good compliance for exhaust air
- Higher variation in the occupied zone
  - Pole 1 placed in an area with a higher concentration of people



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Conclusion

- Heating by displacement ventilation with high supply temperature during night seems to create good thermal comfort
- Temperature and CO_2-stratification in the room because of the use of displacement ventilation
- Good consistency between the two-zone-model and the measured data
  - Two-zone-model has to be modified to take into account the night heating mode better
- The users of the building is satisfied with the heating and ventilation system!
  - Some minor adjustments in the startup of the ventilation system

Photo: Robin Hayes

Ventilation Performance of Natural Ventilation Building with Solar Chimney

Presenting Author:
Haruna Yamasawa
(Osaka University)

Co-author:
Toshio Yamanaka,
Yoshihisa Momoi, Shogo Ito,
Kitaro Mizuide and Takuro Fujii

Natural Ventilation System

Uses renewable energy when ventilating

So, Saves the energy of

Heat source	Air conveyance	Ventilation

40% of the whole at office

But, Affected by unstableconditions

→Difficult to predict performance before construction

Designing & Controlling method is not yet established

Aim of this study is to...

Establish the method of
Designing & Controlling NV System

Easy & simple way of predicting
Ventilation performance
is needed

Fall of 2017 & Spring of 2018
Measurement at a natural ventilated city hall
was conducted

About Measured building

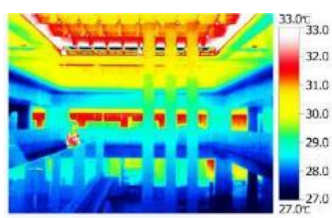
Natural ventilated city hall in Tokushima, Japan

About Measured building

Two features of the building

Measurement at large void space

Summer of 2017



Vertical temperature distribution measurement

Visualization of ventilation route measurement

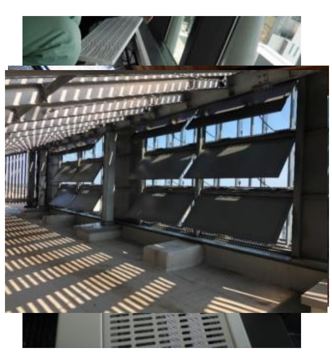
About Measured building

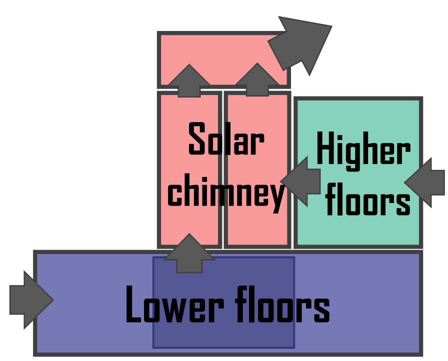
Two features of the building

NV system in mid-season

Fall of 2017 & Spring of 2018

Ventilation flow rate **measurement**





Calculation of flow rate – Solar chimney

Flow rate through solar chimney

1 Wind velocity distribution

$$Q_v = \frac{1}{N_v}\Sigma_{i=1}^{N_v}(v_i \times A_V)$$

Velocity × Area
＝Flow rate

2 CO_2 concentration distribution

$$Q_c = \frac{M}{\frac{1}{N_C}\Sigma_{i=1}^{N_C}(C_i - C_0) \times 10^{-6}}$$

Steady
Tracer gas method

3 differential pressure at exhaust opening

$$Q_p = \alpha A_{VT}\sqrt{\frac{2}{\rho}|\Delta p|}$$

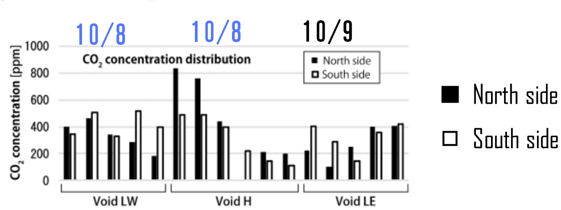
Equation of
ventilation

Calculation of flow rate – Solar chimney

Steady tracer gas method

Air in the chimneys is not fully mixed → **Not suitable**

Distribution of
CO_2 concentration



Distribution does exist

Differential pressure

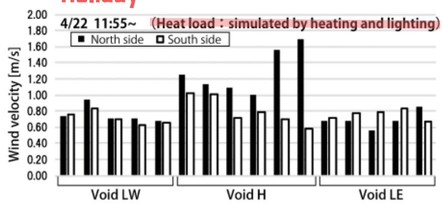
Distribution and pressure loss were not fully taken into account
→ **Not suitable**

→**Velocity** measurement was chosen

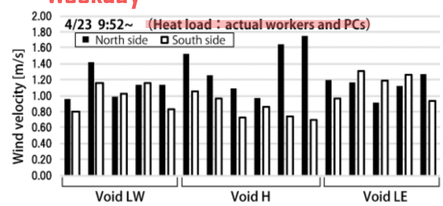
Calculation of flow rate – Solar chimney

Wind velocity distribution

Holiday



Weekday



Higher floors : Agreed with each other

Lower floors : No significant difference was obtained

→**the load was simulated properly**

Air was changed roughly more than **10 times /h**

→**1.5 times** of the simulated value at design phase

Conclusion

AIM: Establish the method of Designing & Controlling NV System

What is needed: Easy & simple way of predicting ventilation flow rate

What has been done:

Methods for calculating flow rate were compared

Ventilation flow rate was calculated

→ACH was **1.5 times** of the simulated value at design phase

What's NEXT?

Modelling and simulating has to be done with using measurement data

Ventilation Performance of Office Building with Natural Ventilation Shaft

OSAKA UNIVERSITY TOYO UNIVERSITY NIKKEN EXPERIENCE, INTEGRATED

Toshihiko Sajima（Osaka University）

Eunsu Lim（Toyo University）

Toshio Yamanaka（Osaka University）

Iwao Hasegawa（NIKKEN SEKKEI LTD）

Akihiro Matsumoto（NIKKEN SEKKEI LTD）

AIVC 2018

■Research Background

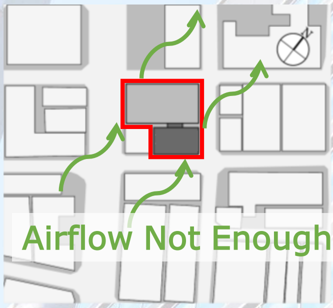
Natural Ventilation

- ■Saving Energy
- ■Improvement of IAQ

Office building introducing natural ventilation is increasing.

However

■Research Background



Natural Ventilation
- ■Saving Energy
- ■Imprvement of IAQ

Office building introducing natural ventilation is increasing.

However

High Density Block Area

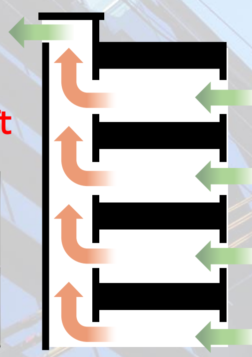
➡ The way of ensuring stable ventilation is very important matter of natural ventilation system.

Purpose of Research

Evaluation of the Ventilation Performance

Ventilation System

the buoyancy force
through a ventilation shaft



Summary of Research

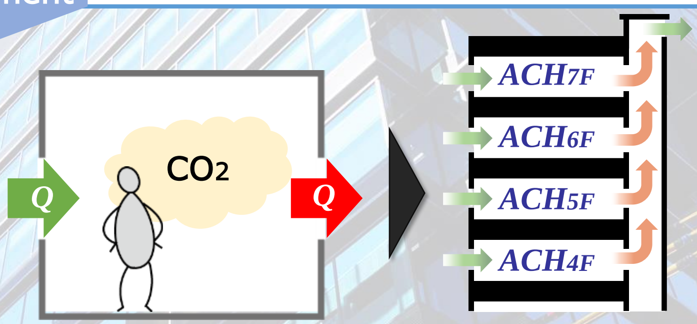
- On-site Measurement
- CFD Analysis
- Flow Network Calculation

Ventilation Performance of Office Building
with Natural Ventilation Shaft

Summary of Research

On-site Measurement

The air change rate (ACH) of target rooms were estimated using CO_2 generated from occupants as tracer gas.



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Ventilation Performance of Office Building with Natural Ventilation Shaft

Summary of Research

On-site Measurement

CFD Analysis

Flow Network Calculation

The air change rate were estimated using CO_2 generated from occupants as tracer gas.

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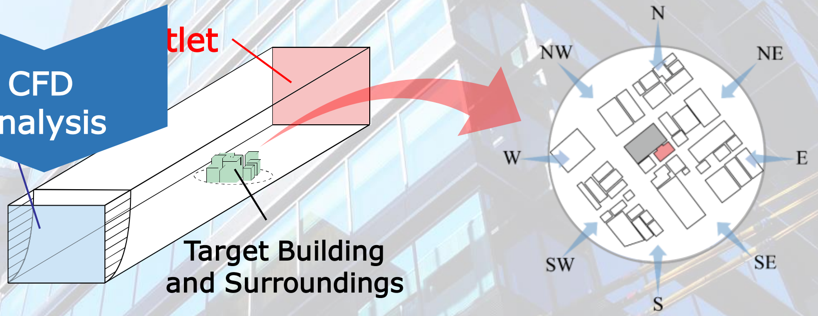
Ventilation Performance of Office Building with Natural Ventilation Shaft

Summary of Research

The experiments at the wind tunnel was modeled. The CFD analysis were performed for every 45° of wind direction, and 8 cases were analyzed in total.

CFD Analysis



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Ventilation Performance of Office Building with Natural Ventilation Shaft

Summary of Research

On-site Measurement

The air change rate were estimated using CO_2 generated from occupants as tracer gas.

CFD Analysis

The experiments at the wind tunnel was modeled.

Flow Network Calculation

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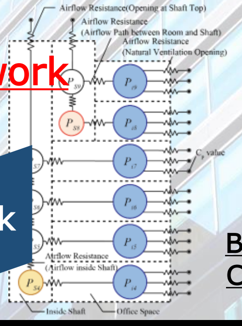
Ventilation Performance of Office Building with Natural Ventilation Shaft

Summary of Research

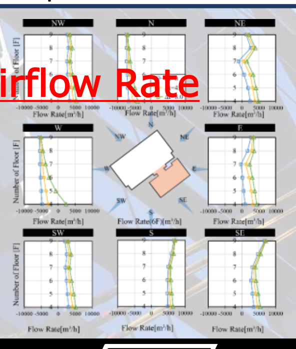
The airflow rate was calculated by changing the boundary conditions such as the external wind speed and the outside air temperature.

Flow Network Model



Boundary Condition

Airflow Rate



Flow Network Calculation

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Ventilation Performance of Office Building with Natural Ventilation Shaft

Summary of Research

On-site Measurement — The air change rate were estimated using CO_2 generated from occupants as tracer gas.

CFD Analysis — The experiments at the wind tunnel was modeled.

Flow Network Calculation — The airflow rate was calculated by changing the boundary condition.

Ventilation Performance of Office Building with Natural Ventilation Shaft

Summary of Research

On-site Measurement

CFD Analysis

Flow Network Calculation

➢Detail

➢Result

Thank you for your attention!

OSAKA UNIVERSITY AIVC 2018

Indoor air quality measurements in 38 schools of South-Western Europe

P. Blondeau, M.O. Abadie, S.M. Almeida, V. Manteigas, J. Lage, K. Gonçalves, A. Fernandez, C. Walsh, E. Prescott, J. Lizana, F.J. Palomo-Guerrero, A. R. Gamarra, J. L. Alexandre

WWW.CLIMACT.NET

Frame of the study

ClimACT

The ClimACT project

- 9 partners from Portugal, Spain, Gibraltar and France
- Funded by the INTERREG SUDOE programme through the European Regional Development Fund (ERDF)
- Develop tools to support the transition to a low carbon operation of schools in South-western Europe: teaching aids, serious games, tools for the follow-up of environmental performance, investment decision-making tool, business models for energy investments,…
- Measures tested and environmental audits carried out in 38 pilots schools (primary to University)
  - Energy and water consumptions
  - Transports from home to school
  - Green procurements
  - Waste management
  - Green spaces
  - Comfort and indoor air quality

Interreg Sudoe ClimACT

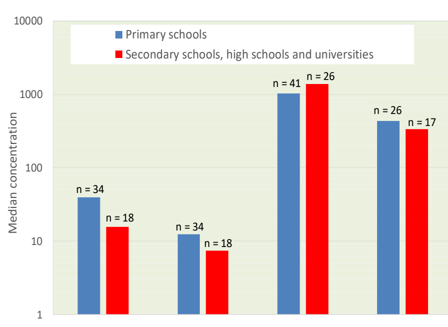
WWW.CLIMACT.NET

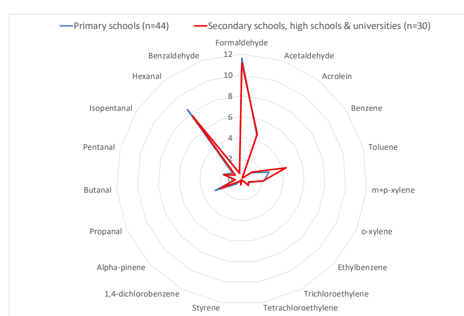
Methodology of IAQ audits

- **Concentration measurements of a large number of well-known pollutants**
  - Continuous monitoring of CO, CO_2, TVOCs, $PM_{2.5}$, PM_{10} concentrations over 2 days (P, S, Gib) or 7 days (F)
    - → Time series of concentrations with a short time step: possibility to consider mean concentrations during the occupancy period (real exposure)
  - Passive sampling over 1 week and laboratory analysis of 19 specified VOCs and aldehydes
    - → Mean concentration over the measurement period
- IAQ assessment by reference to **guidelines selected from health agencies or national regulations**

Data analysis

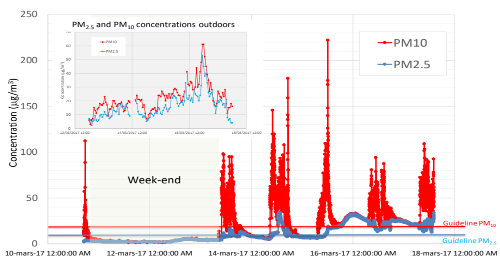
- Comparison of IAQ in the 4 countries
- Comparison of IAQ in primary schools vs grammar/high/university schools

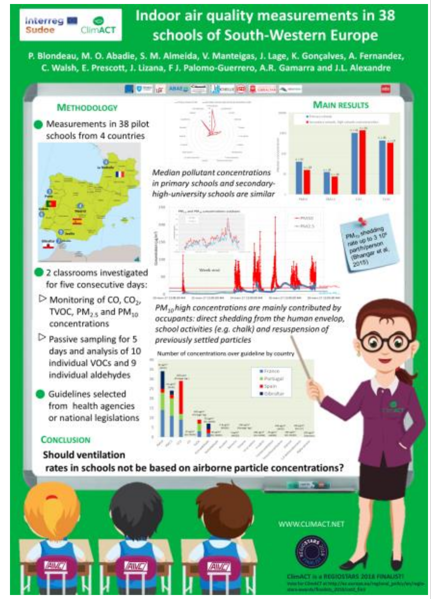




Data analysis

- Analyses of concentration profiles to understand the dynamics of pollutant concentrations and identify the main pollutant sources





- Is CO_2 really the good criterion to design ventilation systems in schools?

ClimACT

To encourage the transition to Low Carbon Schools through the development of technical and educational tools and activities

A study of running set-points and user IEQ satisfaction perspectives in the Norwegian commercial building stock

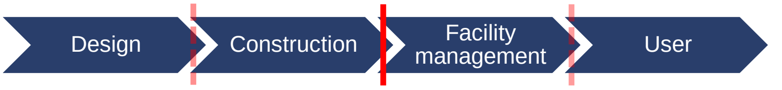
Niels Lassen

Skanska Norway AS, niels.lassen@skanska.no

INTRODUCTION - 1

- EN 15251 and ISO 7730 standards specify seasonal bands; 2°C for class I/A, 3-4°C for class II/B, 5-6°C for class III/C
- International studies have found that commercial buildings with central HVAC in practice run with smaller temperature dead-bands than this (1-2°C), and often cooler in summer than winter.
- Temperature and air quality to be the second and fifth largest sources of dissatisfaction among building occupants (Kim et al. 2013).
- The three classes did not show different comfort/acceptability outcomes (Arens et al. 2010).
- (Leaman & Bordass, 1999). Two of five “killer variables” are: *opportunities for personal control* and a *rapid response environment with access to information and feedback regarding complaints etc*
- *Perceived control* (Hellwig 2015). The following can be influenced through the design and operation of a building: *expectations, constraints and current feedback experiences*

Objective



- Investigate and understand
  - Operating temperature set-points
  - FM perceptions of user IEQ preferences
  - Practices for interaction with users

- Use interviews of facility management coordinators to gain indicative answers to these three questions.

RESULTS AND DISCUSSION - 1

Operating temperature set-points

- mostly determined and adjusted by the individual building operations manager
- Some of the respondents reported that they have lower temperature set points in summer than winter (not part of interview)

	Value
Average heating set point	21.1 °C
Average cooling set point	23.0 °C
Calculated average dead-band	1.95 °C
Range in dead-band between respondents	1.0-4.0 °C

Users perceptions

- complaints about “bad air” seldom were due to high CO_2
- complaints on IEQ measures often were connected to other factors for well-being
- most of the respondents prohibited occupants to open windows

	Value
Average temperature where users complain about “too cold”	19.9 °C
Average temperature where users complain about “too hot”	23.9 °C

RESULTS AND DISCUSSION - 2

“Which factors are most important for keeping building occupants happy with IEQ conditions?”

- Three most given answers are not connected to the indoor climate itself, but to “psychological” factors in the interaction with users. Responses are well in line with theory, (Leaman & Bordass and Hellwig)

Taking the users/complaints seriously and show action	Influencing and meeting the expectations of the users, explaining reasons for why	Good communication with the users and for the user to have a real person to speak to
6/10	5/10	7/10

Perceptions and procedures for user interaction

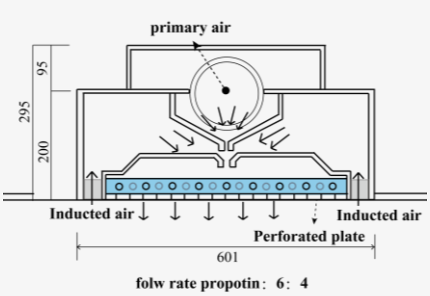
- No systematic interaction besides KPI
- Prefer a “human approach” for handling user interaction

Indoor Environment in Sickroom with Ceiling Induction Diffusers and Measuring Method of Ventilation Effectiveness Using Tracer Gas

LIU PEIHUAN

Toshio Yamanaka , Ying Li , Mari Kuranaga

Introduction



Ceiling Induction Diffusers

- Low draft
- Low energy consumption

Experiments instruction

IMITATIVE WARDS

- Normalized concentration
- Local mean age of air
- Radiation heat transfer
- Air velocity

CO_2 analyzer

- Responsiveness
- Approximate curve
- Influence on experiment results under different air change

Experiments methods

Normalized concentration
Local mean age of air

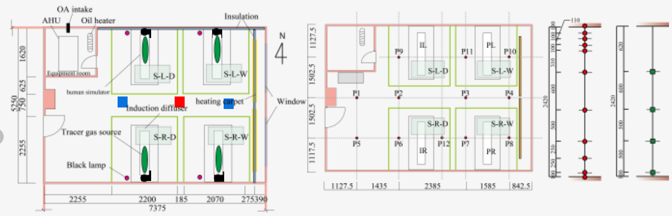
- Tracer gas position: 4 beds, interior zone, perimeter zone
- Exhaust vent position: 1EC,2EC,4EC
- Curtain: with /without

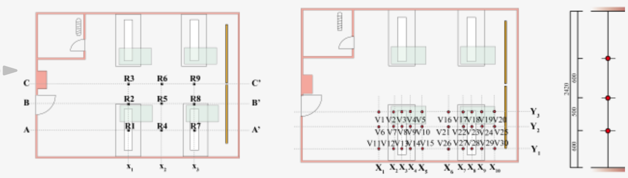
Radiation heat transfer
Air velocity

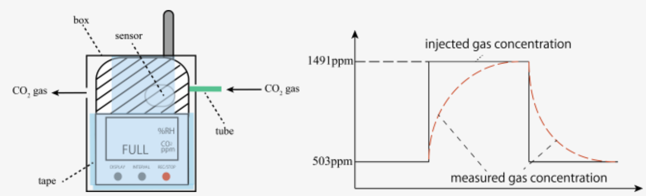
- The air flow around the bed
- The radiation from four diffusers

Responsiveness of CO_2 analyzer

- Step up, step down
- convolution







Results

For further results...

FACULTY OF ENGINEERING AND ARCHITECTURE

DEPARTMENT ARCHITECTURE AND URBAN PLANNING
RESEARCH GROUP BUILDING PHYSICS, CONSTRUCTION & SERVICES

DEVELOPMENT OF A ZONAL MODEL TO ASSESS INDOOR CLIMATE AND DAMAGE RISKS TO ART WORKS IN CHURCH BUILDINGS

Lien De Backer, Arnold Janssens, Michel de Paepe
Presenter: Arnold Janssens

39th AIVC Conference
Smart ventilation for buildings

GHENT UNIVERSITY

Lien De Backer, 2018, *Preventive conservation of works of art in historic buildings: assessment and modelling*. Doctoral dissertation (supervisors A. Janssens & M. De Paepe), Ghent University

BACKGROUND

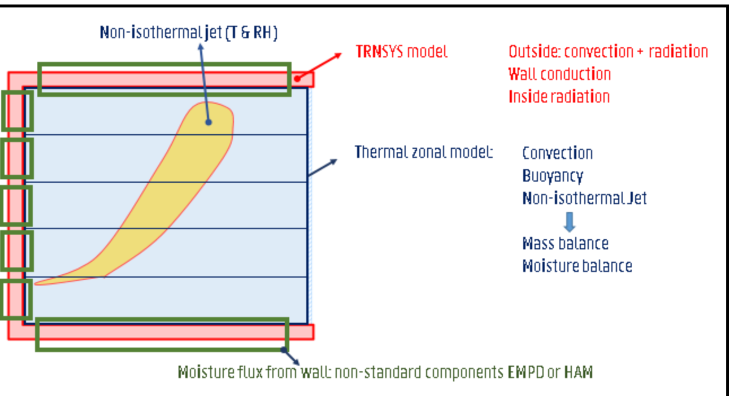
- Panel paintings part of European cultural heritage
- Often exhibited in historic buildings with suboptimal conditions
- Climate induced damage due to differential shrinkage/expansion of panel boards and paint
- Strictly controlled climate not feasible in historic location
- Simulations to assess specific climate impact on panel response

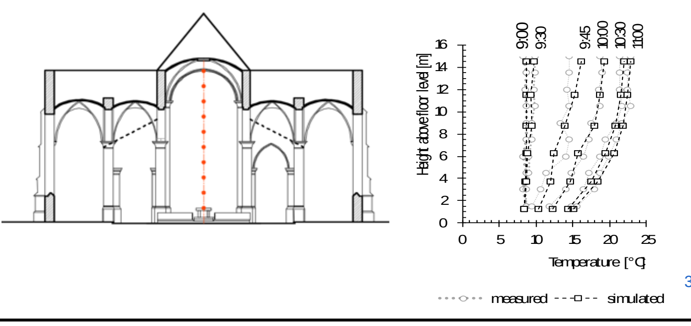
Conservation works 'Nood Gods' (unknown master)
Church of our Lady, Watervliet, Belgium

GHENT UNIVERSITY

MODELLING STRATEGY

- Coupling of models:
  - BES simulation environment TRNSYS (v17)
  - Thermal-zonal model
  - Moisture buffering and transport models.
- Calibration of initial integrated model using measurement data
- Testing adjustments to heating system set-points using calibrated model





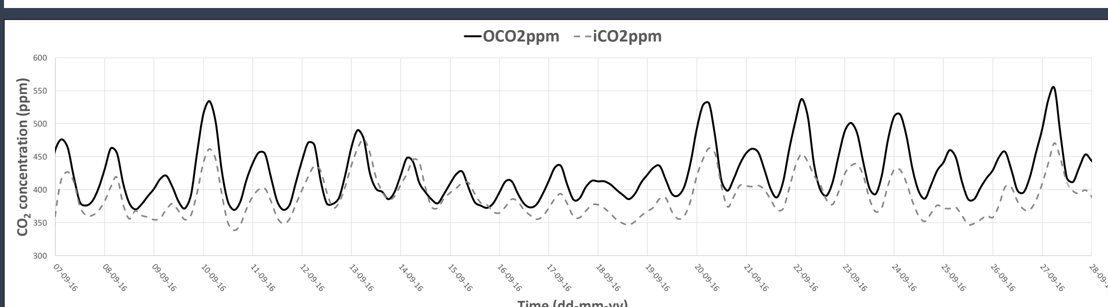
GHENT UNIVERSITY

Effects of Meteorological factors on CO_2 concentration

Maria Marrero , João Carrilho, Manuel Gameiro da Silva
ADAI-LAETA, Department of Mechanical Engineering, University of Coimbra, Portugal

Introduction

- The diurnal cycle of ambient CO_2 has a peak-to-peak amplitude of 100 ppm.
- Indoor CO_2 concentration follows outdoor CO_2 concentration attenuated with delay.
- **What weather patterns influence CO_2 concentration variations in Horst, The Netherlands?**



Method

Experimental site

City Hall, Horst, The Netherlands

An administrative building located in the centre of the town. The climate is a mild temperate fully humid climate with

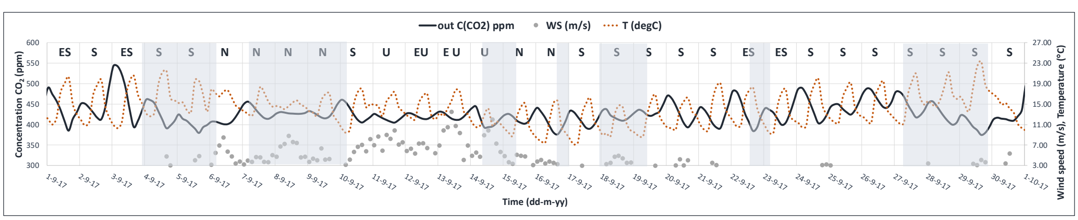
Data acquisition

- Weather station
- CO_2 sensors
- NOAA database
- Natural Earth model
- HYSPLIT model

Data processing

- Noise filter: Savitzky-Golay FIR filter
- Relationships between outdoor CO_2 concentration and meteorological variables: Linear regressions and R-square coefficient determination.

Results



ES: Extremely Stable, S: Stable, N: Neutral, U: Unstable, EU: Extremely Unstable
The shaded areas correspond to overcast periods.

- CO_2 diurnal cycle is due to **photosynthesis** and traffic emissions.
- The amplitude varies according to the intensity of the **turbulent dispersion** (mechanical and thermal). **Unstable atmosphere** produces more turbulent dispersion.
- On **cloudy days** the activity of the vegetation slows down, reducing the concentration of CO_2.
- High specific humidity means high rates of evaporation, **less water available** for production of CO_2.
- **Stagnation events** shoot up CO_2 concentration in Horst.

Conclusion

- The diurnal cycle is dominated by the **photosynthesis-respiration cycle** of the vegetation surrounding the building and the traffic.
- **Dispersion processes** define the CO_2 concentration diurnal cycle.
- The cycle dims when:
  - **High temperature** produces thermal turbulence and **windy days** with high mechanical turbulence.
  - the photosynthesis-respiration cycle is blocked by **lack of sun**.
- Further measurements for longer periods and work on rigorous modelling of the outdoor and indoor CO_2 concentration relationship with any parameters must be carried out in future.

For further information you can: visit my poster

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18-Sept-2018

What is smart ventilation
Presentation of the AIVC definition

François DURIER
CETIAT

CETIAT
ensemble, innover et valider

Ventilation
Information
Paper
n° 38

March 2018

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International Energy Agency's
Energy in Buildings and Communities
Programme

AIVC

Air Infiltration and Ventilation Centre

What is smart ventilation?

François Durier, CETIAT, France
Rémi Carrié, ICEE, France
Max Sherman, LBNL, USA

1 Introduction

In March 2017, AIVC identified smart ventilation for buildings as a new and important topic to be addressed.

of contaminants, operation of other air moving and air cleaning systems.

In addition, smart ventilation systems can provide information to building owners, occupants, and managers on operational

1 Introduction

In March 2017, AIVC identified smart ventilation for buildings as a new and important topic to be addressed.

Several actions were defined by AIVC Board about this topic in order to exchange and disseminate information on this topic. A working group of AIVC experts from several countries was created. One of its tasks was to agree on a definition of smart ventilation.

AIVC VIP n°38 – What is smart ventilation?

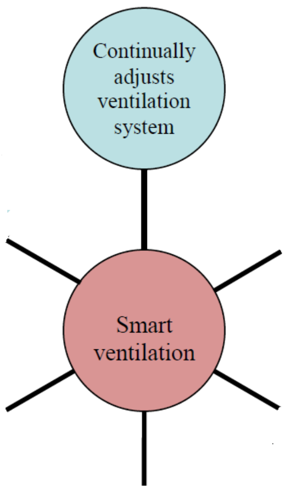
François Durier, CETIAT, France
Rémi Carrié, ICEE, France
Max Sherman, LBNL, USA

5 Acknowledgments

The authors would like to thank the following people who contributed to set up the definition of smart ventilation:

Iain Walker (LBNL, USA), Pawel Wargocki (DTU, Denmark), ~~Willem De Gids (VentGuide,~~ Netherlands), Wouter Borsboom (TNO, Netherlands), ~~Steven Emmerich (NIST, USA),~~ Andrew Persily (NIST, USA), Carsten Rode (DTU, Denmark), Benjamin Jones (Nottingham University, UK), Karel Kabele (Czech Technical University Prague, Czech Republic), Peter Wouters (INIVE, Belgium), Maria Kapsalaki (INIVE, Greece).

Main features of smart ventilation



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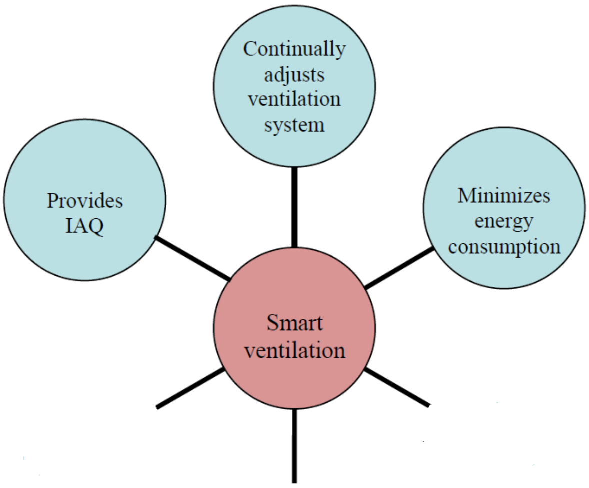
Main features of smart ventilation



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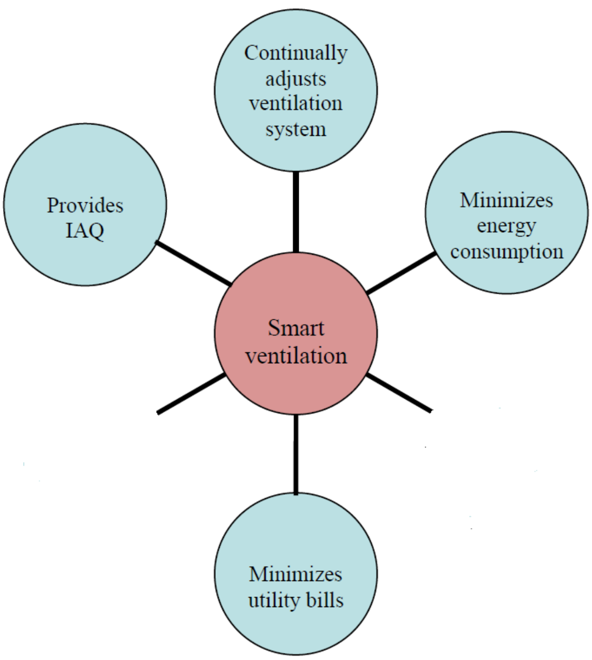
Main features of smart ventilation



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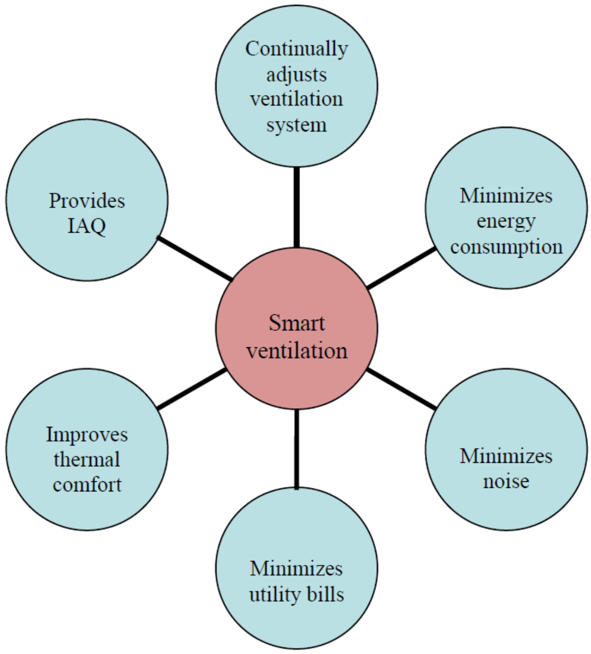
Main features of smart ventilation



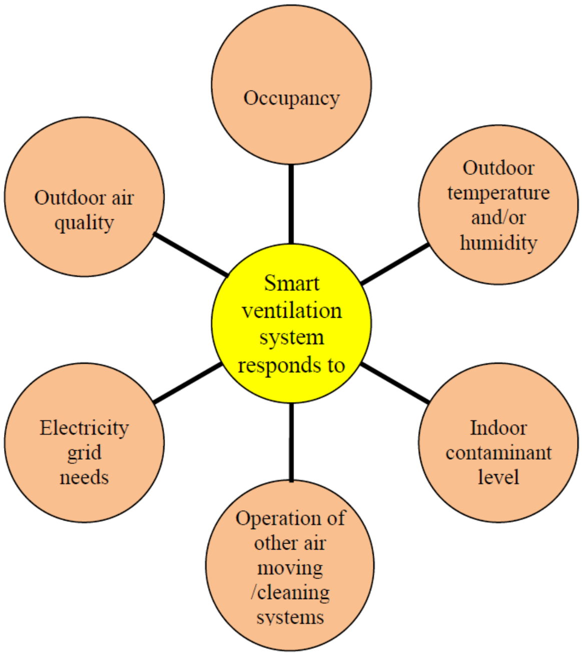
AIVC VIP n°38 – What is smart ventilation?

1st paragraph of the definition

" Smart ventilation is a process to continually adjust the ventilation system in time, and optionally by location, to provide the desired IAQ benefits while minimizing energy consumption, utility bills and other non-IAQ costs (such as thermal discomfort or noise)."

AIVC VIP n°38 – What is smart ventilation?

Parameters to which a smart ventilation system can respond



AIVC VIP n°38 – What is smart ventilation?

2nd paragraph of the definition

" A smart ventilation system adjusts ventilation rates in time or by location in a building to be responsive to one or more of the following:
occupancy, outdoor thermal and air quality conditions, electricity grid needs, direct sensing of contaminants, operation of other air moving and air cleaning systems."

AIVC VIP n°38 – What is smart ventilation?

3rd paragraph of the definition

"In addition, smart ventilation systems can provide information to building owners, occupants, and managers on operational energy consumption and indoor air quality, and signal when systems need maintenance or repair."

AIVC VIP n°38 – What is smart ventilation?

Other contents of VIP n°38

- 4 additional paragraphs to the definition
  - *Being responsive to occupancy means…*
  - *Smart ventilation can time-shift ventilation to periods when…*
  - *Being responsive to electricity grid needs means…*
  - *Smart ventilation systems can have sensors…*
- Tables with more explanations and examples

Information that can be delivered by a smart ventilation system (3rd paragraph of the definition)					
Text from the definition	*Information that can be collected by sensors*	*Information that can be derived from the information collected by sensors*	*To whom can this information be useful?*		
			Building owners	*Building occupants*	*Building managers*
Smart ventilation systems can provide information to building owners, occupants, and managers on operational energy consumption and indoor air quality as well as signal when systems need maintenance or repair.	Presence of occupants Number of occupants	Ventilation needs	To know occupation and use of the building/zones/rooms		
	Outdoor temperature Outdoor humidity	Cooling needs, ventilative cooling potential, heating needs	For information and possible actions to reduce heating/cooling needs		To manage heating/cooling, including ventilative cooling
	Outdoor contaminant concentrations	Outdoor air quality index	For information and possible actions to reduce contaminant transfer to indoors		
	Operating conditions of the fans	Electrical consumption, ventilation rate	For information		The last paragraph of the definition provides more explanations: *Smart ventilation systems can have sensors to detect air flow, systems pressures or fan energy use in such a way that systems failures can be detected and repaired, as well as when system components need maintenance, such as filter replacement.*
	Indoor contaminant concentrations	Indoor air quality	For information and possible actions, to limit indoor exposure to contaminants		
	Operating conditions of the ventilation system (pressures, flow rates, velocities) and of the other air moving/cleaning systems	Energy use, ventilation rate, maintenance or repair needs	For information and possible actions (to improve system effectiveness		

Table 3: Additional explanations and examples/comments for the 3rd paragraph of smart ventilation definition

AIVC VIP n°38 – What is smart ventilation?

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Other contents of VIP n°38

- Perspectives
  - Does smart ventilation mean complex systems?
  - Smart ventilation: a contributor to smart buildings
  - Smart ventilation in standards and regulations
    - Europe: *standards EN 16798-1:2017 and EN 16798-7:2017, European regulation 1253/2014*
    - USA: *ASHRAE Standard 62.2-2016*

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A review of smart ventilation energy and IAQ performance in residential buildings

Gaëlle Guyot
Cerema Centre-Est & LOCIE, Univ. Savoie Mont Blanc, France
Iain Walker & Max Sherman
LBNL, USA

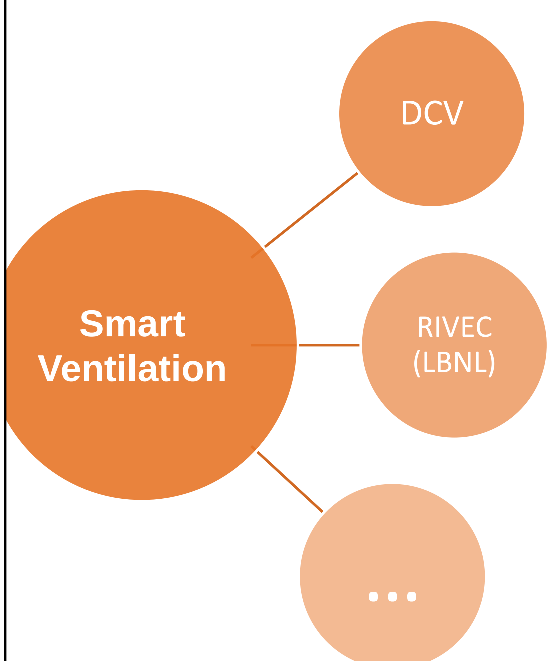
Outline

- Scope
- Review procedure
- Overview of the results
- Feedbacks & Perspectives

Our scope : smart ventilation strategies

- **Smart ventilation (Durier et al., 2018) *: a process to continually adjust the ventilation in time and optionally by location, to provide the desired IAQ benefits while minimizing energy consumption, utility bills and other non-IAQ costs (such as thermal discomfort or noise)***

- **From a literature review (not a market survey)**
  - *Guyot, G., Sherman, M.H., Walker, I., 2017. Residential smart ventilation: a review. Lawrence Berkeley National Laboratory.*



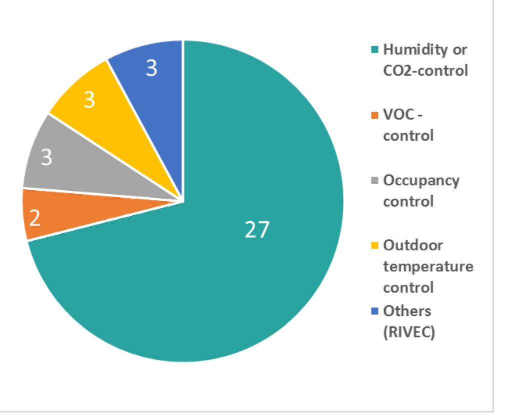
- Over 30 years old & widely used in countries as FR, BE, NT
- Mostly CO_2 or humidity based with a wide variety of systems and strategies

- RIVEC prototype (Sherman and Walker, 2011)
- ACH = f(outdoor conditions, utility peak loads, occupancy, operation of other air systems)
- Airflows Equivalence principle (ASHRAE 62.2)
- To be continued …

Review procedure

- 38 field and modelling studies on energy and/or IAQ benefits of residential smart ventilation from 1979 to 2016

- Type of used parameter for control
  - *With some of the studies covering several parameters*



Overview of the results

- A summary table

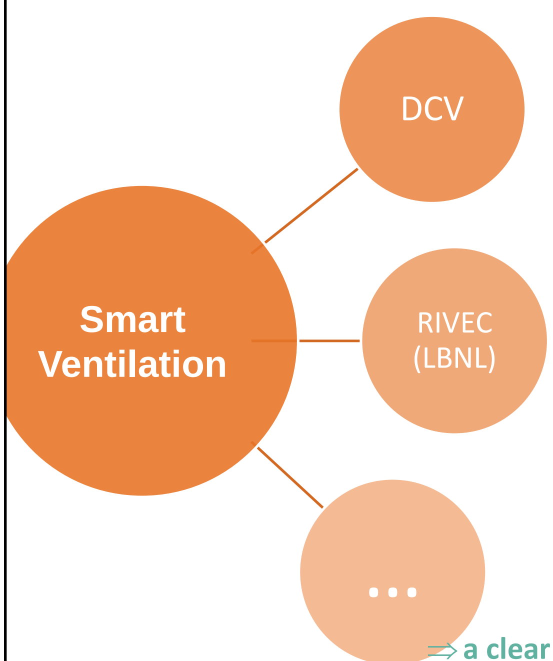
Reference *Country*	Type of home	Method	Type of system and regulation	Type of sensor (Humid rooms + Dry rooms)
(Pavlovas, 2004) ***Sweden***	A typical Swedish apartment	Modeling (IDA Indoor Climate and Energy)	Exhaust-only, whole house + global regulation	1) CO_2 DCV with sensors in humid rooms, 2) RH DCV with sensors in humid rooms, 3) occupancy DCV

Overview of the results

- A summary table

Control strategy	Main findings / comments	IAQ performance	Energy savings
Exhaust airflow 10 L.s-1 or 30 L.s-1	Indoor doors closed or open were also tested	CO_2 and occupancy DCV: similar CO_2 concentrations but increase the risk for high humidity levels RH DCV: increases CO_2 concentrations	Annual heat demand savings: >50% (CO_2 and RH) 20% (occupancy control)

Overview of the results



- Over 30 years old & widely used in countries as FR, BE, NT
- Mostly CO_2 or humidity based with a wide variety of systems and strategies
- IAQ : various results
- Energy savings : -26% + 60%

- RIVEC prototype (Sherman and Walker, 2011)
- ACH = f(outdoor conditions, utility peak loads, occupancy, operation of other air systems)
- IAQ maintained, sometimes improved
- Energy savings : >40%, 500-7000 kWh/year/household

⇒ a clear potential for improve IAQ and save energy

Feedbacks

- **Very difficult to compare performance results between different studies, for at least four reasons:**

1. Differences in the types of used smart ventilation strategies
    - Often a lack of precise data on :
        - The type of measuring technology,
        - The location of sensors (rooms – which rooms, ducts)
        - The type of control (mechanical or electronic of inlets and outlets cross-sectional area, direct control of fan speed, of dampers)
        - The control algorithm (value of set points + rules)
        - …

⇒ "humidity-based DCV" performance > "CO_2-based DCV" = nonsense !

Feedbacks

- **Very difficult to compare performance results between different studies, for at least four reasons:**

2. A lack of information on the conditions of the studies

    - Climate, occupancy, energy performance level, range of ventilation rates, building materials emission and absorption characteristics.

⇒ A study can give poor results for given conditions, but this does not necessarily mean that the ventilation system is bad

Feedbacks

- **Very difficult to compare performance results between different studies, for at least four reasons:**

3. Differences in measuring IAQ-related parameters

   - Neither a common single parameter / set of parameters, nor a universal method to calculate/measure the performance indicators
   - Often differences on the IAQ performance indicators. For instance, the average CO_2 concentration is often given without information on either the location of the measurement (which room) or the averaging time used (1 day, 1 week, 1 year).

Feedbacks

- **Very difficult to compare performance results between different studies, for at least four reasons:**

4. Differences in “reference” cases

   - Smart strategies are always smart once compared to a “reference”
   - Reference cases (include. reference airflow rates), are different in each standard or code

⇒ Performance levels depend on reference cases

⇒ Performances expressed only using a comparison with reference cases = unusable

Key questions for future studies and system design & development

- What are the relevant pollutants to sense for residential ventilation control ?
  - Can we sense them with sufficient accuracy and reliability for control ?
- Could we better understand the differences between contaminant sources between occupied and unoccupied dwellings ?
- Can we reliably detect occupancy so as to realize the potential savings?
- Could we develop better indoor air quality metrics for residential ventilation control ?
- Is that suitable to include air cleaning in ventilation controls ?

Perspectives

- **Expectations (performances) on smart ventilation = Not an end in itself**
  - Not only a scientific and technical issue
- **But a strong link with social and regulatory context …**

Thank you for your attention !

gaelle.guyot@cerema.fr

Further information in:

Guyot, G., Sherman, M.H., Walker, I.S., 2018. Smart ventilation energy and indoor air quality performance in residential buildings: A review. Energy and Buildings 165, 416–430. https://doi.org/10.1016/j.enbuild.2017.12.051

Why should we care about ductwork airtightness ?

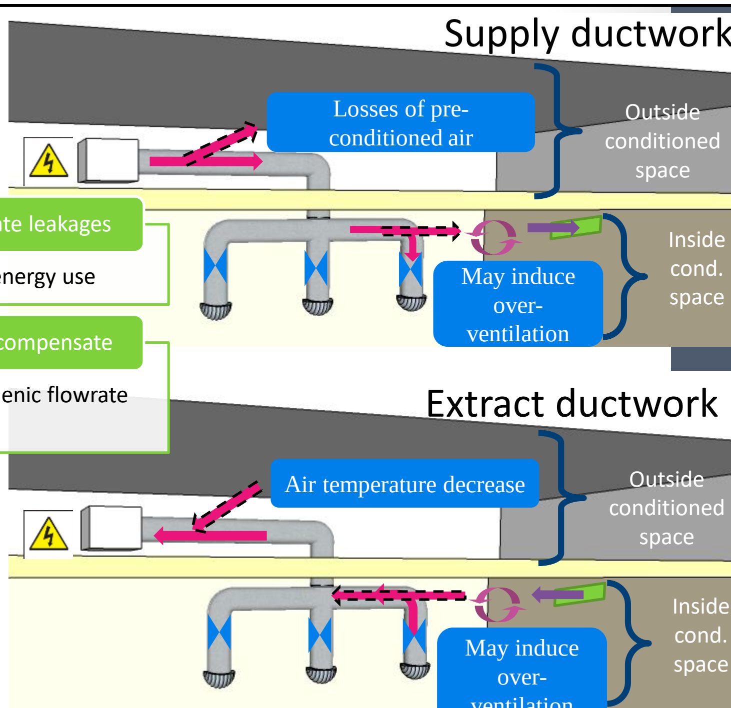
AIVC conference,
September 18th, 2018

Valérie Leprince, PLEIAQ
Valerie.leprince@pleiaq.net

Outline

- Impact of ductwork leakages
- Ductwork airtightness level
- Evolution in regulatory and programme requirements in EU countries
- Program of the session

IMPACT OF DUCTWORK LEAKAGES



The fan compensate leakages

- Increase of fan energy use

The fan does not compensate

- Decrease of hygienic flowrate
- Decrease of IAQ

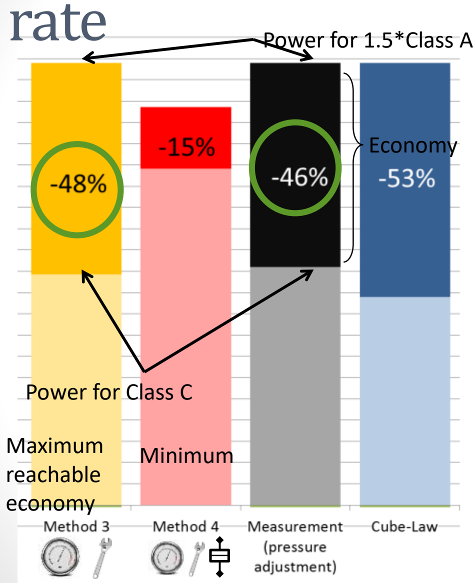
Fan energy use, test on laboratory replication of real ductwork system

- Area 18.7 m²
- Extract fan constant pressure
- 8 self- adjusting air terminal devices
- Airflow rate:
  - Max : 525 m³/h
  - Min : 260 m³/h
- Measurement and calculation method

Class C → Drilling → 1.5 *Class A

Source : (Berthault, Boithias, & Leprince, 2014)

Results for maximum airflow rate



- Decrease leakages from 1,5 class A to Class C can almost **divide Fan energy use by 2**

Source: Leprince, Carrié, AIVC 2017

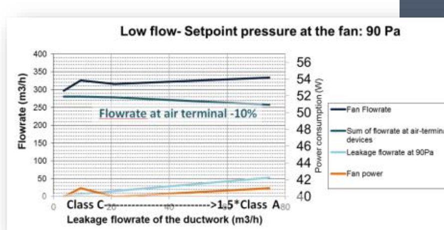
Energy use impacts

- Impact on overall building energy use:
  - According to (Soenens, 2011) the total energy consumption related to ventilation can **be reduced by over 30%** by achieving an airtight ventilation system.
  - According to (Dyer, 2011) in a pharmaceutical plant over a 30 years life of the building the energy **penalty** associated with excessive duct leakage is **more than 1.3 million dollars**

=> More studies on the impact on heating and cooling are needed

IAQ impacts

- Duct leakage:
  - Reduces flowrates at air terminal devices, unless fan compensates
    - A decrease of 10% of flowrate has been observed by (Berthault, 2014) if the fan is not re-adjusted
  - Suspicions:
    - Increases dust accumulation in filters, heat exchangers, ducts, …
    - Weakens contamination protection of sensitive areas (operating theatres, clean rooms, etc.)

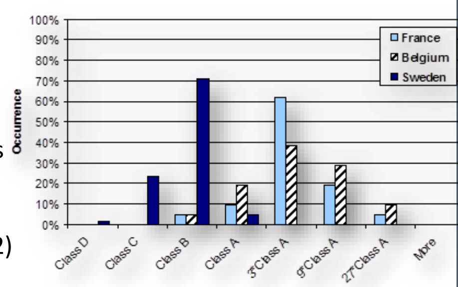


=> More studies on this field are needed

DUCTWORK LEAKAGE LEVELS

Ductwork leakage levels

- SAVE-DUCT project has shown striking difference between Sweden, Belgium and France (Carrié, 1999)
  - In **Sweden,** since 1966, the AMA tightness requirements have been raised to reach **Class C** for every ductwork since 2007 (Andersson, 2012)
- In US: duct leakage in 11 large buildings shown to represent on average **28% of the fan flow** (Modera, 2013)



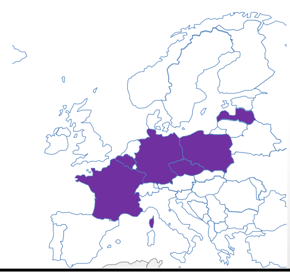
EVOLUTION IN REGULATORY OR PROGRAMME REQUIREMENTS

Evolution in regulatory or programme requirements

- In **Sweden** ductwork airtightness is required
  - Since 1966
  - Since 2007: **Class C** required
- In **Portugal** for large building
  - Since 2006 ductwork leakage below **1.5 l/s.m² under 400 Pa**
- In **Belgium**
  - Taken into account in calculation method, but no minimum requirement
- In **UK**
  - **Test mandatory** for system with design flows **> 1 m³/s**
  - For low pressure ducting no test required but taken into account in calculation
  - Test typically performed by ducting contractor
- In **France**
  - Since 2013
  - Effinergie + label requires **Class A**
  - Test has to be performed by a **qualified** independent **technician**

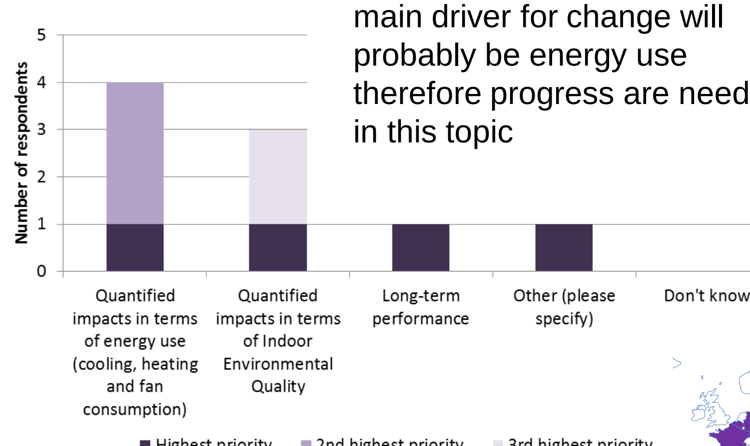
How ductwork airtightness is taken into account in regulations?

- Result of a Tightvent Airtightness Association Committee (TAAC) survey
  - Only France (RT2012) and Belgium (EPB) consider ductwork airtightness as an input in EP-regulation
    - But there is no minimum requirement
    - In France if a value better than default value is used then it has to be justified (testing or certified quality approach)
  - Awareness is low

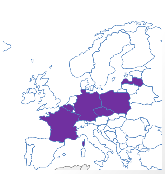


Source Leprince, Carrié, Kapsalaki, AIVC 2017

What is in your view the progress needed to promote ductwork airtightness in your country?



- As for building airtightness the main driver for change will probably be energy use therefore progress are needed in this topic



Program of this Topical Session

- Duct leakage testing in Portugal, a consulting engineer view and experience
  - Carlos Lisboa
- Ductwork airtightness in the UK: requirements and assessment of installed performance
  - Marcus Lightfoot
- Statistical analysis of about 1,300 ductwork airtightness measurements in new French buildings: impacts of the type of ducts and ventilation systems
  - Bassam Moujalled
- Ventilation ductwork systems certification for a better air tightness,
  - Marie-Clemence Briffaud
- The new air tightness class in ductwork - Aeroseal technology to seal leakages in new/retrofit ductwork and duct components - the foundation for highest energy efficiency in ventilation systems
  - Jorg Mez

Topical session: Ductwork Air Tightness:
Ongoing works in some European countries.

Duct leakage testing in Portugal, a consulting engineer view and experience

Carlos Lisboa

BLC NAVITAS energy advisors

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Office +351 214 415 546
Cell +351 919 263 880

Learning objectives:

- Ductwork air tightness importance;
- Values of air leakage rates measured in existing air duct systems;
- Ductwork air leakage testing, legal requirements;
- Ductwork air leakage testing, practice;
- Conclusions and recommendations.

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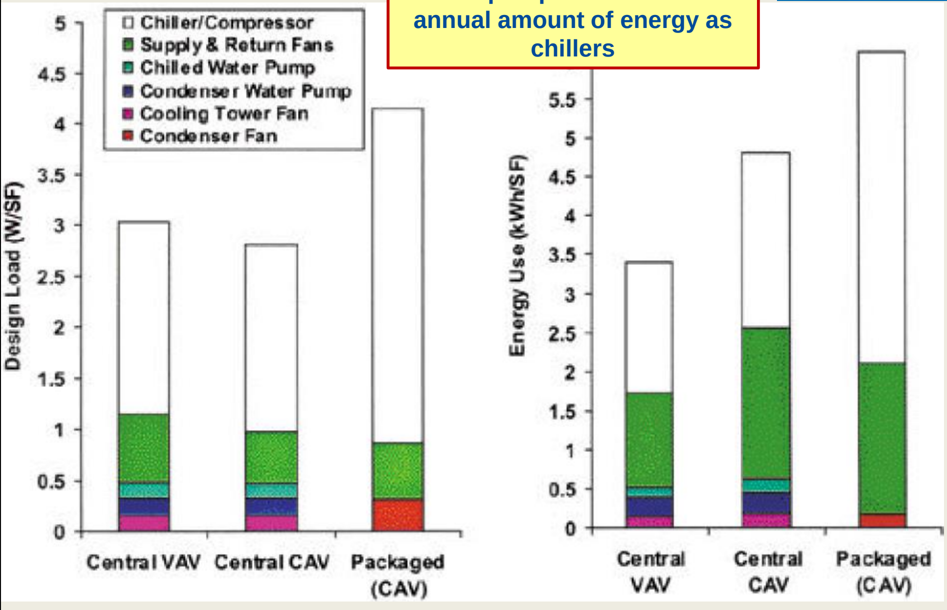
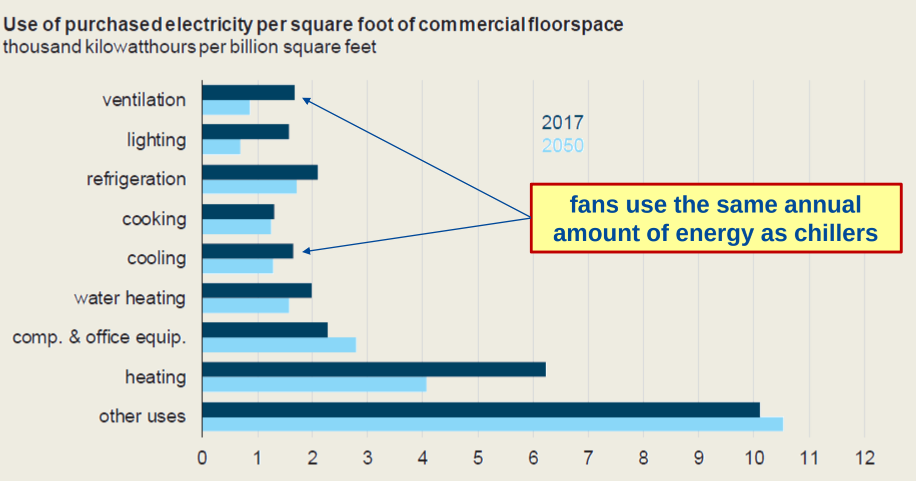
fans&pumps use the same annual amount of energy as chillers

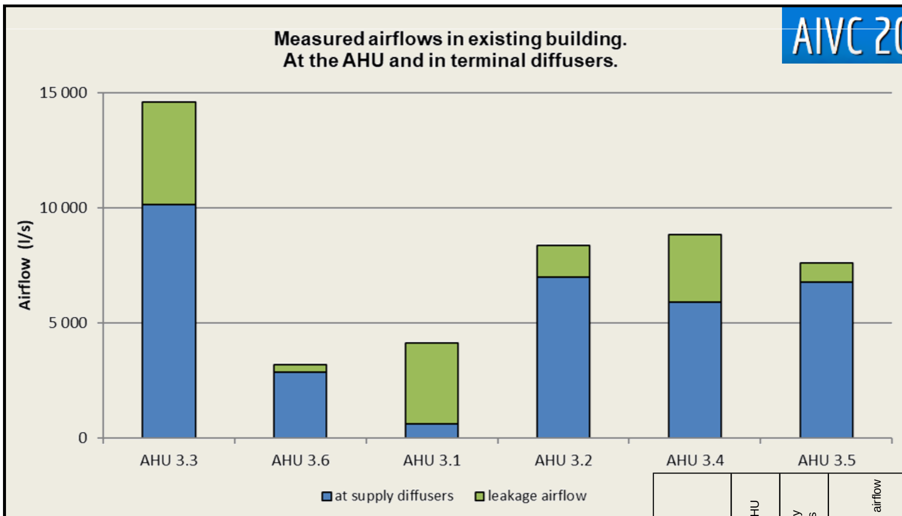


*USA Department of Energy (DOE). Annual Energy Outlook **1998**.*

AIVC 2018



*USA Department of Energy (DOE). Annual Energy Outlook **2018**.*



AHU	at the AHU (l/s)	at supply diffusers (l/s)	leakage airflow (l/s)	leakage airflow (%)
AHU 3.3	14 601	10 136	4 465	31%
AHU 3.6	3 175	2 873	303	10%
AHU 3.1	4 120	602	3 518	85%
AHU 3.2	8 369	6 969	1 400	17%
AHU 3.4	8 837	5 913	2 924	33%
AHU 3.5	7 589	6 772	817	11%

Existing ductwork systems can have huge leakage rates

“In practice a whole different theory applies ☺ ”

When, in practice, real world systems move away from ideal conditions unexpected results happen, compromising the established objectives, regarding efficiency and effectiveness.

Leaky airduct systems are a good example of this fact and should be effectively dealt with.

Legal requirements in Portugal

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Dispatch (extract)-15793-G/2013. Test and provisional acceptance of systems. Maintenance plan.

- Leakage tests are mandatory except when the construction works contract explicitly excludes them;
- Ductwork must have a leakage rate of less than 1,5 $l/s/m^2$, when tested at a pressure of 400Pa;
- The sample to be tested shall be, at least, 10% of the ductwork;
- If the test fails a second test covering 20% of the ductwork must be performed;
- If the second test fails, the full ductwork must be tested.

Legal requirements in Portugal

AIVC 2018

- EN 12237: 2003, Class A, at 400Pa, establishes a leakage airflow limit of 1,33 $l/s/m^2$;
- **The requirements** of the portuguese law, 1,5 $l/s/m^2$, when tested at a pressure of 400Pa **are under Class A**;
- The Portuguese law does not refer to the European standard EN 12237: 2003;
- Ductwork leakage tests are mandatory by law since 2006.

Ductwork air leakage testing, practice in Portugal

The practicing experience in our company, on design and field inspection works, shows that:

- When forced to comply with the design specification, of ductwork leakage testing according to EN 12237: 2003, achieving a minimum performance of Class B, the reaction of the contactor is always surprise and lack of experience in performing the test;
- We need to guide the contractor on the test procedures;
- We have never worked with a contractor that owned the leakage test equipment. They either rent it or propose a test with a custom made equipment;
- Our general feeling, based on conversations with other professionals, in the market, is that very few leakage tests are performed.

Ductwork air leakage testing, practice in Portugal

- Class B ductwork can easily be achieved in ductworks of circular cross section if adequate installation procedures are met and adequate duct joining accessories are applied;
- The test itself takes around 10 minutes to perform, after correctly preparing the duct sample to test;
- Avoiding ovalization due to incorrect handling of ducts, namely transport or storage of straight duct sections in the horizontal position, stacked or not, without adequate rigid circular end caps. When rigid end caps are not used, to prevent ovalization, straight ducts must be transported and stored in the vertical position;
- The first part of the installed ductwork must be immediately tested to identify and correct possible inadequate installation procedures that, otherwise, would be repeated in subsequent parts of the ductwork

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Ductwork air leakage testing, practice in Portugal

When using 3D BIM models of the ductwork, with adequate level od detail, prefabrication of ductwork can be done, increasing quality of the finished job and decreasing installation time. Using this method, in a recent job, the tested samples reached, on average, leakage class C, and, in one of the last duct samples even reached class D.

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Ductwork air leakage testing in Portugal. Survey.

In order to have a more objective information on ductwork air leakage testing, we performed an **online survey** on the biggest contractors in the market. The survey sample was:

- 15 contractors;
- Total of nearly 180 M€ of sales (2016) for the 15 contractors;
- Answers are anonymous;
- Only 11 contractors answered the survey questions.

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Ductwork air leakage testing in Portugal. Survey.

How many ductwork air leakage tests has your company performed in the last five years?

range	answers
0	0
< 5	1
6 to 10	0
11 to 50	6
51 to 100	2
> 100	2

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Ductwork air leakage testing in Portugal. Survey.

What kind of test equipment do you use?

type	answers
custom made	2
test equipment conceived for leakage testing, rented	5
test equipment conceived for leakage testing, owned	4

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Ductwork air leakage testing in Portugal. Survey.

The survey results confirms that leakage tests, in Portugal, are seldom performed, since:

- 64% of contractors performed, on average, at most, 10 leakage tests per year;
- 82% of contractors performed, on average, at most, 20 leakage tests per year;
- Only four contractors own leakage test equipment, which indicates that, the remainder seven performed a small number of tests per year.

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Questions?

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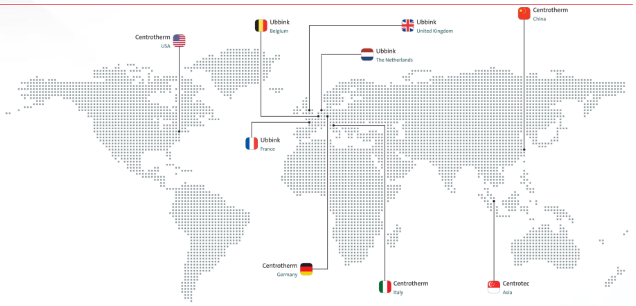

Ductwork airtightness in the UK

Requirements and assessment of installed performance

MARCUS LIGHTFOOT SEPTEMBER 2018

Why should be ductwork airtight?

A ductwork system that has limited air leakage, within defined limits, will ensure that the design characteristics of the VAC system are sustained. It will also ensure that energy and operational costs are maintained at optimal levels.

Agenda

- UK building regulations and compliance guides
- Current requirements
- Field measurement
- What is needed?
- Challenges

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Building regulations & compliance guides: NON-DOMESTIC

- The below UK Building Regulations only set standards for ductwork airtightness in buildings **other than dwellings** and refer to the **B**uilding **E**ngineering **S**ervices **A**ssociation's or **BESA**'s publication **DW 144** *Specification for Sheet Metal Ductwork Low, medium and high pressure/velocity air systems*, which specifies the limits of air leakage for various pressure classes of ductwork systems.

- Part L1A: Conservation of fuel and power in new dwellings
  Part L1B: Conservation of fuel and power in existing dwellings
  Part L2A: Conservation of fuel and power in new buildings **other than dwellings**
  - Refers to BESA DW144 for ductwork air leakage classes and testing
- Part L2B: Conservation of fuel and power in existing buildings **other than dwellings**
  - Refers to BESA DW144 for ductwork air leakage classes and testing
- Part F: Ventilation
  - Refers to BESA DW144 for ductwork air leakage classes and testing

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Building regulations & compliance guides: DOMESTIC

- Only the so-called **domestic** ventilation compliance guide gives non-statutory guidance about optimal ductwork installation.
- However, the UK has tried to estimate the impact of air leakage in ductwork systems in its energy performance calculation (**S**tandard **A**ssessment **P**rocedure or **SAP**) by introducing so-called in-use factors for **S**pecific **F**an **P**ower or **SFP** and thermal efficiency, which were developed to reflect the impact of typical installation and operation practices of ducted, central mechanical ventilation systems using rigid, semi-rigid and most of all flexible ductwork systems.

Table 4h: In-use factors for mechanical ventilation systems

In-use factors are applied to the data for mechanical ventilation systems in all cases

Type of mechanical ventilation	Approved install-ation scheme	In-use factor for Specific fan power			In-use factor for Efficiency	
		Flexible duct	Rigid duct	No duct	Uninsulated ducts	Insulated ducts [a]
Mechanical extract ventilation, centralised [a]	No	1.70	1.40	-	-	-
	Yes	*	*	-	-	-
Mechanical extract ventilation or positive input ventilation from outside, decentralised [a]	No	1.45	1.30	1.15	-	-
	Yes	*	*	*	-	-
Balanced whole house mechanical ventilation, without heat recovery [a]	No	1.70	1.40	-	-	-
	Yes	*	*	-	-	-
Balanced whole house mechanical ventilation, with heat recovery [a]	No	1.70	1.40	-	0.70	0.85
	Yes	*	*	-	*	*
Default data from Table 4g (all types) [b]		2.5			0.70	

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CURRENT REQUIREMENTS

- **Domestic**
  - None, but SAP's 'in-use factors' are a start.
- **Non-domestic**
  - The ductwork system designer specifies how airtight the ventilation ductwork system should be.
  - The limits of air leakage for the various pressure classes of ventilation ductwork systems in buildings other than dwellings are specified in Table 1 of BESA's publication DW/144 (see below).
  - Typically/logically high pressure or airtight ventilation ductwork systems are specified for clean rooms.

Table 1 Ductwork Classification and Air Leakage Limits

Duct pressure class	Static pressure limit		Maximum air velocity	Air leakage limits litres per second per square metre of duct surface area
	Positive	Negative		
1	2	3	4	5
	Pa	Pa	m/s	
Low pressure – Class A	500	500	10	$0.027 \times p^{0.65}$
Medium pressure – Class B	1000	750	20	$0.009 \times p^{0.65}$
High pressure - Class C	2000	750	40	$0.003 \times p^{0.65}$
High pressure - Class D	2000	750	40	$0.001 \times p^{0.65}$

Where *p* is the differential, pressure in pascals.

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FIELD MEASUREMENT

- **Domestic**
  - Not regulatory.
- **Non-domestic**
  - Air leakage testing (in accordance with DW/143 Ductwork Air Leakage testing) of ductwork systems served by fans with a design flow rate of 1 m3/s and high pressure/airtight (class D) ductwork systems is mandatory.
  - The ductwork system designer may also demand random air leakage tests of medium and low pressure ventilation ductwork systems in his/her specification and choose which ventilation ductwork systems to test.

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WHAT IS NEEDED?

- **Domestic**
  - In my opinion a regulatory requirement for ductwork airtightness and air leakage testing because the 'in-use factors' only try to estimate the installed performance more accurately, but 1. they still may not reflect the actual installed performance, 2. they don't set minimum standards for ductwork airtightness and 3. they don't recognise truly airtight ductwork systems.
  - Laboratory testing can identify systems, which are inherently airtight, but testing installed systems is the only way to assess if the installation or specific ductwork system types meet the required level of performance.
  - I believe that a regulatory requirement for ductwork airtightness and air leakage testing will motivate the supply chain to specify and install airtight ductwork systems with mechanical connections, which are readily available in the market.
- **Non domestic**
  - Sufficiently tackled in the building regulations for now, but every effort should be made to educate the market about the energy savings potential and effectiveness of airtight ductwork.

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CHALLENGES

- **Domestic**
  - Any regulatory assessment of more efficient and effective central, mechanical ventilation systems will probably be resisted by developers and drive them to cheaper and easier to install systems, e.g. background ventilation + intermittent extract fans. These systems are cheap, but the IAQ implications in airtight dwellings are not widely understood/appreciated yet.
  - Will competence schemes like BPEC and NICEIC deliver considering the attention required to install airtight ductwork systems and/or will ductwork systems with airtight, mechanical connections reduce the need for such schemes?
- **Non-domestic**
  - Ideally, the ductwork system designer/specifier will witness the air leakage test, which is often done by the installer, but this may not always be the case.

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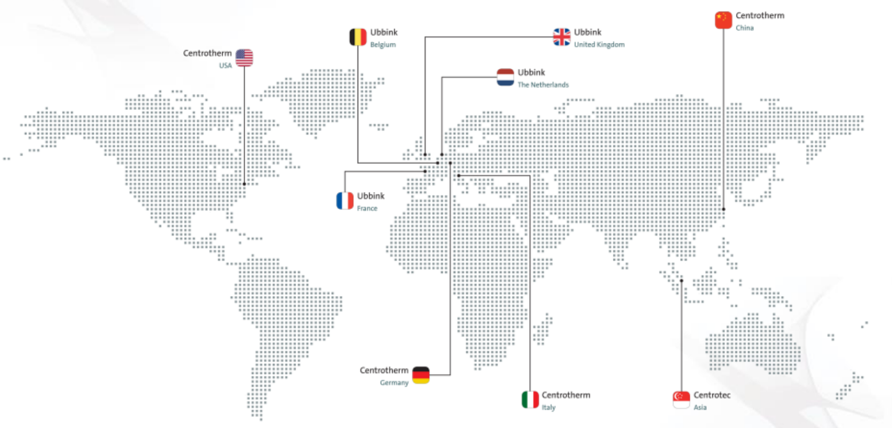

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Statistical analysis of about 1,300 ductwork airtightness measurements in new French buildings

Impacts of the type of ducts and ventilation systems

Bassam Moujalled*, Valérie Leprince, Adeline Mélois
*bassam.moujalled@cerema.fr

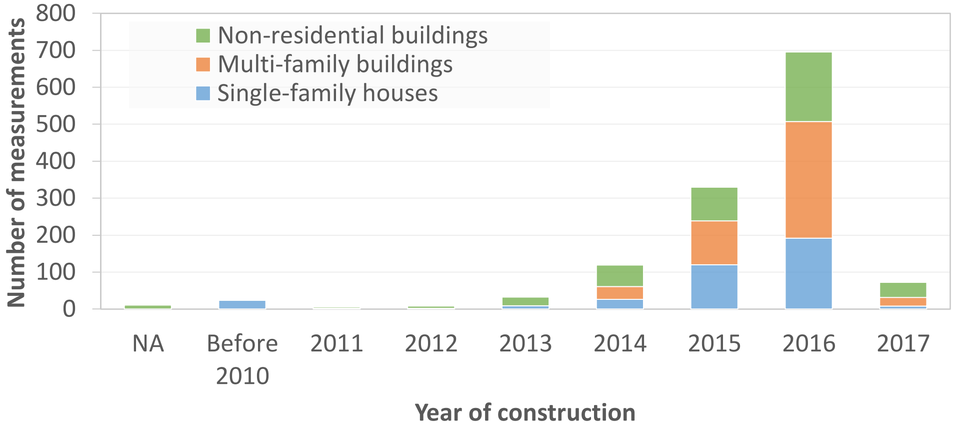
Introduction

French context of ductwork airtightness

- No mandatory requirement in France for ductwork airtightness
  - ✓ *measurement only required if a better value than the default value is used in the EP calculation*
- Since 2013, the French EP-labels “Effinergie+” and “BEPOS Effinergie 2013” requires **at least Class A to be justified by measurement**
- Test to be performed by certified tester according to a national qualification scheme for ductwork testers
  - ✓ *82 certified testers in 2018*
- Since 2017, field data are gathered in a common database
  - ✓ *Currently, 1,306 measurements have been recorded in the database*

Database overview

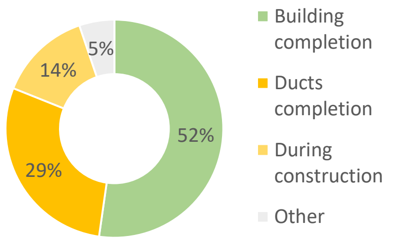
Evolution of the number of measurements



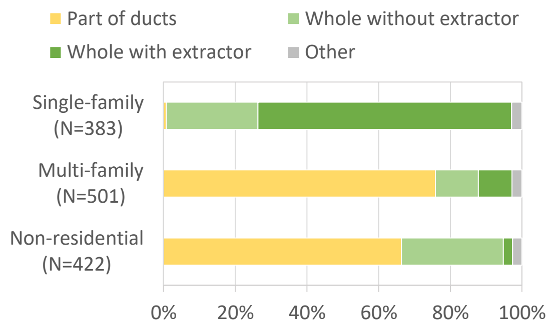
Database overview

Characteristics of measurements

Measurement time

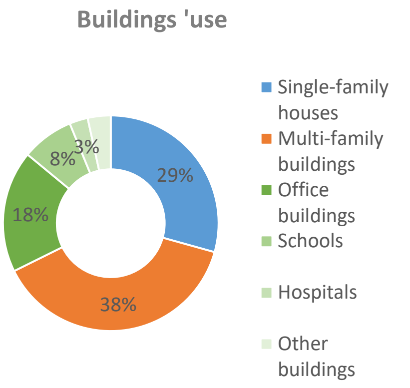


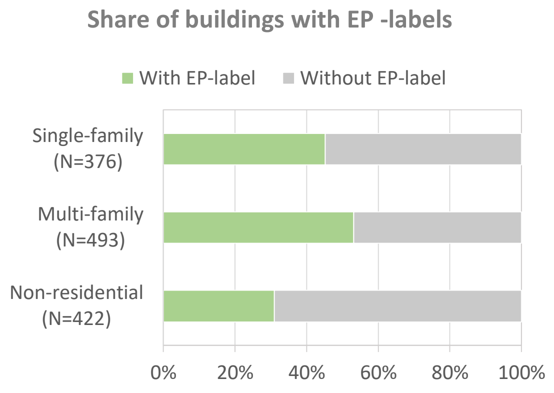
Measured extent of the ductworks



Database overview

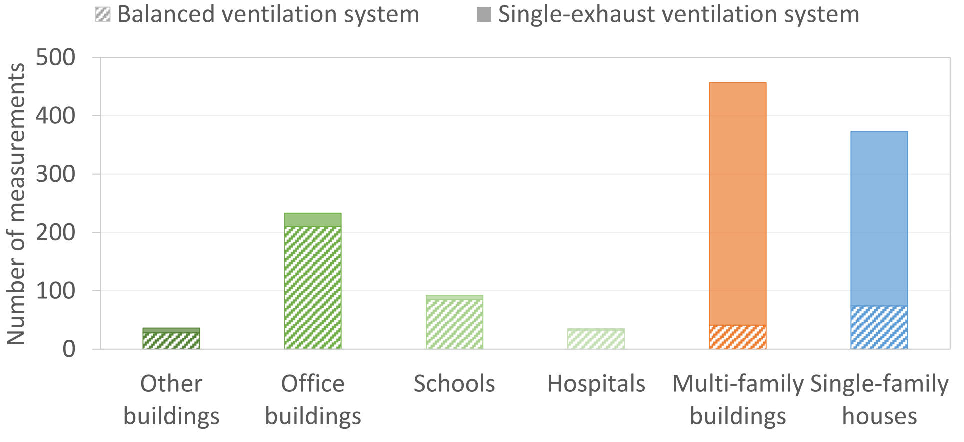
Characteristics of buildings





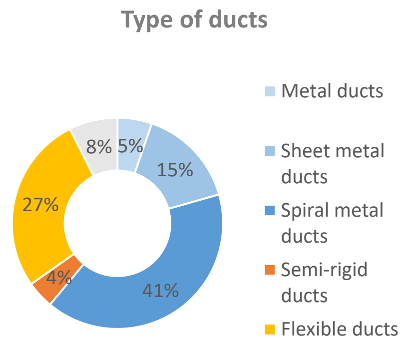
Database overview

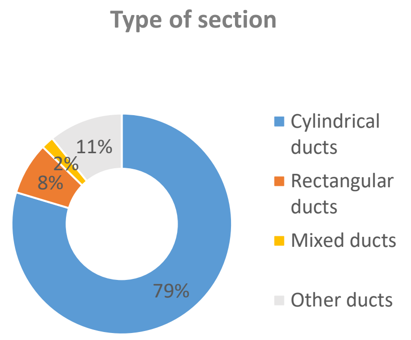
Type of ventilation system



Database overview

Characteristics of ductworks





Database overview

Characteristics of ductworks

Type of ventilation	Type of ducts	Office buildings	Schools	Hospitals	Multi-family buildings	Single-family houses
Balanced ventilation	Metal	79% (146)	83% (77)	83% (26)	4% (18)	8% (32)
	Semi-rigid	5% (10)	2% (2)	6% (2)	1% (6)	4% (17)
	Flexible	3% (6)	6% (6)	0% (0)	2% (13)	5% (19)
Single-exhaust ventilation	Metal	11% (21)	7% (7)	6% (2)	80% (360)	5% (20)
	Semi-rigid	0% (1)	0% (0)	0% (0)	1% (6)	3% (11)
	Flexible	0% (0)	0% (0)	3% (1)	10% (46)	72% (265)

Database overview
Characteristics of ductworks

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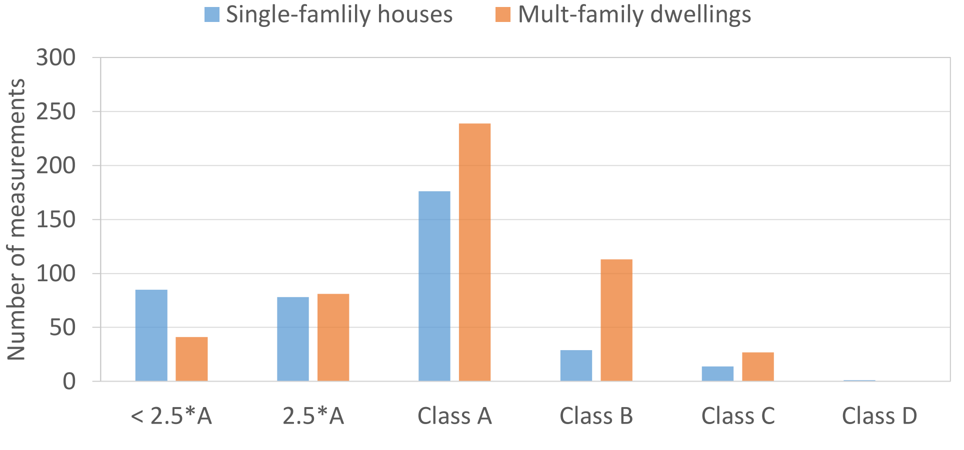
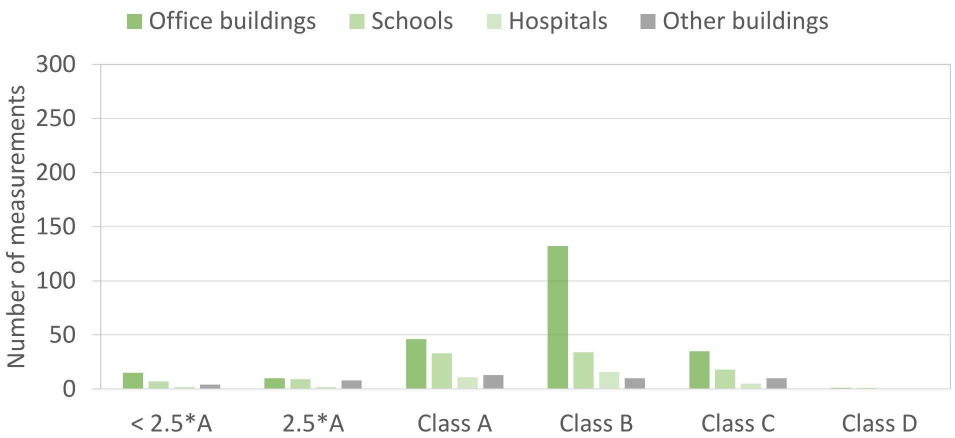
Measured ductwork airtightness
Residential buildings



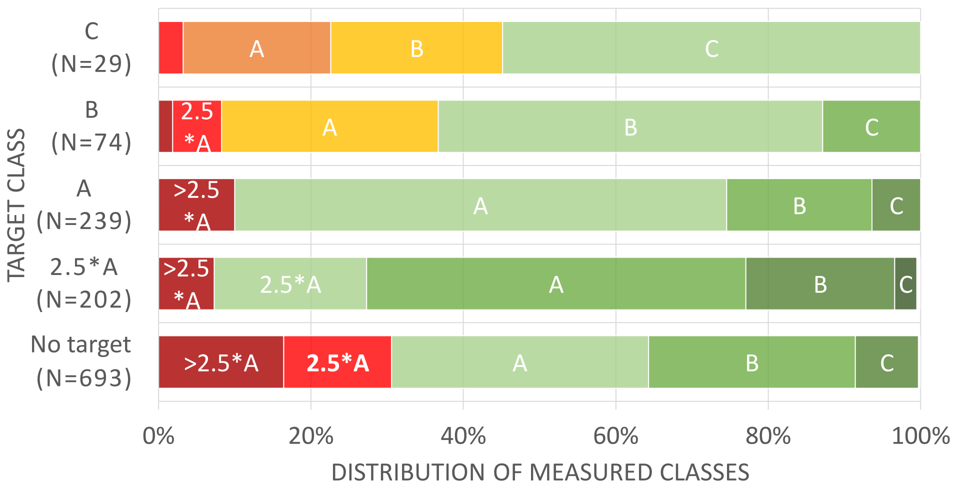
Measured ductwork airtightness

Non-residential buildings



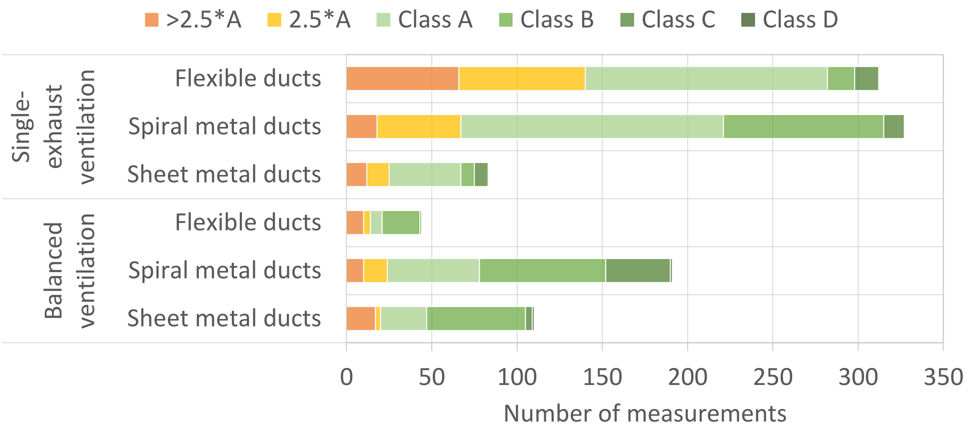
Measured ductwork airtightness

Measured ductwork airtightness classes



Measured ductwork airtightness

Impacts of ducts and ventilation systems



Conclusions

- **1,306 ductwork airtightness measurements in the database**
  - ✓ **Number of tests growing each year**: 696 tests in 2016.
- **New residential buildings:**
  - ✓ Both multi-family buildings and single-family houses with mainly single-exhaust mechanical ventilation systems
  - ✓ **Most measured ductworks met leakage class A**

Conclusions

- **New non-residential buildings:**
  - ✓ office buildings, schools, and hospitals with mostly balanced mechanical ventilation
  - ✓ **almost half of them met class B**
- **Target class → not widely achieved, especially for class C**
- **Ductwork airtightness performance seems to be related to the ventilation system and the type of ducts**

Results only apply to the buildings of the database

Thanks…

www.cerema.fr

Ventilation ductwork systems certification for a better air tightness

39th AIVC - 7th TightVent & 5th venticool Conference September 2018 – Juan-les-Pins

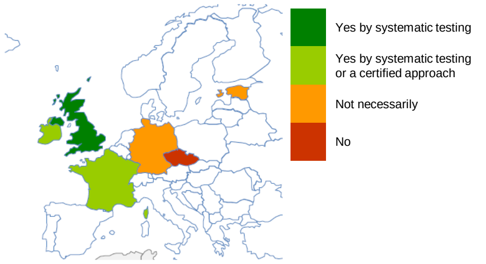
Marie-Clémence BRIFFAUD
Project Development Manager
mc.briffaud@eurovent-certification.com

Air tightness as a key lever towards…

- ✓ High air tightness ⟺ low leakage
- ✓ *Better **energy efficiency** of the ventilation system*
- ✓ *Possibility to achieve **nearly zero-energy buildings***

- ✓ High air tightness ⟺ low permeability to pollutants
- ✓ ***Better Indoor Air Quality***

Air tightness requirements for buildings in European countries



Do minimum building airtightness requirements exist in energy performance (EP) regulations?

Does compliance to this requirement need to be justified?

Source: Survey on building and ductwork airtightness requirements in Europe, Results presented during TightVent Airtightness Association Committee-TAAC of January 2017

Reminder : air tightness class (1/2)

- ✓ The air-tightness class rating goes from A (*worst*) to **D *(best)***
- ✓ **Leakage factor** f = leakage rate / ductwork surface area
- ✓ **$f \leq f_{max\_X}$** shall be **true for 10 pressures** in the pressure range to rate "class X"

Pressure range

Air tightness (- to +)

Air tightness class	*Static gauge pressure limit (p_s) [Pa]*		*Air leakage limit (f_{max}) [$m^3 \cdot s^{-1} \cdot m^{-2}$]*
	Positive	Negative	
A (worst)	500	500	$0.027 \times p_t^{0.65} \times 10^{-3}$
B	1000	750	$0.009 \times p_t^{0.65} \times 10^{-3}$
C	2000	750	$0.003 \times p_t^{0.65} \times 10^{-3}$
D (best)	2000	750	$0.001 \times p_t^{0.65} \times 10^{-3}$

Table 1 : Air tightness classification for DUCT-MC (according to EN 12237:2003)

Reminder : air tightness class (2/2)

Example: The test pressure p_t is 100 Pa so the leakage limit is

- $f_{max\_A} = 0{,}027 \times 100^{0{,}65} \times 10^{-3} = 0{,}539 \times 10^{-3}\ m^3{\cdot}s^{-1}{\cdot}m^{-2}$
- $f_{max\_B} = 0{,}009 \times 100^{0{,}65} \times 10^{-3} = 0{,}180 \times 10^{-3}\ m^3{\cdot}s^{-1}{\cdot}m^{-2}$
- $f_{max\_C} = 0{,}003 \times 100^{0{,}65} \times 10^{-3} = 0{,}060 \times 10^{-3}\ m^3{\cdot}s^{-1}{\cdot}m^{-2}$
- $f_{max\_D} = 0{,}001 \times 100^{0{,}65} \times 10^{-3} = 0{,}020 \times 10^{-3}\ m^3{\cdot}s^{-1}{\cdot}m^{-2}$

$\boxed{0{,}150 \times 10^{-3}\ m^3{\cdot}s^{-1}{\cdot}m^{-2}}$

If the leakage factor f is $0{,}150 \times 10^{-3}\ m^3{\cdot}s^{-1}{\cdot}m^{-2}$ the system fulfills the requirements of class… **B**

But class B will be confirmed only if $f \leq f_{max\_B}$ for …

…9 other test pressures between -750 and +1000 Pa!

Eurovent Certified Performance mark for Ventilation Ducts (DUCT)

The **DUCT** programme scope currently covers :

- ventilation ductwork **systems**
- composed of elements with **integrated sealing solution**
- air-tightness class rating equal or better than A

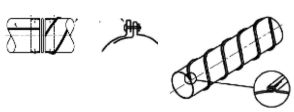
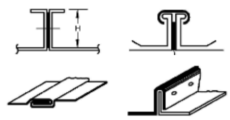
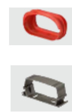
3 sub-programmes :

- ✓ **Rigid metallic** ductwork systems with **circular** cross-section (DUCT-MC)
- ✓ **Rigid metallic** ductwork systems with **rectangular** cross-section (DUCT-MR)
- ✓ **Semi-rigid non-metallic** ductwork systems predominantly made of plastics (DUCT-P)

Launched in September 2016

Eurovent Certified Performance mark for Ventilation Ducts (DUCT)

Integrated sealing solutions			
Use \ Sub-prog	**DUCT-MC**	**DUCT-MR**	**DUCT-P**
cross-sectional (transverse) joints	• Single (or more) lip(s) rubber sealing ring • Beaded sleeve joint* • Flange with gasket • Drawband clamps with gasket*	• Companion angles flange connection* • Slide-on or slip-on flange connection* • Other flange connection • Welded flange	• Seal ring • Clamp
longitudinal seams	• Spiral seam* • But weld seam • Grooved / Pipe lock /Flat lock seam • Snap lock seam	• Pittsburgh lock seam • Button punch snap lock seam • Grooved / Pipe lock /Flat lock seam* / Double corner seam • Standing seam* • Single corner seam	/

*illustrations from HVAC Duct construction standards, SMACNA, 2005

Eurovent Certified Performance mark for Ventilation Ducts (DUCT)

Sealing solutions NOT integrated (excluded from certification scope)		
DUCT-MC	**DUCT-MR**	**DUCT-P**
• Tape** (peal and seal; pressure sensitive, etc.) • Mastic sealant • Liquid sealant	• Tape (peal and seal; pressure sensitive, etc.) • Caulk/Mastic sealant • Liquid sealant • Transverse joints installed on construction site (Drive slip*, S slip*, Hemmed S slip, Double S slip, Standing S slip*, Standing seam)	Tape (peal and seal; pressure sensitive, etc.)


* illustrations from HVAC Duct construction standards, SMACNA, 2005
** illustration from Improving ductwork - A time for tighter air distribution systems, AIVC, 1999

www.eurovent-certification.com / www.certita.fr

Eurovent Certified Performance mark for Ventilation Ducts (DUCT)

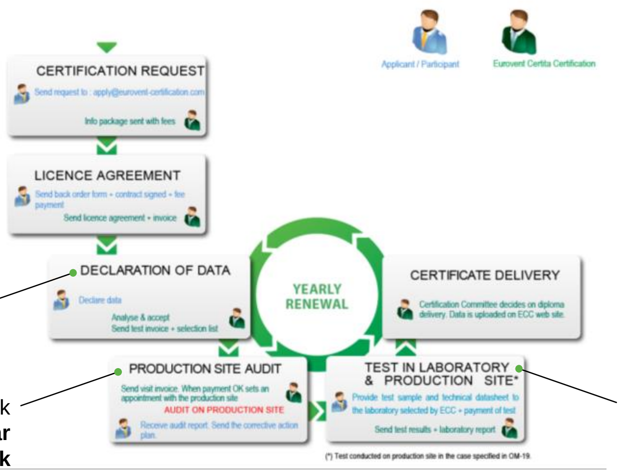
Certified characteristics and corresponding testing standard

Characteristic \ Sub-programme	DUCT-MC	DUCT-MR	DUCT-P
Dimensions compliance	EN 1506:2007	EN 1505:1998	-
Air tightness class (A, B, C or D)	**EN 12237:2003**	**EN 1507:2006**	**EN 12237:2003**
Static gauge pressure limits (positive and negative) in Pa	EN 12237:2003	EN 1507:2006	-
Design operating pressures (positive and negative) in Pa	-	-	EN 12237:2003
Minimum and maximum service temperatures in °C	-	-	RS/2/C/004P*
Resistance to external pressure : force F in N	-	-	RS/2/C/004P*

*Rating standard of DUCT-P sub-programme. Consistency with draft standard prEN 17192:2018 - *Ductwork - Non-metallic ductwork - Requirements and test methods* - was ensured. Update of certification documents will be made once into force.

Eurovent Certified Performance mark for Ventilation Ducts (DUCT)

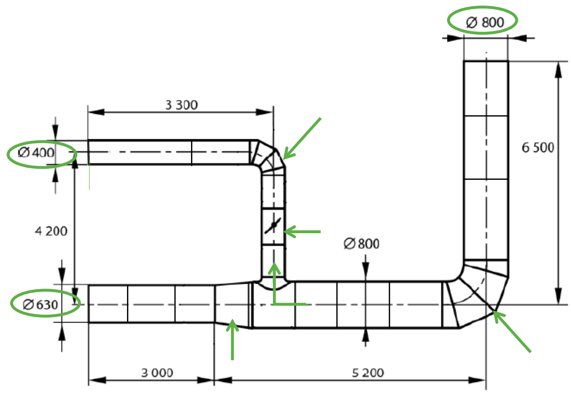
All the products covered by the sub-programme



On-site sampling of ductwork system elements from **regular production and/or stock**

Independent laboratory

Eurovent Certified Performance mark for Ventilation Ducts (DUCT)



Source : CETIAT "Etanchéité des réseaux aérauliques - Guide pratique"

Typical ductwork system to be tested (example for DUCT-MC)

Rules for DUCT-MC

- ✓ sizes : 3 ≥ 3
- ✓ Bends : 2 ≥ 2
- ✓ Bifurcations : 1 ≥ 1
- ✓ Transformation : 1 ≥ 1
- ✓ Tech. Ductwork Product : 1 ≥ 1

- **Same (≈) TDS for all manufacturers**
- **The TDS changes every year**

Eurovent Certified Performance mark for Ventilation Ducts (DUCT)

Audit key points

Typical ductwork system elements directly **sampled** from production line or stock

Same process and **same quality control points** from one production site to another

Quality management system requirements fulfilled at all times

Proper use of **ECP mark**

Products compliant with **declaration**

Corrective actions progress satisfactory (if any)

www.eurovent-certification.com / www.certita.fr

How does a certification programme work?

Decision of certification

Test results OK

Audit OK

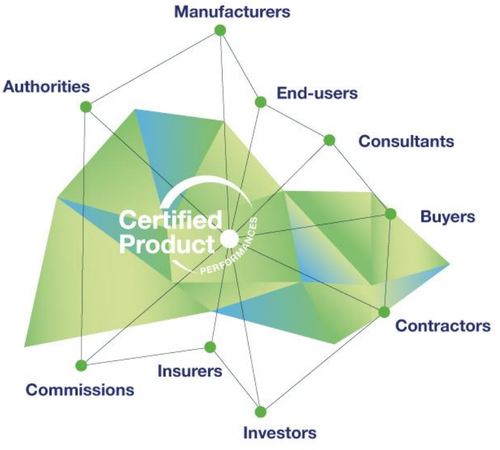
Certificate delivered
(or renewed)

Eurovent Certified Performance mark for Ventilation Ducts (DUCT)

Possible evolutions

Examples of evolutions to be considered in the near future :

- Extensions of the scope : double-wall (insulated) ductwork, flat-oval metallic ductwork, rigid non-metallic ductwork, etc.
- Introduction of new criteria (hygiene…)
- New regulations or standards to comply with
- Acceptance of external performance tests under specific conditions (recognition agreements with accredited testing bodies)
- …



Thank you for your attention.

Any questions?

PRODUCT AND SERVICES FOR BETTER AIR DUCT SYSTEMS

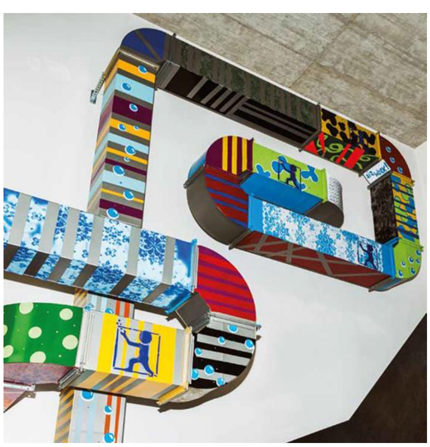
The new air tightness class in ductwork

Aeroseal technology to seal leakages in new & retrofit ductwork / components, the foundation for highest energy efficiency in ventilation systems and to fullfill today's european standards

18-19 September 2018 – Antibes Juan-les-Pins
39th AIVC Conference Smart ventilation for buildings
7th TightVent Conference

EU-Dipl.BW Jörg Mez – MEZ-TECHNIK GmbH

PRODUCT AND SERVICES FOR BETTER AIR DUCT SYSTEMS



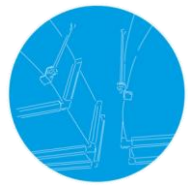
„Tight air duct systems are the **foundation** for an efficient, hygienically safe and comfortable operation of a ventilation system"

Therefore a **maximum in ductwork air tightness must be our first target** in order to get the best out of a ventilation system

The hole process chain in ventilation is responsible to reach this target

1. PLANNING

2. PRODUCTION



3. INSTALLATION

4. SERVICE

AIRWORKER

1. Planning phase: What to keep in mind!

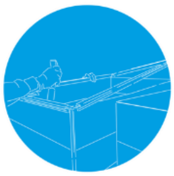
- **ATC 3 (C) is mandatory for nearly all installed duct system** to fullfill European Standards related to air as defined in **EN 16798 part 3**, EN 12599
- **ATC 2 (D) is mandatory for highest hygienic standards according to EN 15780 / VDI 6022** such as for
  - labatories,
  - treatment areas in hospitals
  - high quality offices (?)
- **ATC 1 (new)** is not reachable at all for installed classic duct systems with a traditional process chain and with traditional construction methods and components

mez-AEROSEAL AIR DUCT DIAGNOSTICS & SEALING

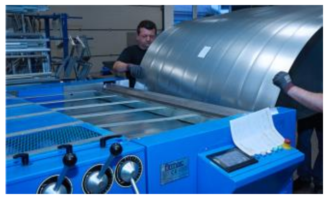
PRODUCT AND SERVICES FOR BETTER AIR DUCT SYSTEMS

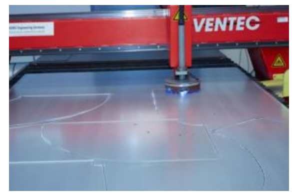
mez technik AIR SYSTEM PRODUCTS

2. Production phase: Quality gap - automatisation VS handcraft



- Machinery for manufacturing of straight rectangular / round ducts (represent avarage 40-50% in sqm of a duct system)





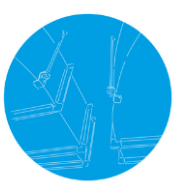
- Handcraft manufactured fitting parts such as ellbow pieces etc. (represent 50-60% in sqm of a duct system)

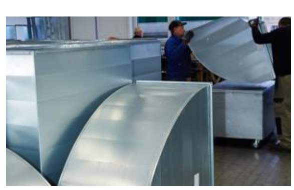
mez-AEROSEAL AIR DUCT DIAGNOSTICS & SEALING

PRODUCT AND SERVICES FOR BETTER AIR DUCT SYSTEMS

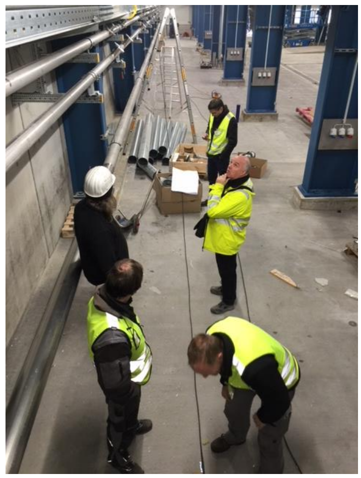
mez technik AIR SYSTEM PRODUCTS

3. Installation phase: 100% handcraft – out of quality control





3. Installation phase:
Responsibility of the installer



Process chain of production-transport-installation:
Means to loose one air tightness class in average in each step!

- Specification of air thightness class **ATC 2 (D) for production** has to be the minimum standard.
- **ATC 2 (D) or ATC 3 (C) is impossible to reach** for a **COMPLETE** installed air duct system on site with traditional methods.

There is a big gap between specified standards and reality on site which shows 15-40% leakage in average

Looking a bit closeer into that…

- Most air duct systems do **not even reach ATC 5 (A, approx 6% leakage) or ATC 6 (2,5xA, approx 15% leakage)**
- Known studies speak about **15% of leakage and more**
- A **average leakage in the USA of 28%** (Modera, 2013)
- More than 100 projects run by MEZ-TECHNIK and Aeroseal partners from 2015 until today **prove leakages of 15 to 40% and more** for complete systems **in new and old non-residential buildings in Europe**
- Still only very **few independend quality control** (air thightness tests) in Europe happens
- So far testing practis of **only 10% of total surface** (in the best case..) does reflect the real system leakage.

How to solve and improve this situation?

- We need a change the process chain of new construction of air duct systems
- Building owner / Investor needs a guarantee for quality and specified ATC 3 (C), ATC 2 (D) for a total system including it's components
- Retrofit of existing systems already in use is possible in an easy and economical way

„The air tightness class" AEROSEAL is the solution!

PRODUCT AND SERVICES FOR BETTER AIR DUCT SYSTEMS

What is Aeroseal?

- It's a 22 years old approved technology from the US, invented by Marc Modera at Berkley Labs
- The technology was Introduced to Europe and some other countries outside the US by MEZ-TECHNIK in 2015
- 18 Mez-Aeroseal-Service partners(Licensees) provide on-site-services so far in Europe & NZ – target to establish approx. 250 machines in Europe within the next years.
- More then 400 machines are in use worldwide (USA, UAE, AU, Asia) today
- Our european licensees perfomed in more then 100 new & retrofit projects in Europe so far

PRODUCT AND SERVICES FOR BETTER AIR DUCT SYSTEMS

Benefits of Aeroseal technology

- Reduces leakage in average more then 90%
- Seals gaps up to 15mm
- Hold preassure up to 2.000 Pa
- Works on sheetmetal, concrete, stone, plastic…
- Fullfills all relevant requirements in terms of hygiene, fire protection, VOC
- If dust on surface < 3mm no cleaning before process necessary
- Needs only 1-2 person to operate the process
- 2 hours after sealing system can be used again
- Amortisation of the process costs 1-5 years

PRODUCT AND SERVICES FOR BETTER AIR DUCT SYSTEMS

What is the sealant compound?

- Polyvinylacetat (PVAC/PVA)
- Corresponds to all relevant UL, VDI, EN standards
- Temperature range from -29°C to +249°C
- Durability of 30+ years
- Gurantee of 5 years of application
- VOC tested
- Fire Damper tested
- FDA conformity
- Can be used for fire rated smoke exhaust ducts sheetmetal and silicate ducts (PROMAT) as confirmed by German Ministry for construction

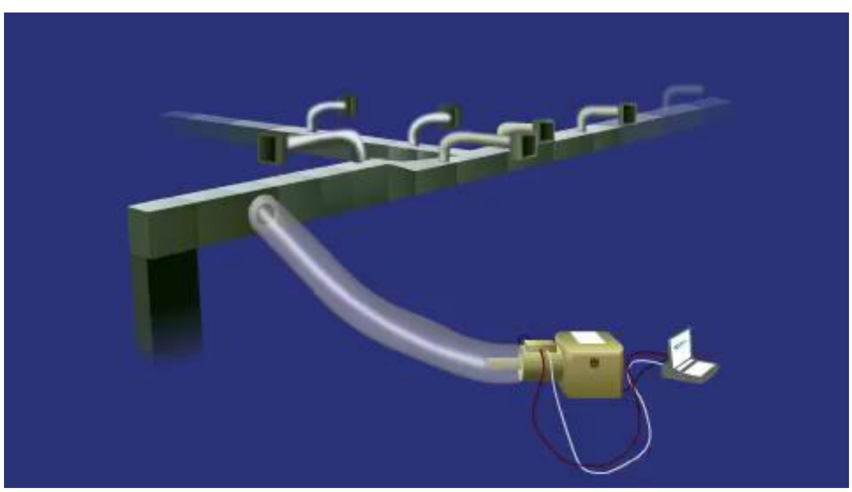
PRODUCT AND SERVICES FOR BETTER AIR DUCT SYSTEMS

How does the process work?

1. Define the systems to be sealed (Average 120 Meters lengths)
2. Disconnect (or not) the AHU's
3. Close all outlets/inlets
4. Take care about or protect dampers, sensors and heat exchangers
5. Connect the Aeroseal-Equipment
6. Do a process integrated pre-leakage test of the total area to be sealed
7. Seal the complete system (5-60min average)
8. Do a final leakage test and create a corresponding certificate
9. Re-establish the system
10. Balancing of the system

PRODUCT AND SERVICES FOR BETTER AIR DUCT SYSTEMS

How does the sealing process work?



Note: Live demo on Thursday 20th afternoom at ADEME TAAC Meeting!

Examples how does it works in practice

MEZ-AEROSEAL projects	Surface air ducts overall (m²)	Leakage overall (l/s)		Air tightness class (Average)		Reduction of leakage overall
		Before MEZ-AEROSEAL	After MEZ-AEROSEAL	Before MEZ-AEROSEAL	After MEZ-AEROSEAL	
Nursing home and community centre, Ottnang/Austria	707	94	5	B	D	95%
Retirement home „Franziskus", Linz/Austria	288	124	13	B	D	89%
Cardiology Clinic Filip Vtori, Skopje/Macedonia	7.366	10.831	345	A	D	97%
Production building IST METZ GmbH, Nürtingen/Germany	182	130	4	A	D	97%
Residential/Commercial/Hospital building Merkurhof, Rapperswil/Switzerland	436	77	22	B	D	72%
Apartment building, Montreuil/France	834	622	64	Ca. A	C	90%
Office building Conseil Général Gironde, Bordeaux/France	288	861	66	3,1*<A	B	92%
University Paris Ouest, Nanterre/France	2.079	2.787	217	1,4*<A	C	92%
Shopping centre Vill'up, Paris/France	1.186	1.424	78	1,2*<A	C	95%
Nursery, Les Ulis/France	346	914	66	2,7*<A	B	93%
Maternity Hospital „Casablanca Félicité", Paris/France	1.350	1.661	88	1.3*<A	C	95%
Nanotechnological laboratory « Campus Institut Mines Télécom », Evry/France	165	140	4	A	D	97%

- Results corresspond to customer targets – target is not always D!
- If it's starting at „B" these were usually small systems/sections or hand sealed additionally on site before application of Aeroseal

Case Study: Cardiology Clinic Filip Vtori Skopje (Macedonia)

Target: Compensate shortcomings of the ventilation system and ensure the building's opening in a timely manner

Preseal leakage: class A and worse

Postseal leakage: class D and better

Leakage: Improvement between 93 and 98%

PRODUCT AND SERVICES FOR BETTER AIR DUCT SYSTEMS

Case Study: Casablanca Félicité, Paris (FR)

Target: Air tightness class C

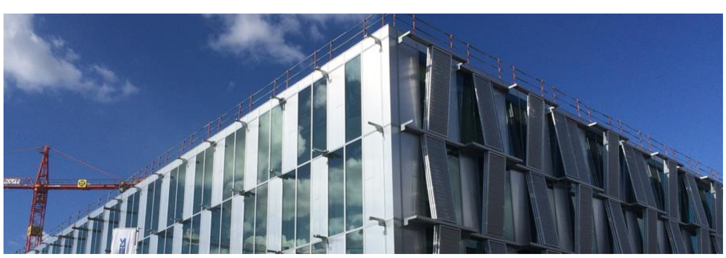
Preseal leakage: Initial leakage in 14 sections: 1660,9 l/s (5979,2 m^3/h)

Postseal leakage: Final leakage in 14 sections: 87,7 l/s (315,7 m^3/h)

Leakage: Reduction in total 94,7%

PRODUCT AND SERVICES FOR BETTER AIR DUCT SYSTEMS

Case Study: EPFL Lausanne



Target: Improvement energy efficiency and reduction of whistling and draft

Leakage: reduction of 94,1% in average on 10 rizer air duct sections

PRODUCT AND SERVICES FOR BETTER AIR DUCT SYSTEMS

Case Study: University of Nanterre (FR)

Target: Reducing leakage from 2 x class A to class B

Preseal leakage: 2.786,5 l/s (corresponds to 2 x class A)

Postseal leakage: 217,2 l/s (corresponds to class C)

Leakage: Reduction by 92,2%

"We were very pleased with the performance of AEROSEAL. Before the intervention, leakage losses were about 50% of the total air flow, and only about 3% after sealing "

PRODUCT AND SERVICES FOR BETTER AIR DUCT SYSTEMS

Case Study: Digiplex Data-Center Fetsund (NO) AHU's

Executing company:	MEZ-TECHNIK & GK Norge AS
Target:	Sealing of 36 Munters AHUs to max. below class D
Preseal leakage:	18 - 70 l/s per AHU
Postseal leakage:	2,5 - 5 l/s
Reduction of leakage:	85 - 93%

PRODUCT AND SERVICES FOR BETTER AIR DUCT SYSTEMS

Thank you very much for your attention!

Any questions?

Key findings on Ventilative Cooling
Learnings from Annex 62

Peter Holzer, Philipp Stern

Institute of Building Research & Innovation

Vienna, Austria

Juan-les-Pins
20/09/2018

KEY-PERFORMANCE PARAMETERS

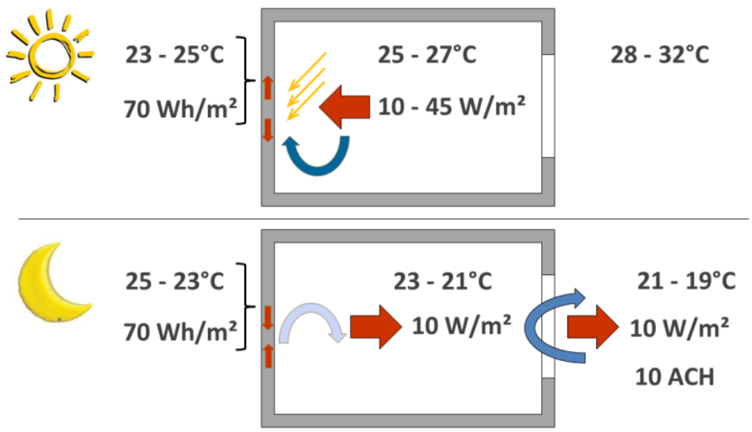
- AIRFLOW
- TEMPERATURE
- USABILITY and RELIABILITY

1
AIRFLOW

AIRFLOW

- Sufficient airflow, whether naturally or mechanically induced is crucial for Ventilative Cooling systems
- the percentage opening area to floor area ratio (POF) has to be around 2-8%
- in temperate climates with dry hot summers POF has to be high
- ACH of greater 3 h^{-1} is mandatory
- ACH of 10 h^{-1} is recommended

Storage and Discharge of Thermal Loads



Airflow Through Architectural Apertures

$$U_m = \sqrt{C_1 U_{10}^2 + C_2 h \Delta T + C_3} \qquad (1)$$

$$Q = \frac{1}{2} A U_m \qquad (2)$$

A	Opening area [m²]
C_1	Wind constant (0.001)
C_2	Buoyancy constant (0.0035)
C_3	Turbulence constant (0.01)
h	Window height [m]
Q	Volume flow rate [m³/s]
U_{10}	Reference wind speed measured at the height of 10 m [m/s]
U_m	Mean velocity [m/s]

Example:

Window:

Height = 2m, Width = 0,5m

2K Temperature Difference

Windspeed 2 m/s

→ U_m = 0,17 m/s

→Q = 300 m³/h

(ACH ~4,2 for sample room)

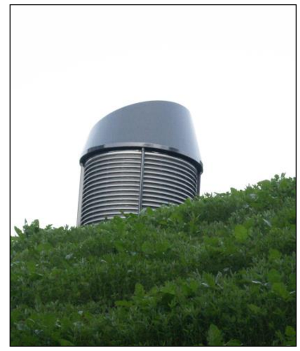
By de Gids & Pfaff

Enhance airflow by powerless ventilators

– Venturi ventilators reach pressure coefficients up to (– 1), leading to remarkable negative pressures of:

→ 4 Pa at an undisturbed wind speed of 2.5 m/s

→ up to 60 Pa at an undisturbed wind speed of 10 m/s.



$$p_{wind} = C_p \, {}^{\rho}/_{2} \, v^2 \quad (3)$$

C_p	Pressure coefficient (negative value)
p_{wind}	Wind pressure, additive to static pressure of the free stream [Pa]
v	Flow speed of the free stream [m/s]
ρ	Air density at sea level (1.204 kg/m³)

Design for very low pressure drop in the VC systems

– Driving forces of buoyancy are typically low (e.g. stack ventilation)

– If driving force is buoyancy, typically design for less than 5 Pa

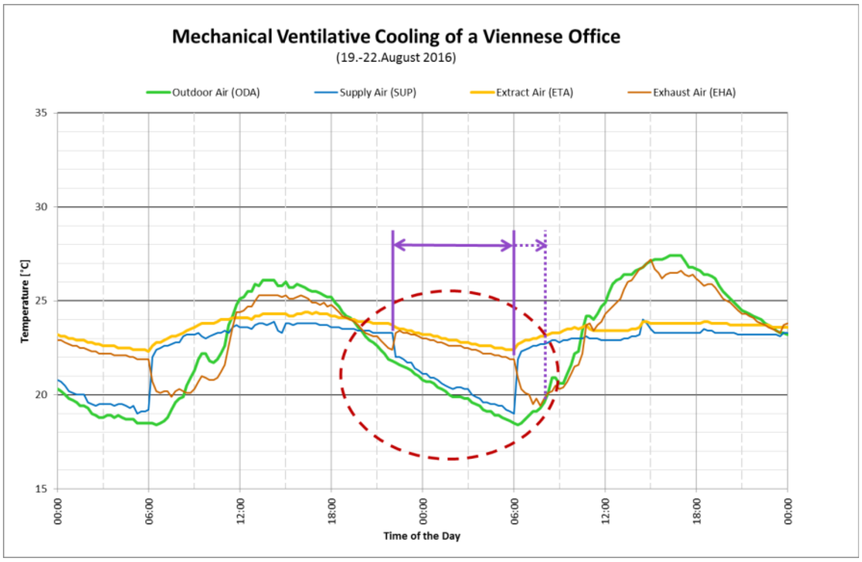
– In case of mechanical ventilation, design for less than 100 Pa

2
TEMPERATURE

Exploit available temperature differences, limit VC to periods which physically make sense

- A threshold ΔT of 2 K or higher is recommended
- 1.000 m^3/h can carry the thermal load of 340 W at a temperature rise of 1 K

Exploit available temperature differences, limit VC to periods which physically make sense



Design the VC system for summer comfort at increased air temperatures

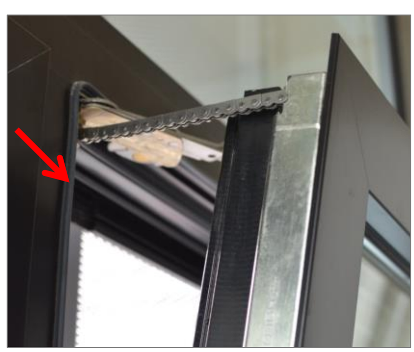
– Use of thermal mass is more effective at elevated indoor air temperatures
– Air movement is the most effective mean of extracting heat from the human body
– Air circulation fans allow indoor temperatures to increase by >2°K.
– This can reduce the building's cooling need significantly

→ **personal control increases acceptability!**

3
USABILITY & RELIABILITY

Focus on user integration

- User integration is crucial for a functioning VC system
- Users tend to open windows during warm periods and usually keep windows shut during cold and windy weather
- Case study documentation show best results when automated components also allow for manual control

Strictly emphasise Operability and Reliability of VC components

- Treat safety and security measures from early design stages on
- entrapment prevention is mandatory
- placed at heights above 2 m or
- use pressure sensitive sealing

Recognise the importance of post occupancy optimisation

- Problems of the control system are often only revealed over the course of a whole year
- Occupants take less responsibility for maintaining indoor climatic conditions after the first months of occupation

Example for the importance of post occupancy optimisation

- Protection against rain, burglary and fall is ensured
- Usage of the window for VC is compromised by use of windowsill



4 CONCLUSIONS

4 CONCLUSIONS

- **Favour airflow through architectural apertures**
- **Enhance airflow by powerless ventilators**
- **Design for very low pressure drop**
- **Make the most of available temperature differences, limit VC to periods which physically make sense**
- **Strictly emphasise Operability and Reliability of VC components**
- **Recognise the importance of post occupancy optimisation**

Further Information Available At

venticool.eu/annex-62-home

Annex 62 Deliverables

– Design Guidelines
– Ventilative Cooling Source Book
– Case Study Brochures
– International VC Application Database

Announcement of New Annex

– Annex 80 Resilient Cooling for Residential and Small Commercial Buildings
– Preparation Phase until June 2019
– Next Preparation Meeting
on Thursday 9:00 at Louis Armstrong Room

venticool
the international platform for ventilative cooling

EBC
Energy in Buildings and Communities Programme

Thank you for your attention

Institute of Building Research & Innovation

RESEARCH COOPERATION

FFG

References

Heiselberg, P. et al. (2018) Ventilative Cooling Design Guide, Department of Civil Engineering, Aalborg University

Holzer, P. et al. (2017). Ventilative Cooling on the test bench - Learnings and conclusions from practical design and performance evaluation, 38th AIVC Conference Nottingham

Holzer, P. (2016). Presentation at IEA cross-linking workshop (Vienna 20.10.2016) https://nachhaltigwirtschaften.at/de/iea/technologieprogramme/ebc/iea-ebc-annex-62.php

Holzer, P., Moherndl, P., Psomas, T., O'Sullivan, P. (2016). International Ventilative Cooling Application Database, http://venticool.eu/annex-62-publications/ventilative-cooling-application-database/

Holzer, P., Psomas, T. (2018) Ventilative Cooling Sourcebook, Department of Civil Engineering, Aalborg University

Kolokotroni, M., Heiselberg, P. (2015). Ventilative Cooling State-of-the-Art Review, Department of Civil Engineering, Aalborg University

VELUX

Status and recommendations for better implementation of Ventilative cooling into Danish standards, legislation and compliance tools

Main author: Christoffer Plesner, MSc. Eng. (VELUX A/S)

Co-author: Michal Pomianowski, MSc. Eng., PhD (Aalborg university)

39th AIVC – 7th TightVent & 5th Venticool conference, 2018

September 18-19th, 2018 @ Antibes-Juan-Les-Pins, France

Introduction

- **Background:**
  - Increasingly stricter energy requirements in buildings have caused more airtight and well-insulated buildings
  - Ventilative cooling of indoor spaces shows high energy savings and comfort improvement potential in e.g. new buildings

- Very well insulated
- Very airtight

- Elevated humidity, stuffy air
- Risk of overheating
- Need for ventilation
- Need for cooling

- Focus on thermal comfort (ventilative cooling)

- **What is ventilative cooling?**
  - Ventilative cooling (VC) can be described as the effective use of outside air by means of natural, mechanical, or hybrid ventilation strategies to reduce or eliminate the need for mechanical cooling (A/C)

Introduction

- **Aim of paper:**
  - To describe the current status and future recommendations for better implementation of ventilative cooling in standards, legislation and compliance tools in Denmark
- **Target group:**
  - Building designers, builders and experts working with building energy performance standards, legislations and compliance tools
  - Help target groups with concrete recommendations, for better future implementation of ventilative cooling, e.g.
    - How ventilative cooling is implemented
    - What can be done to improve the implementation

Introduction

- **Rationale:**
  - The work is part of the IEA EBC Annex 62, Subtask A (methods & tools), where 1 task was: "Recommendations for standards and legislation"
- **IEA EBC Annex 62:**
  - Research of IEA Annex 62 on "Ventilative Cooling" - 4 years from 2014-2017 that operates under International Energy Agency (IEA)
  - "The main goal is to make ventilative cooling an attractive and energy efficient cooling solution to avoid overheating of both new and renovated buildings" [venticool.eu]
- **Agenda:**
  - Methods
  - Status
  - Recommendations

IEA EBC
Annex 62
The IEA project
on ventilative cooling
EBC

Methods

- **How was the information gathered?**
  - Obtained by questionnaires answered by experts in 11 countries, all of which participate in IEA Annex 62
    - Which ventilative cooling parameters are integrated into Danish standards, legislation and compliance tools?. e.g. if:
      - Cross ventilation is included, which calculation time step is used for thermal comfort and if the position of windows is taken into account.
  - This paper only contains the findings from Denmark, incl. general conclusions from the main work
  - For all country inputs see Background report on Venticool's page:
    - http://venticool.eu/wp-content/uploads/2018/09/venticool_ebc62__background_report.pdf

Methods (questionnaire)

- Denmark: eg. Residential (**hourly calculations**), non-res (**monthly**)

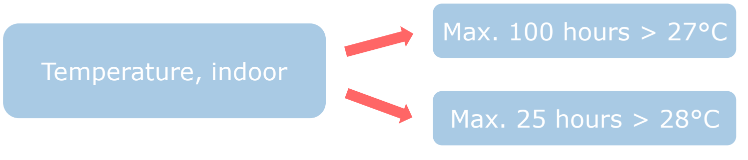
	Danish standard for NV, MV & HV; DS 447:2013		Danish legislation, BR15		Compliance tool Be18	
Parameters	**Residential**	**Non-residential**	**Residential**	**Non-residential**	**Residential**	**Non-residential**
Single-sided ventilation	Yes	Yes	No	No	Not specific but there is link between anticipated air flow and effective window area.	Not specific but there is link between anticipated air flow and effective window area.
Cross ventilation	Yes	Yes	No	No	Not specific but there is link between anticipated air flow and effective window area.	Not specific but there is link between anticipated air flow and effective window area.
Stack ventilation	Yes	Yes	No	No	No	No
Night cooling	Yes	Yes	No	No	Yes, separate air flow can be specified.	Yes, separate air flow can be specified.
Free cooling	Yes	Yes	No	No	Yes, by natural ventilation, then no fan energy consumption.	Yes, by natural ventilation, then no fan energy consumption.
Hybrid systems	Yes	Yes	No	No	Yes, natural and mechanical system can be specified in one building.	Yes, natural and mechanical system can be specified in one building.
Position of windows in building	Yes	Yes	No	No	No	No
Is wind included in your calculation?	Yes [11]	Yes [12]	No	No	No	No
Effect of having manual or automatic window operation	Yes	Yes	No	No	Yes, automatic control would increase anticipated air flow.	Yes, automatic control would increase anticipated air flow.
Steady-state or dynamic calculation?	Steady state and dynamic calculation [11]	Steady state and dynamic calculation [12]	*Thermal comfort may be documented by simplified dynamic calculation.	*Thermal comfort to be documented by dynamic calculation. ** Energy performance is documented through steady-state calculation	Simplified hourly calculation Energy: Steady-state	Thermal comfort: Not included in compliance tool. Energy: Steady-state monthly
Time-step (monthly or hourly)?	Monthly and hourly [11]	Monthly and hourly [12]	Comfort: hourly calculation Energy performance: monthly calculation	Comfort: hourly calculation Energy performance: monthly	Comfort:hourly Energy performance: monthly calculation	Monthly
Indicate important issue not included in this table			Question if legislation directly address Ventilative Cooling or cooling by means of air. For Danish case the answer would be No	Question if legislation directly address Ventilative Cooling or cooling by means of air. For Danish case the answer would be No		Thermal comfort: Not included in compliance tool. Overheating hours are recalculated to Watts and add as punishement for energy performance

Status of VC; Standards (DK)

- **DS 447:2013 (design and criteria standard on ventilation systems)**
  - Useful overview of requirements and what to include when designing and dimensioning ventilation systems, e.g.:
    - Natural ventilation systems using passive techniques for e.g. ventilative cooling
    - Both natural, mechanical and hybrid ventilation systems are defined, as well as demand controlled ventilation and summer comfort

Status of VC; Legislation (DK)

- **BR 18, 2018**
  - Only national building legislation and no regional legislations
  - Minimum required ventilation air flow rates are defined for indoor air quality) and not for thermal comfort
    - Ventilative cooling is not explicitly addressed in Danish Building Regulations.
  - Thermal comfort criteria are mandatory for residential buildings
    - Should be proved by simplified (hourly) calculations that:



  - Thermal comfort calculations for non-residential buildings require dynamic tools that is able to take the Danish Design Reference Year (DRY) weather data set into account
  - How to use the windows, night cooling possibilities, window control and automation is not mentioned

Status of VC; Compliance tools (DK)

- **BE18, 2018**
  - An additional feature to the official compliance tool to evaluate thermal comfort was implemented (from 2015)
    - "Summer comfort" module evaluates thermal comfort in summer in residential buildings (for a critical room with the highest risk of overheating) by **hourly calculations** (total hours above 27°C and 28°C)
  - Allows users to input a **fixed** ventilation rate for ventilative cooling, but does not assist them in determining the value
  - Thermal comfort improvements due to elevated air velocity not supported
  - For the energy compliance check, 12 simple (steady-state) **monthly calculations** are performed - unable to capture the dynamic character of the ventilative cooling performance

Recommendations; Standards (DK)

- More "design specific" national standards guiding how to achieve well-functioning ventilative cooling systems, e.g. the integration of ventilation components for ventilative cooling
- Several parameters should be taken into account, such as:
  - Acknowledgement of natural and mechanical ventilative cooling
  - Acknowledgement of night cooling
  - The support of calculation methods that fairly treat natural ventilative cooling for determination of air flow rates including e.g.:
    - Dynamics of varying ventilation
    - Effects of location, area and control of openings

Recommendations; Legislation (DK)

- Thermal comfort criteria with respect to overheating in non-residential buildings, e.g. offices, schools, day-care institutions are still up to the investor
  - These criteria are not explicitly defined and should be set in order
- Legislation should be more specific with regards to ventilation strategies in order to cool/maintain acceptable thermal comfort, like for natural ventilation strategies:
  - Single-sided, cross- and stack-ventilation should be clearly identified with respect to e.g. realistic ventilation capacities

Recommendations; Compliance tools (DK)

- Have the possibility for:
  - Variable air flow rates
  - Ventilation time schedules
  - Simple control strategies should be the first to be implemented for the ventilation strategy description (assuming that calculation is hourly)
- For evaluation of “energy performance” and “thermal comfort” - Key performance indicators, such as Cooling Requirements Reduction (CRR) and Ventilative Cooling Seasonal Energy Efficiency Ratio (SEER) should be included in compliance tool calculations

Recommendations; Compliance tools (DK)

- To allow for ventilative cooling to be treated in compliance tool evaluations, several parameters should be considered:
  - Assessment of overheating, e.g.:
    - Thermal comfort indicators, including adaptive temperature sensation
    - Energy performance indicators like e.g. virtual cooling needs, cooling consumptions etc.

- Assessment of increased air flows when efficient ventilative cooling systems are used:
  - Differentiation should be made i.e.:
    - Cross- or stack ventilation vs. single-sided ventilation
    - Automated systems vs. manual control
    - Large vs. small opening areas (only roughly included in Denmark
  - Airflows should be based on building physics for e.g. dynamic tools (using pressure equations) or on "coefficients" which increase air flows based on the chosen system.

Conclusion #1

- Generally, ventilative cooling is not very well included in standards, legislation and compliance tools across the evaluated countries , ranging from very simplified to detailed methods, e.g. from pure monthly average models to more dynamic hourly-based models.

- Most European compliance tools, uses the monthly average models that could underestimate the cooling potential of ventilative cooling, where there in Denmark has been made an improvement:
  - The implementation to the official compliance tool of a "Summer comfort" module that performs **hourly calculations** of <u>thermal comfort</u> in summer in residential buildings only

- Legislation should include or refer to guidelines, standards or compliance tools on how to calculate the cooling effect, resulting temperatures and the energy performance

Conclusion #2

- The full effects of ventilative cooling which are evaluated should reflect the real conditions for the building, control, use and climate, e.g. the actual building physics and geometry.

- The benefits of ventilative cooling are widely acknowledged, though its use by e.g. designers or architects strongly depend on a few intertwined challenges:
  - The adequate modelling of natural ventilation and especially of air flows
  - The share of energy for cooling for summer comfort and overheating risk is to become equivalent to energy consumption for heating in winter
  - To adequately predict the expected "thermal comfort and cooling requirements", and the "energy performance" when using ventilative cooling in buildings, e.g. using:
    - Static models (e.g. Fanger PMV model)
    - Adaptive models (e.g. adaptive comfort model))

The influence of thermal mass on the predicted climate cooling potential in low energy buildings

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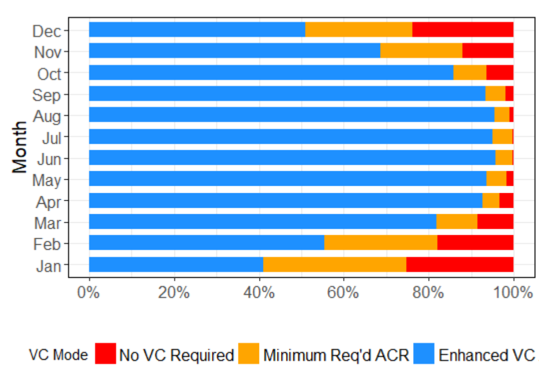
Introduction

- Early stage prediction of climate cooling potential for buildings important
- Estimation techniques of the available climatic cooling potential (CCP) from natural sources been put forward by many researchers
- Recent early stage CCP analysis tool developed by Annex 62 excluded thermal mass (as do many others)



Objective

When a portion of the total hourly incident heat gain rate is allowed to accumulate in an energy storage medium (both charge & discharge) during the occupied hours, What is the effect on:

- Predicted monthly hours that require an enhanced ventilative cooling (VC) rate
- Predicted distribution of required ventilation rates to satisfy cooling needs

- This work investigated the effect of including a notional amount of thermal mass
- Proposes an energy accumulation term in the energy balance model used to predict cooling potential

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Methodology – Example Building & Climate

To investigate this objective:

- We Used details from low energy retrofit testbed to develop CCP model
  - Open Plan Office
  - High thermal mass
  - High thermal performance
  - Reasonable levels of occupancy density
  - Reasonable levels of ensible internal gains
- We Used climate data from Cork, Ireland
- We Used CCP approach from IEA-EBC Annex 62

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Methodology – Energy Balance Model

- Approach based on Emmerich Polidoro & Axley (2011) and IEA-EBC Annex 62
- Existing steady state energy balance model with no thermal storage
- Compares a balance point temp with external temp & indoor adaptive comfort limits

Constant indoor air temperature

Total hourly heat gain rate

$$T_{bp}(t) = T_{sp}(t) - \frac{\boldsymbol{Q_T(t)}}{\dot{m}_n c_p + \sum UA}$$

min vent airflow rate

- May over estimate CC in high thermal inertia environments
- Predictions of required ACR quite high can lead to rejection of passive solutions

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Methodology – Simplified Thermal Storage

- Charging & Discharging thermal storage is a coupled, dynamic, non steady process, difficult to include in steady state model
- Limit the daily energy accumulation in the thermal mass below that req'd for 1K increase in material temperature
- This allows a reasonable assumption of a steady energy accumulation rate

$$\hat{Q}_T(t) = \boldsymbol{Q_T(t)} - \hat{Q}_{acc}(t)$$

New hourly heat accumulation rate

$$E_{1k} \geq E_{acc} = \sum_{t=1}^{n} \hat{Q}_{acc}(t)\,\Delta t$$

Total Daily Energy Accumulation Limit

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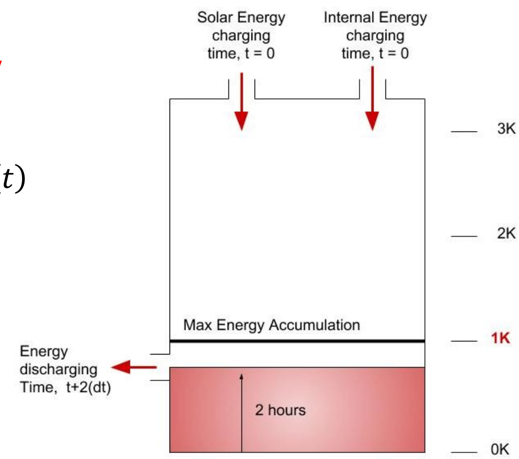
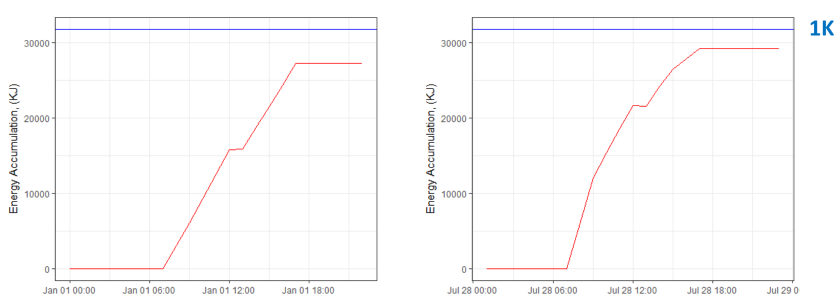
Methodology – Energy Accumulation Term

$$\overbrace{\hat{Q}_{acc}(t)}^{\text{hourly heat acc. rate}} = \overbrace{Q_s\boldsymbol{\alpha}(t)}^{\text{Solar Energy Charging}} - \overbrace{Q_s\alpha(t-\boldsymbol{\tau})}^{\text{Solar Energy discharging}} + \overbrace{\boldsymbol{h}A(T_{sp}-\boldsymbol{T}_{tm})(t)}^{\text{Convective Energy Charging}}$$

- Set the terms α, τ, h above to ensure charging does not exceed daily maximum limit
- Evaluate these terms at each occupancy period to Identify numerical values
- 3K temp difference set between thermal mass and indoor air



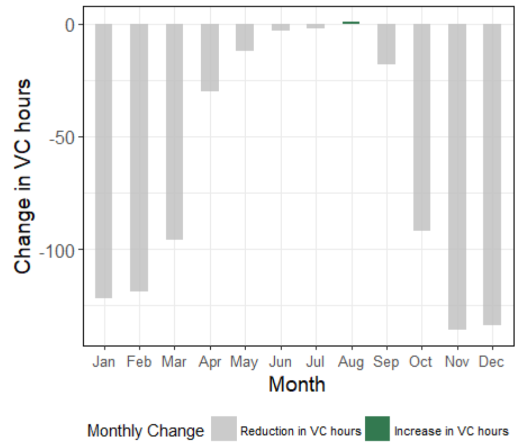
Methodology – Simplified Thermal Storage



- Typical daily energy accumulation profiles
  - January & July
- All energy accumulation assumed to be dissipated over night
- Max night time heat removal rate of 1.75 ACH

Results – Effect on enhanced VC Hours

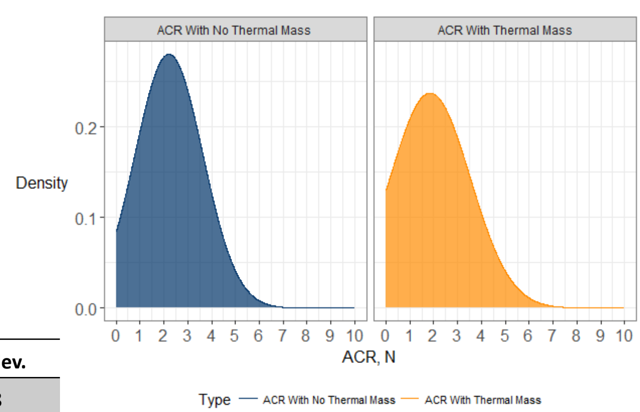
- Large decrease in enhanced VC hours in winter months (27% total reduction)
- Little or no change in VC hours for summer months
- VC is needed in summer even with modest thermal storage



Mode	Description	No TM (hrs)	With TM (hrs)
0	Heating mode	321	704
1	Cooling with Min airflow	454	834
2	Cooling with VC airflow	2875	2112

Results – Effect on Required ACR Values

- Mean ACR reduces overall by 32%
  - 2.8 ACH to 1.9 ACH
- Max ACR reduces by 18%
  - 14.9 ACH to 12.3 ACH
- Increased skewness in distribution
  - 0.14 to 0.42
  - Increased VC using min airflow rates



Type	mean	median	max	Std. dev.
No TM	2.8	2.9	14.9	1.8
With TM	1.9	2.3	12.3	1.7

Conclusion & Next Steps

- CCPA affects early stage design decisions on vent strategies
- Simplified approach presented demonstrates the importance in developing techniques that can include thermal storage in CCPA
- Approach limited by:
  - Maximum threshold for energy accumulation to maintain temp inc. to 1K
  - Assuming thermal mass temperature remains constant during charging
  - Proper validated definition of input terms and surface interactions
- Work ongoing using validated dynamic simulations:
  - Develop standard simplified response profiles for thermal mass temp
  - Proper quantification of input terms

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Thank You

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VALIDATION OF DYNAMIC MODEL BSIM TO PREDICT THE PERFORMANCE OF **VENTILATIVE COOLING** IN A SINGLE SIDED VENTILATED ROOM

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Estia

International Energy Agency
Energy Conservation in Buildings and Community Systems Programme

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Content

- BSim Validation according to EN 15255.
- Case building and measuring campaign
- Six operational conditions considered
- Model inputs
  - Solar radiation
  - Discharge coefficient C_d
  - Vertical air temperature distribution
- Results
- Conclusions

This project has received funding from the European Union'sHorizon 2020 research and innovation programme under grant agreement **No 649865**

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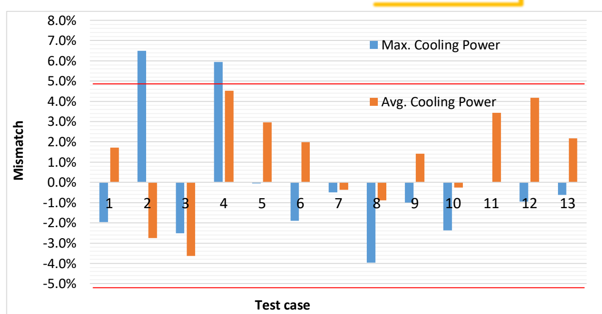
refurb

EN 15255: Thermal performance of buildings – Sensible room cooling load calculation – General criteria and validation procedures

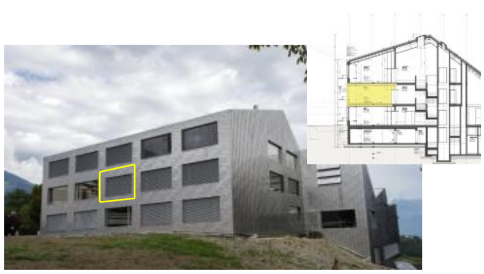
Test	Column Title
1	Reference case
2	Test 1 + modification of the thermal inertia
3	Test 1 + modification of the internal gains
4	Test 1 + modification of the glazing system
5	Test 1 + modification of the system control
6	Test 1 + intermittent operation of the system
7	Test 6 + modification of the thermal inertia
8	Test 6 + modification of the internal gains
9	Test 6 + modification of the shading
10	Test 6 + modification of the ventilation
11	Test 6 + modification of the max. cooling power
12	Test 6 + modification of system control
13	Test 6 + modification of the shading control

BSim tool validation

max ± 5 % mismatch allowed



Case building and measuring campaign



Section view Plan view

- School building
- Location: St-Germain, Switzerland
- Room 5.3 X7.6 X 3.3m
- Window:1 m² openable & 7 m² fixed
- Heavy construction
- Mechanical ventilation
- Natural ventilation
- External shading

Measurements were conducted for 6 weeks from 1-7-2015 till 13-8-2015

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Six operational conditions considered

Table 2: Overview of 6 test cases.

Case	Blinds position	Mech. ventilation	Window position	Intern. gains [W]
1	Standard	On	Closed	300
2	Standard	Off	35% open (nigh)	300
3	Standard	Off	35% open (permanent)	300
4	Standard	Off	62% open (permanent)	300
5	Standard	Off	Closed	300
6	Open	Off	Closed	300

Standard blind position refers to following daily repeated position in standard time:
- Blind is completely open at 06:00
- Blind is closed at 13:00 at pitch angle of 45°
- Blind is completely closed at 17:00

Blind is completely closed during the weekend

Heat gains resemble people load and are activated from 07:00 till 11:00 and 12:00 till 16:00

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Model inputs

Solar radiation

Only the global radiance in W/m^2 was measured for this study. To divide the global radiation into a direct and diffuse horizontal radiation, the model of Perez (Perez, 1992) was applied.

Discharge coefficient C_d

The CO_2 was used as tracer gas. By means of the decay method the air flow through the window was estimated

$$Q = -\frac{1}{6} ln\left(\frac{C_0}{C_i(t)}\right)$$

At which the C_0 is the initial CO_2 concentration and $C_i(t)$ the concentration at time x. With the obtained air flow through the window, the Cd coefficient is estimated (derived by Flourentzou, 1997).

$$C_d = \frac{Q}{\frac{1}{3}A\sqrt{\frac{(T_i - T_e)gH}{\overline{T}}}}$$

Blind position	Opened	45°	Closed
Cd	0.60	0.44	0.43

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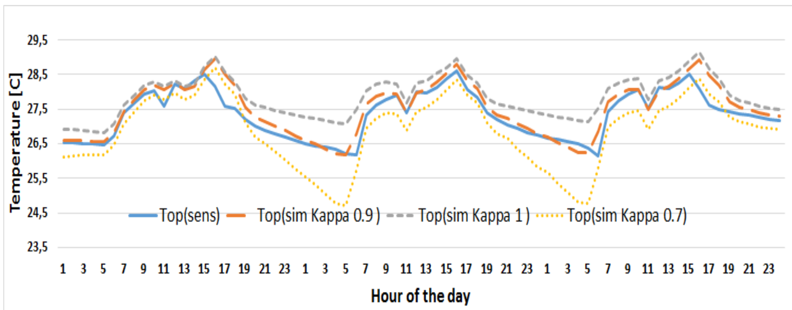
Model inputs

Vertical temperature distribution

Kappa Coefficient”. The Kappa value is a coefficient which is related to a linear simplification of the actual vertical temperature profile. To assess the sensibility of models to this coefficient several simulations with Kappa values 1, 0.9 and, 0.7 were conducted.



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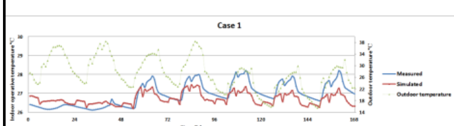
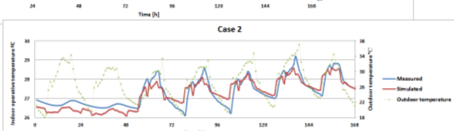
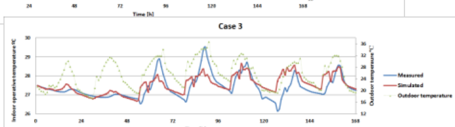
Results



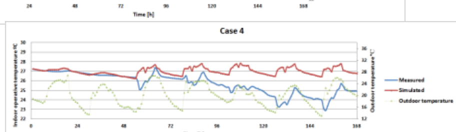
mechanical ventilation



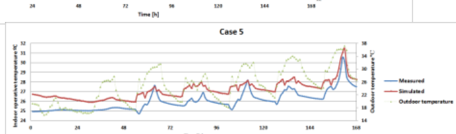
natural ventilation 35% (night)



natural ventilation 35% (day and night)



natural ventilation 62% (day and night)



no ventilation/ blinds stand./opened

Conclusions

1. Good understanding of indoor air distribution is required!
2. Good understanding of software used is required!
3. Reliability of simulation results of natural (single sided) ventilation are comparable to results for mechanical ventilation strategy.
4. Good estimation of natural ventilation performance was obtained in presented study.
5. Validation against EN 15255 is recommended but non compliance in some tests can be reasoned by discrepancy between input from standard and input possibilities of particular software.
6. Check the robustness of the model for one parameter at the time and for combined parameters!

Thank you for attention.

Questions?

KU LEUVEN

Ventilative cooling in a school building: evaluation of the measured performances

Hilde Breesch

Bart Merema, Alexis Versele

International Energy Agency

Ventilative Cooling Case Studies

Energy in Buildings and Communities Programme

May 2018

EBC

Energy in Buildings and Communities Programme

- Lecture rooms on KU Leuven Ghent Technology Campus
- Evaluation
  - Thermal summer comfort
  - Performances of ventilative cooling

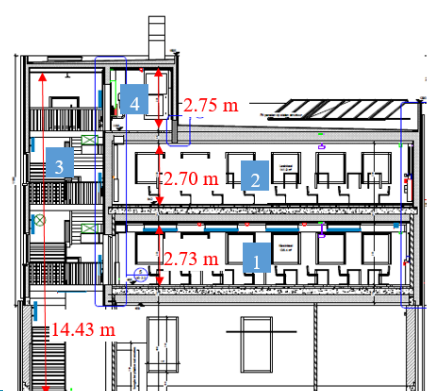
Overview

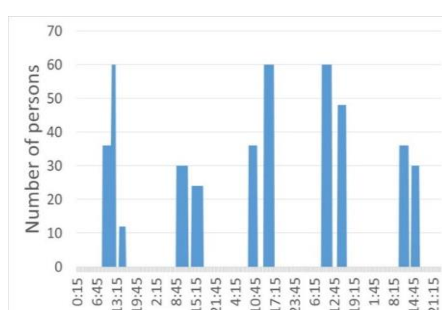
- Case study building
- Measurement set up
- Results
- Conclusions & Lessons Learned

Case study building

Test lecture rooms KU Leuven Ghent Technology Campus (BE)

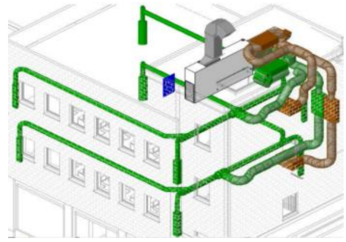
- PassiveHouse standard
- Zone 1 and 2: Floor area = 140 m² and varying occupancy

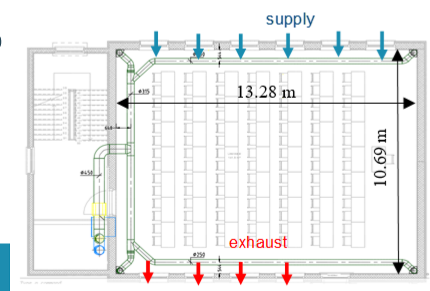




Ventilative cooling

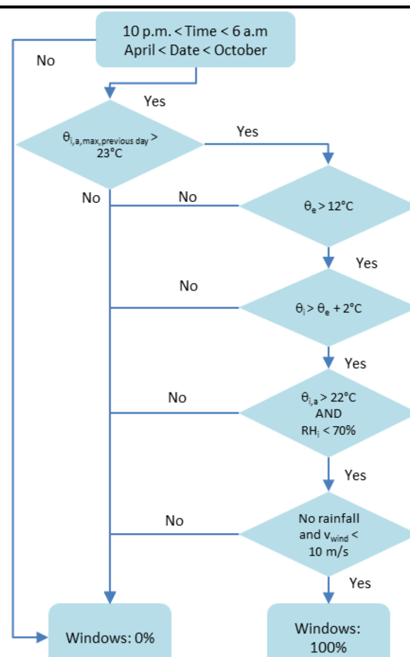
- Indirect evaporative cooling in AHU
  - Max 4400 m³/h
  - Max cooling capacity 13.1 kW
  - Activated: $T_i > 26°C$ or $T_e > 22°C$
- Natural night ventilation
  - Cross ventilation
  - Effective opening area = 4%





Ventilative cooling

- Control night ventilation
  - April – Oct
  - 22h-6h
  - $T_i > T_e + 2°C$
  - $T_{i,max,\ previous\ day} > 23°C$
  - $T_e > 12°C$
  - $RH_i < 70\%$
  - $v_{wind} > 10$ m/s
  - No rainfall

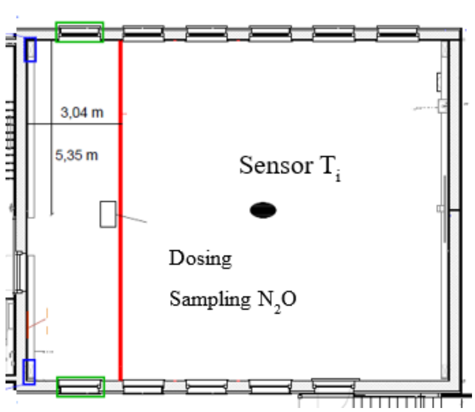


Overview

- Case study building
- Measurement set up
- Results
- Conclusions & Lessons Learned

Airflow rate night ventilation

- Tracer gas (N_2O) measurements



Ghent Technology Campus
Faculty of Engineering Technology
KU LEUVEN

Indoor & outdoor climate

- Extensive data monitoring system
  - Indoor: T, CO_2, RH, occupancy
  - Operation AHU, night ventilation, IEC, heating, etc.
  - Own weather station: solar radiation, T, RH, wind speed & direction
  - 1 min interval
- Monitoring: May 22 – Sept 30, 2017
- Belgian climate
  - Temperate without dry season with warm summer
  - 2017: 33 days $T_{e,max}$ > 25°C & 7 days $T_{e,max}$ > 30°C

Overview

- Case study building
- Measurement set up
- Results
  - Night ventilation:
    - Airflow rate
    - room air temperature profile
  - Operation of ventilative cooling
  - Thermal summer comfort
- Conclusions & Lessons Learned

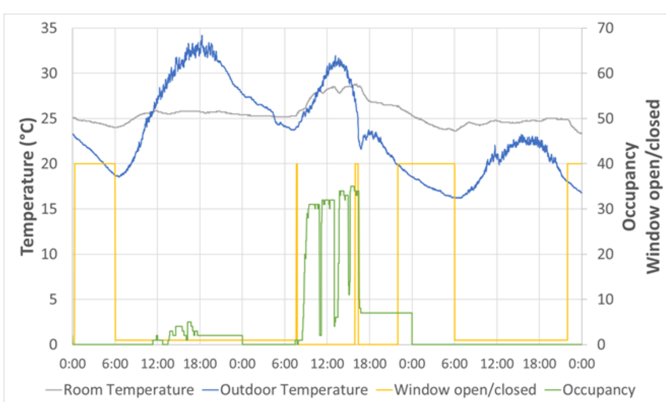
Airflow rate night ventilation

Ventilation mode	ACR (h^{-1})	Wind velocity (m/s)	Wind direction	ΔT (°C)
Cross ventilation	4,18 ± 0,42	1,9	WNW	4,3
Cross ventilation	3,76 ± 0,38	2,1	ESE	1,6
Cross ventilation	3,04 ± 0,30	2,2	ESE	2,4
Single sided	2,05 ± 0,21	2,3	SSW	No data
Single sided	2,00 ± 0,20	2,68	S	No data
Single sided	1,17 ± 0,12	1,45	SSW	5,1
Single sided	1,56 ± 0,16	1,78	S	8,6

- Cross ventilation: 2.2 to 4.6 h^{-1}

Operation Ventilative Cooling

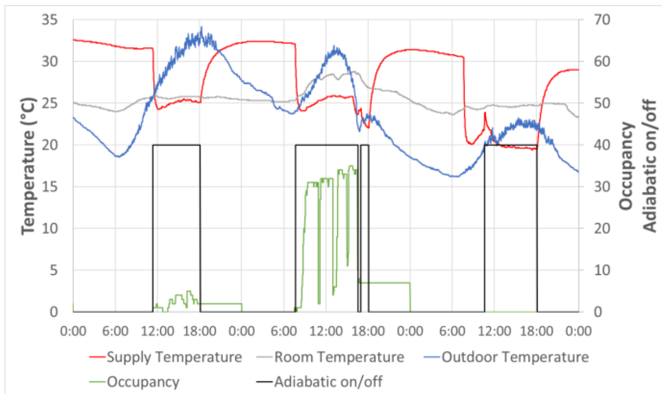
- Operation night ventilation during warm period



- night ventlation 45% of night hours (22h-6h)

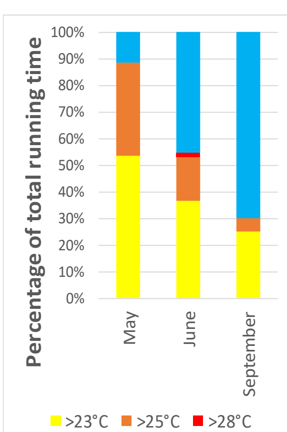
Operation Ventilative Cooling

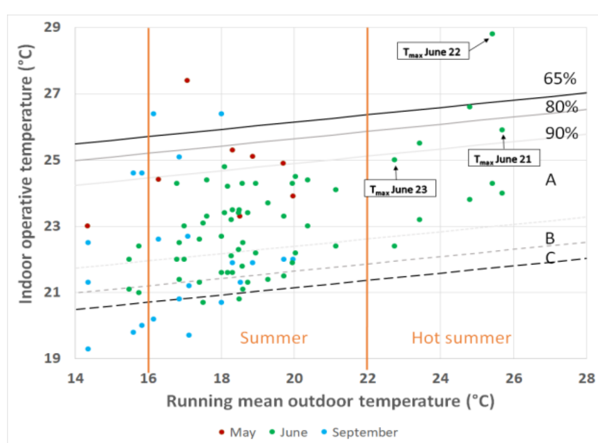
- Operation IEC during warm period



- IEC: 66% of AHU operation hours

Thermal summer comfort





Overview

- Case study building
- Measurement set up
- Results
- Conclusions & Lessons Learned

Conclusions

- Thermal summer comfort
  - in general good
  - high temperatures during heat waves and/or high occupancy
- Indirect evaporative cooling
  - Significantly lowers supply temperature
  - In use during 2/3 during AHU operation hours
- Night ventilation
  - In use during almost ½ night hours (22h-6h)
  - ACR is low to moderate
  - Whole lecture room is cooled

Lessons Learned

- Extensive data monitoring system
  - To detect malfunctions
  - To improve control of systems
  - To optimize building performance
- Do not forget the users
  - Inform them about automated systems
  - Educate them

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FREEVENT

Ventilative Cooling and Summer Comfort in 9 buildings in France (FREEVENT project)

Andrés LITVAK* (CDPEA/APEBAT), currently at Cerema
Anne Marie BERNARD (Allie'Air),
Nicolas PIOT (EGE),
Damien LABAUME (ALDES)

ALLIE'AIR EGE ACA-O APEBAT aldes ADEME

FREEVENT Guide :

Ventilative Cooling and Summer Comfort - DESIGN GUIDE (F)

FREEVENT Results :

Ventilative cooling and summer comfort: Freevent project in France

25 April 2018

http://aivc.org/resource/ventilative-cooling-and-summer-comfort-freevent-project-france?collection=36632

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Ventilative Cooling major issues

- Heat wave periods are more and more frequent.
- Energy Transition, bioclimatic architecture and passive house buildings : how to guaranty summer comfort without air-conditionning ?
- Non air-conditionned new or refurbished buildings show summer overheating issues (loads containment)
- many recent post-occupation evaluation studies revealed that new buildings with high thermal inertia, high insulation and airtight performances show very often overheating periods in summer or in mid-seasons with high indoor loads.

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Ventilative Cooling Challenge

- Thermal Energy Evacuation

Evening 18:00

28°C

Thermal energy evacuation :

Morning 8:00

26°C

22°C

18°C

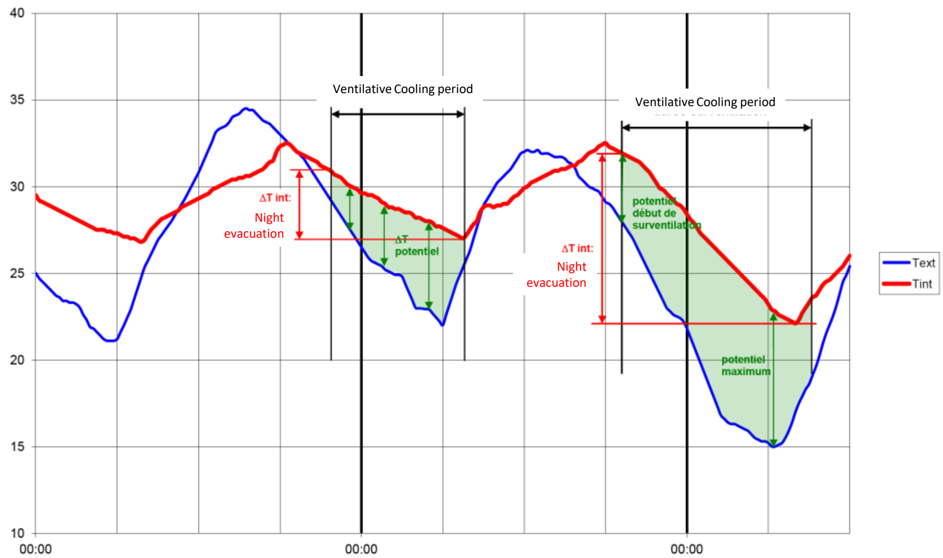
The challenge of ventilative cooling :

Unload in a brief summer sparsely cold night all the accumulated heat during a hot long day, then preserve coolness as long as possible.

OPTIMIZATION OF THERMAL PERFORMANCE AND COMFORT

- To characterize the ventilative cooling performance
- Accounting for all the comfort issues related to ventilative cooling :
  - Temperature (over-heating, too cold in the morning)
  - Acoustics (inside, outside)
  - Air velocity
  - IAQ
- Bioclimatic Architecture and Ventilative cooling

Thermal Potential and Heat Evacuation



Learnings from previous field measurement works

- the gains announced in temperature are in the range of 5 ° C.
- ventilative cooling strongly reduces the hours of overheating in continental climate and lower consumption of air conditioning and ventilation of 10%
- ventilative cooling divides by two hours of discomfort and/or earn an average 40% off on energy consumption in Mediterranean climate.

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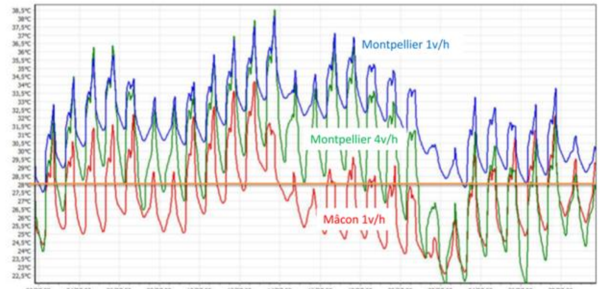
Methodology

- 9 French buildings equipped with ventilative cooling systems have been selected to **be audited through user surveys, onsite measurement campaigns and numerical simulations**
- a further analysis through **extensive field measurement monitoring** was conducted in 6 of the latter sites in order to assess gains on summer comfort from ventilative cooling systems
- All sites have been chosen in South of France, in order to account for challenging summer comfort conditions.
- Measurements were monitored during summer periods. The table below shows all the diagnosed operations characteristics.

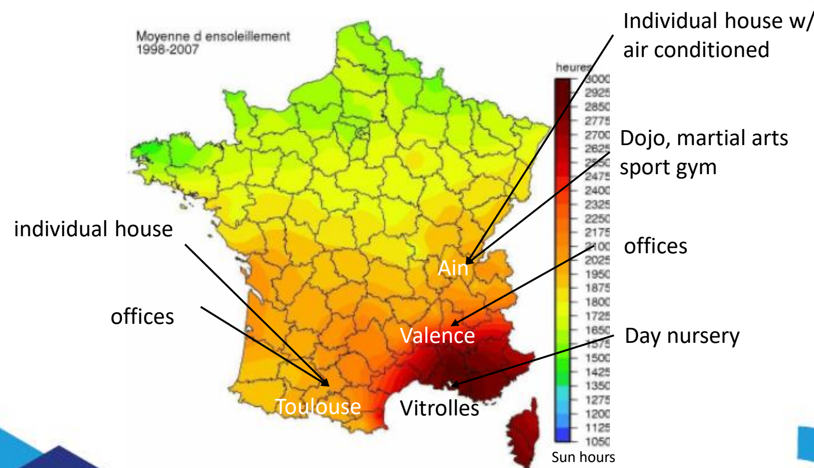
Ventilative Cooling Air Flowrates

- The air flowrate depends mainly on the cooling potential of the site.
- Modelling on identical buildings in Mâcon and Montpellier show better results of 1 ACH in Mâcon, and 4 ACH in Montpellier.
- Usually, one should **aim at 2 to 6 ACH**

Comparison of 2 sites :
better results in Mâcon (1 vol/h) than in Montpellier (4 vol/h) !



ON SITE MEASUREMENTS AND FEEDBACK



Measurement Protocol

1) temperature measurements in some premises ;
2) When possible, relative humidity measurements and CO_2 measurements in these premises ;
3) assessment of the ventilation airflow rate in case of mechanical ventilation ; when possible, assessment of the absorbed power of the fans ;
4) characterization of windows openings and assessment of natural ventilation airflows.

Indicators

Ventilative cooling temperature gain G(°C) is defined during the ventilative cooling period as :

$$G\ (°C) = (T_{in\_t_0} - T_{in\text{-}mini})$$ where,

- T_{in_t0} is the inside temperature when ventilative cooling starts
- $T_{in\text{-}mini}$ is the minimum temperature during the ventilative cooling period

The average ventilative cooling potential Π (°C) is defined as the average difference between inside and outside temperatures during the period:

$$\Pi\ (°C) = \sum (T_{in} - T_{out}) / \text{number of measurements}$$

The occupants comfort, assessed with the PMV and PPD indicators, according to the definition of the corresponding norm (ISO, 2005).

Indicators

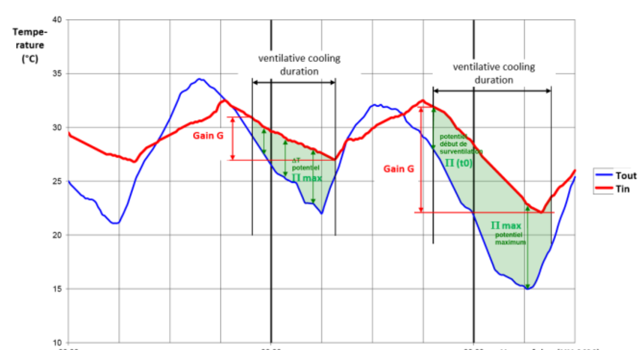


Figure 1: Thermal cooling potential Π and temperature Gain G based on outside and inside temperatures.

Discussion

The values G and Π **indicate if a better use of the site potential could be achieved**.

These indicators show if the site potential has been fully used to its maximum.

Assessed as an average on season, it can then qualify the system performance or indicate that increasing airflow, for instance by mechanical assistance, could be useful.

Indicators

Energy recovered Crec (kWh) during the ventilative cooling period :

$$\text{Crec (kWh)} = \Sigma\,(P_{rec})\,/1000 = \Sigma\,(|1{,}22.Q.(T_{out}-T_{in})|)\,/\,1000 \qquad \text{where,}$$

- Q is the ventilation airflowrate (l/s) : $\Sigma\,(|1{,}22.Q.(T_{out}-T_{in})| - \text{Pabs})\,/\,1000$

Energy Efficiency Ratio EER(-), assessed as the ratio between the recovered Energy and the absorbed Energy by the fans during the ventilative cooling period :

$$\text{EER} = \text{Crec}/\,\Sigma\,(P_{abs}.\text{nh}/1000) \qquad \text{where}$$

- P_{abs} : absorbed power (W) by the fan ($P_{abs}=0$ for natural ventilation).
- nh (h) is the number of hours of the ventilative cooling period

The EER optimization depends on evacuation potential. A performant EER doesn't mean necessarily an efficient ventilative cooling.

Findings

- A very good gain obtained with inside T° at 17°C in the morning (too cold) is not what we try to achieve. The use of night ventilation should be stopped when indoor temperature is achieved by a correct temperature control.

- A very good gain with inside T° drop from 36°C in the evening to 26°C in the morning is still not comfortable (too hot). The potential is used though and on this site, it is not possible to improve the system a lot anyway. Internal loads, solar protections to reduce the temperature increase at day have to be checked. If not, switching to active cooling may be necessary

Findings

- A very low T° drop from 26°C to 24°C would characterize a very good building with high inertia and thermal capacity that will never heat higher than 26°c during the day : **poor gain but perfect comfort.**

- A poor gain with inside T° drop from 36°C in the evening to 26°C in the morning is still not comfortable (too hot), but the night ventilation doesn't use all the site potential. It can be improved by increasing airflow (mechanical assistance for natural ventilation, sizing of components…)

Conclusion

- Mixed results, however in all cases, the recovered energy and the assessed performance (EER) shown interesting potentials.
- The concept of heat evacuation potential allows the designer to determine the expected performance of the system. On these sites, the effective ventilative cooling heat evacuation was 2 to 4 ° C while the potential of destocking was 4 to 16 ° C (in very peculiar conditions for the latter).
- The main difficulties and barriers identified were:
  - Undersizing design of ventilative cooling airflow rates
  - Stopping or declining ventilative cooling airflow rates (due to noise, cleanliness of filters, or the absence of the manually operated air supply...)
  - wrong settings of regulations and controls

Conclusion

- We identified 3 parameters to optimize the thermal and the comfort performance through ventilative cooling : thermal decrease, EER and indoor comfort.
- Hence, it is necessary :
  - To characterize the ventilative cooling performance : heat evacuation and EER
  - To account for all the comfort issues related to ventilative cooling :
    - Temperature : preventing indoor environments from over-heating in the evenings or too cold mornings
    - Acoustics (inside, outside)
    - Air velocity

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Key points for success

- Upstream bioclimatic design : Ventilative cooling will not compensate a poor design of internal and external loadings.
- Adapted dimensioning that accounts for all comfort criteria
- Involvement of owners / maintainer and occupants in the first years for fine-tuning operation.

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THANKS !

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Introduction to demand controlled ventilation in France

35 years of wide scale experience

Hygiene: an old preoccupation in France

Air confiné : air vicié
Confined air: stale air / waste air

Logement aéré (bon)
Airy dwelling (Good)

Logement sans air (Mauvais)
Dwelling without air (Bad)

Maison humide, maison malsaine
Wet house, unhealthy house

Source : Armand Colin - 1900

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French national regulatory context

FRENCH REGULATIONS	DEVELOPMENT OF TECHNOLOGY
1937 - Health regulations of the city of Paris - *ventilation by high and low vents*	Demand controlled ventilation appears in Sweden

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FRENCH REGULATIONS (cont.)	DEVELOPMENT OF TECHNOLOGY (cont.)
2000 - 2nd French thermal regulation	**Since 2000:** Development of low energy ventilation systems, heat recovery ventilation, low consumption motors, connectivity development
2012 - 3rd French thermal regulation – RT 2012	
2020/2021 – ***Coming :*** French thermal and environnemental regulation	

Overview of demand controlled ventilation in France

- Demand controlled ventilation has become the ventilation reference in France
  - When needed in the room, extract air flow is higher or lower compared to the fixed national reference
  - Mean value on one year is lower than constant air flow
- Demand controlled ventilation system (Humidity, CO_2, presence) are evaluated with Technical Apraisal Procedure
- Robust and reliable solution
- Importance of design, installation and maintenance of systems.
- Need to set up a mandatory reception of ventilation facilities to ensure the system performance
  - At EU Level : in the next EPBD
  - At French level : in the national regulation

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From Technical Appraisal of Demand-Controlled Ventilation Systems to IAQ Assessment Using the software MATHIS

39th AIVC Conference - Antibes

18/09/2018 – François Demouge

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Regulatory Framework
Default ventilation system in dwellings

Prescriptive Rules
- Defined by the National Regulation Body (*arrêté du 24 Mars 1982 modifié*)

Fixed architecture
- Overall and permanent ventilation system
- Outlets in technical rooms (kitchen, bathroom,…)
- Inlets in living spaces (living, bedrooms,…)

Fixed Volume flow rates at outlets
- Minimum flow rates to be reached
- Function of the number of principal rooms

Possibility of Lowered flow rates
- Automatically controlled system
- Specific Authorization of the National Regulation Body

Technical Appraisal Procedure (ATEC)

Innovative Ventilation Systems

Voluntary procedure
- Does not replace prescriptive rules

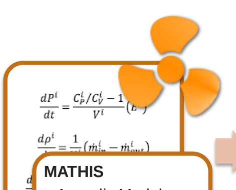
For the ventilation market
- Expert valuation on IAQ performance
- Valorization of energy saving

Under the Expert Committee GS14.5 supervision
- Sets the requirements to meet for each family of systems
- Defines the calculation procedure to follow as proof of performance using the software MATHIS

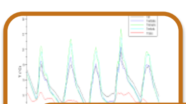
MATHIS Software

A Thermo-Hygro-Aeraulic Nodal model

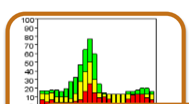
Building & Environment Data
- Geometry
- Ventilation System
- Wall Materials
- Occupancy
- …
- Weather
- Wind Pressure Coefficient



MATHIS
- Aeraulic Model
- Thermal Model
- Humidity model
- Species transport
- …



Transient Results
- Pressure
- Temperature
- Species Fractions
- Flowrates
- Heat losses
- …



Applications
- HVAC Design
- IAQ
- Thermal Comfort
- …

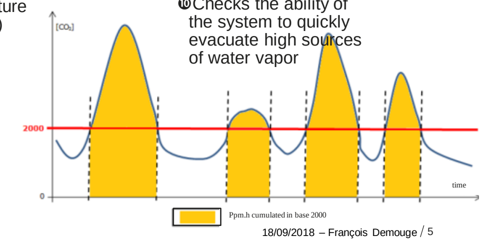
Users :

ATEC Calculations
Principles

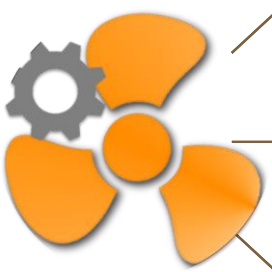
Main objectives
- Check the system efficiency in the management of an acceptable IAQ
- Quantify the performance of the system with regards to energy savings

Deterministic scenarios
- Outdoor conditions during heating season
- Various size of dwellings
- Envelope airtightness
- Occupancy (Number of persons, housing activities, furniture hygroscopy,…)

"IAQ" Criteria
- CO2
  - based on CO2 volume fraction evolution (see below)
  - ➓ Gives information on air renewal during occupancy
- Humidity
  - Number of hours when relative humidity is higher than 75% in technical rooms
  - ➓Checks the ability of the system to quickly evacuate high sources of water vapor



Ventilation Systems (V.S.) under Technical Appraisal
To date, mainly humidity-controlled V.S.



FAN ASSISTED V.S.
- Exhaust or balanced
- Individual or collective
- Simulation done at the scale of one dwelling
- Air terminal devices modelled as operating at their rated pressure
- Corrections are applied on the mean flowrate used for energy saving calculations with regards to fan control method

HYBRID V.S.
- Exhaust
- Collective dwelling refurbishment
- Low rated pressure
- Simulation done at the scale of a whole building
- Modeling of ductwork and hybrid fan operating modes (mechanical and natural)

COMPATIBILITY BETWEEN AIR CONDITIONING AND V.S.
- Full thermo-hygro-aeraulic calculations
- Whole year (both heating and cooling AC mode)
- Comparative study between « with » and « without » the AC system

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Needs for better Assessment of IAQ

Conclusion and perspective

- Scientific knowledge and public awareness on IAQ have progressed
- IAQ French Observatory

Growing health protection demand from end users

- Cheaper electronics components
- Probes for any gas
- Multi-control algorithmic

Growing Innovation capability from manufacturers

- Little opportunities for manufacturers to design higher added value products

Need to promote other criteria than energy saving performance

- *Loi pour un État au service d'une société de confiance* (ESSOC)

Towards a performance-based regulation code

A middle term project is currently underway at CSTB, “MATHIS-QAI”, in order to integrate pollutants such as Formaldehyde, COVT, Radon and Fine Particles, as a step towards an IAQ-oriented ventilation engineering using suitable modelling tools

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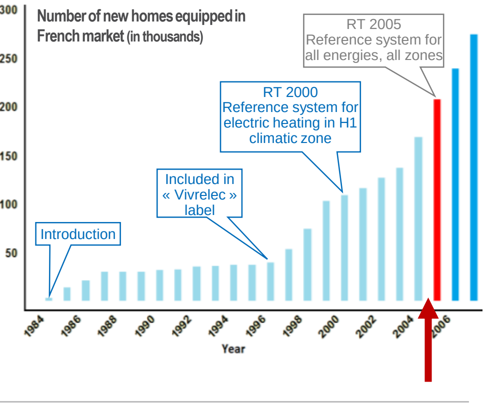
MECHANICAL HUMIDITY-CONTROLLED EXHAUST UNITS : FEEDBACK ON INSTALLATION, MAINTENANCE AND AGING

Stéphane Berthin, François Parsy, Aereco SA

CONTEXT

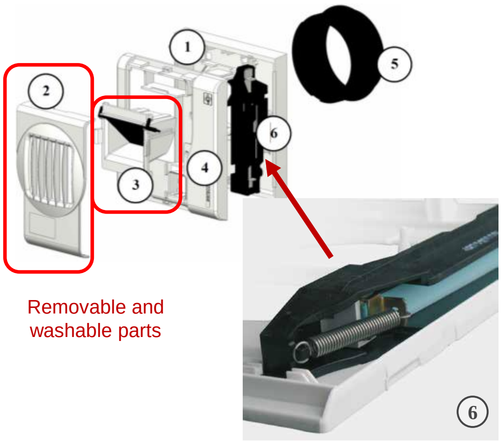
Spreading of humidity-controlled ventilation system

- Humidity controlled ventilation system created in 80's and widely spread, in Europe (10 millions equipped dwellings nowadays, 50% in France)
- In 2006, requiring from the French Ministry for Housing to test the performance of systems after many years in-situ working
- COSTIC laboratory mandated to collect and test performance of aged humidity-controlled units
- In addition to that, Aereco established profiles of anomalies encountered in-situ on humidity-controlled systems

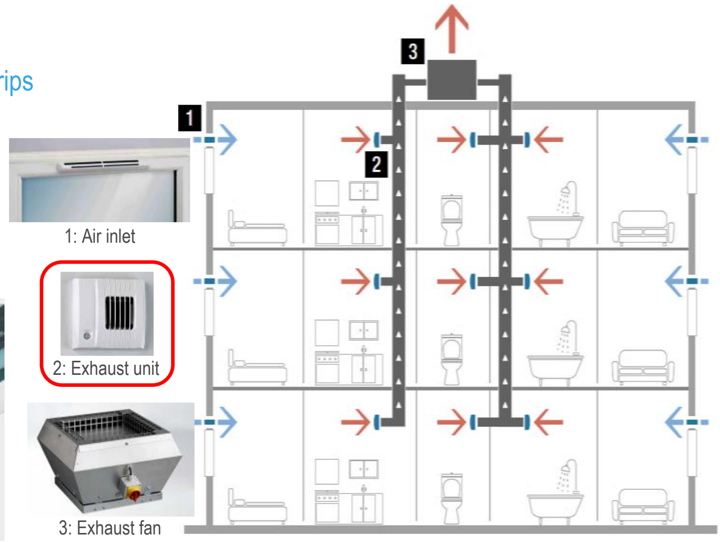


HUMIDITY-CONTROLLED UNITS

Mechanical sensor/actuator based on nylon strips



Removable and washable parts



COLLECTION SITE

21 social housings selected in Parisian suburb

COLLECTION SITE

21 social housings selected in Parisian suburb

AERECO

ANOMALIES LINKED TO BAD USE OF THE EXHAUST UNITS

Bad installations

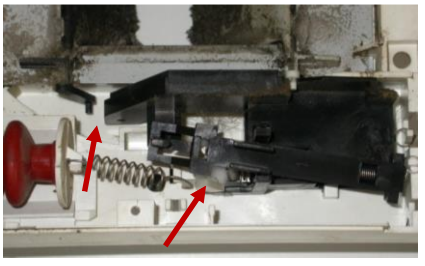
- **12%** (4 / 33) of the exhaust units installed in the wrong room (kitchen unit in bathroom,…)
- another **6%** (2 /33) of the exhaust units not in accordance with the apartment size (F5 kitchen unit in F3 apart….)
- Globally **55% of the dwellings** (6 / 11) presented a non conformity linked to installation

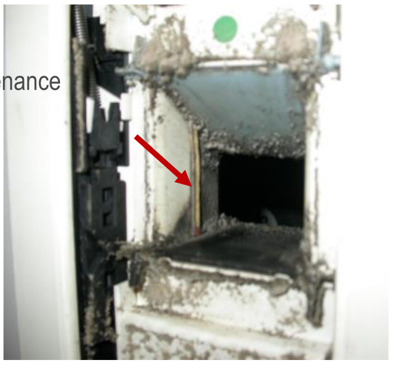
AERECO

ANOMALIES LINKED TO BAD USE OF THE EXHAUST UNITS

Degradations by the occupant

- **14%** (5 / 33) of the collected had damage either due to :
  - voluntary modification by the occupant
  - bad disassembly/re-assembly of the washing element after maintenance





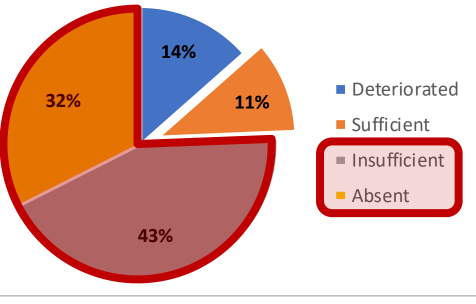
- Globally **36% of the dwellings** (4 / 11) presented unit degradation by the occupant

ANOMALIES LINKED TO BAD USE OF THE EXHAUST UNITS

Lack / absence of maintenance/cleaning

- totally **74%** (28 / 38) of the exhaust units showed absence of sufficient maintenance…

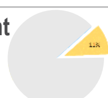
  … which concerns **91%** of the dwellings (10/11)



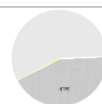
ANOMALIES LINKED TO BAD USE OF THE EXHAUST UNITS

Lack / absence of maintenance/cleaning (bathroom)

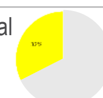
11% (4/32) with **sufficient**



43% (16/32) with **insufficient**



32% (12/32) with detrimental **absence of cleaning**



ANOMALIES LINKED TO BAD USE OF THE EXHAUST UNITS

Lack / absence of maintenance/cleaning : auto adjusted units (constant airflow for whatever pressure)

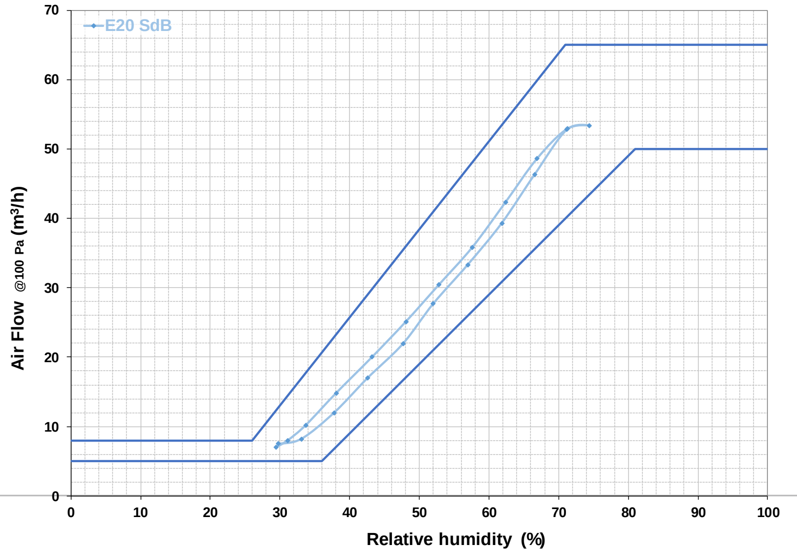
sufficient cleaning

insufficient cleaning

detrimental lack of cleaning

INTRINSIC PERFORMANCES OF THE EXHAUST UNITS

Manufacturing tolerance gauge



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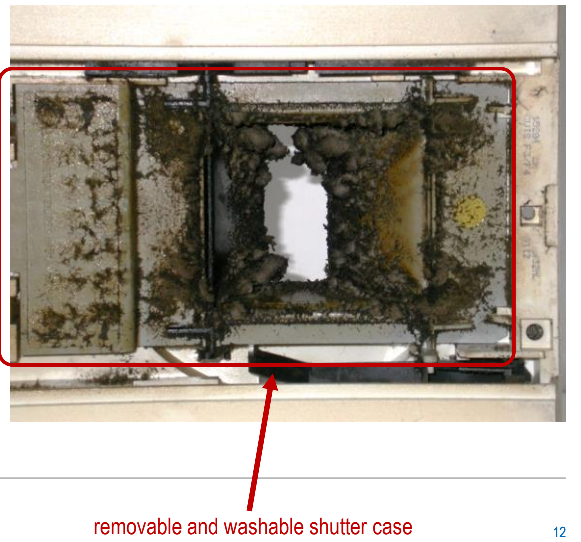
PERFORMANCE OF EXHAUST UNITS IN ABSENCE OF MAINTENANCE

Kitchen humidity controlled exhaust unit *(front side)*



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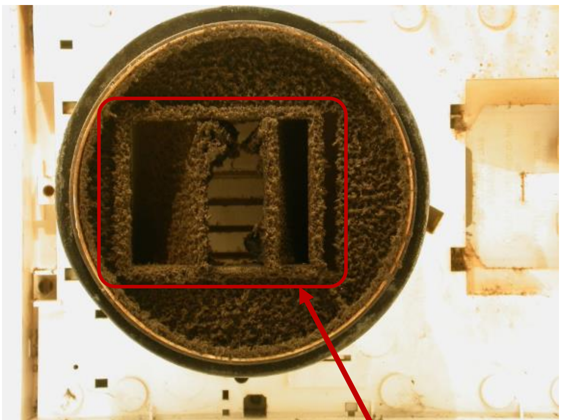
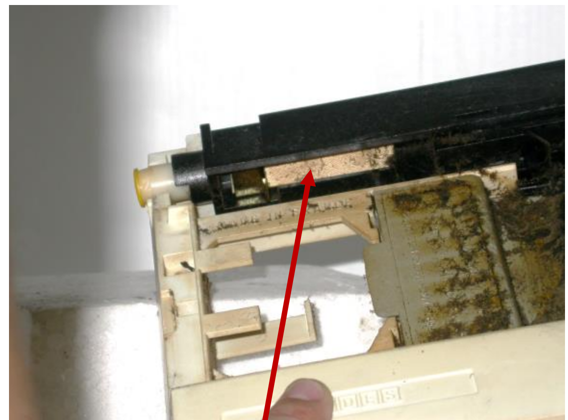
removable and washable front cover

removable and washable shutter case

PERFORMANCE OF EXHAUST UNITS IN ABSENCE OF MAINTENANCE

Kitchen humidity controlled exhaust unit *(back side and sensor)*





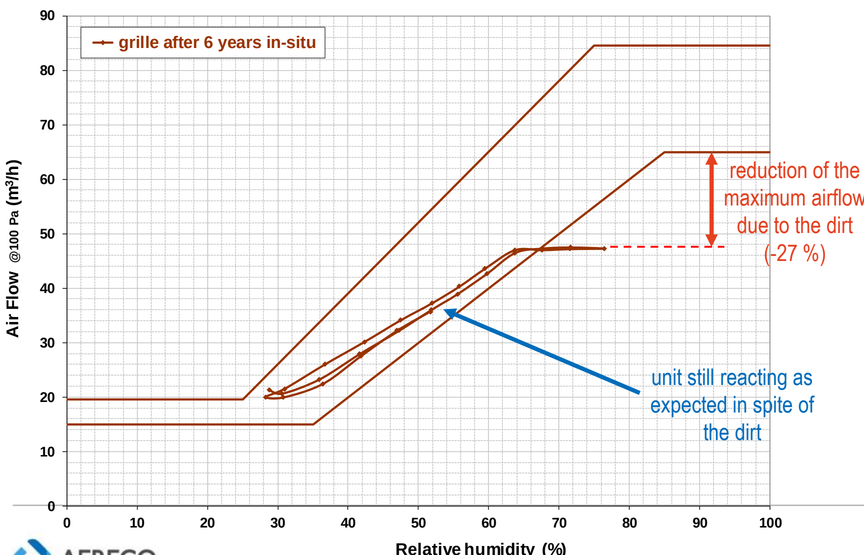
removable and washable shutter case

sensor nylon strips

AERECO

PERFORMANCE OF EXHAUST UNITS IN ABSENCE OF MAINTENANCE

Kitchen humidity controlled exhaust unit after 6 years



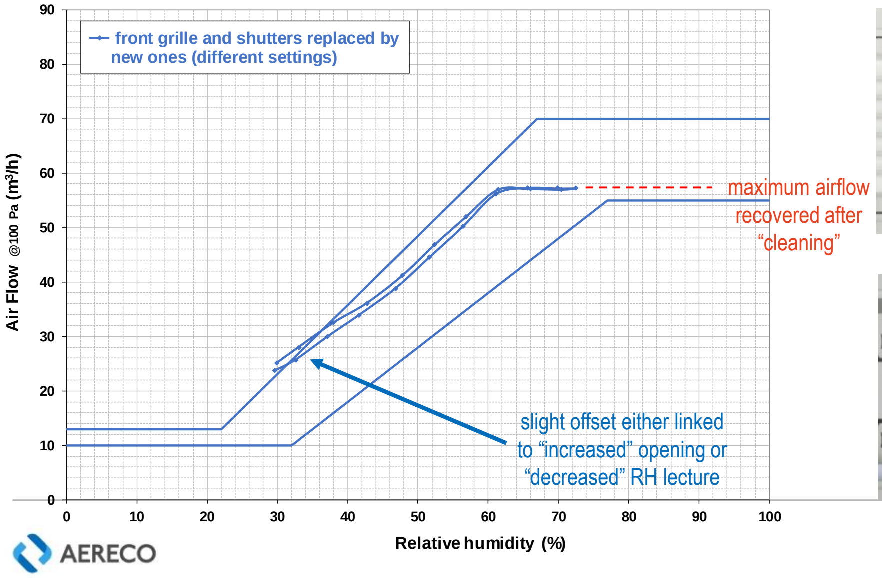
AERECO

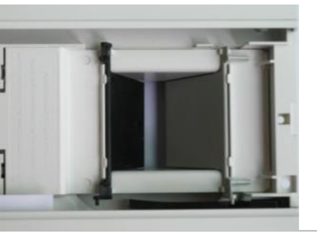
PERFORMANCE OF EXHAUST UNITS IN ABSENCE OF MAINTENANCE

Kitchen humidity controlled exhaust unit with cleaned (new) front grille and shutter case

PERFORMANCE OF EXHAUST UNITS IN ABSENCE OF MAINTENANCE

Kitchen humidity controlled exhaust unit with cleaned (new) front cover and shutter case

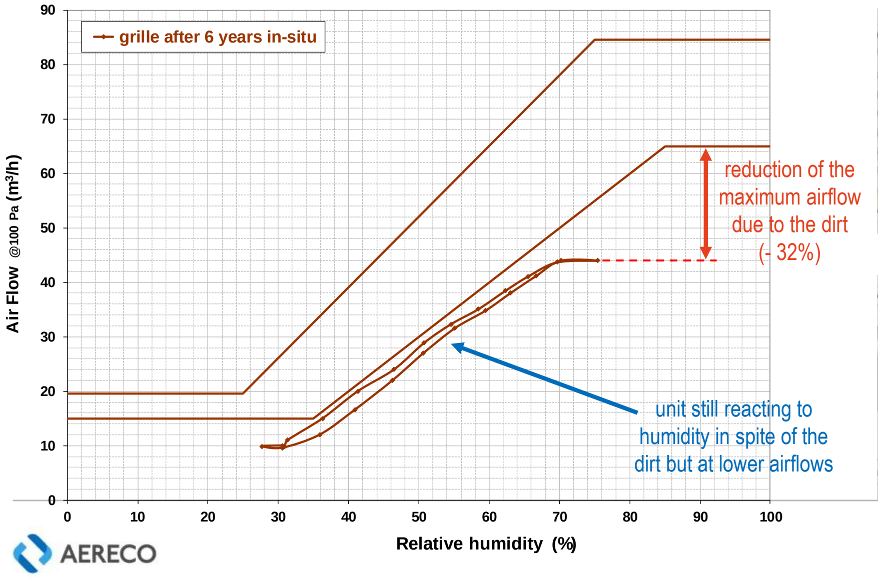




AERECO

PERFORMANCE OF EXHAUST UNITS IN ABSENCE OF MAINTENANCE

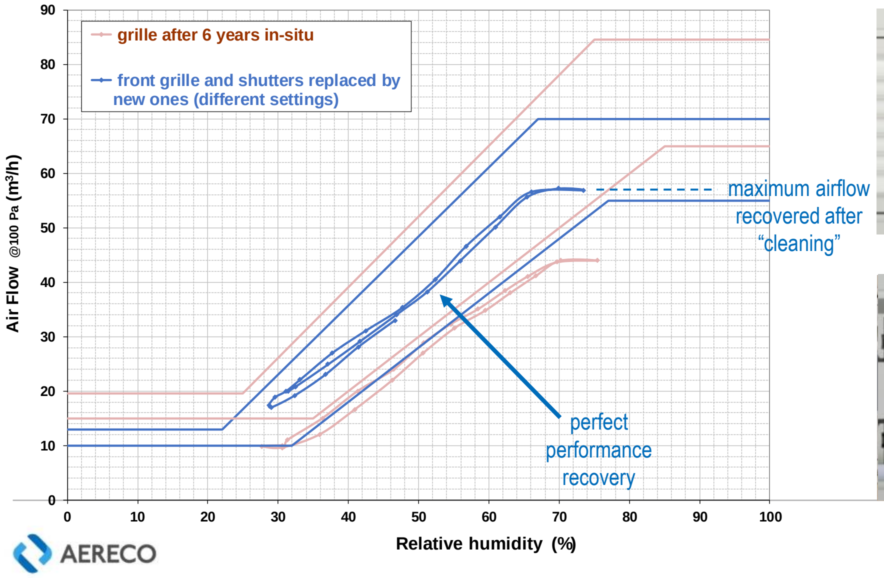
Kitchen humidity controlled exhaust unit (installed in bathroom!) after 6 years

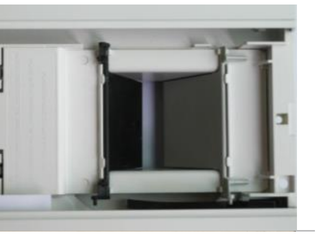


AERECO

PERFORMANCE OF EXHAUST UNITS IN ABSENCE OF MAINTENANCE

Kitchen humidity controlled exhaust unit installed in BATHROOM with cleaned (new) front grille and shutter case





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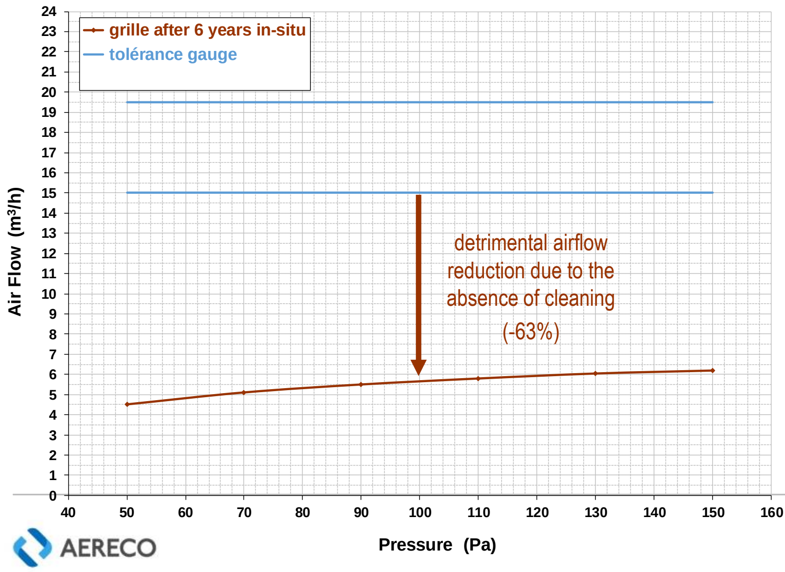
COMPLEMENT : SELF ADJUSTING EXHAUST UNITS IN ABSENCE OF MAINTENANCE

Dressing airflow auto adjusting exhaust unit (for compensation of pressure duct variations)



AERECO

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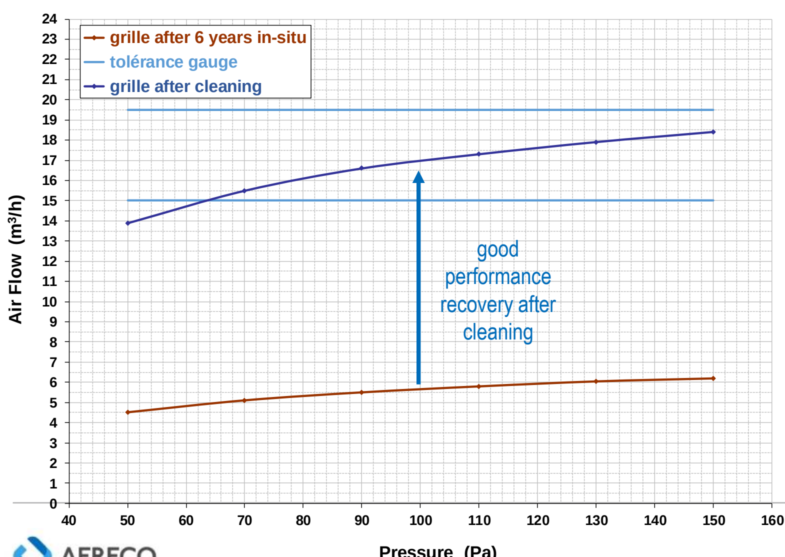

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SYNTHESIS

Humidity controlled exhaust units

BEFORE CLEANING :

- 100% of the (non damaged) collected units showed a conform hygroscopic behaviour
- 46% of the collected units fit the factory specification
- the other 54% showed air flow reduction until 34%, but …

  … still increasing air flow when needed (for longer time) and decreasing when unnecessary
- hygroscopic shifts were under 2%RH for the kitchen units and 5%RH for the bathroom units

CONCLUSION:

- **100% of the (non damaged) collected units still modulate according to humidity**
- **with evacuation time depending on the maintenance level**

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SYNTHESIS

Humidity controlled exhaust units

AFTER CLEANING :

- 75% of the units complied with factory specifications
- the other 25% showed an increase of air flow lower than 3 m^3/h for the kitchen units and 2 m^3/h for the bathroom units

CONCLUSION:

- **air quality always ensured**
- **maintenance is important !**

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THANK YOU

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www.aereco.com

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HUMIDITY-CONTROLLED MECHANICAL EXHAUST VENTILATION (HC-MEV) : LONG-TERM DURABILITY

Elsa Jardinier, François Parsy, Stéphane Berthin (AERECO SA)
Gaëlle Guyot (CEREMA)

Cerema

18/09/18

OUTLINE

Assessment of HC-MEV systems : monitoring studies in residential buildings

- Principles of HC-MEV

- 2007 – 2009 “Performance monitoring study”:
In-situ assessment of HC-MEV **systems** in terms of IAQ and energy

- 2017 – 2020 “Follow-up study”:
Long term assessment of HC-MEV **systems and components**

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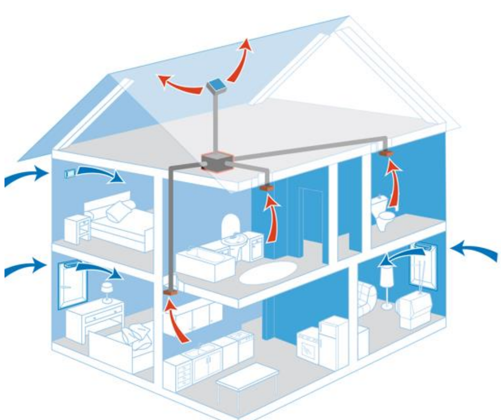
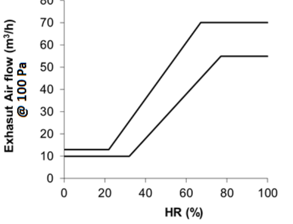
PRINCIPLES OF HC-MEV

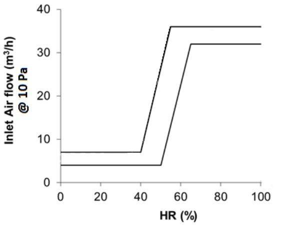
Air circulation principle



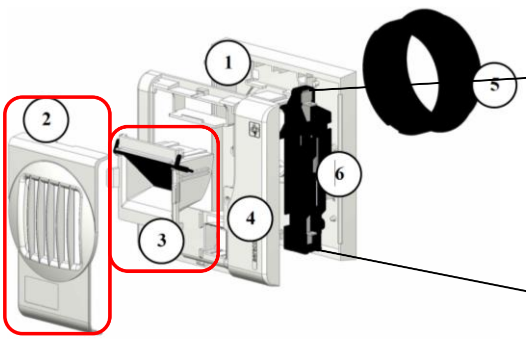
Exhaust : air flow



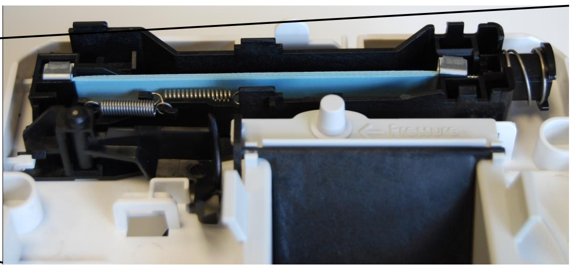
Inlet : air distribution



HYGROSCOPIC VENTILATION UNITS



Grid and Case are removable and washable



Hygroscopic mechanical sensor/actuator out of the flow

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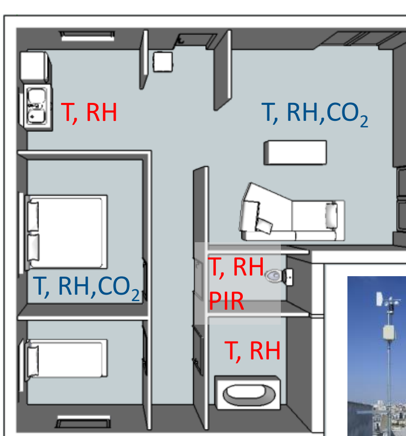
2007 – 2009 MONITORING

Large scale monitoring study on residential buildings

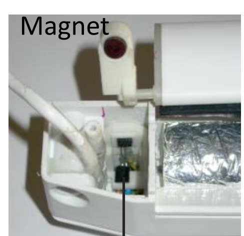
Site	Paris	Lyon
Type	1 to 4 bedrooms	1 to 4 bedrooms
Height	8 floors	6 floors
Monitored	19 dwellings	10 dwellings

2007 – 2009 MONITORING

Instrumentation and metrology



T
RH
CO_2
Wind



Unit	Aperture	Pressure	Air flow
Inlet	Measured	/	Computed @ 10 Pa
Exhaust	Measured	Measured	Computed

2007 – 2009 MONITORING

Main results

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2007 – 2009 MONITORING

Main results

- Expected level of IAQ despite over occupation (CO_2 < 1500 ppm ; Zero condensation risk)

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- 55% energy savings on heat losses on the statistical French occupation

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- Measured fan consumption reduction of 35% - 50% in comparison with constant airflow

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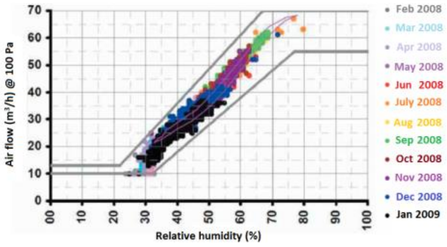

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2007 – 2009 MONITORING

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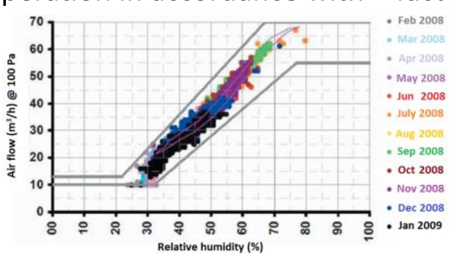

- Validation of the French agreement simulation tool

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OUTLINE

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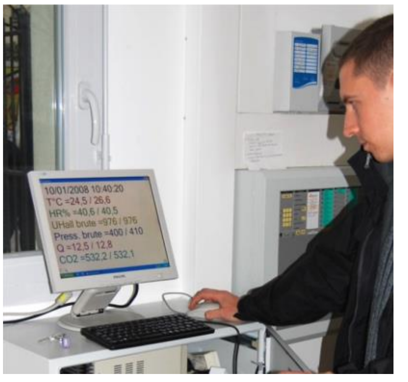
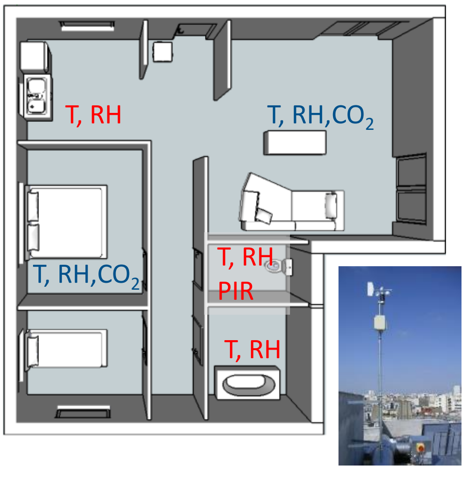
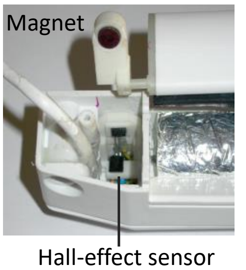


2017 – FEASIBILITY OF A FOLLOW-UP STUDY

Existing instrumentation (electronic sensors)



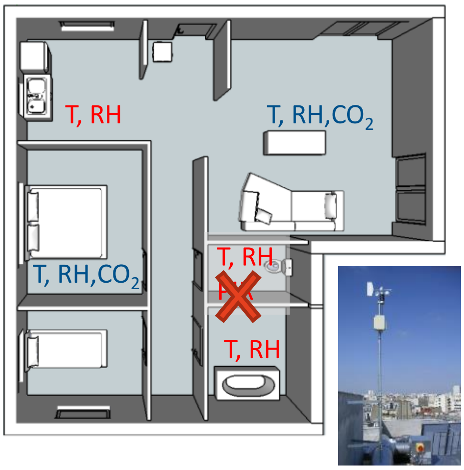
T
RH
CO_2
Wind



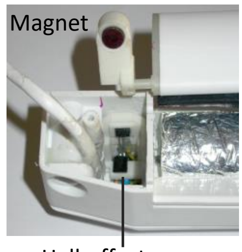
Hall-effect sensor

2017 – FEASIBILITY OF A FOLLOW-UP STUDY

Existing instrumentation (electronic sensors)



T
RH
CO_2
Wind



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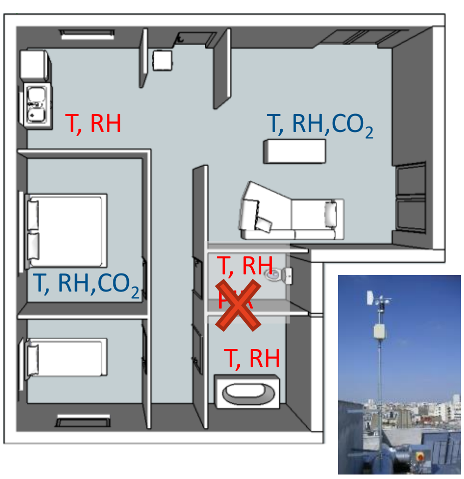
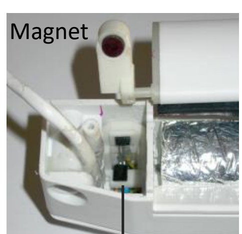


~~T~~
~~RH~~
~~CO_2~~
~~Wind~~



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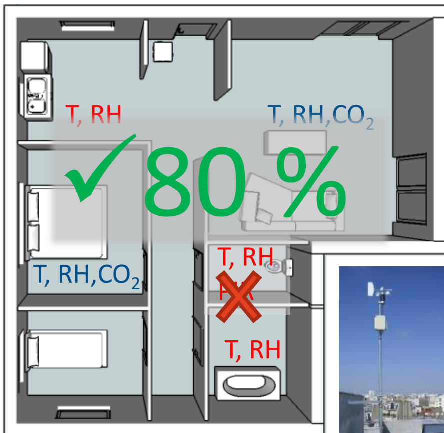

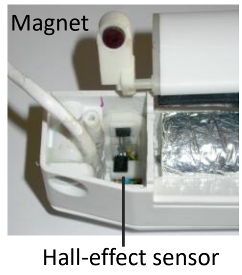

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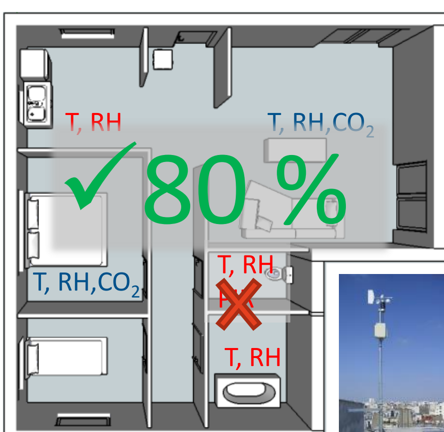

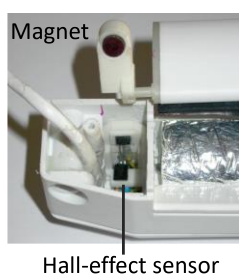

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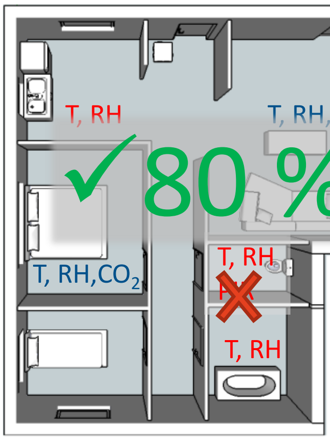
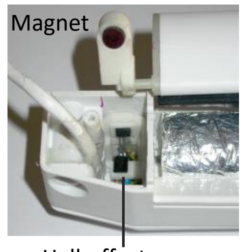


Wind



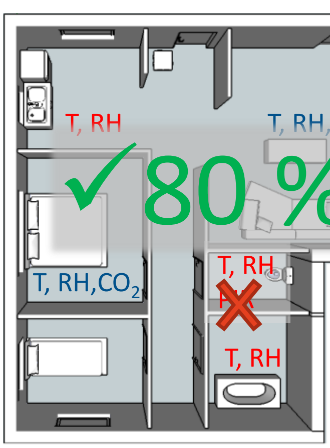
Hall-effect sensor

Periodic perturbations

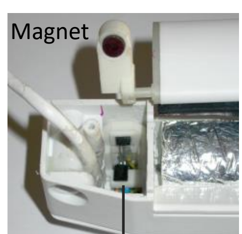
Fourier transform treatment

2017 – FEASIBILITY OF A FOLLOW-UP STUDY

Existing instrumentation (electronic sensors)



Wind



Hall-effect sensor

Periodic perturbations

Fourier transform treatment

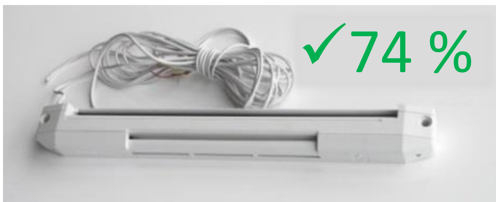
⇒ Preliminary characterisation of ventilation units

On-site, no recalibration

2017 – FEASIBILITY OF A FOLLOW-UP STUDY

On-site,
no recalibration

Installed inlets : preliminary results

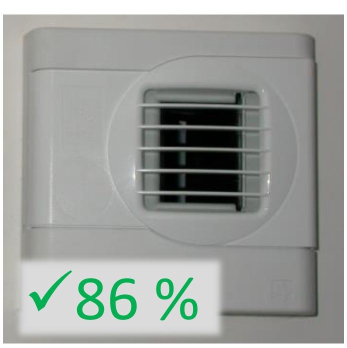


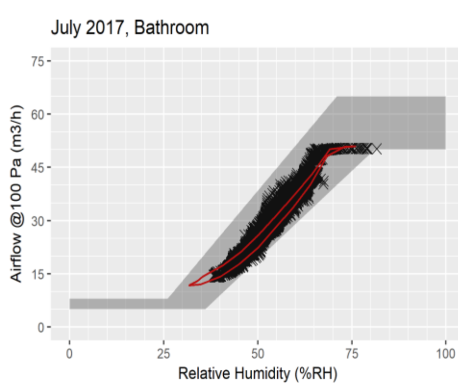
Issue	Nb	Possible explanation
Blocked aperture	4	Occupant intervention Unhooked actuator
Incoherent range	2	Unhooked Hall effect sensor
Low dynamics	2	Occupant intervention Misplaced Hall-effect sensor

2017 – FEASIBILITY OF A FOLLOW-UP STUDY

On-site,
no recalibration

Installed exhaust units : preliminary results

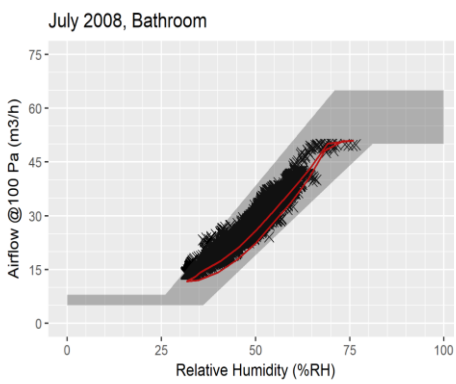


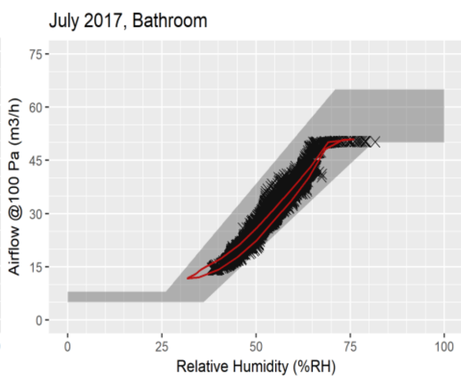


2017 – FEASIBILITY OF A FOLLOW-UP STUDY

Installed exhaust units : 2008 – 2017 comparison

On-site,
no recalibration





⇒ **1,5 % average drift over 9 years**

< ± 1,8 % accuracy of the electronic RH sensors

⇒ Opportunity for a “follow-up study”

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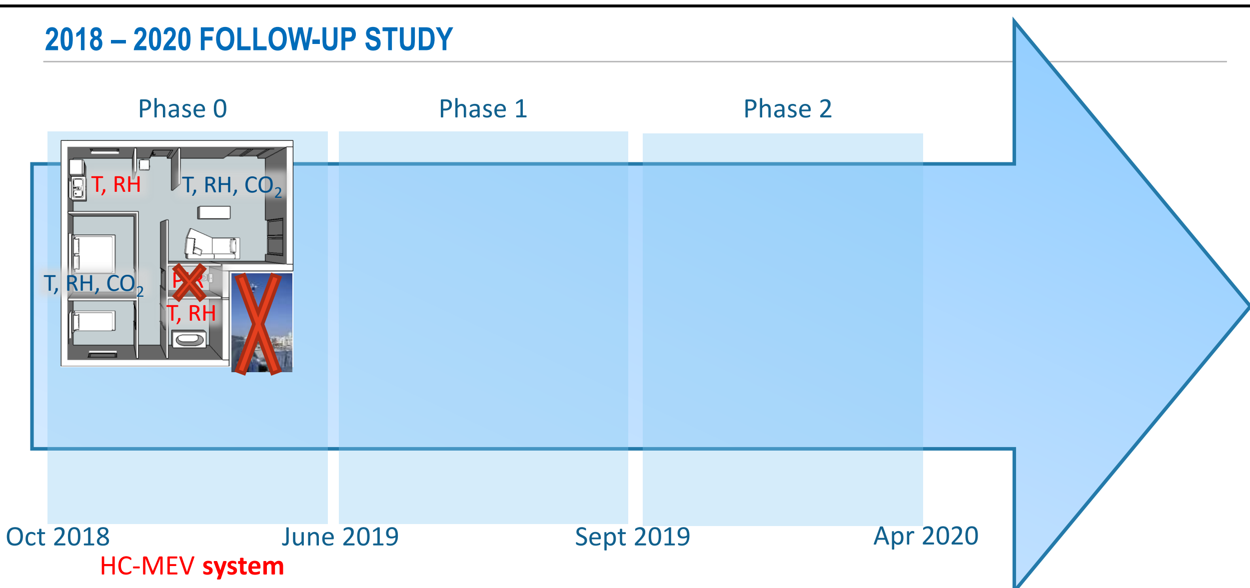
2018 – 2020 FOLLOW-UP STUDY

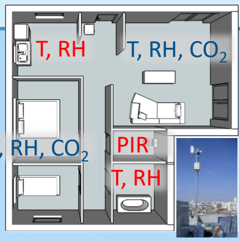


HC-MEV **system** qualification

AERECO Cerema

2018 – 2020 FOLLOW-UP STUDY

Phase 0 | Phase 1 | Phase 2



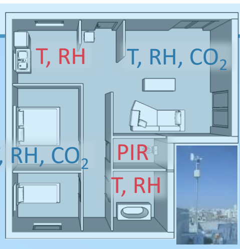
Data collection
No recalibration

Oct 2018 | June 2019 | Sept 2019 | Apr 2020

HC-MEV **system** qualification

2018 – 2020 FOLLOW-UP STUDY

Phase 0 | Phase 1 | Phase 2



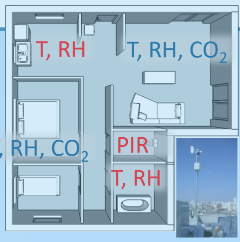
Data collection
No recalibration

Electronic Sensors recalibration

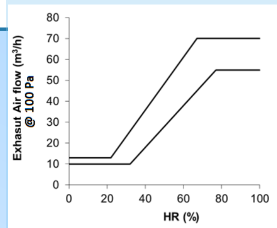
Oct 2018 | June 2019 | Sept 2019 | Apr 2020

2018 – 2020 FOLLOW-UP STUDY

Phase 0 | Phase 1 | Phase 2



Data collection
No recalibration



Electronic Sensors recalibration
Ventilation units tests before/after cleaning

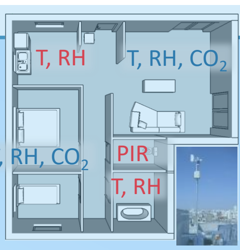
Oct 2018 — June 2019 — Sept 2019 — Apr 2020

HC-MEV **component aging** qualification

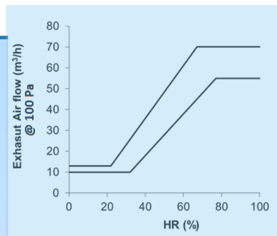
AERECO Cerema

2018 – 2020 FOLLOW-UP STUDY

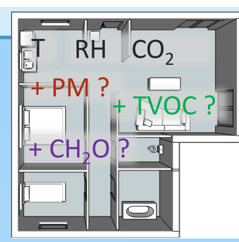
Phase 0 | Phase 1 | Phase 2



Data collection
No recalibration



Electronic Sensors recalibration
Ventilation units tests before/after cleaning



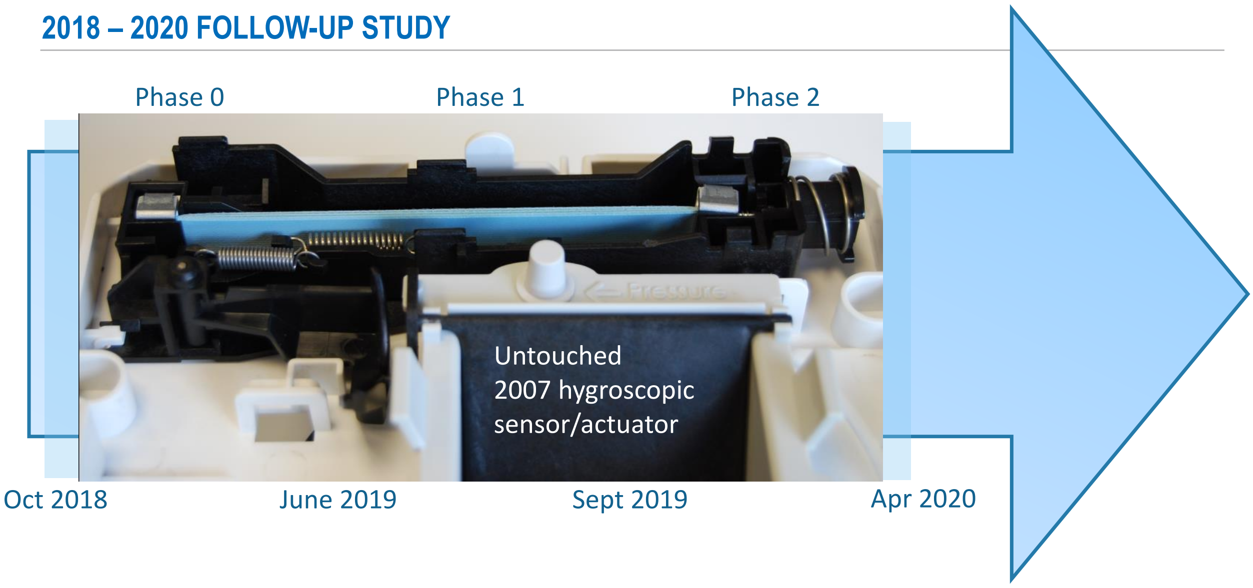
Enlarged IAQ study
Calibrated sensors

Oct 2018 — June 2019 — Sept 2019 — Apr 2020

Enlarged
HC-MEV **system** qualification

AERECO Cerema

2018 – 2020 FOLLOW-UP STUDY



AERECO Cerema

CONCLUSION

- Rare installation for large scale HC-MEV performances assessment

- 2007 – 2009 “Performance monitoring study”:
Good performances of HC-MEV systems in terms of IAQ and energy

- 2017 – 2020 : Opportunity for a study after ten years of in-situ operation:
Long term assessment of HC-MEV systems and components

AERECO Cerema

THANK YOU

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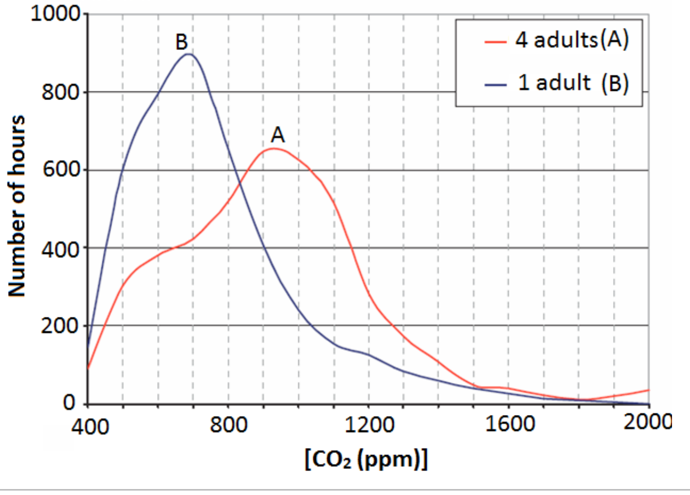
2007-2009 MONITORING

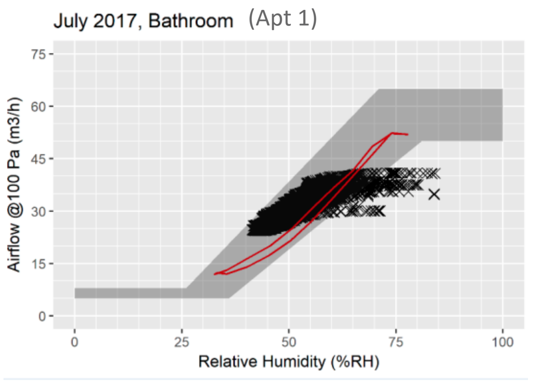
Typical CO_2 repartition

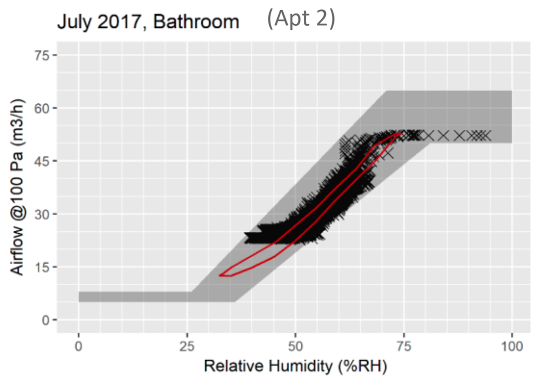


2017 – FEASIBILITY OF A FOLLOW-UP STUDY

On-site,
no recalibration

Exhaust units excluded from drift computation





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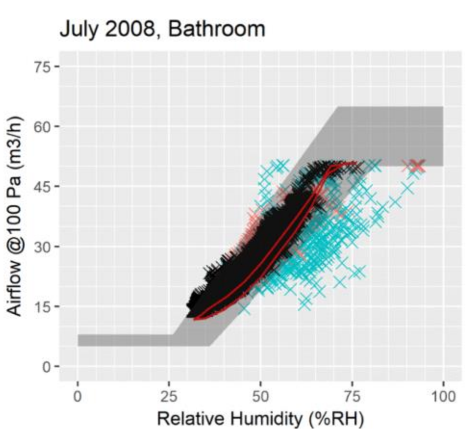
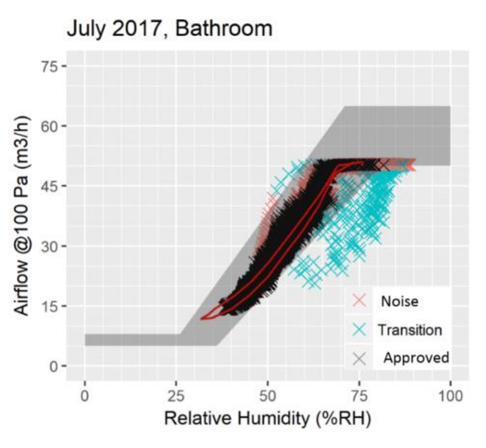
2017 – FEASIBILITY OF A FOLLOW-UP STUDY

On-site,
no recalibration

Transitions and electronic noise





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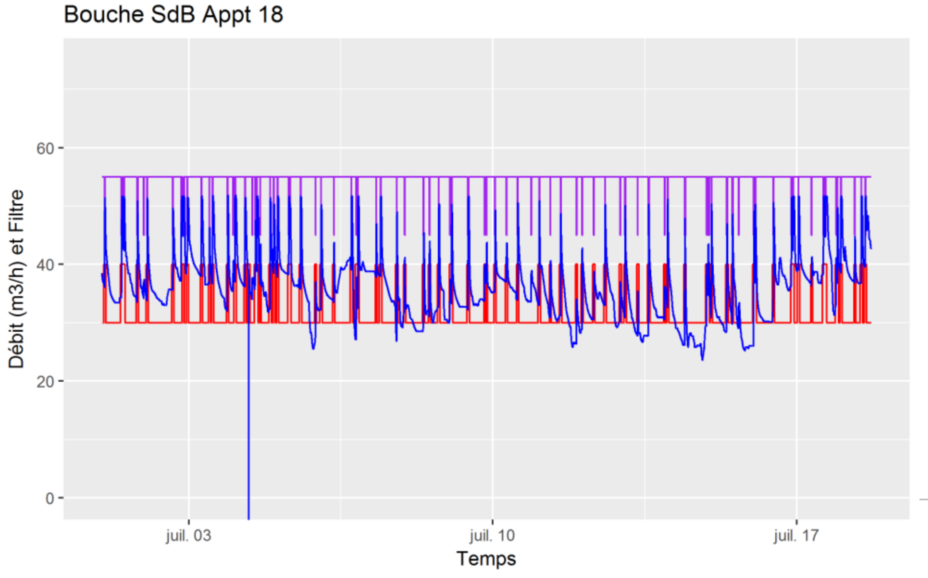
2017 – FEASIBILITY OF A FOLLOW-UP STUDY

Transitions and electronic noise



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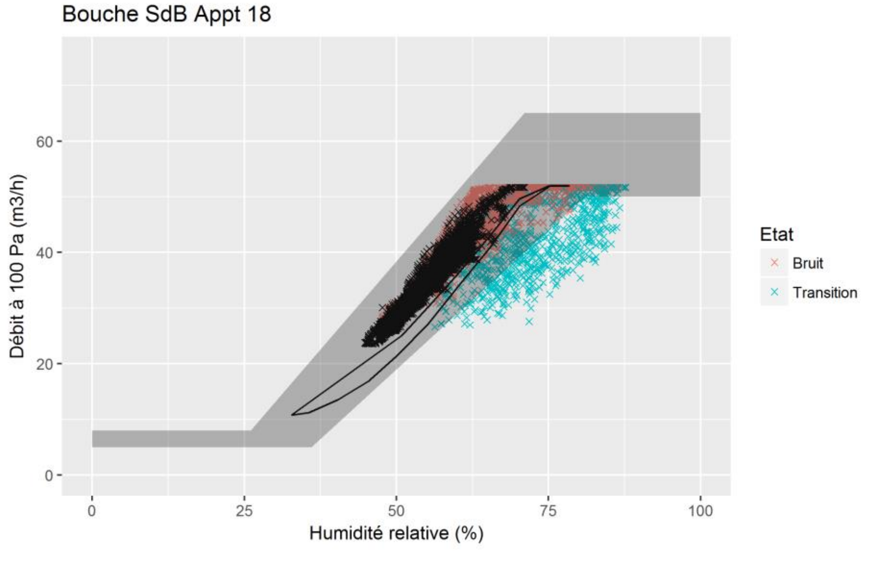
2017 – FEASIBILITY OF A FOLLOW-UP STUDY

Transitions and electronic noise



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United Technologies

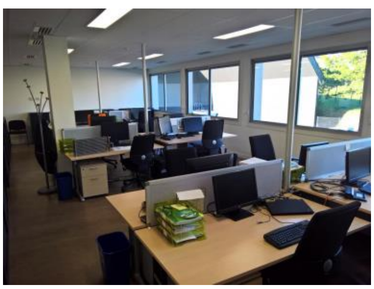
Climate | Controls | Security

Occupancy controlled ventilation in refurbished office building, combining presence and CO_2 detection

Philippe Petit,
Roland Clavel,
Jean-Michel Navarro

United Technology Corporation
HVAC Research & Design Center
CULOZ, France

BUILDING DESCRIPTION



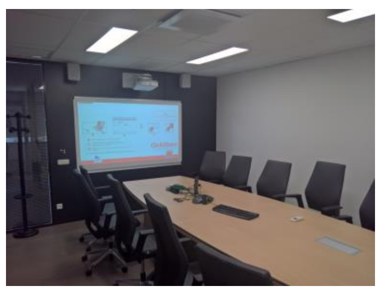


Table 1: number and distribution of occupants in the different types of rooms

Level	Open Space	Individual office	Meeting room	Total
Level 0 - North	12	3	0	15
Level 0 - South	12	2	12	26
Level 1 - North	12	1	10	23
Level 1 - South	12	4	0	16
TOTAL	48	10	22	**80**

2 x 260 m2 / 1630 m3 **25 m3/h /occupant - AHU 2 000 m3/h**

VENTILATION STRATEGY

VENTILATION RATE

BUILDING OCCUPANCY

Offices
Presence detector

Open Space
CO2 sensors

- Constant Air Pressure = 50 Pa
- Air Flow regulator calibrated on design value
- AHU pressure Control .
- Minimum Air flow during vacancy periods

Fresh air flow control

(1)air flow regulator (2)“all or little” register (3) modulating damper

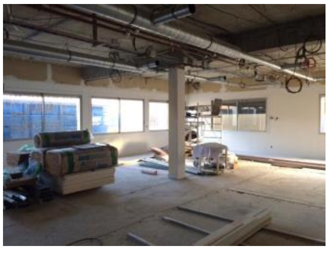
CONSTRUCTION FOLLOW UP

INSTALLATION

- Conformity towards drawings.
- Flexible pipes minimum length.

COMMISSIONING

- Rigid pipe air tightness .
- Fresh air control measurements.



Installers collaboration + MANAG’R methodology

FRESH AIR CONTROL MEASUREMENT

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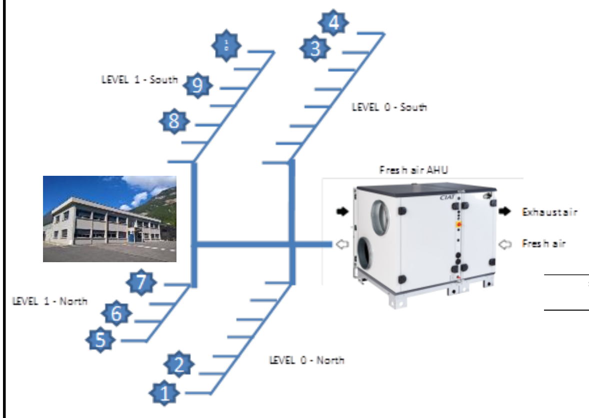

- Compact Double flux AHU with Heat Recovery
- 10 Fresh Air measurement location
- AHU discharge pressure set point : 90 Pa

Table 1: Pressure and air flow at different fresh air circuit locations

# point	Room type	Measurements P(Pa)/Qv(m^3/h)	Nominal Air flow m^3/h	Gap % ref. nominal
1	Individual office	78/31	25	+24
2	Open-space	75/55	60	-8
3	Individual office	74/25	25	0
4	Open-space	74/57	60	-5
5	Open-space	68/-	90	-
6	Open-space	73/-	90	-
7	Meeting room	66/210	250	-16
8	Individual office	70/-	30	-
9	Open-space	71/100	90	+11
10	Open-space	73/102	90	+13

CO2 LEVEL MEASUREMENT

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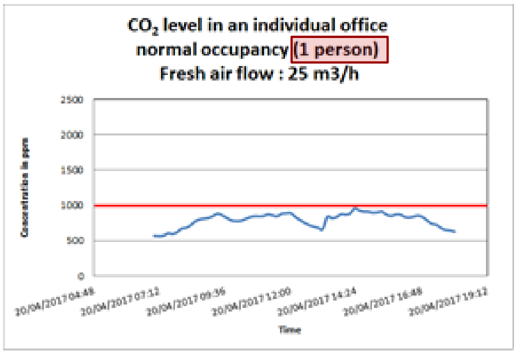
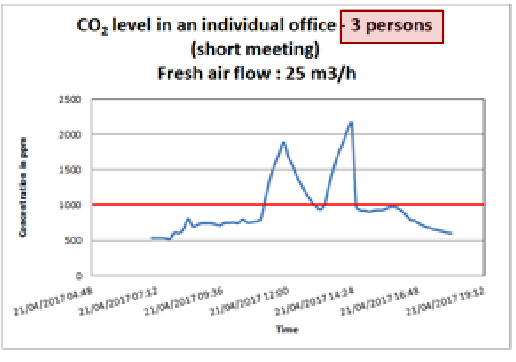
INDIVIDUAL OFFICE





ICONE Index = **0**

ICONE Index = **1**

CO2 LEVEL MEASUREMENT

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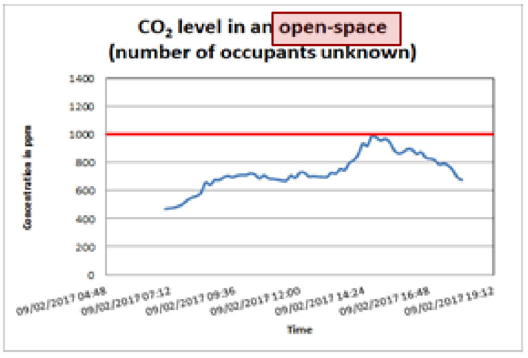
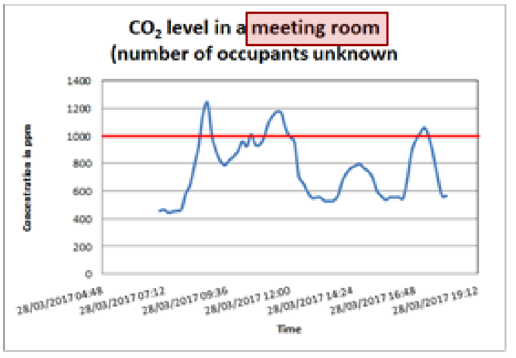
OTHER ROOMS





ICONE Index = **0**

ICONE Index = **1**

CO2 and PM2,5 COMBINED CONTROL

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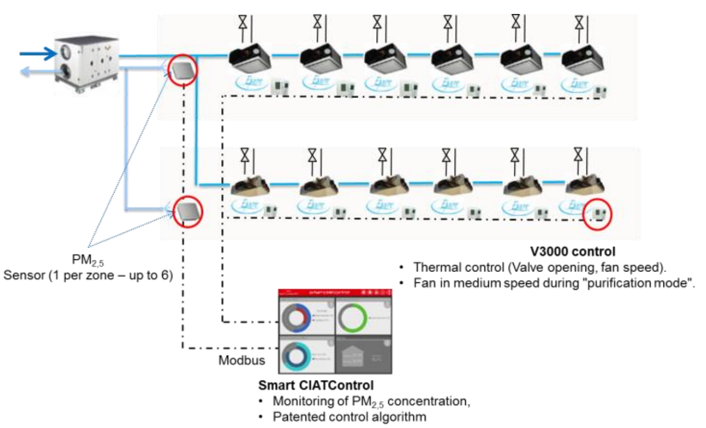

- Pm2,5 sensors at each Level
- Epure Dynamics Algorithm
- Epure filter type on each fan coil
- CO2 and Pm2,5 control

CONCLUSION

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- **A+ certified material** and **efficient HVAC equipment**
- Appropriate design with **25 m3/h fresh air/occupant**
- **ADEME MANAG'R** approach for HVAC installation , commissioning and control
- **0 < ICONE Index < 1** demonstrated for different rooms
- Possibility to combine CO2 and Pm2,5 control with **Epure Dynamics Solution**

BACK UP

ICONE INDEX

- **CSTB** / 2007 introduce Air Stuffiness Index
- ICONE = f (occurrence and intensity CO2 concentrations)
- Reflect balance between air exchange rate and room's occupancy density

Tableau 1. État du confinement de l'air intérieur suivant la valeur de l'indice ICONE.
Indoor air stuffiness according to the ICONE index score.

ICONE	État du confinement	Incertitude
0	Confinement nul	+ 0,2
1	Confinement faible	± 0,2
2	Confinement moyen	± 0,3
3	Confinement élevé	± 0,3
4	Confinement très élevé	± 0,3
5	Confinement extrême	± 0,3

- Mandatory control of indoor air quality (schools , nurseries…)

MANAG'R METHOD

Types d'outils	Codes	Noms des outils
Outils méthodologiques (MET)	MET1 MET2 MET3	Guide méthodologique Fils conducteurs pour chaque acteur Note méthodologique MANAG'R
Outils techniques (TEC)	TEC1 TEC2 TEC3 TEC4 TEC5 TEC6 TEC7 TEC8	Grille d'analyse du site et du bâtiment existant Outil de définition de l'ambition de la MOA Grille des prescriptions QAI du programme Grille d'analyse des réponses de la MOE Guide MANAG'R des entreprises : *- prescriptions QAI du DCE* *- aide aux entreprises pour l'établissement des offres* *- analyse des réponses, négociations et conséquences opérationnelles* *Check-list* des points de contrôle pour les différents audits du chantier Procédures de contrôle et d'évaluation en lien avec la qualité de l'air (diagnostic, r Clauses contractuelles du contrat de maintenance
Outils d'évaluation (EVA)	EVA1 EVA2 EVA3	Tableau de bord de suivi MANAG'R Document cadre d'évaluation du retour d'expérience Enquête de satisfaction à réception + 10 mois
Outils de sensibilisation et de formation (COM)	COM1 COM2 COM3	Objectifs pédagogiques Déroulés pédagogiques Canevas des supports pédagogiques *- S'engager avec MANAG'R* *- Concevoir avec MANAG'R* *- Construire avec MANAG'R*

- Methodology for integrating I.A.Q during construction process (ADEME)
- Tool kit for each actors at each step of the project

EPURE DYNAMICS

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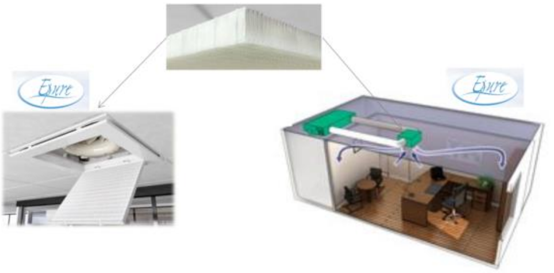
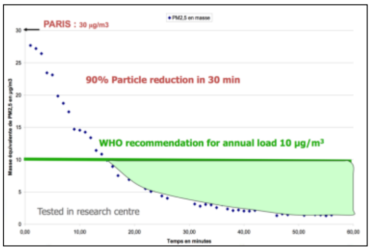


- High performance filter
- « Purification » mode
- Smart BMS control



INTEGRATING UNCERTAINTIES DUE TO WIND AND STACK IN DECLARED AIRTIGHTNESS RESULTS - WORKING GROUP

AIVC Conference

September 2018

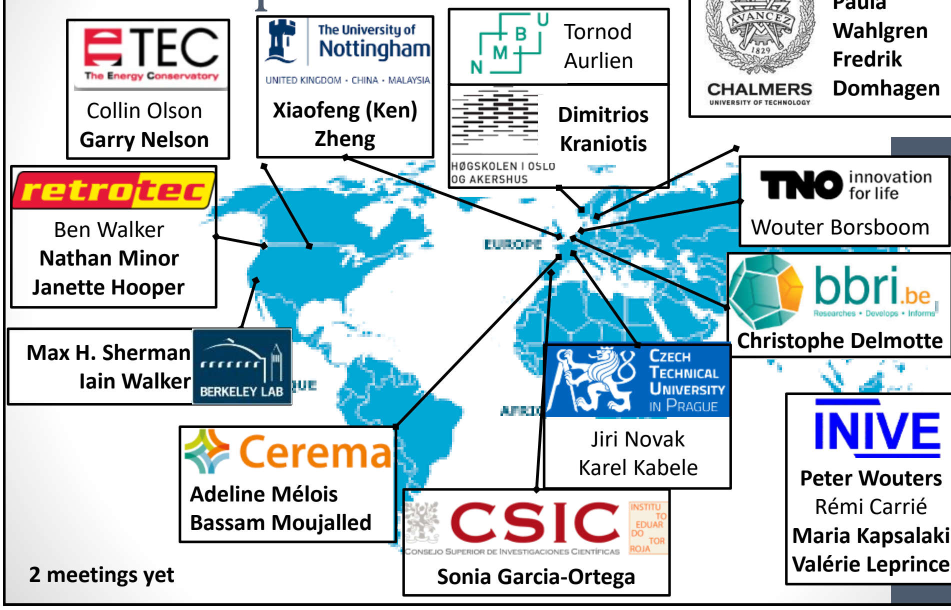
Valerie Leprince

Context this working group

- AIVC project of 2017:
  - Improve the integration of uncertainties due to wind and stack in declared airtightness results in measurement standards, taking into account both scientific and practical issues
- Final objective:
  - Improve airtightness test method (inc. calculation) to improve its reliability and its feasibility.
  - Define a method to calculate the impact on wind and stack on the test result:
    - either to better estimate the uncertainty
    - or to correct result
  - Better understand the uncertainty to improve the calculation and measurement method

$\Rightarrow$Improve ISO 9972

Participants



2 meetings yet

Work performed during meetings

- State of the art of work performed and needed in the field
  - Split in 6 working topics
  - Gathering of articles on each topic (more than 20 papers gathered)
  - Discussion around conclusions of those papers and work needed
- Presentation of ongoing work
  - Dimitrios Kraniotis, Wiseair project
  - Xiaofeng Zheng, findings of experimental study

Working topic on the subject

Topic 1: Wind description

Sub-Topic 1.1: Description of wind speed, gust, turbulence, spectrum

Sub-Topic 1.2: The wind speed at building/leakage level

Topic 2: Simulating the impact of wind and stack on the result of airtightness test

Sub-Topic 2.1: Simulating the impact of steady wind and stack

Sub-Topic 2.2: Simulating the impact of fluctuating wind and stack

Topic 3: Measuring the impact of wind and stack on the result of airtightness test

Sub-Topic 3.1: Measuring the impact on site

Sub-topic 3.2: Measuring the impact in laboratory

Topic 4: Define a calculation method to estimate the impact of wind and stack on the result of airtightness test

Sub-topic 4.1: Define a calculation method to estimate the uncertainty due to wind and stack (Complete calculation and simplified calculation)

Sub-topic 4.2: Define a calculation method to correct results

Topic 5: Main drawbacks of ISO 9972:2015 regarding uncertainty due to wind 5(inc. Linear regression)

Topic 6: Measuring wind speed or external pressure on site

AIVC2018 TS on Wind impact

- Wind speed in building airtightness test protocols: a review
  - Adeline Mélois
- Experimental study of enclosure airtightness of an outdoor chamber using the pulse technique and blower door method under various leakage and wind conditions
  - Xiaofeng Zheng
- Experimental Investigation of the Impact of Environmental Conditions on the Measurement of Building Infiltration, and its correlation with Airtightness
  - Alan Vega Pasos
- Uncertainties in Airtightness Measurements – Choosing the Right Regression Method and the Best Sequence of Pressure
  - Martin Prignon
- Numerical and experimental identification of factors influencing the pressure homogeneity during an airtightness test in a large building
  - Loubna Qabbal
- Chairpersons: Valérie Leprince and Christophe Delmotte

Wind speed in building airtightness test protocols: a review

Adeline Mélois, F. R. Carrié, M. El Mankibi, and B. Moujalled

Context: PhD

- **Subject: Impact of the wind on building air leakage measurement**

Direction: François Rémi Carrié (ICEE) and Mohamed El Mankibi (ENTPE)

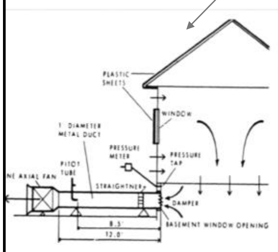
Evolution of measurement methods

1950s | 1960s | 1970s | 1980s | 1990s | 2000s | 2010s

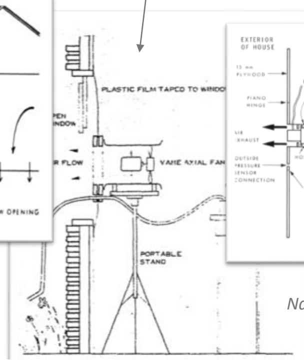
Tracer gaz airleakage evaluations

Fan pressurization tests

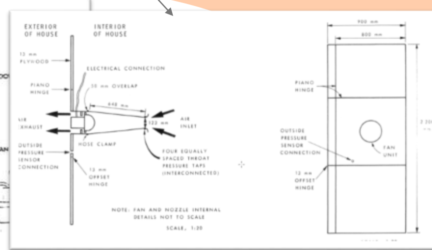
$$Q = C.\Delta P^{n}$$



Test bench used by Tamura in 1967-1968



Experimental measuring device used by Stricker in 1974



Exhaust fan apparatus developed by the National Research Council of Canada in 1980

Cerema

Evolution of measurement methods

1950s | 1960s | 1970s | 1980s | 1990s | 2000s | 2010s

Tracer gaz airleakage evaluations

Fan pressurization tests

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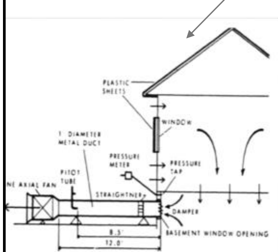
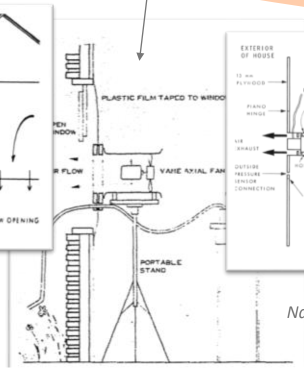


Test bench used by Tamura in 1967-1968



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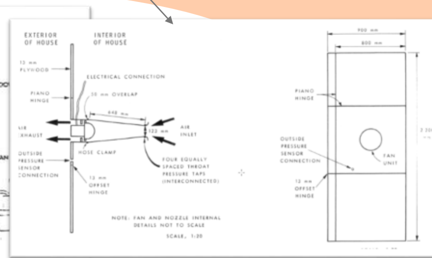

Exhaust fan apparatus developed by the National Research Council of Canada in 1980

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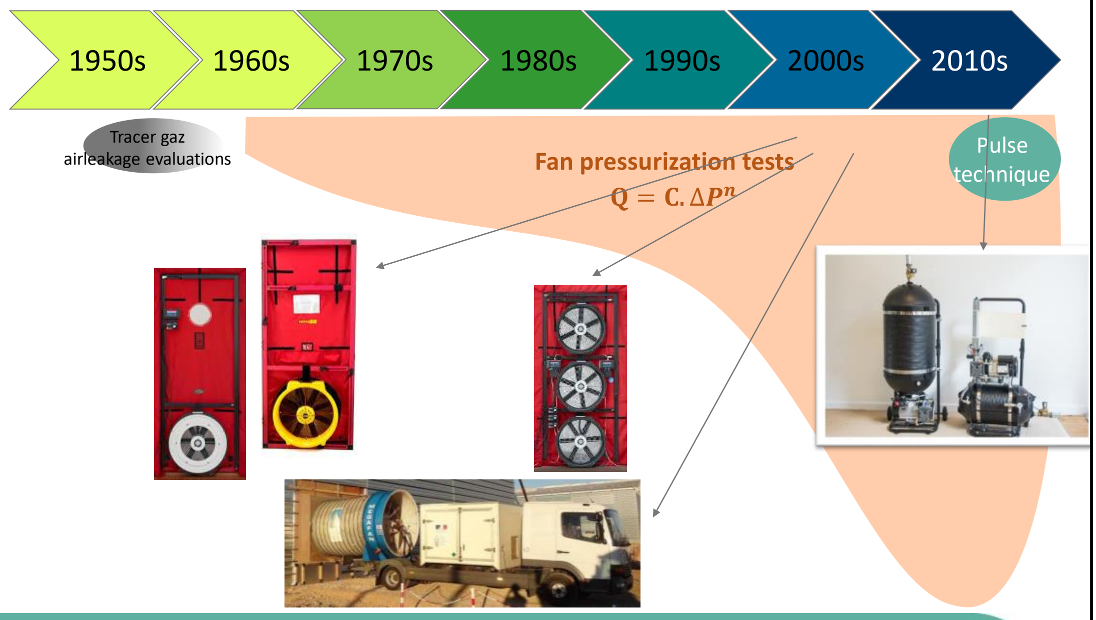
Evolution of measurement methods



Focus on fan pressurization method

- **One simplified relation:** $Q = C.\Delta P^n$

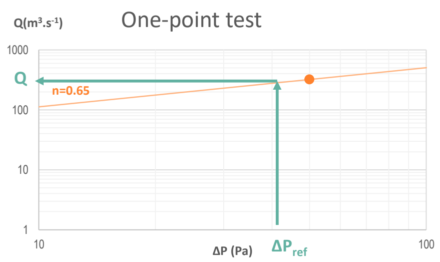
  - Q is the volume flow rate [$m^3.h^{-1}$]
  - ΔP is the indoor-outdoor pressure difference [Pa]
  - C is the air leakage coefficient [$m^3.s^{-1}.Pa^{-n}$]
  - n is the flow exponent [-].

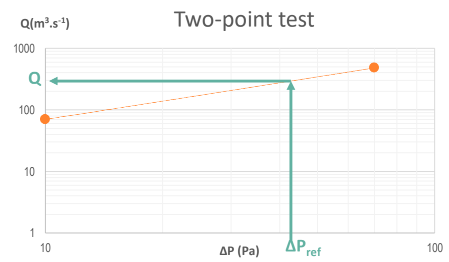
? Why not directly impose ΔP and measure Q?

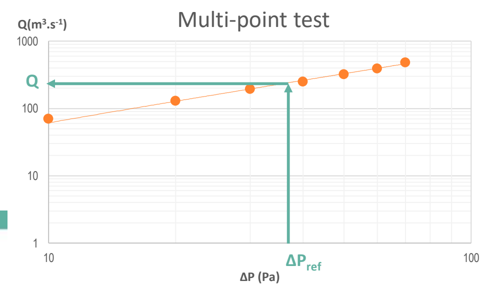
→ due to weather conditions and measuring devices precision, it is almost impossible to impose exactly a given ΔP

Focus on fan pressurization method

- **One-point test to multi-point test**







Wheather conditions in past and current protocols (1/2)

- **Recommandations and requirements regarding wind speed**
  - 1978, Nevander & Kronvall: wind velocity not higher than 8 m.s^{-1}
  - 1978, Kronvall: wind speed limit at 5 m.s^{-1}

  - 1980 – 1983: first standards

Standard Requirements	**Swedish standard SS 02 15 51 (1980)**	**Norway standard NS 8200 (1981)**	**American standard ASTM E779-81 (1981)**	**Canadian standard (1983)**
Climatic limits: wind speed	< 10 m.s^{-1}	< 6 m.s^{-1}	< 4.4 m.s^{-1}*	< 5.5 m.s^{-1}

**"ideal wind conditions" ≤ 5 mph (2.2 m.s^{-1})*
"with caution" from 5 mph to 10 mph (2.2 to 4.4 m.s^{-1}).

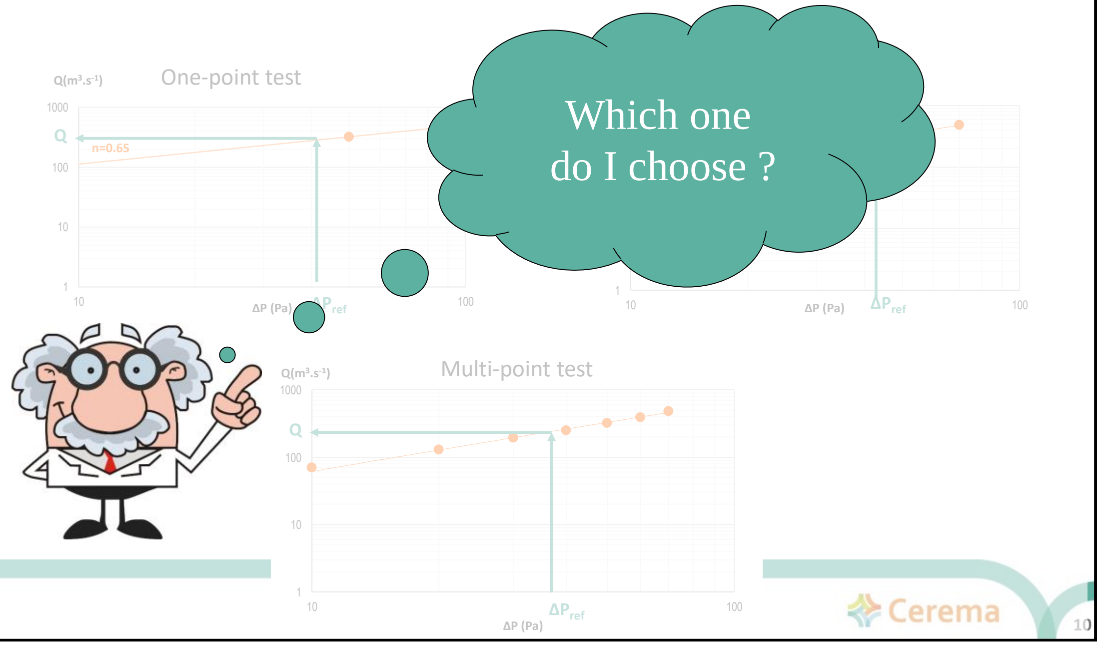
Wheather conditions in past and current protocols (2/2)

- **Recommandations and requirements regarding wind speed**
  - 2017: currently used standards

Standard Requirements	**ASTM 779-10**	**ISO 9972**
Wind speed	Strong winds shall be avoided	Strong winds are to be avoided It is "recommended" that • wind speed near the ground ≤ 3 m.s^{-1} • meteorological wind speed ≤ 6 m.s^{-1} or ≤ 3 on the Beaufort scale
Temperatures	Large indoor-outdoor temperature differences shall be avoided Product of the indoor/outdoor air temperature difference by the height of the building shall be ≤ 200 m.°C	Large indoor-outdoor temperature differences are to be avoided It is "recommended" that the product of the indoor/outdoor air temperature difference by the height of the building ≤ 250 m.K
Zero-flow pressures		The test is not valid if one zero low pressures average (in absolute) > 5 Pa

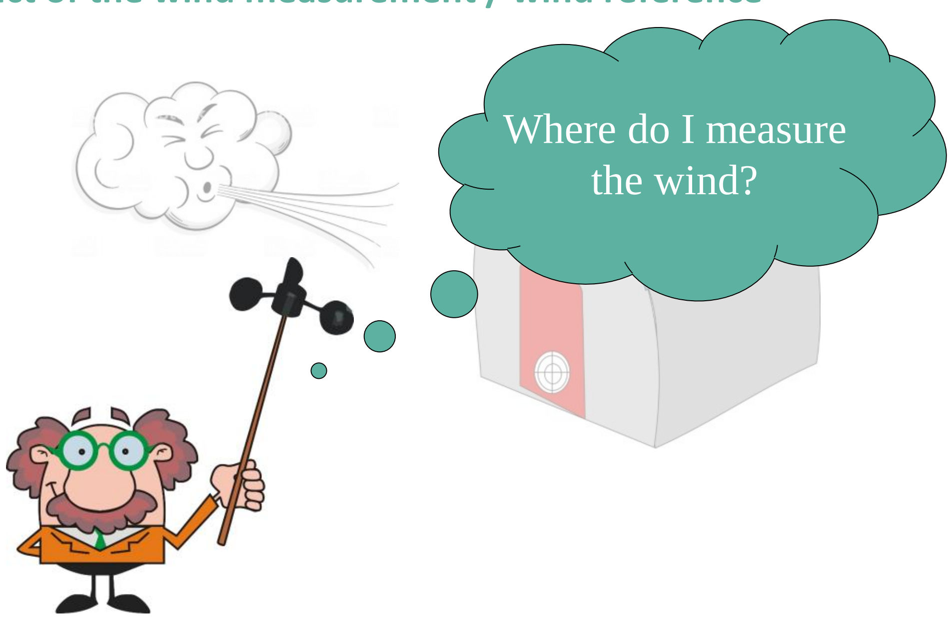
Impact of the number of points?

- One-point test to multi-point test

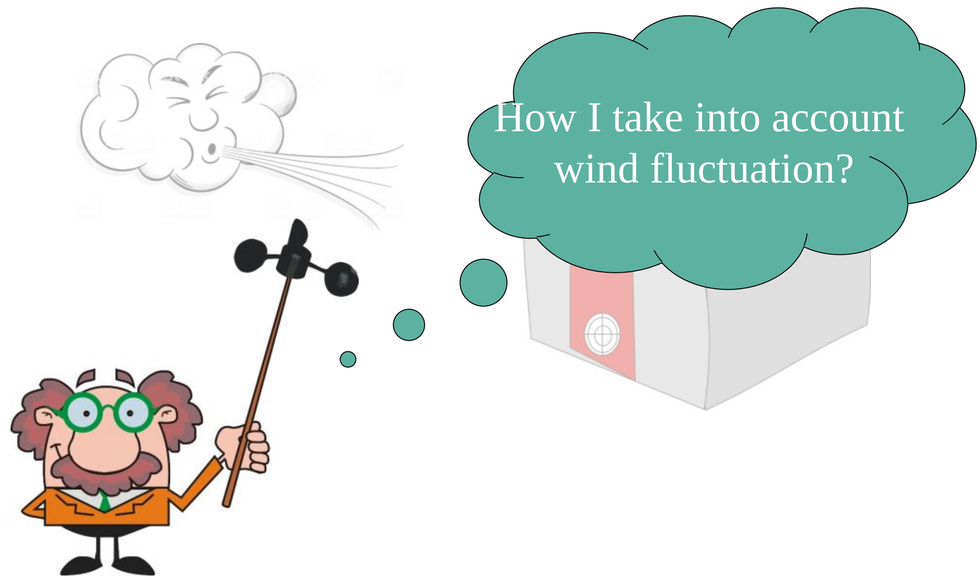


Impact of reference pressure and zero-flow pressure measurements

Impact of the wind measurement / wind reference



Impact of unsteady wind



Cerema

AIVC TightVent Europe venticool

Thanks

adeline.melois@cerema.fr

University of Nottingham
UK | CHINA | MALAYSIA

AIVC 2018

Experimental study of enclosure airtightness of an outdoor chamber using the pulse technique and blower door method under various leakage and wind conditions

Presenter: Xiaofeng Zheng

Authors: Xiaofeng Zheng, Joe Mazzon, Ian Wallis, Christopher J Wood

University of Nottingham
UK | CHINA | MALAYSIA

AIVC 2018

Introduction

Principle

Equipment and setup

Test results

Conclusions

Buildings, Energy and Environment Research Group
Faculty of Engineering
University of Nottingham, United Kingdom

University of Nottingham UK | CHINA | MALAYSIA

Introduction-Research activities

AIVC 2018

1. Real houses natural environment 36th AIVC

2. House-sized chamber sheltered environment 38th AIVC

3. Small chamber natural environment 39th AIVC

4. Impact of steady wind on the pulse test 39th AIVC

5. Pulse → Infiltration (one dwelling) 39th AIVC

6. Pulse vs. BD in an extended range 39th AIVC

7. Pulse → Infiltration (multiple dwellings) Hopefully 40th AIVC

8. Further systematic study of wind impact Hopefully 40th AIVC

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University of Nottingham UK | CHINA | MALAYSIA

Introduction

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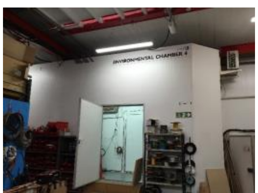

Sheltered environment comparison (Oct-2015)

Natural environment comparison (Feb-2017)

Impact of steady wind (Oct-2017)

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Principle

AIVC 2018

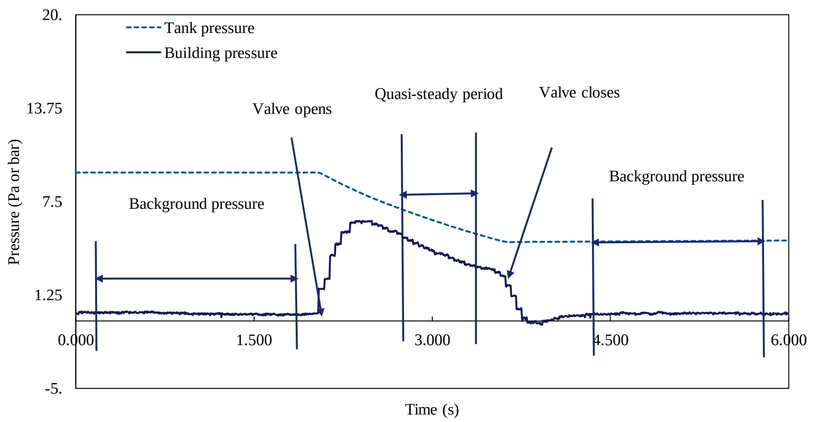
The pulse technique is implemented by releasing a measured amount of compressed air from an air tank over short period of time (1.5 s) to the test space and monitor the pressure response in the space.

Tank unit

Control unit

Principle

AIVC 2018



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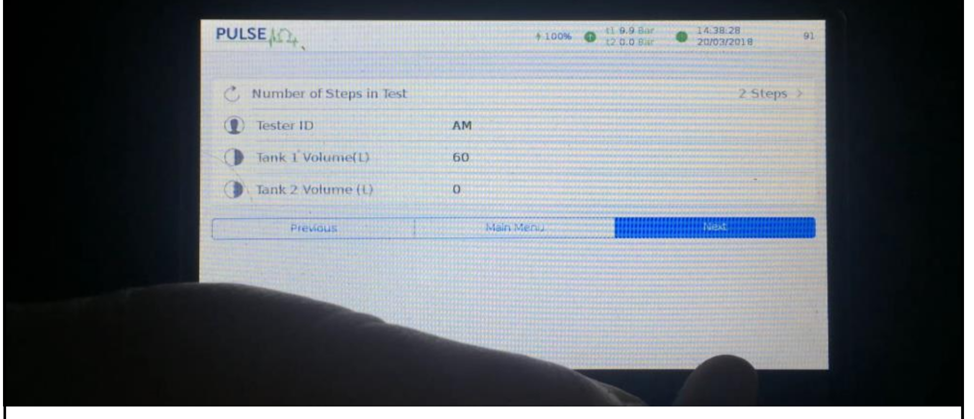
Principle

Enter tester info and building info



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Test chamber

2.84m×2.23m×2.03m

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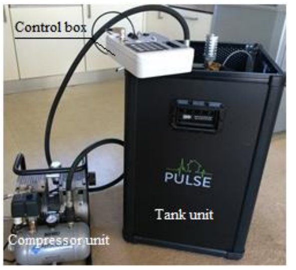
Equipment

PULSE-80 | DBB | PULSE-60



NC tests

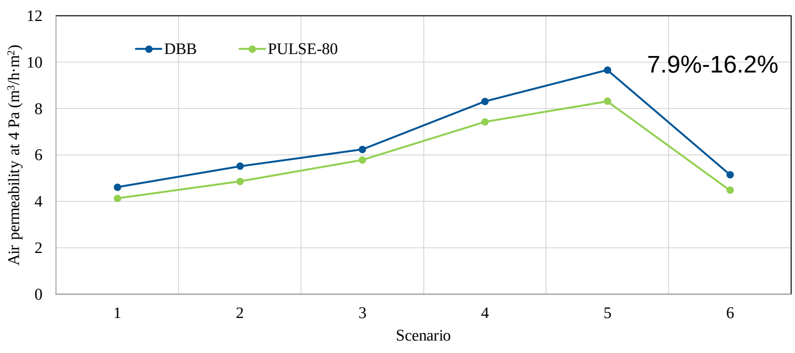
SW tests

NC test scenarios

Openings sealed in various scenarios for the NC tests

Scenario	1	2	3	4	5	6
Descriptor	Compliance test: All openings were sealed except background vents	Air brick unsealed	Radiator vent and static vent unsealed	Trickle vents, sink traps, boiler vent, dryer vent and passive stack vent unsealed	Bathroom vent, cooker extract and shower vent unsealed	All openings were sealed except background vents and boiler vent

Results-NC test



Trend of P4 in the six scenarios given by DBB in pressurisation mode and PULSE-80

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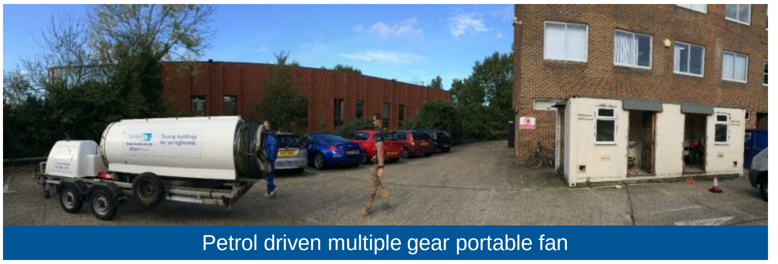
SW test setup

Setup of blower door (fan off only)

Setup of Pulse unit



Petrol driven multiple gear portable fan

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SW test setup

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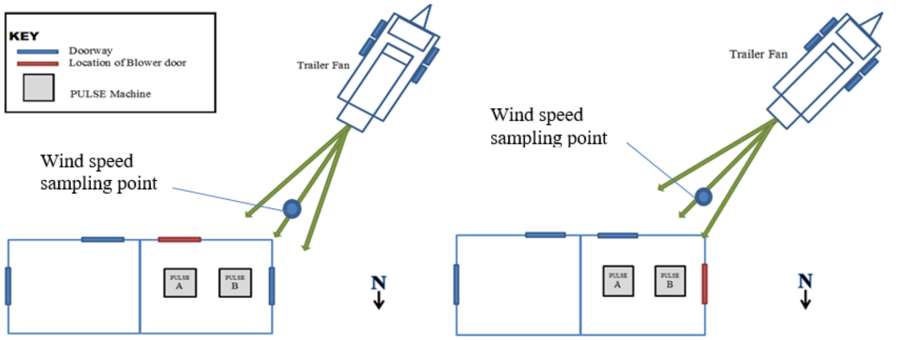

Wind direction 1 (used in scenario 1,2 and 3)

Wind direction 2 (Only used in scenario 3)

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SW test scenarios

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Scenario	1	2	3a	3b
Vent conditions	Shower extract vent was sealed	Shower extract, tumble drier vent, cooker hood vent, and static vent were sealed	Shower extract, radiator vent, cat flap, cooker hood vent, and static vent were sealed	
Wind direction	1	1	1	2
Baseline	Fan off	Fan off	Fan off	Fan off
Wind 1 (m/s)	2.5-3.5, up to 4	2.5-3.5, up to 4	2.5-3.5, up to 4	2.5-3.5, up to 4
Wind 2 (m/s)	4-5, up to 7	4-5, up to 7	n/a	n/a
Wind 3 (m/s)	6.5-7.5, up to 8.7	6.5-7.5, up to 8.7	n/a	n/a
Wind 4 (m/s)	n/a	8.5-9.5, up to 11.7	n/a	n/a

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Results-SW test

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Air permeability at 4 Pa ($m^3/h{\cdot}m^2$) measured by DBB and PULSE-60 for fan off condition

Equipment	DBB	PULSE-60	Mean % difference between DBB and PULSE 60
	P4($m^3/h{\cdot}m^2$)	P4($m^3/h{\cdot}m^2$)	
Scenario 1:	9.87	9.89	-1.69%
	10.07	10.03	
	9.75	10.28	
Mean	9.90(±1.75%)	10.07(±2.10%)	
Scenario 2:	8.18	7.68	-1.62%
	7.70	8.09	
	7.85	8.34	
Mean	7.91 (±3.45%)	8.04 (±4.41%)	
Scenario 3:	9.00	9.53	-10.84%
	8.95	9.48	
	7.98	10.05	
Mean	8.64 (±7.68%)	9.69(±3.79%)	

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Results-SW test

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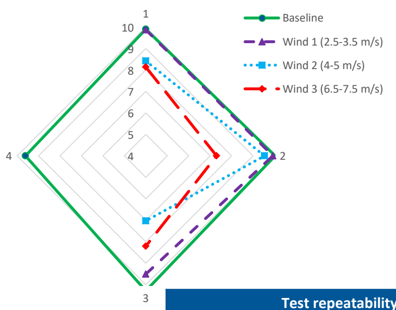
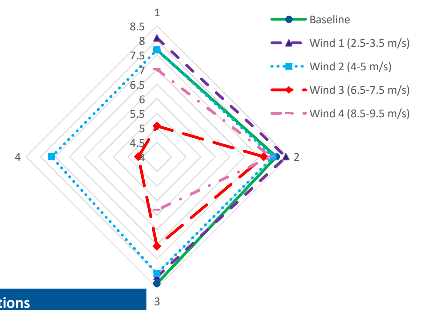
Impact of various wind conditions on the measurement of air permeability at 4 Pa ($m^3/h{\cdot}m^2$) in 3 different scenarios

Scenario 1



Scenario 2



Test repeatability in different conditions					
Test condition	Baseline	Wind 1	Wind 2	Wind 3	Wind 4
Scenario 1	±3.4%	±2.7%	±15.7%	±7.3%	n/a
Scenario 2	±4.40%	±2.10%	±2.50%	±25.60%	±15.80%
Wind condition compared to baseline					
Scenario 1	n/a	-1.9%	-16.3%	-20.8%	n/a
Scenario 2	n/a	2.11%	-2.73%	-24%	-14.10%

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Results-SW test

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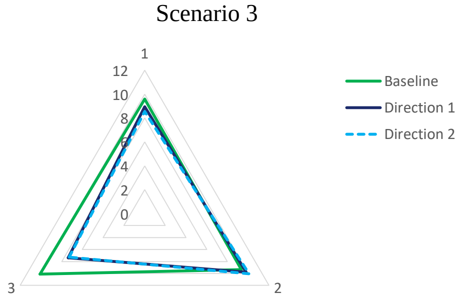

Test repeatability in different conditions			
Test condition	Baseline	Direction 1	Direction 2
Scenario 3	±4.3%	±15.2%	±16.8%
Wind direction compared to baseline			
Scenario 3	n/a	-10.0%	-10.9%

Conclusions

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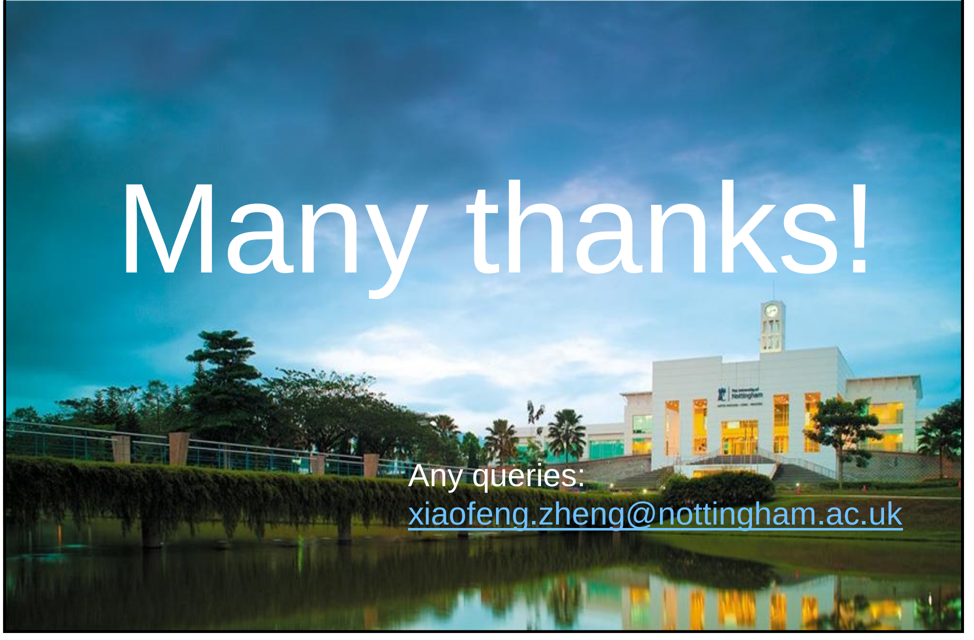
- In NC tests, the DBB and the pulse methods followed a similar trend, with a slightly larger discrepancy than (Zheng 2017).
- In SW tests, a similar overall deviation range with that obtained in the NC tests was achieved. But both are slightly higher than that obtained in previous sheltered environment study. It is considered that blower door installation, weather condition, pulse model and extrapolation might contribute to the increase in deviation between the two methods in measuring P4.
- When the wind is less than 3.5 m/s, the impact of wind on the pulse test is negligible. When the wind speed was increased to between 4.5 m/s and 9 m/s, the pulse test became less repeatable, and the measured air permeability was decreased by 2.7%-24%. The initial results also suggested the opening distribution might change the way wind impacts the pulse measurement.
- This steady wind study provides insight of how wind affects the pulse measurement based on a small outdoor chamber. These tests represent the observations seen on a limited number of tests for this case study and further experimental investigations are now required in the field of actual dwellings to determine the validity of the findings in this study.

AIVC 2018



Many thanks!

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Experimental investigation of the impact of environmental conditions on the measurement of building Infiltration, and its correlation with Airtightness

Alan Vega Pasos, Xiaofeng Zheng, Vasileios Sougkakis, Mark Gillott, Johann Meulemans, Olivier Samin, Florent Alzetto, Luke Smith, Stephen Jackson, Christopher Wood

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Introduction

Introduction

- Infiltration can be affected by factors such as
  - external terrain
  - leakage distribution
  - sheltering factor, but mainly
  - Air tightness
- Existing research: models, and understanding of physical phenomena
- Research gap: airtightness quoted at 4 Pa and correlation with air infiltration. Measurements and comparisons between pressure differentials and environmental conditions

Method & Test House

Method

Tracer gas → Constant Concentration → Long tests (days) → 15 tests

Tracer gas → Decay Method → Short tests (hours) → 19 tests

- INNOVA 1412I gas analyser.
- LumaSense 1303 multipoint gas sampler and doser.
  - Tracer gas, CO2.

Pressure monitoring → Wind effect → One sensor every facade

Pressure monitoring → Buoyancy effect → Highest indoor place

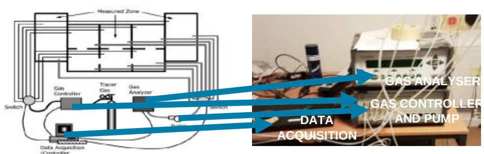
→ Connected to same reference → ΔP → Measuring every second

Environmental conditions → Wind → Measuring every second

Environmental conditions → Temperature → Indoor / Outdoor → ΔT

Pulse method → Tests every day → At least 3 valid tests per day → 29 testing days

Is there a correlation?



Method

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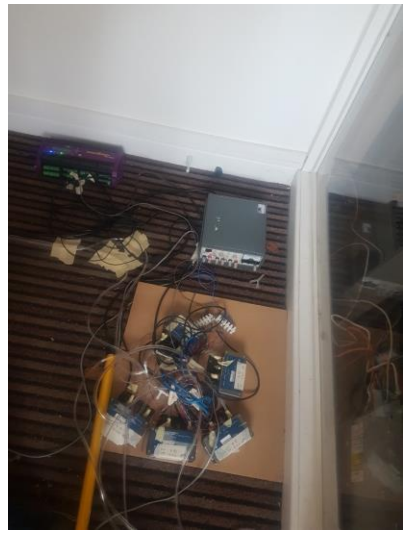
Method



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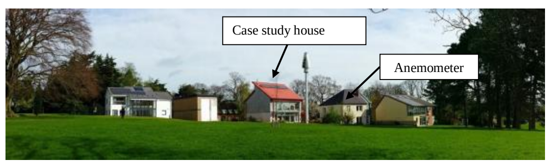
Method

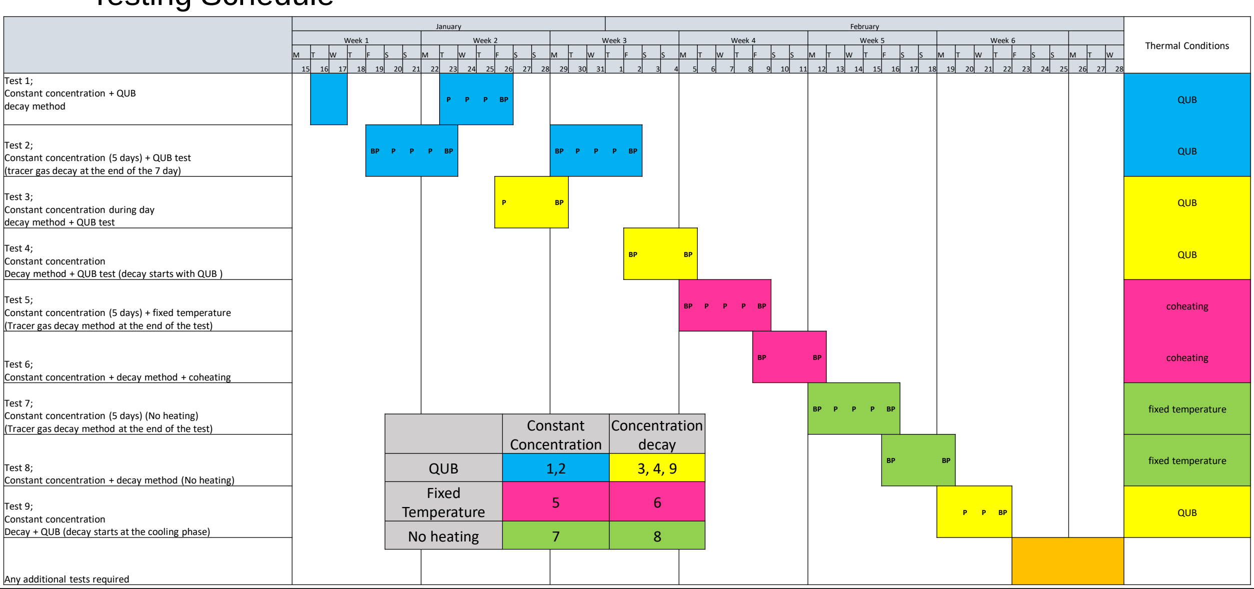
Test House

- Location: University Park Campus, Nottingham, United Kingdom
- Pressure tappings in each façade of the building plus one in the highest (indoor) part of the building
- Divided in six thermal zones
- Weather measuring:
  - Indoor temperature: one sensor in each zone
  - Outdoor temperature: two sensors
  - Wind speed: Weather station located 10 meters away



Method

Testing Schedule



	Constant Concentration	Concentration decay
QUB	1,2	3, 4, 9
Fixed Temperature	5	6
No heating	7	8

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Method

Testing Schedule

Test	Date	Tracer gas test	Heating conditions	Duration
1	18–23 Jan	Constant Concentration for 110 hours + decay method for 8 hours	Heating from 5 pm to 12 am	5 days
2	23-26 Jan	Constant concentration for 61 hours + decay method 5 hours (7am to 12 pm)	Heating from 5 pm to 12 am	3 days
3	26-29 Jan	Constant concentration from 3 pm to 7 am and decay method from 7 am to 3 pm.	Heating from 5 pm to 12 am	3.5 days
4	29 Jan – 02 Feb	Constant concentration for 80 hours + decay method for 8 hours	Heating from 5 pm to 12 am	4 days
5	02-05 Feb	Constant concentration from 2 am to 6 pm and decay method from 6 pm to 2 am.	Heating from 6 pm to 12.00 am	3 days
6	05-09 Feb	Constant concentration for 86 hours + decay method 7 hours	Constant temperature 23°C	4 days
7	09-12 Feb	Constant concentration from 4 pm to 6 am + decay method from 6 am to 4 pm.	Constant temperature 23°C	3 days
8	12-16 Feb	Constant concentration for 85 hours + decay method 5 hours (7am to 12 pm)	No heating, allowing heat losses	4 days
9	16-19 Feb	Constant concentration from 3 pm to 7 am and decay method from 7 am to 3 pm.	No heating, allowing heat losses	3 days
10	19-22 Feb	Constant concentration from 8 am to 12 am and decay method from 12 am to 8 am.	Heating from 5 pm to 12 am	3 days
11	23-28 Feb	Constant concentration for 131 hours + decay method for 9 hour	Heating from 5 pm to 12 am	6 days
12	28 Feb – 01 Mar	Decay method for 24 hours	Heating from 5 pm to 12 am	1 day

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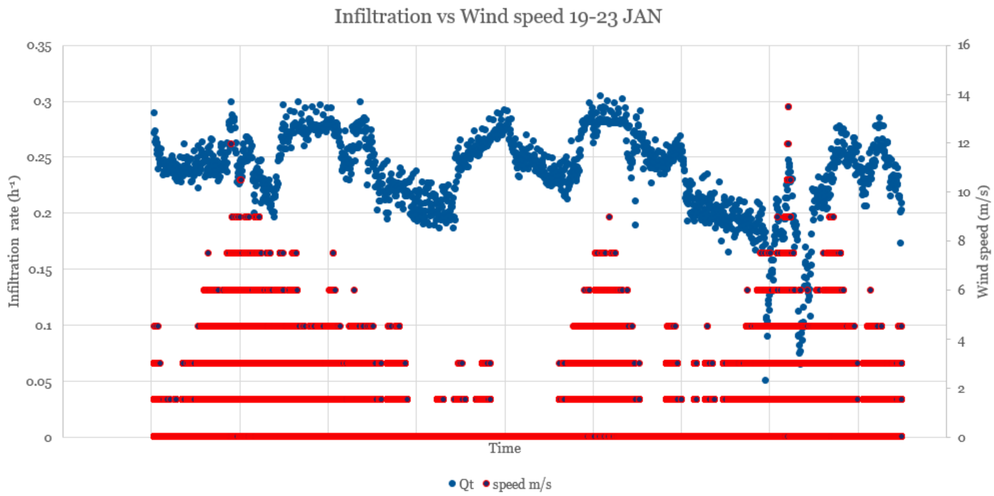
Results

Impact of Wind on Air Infiltration



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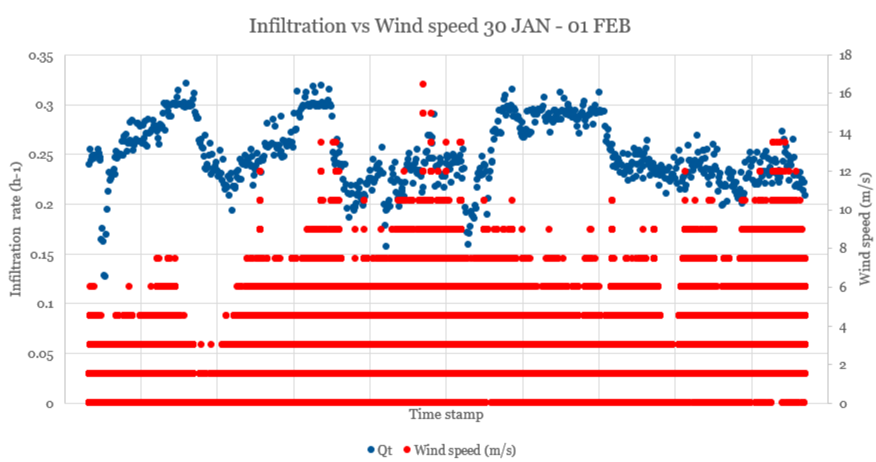
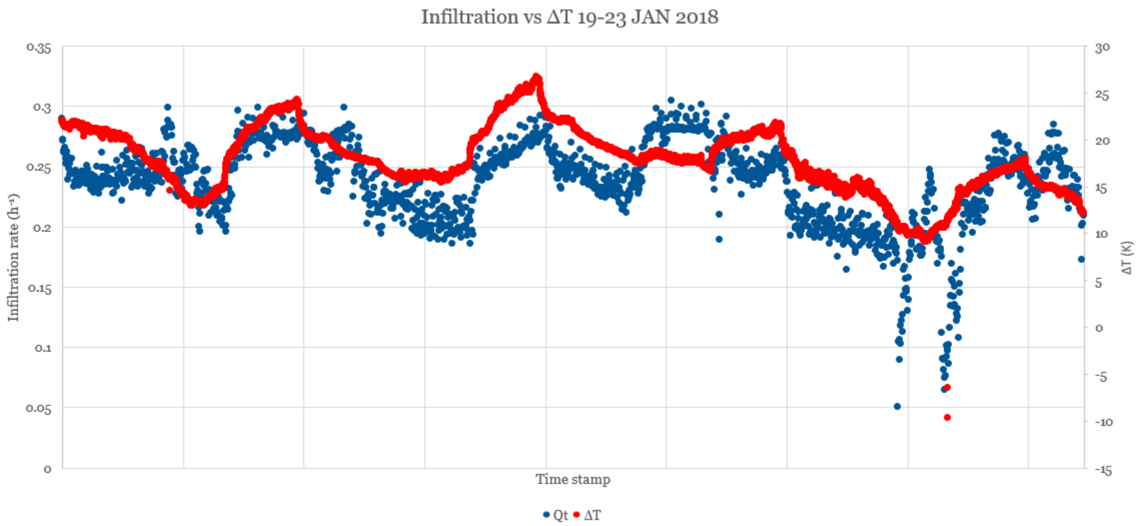
Results

Impact of Wind on Air Infiltration



Results

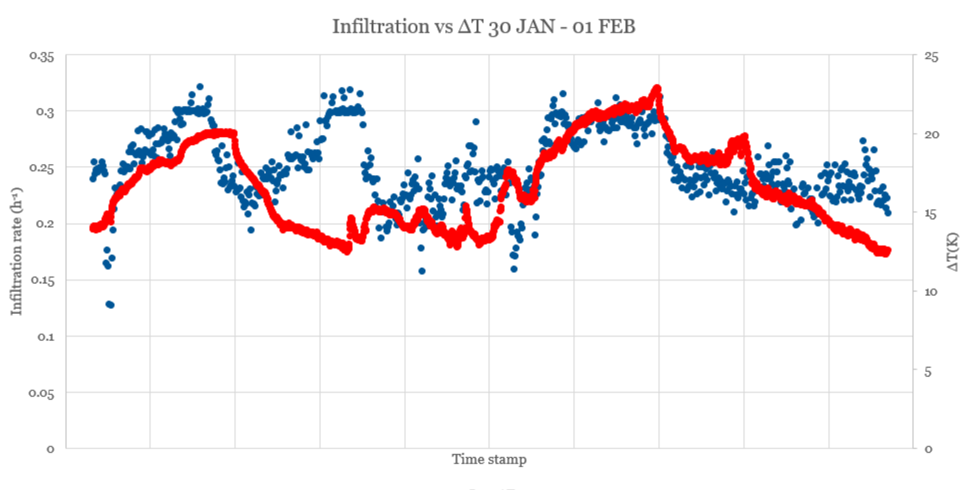
Impact of ΔT on Air Infiltration



Slide: 11 of 22

Results

Impact of ΔT on Air Infiltration



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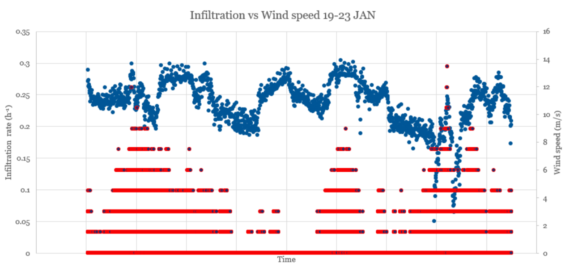
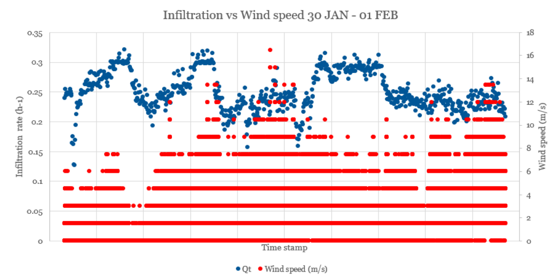
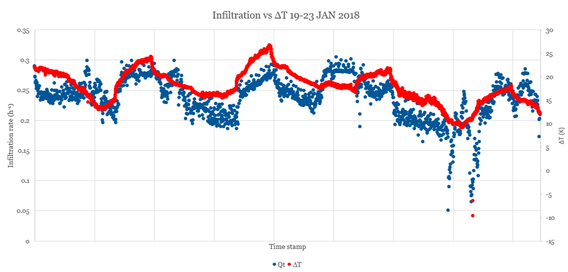
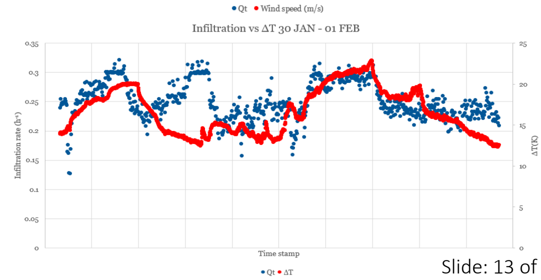
Results

Impact of Wind and ΔT on Air Infiltration









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Results

Impact of Wind and ΔT on Air Infiltration

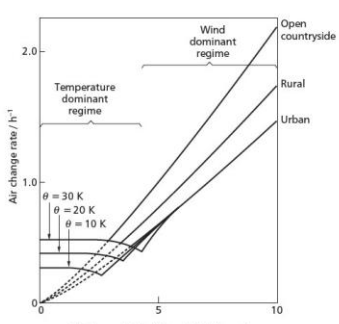

Figure 4.12 Transition from stack to wind dominant flow (source: Liddament, 1996)

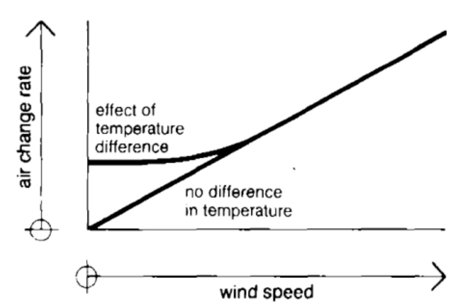

Figure 1.4 Infiltration characteristics

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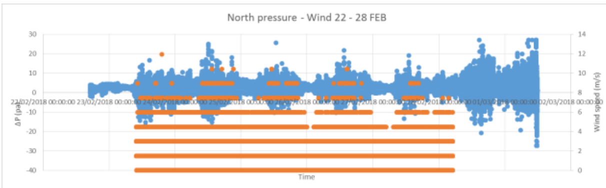
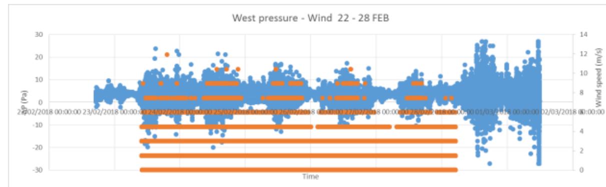
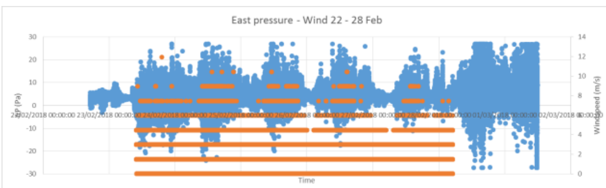
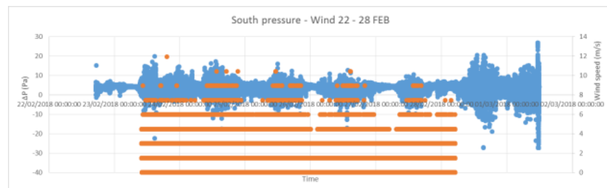
Results

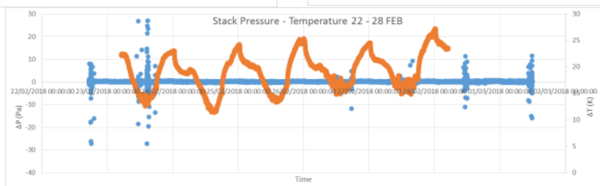
Impact of Environmental Conditions on ΔP











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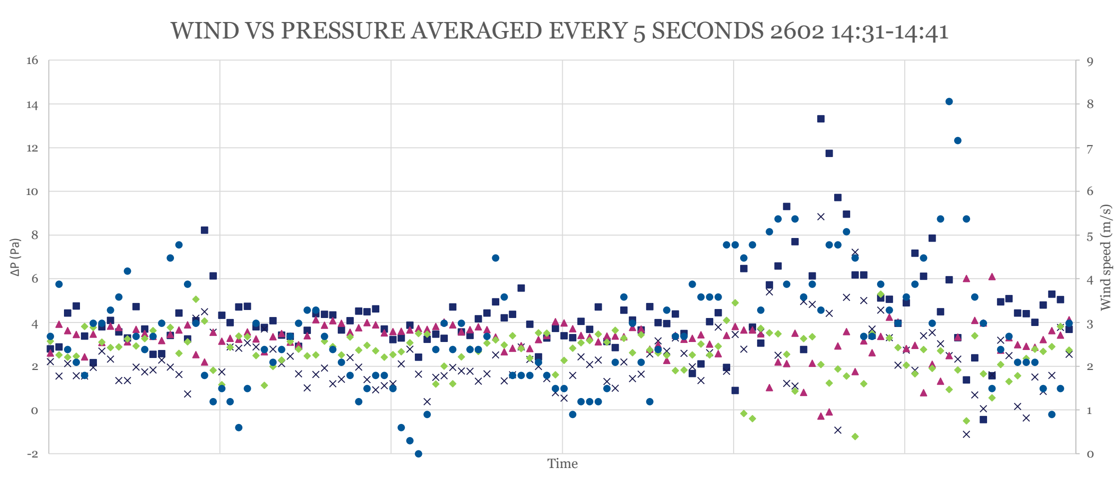
Results

Impact of Environmental Conditions on ΔP



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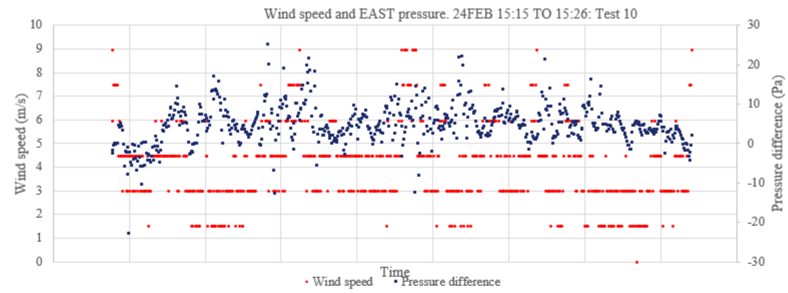
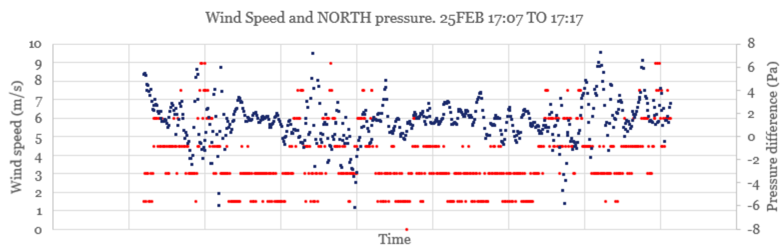
Results

Impact of Environmental Conditions on ΔP





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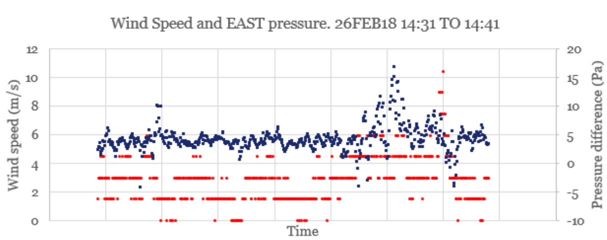
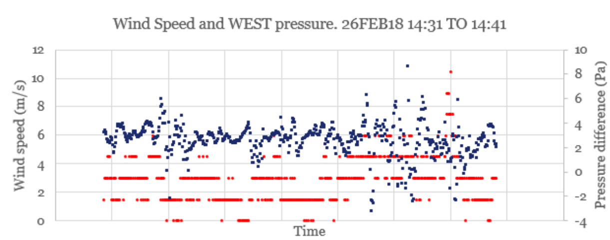
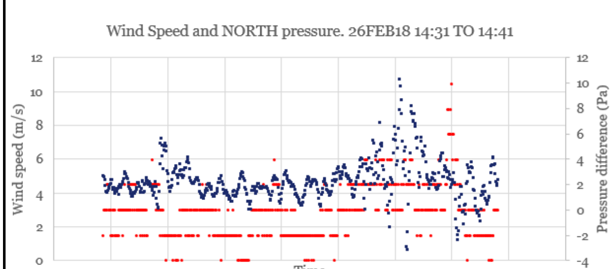
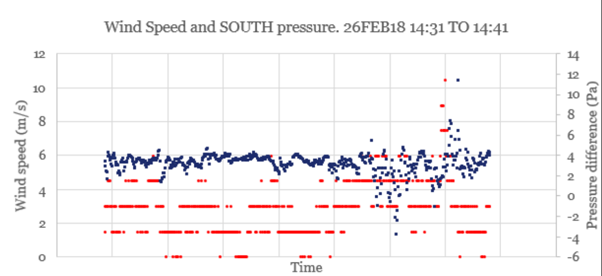
Results

Impact of Environmental Conditions on ΔP



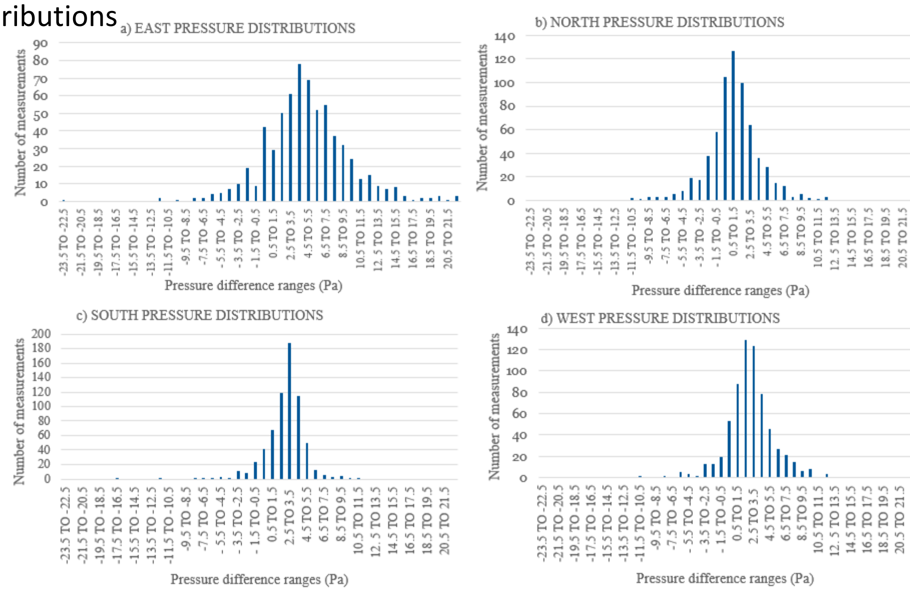






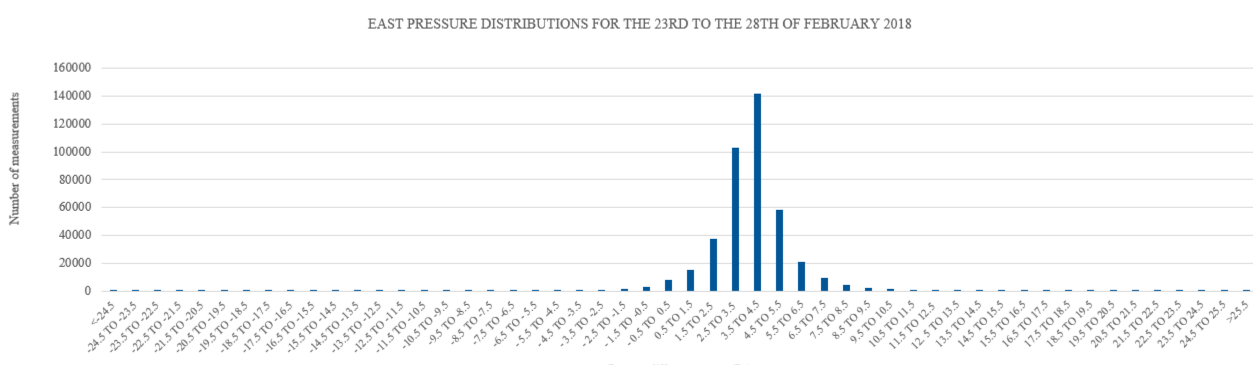
Results

ΔP Distributions



Results

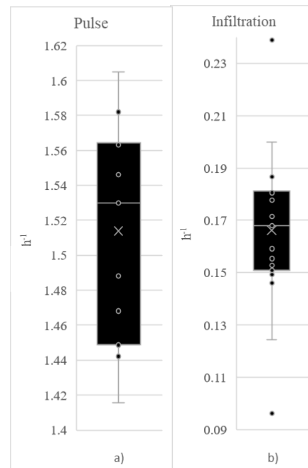
ΔP Distributions



Results

Infiltration Rate and Pulse

		Infiltration Rate (h^{-1})							
				Decay method					
		Constant Concentration		Analyser		CO2 Sensors		PULSE (h^{-1})
Test	Sub test	Range	Average	Average	Regression	Average	Regression	
1		0.05-0.304	0.236788					1.563012
2		0.186-0.274	0.225715	0.1794	0.178	0.1702	0.1583	1.581951
3	3.1			0.1527	0.1455	0.142	0.1439	
	3.2	0.122-0.26	0.213518	0.1506	0.1478	0.1562	0.1491	1.604865
4	4.1			0.1642	0.1775	0.1803	0.2	
	4.2	0.126-0.321	0.250261	0.1367	0.1322	0.1687	0.1665	1.564172
5	5.1	NOT VALID		0.1819	0.1835	0.1735	0.1764	
	5.2			0.1815	0.1829	0.1714	0.1751	
	5.3			0.1844	0.185	0.1768	0.1785	1.545928
6		0.18-0.298	0.256791	0.1504	0.1499	0.1562	0.1545	1.442151
7		0.188-0.262	0.246959	0.1548	0.1492	0.1503	0.1424	1.448636
8	8.1	0.136-0.204	0.17229					
	8.2	0.095-0.268	0.182168	0.1616	0.1551	0.1525	0.1521	1.415609
9	9.1	0.112-0.171	0.146068	0.1619	0.1653	0.1535	0.156	
	9.2	0.089-0.195	0.138139	0.1311	0.1269	0.1221	0.1176	
	9.3	0.073-0.249	0.143226	0.0978	0.099	0.0935	0.0946	1.529767
10	10.1	0.173-0.226	0.19947	0.189	0.1935	0.1819	0.1877	
	10.2	0.21-0.245	0.223794	0.1847	0.1913	0.1833	0.1873	
	10.3	0.215-0.24	0.224196	0.1985	0.2042	0.1959	0.2012	1.488186
11		0.194-0.288	0.239945	0.1745	0.1737	0.1642	0.1597	1.468089
12		N/A		0.244	0.2426	0.2348	0.2343	N/A



Conclusions

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Conclusions

- There seems to be a correlation between the changing infiltration rates and the airtightness level (@4Pa) → typically around 1/10th.
- Confirmation of theory and previous studies regarding the dependency of air infiltration on temperature (base level) and wind.
- Immediate change in pressure difference due to high wind gusts (not observable by changes in temperature difference)
- Pressure differentials due to the act of environmental conditions occur mostly between 1.5 to 4.5 Pa → Opportunity to measure airtightness at lower ΔP.

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THANK YOU

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Uncertainties in airtightness measurements: regression methods and pressure sequences

Presenter: Martin Prignon

Authors: Martin Prignon[1], Arnaud Dawans[2] and Geoffrey Van Moeseke[1]

[1] *Architecture et Climat, Université catholique de Louvain*
[2] *Entreprises Jacques Delens*

Jacques Delens

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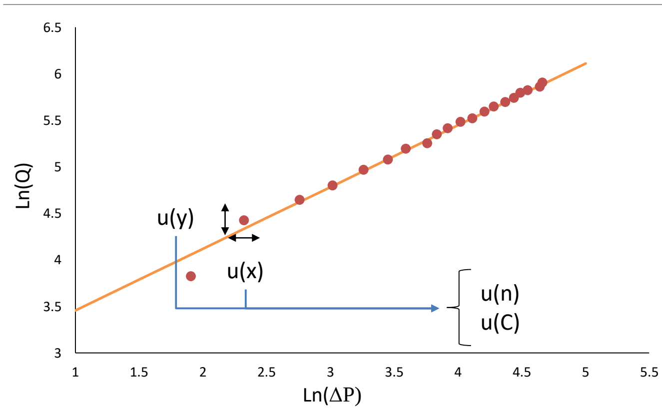
Hypotheses behind the Ordinary Least Square (OLS) method



- H1: $u(x) \approx 0$
- H2: $u(y) = C$

The OLS method provides reliable regression parameters and reliable uncertainties for these parameters

Alternative methods

- Okuyama and Onishi, 2012 ➔ Iterative Weighted Least Square (IWLS)
- Delmotte, 2017 ➔ Weighted Line of Organic Correlation (WLOC)

Take into account non-constant uncertainties in both directions

The "repeatability" study

Case study

- Apartment in Brussels
- New construction (2017)
- Unoccupied
- Masonry walls
- Volume : 228 m^3
- Floor area : 90 m^2

Testing conditions

- 30 tests within a 10 days period
- Same operator, same equipment

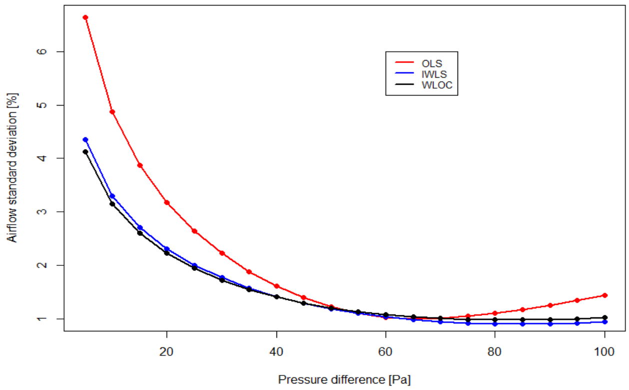
➔ Reproducibility

	Number of tests	Average airflow rate at 50 Pa (m^3/h)	Standard deviation (%)
(Persily, 1982)	17	3860	1.1 %
(Kim & Shaw, 1986)	7	1104	1.6 %
(Delmotte & Laverge, 2011)	10	732	1.4 %
(Novak, 2015)	92	1005	1.8 %
(Bracke et al., 2016) (1)	58	234	1.4 %
(Bracke et al., 2016) (2)	53	132	2.3 %
This paper	30	253	1.2 %

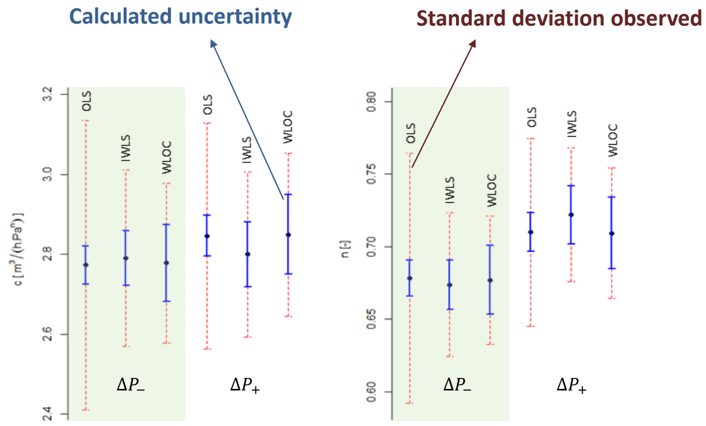
Airflow standard deviation and average for different regression methods

	Average airflow rate at 10 Pa (m^3/h)	Average airflow rate at 50 Pa (m^3/h)	Average airflow rate at 100 Pa (m^3/h)
OLS	82.70	252.62	409.15
IWLS	82.07	252.77	410.70
WLOC	82.76	252.80	409.17

$\Delta_{methods} < 1\%$



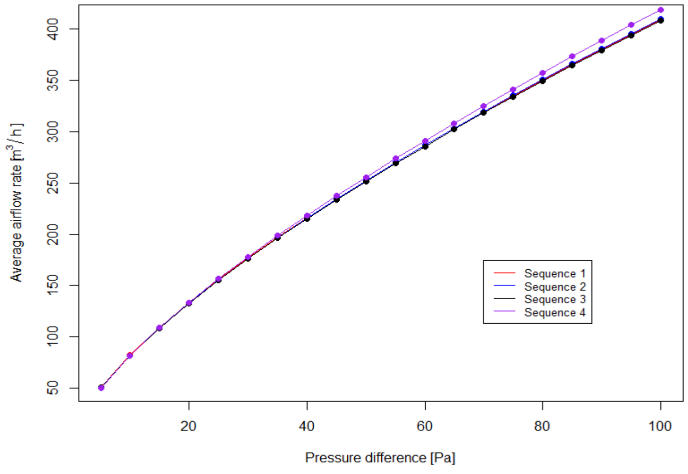
Uncertainties in regression parameters



1. Standard deviation of regression parameters is higher with OLS than with IWLS and WLOC
2. The uncertainties calculated with IWLS and WLOC fit better the standard deviation than OLS
3. The calculated uncertainties are still underestimating the standard deviation observed

Uncertainties considered
- Measurement equipment
- Zero-flow pressure approximation

Impact of the sequence of pressure on average airflow

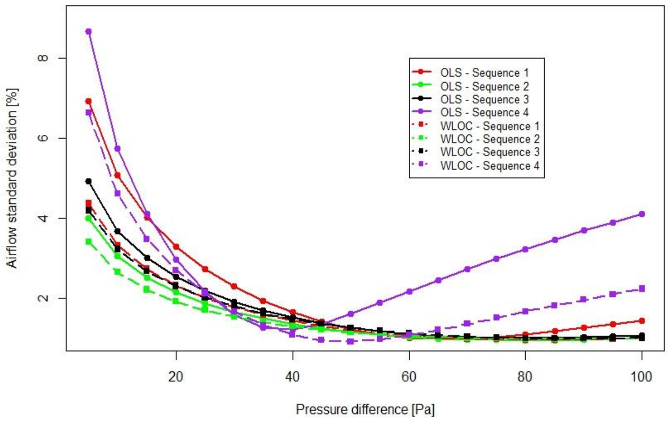


- Sequence X: *a:b:c (d)*

a = lowest pressure measurement
b = step between two pressure measurements
c = highest pressure measurement
d = number of measurements

- Sequence 1: *5:5:100 (20)*
- Sequence 2: *10:5:100 (19)*
- Sequence 3: *10:10:100 (10)*
- Sequence 4: *5:5:50 (10)*

Impact of sequence of pressure on the airflow standard deviation



1. Sequence 4 (*5:5:50*) leads to bad results at low and high pressure for both OLS and WLOC
2. Sequence 1 (5:5:100) leads to higher standard deviation at low and high pressure station with OLS but not with WLOC
3. For all sequences, WLOC leads to lower standard deviation than OLS

Conclusion and next steps

Main observations

- Results of “repeatability” study consistent with literature
- OLS, IWLS and WLOC lead to the same $\mu(Q)$
- IWLS and WLOC give lower $\sigma(Q)$ than OLS (at low and high pressure)
- $u(n)$ and $u(c)$ computed with IWLS and WLOC are more reliable than with OLS
- IWLS and WLOC are less impacted by a change in sequence pressure
- The highest pressure station should be taken higher than 50 Pa

Further work

- Important work remaining in the estimation of uncertainties (components related to hypotheses as such as the pressure homogeneity)

Q&A

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Numerical and experimental identification of factors influencing the pressure homogeneity during an airtightness test in a large building

Loubna Qabbal[1, 2, 3], Lucille Labat [4], Hassane Naji [2, 3], Zohir Younsi[1, 2, 3], Sabrina Talon [4]

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[2] *Univ. of Artois, Laboratoire Génie Civil & géo-Environnement (LGCgE EA 4515), Technoparc Futura, F-62400 Béthune, France*
[3] Lille University Northern France, LGCgE -EA 4515, F-59000 Lille, France
[4] *Cerema Centre–Est / Département Laboratoire d'Autun, Boulevard Giberstein - BP 141 71405 AUTUN Cedex, France*

❑ Objectives and approach

- The standard (NF EN 9972, 2015) and its application guide (FD P50-784, 2016) do not require the use of specific equipment for the measurement of air permeability of the building envelope.
- However, the guide requires among other things verification of the following criterion to justify the homogeneity of pressure:

$$\Delta P \leq \mathrm{Max}\{2\mathrm{Pa}\,;\ 10\%\ \Delta P_{Measured}\}$$

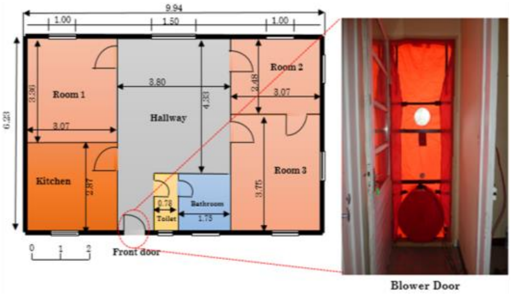
✓ **The main objective of this study is to determine the different factors causing the heterogeneity of the pressure during an air permeability test in a large-volume building.**

- **Step 1**: Experimental and numerical airtightness study for a single-family home (SRT <3,000 m2)
  - Location in the CEREMA site
  - The experimental study was to Extract the necessary data for the numerical model,
  - Determine the parameters to test in the model of the building of large volume
- **Step 2**: Numerical study of a large volume building (S_{RT}> 3,000 m²)
  - Influence of the shape of the leaks, the location and their sizes, the geometry of the rooms and aeraulic connections

L. QABBAL

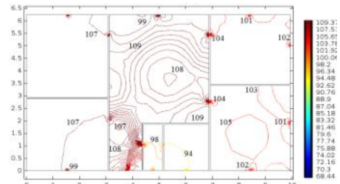
❑Results and discussion

The single family house considered

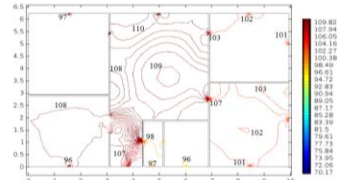


Air permeability test

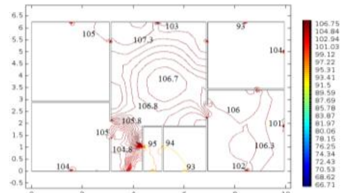
❖ Effect of internal partitions



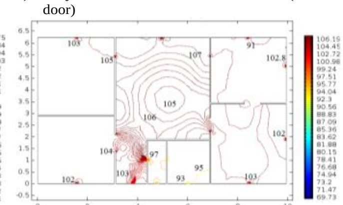
a) All communication doors are closed



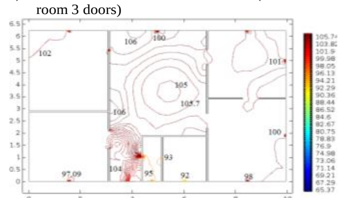
b) Only one internal connection 0.70 m (kitchen door)



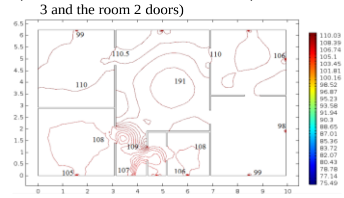
c) Two internal connections 0.70 m (kitchen and room 3 doors)



d) Three internal connections 0.70 m (kitchen, room 3 and the room 2 doors)



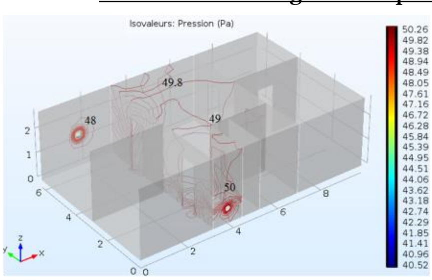
e) Six internal connections 0.70 m (kitchen, room 3, room 2 and the bathroom doorst)



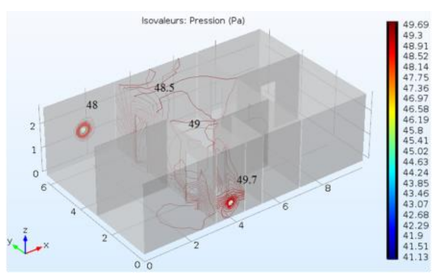
f) All internal connections (doors) 0.70 m are open

❑Results and discussion

❖ Air leaks according to the equivalent hole



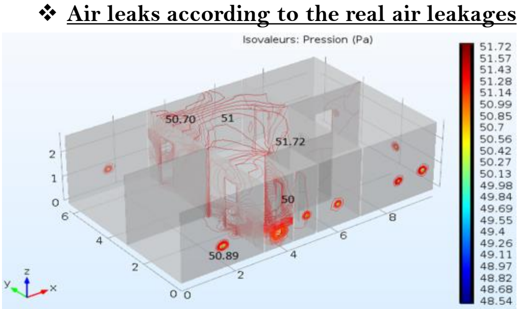
a) Square leakage with internal walls



b) Circular leakage with internal walls

- The model of air leaks **according to the equivalent hole** in the building envelope does not reflect the actual leakages

❖ Air leaks according to the real air leakages



- The pressure throughout the house is homogeny and the mean value of the pressure difference is of order of 50 Pa.
- If the air leakages are calculated using the equivalent hole, we can consider spreading the equivalent area over the entire building to have the same location as in reality (locations being identified during air permeability test).
- The shape of the modeled leaks does not influence the results. For each part of the building, the number and position of the leak have little influence on the result, so that we can model, in each room, a single leak in the current part of a vertical wall.

❑ Conclusion

The air permeability measurement in large volume buildings is not always obvious since we have to meet certain requirements of the ISO 9972, 2015 and its application guide (FD P50-784, 2016). Among the difficulties during an airtightness test, especially in buildings of large volume: check the homogeneity of pressure.
On the basis of the numerical results obtained, the following conclusions can be drawn:

- Identify critical areas, which are generally the rooms furthest away from the fan, located on the top floor of the building, or in an area that could be poorly connected to the rest of the building, due to architectural specificities or reduced communications.
- Target parts where the leaks are located and try to connect them with the rest of the building.
- Use enough fans and try to spread them over the entire building to pressurize/depressurize the rooms.
- Avoid installing the fan door in isolated locations from the rest of the building.

Thanks!

I invite you to come and see my poster N° P021 to exchange with you

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lucille.labat@cerema.fr

Ventilation Requirements

Regulations
Standards
Recommandations

AIVC 39th Conference
September 2018
Juan Les Pins France

Willem de Gids
VentGuide NL

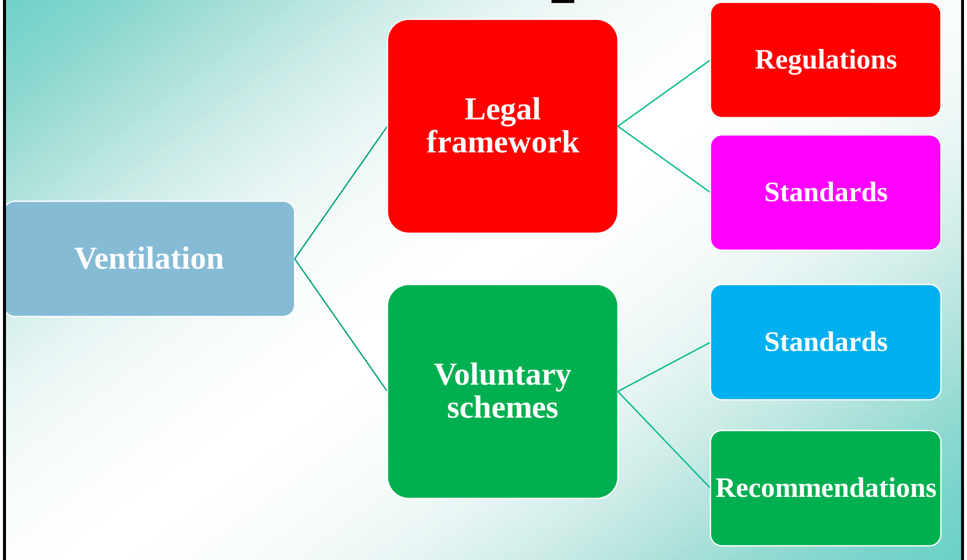
Wouter Borsboom
TNO

AIVC Project

Rationale behind ventilation requirements and regulations	
Reasons behind launching this activity	International there are many different requirements and regulations for ventilation. Sometimes the variation is more than a factor of five. There are strong drivers to reduce energy consumption for HVAC, and therefore the spread in requirements and regulation is worthwhile to study. To reduce ventilation flows there is a necessity to understand the reasons behind. Demand control to reduce this flows is in many countries growing but the control parameters are quite different, for instance humidity versus CO_2 control. If you don't know the reasons for ventilation, you cannot decide when and to what level you can reduce the ventilation flows.
Objectives	The goal is: • to collect information about the rationale behind ventilation requirements in different countries • to analyse these data, differences, similarities • to categorize them .for instance climate conditions • recommendation based on latest research findings
Approach outline (including exchange channels)	Questionnaire VIP Presentations at workshops or conferences TechNote
Partnerships	
Networks involved	AIVC
Partners involved	Korea, US, NL, Partner search: Portugal, Spain, Norway, Finland, Greece, Italy, Denmark, France, Sweden, Belgium, Germany, New Zealand, Japan, Czech Republic, Austria, Swiss, Hungary, Russia…?

Deliverables	
Deliverable n° 1	
Type and title	VIP on regulations and requirements
Leaders	TNO, VentGuide

Ventilation requirements



Information on requirements

Through answers on questionnaires from Board members of AIVC countries

- ASHRAE 62.1
- ASHRAE 62.2
- Part F UK

Information on requirements

<u>From Literature:</u>

- Nejc Brelih*1, Olli Seppänen1
  VENTILATION RATES AND IAQ IN EUROPEAN STANDARDS AND NATIONAL REGULATIONS (2011)
- *C. Dimitroulopoulou*
  Ventilation in European Dwellings (2012)
- <u>Maria Bocanegra-Yanez</u>[1], Gabriel Rojas[2], Daria Zukowska-Tejsen[3], Esfand Burman[4], Guangyu Cao[5], Mathieu Pierre Yves Hamon[5] and Jakub Kolarik
  Design and operation of ventilation in low energy residences – A survey on code requirements and building reality from six European countries and China (2015)

Analyses based on minimum values reported or found in literature

Data has to be evaluated by experts per country

Data for offices and schools is available but not yet analysed

Excel sheet dwellings

land	Reqs/Regs livingroom	unit									other room	kitchen			bathroom	toilet	tot			
AIVC		dm3/s m2	dm3/s pp	m3/h m2	m3/h pp	m3/h	h-1	ppm CO2	floorarea	supply		dm3/s	m3/h	h-1			dm3/s m2	m3/h m2	h-1	dm3/s
Aus																				
Be		1									1	21			14	7				
Ch					30									3					1	
Den		0,3									0,3	20			15	10	0,3		0,51	
Fr										x			75-135		30	30			0,4	
It												41,7			21,7	8,3			0,3	
Jap							0,5				0,5									
NL		0,9									0,9	21			14	7				21-54
NZ							0,35		1/20th		0,35	12 50			10 25					
No				1,2									36-108		54-108	36		1,2	0,48	
SK							0,5				0,5	0,5							0,5	
Sp								y<900 5000000ppmh>1600												
Swe		0,35									0,35	10 15			10 30	10				
UK									1/20th			13-30			8	6			0,43	17-29
USA												21 300			20 25					42
Non AIVC																				
Aut																			0,15	
Bu																			0,26	
Cz							0,3-0,6				0,3 - 0,6		100		75	25			0,5	

Quantities and Units

unit								
dm3/s m2	dm3/s pp	m3/h m2	m3/h pp	m3/h	h-1	ppm CO2	floorarea	supply

Exposure (concentration * time)	ppmh
Concentration	ppm

Flowrate	per person	per m^2
	expressed in	dm^3/s or m^3/h

Air change rate	h^{-1}

Provisions	window openings as % of floor area
	supply
	exhaust
	range hood

Comparing requirements

Depending on:

- Dimensions
  - Floor area
  - Room volume
  - Building volume
- Number of rooms
- Number of persons
- Type of system
  - Natural ventilation
  - Mechanical ventilation
  - Range hood yes or no
- etc

Kitchen

Dimensions:

Height	2.65 m
Width	4.53 m
Depth	2.50 m
Volume	30 m^3

Possible criteria for kitchen:

- Dilution of odour
- Extraction of contaminants
- Under pressure to prevent spreading

Bathroom

Dimensions:

Height	2.65 m
Width	2.90 m
Depth	1,95 m
Volume	15 m^3

Possible criteria for bathroom

- Ventilation for 2 persons
- Control of water vapour
- Under pressure to prevent spreading

Toilet

Dimensions:

Height	2.65 m
Width	1.10 m
Depth	1.37 m
Volume	4 m^3

Door leakage 5 $dm^3/s.\ Pa^n$

Equals to about 60 cm^2 door cut

Possible criteria for toilet:

- Ventilation for 1 person
- Dilution of odour
- Under pressure to prevent spreading

Livingroom

Dimensions:

Height	2.65 m
Width	5.10 m
Depth	8.50 m
Volume	115 m^3

Possible criteria for living:

- Ventilation for 6 persons
- Dilution of odour

Bedroom

Dimensions:

Height	2.65 m
Width	4.20 m
Depth	4.50 m
Volume	50 m^3

Possible criteria for living:

- Ventilation for 2 persons
- Dilution of odour

Whole house

Dimensions:

Height	7.5 m
Width	5 m
Depth	10 m
Volume	375 m^3

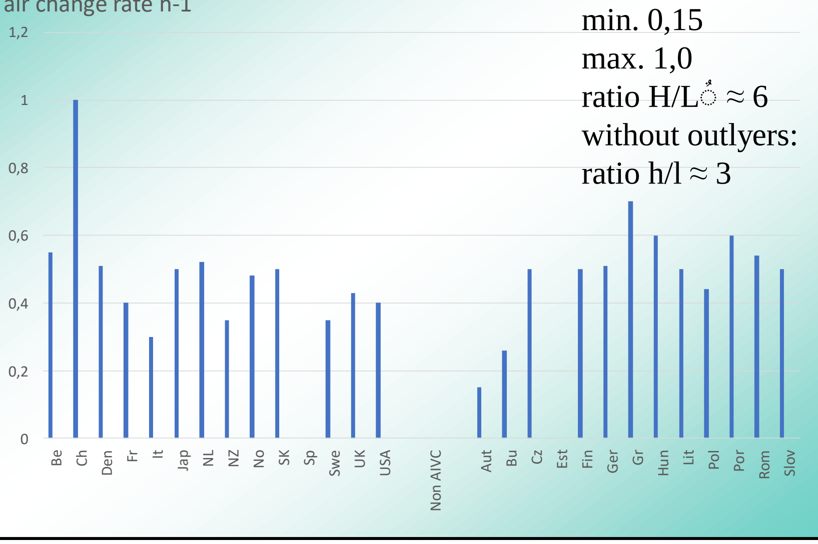
3 bedrooms

Possible criteria for house:

- Ventilation for 4-8 persons
- Dilution of odour
- Control of water vapour
- Control of contaminants

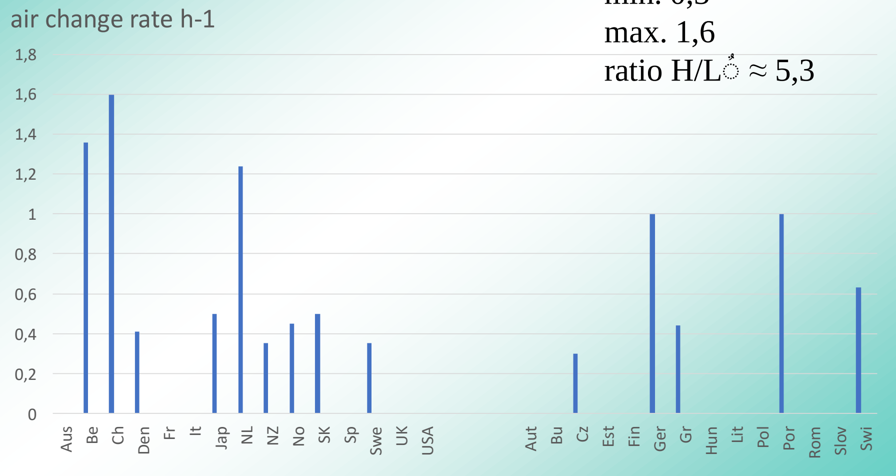
Whole house rates (375m^3)

average 0,48
min. 0,15
max. 1,0
ratio H/L ≈ 6
without outlyers:
ratio h/l ≈ 3



Living (115m^3)

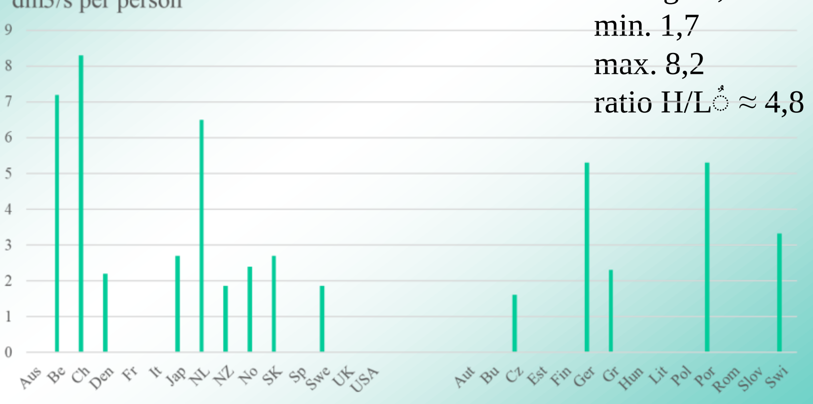
average 0,78
min. 0,3
max. 1,6
ratio H/L ≈ 5,3

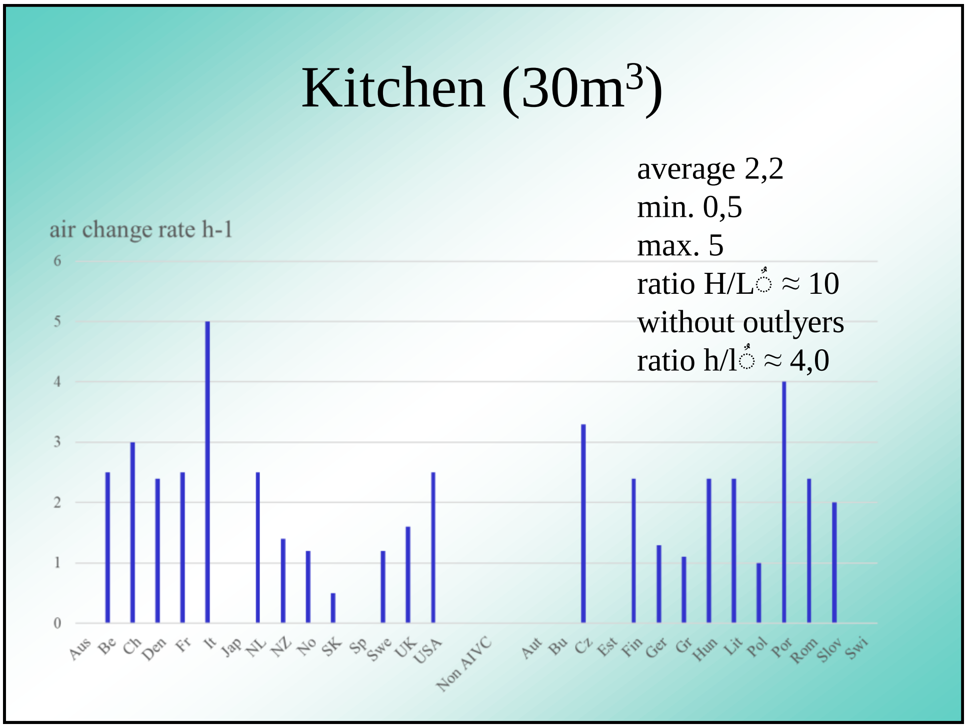


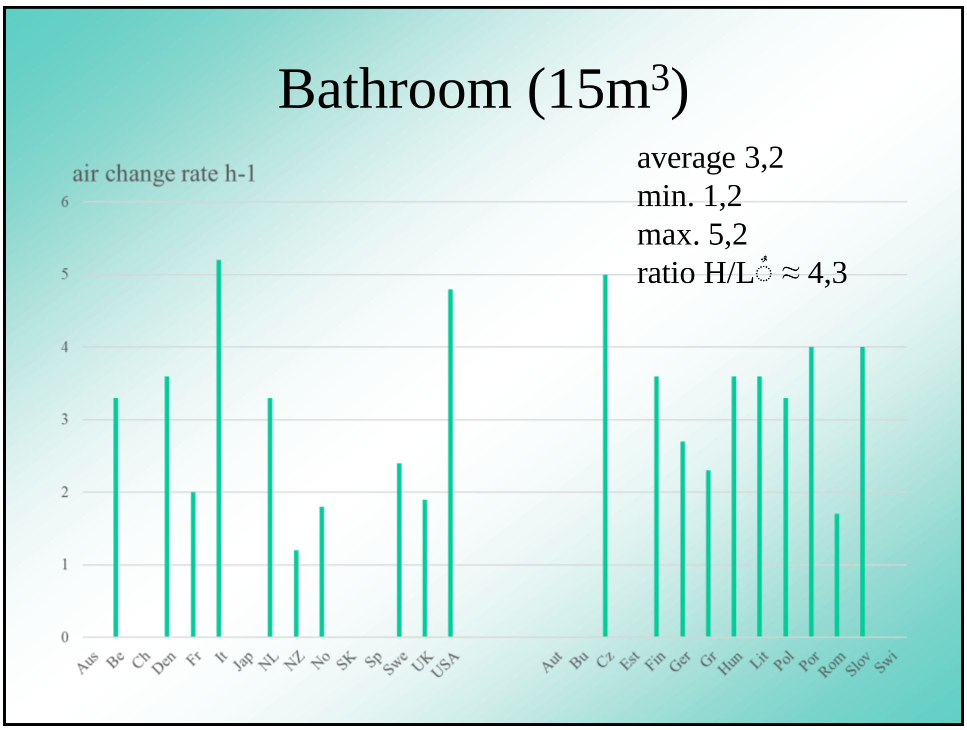
Living (6 persons)

7 dm3/s pp ≈ eq.1200 ppm CO_2

average 3,8
min. 1,7
max. 8,2
ratio H/L ≈ 4,8

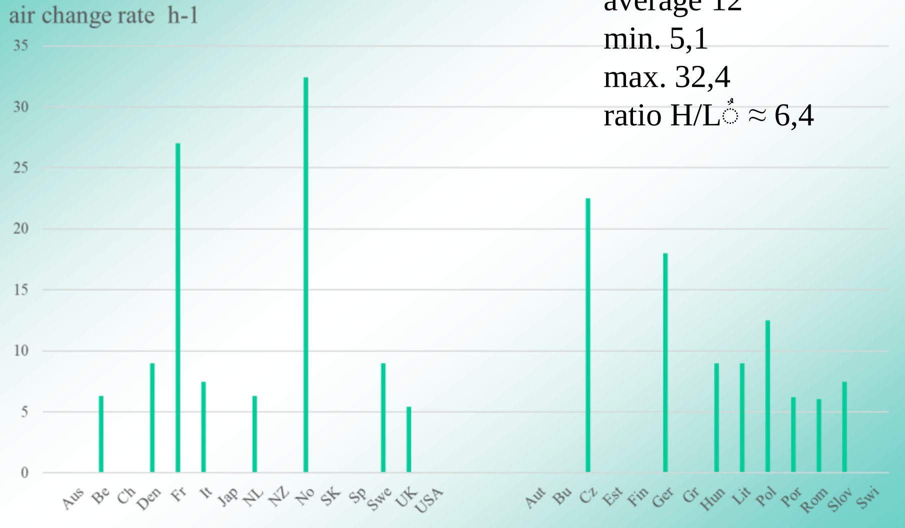



Kitchen (30m³)
average 2,2
min. 0,5
max. 5
ratio H/L ≈ 10
without outlyers
ratio h/l ≈ 4,0
air change rate h-1
6
5
4
3
2
1
0
Aus Be Ch Den Fr It Jap NL NZ No SK Sp Swe UK USA Non AIVC Aut Bu Cz Est Fin Ger Gr Hun Lit Pol Por Rom Slov Swi


Bathroom (15m³)
average 3,2
min. 1,2
max. 5,2
ratio H/L ≈ 4,3
air change rate h-1
6
5
4
3
2
1
0
Aus Be Ch Den Fr It Jap NL NZ No SK Sp Swe UK USA Aut Bu Cz Est Fin Ger Gr Hun Lit Pol Por Rom Slov Swi

Toilet (4m^3)

average 12
min. 5,1
max. 32,4
ratio H/L ≈ 6,4



Last presentation of this session

Wouter Borsboom presents
Answers
from AIVC Board members on questionnaire

Concerning
Rational behind the regulations and standards

IAQ in working environments in Belgium: alternative approaches to CO2 requirement

Samuel Caillou (BBRI), Jelle Laverge (Ugent), Peter Wouters (BBRI)
BBRI – Belgian Building Research Institute, Belgium
UGent - Ghent University, Belgium

In 2016, a new regulation for working environments came into force in Belgium, including IAQ requirement

- Context of this regulation
  - For working environments: offices, schools, etc.
  - The employer is responsible
- Previous requirement (before 2016)
  - Min 30 m³/h per **worker** in the room
- New requirement (since 2016)
  - Enough fresh air for workers in workplaces
  - **CO_2 concentration < 800 ppm (absolute value)**

→ 14 l/s.pers (50 m³/h.pers)

Problems / challenges of this new regulation

- Stricter ventilation requirement
  - 800 ppm → 14 l/s.pers (50 m³/h.pers)
  - Is this higher flow rate always necessary?
- Is CO_2 a good tracer for all indoor pollutants?
  - For persons → ok
  - What about VOC's, material emissions, etc.?
- Absolute value
  - What if outdoor concentration of 500-600 ppm (city environments)
  - CO_2 is a tracer (for persons) rather than a pollutant

Example 1 : requirement 800 ppm CO_2

- Office 15 m² / 1 person (occupation : 15 m²/person)

Office	
Flow per person	14 l/s.pers
Flow per m²	-
Total	14 l/s

- **Meeting room or school 70 m² / 20 persons (3,5 m²/pers)**

Meeting room	
Flow per person	14 l/s.pers
Flow per m²	-
Total	**280 l/s**

= 1000 m³/h!

A working group has been created

- Involving
  - Researchers, contractors, manufacturers, designers, authorities, social partners, etc.
- Objective
  - Find alternative requirement(s) with the same ambition level for IAQ

What are the basic IAQ concerns in working environments?

- Bioeffluents from persons (CO_2 is a tracer)
  - **Ventilation flow rate is needed**
- Pollutants from materials and furniture (VOC, …)
  - **Choice of low emission materials**
  - **Ventilation flow rate is needed**
- Others
  - Outdoor air pollution → filtration + globlal improvement OAQ
  - Fouling of the system → correct maintenance
  - Specific pollutants → specific solution: exhaust hoods, protection equipments, etc.

Problem of pollutants from materials and furniture

- CO_2 is not a good tracer!
- Lots of possible pollutants, from irritating to toxic or carcinogenic
- Depends on
  - Type of materials
  - Amount (surface) of materials





Approach 2: two levels of requirement depending on material emissions

- If no attention to material emissions
  - Or min flowrate of 14 l/s.pers (50 m³/h.pers)
  - Or maximum CO2 of 400 ppm above outdoor (= 800 ppm absolute)
- If low emission materials have been used
  - Or min flowrate of 7 l/s.pers (25 m³/h.pers)
  - Or maximum CO2 of 800 ppm above outdoor (= 1200 ppm absolute)

Example 2 : two levels of requirement depending on material emissions

- Office 15 m² / 1 person (occupation : 15 m²/pers)

Office	(very) low emission	Non-low emission
Flow per person	7 l/s.pers	14 l/s.pers
Flow per m²	-	-
Total	7 l/s	14 l/s

- **Meeting room or school 70 m² / 20 persons (3,5 m²/pers)**

Meeting room	(very) low emission	Non-low emission
Flow per person	7 l/s.pers	14 l/s.pers
Flow per m²	-	-
Total	**140 l/s**	**280 l/s**

→ 500 or 1000 m³/h! in function of the materials

Approach 3: the higher flowrate for the most critical pollutant (based on method 2 from FprEN16798-1:2016)

- Look at the most critical pollutant between
  - Persons
  - Material emissions

DRAFT prEN 16798-1

- The higher of these 2 flowrates
  - 7 l/s.pers (25 m³/h.pers) ← Class II in the standard
  - Flowrate per m² ← Class II in the standard

    Very low emissions: 0,35 l/s.m²
    Low emissions: 0,7 l/s.m²
    Non-low emission: 1,4 l/s.m²

Example 3 : the higher flowrate for the most critical pollutant

- Office 15 m² / 1 person (occupation : 15 m²/pers)

Office	very low emission	Non-low emission
Flow per person	7 l/s.pers	7 l/s.pers
Flow per m²	0,35 l/s.m²	1,4 l/s.m²
Total	7 l/s	**21 l/s**

- **Meeting room or school 70 m² / 20 persons (3,5 m²/pers)**

Meeting room	very low emission	Non-low emission
Flow per person	7 l/s.pers	14 l/s.pers
Flow per m²	0,35 l/s.m²	1,4 l/s.m²
Total	**140 l/s**	**140 l/s**

→ 500 m³/h! Whatever the materials

Pros and cons of the 3 approaches

Comparison Criteria	Approach 1	Approach 2	Approach 3
Expected impact on real IAQ	In theory high but difficult applicability in practice	High and better applicability expected	High and better applicability expected
Incentives for better source control	No	Yes, roughly	Yes, case to case
Incentives for better ventilation system	Yes but high flow rate	Yes, flow rate depends on emissions, but sometimes high flow rate (meeting room)	Yes, flow rate depends on emissions
Ease of conformity control	Easy: CO2 meting	Easy for CO2 meting + need framework for emissions	Flow meting more difficult but CO2 also meting possible + need framework for emissions
Ease of design and installation	Easy to calculate	Easy to calculate flow rates + need framework for emissions	Easy to calculate flow rates + need framework for emissions
Economic impact (for new building)	Very high (higher flow rates)	Choice between effort on materials or flow rates	Choice between effort on materials or flow rates
Applicability for existing buildings	Difficult (higher flow rates)	Ok if low emission, but sometimes high flow rate (high emission + meeting room)	Ok, flow rate depends on emissions

Pros and cons of the 3 approaches

Comparison Criteria	Approach 1 800 ppm	Approach 2 2 levels	Approach 3 Most critical pollutant
Expected impact on real IAQ	In theory high but difficult applicability in practice	High and better applicability expected	High and better applicability expected
Incentives for better source control	No	Yes, roughly	Yes, case to case
Incentives for better ventilation system	Yes but high flow rate	Yes, flow rate depends on emissions, but sometimes high flow rate (meeting room)	Yes, flow rate depends on emissions
Ease of conformity control	Easy: CO2 meting	Easy for CO2 meting + need framework for emissions	Flow meting more difficult but CO2 also meting possible + need framework for emissions
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Applicability for existing buildings	Difficult (higher flow rates)	Ok if low emission, but sometimes high flow rate (high emission + meeting room)	Ok, flow rate depends on emissions

How to define low emission materials?

- Need robust compliance framework

- Proposition for today
  - Based on the existing regulation in Belgium for floor materials only
  - Maximum emission levels for more than 160 pollutants
- Update in the future
  - Future regulation in Belgium for paintings?
  - Future framework/regulation for furniture?

Thank you for your attention

Samuel Caillou (BBRI), Jelle Laverge (Ugent), Peter Wouters (BBRI)
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UGent - Ghent University, Belgium

How should we characterize emissions, transport, and the resulting exposure to SVOCs in the indoor environment?

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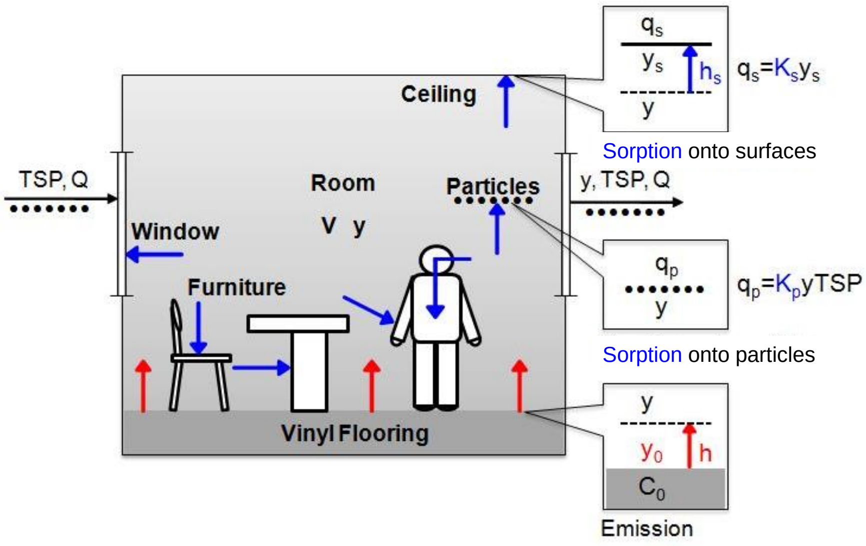
1 VOCs and SVOCs are important indoor pollutants

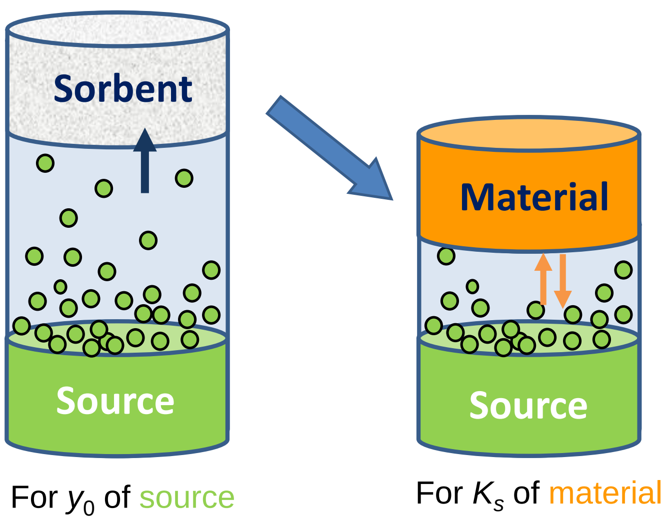



- **Volatile organic compounds (VOCs)**
  - Vapor pressure ≥10 Pa at 20 ºC
  - Examples: formaldehyde, benzene, butanol, etc.
  - Sources: paints, adhesives, carpets, pressed-wood products, floorings, etc.
  - Effects: reduced worker productivity, eye and respiratory irritations, headaches, fatigue, asthmatic symptoms, and cancers
- **Semivolatile organic compounds (SVOCs)**
  - Vapor pressure in range of 10^{-9} to 10 Pa
  - Examples: phthalate plasticizers, brominated flame retardants, and organophosphate pesticides
  - Sources: polyvinyl chloride (PVC) products, lotions, nail polish, cling film, shampoo, computers, televisions, foams, shower curtains, etc.
  - Effects: endocrine disrupting to neurodevelopment and reproductive development

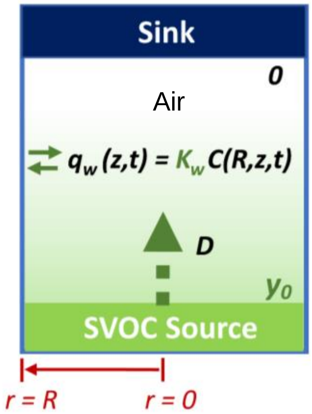
1 SVOCs – Emissions, transport, and exposure



2 Measuring parameters – Diffusion sampler method for y_0 and K_s



2 Diffusion sampler method – Model



- **Governing equation:**

$$\frac{\partial C(r,z,t)}{\partial t} = \frac{1}{r}\frac{\partial}{\partial r}\left(rD\frac{\partial C(r,z,t)}{\partial r}\right) + D\frac{\partial^2 C(r,z,t)}{\partial z^2}$$

- **Boundary condition:**

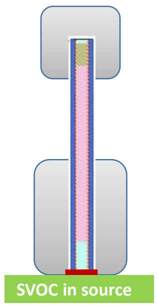
  Surface of emission source

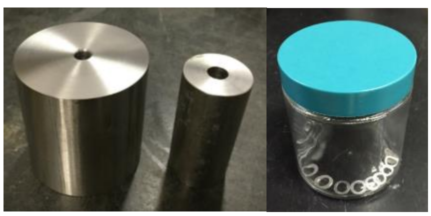
  Surface of sink (sorbent)

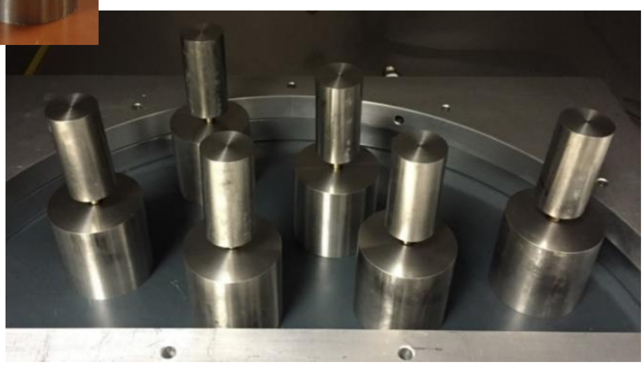
  Tube surface

Mass collected vs. Sampling period!

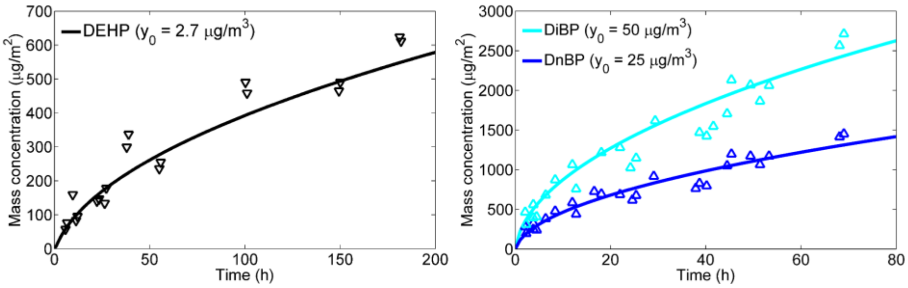
2 Diffusion sampler method – Measuring y_0





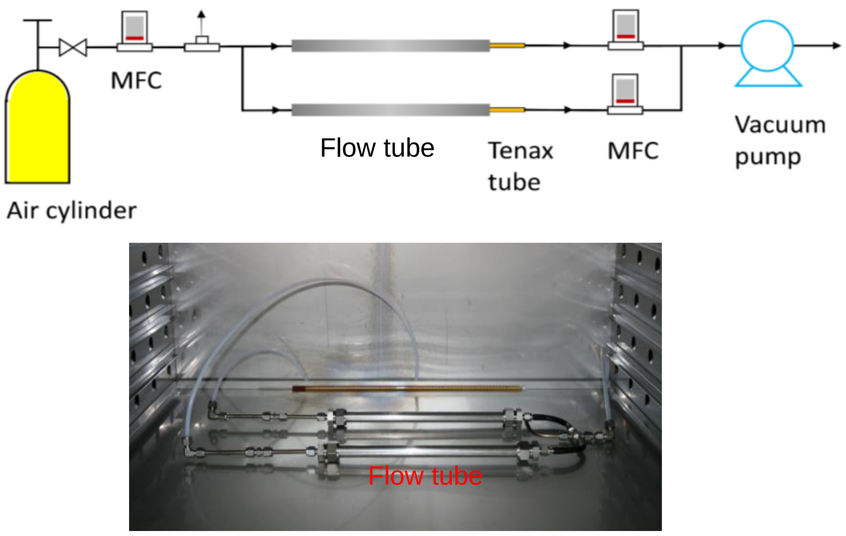


2 Diffusion sampler method – Measuring y_0

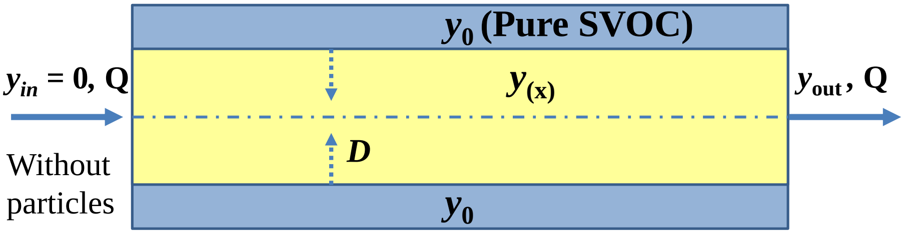


DEHP **DiBP and DnBP**

3 Measuring parameters – Flow tube method for V_p and K_p

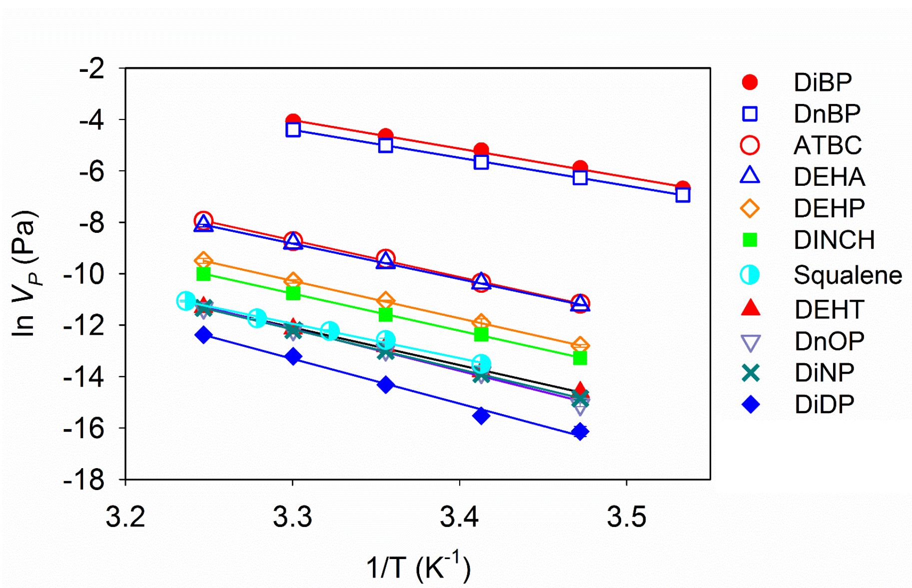


3 Flow tube method – Measuring V_p

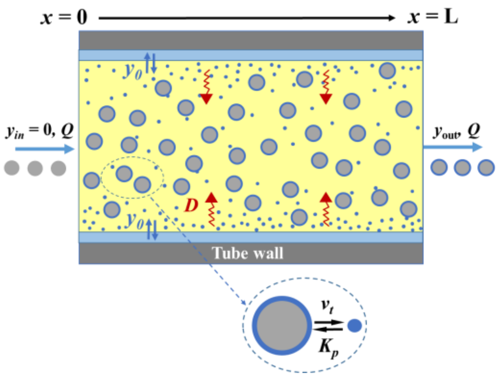


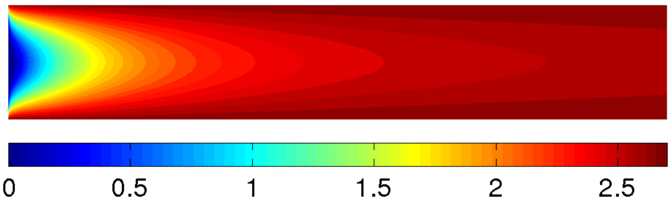
$y_{out} = V_p$

3 Flow tube method – Measuring V_p



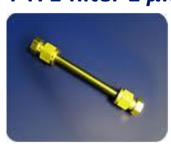
3 Flow tube method – Measuring K_p



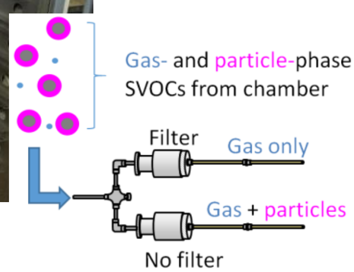


3 Flow tube method – Measuring K_p

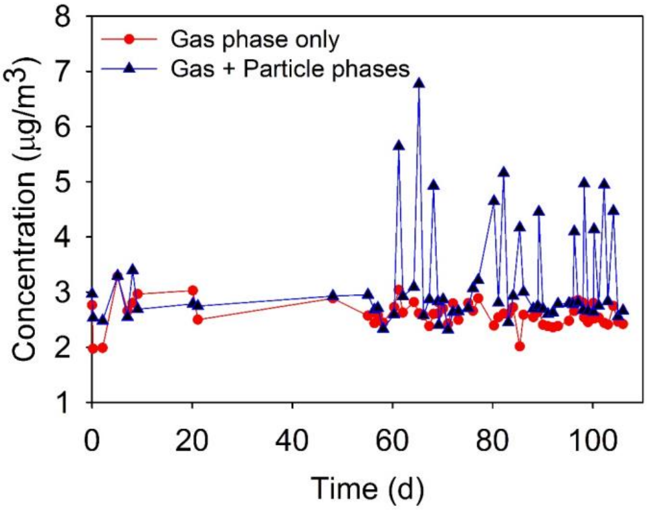
Particle capturing PTFE filter 1 μm



Tenax tube



3 Flow tube method – Measuring K_p (DEHP)



$$K_p = \frac{q_p}{y \cdot A_p}$$

K_p = 300 ± 60 m

4 Estimating steady-state, gas-phase concentration of SVOCs

Steady-state mass balance on SVOC in room

$$h \times (y_0 - y) \times A = Q \times y + Q \times (K_p \times TSP \times y)$$

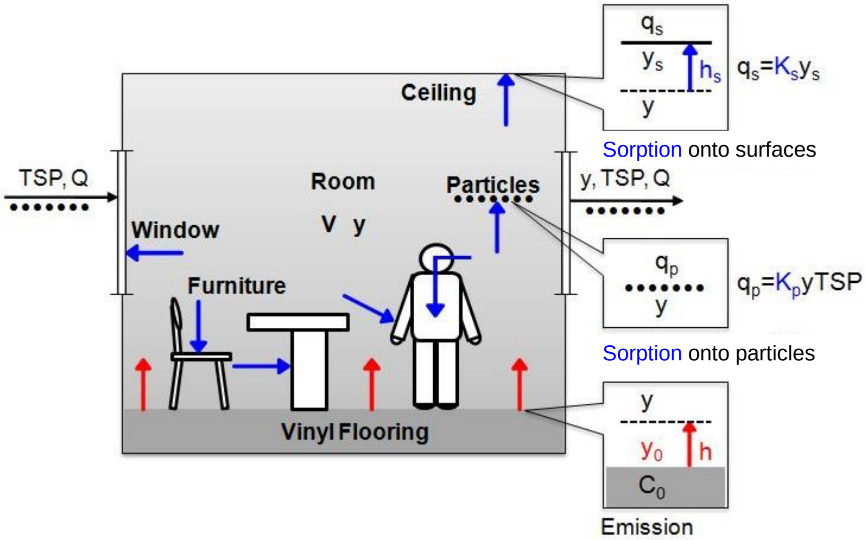
Gas-phase concentration is given by

$$y = \frac{h \times y_0 \times A}{h \times A + Q^*}$$

where

$$Q^* = (1 + K_p \times TSP) \times Q$$

1 SVOCs – Emissions, transport, and exposure



4 Estimating exposure to SVOCs

Exposure pathway	Equation
Inhalation (air)	$y \times InhR \times ED$
Inhalation (particles)	$y \times K_p \times TSP \times InhR \times ED$
Ingestion (dust)	$y \times K_{dust} \times IngR$
Dermal sorption (from air)	$(y \times k_{p\_g} \times SA \times f_{SA} \times ED)/BW$
Total	

4 Particle + dust partition coefficients + skin permeability

Parameter	Units	Equation
Particle/air partition coefficient (K_p)	$m^3/\mu g$	$K_p = f_{om\_part} \times K_{oa}/\rho_{part}$
Dust/air partition coefficient (K_{dust})	m^3/mg	$K_{dust} = f_{om\_dust} \times K_{oa}/\rho_{dust}$
Permeability through stratum corneum (k_{p_cw})	cm/s	$\log(k_{p\_cw}) = 0.7 \log(K_{ow}) - 0.0722\, MW^{2/3} - 5.252$
Ratio of stratum corneum to viable epidermis (B)	-	$B = [k_{p\_cw} \times (MW)^{2/3}]/2.6$
Permeability through stratum corneum/viable epidermis (k_{p_w})	cm/s	$k_{p\_w} = k_{p\_cw}/(1+B)$
Permeability from skin surface to dermal capillaries (k_{p_b})	cm/s	$k_{p\_b} = k_{p\_w} \times K_{wa}$
Overall permeability from bulk air to dermal capillaries (k_{p_g})	m/d	$k_{p\_g} = [(1/v_d) + (1/k_{p\_b})]^{-1} \times 864$

4 Exposure parameters for 3-year old child

Parameter	Child	Units
Inhalation rate (*InhR*)	0.64	$(m^3/kg)/d$
Dust ingestion rate (*IngR*)	4.3	(mg/kg)/d
Skin surface area (*SA*)	0.61	m^2
Fraction skin exposed (f_{SA})	1	(-)
Exposure duration (*ED*)	0.91	(-)
Body weight (*BW*)	13.8	kg

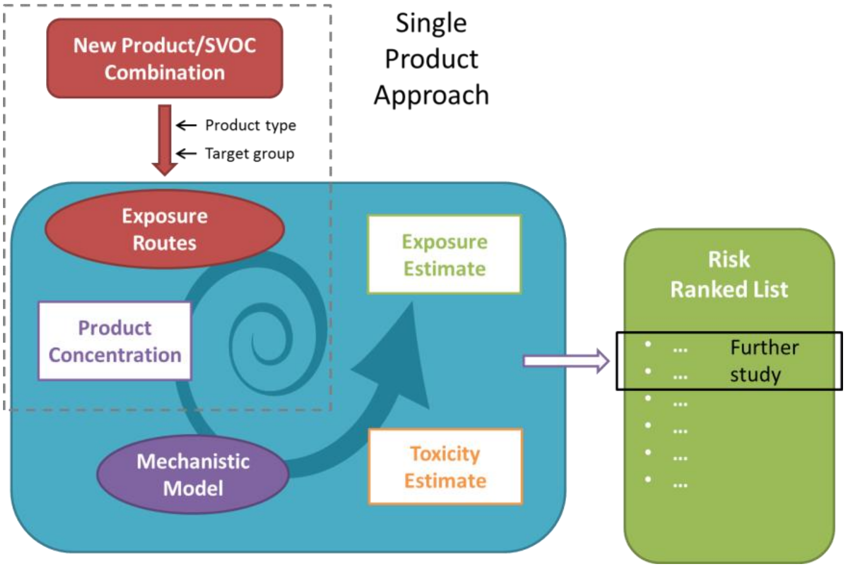
4 Estimating exposure to SVOCs in various products

Exposure pathway	DEHP (μg/kg)/d	DnBP (μg/kg)/d	BDE-47 (μg/kg)/d	Chlorpyrifos (μg/kg)/d
Inhalation (air)	0.12	0.34	1.4×10^{-4}	0.32
Inhalation (particles)	0.57	0.02	3.5×10^{-5}	0.01
Ingestion (dust)	18	1.6	3.2×10^{-3}	0.59
Dermal sorption (from air)	1.1	2.7	1.0×10^{-5}	0.23
Total	20	4.6	3.5×10^{-3}	1.15

5 Conclusions – Emissions, transport, exposure, and risk

- To make rapid exposure estimates for SVOCs:
  - Need critical parameters such as y_0, K_p, K_{dust}, and K_{skin}
- Must evaluate materials and products to make sure that emissions of SVOCs are consistent with assumed mechanisms
- Rapid estimates of exposure can be combined with quick estimates of toxicity (generated, for example, by ToxCast™) for risk-based prioritization

5 Conclusions – Emissions, transport, exposure, and risk



Problems measuring $PM_{2.5}$ concentrations

Dr Benjamin Jones
Assistant Professor
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Outline

- Health based standards
- Locations
- Devices
- Measurements
- Problems

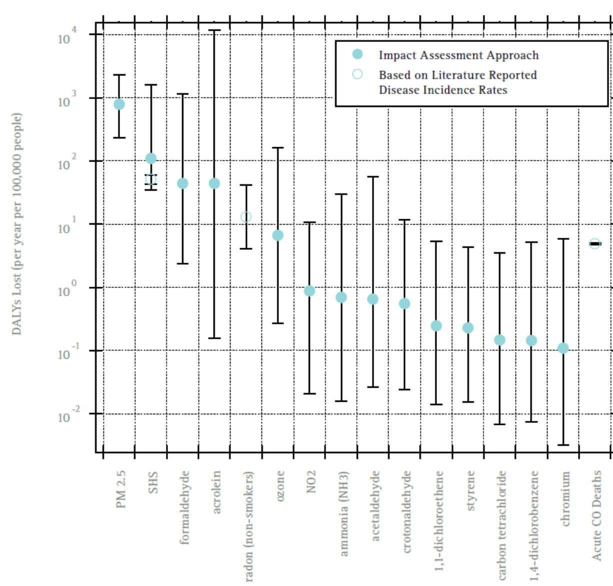
The Air Quality Team






TNO innovation for life

Why the focus on $PM_{2.5}$?



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Standards and Norms

new and health based

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Health based standards and norms

…that might use $PM_{2.5}$ as a metric

1. Ratings systems
2. Sub-indices
3. Exposure limit values
4. Health adjusted life years

All need *in-situ* measurement of $PM_{2.5}$ concentrations

(As discussed by AIVC Workshop on IAQ Metrics in 2017)

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Locations

of test environments

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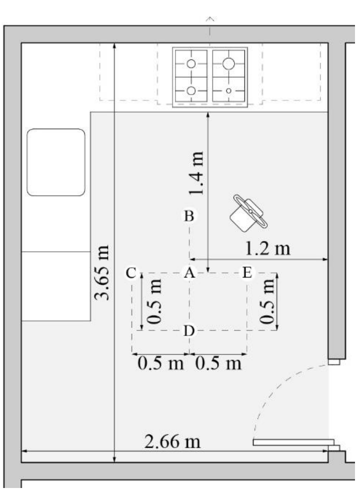
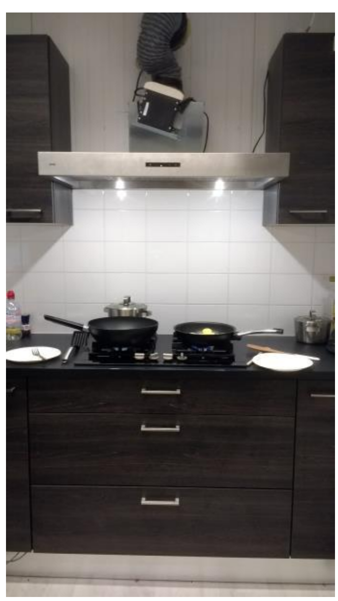
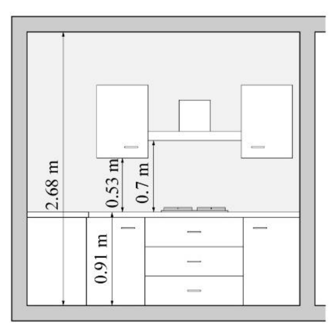
Location 1: indoor chamber







Location 2: outdoor chamber

Location 3: domestic kitchen

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Devices

for diagnostics

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Devices: Gravimetric and optical; integrating and temporal.

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Measurements

of $PM_{2.5}$ concentrations

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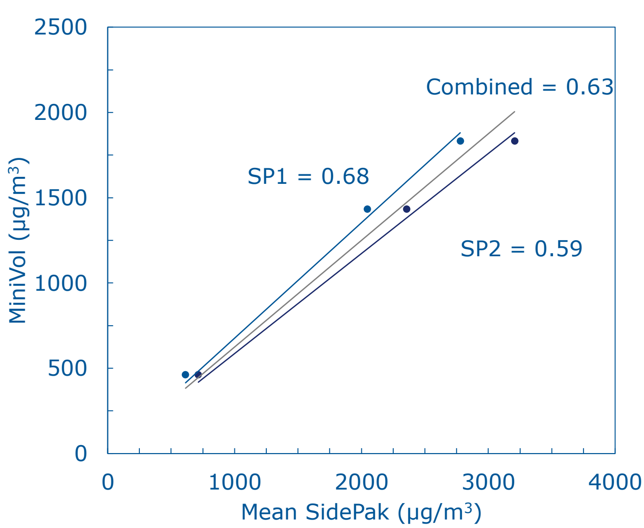
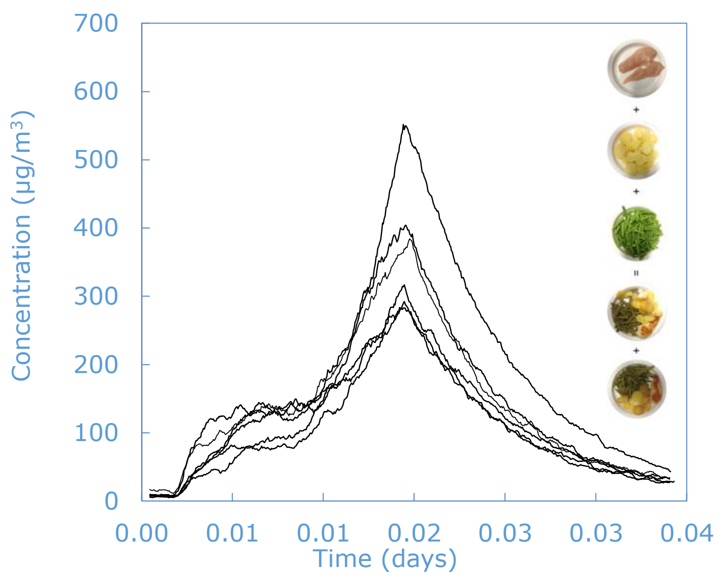
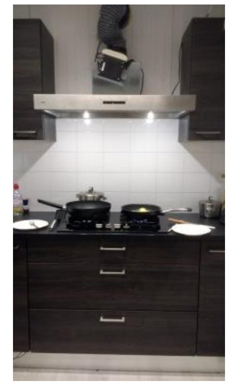
Gravimetric Sampling (Toast)

x2

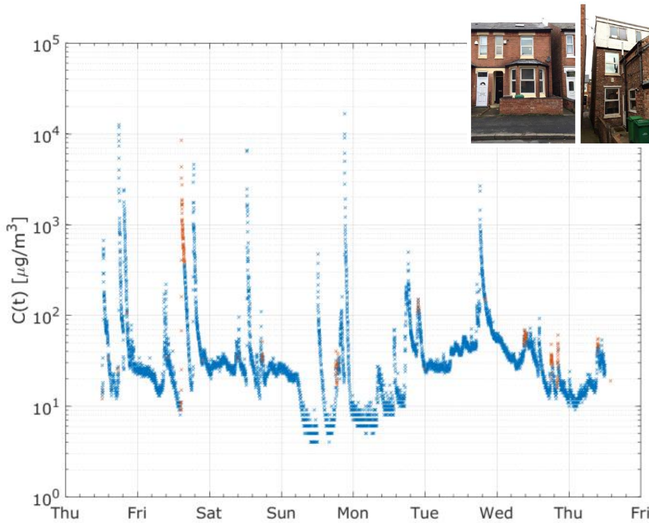


Temporal Changes: Repeatability

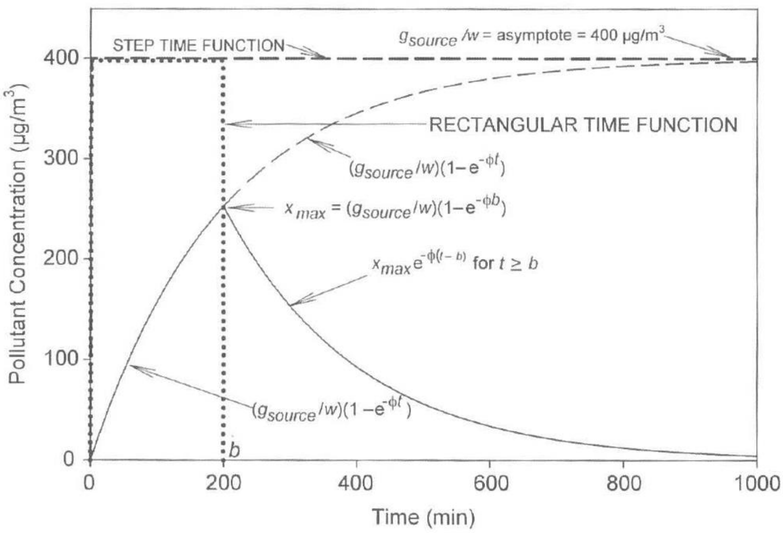




Temporal Changes: Confounding (RH>70%)

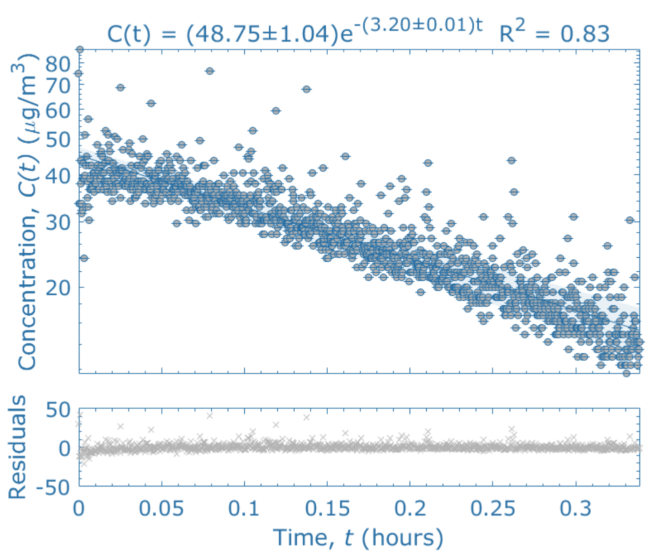


Expected concentration for steady conditions

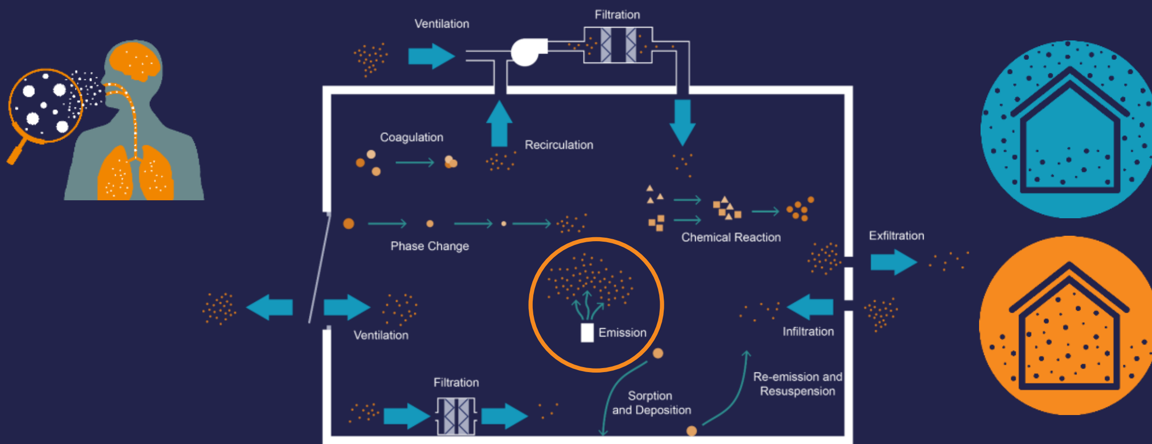


Ott WR, Steinemann AC, Wallace LA. Exposure Analysis: CRC Press; 2006.

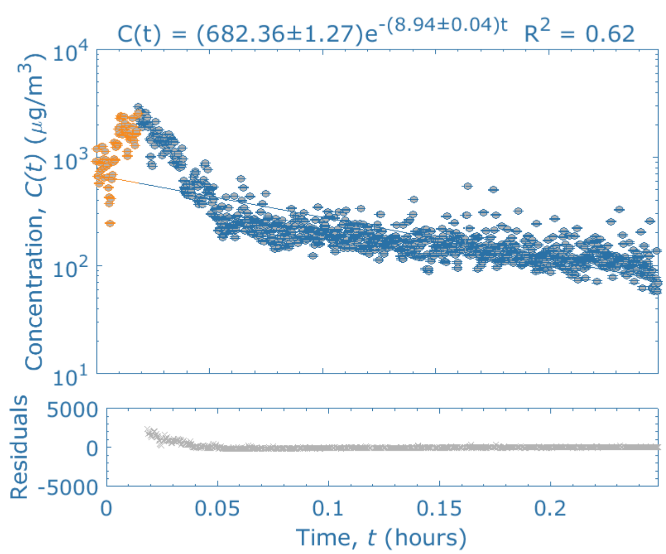
Pure dilution



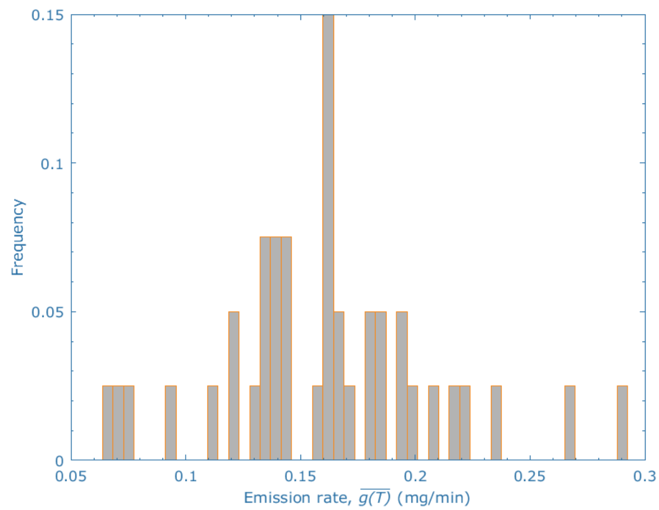
Pollutant behaviour



Variable dilution: deodorant



Distributions of emission rates



39 measurements

Diagnostic Techniques

for measuring $PM_{2.5}$ concentrations

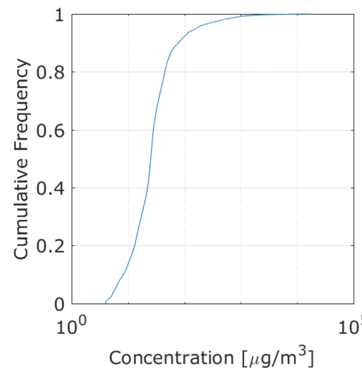
A probabilistic problem

1. WHO recommends average concentration breathed
   - 25µg/m³ per day 10µg/m³ per year
2. U.S. National Ambient AQ Standards require:
   - 35µg/m³ per day 12µg/m³ per year
3. WELL Buildings Institute require:
   - Threshold of 15µg/m³ measured once per hour with device with resolution of ≤10µg/m³

How to comply?

Consider:

- Measurement location
- Measurement uncertainty and data presentation
- Sampling and reporting frequencies
- Time weighting



Reference and Equivalence

- It's not simple
- UK Air Quality Directive accepts ±25% uncertainty for $PM_{2.5}$ and ±15% for other contaminants
- Outdoor measurements since 1987
- UK Gravimetric sampler must follow the *Reference Method* (EN 12341:2014)
- In the US the same procedures are enshrined in federal regulation
- Real time measurements must show *Equivalence* with the *Reference Method* (EN 16450:2017)
- Standard calibration: NIST latex spheres or Arizona dust (ISO 12103-1:2016)?
- Without these diagnostic considerations, a measurement is scientifically meaningless, although it may get you a gold star!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RATIONAL BEHIND VENTILATION AND REGULATIONS

Wouter Borsboom, Willem de Gids

innovation for life

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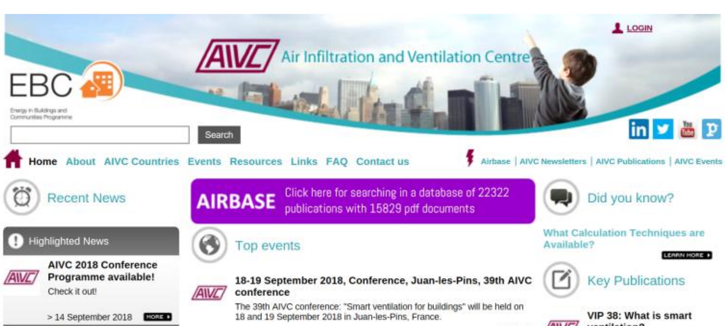
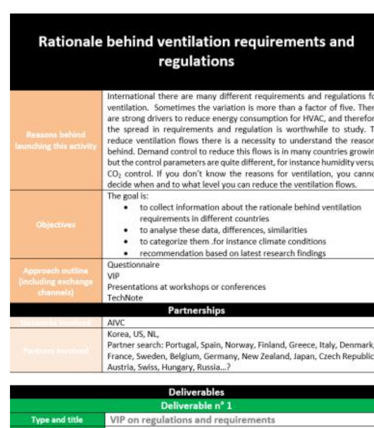
innovation for life

AIVC PROJECT





Rationale behind ventilation requirements and regulations	
Reasons behind launching this activity	International there are many different requirements and regulations for ventilation. Sometimes the variation is more than a factor of five. There are strong drivers to reduce energy consumption for HVAC, and therefore the spread in requirements and regulation is worthwhile to study. To reduce ventilation flows there is a necessity to understand the reasons behind. Demand control to reduce this flows is in many countries growing but the control parameters are quite different, for instance humidity versus CO_2 control. If you don't know the reasons for ventilation, you cannot decide when and to what level you can reduce the ventilation flows.
Objectives	The goal is: • to collect information about the rationale behind ventilation requirements in different countries • to analyse these data, differences, similarities • to categorize them .for instance climate conditions • recommendation based on latest research findings
Approach outline (including exchange channels)	Questionnaire VIP Presentations at workshops or conferences TechNote
Partnerships	
	AIVC
	Korea, US, NL, Partner search: Portugal, Spain, Norway, Finland, Greece, Italy, Denmark, France, Sweden, Belgium, Germany, New Zealand, Japan, Czech Republic, Austria, Swiss, Hungary, Russia...?
Deliverables	
Deliverable n° 1	
Type and title	VIP on regulations and requirements
Leaders	TNO, VentGuide

FROM EXPOSURE TO PROVISIONS

Exposure (concentration * time)		ppmh
Concentration		ppm

Flowrate	per person	
	per m2	
	expressed in	dm3/s or m3/h

Air change rate	h-1

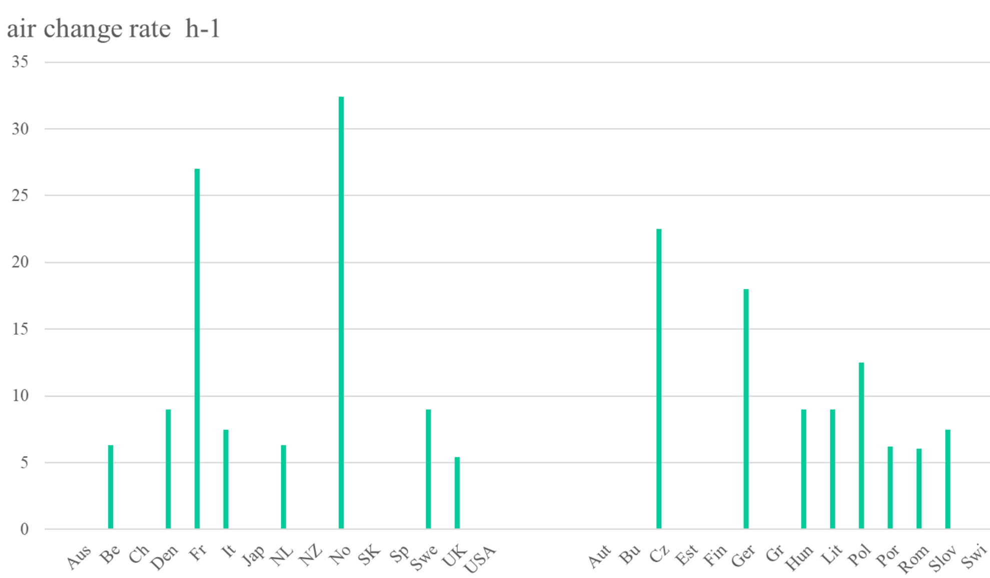
Provisions	openings floor area
	supply
	exhaust
	range hood

TOILETS

REPORTED RATIONAL OF AIVC COUNTRIES TOILETS

- Extraction of odours
- Smell
- Preventing of spreading of odours
- Humidity of human activities
- Humidity control close to the main source
- Dilution of contaminants of human activities

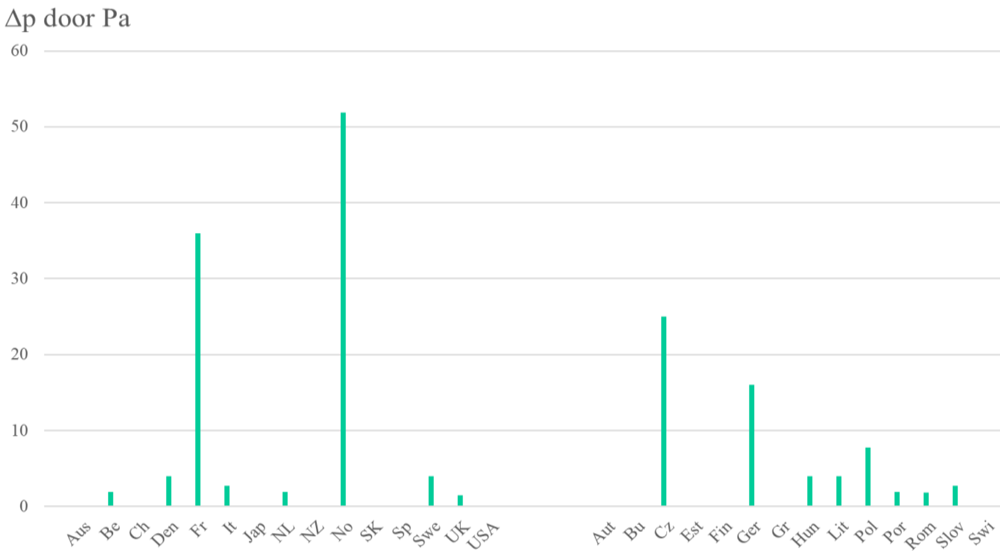
(MINIMUM) AIR CHANGE RATES



POSSIBLE PHILOSOPHIES TOILET

- **Odour control**
- **Preventing spreading of odours**
- Ventilation of 1 persons?
- Local exhaust?
- Humidity control?

PRESSURE DIFFERENCE TOILET / HALLWAY



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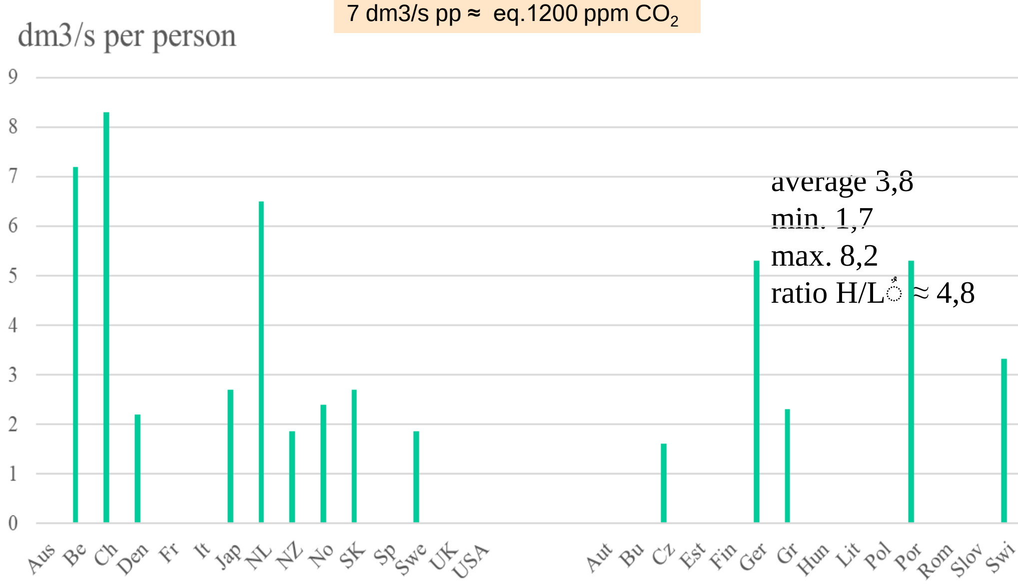
LIVING

REPORTED RATIONAL OF AIVC COUNTRIES, LIVING

- Human occupation, bio-effluents
- Human activities (bio-effluents, washing, showering, dishes, cooking)
- Dilutions of pollutants/contaminants
- Formaldehyde concentration and time
- Cooking fumes, combustion products
- Bacteria, viruses
- Solve sick house
- Radon (radioactive gasses)

LIVING (6 PERSONS)

7 dm3/s pp ≈ eq.1200 ppm CO_2



POSSIBLE PHILOSOPHIES LIVING

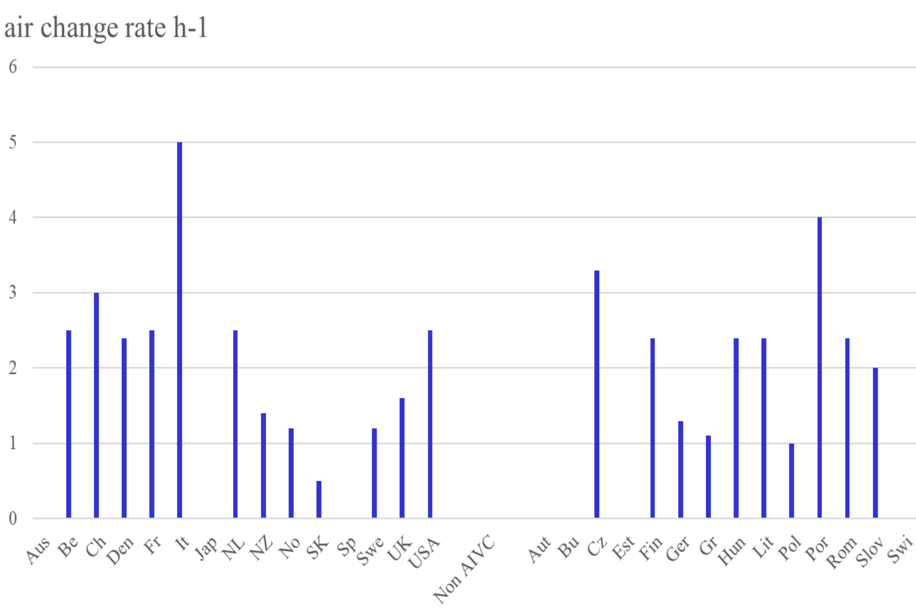
- **Dilution of contaminates from occupants (odour)**
- Still need for ventilation for emission of building materials?
- Moisture, humidity control?
- Radon?

KITCHEN

REPORTED RATIONAL OF AIVC COUNTRIES KITCHEN

- Odour, smell
- Control humidity (close to the main source)
- Cooking pollutants extraction
- CO
- Moisture from loundry and washing
- Ventilation to solve sick house problem

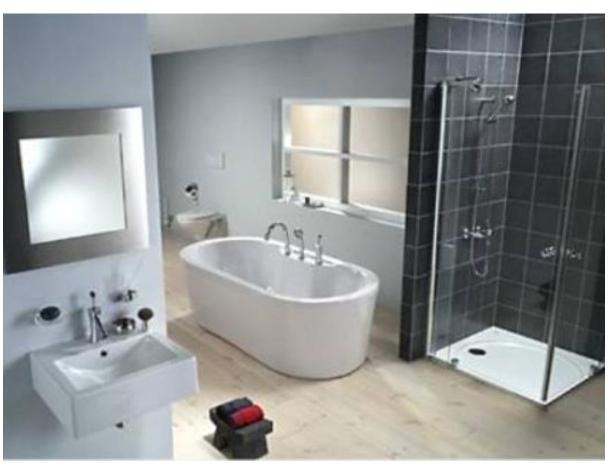
(MINIMUM) AIR CHANGE RATES KITCHEN



POSSIBLE PHILOSOPHIES KITCHEN

- **Main activities in the kitchen is cooking**
- **Exhaust from the cooking products!**
- Still a need for moisture control?
- Still a need for dilution of other pollutants?

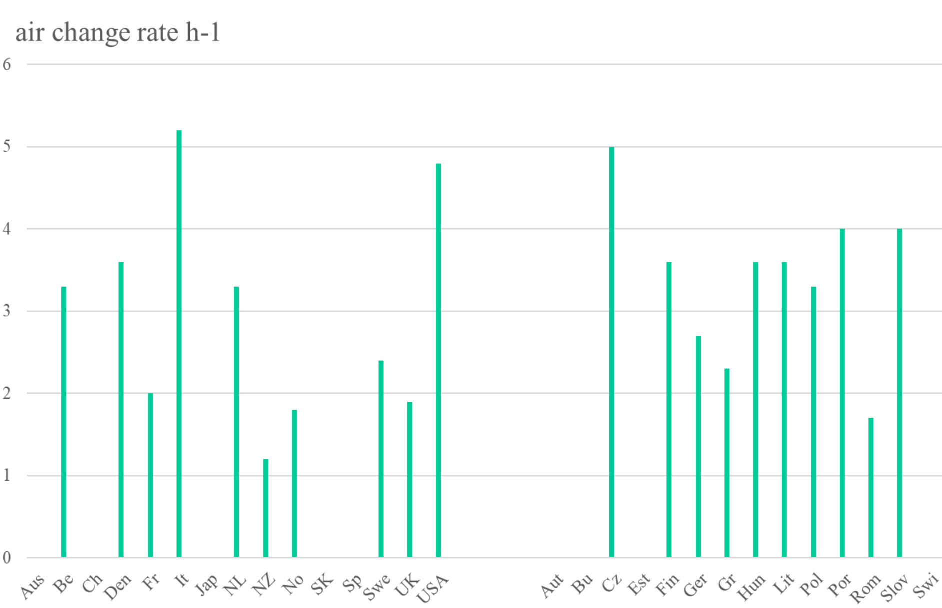
BATHROOM



REPORTED RATIONAL OF AIVC COUNTRIES BATHROOMS

- Humidity control from human activities
- Humidity control close to the main source
- Dilution of contaminants from human activities
- Odour

(MINIMUM) AIR CHANGE RATES



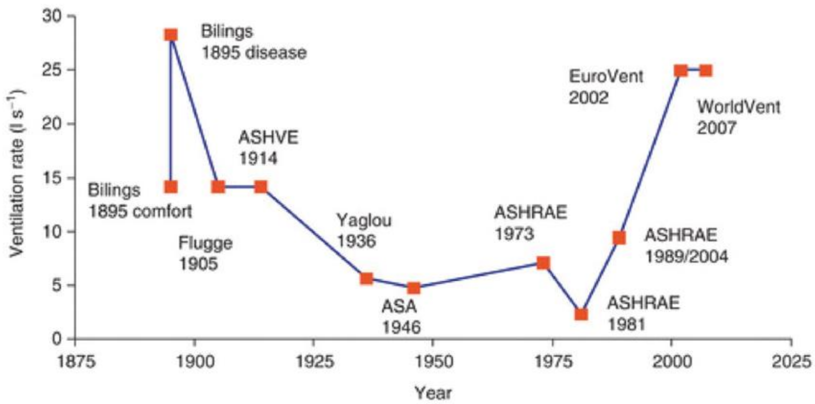
POSSIBLE PHILOSOPHIES BATHROOM

- Production approx. 1 g/s showering
- After 3-5 minutes, saturation of water vapour in the air, normal ventilation rate (20-50 dm3/s)
- Tiles on the wall condensation, ceiling plasterwork absorption
- Air humidity control should not be the priority but time to dry out the plasterwork and tile joints

POSSIBLE PHILOSOPHIES BATHROOM

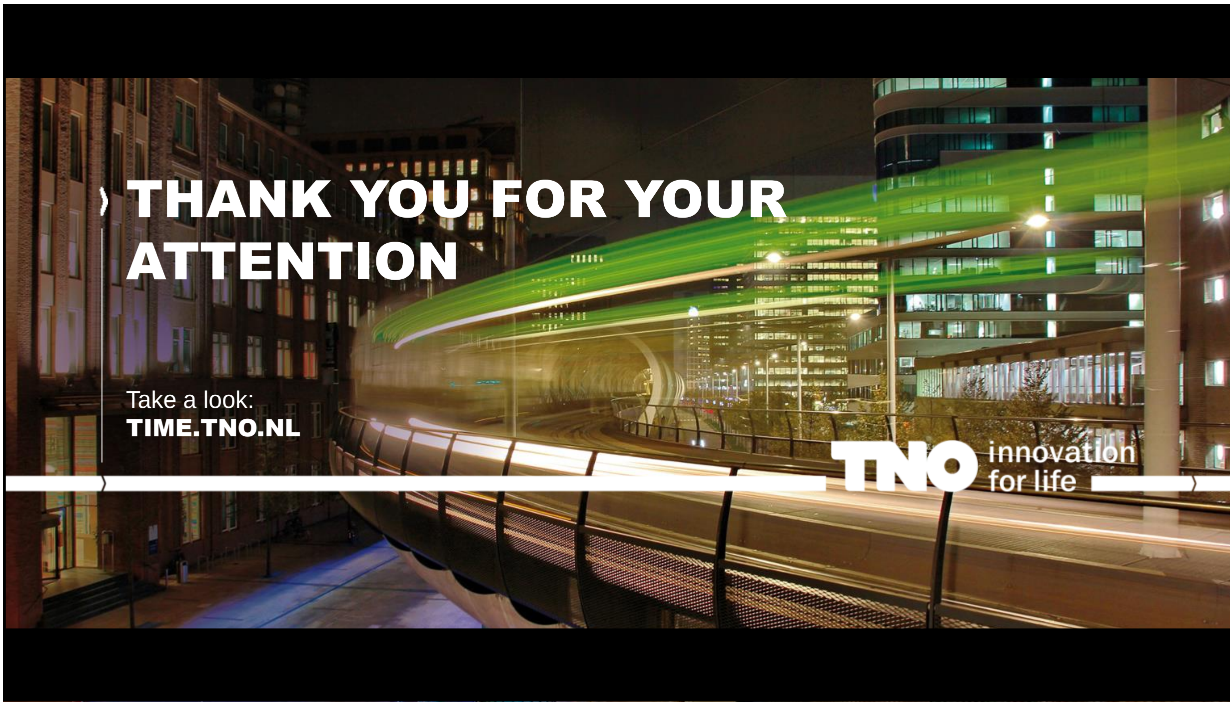
- **Control of humidity**
- Local exhaust, enclosure or room control?
- Still need for odour control?
- Still need for control of other pollutants?

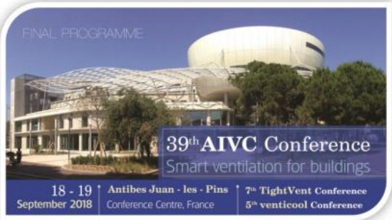
VARIATION OF VENTILATION REQUIREMENTS PER PERSONS IN TIME



OBSERVATION & CONCLUSIONS

- It seems that:
  - experts studied literature and made best guesses for the ventilation levels
  - No solid scientific reports are found as background
- New studies show a need for other solutions for cooking fumes (PM, NOx)
- **Can AIVC play a role in an more universal approach for ventilation requirements based on exposure, taking into account national circumstances?**
- **We think we can**


THANK YOU FOR YOUR ATTENTION
Take a look:
TIME.TNO.NL
TNO innovation for life



18-sept-2018

Noise Radiated by Circular Ventilation Ducts

François BESSAC
CETIAT

CETIAT
ensemble, innover et valider

Context

Noise remains a major concern for occupants of buildings or dwellings

Ventilation is one of the main source of noise for occupants

- Noise usually comes from air inlets / outlets in the room
  - Can be assessed by acoustic calculations from source (fan) to end diffusers
  - Calculation done for airborne noise <u>inside</u> ductwork

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Context & objectives

Ventilation ducts convey noise
➔ this noise can pass through the duct walls to radiate in the rooms

Sound <u>insulation</u> of ventilation ducts ?
ability to resist to the transmission of sound from inside to outside

No standard
Almost no data
Low knowledge

➔

Measurements
Comparison

Ducts under test

Rigid ducts

- Spiral galvanized steel (simple / double layer)
- Expanded PolyEthylene EPE
- Polystyrene PS

Flexible ducts

- PVC film round spiral
- Aluminium/PVC film round spiral
  - Thermally or acoustically insulated

Semi-rigid duct

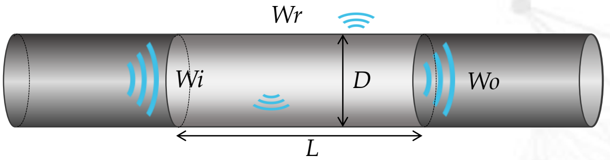
- Plastic, externally corrugated

Metric for Sound Insulation of Ducts

Breakout (TL): sound insulation for rigid duct

- Intrinsic characteristic of the duct
- Related to Sound intensity : incoming / radiated

$$TL = 10\,log\left(\frac{Wi/Ai}{Wr/Ar}\right)$$



Incoming
- *Sound power Wi*
- *Area Ai =* $\pi D^2/4$

Radiated
- *Sound power Wr*
- *Area Ar =* πDL

$$TL = L_{wi} - L_{wr} + 10log\left(\frac{A_r}{A_i}\right)$$

Used for the measurement, taking into account the areas A_r and A_i

Hypothesis: incoming sound power remains constant over the length of the duct under test

Measurement principle

Double reverberant room

Plenum

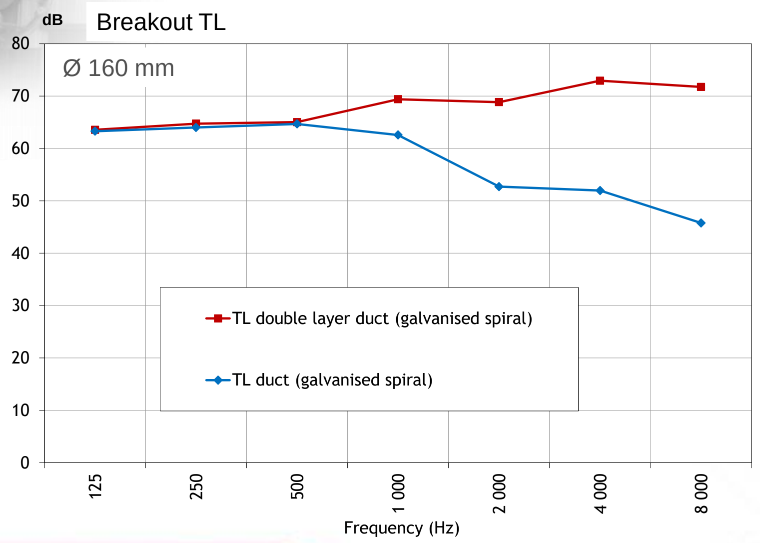
Measurement of:

L_{wi}: incoming Lw

L_{wr}: radiated Lw

Some issues
- Short duct in test → low radiated W_r
- Long duct
  → may include losses by the junctions
  → internal losses
- Small diameters → difficult to measure incoming W_i

Experimental result - Rigid duct



Galvanised spiral duct

Simple / doubler layer

- High performance
- Same sound insulation for low frequencies

Double layer duct

- Better for high frequencies
- External and internal ducts are decoupled

Flexible PVC film spiral duct

General:

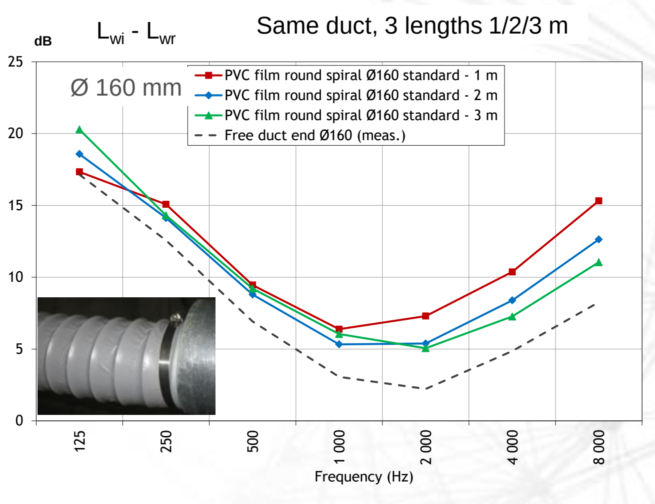
- Very low attenuation! As if the duct were transparent
- Only ~ 5/7 dB at 1000/2000 Hz

High freq.

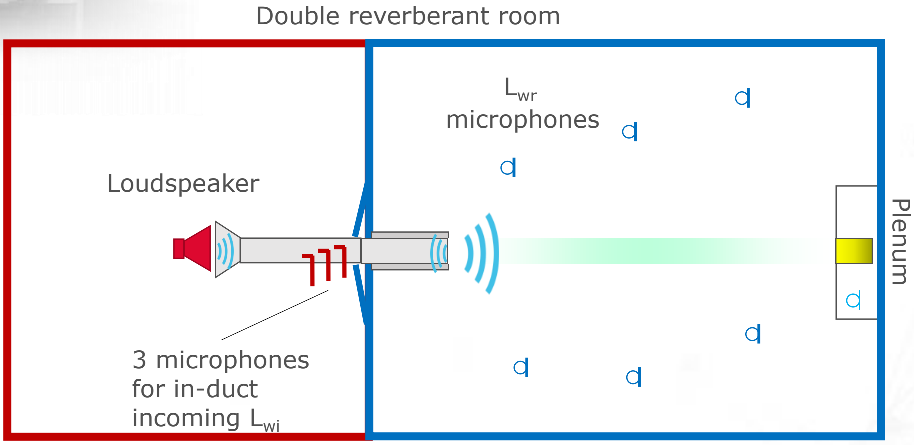
- Better result for shorter duct sample (less radiated area)

Low freq.

- Same result whatever the length
- Negative slope: not due to the duct but to the acoustic impedance disruption of the end of **free duct**



Free end configuration

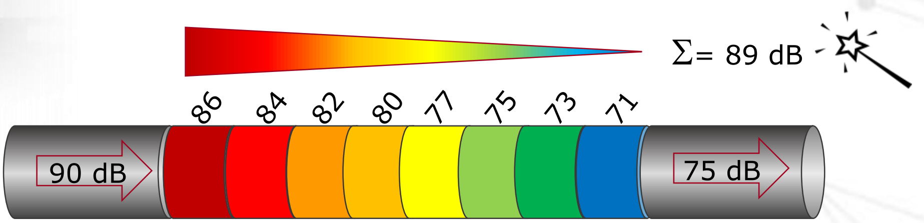


For free opening duct

- At low frequencies, the acoustic impedance disruption of the free open creates reflexions

  A large part of acoustic waves is reflected and does not radiate into the room

Physics for low insulation duct



Low insulation: a large part of acoustic energy passes through the duct

- The avalaible in-duct sound quickly decreases
  - not by absorption but by transmission losses
- **The first decimeters** are the more contributing to radiated noise

Meaningful metrics: Raw Insertion Loss RIL= L_{wi} - L_{wr}

- Unrelated to the length or sections …

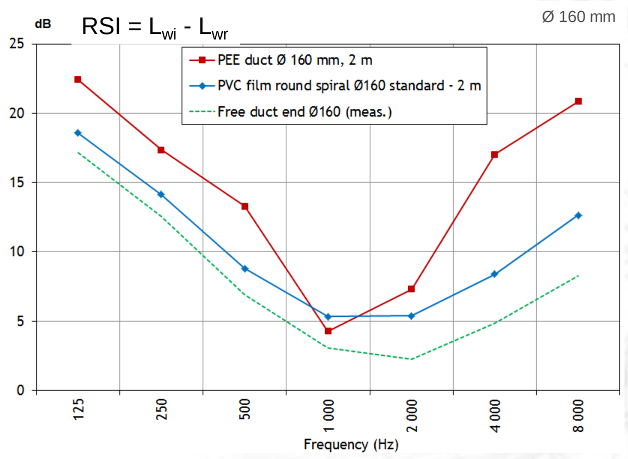
PEE vs PVC film duct

PVC film round spiral

- Very low insulation
  - slightly better than the free open duct

EPE duct

- Slightly better than PVC film duct
- Except at 1000 Hz … **as if there were no duct**



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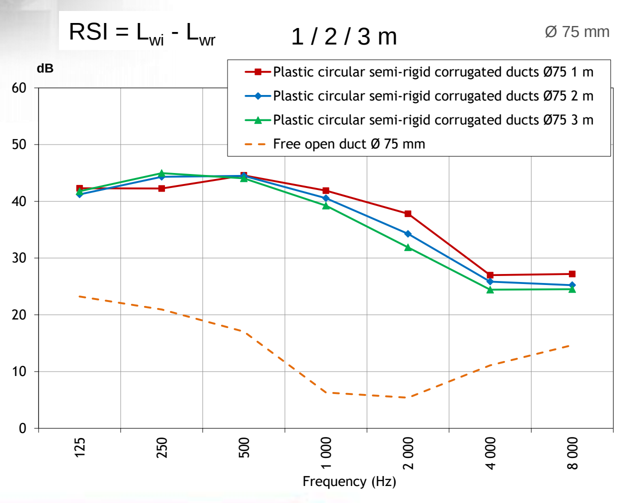
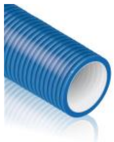
Plastic semi-rigid corrugated duct





High insulation at low frequencies

- Because the duct is very rigid : perfectly circular shape + siffness of the corrugation
- Smaller diameter

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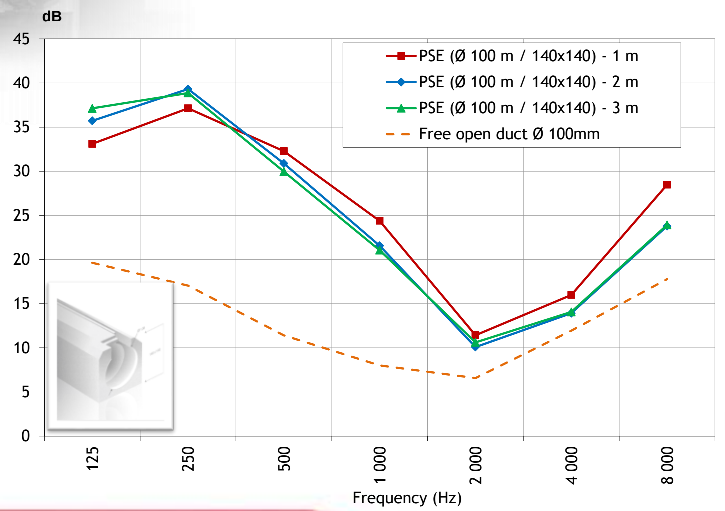
Expanded polystyrene 140x140 Ø100 mm



Good insulation at low frequencies

- Due to the stiffness of the external square shape of the duct

Quite transparent at high frequencies

- Very light material

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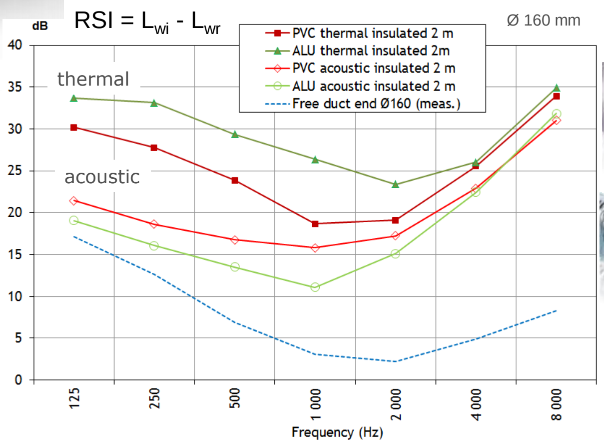
Acoustical vs thermal insulation



Soft ducts, double layer + insulation

2 manufacturers

- Alu
- PVC
- Thermal OR acoustical insulation

Results for sound insulation

- Thermal duct better than acoustic
- Acoustic duct has perforated inner layer … sound passes through more easily: less good insulation
- For insertion loss (use as silencer), results are the opposite

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Conclusions

Sound radiated by ducts is usually neglected

- Sound insulation performance of ventilation duct is not known

Tests on various ventilation ducts

- Rigid circular galvanised ducts have high performance
- Several flexible ducts (PVC film, EPE) can be very transparent, **as if there were no duct!**
- The rigid shape (plastic corrugated duct or polystyrene) improve sound insulation at low frequencies

Conclusions & Outlook

Metric to describe the sound insulation

- For high sound insulation ducts, **intrinsic breakout** is suitable
- For low insulation ducts, RSI = $L_{wi} - L_{wr}$ can be applied,
  - **Noise mainly escapes from the first decimeters**

Future:

- Characteristics to include for ducts description
  - A **test standard** is required, but complicated measurement
  - A **universal metric** has to be defined for both high and low sound insulation ducts and in between

Thank you for your attention

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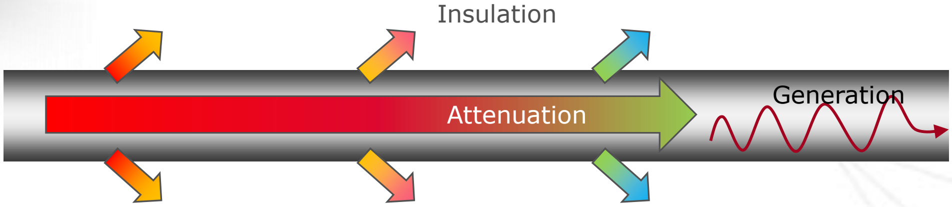
3 acoustic characteristics of ducts



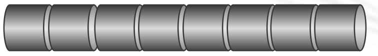
Sound absorption: the noise decreases along the duct due to the absorption (cf. silencers)

Noise generation: noise due to the air velocity (for corrugated or non-smooth ducts)

Sound insulation: ability to resist to the transmission of sound from inside to outside

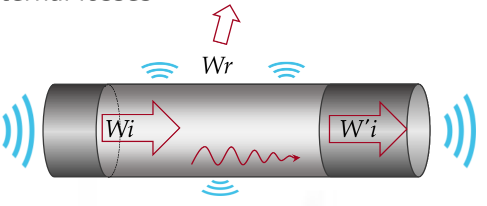
Physical principle

Let's discretise a duct with segments



- For each segment, the balance of power is: $W_i = W_r + W'_i$

  Neglecting the internal losses



$$L_{w'_i} = 10log\left(10^{L_{wi}/10} - 10^{L_{wr}/10}\right)$$

Noise radiated by duct with low TL

Calculation of L_{wr} radiated by a duct for low breakout

$$L_{wr} = L_{wi} + 10log\left(\frac{A_r}{A_i}\right) - TL$$

Length: 4 m
8 segments of 0.5 m
Ø 160 mm

L_{wi} = 90 dB
TL = 17 dB
10 log(Ar/Ai) = 11 dB / segment

For each segment, balance of power

Segment #	1	2	3	4	5	6	7	8	
Distance from duct entrance (m)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	
Incoming Lw of the segment (dB)	90.0	88.8	87.5	86.3	85.0	83.8	82.5	81.3	overall
Lw radiated by the segment (dB)	84.0	82.7	81.5	80.2	79.0	77.7	76.5	75.2	**89.5**
Contribution of the segment	27.7%	20.8%	15.6%	11.7%	8.8%	6.6%	5.0%	3.7%	
Overall Lw radiated by all segments (dB)	84.0	86.4	87.6	88.3	88.8	89.1	89.4	89.5	

For tl

Noise mainly escapes from the first decimeters of the duct

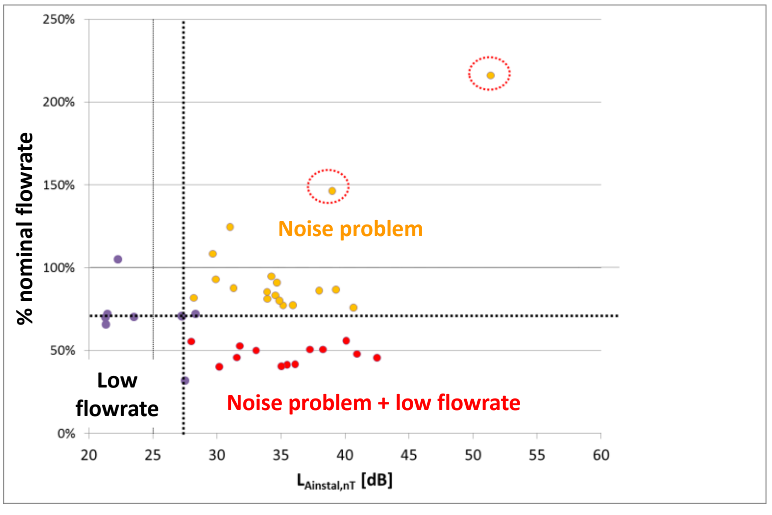
Breakout is not suitable to describe "low insulation" ducts

The raw "insertion loss" could be used

Improvement of the acoustical performance of mechanical ventilation systems in dwellings: a case study

Samuel Caillou, Arne Dijckmans
BBRI – Belgian Building Research Institute, Belgium

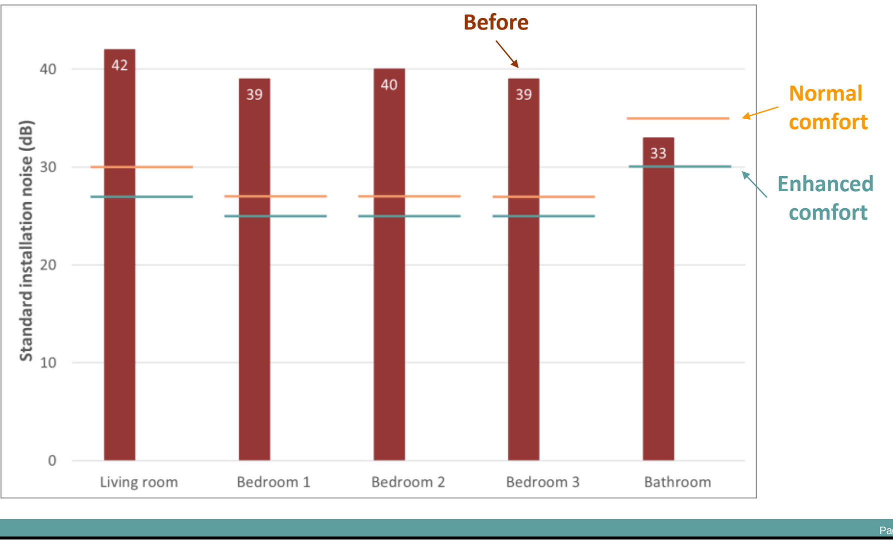
Noise due to mechanical ventilation systems in dwellings: **a very common problem!**



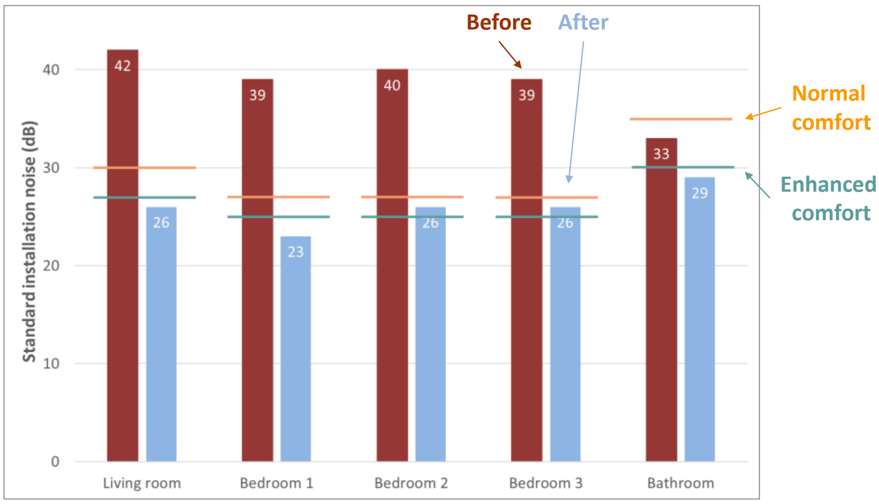
Objective of this case study

- Step by step improvement of a given ventilation system
  - To identify **common causes of noise problems**
  - To prove that **satisfying the acoustical requirements is possible** using simple solutions.

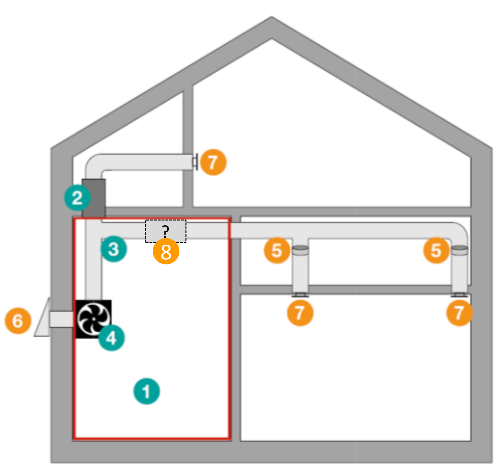
Measured noise level were much higher than requirements in NBN S 01-400-1 (before optimisation)



Measured noise level were much higher than requirements in NBN S 01-400-1 (before optimisation)



The initial system was **not so badly designed**, but **some potential improvements** have been identified



Well designed
1) Ventilation unit in technical room
2) Primary sound attenuators (not all)
3) Duct sizing to limit air speed
4) Correct selection of the unit/fan

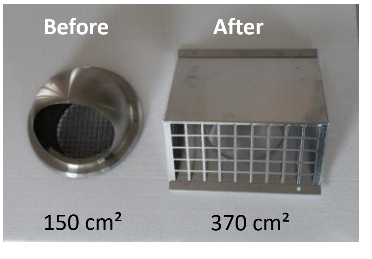
Potentiel improvements
5) Removal of foam sound attenuators
6) Replacement of external ATD
7) Replacement of ATD and adjustment
8) Adding primary sound attenuators

Step 1: Removal of the **in-duct foam sound attenuators** behind the air terminal devices + new flow rate adjustment (ATD)

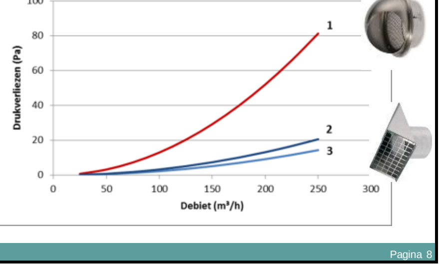
- Why
  - Too high pressure drop of in-duct foam
  - No ATD's in fully open setting

- Result
  - **5-8 dB reduction!**
  - Also in spaces without in-duct foam
- Explanation
  - In-duct attenuators and too closed ATD's create higher pressure drop
  - Lower pressure drop → lower fan speed + less local noise generation

Step 2: Replacement of the **externally mounted air transfer devices**



- Why
  - Too high pressure expected
- Result
  - Not measured (see next step)
- Explanation
  - Larger free section for airflow
    → lower pressure drop
    → lower fan speed



Step 3: Replacement of some air terminal devices

- Why
  - Too high pressure expected

- Result
  - 2-5 dB reduction
    (steps 2 + 3)

- Explanation
  - Lower pressure drop
    → lower fan speed + less local noise generation

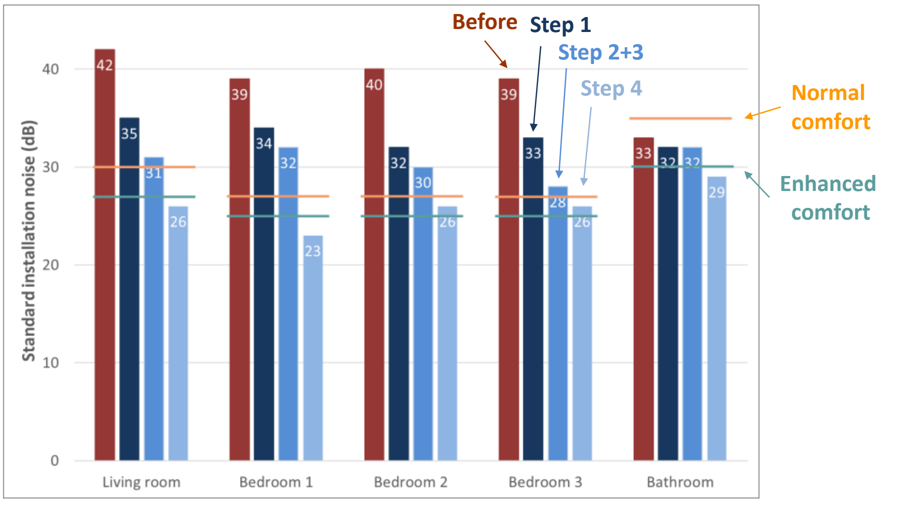
Step 4: Adding some primary sound attenuators

- Why
  - Primary sound attenuators
    were missing on some sections

- Result
  - 2-5 dB reduction
  - 9 dB with additional attenuator (Bedroom 1)

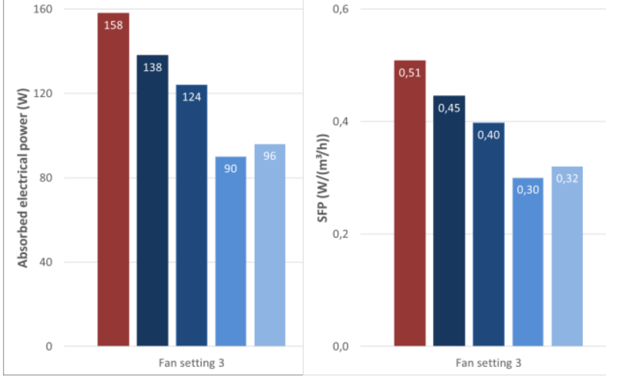
- Explanation
  - Primary sound attenuators are needed to reduce fan noise

After the 4 steps, the reductions of noise levels were



The electrical consuption of the fans also decreased after improvements steps 1 to 3

Power → **Specific Fan Power**
(= Power / Flow rate)



Steps 1 to 3:
- Lower pressure drop
- Lower fan speed
- Lower electrical power

Step 4:
- Adding sound attenuators
- Longer ductwork (not foreseen at design)
- Slightly higher pressure drop

Conclusion: high improvement of the acoustical performance, but with the same ductwork and the same unit/fans!

- Effect of pressure drop
  - Lower pressure drop (better flowrate adjustment, alternative external ATD, alternative ATD's,…)
  - Less local noise generation (flow noise)
  - Lower fan speed → less noise generated by the fans
- In-duct foam sound attenuator
  - Generate more noise than attunated noise! (pressure drop)
- Primary sound attenuators
  - Highly recommanded for all duct

Thank you for your attention

Samuel Caillou, Arne Dijckmans
BBRI – Belgian Building Research Institute, Belgium

Influence of office layout and ceiling height on vertical temperature gradient in office rooms with displacement ventilation

Natalia Lastovets, Risto Kosonen, Panu Mustakallio

Department of Mechanical Engineering
Aalto University

Motivation

- Current simplified models are not able to predict temperature gradient with typical heat loads in rooms with displacement ventilation (DV)
- Inaccurate estimation can result in 2-3 °C temperature difference compared to the design values

As a result:

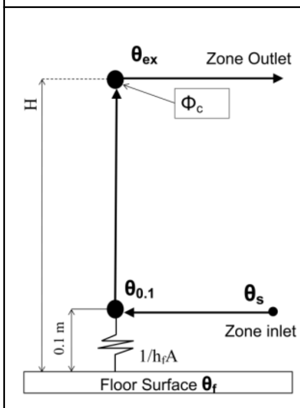
- poor thermal comfort in the occupied zone
- ventilation system is over-sized

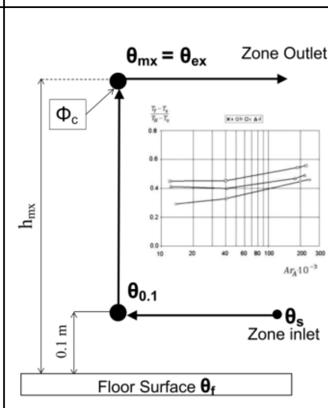
Objectives

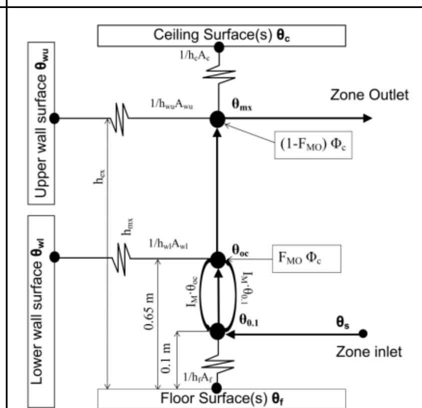
- To study the effect of the different type of heat loads, room height and office layout on the temperature gradient in rooms with DV
- To analyse the possibilities of simplified nodal models to calculate the temperature gradient
- To validate the common models and proposed novel nodal model with different measuring layouts

Simplified models

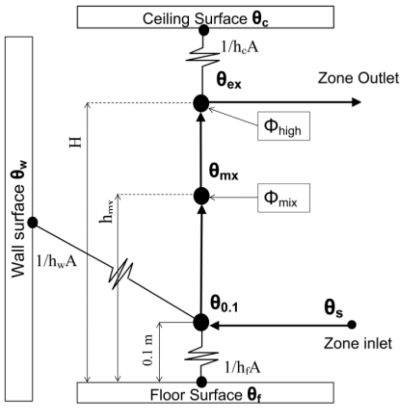
Mundt model	Nielsen model	Mateus model



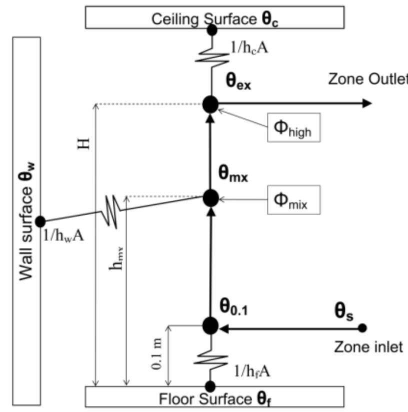




Novel nodal model



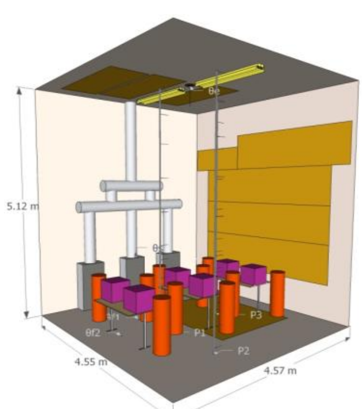
The most of heat loads
in the lower zone of the room



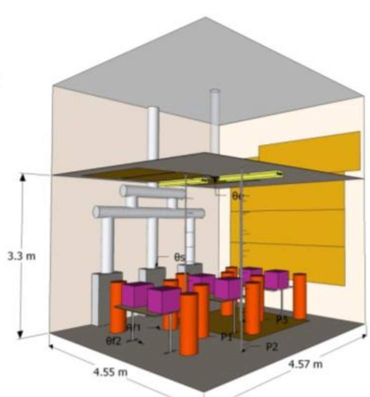
The most of heat loads
in the upper zone of the room

Measurement setup

Influence of the ceiling height



H = 5.1 m



H = 3.3 m

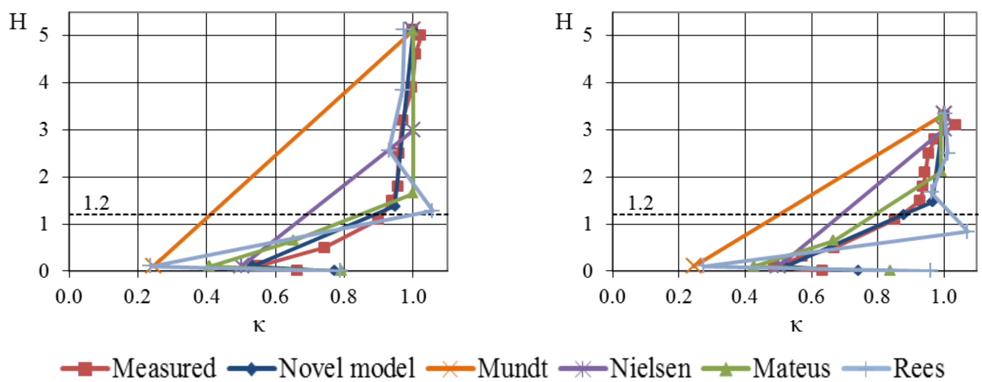
- Person simulators
- Computer simulators
- Heated foils on the wall, floor and ceiling
- Fluorescent lighting units

Results

Influence of the ceiling height

Mostly low-level heat loads

10 people, window and floor heat loads, lighting

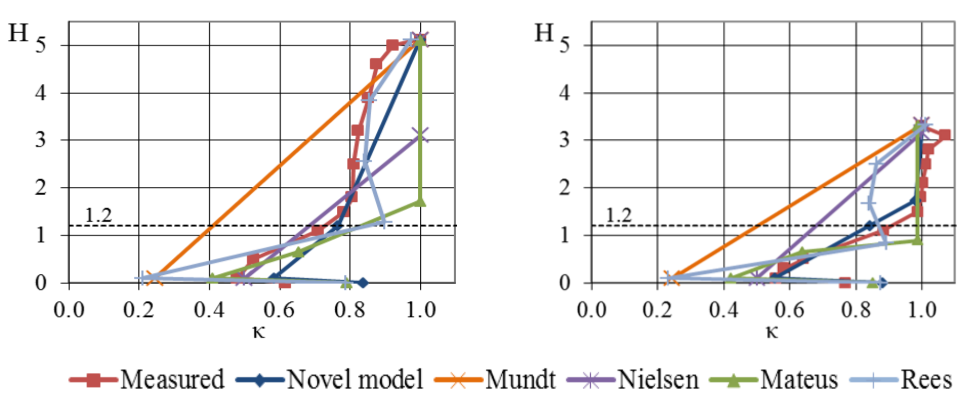


Results

Influence of the ceiling height

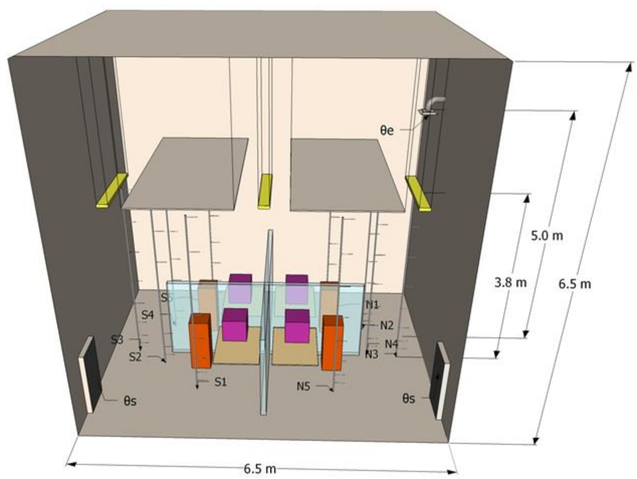
High-level heat loads

10 people, ceiling heat loads, lighting



Measurement setup

Influence of the office layout



Person simulators

Computer simulators

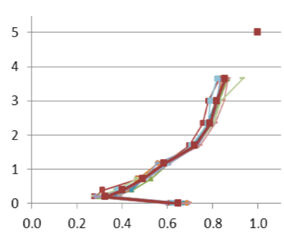
Fluorescent lighting units

Partitions

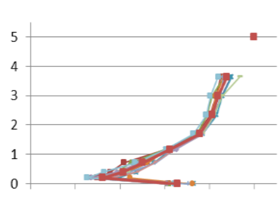
Measurement points:
S1-5, N1-5 – room air temperatures
θs – supply air temperature
θe – exhaust air temperature

Results

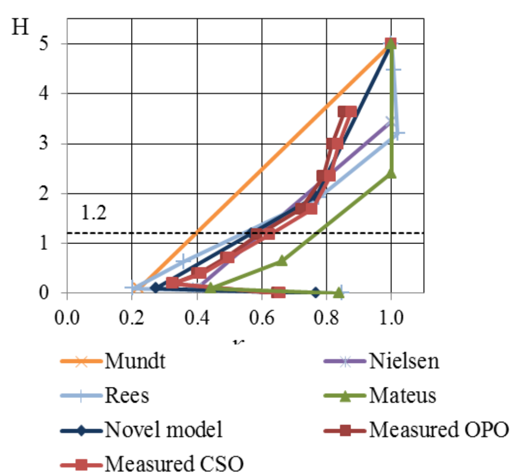
Influence of the office layout



Cubicle-style office CSO



Open-planned office OPO



Conclusions

- Heat load distribution and accurate mixing height calculation are the most essential factors to predict the temperature stratification
- Two-nodal models significantly underestimate the temperatures in the occupied zone
- The influence of the ceiling height depends on the location of heat sources
- Displacement ventilation provides even temperature gradient throughout the simulated office room spaces
- Novel nodal model is able to accurately calculate the all temperatures for all the typical room heights and indoor loads

Ductwork design flaws and poor airtightness:
a case study about a ventilation system reconditioning in a sealed building

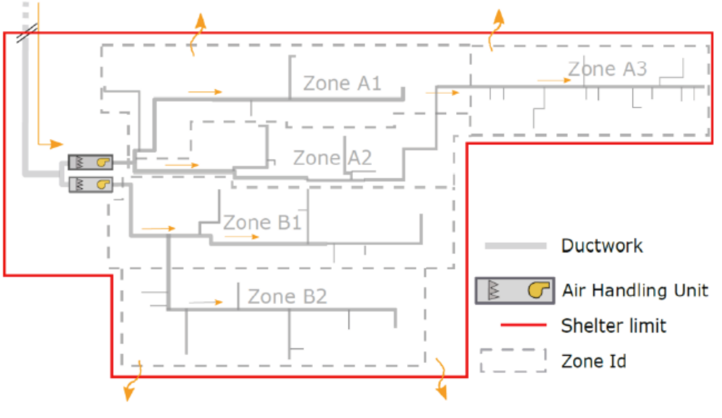
AIVC 18

Fabrice RICHIERI / SNIA - DGAC

HVAC Engineering, Project manager at DGAC (French Civil Aviation Authority)

AIVC 2018
Juan Les pins, 18 septembre 2018

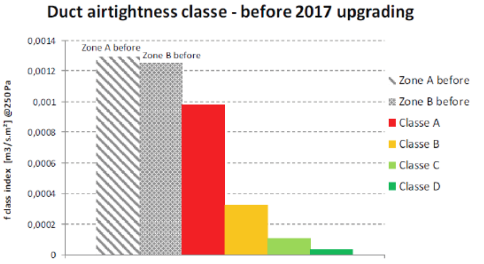
Context : after a period of retrofit (2011-12) of a sealed building (shelter without any openings or windows), a bad IAQ is observed by occupants in some distant part of the building (zone A3).



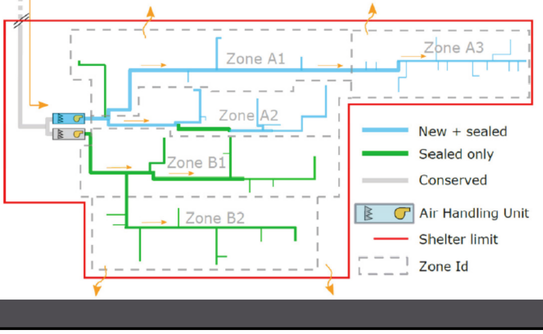
Objectives :

This paper presents the method and results used to identify the causes of the current ventilation dysfunction, based on :

- **measurements** (pressure and airflow rate in the ductwork, airtightness testing of the ductwork),
- **calculation** of pressure drops and total airflow rate,
- **and observations** (duct and internal envelope leakages search, airflow pattern).



SNIA proposed reconditioning measures to allow a well-functioning installation



Conclusion : *"Build tight, ventilate right and make airflow control easier!"*

- The diagnosis showed that the major problem was due to the poor performance of ducts airtightness, where no verifications at the execution of the 2012 refurbishment had been required previously.

- Reconditioning measures allowed delivering a well-functioning installation, with a checked control of all air-outlet airflow rates, as well as a net reduction of the electrical powers absorbed by the fans, like the reduction of the noise nearby AHU.

ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

Ductwork Noise Calculations: Main Outputs of AcouReVe Project

François BESSAC, Camille LEFEBVRE
CETIAT

Catherine GUIGOU-CARTER, Simon BAILHACHE
CSTB

CSTB le futur en construction

CETIAT ensemble, innover et valider

AcouReVe Project

Noise calculations on ventilation ductwork aim to assess the noise radiated by inlets/outlets in the rooms

- Simple calculation approach, based on ductwork elements
  - Straight duct, bends, junctions, dampers, section changes, silencers, manifolds, etc.
- Each element: **Attenuation** \+\ **Sound generation**

AcouReVe project objectives:

- Improve the efficiency of acoustic ductwork calculations
- Check some literature data

CETIAT ensemble, innover et valider

Main actions

Data from literature: synthetised in abacus / tables

- Initial scope or conditions often unknown or outdated

Check or add information on circular elements:

- Sound repartition in asymetric junctions
- Sound attenuation in ventilation straight ducts
- Sound generation and attenuation on (smooth, sharp) bends and junction
- Sound repartition in manifold
- Sound generation and attenuation of dampers

- Interaction between elements (e.g. attenuation of 2 close bends)

Conclusions

Many tests & calculations performed on various elements

The calculation approach is very simple but:

- Consistent with the quality of data available
- Results of standard measurement can be used
    - More acurate calculation approaches exist but elements difficult to characterize, without standardized methodologies

Welcome in front of my poster
for additional explanations

CETIAT

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RAADGEVENDE INGENIEURS
Nieman
Bouwfysica, -techniek en -regelgeving

Towards performance based regulation

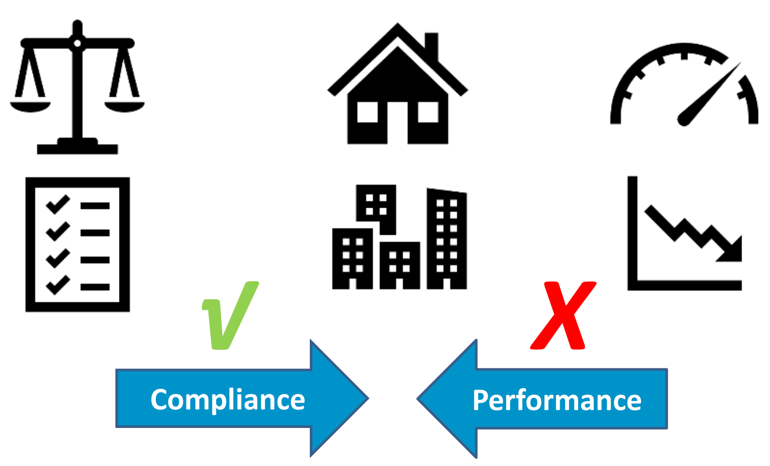
Including air-exchange performance in building regulation

Ir. Harm Valk
Nieman RI / Netherlands

Co-authors: Rob van Holsteijn, William Li (VHK), Jelle Laverge (U-Ghent)

AIVC Conference 18-09-2018 Juan-les-Pins

Compliance and performance



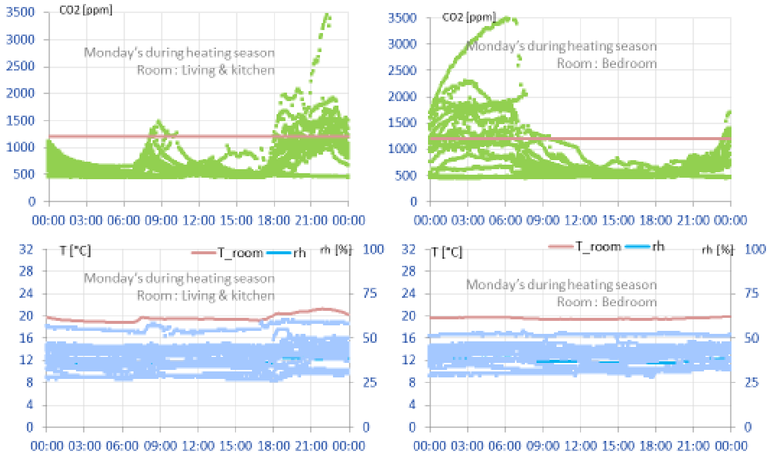
IAQ Field research

MONICAIR

4. RESULTS INDIVIDUAL DWELLING

Dwelling with MEV system type C.2c. Number of inhabitants : 3

- Presented at AIVC 2014



In 't Hart van de Bouw

Building code vs performance

Building code demands

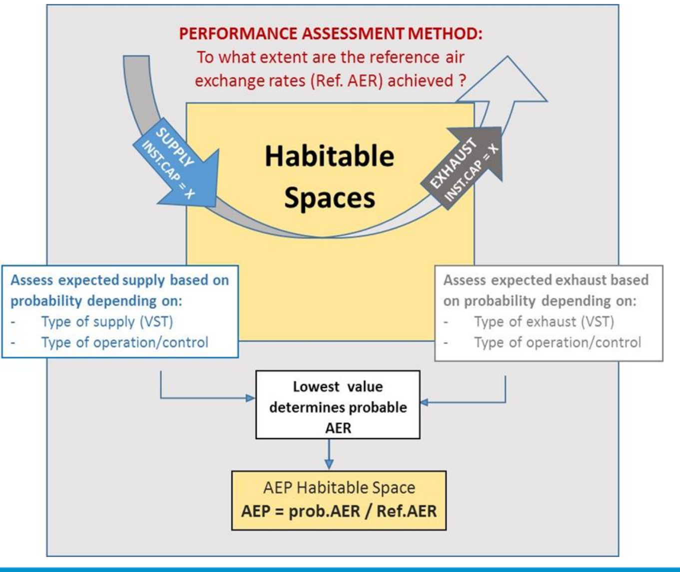
- Capacity
- Boundery conditions
- Climate
- Assumption of use

Performance parameters

- IAQ
- Implementation
- Weather
- Variation in use
- Maintenance
- …

In 't Hart van de Bouw

Assessment method



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Assessment method

- Scope of proposed assessment method:
  - Focus on residential ventilation systems
  - Systems are properly installed
  - Dedicated cooker hood is default
  - Only technical system features as input
- Distinction in:
  - Habitable Spaces
    - ventilation strategy: accommodate air-exchange during presence
    - supply of fresh (outdoor) air is key
    - during absence: basic ventilation rates
  - Exhaust Spaces
    - ventilation strategy: extract sufficient (indoor) air.
    - during absence: airflow necessary for humidity control

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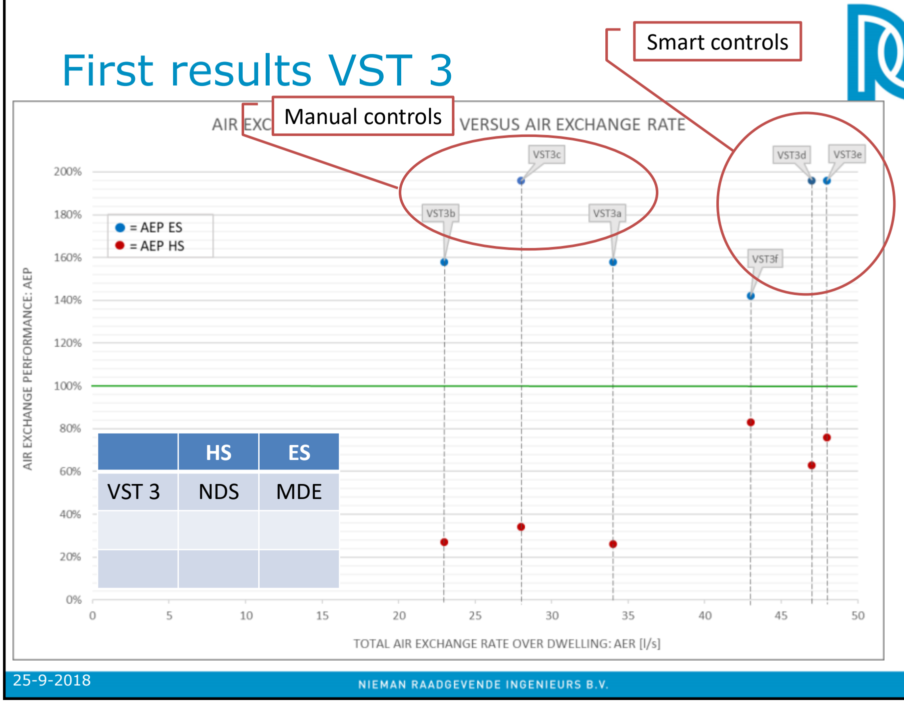
Calculation method

- Occupancy paterns
  - Based on data – fixed in standard
- Type of controls
  - Manual / automated / sensor
- Natural driving force
  - Wind, stack
  - Probability and availability (physics and statistics)
- Building parameters
  - Measurements, number of rooms
  - Air tightness

- AER_{prop} / AER_{ref} = AEP
  - absence and presence for HS and ES

In 't Hart van de Bouw

First results VST 3



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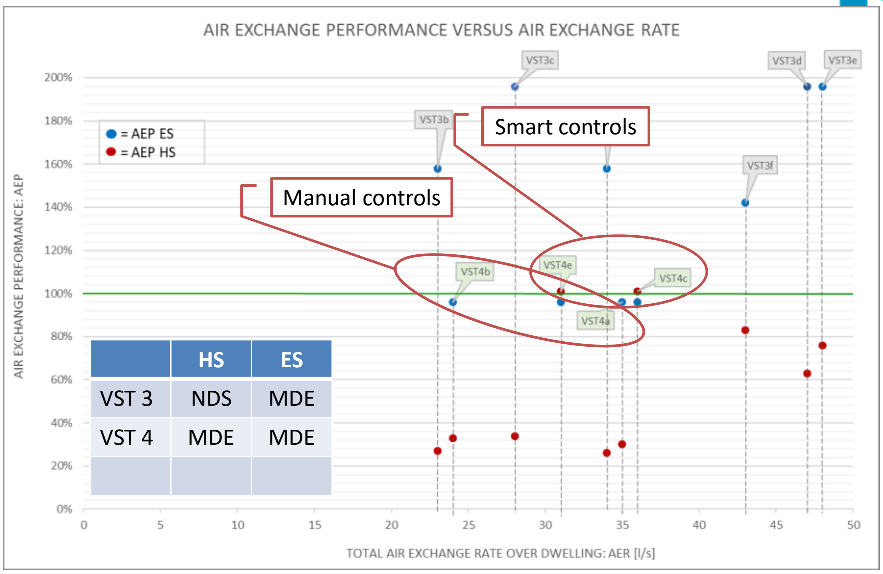
First results VST 3 - 4



	HS	ES
VST 3	NDS	MDE
VST 4	MDE	MDE

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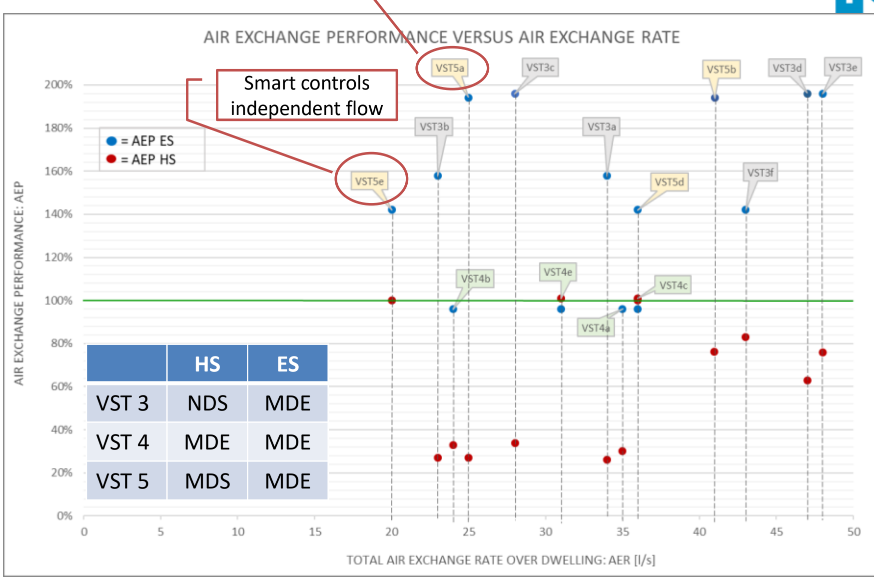
First results VST 3 – 4 - 5



	HS	ES
VST 3	NDS	MDE
VST 4	MDE	MDE
VST 5	MDS	MDE

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Adjustments to building code

Four main adaptations
  – compared to EVIA method

- No differentiation in type of habitable rooms.
- Adjustment of reference AER to Bouwbesluit 2012-rates (instead of Air Exchange Performance classes EN16798-1).
- Determination of the occupancy patterns.
- No inclusion of ventilation performance label.

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Conclusions

- The adjustments gives generic performance values for habitable spaces.
- This method compares ventilation systems on their ability to achieve the requested air exchanges.
  – The performance assessment method cannot be used to predict that IAQ-levels.
- The method makes it possible to set limit values for performance indicators within the context of building regulations.

In 't Hart van de Bouw

RAADGEVENDE INGENIEURS
Nieman
Bouwfysica, -techniek en -regelgeving

Towards performance based regulation

Including air-exchange performance in building regulation

Thank you for your attention! Any questions?

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In 't Hart van de Bouw

NRC·CNRC

Performance of Dual Core Energy Recovery System for Use in Arctic Housing

Boualem Ouazia Ph.D.

Ganapathy Gnanamurugan, Chantal Arsenault and Yunyi Li

The Construction Research Centre / NRC's Arctic program

The 39th AIVC Conference
Juan Les Pins September 18-19, 2018

National Research Council Canada | Conseil national de recherches Canada

Canada

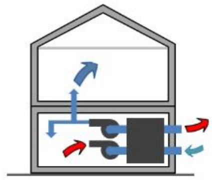
Content

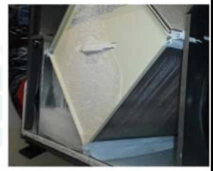
- Introduction
- Methodology
- Dual Core Energy Recovery System
- Results
- Conclusions

Introduction

Project Motivation

- Single core H/ERV units currently installed in the North under-perform in extreme cold.
- At present, no HRVs/ERVs designed/manufactured to meet rigorous requirements operation in the North.
- Frost formation is common in cold regions (T<-10°C)
- Frosting is a significant challenge
  - HRV/ERV failure
  - Decrease effectiveness
  - Under ventilation, etc.
- Defrost strategy or frost protection mechanisms are required
  - Incidentally create an intermittent ventilation
  - cross contamination between exhaust and supply air streams
- Under ventilation leads to IAQ deterioration and mould.





Methodology

- Propose (with industry) innovative air ventilation systems
- Lab evaluation using climatic chambers and an HRV/ERV test rig to simulate

Heating Mode with	Indoor Conditions	Outdoor T [°C]
Conditions Identified by CSA-C439/HVI	22°C & 40%	0, -10, -20, -30, -35
Identified northern conditions	25°C & 55-65%	0, -10, -20, -30, -35

- Side-by-side testing of innovative technologie vs. conventional HRV or ERV unit
- Deployment and extended monitoring of innovative technologies in the Arctic
  - Prove their performance and resilience in harsh arctic climates.

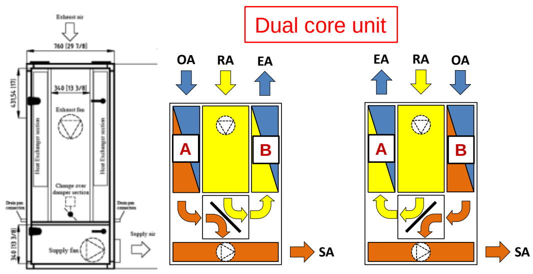
Lab Climatic Chambers

CCHT

Triplex Cambridge Bay NU

Dual Core Energy Recovery System

Parallel Configuration

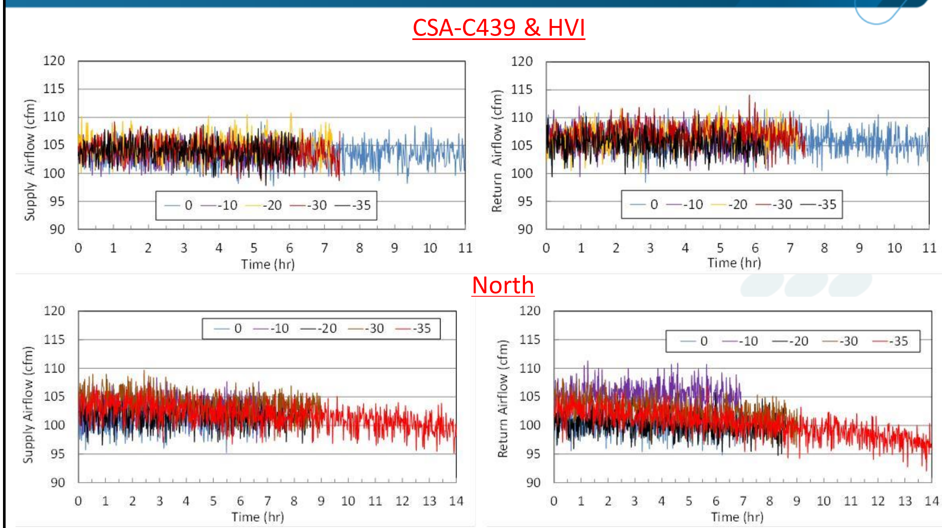


- If exhaust air T < 20°C, unit in energy recovery mode (cycling every 60s)
- If exhaust air T > 20°C and supply air T > 15°C, unit in free cooling (cycling every 3 hours)
- If exhaust air T > 20°C and supply air T < 15°C, unit in energy recovery mode until the supply air T becomes > 15°C then it will revert to free cooling.

- Regenerative technology;
- When one core is defrosting (RA), the other is being used to pre-condition ventilation air (SA, active core);
- Internal damper controlled by 2 thermostats GT1 in the supply air and GT2 in the exhaust air
- GT1 is set to 15°C, GT2 is set to 20°C;
- The cycling damper is used to ensure continuous delivery of fresh air to indoor.

Laboratory Testing - Results

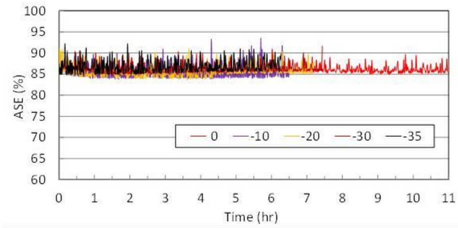
Supply and Exhaust Airflows

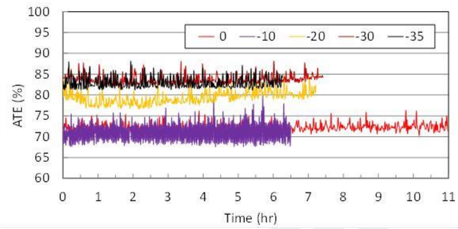


Laboratory Testing - Results

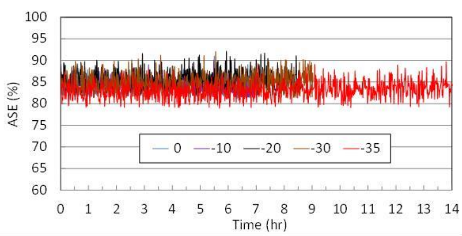
Apparent Sensible and Total Efficiencies

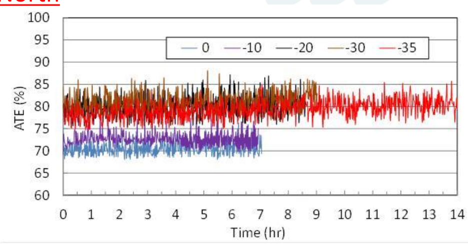
CSA-C439 & HVI





North



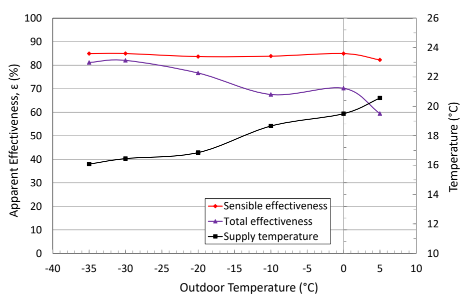


NRC·CNRC

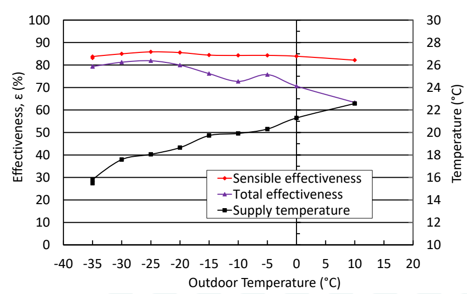
Laboratory Testing - Results

Overall Thermal Performance

CSA-C439 & HVI



North



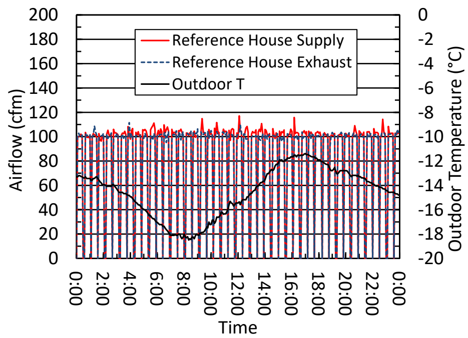
ASE = 82 % to 94%
ATE = 60% to 88 %
SAT = 15.9°C to 20.6°C

ASE = 79 % to 93%
ATE = 59% to 92 %
SAT = 15.3°C to 22.6°C

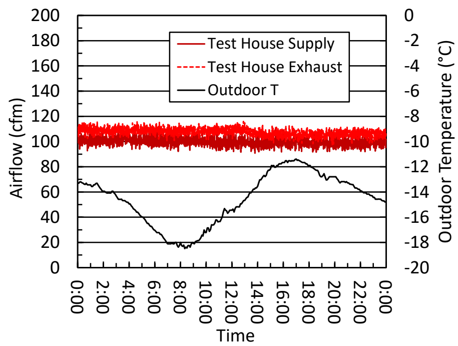
NRC·CNRC

Side-by-side Testing
Ventilation Rate

Reference House with single core ERV



Test House with dual core AHU



Single core ERV was 22% of the time (5.25 hours/day) defrosting
and not supplying outdoor air to the house

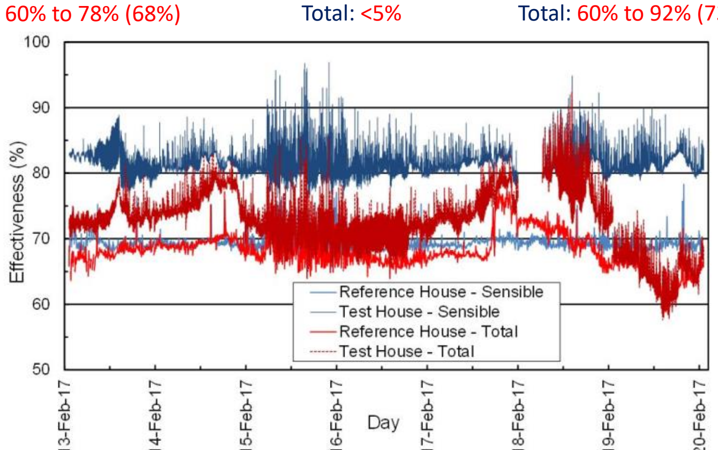
NRC·CNRC

Side-by-side Testing
Apparent Sensible and Total Efficiencies

Single core design
Sensible: 66% to 78% (70%)
Total: 60% to 78% (68%)

Average
Sensible: <12%
Total: <5%

Dual core design
Sensible: 76% to 97% (82%)
Total: 60% to 92% (73%)



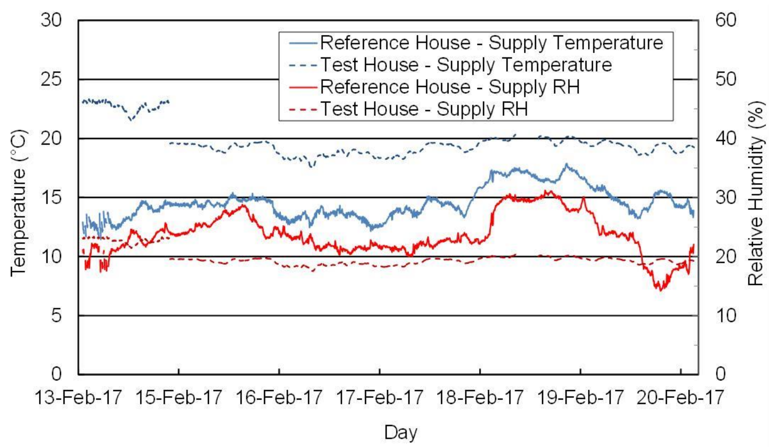
NRC·CNRC

Side-by-side Testing

Supply Air Temperatures

Single Core ERV: 11.5 to 17.9°C vs. Dual Core ERV: 17.5 to 20.3°C

Daily average difference > 3 to 6°C



Extended Monitoring in the Arctic

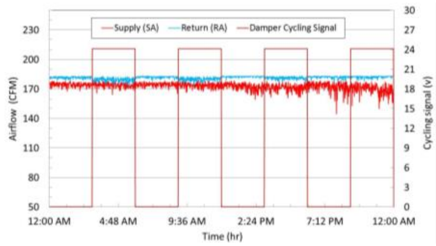
Cambridge Bay (Nunavut)

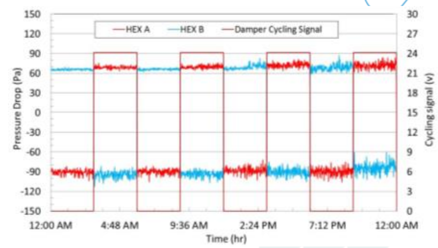
- Confirm the long-term efficiencies
- Provide operational evidence
  - ✓ Required ventilation rate
  - ✓ Supply air temperature
- Determine reliability & durability

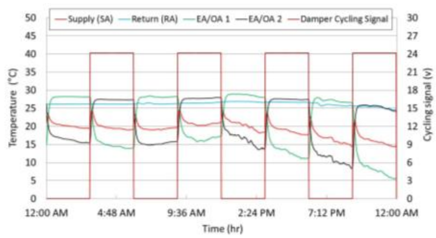
Triplex in Cambridge Bay

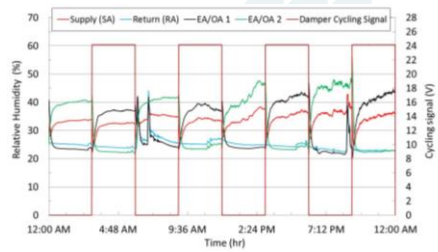
Northern Monitoring (07/09/2017)

Unit in free cooling mode (cycling every 3 hours)





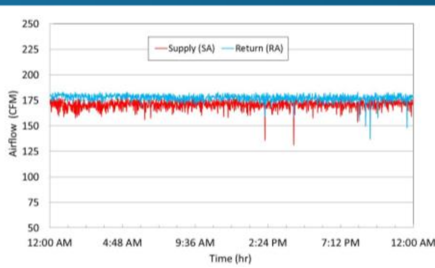


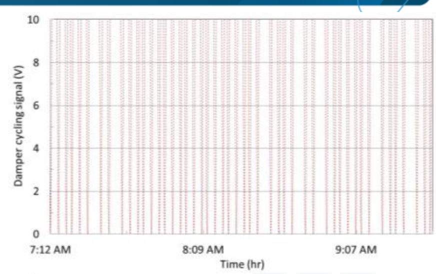


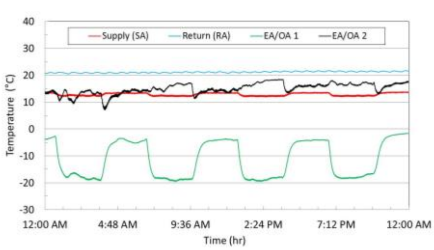
NRC·CNRC

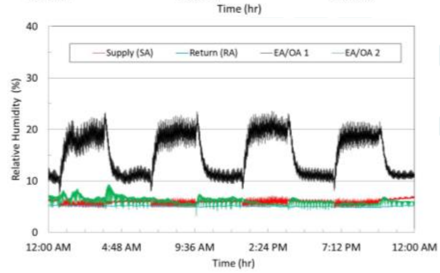
Northern Monitoring (07/09/2017)

Unit in energy recovery mode (cycling every 60s)









NRC·CNRC

Conclusions

- High potential to overcome challenges faced by single core units in the North;
- Had higher ASE and ATE than single core ERV unit (outdoor T < -25°C);
- More frost-tolerant, capable of withstanding outdoor temperatures down to -40°C without deteriorating its thermal performance;
- Showed no sign of frost problems at temperature below -10°C and provided continuous ventilation rate, unlike conventional single core with intermittent ventilation rate;
- Provided higher supply air temperature up to 6°C, above 15°C at outdoor temperature of -35°C;
- Showed a significant saving in heating/ventilation energy consumption, ~6.2% (18.7 MJ/day);
- Performance and resilience proven through extended monitoring in the North.

Thank you

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Experimental analysis of Phase Change Material heat exchanger in ventilated window system

Yue Hu, Per Kvols Heiselberg, Rui Guo

Dept. of Civil Engineering
Aalborg University, Denmark

Concept of ventilated window

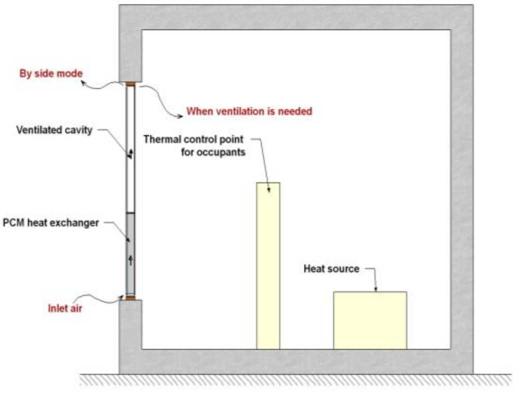


Figure 1. System discription- PCM heat exchanger with ventilated window.

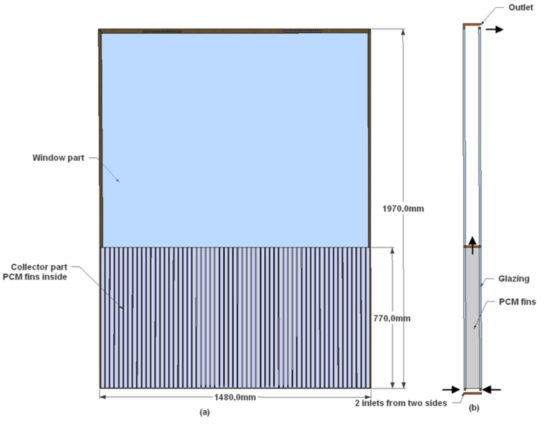


Figure 2. Front view of the PCM heat exchanger with ventilated window.

Operation strategies of ventilated window

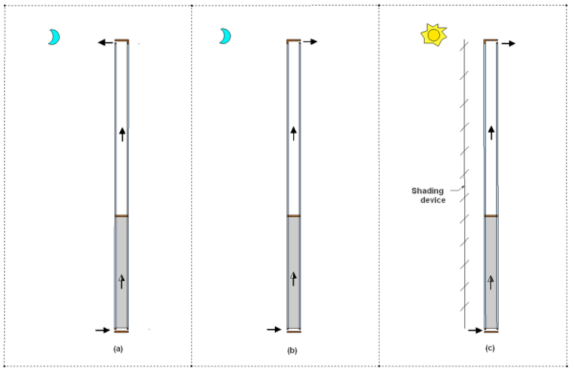


Figure 3. Summer operation strategy (a) night ventilation mode during night; (b) by pass mode; (c) ventilation pre-cooling mode in the daytime.

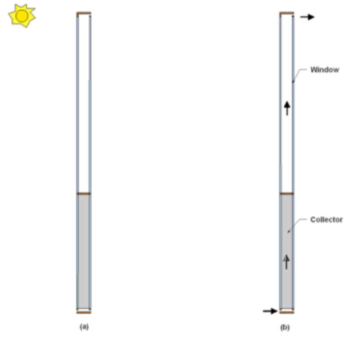
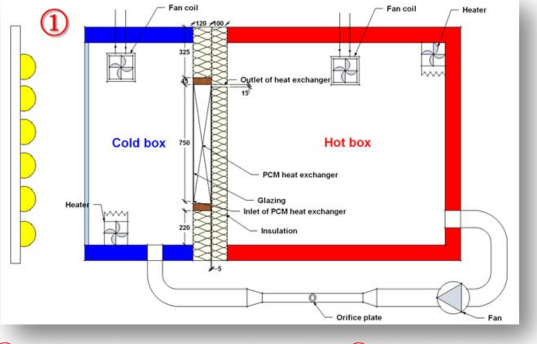
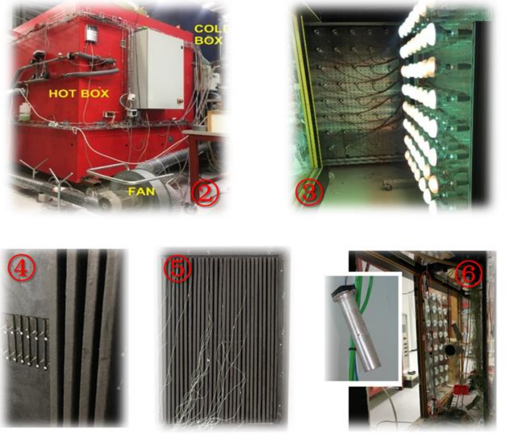


Figure 4. Winter operation strategy (a) Solar energy storage mode to charge the PCM during daytime; (b) Ventilation pre-heating mode.

Experimental setup

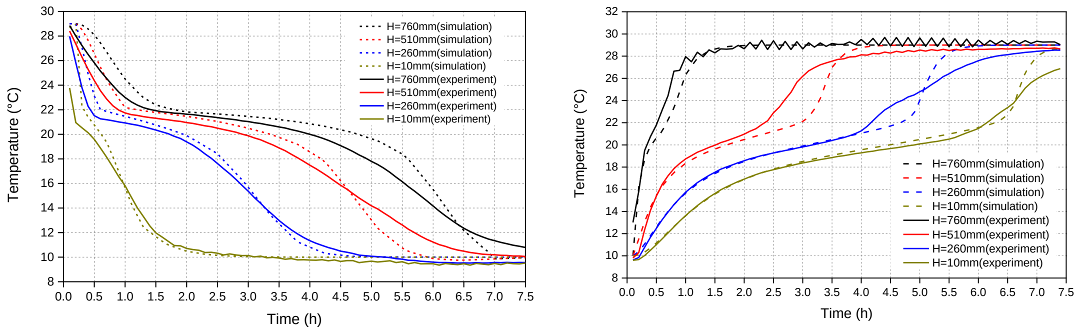




① Hotbox and coldbox setup illustration; ② Facilities in the lab; ③ Artificial sun for solar radiation; ④ Mount PCM plates in the heat exchanger; ⑤ Thermocouples in the heat exchanger; ⑥ Air temperature measurement in the cold box.

Figure 5. The experimental setup with hot box and cold box.

Experimental results for summer case



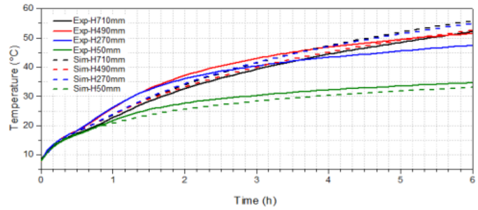
(a) night ventilation mode.
average error between experiment and simulation:2.38%.

(b) ventilation pre-cooling mode.
average error between experiment and simulation:4.79%.

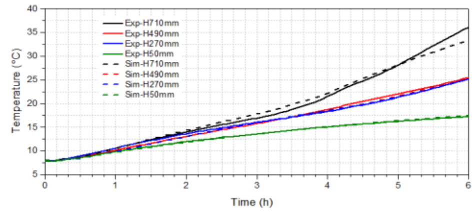
Figure 6. The experimental data compare with simulation results for summer case.

Experimental results for winter case

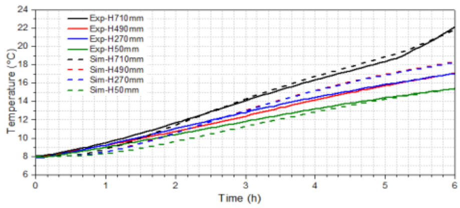
The heat exchanger is in soar energy storage mode. The artifical sun is turned on to provide solar radiation. The average error between experiment and simulation is 5.95%(Figure (a)), 1.82%(Figure (b)), and 4.28%(Figure (c)) respectively.



(a) PCM temperature in the outer part of the plates.



(b) PCM temperature in the middle part of the plates.



(c) PCM temperature in the inner part of the plates.

Figure 7. The experimental data compare with simulation results for winter case.

Thank you!

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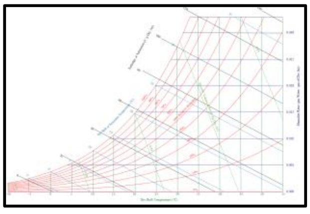
Email: hy@civil.aau.dk

Energy Efficiency of AHU

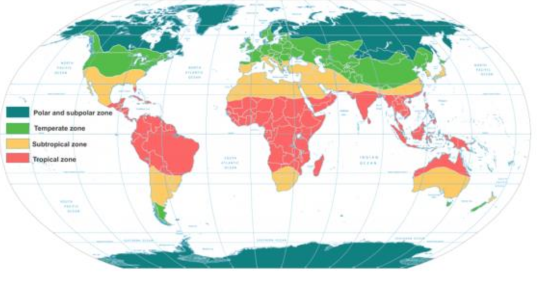


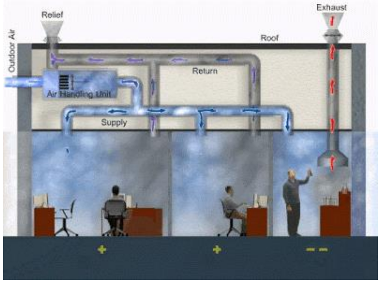
Development of Psychrometric diagram

Kiyan VADOUDI
Eurovent Certita Certification

Introduction

An air handling unit (AHU) is a device, which takes in **outside air**, **heated** or **cooled** it and supplies it as fresh air to the air conditioned room.

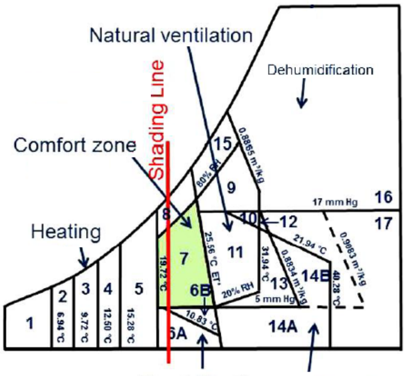




? How to evaluate the AHU energy efficiency for different climatic conditions?!

AHU energy efficiency

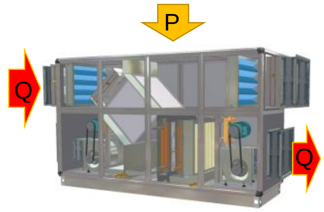
The overall demand of energy for AHU can be summarized into:



Identification of climate control strategies on the Building Bioclimatic Chart (adapted after Givoni)

BIOCLIMATIC NEEDS ANALYSIS	
Heating (< 19.72 °C)	1-5
Cooling (> 25.56 ET*)	9-17
Comfort (19.72 °C – 25.56 °C ET*, 5 mm Hg – 80% RH)	7
Dehumidification (> 17 mm Hg or 80% RH)	8-9, 15-16
Humidification (< 5 mm Hg)	6A, 6B (14)
STRATEGIES OF CLIMATE CONTROL	
Restrict conduction	1-5; 9-11, 15-17
Restrict infiltration	1-5; 16-17
Promote solar gain	1-5
Restrict solar gain	6-17
Promote ventilation	9-11
Promote evaporative cooling	6B, 11, 13, 14A, 14B
Promote radiant cooling	10-13
Mechanical cooling	17
Mechanical cooling and dehumidification	15-16

Strategies of climate control overlaid on a psychrometric chart (After Watson and Labs)



Thermal energy

$$Q_t = Q_l + Q_s$$

1. Latent heating/cooling
2. Sensible heating/cooling

Methodology

Psychrometric diagram for the energy efficiency of AHU:

Geographical Coefficient of Performance (GCOP)=$\sum_{i=1}^{5} COPi\ Wi$

$COPi$ = COP of each zones Wi = Weight of each zone

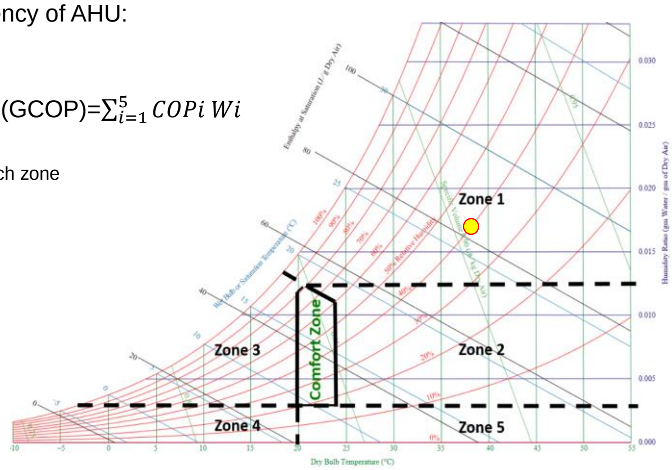
$COP_{Z1} = [(Q_{CC} + Q_{DHU} + Q_{HRS}) / P_{el}].\ W_1$

$COP_{Z2} = [(Q_{CC} + Q_{HRS}) / P_{el}].\ W_2$

$COP_{Z3} = [(Q_{HC} + Q_{HRS}) / (P_{el} + P_{Aux}.)].W_3$

$COP_{Z4} = [(Q_{HC} + Q_{HU} + Q_{HRS}) / (P_{el} + P_{Aux}.)].W_4$

$COP_{Z5} = [(Q_{CC} + Q_{HU} + Q_{HRS}) / (Eq.2 + P_{Aux}.)].W_5$



Comfort zone (Dry bulb temperature 22°c and 50% relative humidity)

Case study

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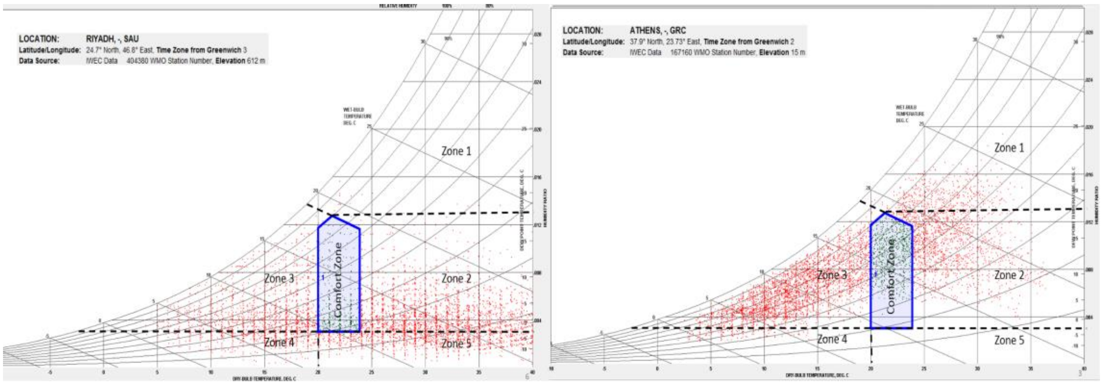
Psychrometric diagram is implemented for two cities:

Climate Consultant (Milne 2016)



CITY	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	COMFORT ZONE
RIYADH	0.23%	40.49%	21.93%	7.15%	22.00%	8.22%
ATHENS	6.27%	19.52%	57.52%	1.83%	0%	14.87%

GCOP = 20.38

GCOP = 23.14

Conclusion

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Based on presented methodology:

- The objective is to present a general approach for different climatic conditions.
- To use the parameters, which are calculating in existing AHU software.
- Due to high complexity of AHU, the methodology is not focusing on the function of each part. Thus, there is no need for correction factors.

Future works:

- For each geographical location, energy classes have to be defined.
- To increase the accuracy of calculation, the zones could increase from 5 to 11.

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Smart ventilation for buildings

Thank you for your attention

Kiyan VADOUDI– **Eurovent Certita Certification**
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Ceiling Radiant Textile

Cooling and Heating performance

Air Conditioning System with PAC

of Ceiling Radiant Textile

What is this system?

Advantages of this syetem

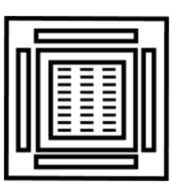
Purpose of our research

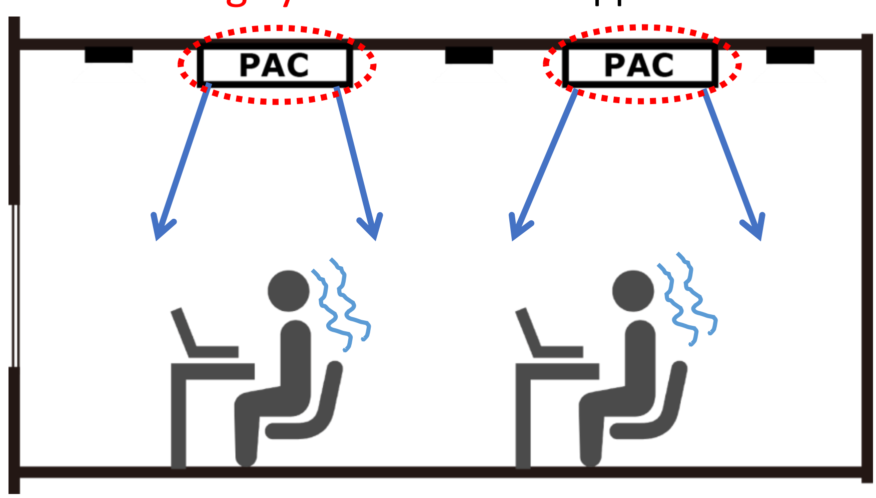
What did we do?

In the offices in JAPAN…

Convectional air conditioning system has been applied commonly.

▼ such as **PAC**





However,

There's a problem about

Drought!

So… We introduce Textile layer below the PAC!

It is expected that

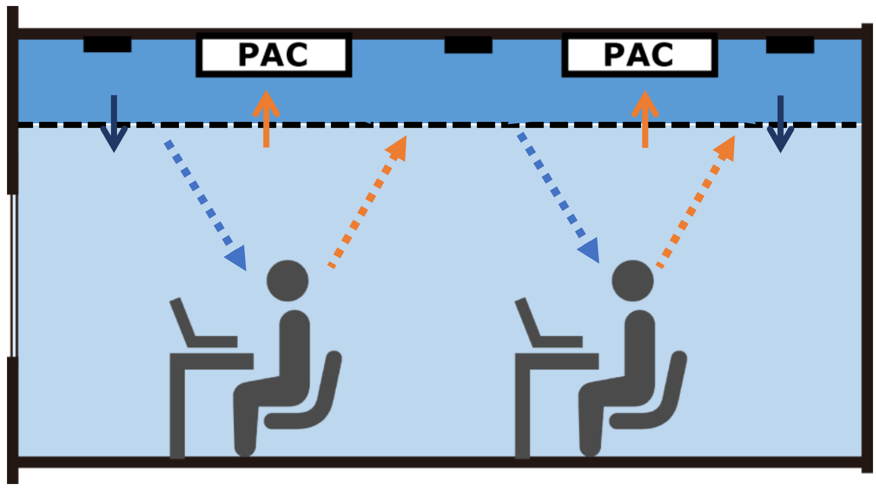
✓ **Radiant effect**

✓ **Exchange air**

▼

It can provide

thermal comfort!



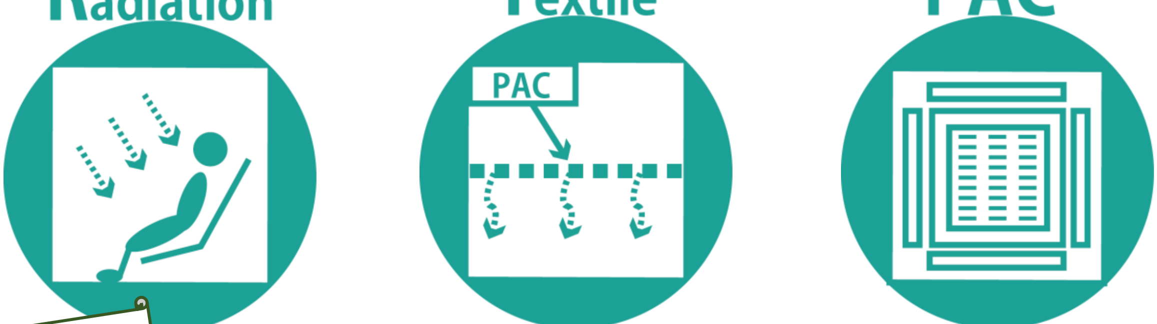
3

3 Advantages of this system are…

Radiation

Textile

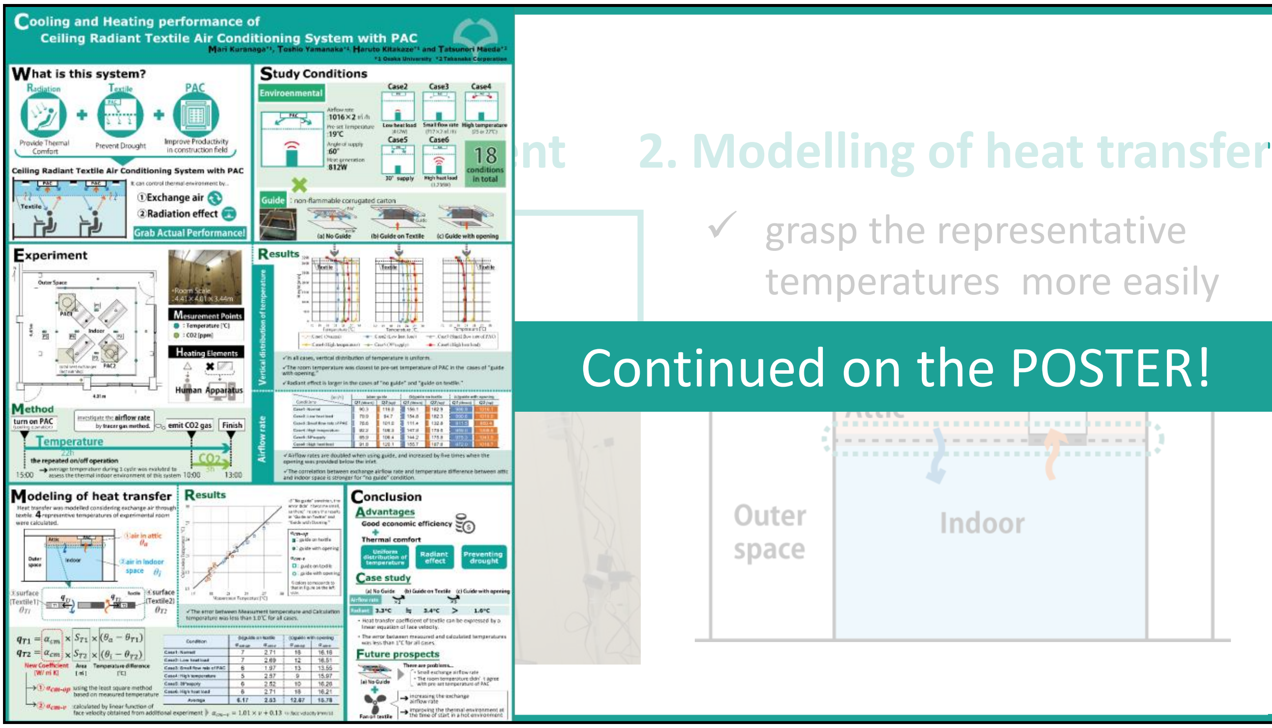
PAC



Purpose

Grab the Actual Performance!

▶ **How can it be introduced in building?**


Cooling and Heating performance of
Ceiling Radiant Textile Air Conditioning System with PAC
What is this system?
Radiation
Textile
PAC
Provide Thermal Comfort
Prevent Drought
Improve Productivity in construction field
Ceiling Radiant Textile Air Conditioning System with PAC
①Exchange air
②Radiation effect
Grab Actual Performance!
Study Conditions
Environmental
Case2
Case3
Case4
Case5
Case6
18 conditions in total
Guide
(a) No Guide
(b) Guide on Textile
(c) Guide with opening
Experiment
Mesurement Points
Heating Elements
Human
Apparatus
Method
turn on PAC
emit CO2 gas
Finish
Temperature
Results
Vertical distribution of temperature
Airflow rate
Modeling of heat transfer
Results
Conclusion
Advantages
Good economic efficiency
Thermal comfort
Case study
Future prospects
2. Modelling of heat transfer
grasp the representative temperatures more easily
Continued on the POSTER!
Outer space
Indoor

39th AIVC Conference
Smart ventilation for buildings

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

Optimal control strategy of air-conditioning systems for buildings requiring strict humidity control

Chaoqun ZHUANG
The Hong Kong Polytechnic University
chaoqun.zhuang@connect.polyu.hk

18 - 19 September 2018 | Antibes Juan - les - Pins Conference Centre, France | 7th TightVent Conference 5th venticool Conference

Research background

Buildings requiring strict temperature and humidity controls can be 10 times more energy intensive than a standard building.

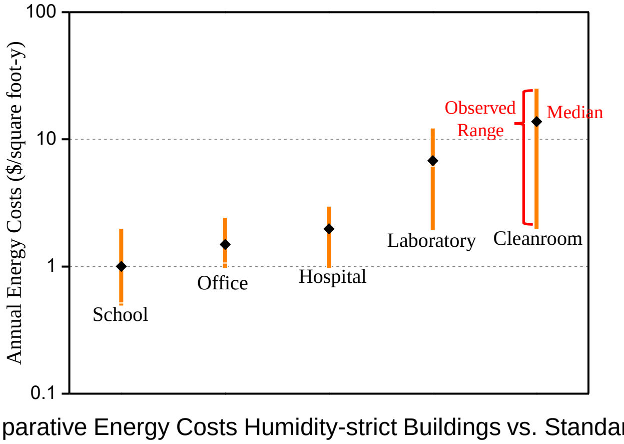


Fig. 1 Comparative Energy Costs Humidity-strict Buildings vs. Standard Buildings
Source: LBNL benchmarking databases

From 1993 to 2015, the area of cleanroom space was **tripled** (from 4.2 to 15.5 million) while the energy intensity only reduced by **2%** (from 31.0 to 30.8 GJ/m^2).
Source: Energy Efficiency in California Laboratory-Type Facilities

Research background

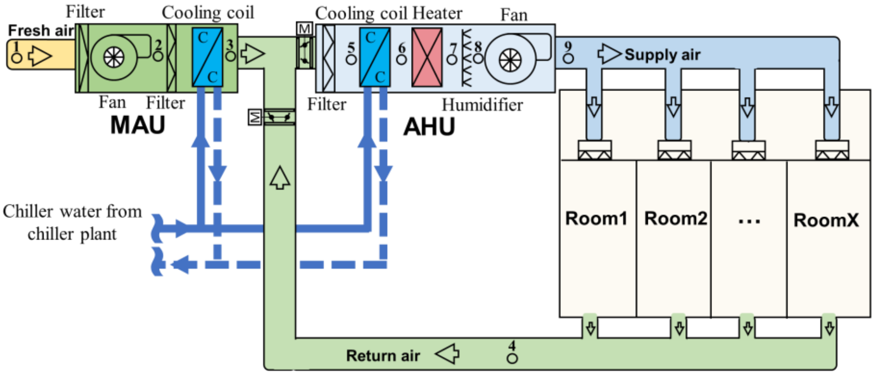


Fig. 1 System configuration of a typical multi-zone air-conditioning system

Table 1 Typical ventilation strategies under hot and humid weather conditions

Operational strategy	Applicable situations	Limitations
Interactive control (IC)	Moderate or cold climate zones	Simultaneous cooling and reheating
Dedicated outdoor air ventilation (DV)	Moderate or cold climate zones, or low internal latent load	High ventilation energy demand
Partially decoupled control (PD)	Hot climate zones, or low internal latent load	Simultaneous cooling and reheating under high internal latent load

Concept of proposed strategy

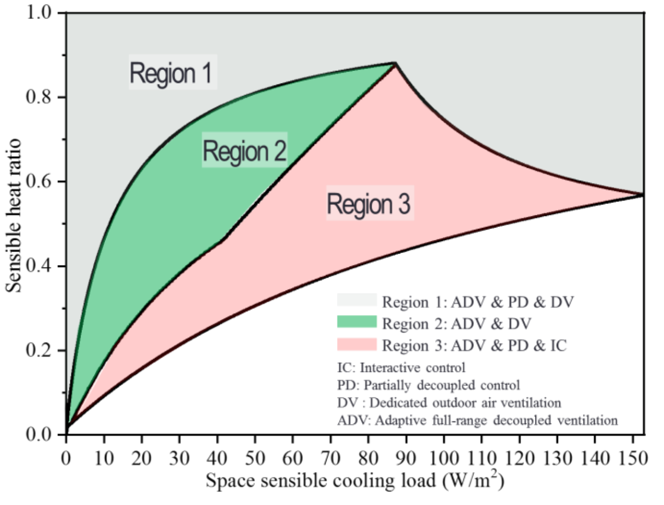


Fig. 2 Preferred ventilation mode in different internal load regions under Hong Kong design weather condition

The proposed "adaptive full-range decoupled ventilation strategy" (ADV) is a ventilation strategy that can **identify the most economical operation mode** under full-range of weather and internal load conditions. The strategy overcomes the limitations of typical ventilation strategies, such as IC, DV and PD.

Thank you !

Validation of a Digital Twin with Measurement Data

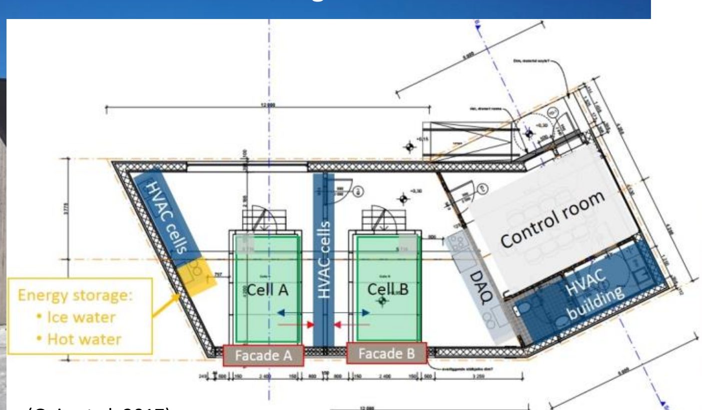
Johannes Brozovsky[1,2], Matthias Haase[1], Nicola Lolli[1]

[1]Department of Architecture, Materials and Structures SINTEF Building and Infrastructure, Høgskoleringen 7b, 7491 Trondheim, Norway

[2]Institute of Building Physics, Technical University of Munich, Arcisstr. 21, 80333 München, Germany

ZEB Test Cell Laboratory

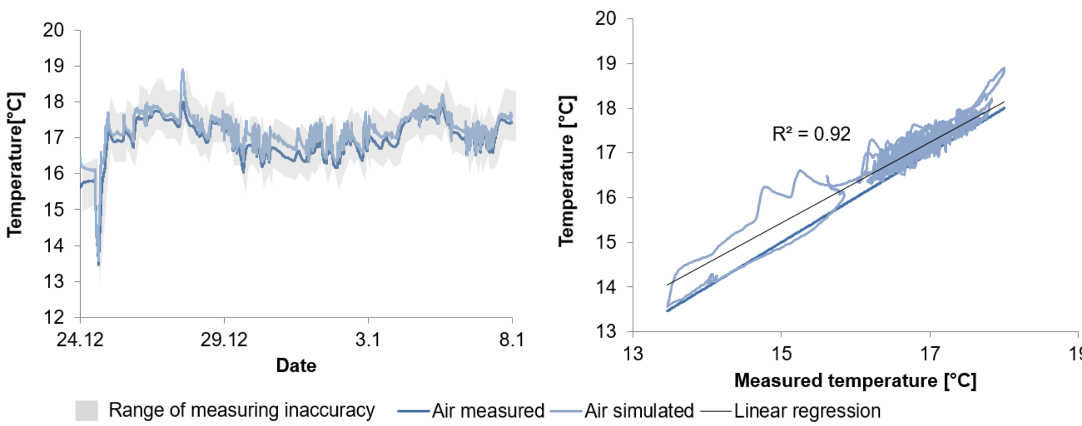
ZEB = Centre for Zero Emission Buildings



(Goia et al. 2017)

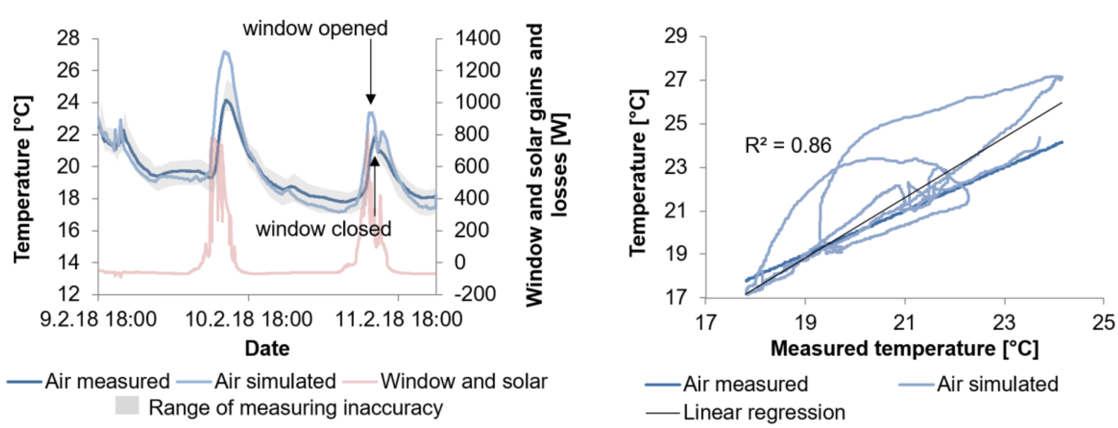
Calibration

Zone air temperature (without opening the window)



Calibration

Zone air temperature (with opened window)



Poster Session

- For more information and if you have questions, please visit at stand no. 15 of the poster session!

Thank you!

CFD analysis of the optimal installation location of adsorption material in two ventilation conditions in residential buildings: natural convection and mechanical ventilation

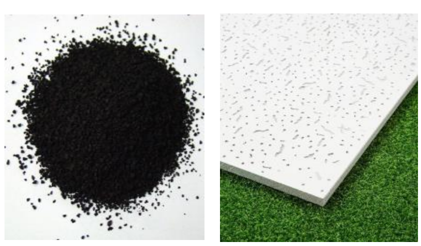
Haneul Choi, Dayoung Kim, Taeyeon Kim*

Department of Architectural Engineering, Yonsei University

Introduction

Installation area

"Health-Friendly Housing Construction Standards propose construction criteria"
suggests a minimum installation area of 10% of the living room and bedroom walls



Adsorption materials

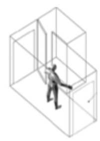
Installation location

Guidelines for the optimal installation location were not provided clearly

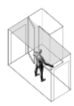
- This study aims **to examine the proper installation location of pollutant adsorption materials in an apartment building using CFD simulation**

Methods

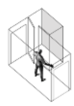
Natural convection conditions(dressing room)



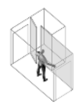
(a) Case 1-0(Baseline)



(b) Case 1-1



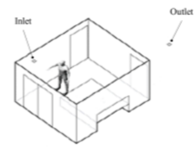
(c) Case 1-2



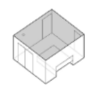
(d) Case 1-3

Simulation cases according to location of adsorption materials in dressing room

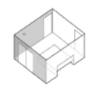
Mechanical ventilation conditions(bedroom)



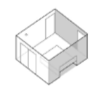
(a) Case 2-0(Baseline)



(b) Case 2-1



(c) Case 2-2



(d) Case 2-3

Simulation cases according to location of adsorption material in bedroom

CFD boundary conditions for the dressing room

	Values
Toluene emission rate	0.32㎎/㎡h
Initial toluene concentration	185.53㎍/㎥
Heat source	55.0W (Human, Sensible heat)
Wall temperature	24℃
Turbulence model	Realizable k-ε turbulence model

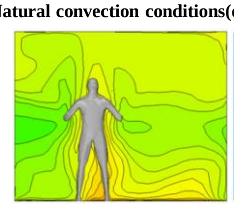
CFD boundary conditions for the bedroom

	Values
Toluene emission rate (Ceiling, wallpaper, flooring, furniture)	0.08㎎/㎡h
Heat source	55.0W (human, sensible heat)
Supply air temperature	20℃
Ventilation rate	0.5 ACH
Turbulence model	Realizable k-ε turbulence model

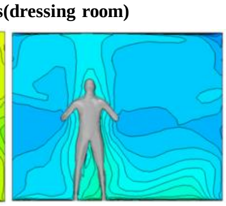
※ The pollutant in the target space was set as toluene according to the Korean standards
※ Toluene was assumed to be a passive scalar and the adsorption surface was analyzed under the condition of a surface concentration of 0

Results

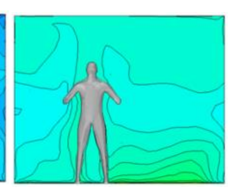
Natural convection conditions(dressing room)



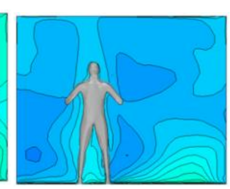
(a) Case 1-0(Baseline)



(b) Case 1-1

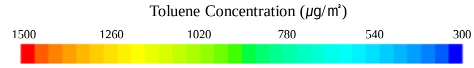


(c) Case 1-2

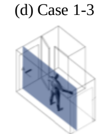


(d) Case 1-3

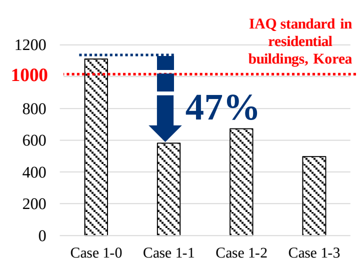
Toluene Concentration (㎍/㎥)



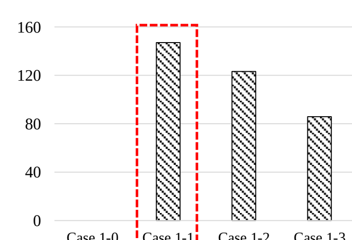
Toluene concentration distribution by cases in dressing room



Section AA'



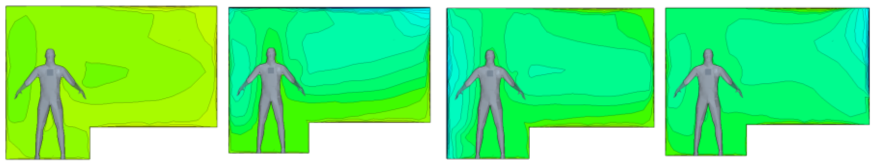
Breathing zone toluene concentration (㎍/㎥)



Concentration reduction / installation area (㎍/㎥/㎡)

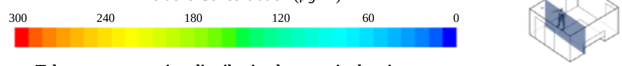
Results

Mechanical ventilation conditions(bedroom)

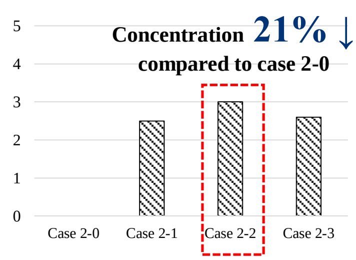


(a) Case 2-0(Baseline) (b) Case 2-1 (c) Case 2-2 (d) Case 2-3

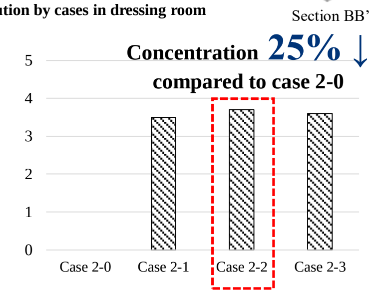
Toluene Concentration (㎍/㎥)



Toluene concentration distribution by cases in dressing room



Breathing zone toluene concentration reduction / installation area (㎍/㎥/㎡)



Room average toluene concentration reduction / installation area (㎍/㎥/㎡)

Conclusion

- Under natural convection conditions, it most effective to install adsorption material
- → in the ceiling given the heat generated from the human body

- Under mechanical ventilation conditions, it most effective to install adsorption material
- → placed near where occupants tend to spend the most time are effective in reducing the concentration of toluene in the breathing zone
- → placed near where air circulation is good and the contact between the pollutant and the adsorption material is active

Acknowledgements

This research was supported by a grant (18RERP-B082204-05) from the Residential Environment Research Program funded by the Ministry of Land, Infrastructure and Transport of Korean government and Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Science and ICT(NRF-2017R1A2B3012914)

Thank you

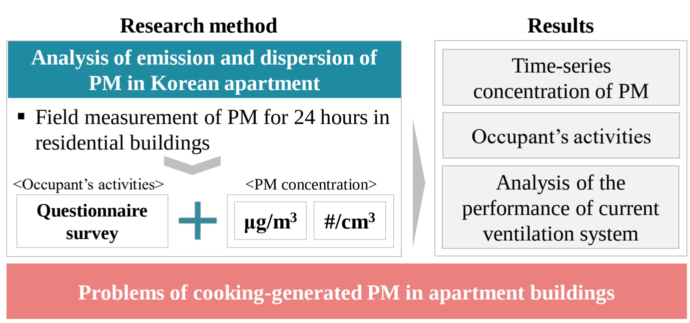
Indoor particle concentration related to occupant behavior of Korean residential buildings

Hyungkeun Kim[1], Hangyeol Park[1], Kyungmo Kang[2], Yun Gyu Lee[2], and Taeyeon Kim*[1]

[1]Yonsei University, Seoul, Republic of Korea
[2]KICT, Goyang-si, Gyeonggi-do, Republic of Korea

Introduction

- Indoor PM generation is caused by an inflow of outside air or occupants' activities
- In particular, cooking-generated PM constitute the largest portion of the indoor PM generation when the PM concentration of the outside air is not high
- In South Korea, most apartment houses are equipped with ventilation devices, however most of residents don't operate ventilation system
- The objective of this study is to analyse current PM condition of Korean residential buildings



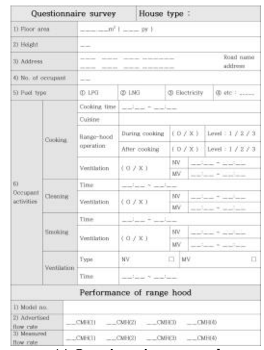
Methods : Field measurement

<Contents of field measurement>

Category	Item	Contents
Target building	Building type	Korean residential buildings(Apartment house, 8units)
	Measurement points	Outdoor, Living room, Kitchen
	Measuring material	Particulate matter
Duration of measurement	Schedule	Dec, 2017
	Measurement period	24 hours(Interval : 30 sec)
Measuring instruments	TSI OPS-3330(4EA)	6 Channel (0.3~0.5, 0.5~0.7, 0.7~1.0, 1.0~2.5㎛)
Questionnaire survey	Occupant activity	Cooking, Ventilation, Cleaning, Smoking

(a) Measuring instruments in the kitchen

(b) Measuring instruments in the living room



Questionnaire survey | House type :
1) Floor area
2) Height
3) Address | Road name address
4) No. of occupant
5) Fuel type | ① LPG | ② LNG | ③ Electricity | ④ etc :
6) Occupant activities
Cooking | Cooking time | Cuisine | Range-hood operation | During cooking (O / X) Level : 1 / 2 / 3 | After cooking (O / X) Level : 1 / 2 / 3 | Ventilation (O / X) NV MV
Cleaning | Time | Ventilation (O / X) NV MV
Smoking | Time | Ventilation (O / X) NV MV
Ventilation | Type NV □ MV □ | Time
Performance of range hood
1) Model no.
2) Advertised flow rate | CMH(1) CMH(2) CMH(3) CMH(4)
3) Measured flow rate | CMH(1) CMH(2) CMH(3) CMH(4)

(c) Questionnaire survey sheet

- The field measurement was conducted on 8 housing units of an apartment house located in a downtown area
- The Occupants' activities were investigated to determine the effects of occupants' activities on the PM concentrations
- The operation and time of occupants' activities– such as cooking, ventilation, cleaning and smoking – were collected through questionnaires

Results : Occupants' activities

<Surveyed data about occupants' activities>

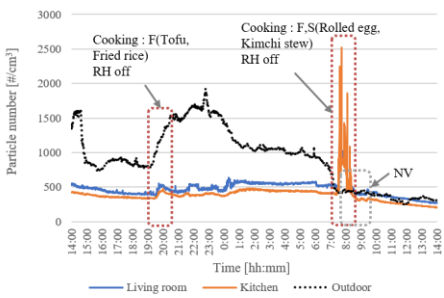
No.	Ventilation		Cleaning		Cooking		Flowrate of rangehood
	n	t	n	t	n	Cooking type	(CMH)
1	-	-	-	-	Bf/D	S/B	285
2	2	30/60	-	-	Bf/L/D	F/S/S	81
3	4	25/20/12/14	1	20	Bf/L/D	F,S/B/B,S	119
4	3	5/25/15	-	-	Bf/L/D	S/S/B,S	245
5	2	20/20	1	15	Bf/L/D	S/ B,F,S/B	95
6	4	25/60/5/20	1	15	Bf/L/D	F,S/ B,F,S/B	95
7	2	30/5	1	15	Bf/L/D	B/B/B,F	125
8	1	25	-	-	Bf/D	B,S/B,F,S	308

Notes
n : Number of times
t : Time(run-time)
Bf/L/D : Breakfast/Lunch/Dinner (Blue text : Range-hood operated)
Type of cooking - B: Broiling, F: Frying, S: Soup

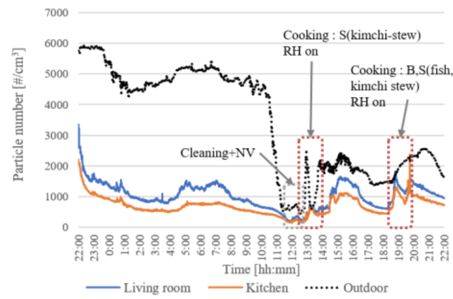
- For ventilation, eight housing units except for one household performed natural ventilation through windows for 23 minutes on average
- Cleaning was done once for 24 hours in six housing units, and the time required for cleaning was 15 to 30 minutes
- Most of them operated the range hood during cooking, and turned it off after cooking
- In most of the housing units, the range hood was operated at a low airflow rate due to noise

Results : PM concentration

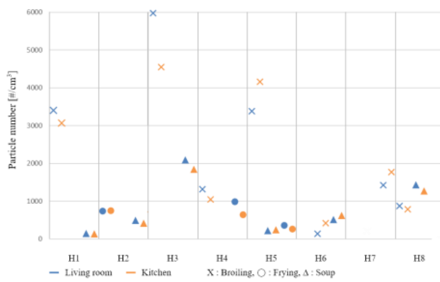
PM concentration of indoor



<PM concentration of house 2>



<PM concentration of house 4>



<PM concentration by each type of cooking>

- In general, the outdoor PM concentrations are very high in houses next to a large road
- Among the rest of occupant activities except for smoking, cooking was found to have the greatest effect on the indoor PM concentration
- In the cooking process, the range-hood was operated most of the time, but the PM dispersed into the living room
- The range-hood was turned off after the completion of cooking in the entire cooking process, which resulted in a slow discharge of PM dispersed in the room
- The broiling method contributes to high PM emissions, it is the most common cooking method among Koreans

Conclusion

1) Difficulty of natural ventilation

- The outdoor PM concentrations are high in most of the housing units
- The indoor PM concentrations increase when natural ventilation is operated through opening windows

2) Emission of cooking-generated PM

- A large amount of PM is emitted in a short time during cooking
- The emitted PM rapidly disperses to adjacent spaces
- The dispersed PM is not directly discharged and remains in the room for a considerable time
- The emission of cooking-generated PM is very high when food is cooked according to the broiling method, which is widely used in Korea

Thank you

Ventilation improvement for make-up air supply system cooking-generated indoor particles

Korea Institute of Civil Engineering and Building Technology
Yonsei University
Researcher (Ph.D. Student)
Kyungmo Kang

Introduction

IAQ with Cooking activities

The major sources in the residential houses

ETS
(Environmental tobacco smoke)

Cooking Activities

Introduction

Make-up air supply system

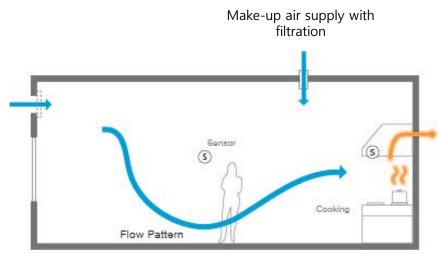
Natural ventilation has been becoming more difficult in Korea.

Two advantages using make-up air supply

1) Induce the concentration to exhaust vent

2) Supply air by filtration

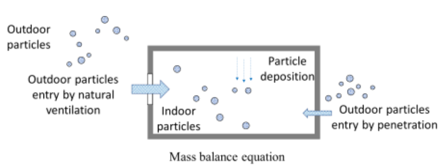
Left: PM_{10}: Below 50㎍/㎥ / Right: PM_{10}: 127㎍/㎥



Ventilation design for cooking activities

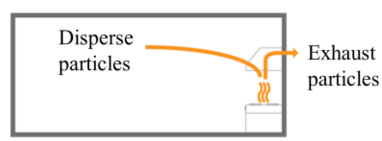
Methodology and Experiments

Mass balance equation and removal efficiency



Mass balance equation

$$V\frac{dN_i}{dt} = aPC_{out} + aVC_{in} - KVC_{in} + S$$



Removal efficiency

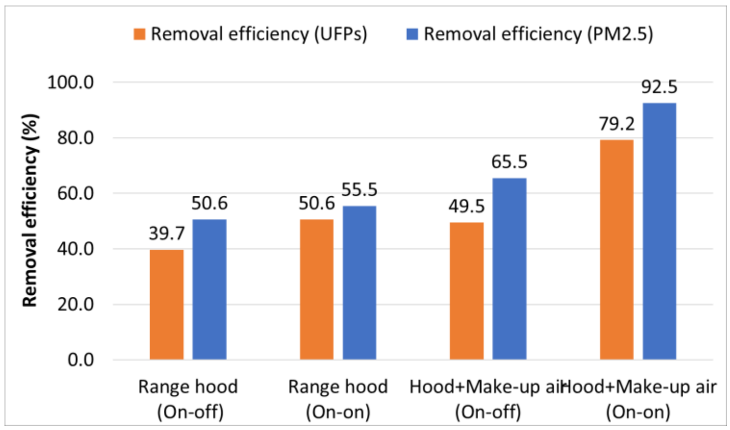
Experiments



- Cooking type: Meat frying
- Cooking time: 15min, (time per 1expeirment:2hr)
- Number of reputation : 9~15 times
- Measurement: $PM_{2.5}$(Dustrak 8532, TSI)
  Ultrafine particles (UFPs , CPC3007, TSI)

Result

Removal efficiency



Make-up air supply system reduces $PM_{2.5}$ and UFPs

Thank You

Presenter : Kyungmo Kang
E-mail :kyungmokang@kict.re.kr

IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

IMT Lille Douai
École Mines-Télécom
IMT-Université de Lille

THE IMPACT ON INDOOR AIR OF BIO-BASED INSULATION MATERIALS: EFFECT OF HUMIDITY AND POTENTIAL MOLD GROWTH

Presented by: Ana Maria TOBON
PhD student

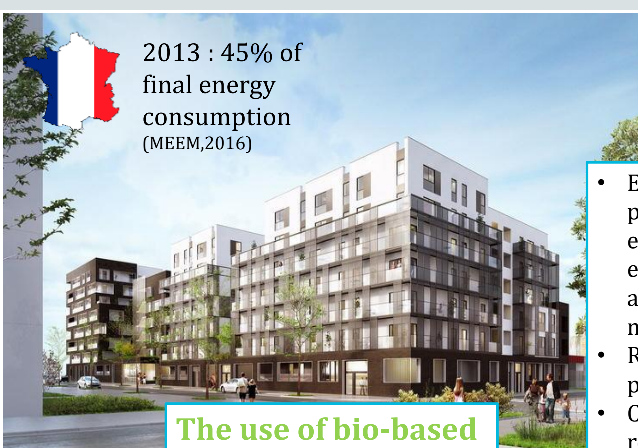
Directed by:
Professor Yves ANDRES, IMT Atlantique
Professor Nadine LOCOGE, IMT Lille-Douai

GEPEA

ADEME

Région PAYS DE LA LOIRE

1. INTRODUCTION



2013 : 45% of final energy consumption (MEEM,2016)

The use of bio-based insulation materials

Energy efficency

- Enhacing insulation properties of building envelopes (retroffiting existing buildings & applying new building norms).
- Reducing petro-based products.
- Conserving natural resources.

1. INTRODUCTION 3

Risks of using bio-based insulation materials : impacts on indoor air quality

Hygrosopicity: promote mold growth

VOCs emissions and microbial VOCs emissions (microbial growth conditions: high relative humidity)

Indoor air quality degradation

1. INTRODUCTION 4

The aim of this work is to (A) characterize VOCs emissions from bio-based insulation materials, (B) analyze the effect of relative humidity on the VOCs emissions and (C) assess materials potentiality to mold growth

A. niger

2. MATERIALS AND METHODS

Wood fiber panel :
90% wood fiber
10% binderfibers

Measure VOCs emissions: CLIMPAQ chamber

CLIMPAQ chamber

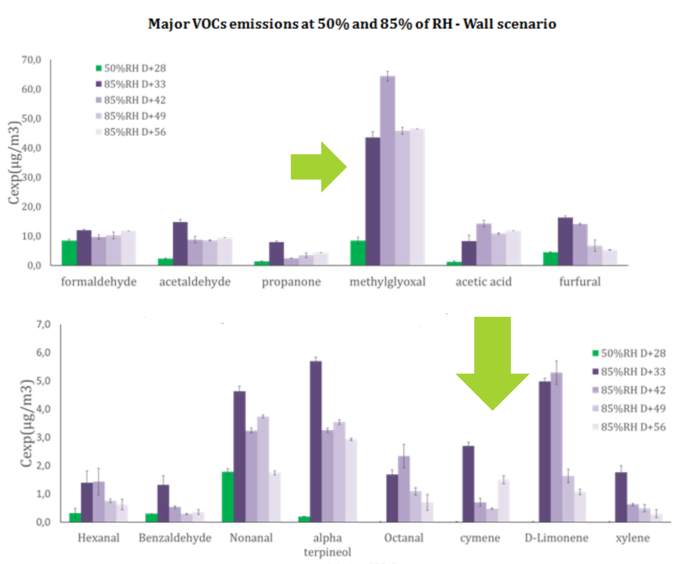
Relative humidity:
50% : 1 sample after 14 days
85% : 1 sample after 3,5,14,21 and 28 days

Sampling: TENAX and DNPH

Analyze: TD-GC-MS and HPLC-MS

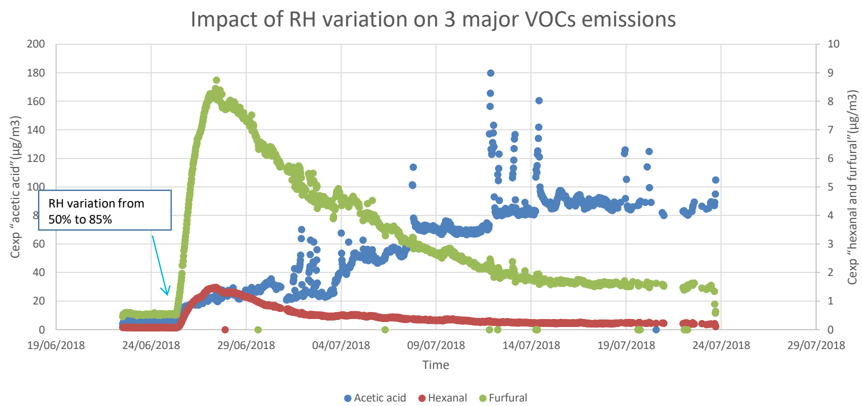
Emissions kinetics: The concentrations of 3 VOCs were continuously measured using an automatic chromatographic analyzer (Airmo VOC C6-C12 Chromatotec ®).

3. EXPERIMENTAL RESULTS



Competition of molecules for adsorption sites

3. EXPERIMENTAL RESULTS 7



Two emissions kinetics were observed when measuring the VOCs concentrations continuously: The coelution « acetic acid+other VOC » concentrations increased, then stabilized and did not come back to the initial level of emission. In the other hand, the « hexanal » and « furfural » concentrations sharply increased when variating RH, and then diminished gradually.

volatility

3. CONCLUSIONS AND PERSPECTIVES 8

- ✓ Variations on relative humidity affect VOCs emissions contributing to indoor air quality degradation. Nevertheless, **the effect of this variation may differ from one compound to another.**
- ✓ Adsorption in porous materials is related to their **microstructure properties** such as porosity, pore size distribution and gas permeability. In order to analyze the adsorption capacity of the tested material, a **BET**(Brunaue, Emett and Telle) test will be performed. Also, the moisture content of the material will be analyzed using the **Karl Fischer** test to analyze the **capacity of the material to retain water**.
- ✓ Other bio-based insulation materials will be tested as well as glass wool.
- ✓ Higher relative humidity can also promote mold development onto the materials, so the test method developed by Le Bayon et al. 2015 will be performed in order **to assess materials resistance to mold growth.**


Thank you!

AIVC 2018 Conference

The Assessment of Particulate Matter (PM2.5) Removal Efficiency on Air Cleaner Products through Full Scale Test in Korea

Korea Institute of Civil Engineering and Building Technology (KICT)
Department of Living and Built Environment Research
Ki Chul Kim

KICT
한국건설기술연구원

1. Introduction

KICT
한국건설기술연구원

Purpose

Purpose of the research

- With the recent rise in particulate matter air pollution in Korea, there has been an urgent need for appropriate measures, and this social climate has resulted in the expansion of market size for air cleaners
- Methods that are currently being applied to domestic air cleaners on the market in Korea include the method to remove particulate matter using a filter, the electrostatic precipitation, which is a method of dust collection that applies high voltage to electrodes and attaches dust particles to the electrode plates, and the method of using activated carbon to absorb and remove gaseous substances
- Therefore, this study aims to investigate the particulate matter (PM2.5) removal efficiency of air cleaners on the market in real life, and it seeks to measure changes in particulate matter concentrations depending on removal method and application area before and after the operation of air cleaners, and thus to estimate the particulate matter removal efficiency of air cleaners based on the results




Hazard of the indoor pollutants

1. Introduction

Research Methods

Research Methods

- In this study, a commercial product with CA1) mark was installed and tested within one hour after removing the package immediately before the test
- The air cleaner was located in the center of the living room, and the changes of particulate matter concentrations in the kitchen and the living room were consecutively measured using the TSI DustTrack II Aerosol Monitor 8532 that provides real-time mass concentration readings

Research Equipment

Number	Removal Method	Application Area (m^2)
1	Electrostatic precipitation technique	40
2	Others (360-degree HEPA air filtration system)	40
3		60
4		80
5	HEPA filter	40

Air Cleaners used for research

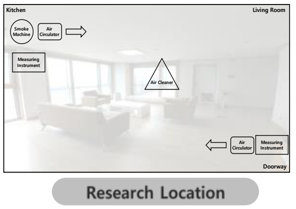
1) CA mark is granted to the products which pass strict tests by certified test agencies in accordance with collective standards for testing indoor air cleaner (SPS-KACA002-132) established by Korea Air Cleaning Association in order to provide consumers with reliable indoor air cleaners

1. Introduction

Research Methods

Research Methods

- Particulate matter was generated randomly for 10 minutes using cigarette smoke with particle less than 1.0 microns in diameter (PM1.0), and the removal efficiency was estimated using the difference in concentrations before and after the operation of air cleaners for 60 minutes
- The test was conducted on the 7th floor of the Zero Carbon Green Home in the Korea Institute of Civil Engineering and Building Technology (KICT)



Research Location

5 min → • Measurement of the initial concentration

10 min → • Generation of Particulate Matter

60 min → • Operation of air cleaner

15 min • Ventilation and shutdown

Research Process

2. Results

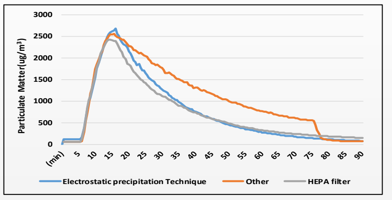
Research Method

Particulate matter removal efficiency

01 Particulate matter removal efficiency by removal method

- Removal Method : Electrostatic precipitation technique & HEPA filter & Others
- Application Area (m^2) : 40
- Airflow Rate : Automatic control

Removal Method	Particulate Matter (㎍/㎥)			Removal Efficiency (%)
	Initial concentration	Maximum concentration	Concentration after operation	
Electrostatic precipitation technique	112	2625	138	94.76
Others	54	2550	550	78.45
HEPA filter	54	2405	206	91.43



Particulate matter removal efficiency by removal method

- Test results confirmed that the particulate matter (PM2.5) removal efficiency of an air cleaner using the electrostatic precipitation technique was 95%, showing that the final concentration was close to the initial concentration after the operation of the air cleaner for one hour, and that of the HEPA filter was 91%, and that of others 78%, respectively

2. Results

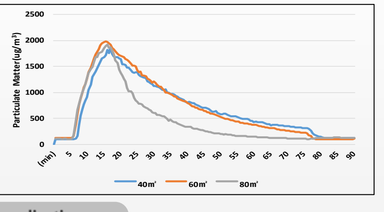
Research Method

Particulate matter removal efficiency

02 Particulate matter removal efficiency by application area

- Removal Method : Others (360-degree HEPA air filtration system)
- Application Area (m^2) : 40, 60, 80
- Airflow Rate : Automatic control

Application Area (m^2)	Particulate Matter (㎍/㎥)			Removal Efficiency (%)
	Initial concentration	Maximum concentration	Concentration after operation	
40	92	1685	307	81.78
60	123	1970	219	88.91
80	102	1850	105	94.32



Particulate matter removal efficiency by application area

- The air cleaners whose application areas are 40㎡, 60㎡ and 80㎡ were used in the test, and it was confirmed that the particulate matter removal efficiency increased to 82%, 89% and 94% as the application areas became larger

Thank you

kichulkim@kict.re.kr

The assessment of surface condensation risk in dwellings
The influence of climate in Spain

Pilar Linares Alemparte. IETcc. CSIC
Sonia García Ortega. IETcc. CSIC

Introduction

The current Spanish IAQ regulation was adapted to accommodate the use of more efficient ventilation systems[1]
Consequence: lower ventilation rates and possible increase of condensation risk

Within the assessment of how lower ventilation rates can affect surface condensation risk
The influence of climate (and the U-value)
Proposal of a new approach

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Method

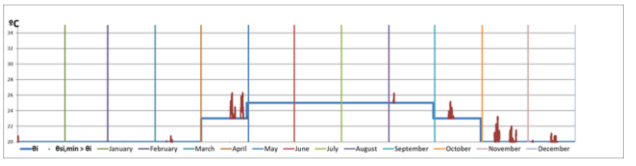
Based on the one described in DA DB-HE/2 (derived from ISO 13788:2012)

Extended: all year

Simplified: U-values are small ➡ eliminated from the calculation process

$f_{RSi,\,min} > f_{RSi}$ ➡ $\theta_{si,min} > \theta_i$

- 5 minutes intervals



- The blue line represents the second term of the equation and the red line the first term above the second term. The peaks of the red line above the blue line represent risks of surface condensation.

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Method

- **Case studies:**
  1: Living/Kitchen + 2 Bedroom + 1 Bathroom
  2: Living + Kitchen+2 Bedrooms + 2 Bathrooms
  3 and 4: Living + Kitchen + 3 Bedrooms + 2 Bathrooms

- **Indoor conditions:**
  - Temperature: 25ºC for hot season, 20ºC for cold season and 23ºC for intermediate seasons.
  - Humidity: Generation of H_2O based on CEN/TR 14788:2007 IN and an occupancy scenario.
  - Continuous ventilation rates

Case study	Total whole dwelling ventilation rate (l/s)
1	14
2	24
3	33
4	33

- **U-values**

	U (W/m²·K)	
	D1	A3
Façade walls	0.26	0.32
Roof	0.23	0.32

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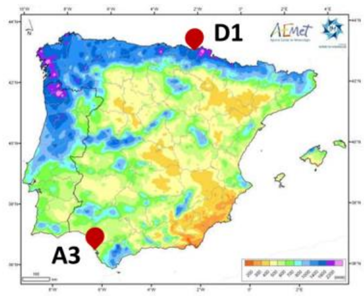
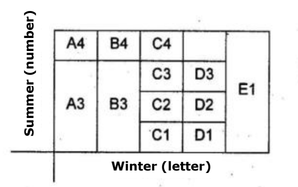
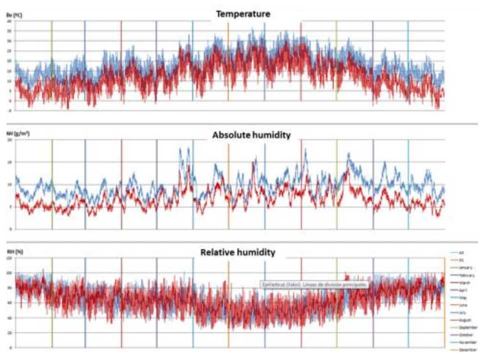
Method

- Climatic zones:
  D1 San Sebastián
  A3 Cádiz







The letter refers to winter conditions and the number to summer conditions

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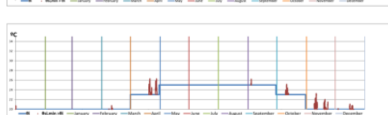
Results

Climatic zone A3.
Variable risk around the year.
Highest peaks of risk in Spring and Autumn, much bigger than in January.
Being the only variables the outdoor conditions and the indoor temperature, this is explained because the relation between outdoor absolute humidity and indoor temperature is higher at those times of the year.

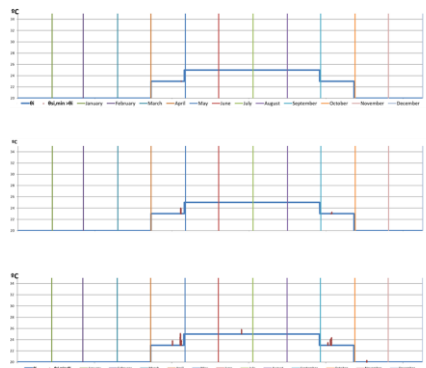


Results

Climatic zone D1

Homogeneous risk around the year.

Only slightly higher in Spring and Autumn in some specific cases.



Conclusions

- Assessment of condensation risk must take into account multiple variables:

  When U-values are low (according to regulations) ➡ The relation between **outdoor absolute humidity and indoor temperature** is the most important factor

- Condensation risk may not only occur in January in all climatic zones, the month when the assessment is usually conducted.

  In climatic zone A3 the bigger condensation risk happens in **Spring and Autumn**

- Therefore, it can be proposed that the condensation risk analysis should be carried out **over a year** instead of only in January in climatic zones where absolute humidity is high in certain times of the year.

Thanks for your attention

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You are in: Home / Presentation — Languages

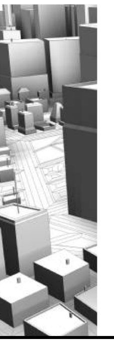
What is CTE?

- Presentation
- Organisations involved
- Performance-Based Codes
- Building Legislation (LOE)

The Technical Building Code. Presentation

Page for the development and dissemination of the Spanish Technical Building Code prepared by the Eduardo Torroja Institute of Construction Sciences. CSIC, in accordance with the collaboration agreement signed with the Architecture and Housing Policy Directorate General of the Ministry for Housing.

The Technical Building Code (TBC)



The Spanish Technical Building Code (TBC) is the normative framework that establishes the safety and habitability requirements of buildings set out in the Building Act (LOE).

To promote innovation and technological development, the TBC has adopted the most modern international approach to building norms: Performance-Based Codes or objectives.

The use of these new regulations based on performance calls for the configuration of a more flexible environment, easily updated in accordance with the development of techniques and the demands of society, and based on the experience of traditional norms.

Spanish society increasingly demands building quality, which means satisfying certain basic requirements both with respect to safety and aspects linked to human welfare.

The TBC is intended as a structured normative framework and seeks to facilitate their application and fulfilment, in harmony with European regulations. Other basic technical regulations, such as the EHE (concrete regulation), will coexist with the TBC and, in principle, will be external references to the code.

The statutory regulations for industrial safety which are dependent on other ministerial departments and that affect installations which are incorporated into buildings, will be given specific consideration.

A stochastic approach to estimate uncertainty in pollutant concentrations in an archetypal Chilean house

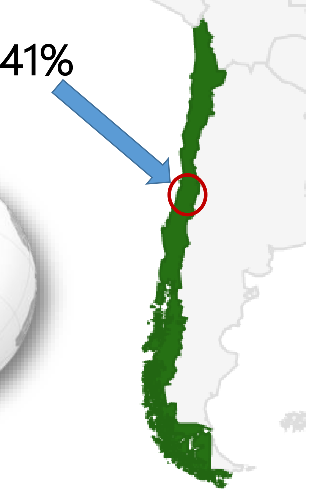
Constanza Molina, Benjamin Jones*, Michael Kent and Ian P Hall

The University of Nottingham, England

AIVC2018

Context

- Chile
- Air pollution exposure was ranked as the 10th greatest risk to morbidity and mortality in 2016
- Great diversity of houses
  - 6m houses, 2.4m in Santiago
  - 7 different climates
- Time spent indoors



To assess the relative influence of several sources of $PM_{2.5}$ in the housing stock of Santiago, Chile.

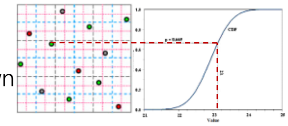
Method

Total housing stock

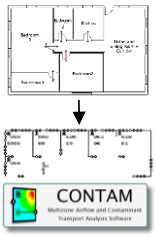
Archetypes

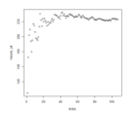
Select inputs

Stochastic parameters using Latin Hypercube sampling and their known probability distribution.



Model and simulate multiple projects





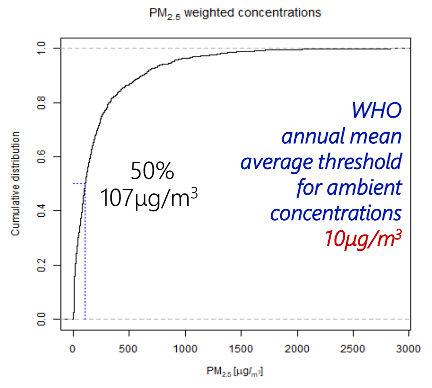
Converged at 1070 projects

Outcome analysis and Sensitivity analysis

$\overline{PM}_{2.5}$

Results and conclusions

Outcomes



*This can be **used to** inform stakeholders and guide housing policies.*

Sensitivity Analysis of the outputs to the inputs

Statistically significant ($p<0.05$)

#1 Cooking meals

#2 6 Heater types

#3 Decay rates

#4 Air Permeability

#5 Flow exponent

***Data shortage** in air permeability and internal air temperatures.*

Thank you

Constanza Molina, Benjamin Jones*, Michael Kent and Ian P Hall

The University of Nottingham, England

* Corresponding author: Benjamin Jones benjamin.jones@nottingham.ac.uk

PEABODY

Dealing with Condensation Damp and Mould at Thamesmead

Peter Rickaby
Energy and Sustainability Consultant

Peter King, Simon Jones
Aereco

Adam Fudakowski
Switchee

Nadira Moreea
Peabody

AECB Convention, 14-15 September 2018

Thamesmead

- Built by GLC in 1970s
  - 2500 homes
  - High-rise tower blocks
  - Medium-rise deck access blocks
  - RC frame and PC panel construction
- Significant fuel poverty
  - DH replaced by individual CH in 2000
  - Under-heated and under-ventilated
  - Condensation, damp and mould
- Significant CDM
  - Stock survey recorded that 18% of homes had damp and mould issues
  - 3000 CDM-related repairs logged in 2015-16, affecting 1900 homes
  - Mould wash and redecoration treatments costing £1275 per home

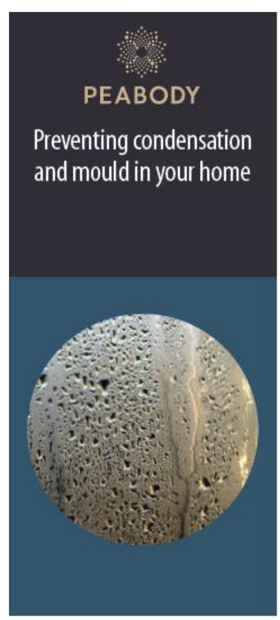
CDM Strategy Objectives

- Manage condensation and mould
- Eliminate CDM where possible
- Mitigate fuel poverty

CDM Strategy

Levels of intervention

- Low risk homes
  - Energy and ventilation advice
    - Delivered to all homes
- Medium-risk homes
  - Energy and ventilation advice
  - Boiler replacement and insulation
    - Where necessary and affordable
  - Switchee smart heating controller
    - Monitors temperature, RH and heating
- High-risk homes
  - Mould washes
  - Energy and ventilation advice
  - Switchee smart heating controller
  - Aereco demand-controlled cMEV
    - RH sensitive continuous ventilation



Ventilation

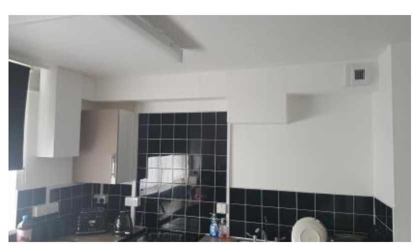
Challenging Specification

- Continuous not intermittent
  - Surveys showed intermittent ventilation ineffective
  - Option of centralised or decentralised MEV
  - PIV not acceptable because of condensation transfer risk
- Capable of delivering 150% of ADF minimum rate
  - To provide capability to deal with high occupancy
  - Occupancy found to be the most significant CDM risk factor
- Demand controlled
  - To combine capacity with efficiency
  - Response range 35%RH to 75%RH
- Quiet: 30 dBA @ 1 m
  - A little too challenging!

The Aereco Quality Standard

AERECO air on demand QUALITY STANDARD

- A joined-up approach that delivers ventilation that works, every time
- DCV provides the capacity to meet ever changing demand
- But only if it’s designed right, installed right and commissioned properly
- The Aereco Quality Standard does exactly that.



Engaging with the all parties involved in the Thamesmead CDM project has enabled Aereco to design, supply, inspect and commission the systems with 100% compliance to the CDM specification.

Aereco DC cMEV at Thamesmead

- All designs eliminate or minimise flexible ducting
  - This reduces noise, improves efficiency and performance, increases life
- Designs include
  - Door undercuts to ensure adequate airflow through the property
  - Sealing of obsolete openings, to eliminate short circuiting

- Installer NJS Electrical's commitment to quality has enabled them to become Aereco's first UK Certified Partner
  - The quality of NJS's work has allowed this two-year process to be shortened
- Aereco will continue to oversee the project for its duration
  - All installations are inspected before sign-off and certification

switchee

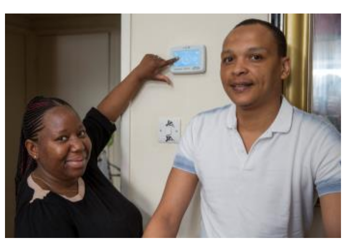
THE FIRST SMART THERMOSTAT FOR AFFORDABLE HOUSING

FIGHTING FUEL POVERTY AND PROVIDING LANDLORDS WITH REMOTE DATA INSIGHTS

£86k*
Saved by Peabody in long-term remedial costs

10.4tonnes
CO2 saved using Switchee p.a.

40
Retrofit CDM solutions monitored using Switchee data



Mr. & Mrs. Jarvis, Peabody residents – claimed £25 pm savings

Mr. Robinson, Peabody resident – claimed 30% savings

ASHDEN AWARD VIDEO

*Estimated savings over a 10 year period (£1,500 net savings per unit)

Switchee online dashboard delivers bespoke, actionable insights to Peabody

Stock Overview

Prioritised action lists

Individual property data

Historical Tracking

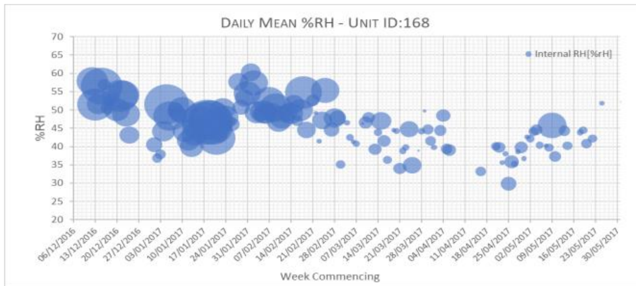
Switchee data highlighting impact of Aereco ventilation

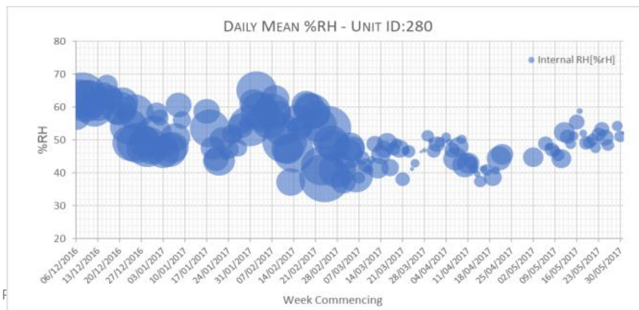
Flat 1 – Argali House
Data Insights (01/02/2017 to 31/03/2017):

Pre-Aereco humidity data

Post-Aereco humidity data

Effectiveness





Effectiveness

- Fuel cost savings (advice) £234/yr/home
- Fuel cost savings (Switchee) £300/yr/home
- CO_2 emissions reduction (total) 18.5 t/yr
- Avoided remedial costs (Switchee total) £8600/yr
- **No ventilation systems switched off**
- **No complaints of ventilation noise or draughts**
- **No reports of mould returning last winter**

Conclusions

- The CDM Strategy is an innovative, systematic and evidence-based approach to a pernicious and long-standing problem
- New technologies such as smart heating controllers and demand controlled continuous ventilation offer affordable and effective interventions
- The comprehensive energy advice programme engages residents and consolidates the effects of interventions by modifying behaviour

Questions

Dealing with Condensation Damp and Mould at Thamesmead

Peter Rickaby
Energy and Sustainability Consultant
Peter King, Simon Jones
Aereco
Adam Fudakowski
Switchee
Nadira Moreea
Peabody

AECB Convention, 14-15 September 2018

A_D :the Japanese body surface area [m^2]
Met :metabolic rate [-]
C_a :age coefficient
C_g :gender factor, Female 0.73, Male 1.00

$$P_{CO_2} = 1.601 \times 10^{-4}(60.63 \times A_D \times Met \times C_a \times C_g)$$

Accuracy Improvement for Estimating Indoor Carbon Dioxide Concentration Produced by Occupants

Masaki TAJIMA
tajima.masaki@kochi-tech.ac.jp
KOCHI UNIVERSITY OF TECHNOLOGY

Background of this work

- CO_2 produced by occupants is often used as a sort of tracer gas for measurement of ventilation aspects at buildings.
- Instead of JIS A 1406[1974] and ASTM D6245, the authors have developed Equations of Japanese CO_2 Production Rate.

More correct

Tracer gas monitor method with using SF_6, N_2O and so on.

VS

More simple and convenient

suit for use condition

CO_2 in exhaled breath (e.g. ASTM D6245, JIS A 1406)

Improvements

- <u>Revising the equation for Japanese CO_2 production rate</u>
  - → transforming the expression
  - → adding the age factor.

$$P_{CO_2} = 1.589 \times 10^{-4} \times (94.4A_D \times 83.9Met \times 21.0C_G - 149.7)$$ -------- Eq.2014

▼

$$P_{CO_2} = 1.601 \times 10^{-4}(60.63 \times A_D \times Met \times C_a \times C_g)$$ ---------- Present work

- <u>Decision of *Met* value</u>
  - Visual judgement ▶ Use of wearable activity meter

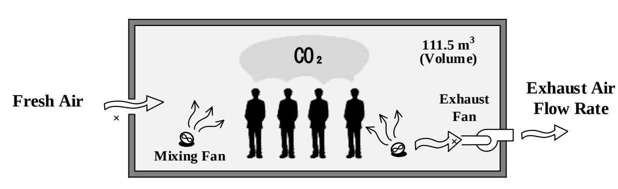
Methodology

1. Accuracy tests for estimation accuracy of *Met* value

   By obtaining Met value utilising a wearable activity meter or a pulse rate monitor, accuracy of occupants' Met value is checked by comparing with Douglas bag method.

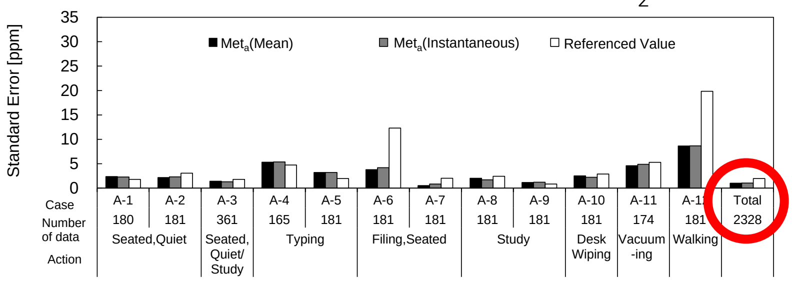
2. Accuracy tests for estimation of carbon dioxide concentration in a ventilated room

   12 cases of experiments were executed in a single zone with 4 occupants.



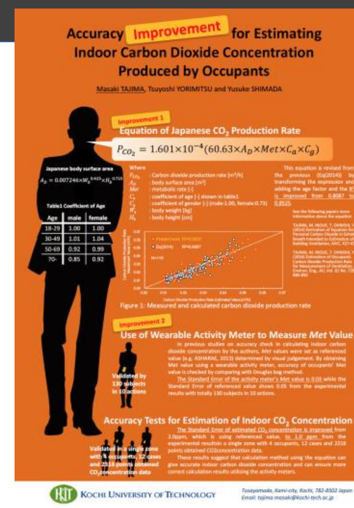
Results

Standard Error of estimated indoor CO_2 conc.

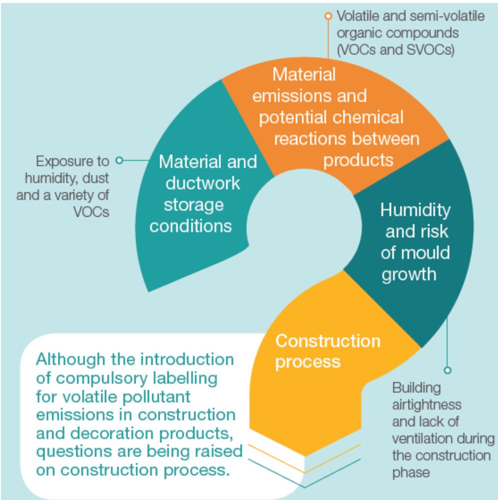


The Standard Error of estimated CO_2 concentration is improved from 2.0ppm, which is using referenced value, to 1.0ppm

These results suggest that estimation method using the equation can give accurate indoor carbon dioxide concentration and can ensure more correct calculation results utilising the activity meters.



Challenges with Indoor Air Quality during Building Construction (ICHAQAI)

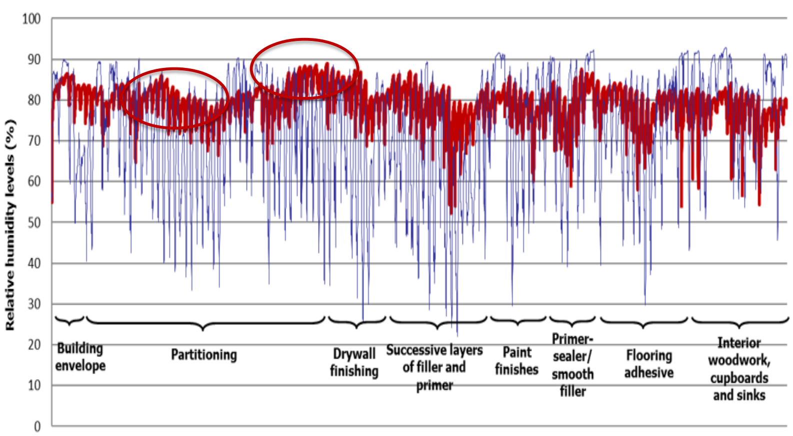


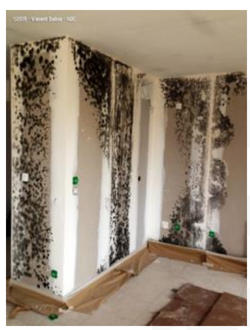
2 goals

1. Increase knowledge by researching contamination factors specific to the construction phase
2. Provide solutions for construction professionals

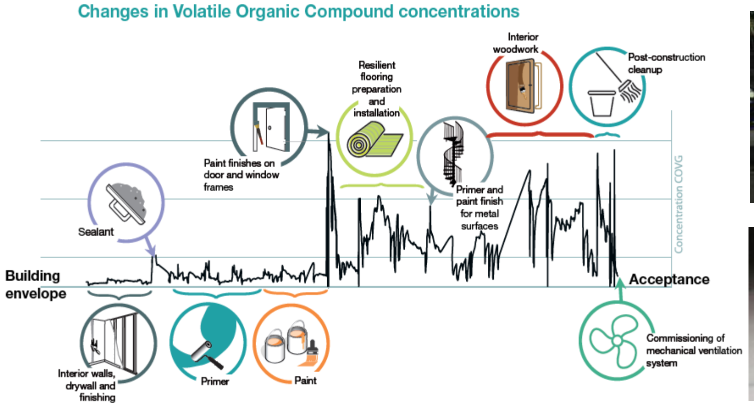
ADEME inddigo EHESP AQC

Disorders caused by high humidity levels





Chemical contaminants and dust



97 solutions to improve IAQ including use of temporary natural or mechanical ventilation systems

39th AIVC Conference

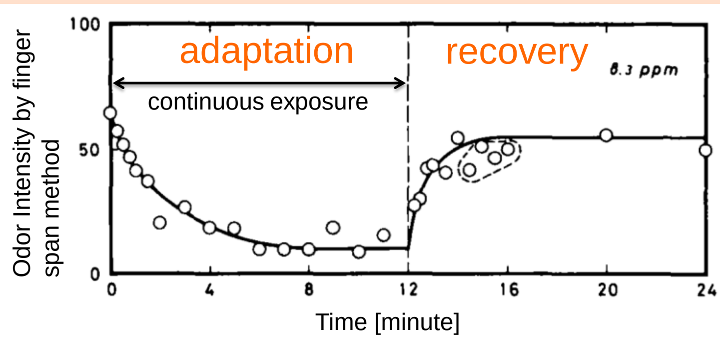
Osaka University

Olfactory adaptation model based on change of odor threshold using impulse response function

Toshio Yamanaka (Osaka University)
Akihisa Takemura (Setsunan University)

Olfactory Adaptation

The figure below shows adaptation and recovery process of olfaction exposed to Hydrogen Sulphide of 8.3ppm by Berglund (1978).



B.Berglund, V.Berglund and T.Lindvall : Olfactory Self- and Cross-Adaptation, Effects of Time of Adaptation and Perceived Odor Intensity, Sensory Process, pp.191-197, 1978

Odor intensity always changes due to olfactory adaptation.

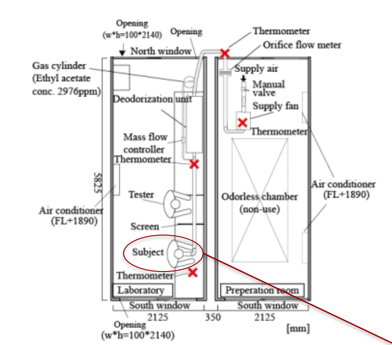
Object of Study

The object of this study is to construct an practical olfactory model for average people which can be applied for predicting the olfactory sensation.

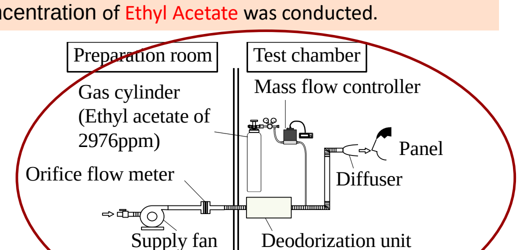
- Firstly, the experiment was conducted to obtain the data of psychological response of odor intensity under the odor concentration with step change on time serious.
- Secondly, the theoretical olfactory model to predict the odor intensity of average people is constructed based on the Weber-Fechner's Law and an impulse response function .
- Lastly, the applicability of the model is verified by comparing the measured data and predicted data.
- Additionally, the model applicability was tested under recovery process of olfactory adaptation using instantaneous exposures of odor under recovering process with fresh air.

Outline of Experiment

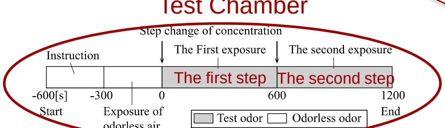
The test to measure the change of odor intensity using 13 panels (i.e. observers) under the exposure of continuous two steps of concentration of Ethyl Acetate was conducted.



Test Chamber

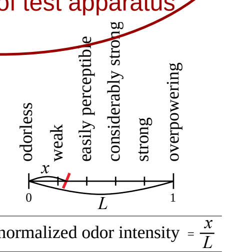


Schematic view of test apparatus



Time schedule of experiment

A sniffing panel



Scale for odor intensity

Adaptation Model Based on Weber-Fechner's Law

5 Osaka Univ.

The odor intensity is assumed to be subject to Weber-Fechner's Law.
The increase of odor threshold is assumed to be calculated by response function.

Exposed odor concentration

$$I_{(t)} = k_c \log_{10} \frac{C_{(t)}}{C_{th0} + \Delta C_{th(t)}}$$

Constant

Increase of odor threshold

Olfactory Threshold under unadapted state

Convolution

$$DC_{th(t)} = \int_0^{\infty} C_{(t-t)} C^*_{th(t)} \, dt$$

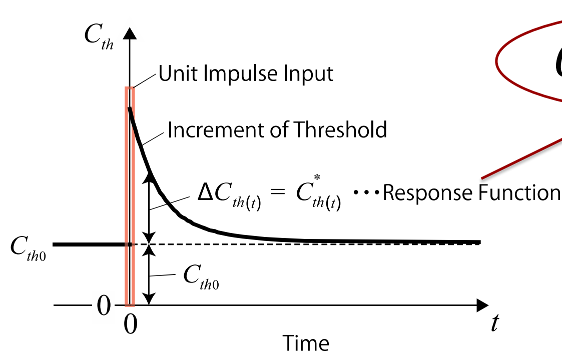
Response function

Definition of Impulse Response Function

6 Osaka Univ.

The impulse response function that is the increment caused by unit impulse can be defined by the exponential function in order to explain the exponential decay of odor intensity.

Increment caused by unit impulse : $C^*_{th(t)}$

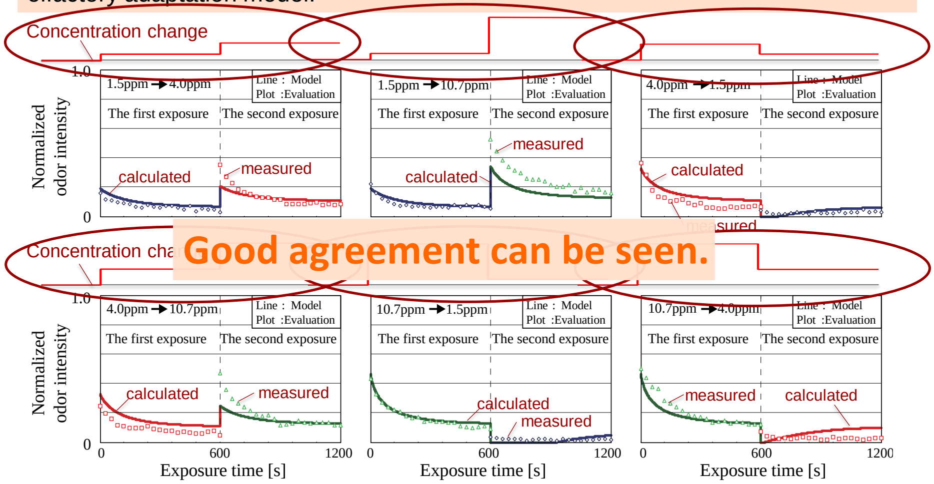


$$C^*_{th(t)} = a \cdot e^{-bt}$$

α and β can be identified by the regression curve of measured data.

Applicability of the Model

The figure shows the comparison between the measured change of odor intensity of averaged data of 13 panels and the change of odor intensity calculated by the olfactory adaptation model.



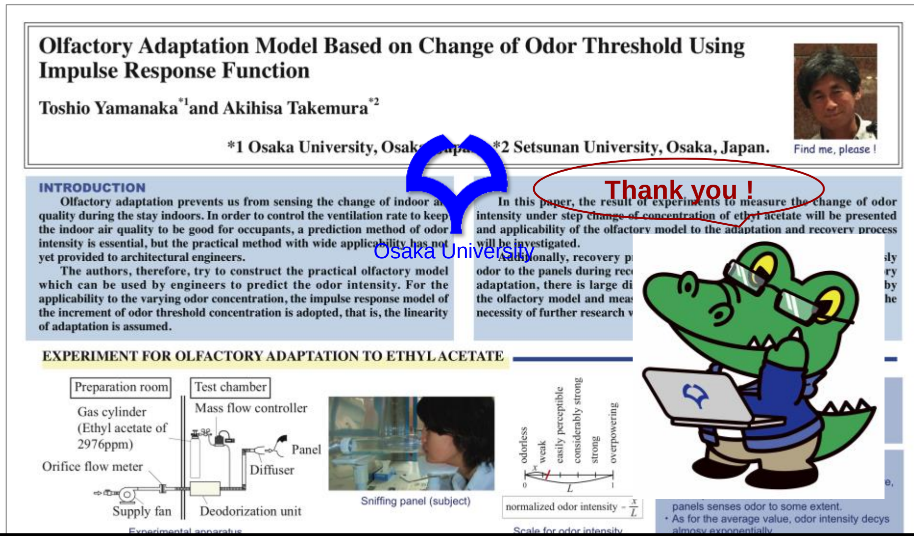
Good agreement can be seen.

Conclusion

From the experiments and investigation on the characteristics of olfactory adaptation and recovery process, the following remarks were concluded:

1. The decay process of odor intensity under adaptation depends on the individual, but the average value of odor intensity decays exponentially.
2. The olfactory model based on Weber-Fechner`s law and impulse response function is valid to predict changing odor intensity under adaptation process using identified model parameters derived from the experimental data.
3. In the recovery process of olfactory adaptation, there is large discrepancy between odor intensity calculated by the olfactory model and measured value by the experiment with 6 panels. The necessity of further research with a large number of panels is confirmed.

See you in front of my poster!!



Regulatory performance-based approaches to residential smart ventilation: a review

Gaëlle Guyot
Cerema Centre-Est & LOCIE, Univ. Savoie Mont Blanc, France
Max Sherman & Iain Walker
LBNL, USA

Outline

- Definitions and context
- Performance-based approaches in 5 standards and regulations
- Perspectives

Definitions

- **Smart ventilation (Durier et al., 2018)** ***: a process to continually adjust the ventilation in time and optionally by location, to provide the desired IAQ benefits while minimizing energy consumption, utility bills and other non-IAQ costs (such as thermal discomfort or noise)***

- **DCV = a subset of smart ventilation**

Definitions

- **Ventilation: prescriptive vs. performance-based approaches**

- **Performance: absolute or equivalent to a "reference system"**

Context

- A number of ventilation standards and national regulations with an allowance for smart ventilation strategies and/or DCV systems in residential buildings

- Simultaneously (often), EP regulations with the opportunity to claim credit for savings from such systems

⇒ **Performance-based approaches defined and required for smart ventilation strategies**

Outline

- Context
- Performance-based approaches in 5 standards and regulations
  - ASHRAE 62.2
  - France
  - Spain
  - Belgium
  - The Netherlands
- Perspectives

ASHRAE 62.2 2016

Compliance required in some State regulations in US and Canada

Performance-based method (equivalent)	Person in charge	Calculated IAQ performance indicators	Credit in EP-calculation	Minimum airflow	Market
Single zone modeling Δt<1h Constant pollutant emission rate	The manufacturer, specifier or designer	No specifically defined pollutant Yearly average relative exposure R<1 At each time-step R_i<5	Rare	Can be null if the total airflow rate equivalence is required over any 3-hour periods	Some DCV systems

Relative Exposure R(t)

$$R(t) = \frac{C(t)}{C_{eq}}$$

To avoid peak exposure

$$R_i = \frac{Q_{tot}}{Q_i} + \left(R_{i-1} - \frac{Q_{tot}}{Q_i}\right) e^{-Q_i \Delta t / V_{space}} < 5 \quad if\ Q_i \neq 0$$

Equation 15

$$R_i = R_{i-1} + \frac{Q_{tot} \Delta t}{V_{space}} < 5 \quad if\ Q_i = 0$$

Where Q_{tot} is the minimum constant ventilation rate calculated according to section 4.1 of the ASHRAE 62.2,
Q_i is the real-time airflow in the variable mechanical ventilation system at time step i,
Δt is the time-step used in the calculation,
V_{space} is the volume of the space.

France

Avis techniques

Performance-based approach (absolute)	Person in charge	Calculated IAQ performance indicators	Credit in EP-calculation	Minimum airflow	Market
Multi-zone modeling Δt =15 min Conventional entry data: meteorological, homes geometries, airleakage distribution, occupancy, ...)	The manufacturer	Per room, over the heating period : 1/CO_2 cumulative exposure indicator E_{2000} < 400.000 ppmh 2/Number of hours $T_{RH>75\%}$ <600 h in kitchen, 1000 h in bathrooms, 100 h in other rooms	Average equivalent extracted airflow (m³/h) can be implemented in the EP-calculation ~ -40%	Switch off not allowed 10-35 m³/h according to the number of rooms in the building	> 30 years > 25 DCV systems with agreements (mostly RH controlled) > 90% new homes

$$E_{2000} = \sum_{t=0}^{T} C_{CO_2>2000}(t) * t < 400\,000\ ppm.h$$

Spain

Documento de Idoneidad Técnica

Performance-based approach (absolute)	Person in charge	Calculated IAQ performance indicators	Credit in EP-calculation	Minimum airflow	Market
Multi-zone modeling Δt =40 s Conventional entry data: meteorological, homes geometries, occupancy, …)	The manufacturer	Per room, over the year : 1/CO_2 cumulative exposure indicator E_{1600} < 500.000 ppmh 2/ Yearly average CO_2 concentration < 900 ppm	Yearly average ventilation airflow could be implemented in the EP-calculation	/	3 DCV systems with agreements (recent procedure)

2017 : Towards a performance-based approach for every new building equipped with any type of ventilation system

Belgium

No more ATG-E since 2015

Former performance-based approach (equivalent)	Person in charge	Calculated IAQ performance indicators	Credit in EP-calculation	Minimum airflow	Market
Multi-zone modeling Δt =5 min Conventional entry data both deterministic and stochastic	The manufacturer	Per person, over the heating period, At least equal that the worst performing reference system : 1/CO_2 cumulative exposure indicator E'_{950} 2/Monthly average RH> 80% on critic thermal bridges from December 1st to March 1st 3/Exposure to a tracer gas emitted in toilets and in bathrooms	An energy saving coefficient f_{reduc} is extrapolated and can be implemented in the EP-calculation	/	35 DCV systems with agreements (mostly CO_2 controlled)

Belgium

No more ATG-E since 2015

- 2014: DCV systems considered as mature enough to be directly integrated in the EP-calculation method
- A study (Caillou et al., 2014b) evaluated the 35 systems gaining the ATG-E through an advanced equivalence method
- 2016: only the energy saving coefficients f_{reduc} given in the tables of an Ministerial Order (Moniteur Belge, 2015) can be used directly in the EP-calculation
  - Sensors accuracy requirement

The Netherlands

Standard NEN 8088 & a complementary performance-based approach

Prescriptive and performance-based approaches (absolute)	Person in charge	Calculated IAQ performance indicators	Credit in EP-calculation	Minimum airflow	Market
Correction factors are given in the standard NEN 8088 for quite a few DCV systems OR A complementary performance-based approach uses a multi-zone modeling, in a semi-probalistic approach	The person involved in EP-calculation (prescriptive approach) OR the manufacturer (performance-based approach)	Per person, over the heating period : Cumulative CO_2 exposure over 1200 ppm: LKI_{1200} < 30.000 ppm.h	Given correction factors directly used in the EP-calculation OR New correction factors are calculated	A function of the number of type of occupants	>35 DCV systems with agreements

$$LKI_{1200} = \sum_{t=0}^{T} \left(\frac{C_{CO_2 > 1200}(t) - 1200}{1000} \right) * t < 30\ kppm.h$$

Equation 22

Where $C_{CO_2>1200}(t)$ is the absolute concentration at which an occupant is exposed at t time-step, if it is higher than 1200 ppm, or 800 ppm above the outdoor concentration.

Conclusion

- **Performance indicators used in performance-based approaches for smart ventilation strategies are related to CO_2 exposure and condensation risk (exc. ASHRAE 62.2)**
- **As many smart ventilation systems types than regulations and performance-based methods …**

Perspectives

- **This background is being used in a PhD thesis about the development of a performance-based approach at the design stage of every new house equipped with any type of ventilation system**
  - ~ EP regulatory calculation

50 kWhep/year/m² !
No condensation !
An healthy indoor air !

Spekkink, D. 2005. Key note presentation on PeBBu, CIB Conference, Helsinki, 2005

Thank you for your attention !

The authors would like to thank Samuel Caillou (BBRI, Belgium), Pilar Linares and Sonia García Ortega (CSIC, Spain), and Wouter Borsboom (TNO, the Netherlands) for their help in the description of the past and current performance-based approaches for DCV systems in their countries.

Further information in:

Guyot, G., Walker, I.S., Sherman, M.H., 2018. Performance based approaches in standards and regulations for smart ventilation in residential buildings: a summary review. International Journal of Ventilation 0, 1–17. https://doi.org/10.1080/14733315.2018.1435025

Type of detection in dry spaces	Type of regulation of air inlets in dry spaces	Local detection in humid spaces with regulation of air outlet Local regulation	Local detection in humid spaces with regulation of air outlet No local regulation	Other or no detection in humid spaces
CO_2-local : at least a sensor in each dry space	Local	0.35	0.38	0.42
	2 zones (night/day) or more	0.41	0.45	0.49
	Central	0.51	0.56	0.61
CO_2- partially local : at least a sensor in each bedroom	Central	0.60	0.65	0.70
CO_2- partially local : at least a sensor in the main bedroom + at least a sensor in the living room	2 zones (night/day) or more	0.43	0.48	0.53
	Central	0.75	0.81	0.87
CO_2-central : at least a sensor in the exhaust duct(s)	Central	0.81	0.87	0.93
Occupancy-local : at least a sensor in each dry space	Local	0.54	0.60	0.64
	2 zones (night/day) or more	0.63	0.67	0.72
	Central	0.76	0.82	0.88
Occupancy-partially local : at least a sensor in each bedroom	Central	0.87	0.93	1.00
Occupancy-partially local : at least a sensor in the main bedroom + at least a sensor in the living room	2 zones (night/day) or more	0.66	0.72	0.78
	Central	0.87	0.93	1.00
Other or no detection in dry	No, local, per zone, or	0.90	0.95	1.00

Towards an health performance-based approach ?

- As proposed in Sherman, M.H., Walker, I.S., Logue, J.M., 2012. Equivalence in ventilation and indoor air quality. HVAC&R Research 18, 760–773. doi:10.1080/10789669.2012.667038

$$DALY = \sum_i Concentration_i * UDE_i$$

Equation 23

$$DALY_{limit} = \sum_i Standard_i * UDE_i$$

Equation 24

Compound	UDE $\left[\frac{\mu DALYS}{year*person} * \frac{m^3}{\mu g}\right]$	Chronic Standard $\left[\frac{\mu g}{m^3}\right]$	Chronic Standard damage $\left[\frac{\mu DALYS}{year*person}\right]$
Priority Pollutants			
1,3 Butadiene	0.02	0.06	0.001
1,4-dichlorobenzene	0.03	0.91	0.024
Acetaldehyde	0.3	3.7	0.96
Acrolein	190	0.02	3.7
Benzene	0.08	0.34	0.025
Formaldehyde	6.8	1.7	11.4
Naphthalene	0.47	0.29	0.14
Nitrogen Dioxide	0.70	40	27
$PM_{2.5}$	500	15	7,500
Other contaminants			
Ammonia	0.23	200	46
Ozone	1.4	147	200
Crotonaldehyde	1.02	N/A	N/A

Table 11: Indoor air contaminants – UDE_i and $Standard_i$ values in order to implement the IAQ equivalence principle according to Equation 23 and Equation 24 , source : (Sherman et al., 2012)

BERKELEY LAB
LAWRENCE BERKELEY NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

Rethinking Occupancy-Based Ventilation Controls

39th AIVC Conference 2018

Iain Walker and Brennan Less
iswalker@lbl.gov

Introduction

Traditionally:

1. Sense occupancy
2. Turn ventilation off (or low setting) if no occupancy

Assumes occupants (and their activities) are the only source

What if we account for other contaminants that are continuously emitted?

- VOCs (e.g., formaldehyde)
- Left over from occupant activities: moisture, odors, particles, etc.

Method

Use simulation software (REGCAP) to calculate relative exposure compared to a continuously operating ventilation system (baseline).

Assumption #1: contaminants emitted continuously.

Assumption #2: contaminants emitted at half rate when unoccupied

Use a real-time control to optimize control strategies

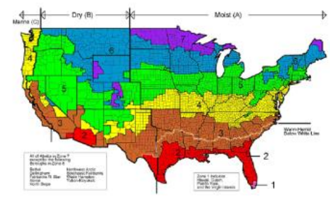
Include infiltration – DOE “Zero energy ready” airtightness 1.5 – 3 ACH50

15 US climate zones

200 m^2, three bedrooms, four occupants

Include operation of kitchen/bath exhaust and clothes dryer

Balanced & unbalanced fans- higher capacity to allow for recovery after occupants return



Occupancy patterns

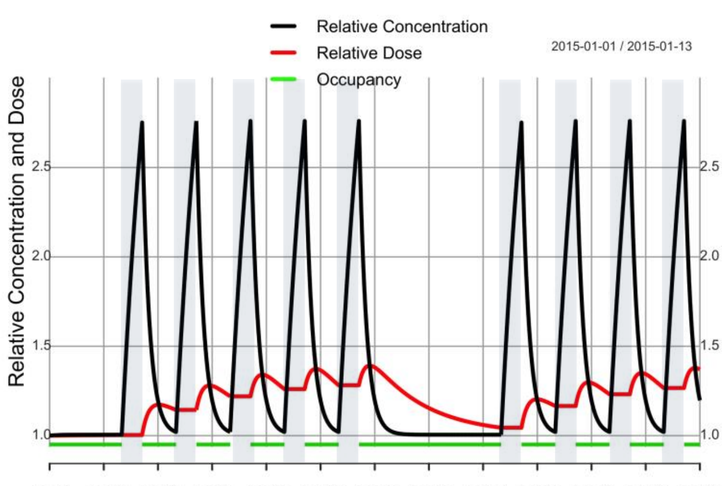
- 1^{st} shift: unoccupied 08 – 17 hr. weekdays
- 1^{st} extended: unoccupied 8 – 22 hr. weekdays + 2 two hour periods each weekend day
- 3^{rd} shift (night shift): unoccupied 21 – 06 hr. weekdays

Smart Ventilation Control

- Real time calculation of exposure and “dose” (24 hour moving average exposure) for ALL times
- Make a decision every 10 minutes to turn fan on or off
  - Fan on if dose or exposure > 1
- During occupied time operate fan to meet target: maintain average relative exposure less than or equal to one
- Unoccupied: maintain average relative exposure less than or equal to five
  - To avoid acute exposure based on ratio of acute to chronic particle exposure levels.

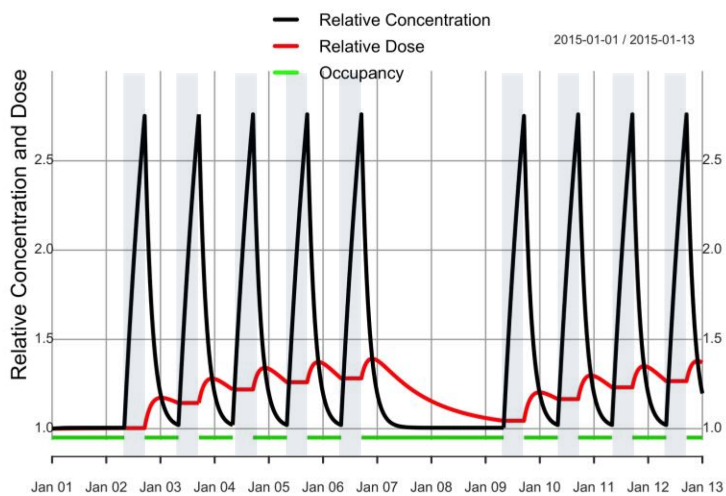
“Traditional” Occupancy Ventilation Control

IAQ Fan Sized to Standard (62.2-2016), Turned Off When Unoccupied



“Traditional” Occupancy Ventilation Control

IAQ Fan Sized to Standard (62.2-2016), Turned Off When Unoccupied



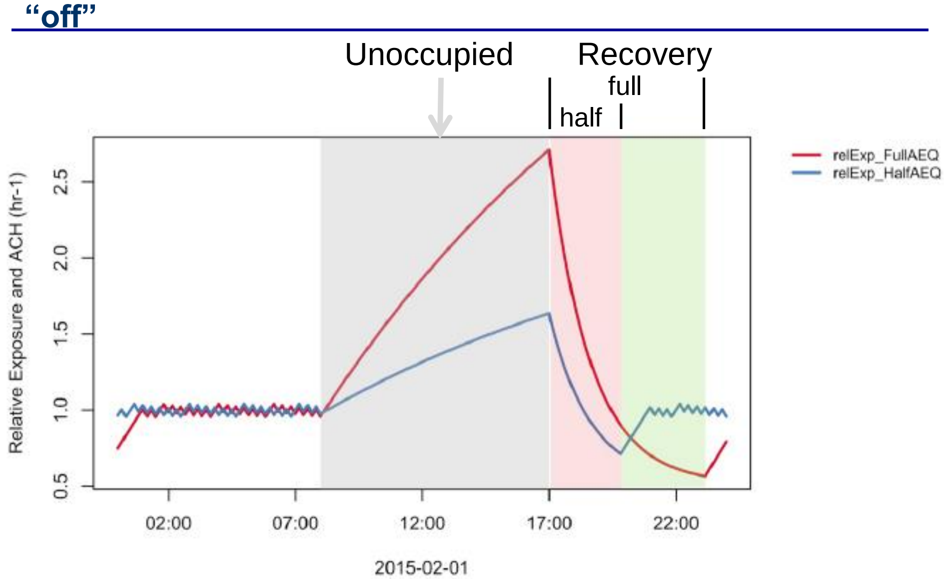
Max Potential, All DOE CZ

Mean Occupied, Relative Conc
1.23

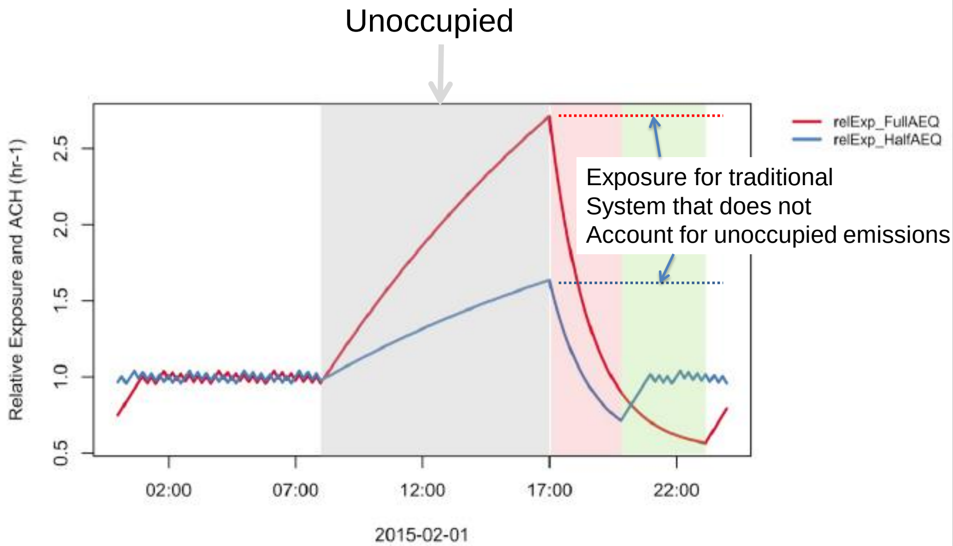
Vent Energy Savings
24%

AER Reduction
18%

Real time controller results- recovery nearly as long as “off”



Real time controller results- recovery nearly as long as "off"

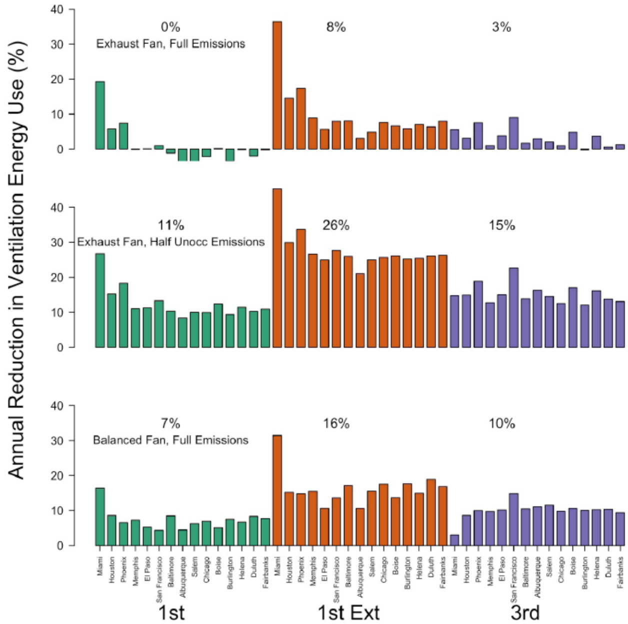


Results: Air exchange and relative exposure

Table 1: Median values for annual average air exchange rate and relative exposure.

Case	Fan Type	Unoccupied Emissions	Air Exchange (ACH)	Relative Exposure
No IAQ fan	None	Full	0.102	4.959
Continuous fan	Exhaust	Full	0.340	1.005
	Balanced	Full	0.358	0.999
Occupancy Controlled	Exhaust	Full	0.326	1.001
	Exhaust	Half	0.298	0.996
	Balanced	Full	0.328	1.007

Results



Why low savings?

1. Recovery period increases ventilation rate when occupants return home

2. In most locations, this shifts ventilation to colder times of day

3. Over-sized fan that is cycled on/off leads to increased mean airflow

Results

- accounting for pollutants emitted during unoccupied periods drastically limited the reductions in average ventilation rate to between 4 and 12%, compared with the 24% reduction not accounting for non-occupied emissions.
- scenarios that assumed pollutant emissions were cut in half during unoccupied times had increased energy savings to an average of 11% for a typical occupancy pattern.

Future work

- Lets figure out this ratio:

$$\frac{\text{occupied emissions}}{\text{total emissions}}$$

Demand controlled ventilation: relevance of humidity based detection systems for the control of ventilation in the spaces occupied by persons

Sébastien Pecceu, Romy Van Gaever, Samuel Caillou

BBRI – Belgian Building Research Institute

Context

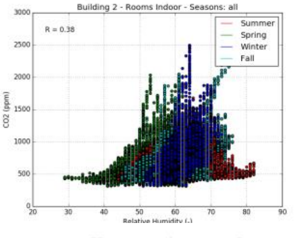
- Applicable Belgian Standard for ventilation of residential buildings: NBN-D50-001:**1991**
- DCV barely mentionned
  " supply or exhaust openings can be equipped with an automatic control system as a function of IAQ, wind pressure, CO2 concentration or humidity"
- On-going pre-normative project on ventilation standard in residential buildings: DCV should be adressed
- Current Belgian DCV practice
  - CO_2 or presence in dry spaces
  - RH in wet spaces
- RH in dry spaces ?

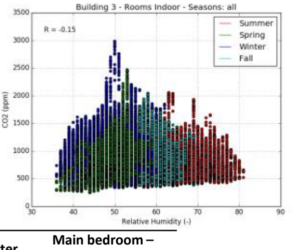
Objective and approach

- Question:
  - Is RH (or related variable) a good tracer of occupancy, and can it be efficiencly used for DCV ?
- Approach
  - CO_2 is a good tracer of human bio-effluents
    correlation between RH and CO_2 from monitoring data
  - Efficiency (IAQ/Energy) of RH DCV ?
    multizone simulations

Data analysis – CO2/RH correlation

- 26 monitored residential buildings
  - > 1 year monitoring
  - Construction: 2004-2010
  - Mostly MHRV sytems
- No to little linear correlation bewteen CO_2 and RH

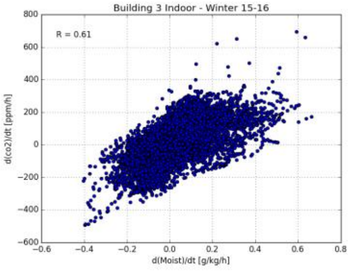




Correlation coefficient statistic	Living room – all year	Main bedroom – all year	Living room – winter	Main bedroom – winter
Average	0.05	0.09	0.07	0.20
Standard deviation	0.14	0.14	0.19	0.13
Maximum	0.38	0.36	0.43	0.54
Minimum	-0.15	-0.29	-0.27	0.01

Data analysis – CO_2/RH correlation

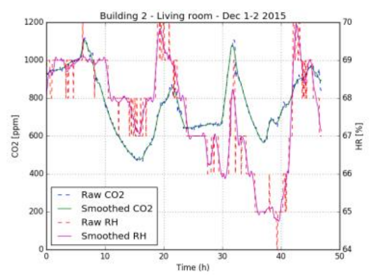
- Correlation with other humidity related variables (AH=absolute humidity in g/kg)
  - CO_2 vs AH → as weak as RH
  - CO_2 vs AH above outside → better but still weak
  - $\frac{d\,CO_2}{dt}\ vs\ \frac{d\,RH}{dt}$
  - $\frac{d\,CO_2}{dt}\ vs\ \frac{d\,AH}{dt}$

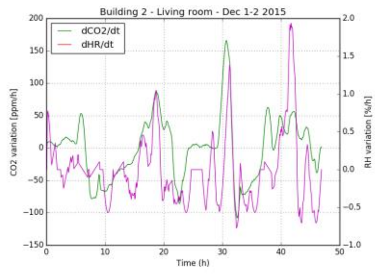


Correlation coefficient statistic	Living room $\frac{d\,CO_2}{dt}\ vs\ \frac{d\,RH}{dt}$	Main bedroom $\frac{d\,CO_2}{dt}\ vs\ \frac{d\,RH}{dt}$	Living room $\frac{d\,CO_2}{dt}\ vs\ \frac{d\,x}{dt}$	Main bedroom $\frac{d\,CO_2}{dt}\ vs\ \frac{d\,x}{dt}$
Average	0.42	0.46	**0.58**	0.44
Standard deviation	0.15	0.13	0.10	0.16
Maximum	0.66	0.73	**0.81**	0.66
Minimum	0.05	0.20	0.35	-0.02

Data analysis – CO2/RH correlation

- Direct CO_2/RH correlation weak
  - RH is not a reliable indicator of human presence wrt CO_2 reference
- Correlation improves
  - Slightly using AH values above outside
  - Significantly when considering derivatives of AH/RH and CO_2
- Efficiency for actual DCV ?



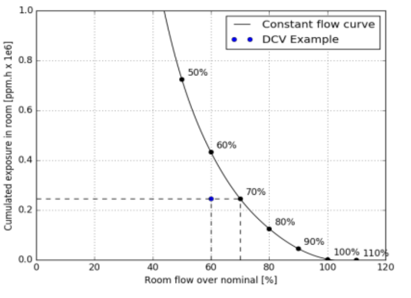


Humidity based DCV – Multizone Simulation (CONTAM)

- Hypotheses
  - Single floor residential building; good airthightness; 4 occupants
  - Mechanical exhaust and supply ; 25 m³/h /occupant in dry rooms
  - IAQ metrics: CO_2 exposure above 1000 ppm (600 ppm above outside) [ppm.h]

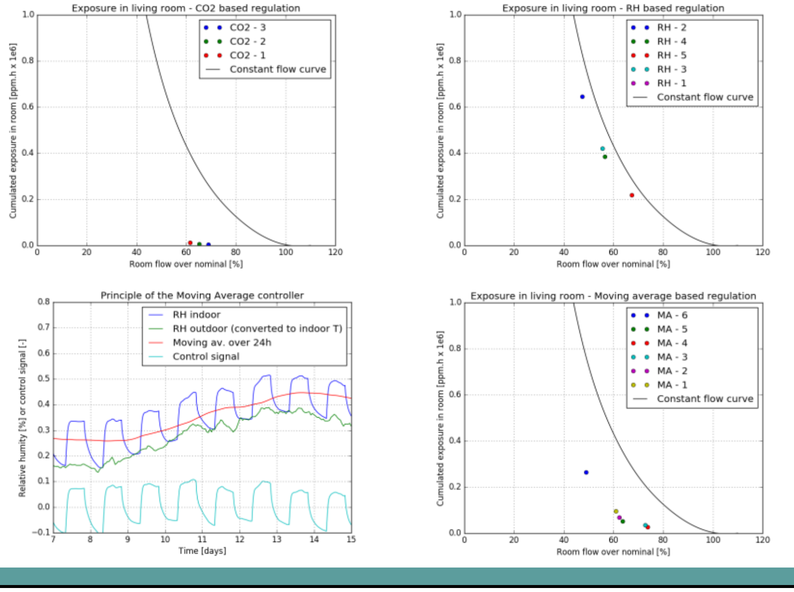
$$E = \int_t CO_2(t)[CO_2 > 1000] - 1000\ dt$$

  - Comparison of DCV strategies with constant flow curve (“efficiency”)



AIVC 2018 – Relevance of DCV based on RH in dry spaces

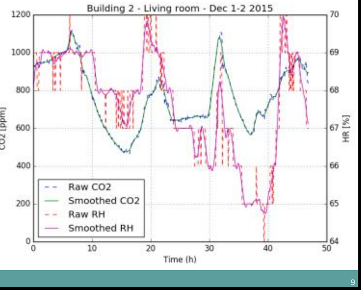
Humidity based DCV in dry spaces – Simulation results



Humidity based DCV in dry spaces – Simulation results

- From the simulation results
  - Direct regulation on RH value not much better than constant flow when looking at the IAQ/Energy trade-off

    More sensitive to outdoor variations than indoor
  - More complex control logic could be efficient (e.g. moving average)
- Should be confirmed in practice
  - RH variations due to human presence are small
  - Acuracy of sensors and controllers wrt the small variations



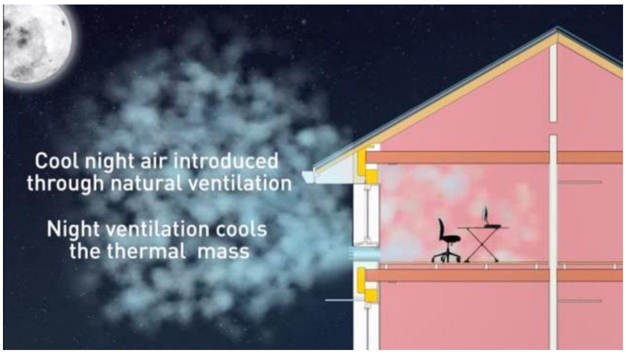
2018 39th AIVC

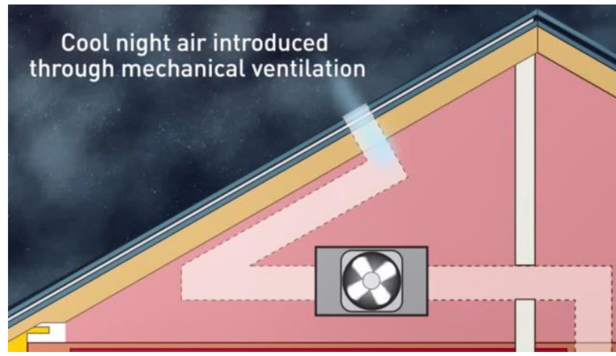
A review of the performance indicators of night-time ventilation

Presenter: Rui Guo
Affiliation: Aalborg University
Email address:rg@civil.aau.dk

CONTENTS

Background





Passive energy technology

Low-temperature outdoor air

Natural
Mechanical
Hybrid

➢ **No framework for night ventilative cooling performance evaluation**

Feasibility of boundary conditions for night-time ventilation

Heat storage efficiency

$$\eta_h = \frac{Q_{hs}}{Q_{hg}} = \frac{c_{dyn} A(\overline{T}_{n,j} - \overline{T}_{n,k})}{Q_{hg}}$$

- Q_{hs} heat storage in building elements
- Q_{hg} daily heat gains
- $\overline{T}_{n,j}$ $\overline{T}_{n,k}$ average building element temperature at daytime j and k respectively
- c_{dyn} dynamic storage capacity of the building elements (kJ/m²K)
- A building elements area (m²)

Cooling potential

$$NCP = \frac{H \rho C_p (T_{i-\max} - T_o)}{3600}$$

- NCP night-time cooling potential (W/m²-h⁻¹)
- H floor height (m)
- ρ air density (kg/m³)
- c_p specific air heat capacity (kJ/kg.℃)
- $T_{i\text{-}max}$ upper operative temperature limit of the comfort zone
- T_o outdoor dry bulb temperature

Application prospect of the night-time ventilation

Performance indicators

Heat removal effectiveness

- Heat removal efficiency $$\eta_H = \frac{Q_n}{\int_{t_s}^{t_e} NCP \cdot S \cdot ACH} = \frac{\int_{t_s}^{t_e} \dot{m}_{air} c_p (T_i(t) - T_o(t))dt}{\int_{t_s}^{t_e} NCP \cdot S \cdot ACH}$$
- Ventilation effectiveness for heat removal $$\varepsilon_t = \frac{T_{out} - T_{in}}{T_m - T_{in}}$$
- Temperature efficiency $$\eta_T = \frac{T_{out} - T_{in}}{\bar{T}_{\mathrm{surface}} - T_{in}}$$
- Decrement factor and daily time lag $$f' = \frac{T_{i,\max} - T_{i,\min}}{T_{o,\max} - T_{o,\min}} \quad \varphi' = \tau(T_{o,\max}) - \tau(T_{i,\max})$$

Reduction in cooling energy use

- Cooling requirements reduction $$CRR = \frac{Q_{t,c}^{ref} - Q_{t,c}^{scen}}{Q_{t,c}^{ref}}$$
- Cooling load reduction efficiency $$f = \frac{(Q_{cm} - Q_{cnv})}{Q_{cm}}$$

Energy efficiency

- Coefficient of performance $$COP = \frac{\int_{t_s}^{t_e} \dot{m}_{air} c_p (T_i(t) - T_o(t))dt}{\int_{t_s}^{t_e} P_e(t)dt}$$
- Potential energy efficiency index $$PEE = \frac{\int_{t_s}^{t_e} \dot{m}_{air} c_p (T_o(t) - T_{out}(t))dt}{\int_{t_s}^{t_e} P_e(t)dt}$$
- Daily average cooling efficiency
- Ventilative cooling seasonal energy efficiency ratio & Ventilative cooling advantage $$SEER_{VC} = \frac{Q_{t,c}^{ref} - Q_{t,c}^{scen}}{Q_{el,v}} \quad ADV_{VC} = \frac{Q_{el,c}^{ref} - Q_{el,c}^{scen}}{Q_{el,v}}$$
- Cooling effectiveness factor $$CEF = \frac{\sum_{j=1}^{m} (\dot{m}_{air,j} C_p (T_{i,j} - T_{o,j})}{A \sum_{k=1}^{n} (I_k)}$$
- Life cycle efficiency ratio $$LCER = \frac{OI_{ref} - OI}{EI - EI_{ref}}$$

Thermal comfort improvement

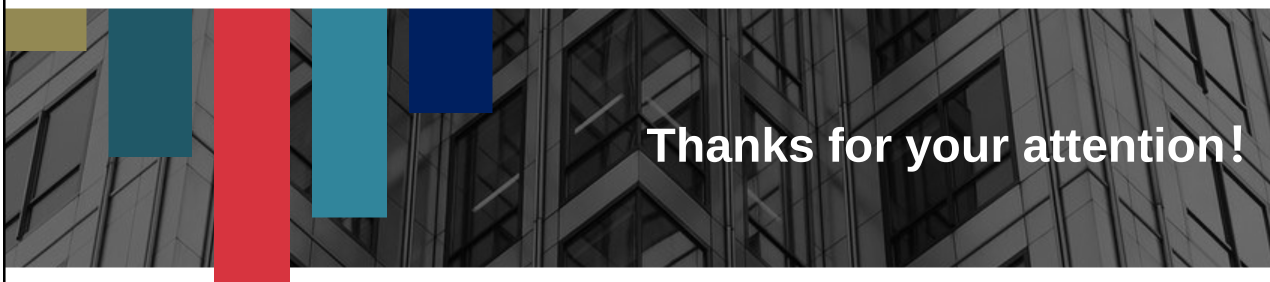
- Percentage outside the range $$POR = \frac{\sum_{t=1}^{Oh} (wf_i \cdot h_i)}{\sum_{t=1}^{Oh} h_i}$$
- Degree-hours criterion $$DhC = \sum_{i=1}^{Oh} (wf_i \cdot h_i)$$
- Long-term percentage of dissatisfied $$LPD(LD) = \frac{\sum_{t=1}^{T} \sum_{z=1}^{Z} \left(p_{z,t} \cdot LD_{z,t} \cdot h_t\right)}{\sum_{t=1}^{T} \sum_{z=1}^{Z} \left(p_{z,t} \cdot h_t\right)}$$
- Weighted discomfort temperature index $$\mathrm{DI} = \sum (T_i - T_{comf,\sup})^2$$

Conclusion

- ➢ **Most of indicators are suitable for simulation analysis**
- ➢ **Other indicators are more suitable for the experiment analysis, since some data is easier to obtain in the field studies**
- ➢ **Thermal comfort improvement indicators are much more prevalent than energy efficiency indicators**
- ➢ **The performance of night ventilation should be represented well by a series of indicators**

Table 1: Summary of applicable conditions for each indicator

Family of indices	Indicator name	Simulation	Experiment
Heat removal effectiveness	Heat removal efficiency	√	
	Ventilation effectiveness for heat removal	√	
	Temperature efficiency		√
	Temperature difference ratio	√	√
	Decrement factor and daily time lag	√	√
Energy efficiency	Coefficient of performance	√	
	Potential energy efficiency index	√	
	Daily average cooling efficiency	√	
	Ventilative cooling seasonal energy efficiency ratio	√	
	Ventilative cooling advantage	√	
	Cooling effectiveness factor		√
	Life cycle efficiency ratio	√	
Reduction in cooling energy use	Cooling requirements reduction	√	
	Cooling load reduction efficiency	√	
Thermal comfort improvement in daytime	Percentage outside the range	√	√
	Degree-hours criterion	√	√
	Long-term percentage of dissatisfied	√	√
	Discomfort over-temperature time percentage and weighted discomfort temperature index	√	√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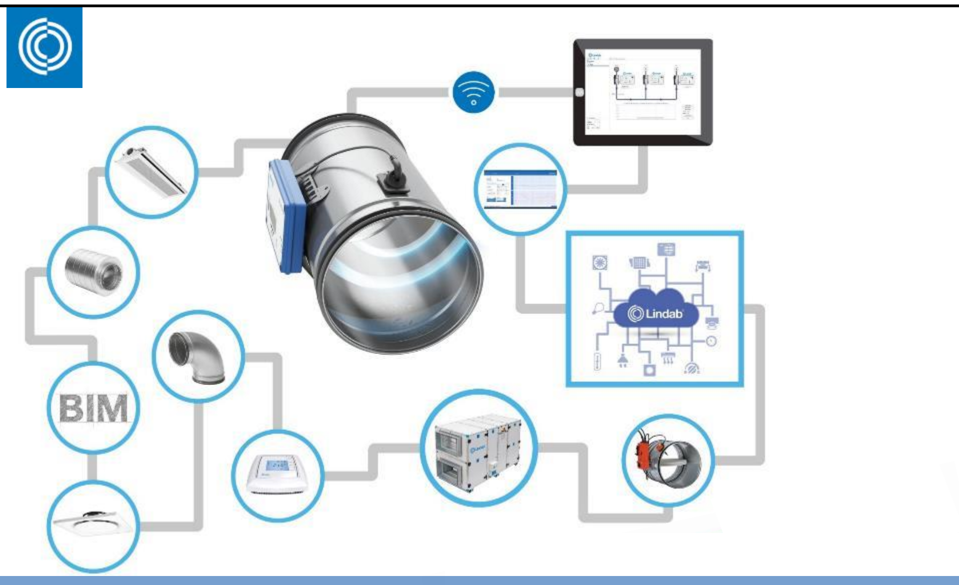
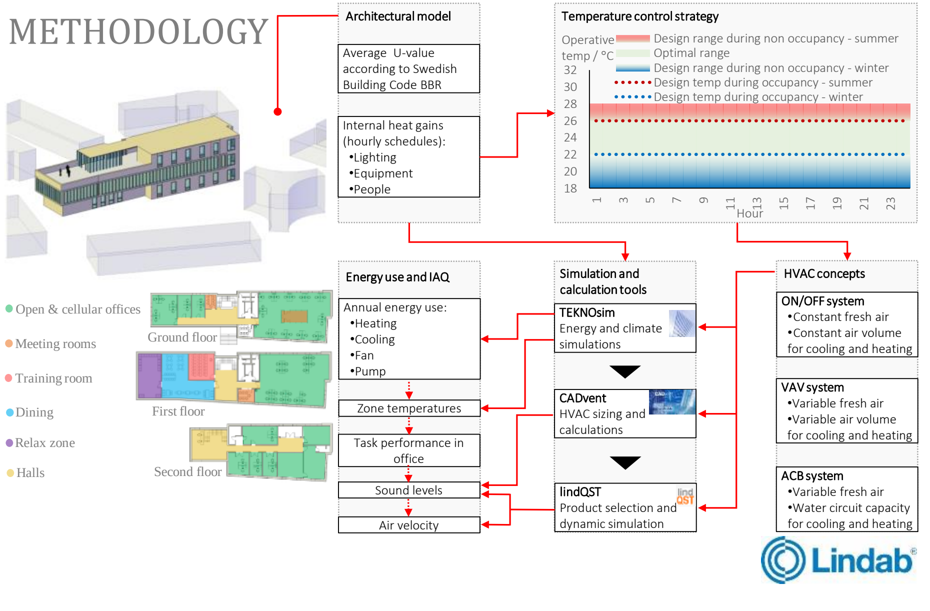


Assessing the energy use and IAQ of various HVAC systems during the early design stage

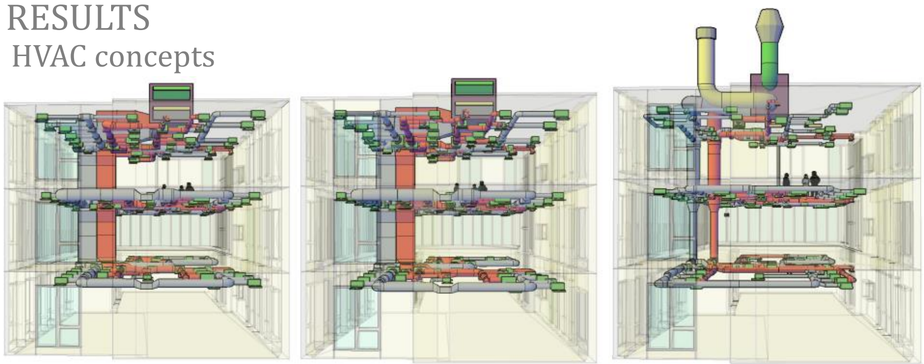
Marwan Abugabbara, Laszlo Sebesten, Jan Behrens
Energy & Climate Solutions – Lindab Ventilation AB

39th AIVC – 7th TightVent & 5th Venticool Conference
Smart ventilation for buildings
Antibes Juan-Les-Pins, France
18 – 19 September 2018

METHODOLOGY

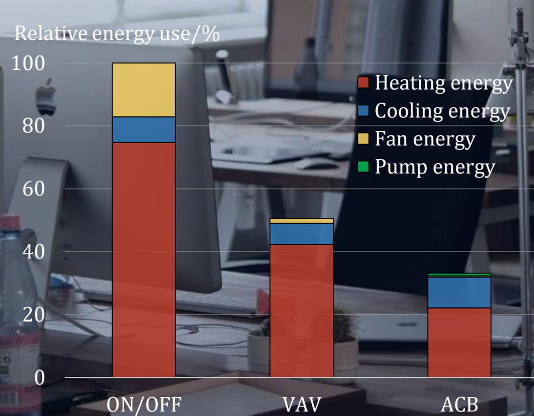


RESULTS
HVAC concepts



ON/OFF	VAV	ACB
• Large ducts and AHU	• Large ducts and AHU	• Small ducts and AHU
• High pressure loss	• High pressure loss	• Low pressure loss
• AHU controls air flow	• Zone control over air flow	• Room control over air flow
• High LCC	• High LCC	• Lowest LCC

Results
Operational energy use



Results
Performance in offices
Relative performance
1.00
0.99
0.98
0.97
0.96
0.95
0.94
0.93
ON/OFF
VAV
y = 0.8579x + 0.1409
R² = 0.9563
y = 1.8027x - 0.8072
R² = 0.8948
0.96
0.97
0.98
0.99
1.00
Relative performance to ACB system
Lindab
P = 0.1647524·T – 0.0058274·T² + 0.0000623·T³ – 0.4685328

FLORIDA SOLAR ENERGY CENTER™
Creating Energy Independence

Measured and Simulated Energy Savings & Comfort Improvement of Smart Residential Ventilation Control Preliminary Results

39th AIVC - 7th TightVent & 5th Venticool Conference

Danny Parker, Eric Martin & Karen Fenaughty
Florida Solar Energy Center, University of Central Florida
Delia D'Agostino, Joint Research Centre, European Commission

18 – 19 September 2018, Antibes, Juan-les-Pins, France

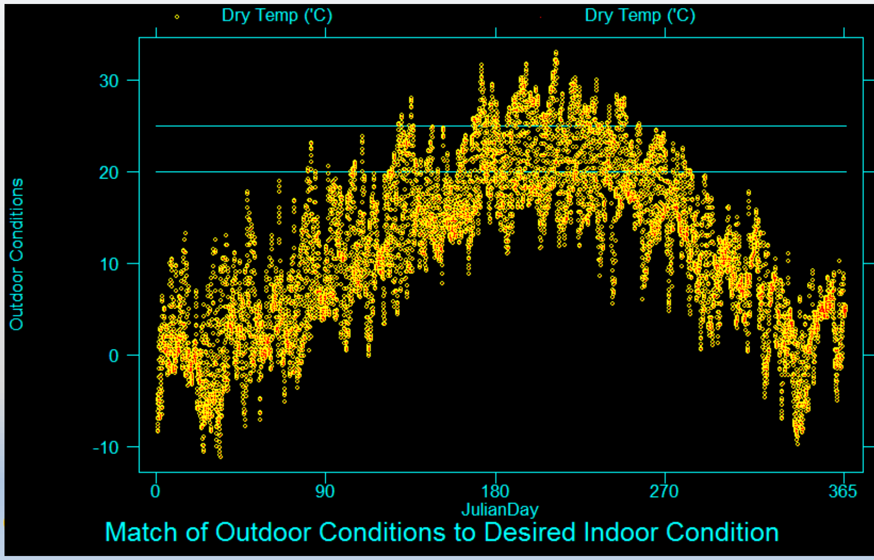
FSEC™
A Research Institute of the University of Central Florida

Smart Ventilation Control

- <u>Objectives</u>
- 1. Use weather to modulate ventilation flow to improve air quality/energy savings
- 2. Maximize heating and cooling energy savings compared to continuous ventilation,
- 3. Maintain similar indoor RH & improved comfort
- 4. Achieve equivalent relative exposure (RE) to pollutant compared with constant ventilation

FSEC™

Milan: Annual Weather: IWEC



Consider Deviation of Weather Outdoors from Idealized Indoor Temperature & Humidity Condition

$$RSS = \sqrt{(\Delta T * X_T)^2 + (\Delta W * X_W)^2}$$

Where:

ΔT (°C) = (indoor temperature) – (outdoor temperature)

X_T = Delta temperature weight

ΔW (g/m^3) = (indoor moisture) – (outdoor moisture)

X_W = Delta moisture weight

Estimated over last 24 hours, weighted recursively relative to current hour

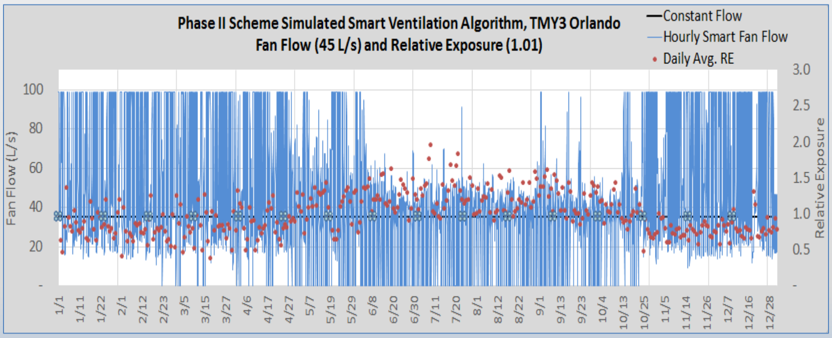
Hourly Fan Flow = (Target Fan Flow * (Average (RSS_1:RSS_{23})/RSS_{24})

Identical buildings that comprise FSEC's Flexible Residential Test Facility

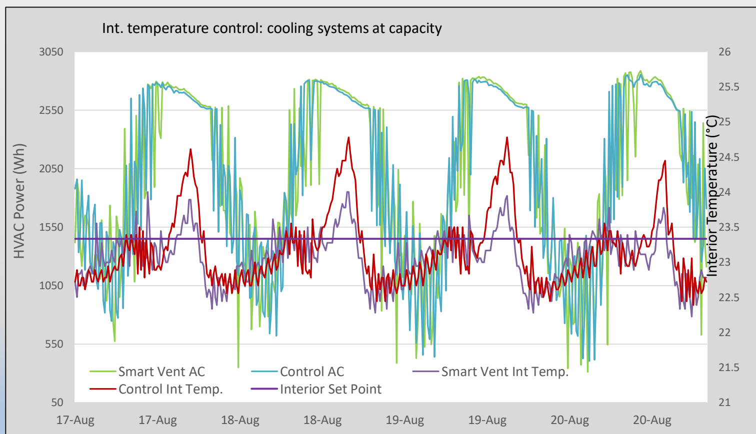
Phase I and II scheme parameters and values

Period (defined by hourly avg. outdoor temp.)	Parameter	Phase I Scheme Values	Phase II Scheme Values
Cooling	Outdoor temp. range for cooling period target	>22°C	>22°C
	Cooling period target fan flow	26 L/s	35 L/s
	Outdoor temp. range for fan lockout (0 L/s)	n/a	>=31°C
Heating	Outdoor temp. range for heating period target	<15.5°C	<15.5°C
	Heating period target fan flow	35 L/s	35 L/s
Floating	Outdoor temp. range for floating period target	<=22°C; >=15.5°C	<=22°C; >=15.5°C
	Floating period target fan flow	65 L/s (fan limit)	99 L/s (fan limit)
	Outdoor W range to adjust floating period target	n/a	>=15g/m3
	Floating period target adjusted for W	n/a	35 L/s
All	Indoor temp. (T)	18°C	18°C
	Delta-temp. weight (X_T)	2	2
	Indoor moisture (W)	12 g/m3	12. /m3
	Delta-moisture weight (X_W)	1	1

Phase II smart ventilation scheme simulated hourly average fan flow and daily average RE



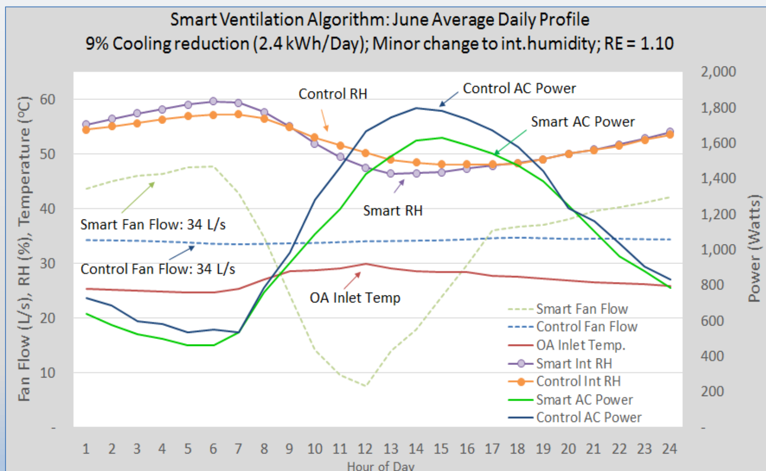
Measured data from August showing reduced indoor temperature generated by the smart ventilation scheme despite air conditioners running at max capacity



Measured energy use during cooling and floating periods for the Phase II scheme

Month	Cooling Energy (kWh)			Fan Energy (kWh)			Total Energy (kWh)			
(n = days of good data)	Fixed	Smart	Savings	Fixed	Smart	Savings	Fixed	Smart	Savings	% Savings
May (n=22)	719	630	89	29	36	(7)	748	666	82	11.0%
Jun (n=22)	822	749	73	29	20	8	851	770	81	9.5%
Jul (n = 26)	1,012	924	88	29	26	2	1,040	950	90	8.6%
Average	851	768	83	29	27	1	880	795	84	9.6%

The June average day profile summarizes Phase II scheme performance



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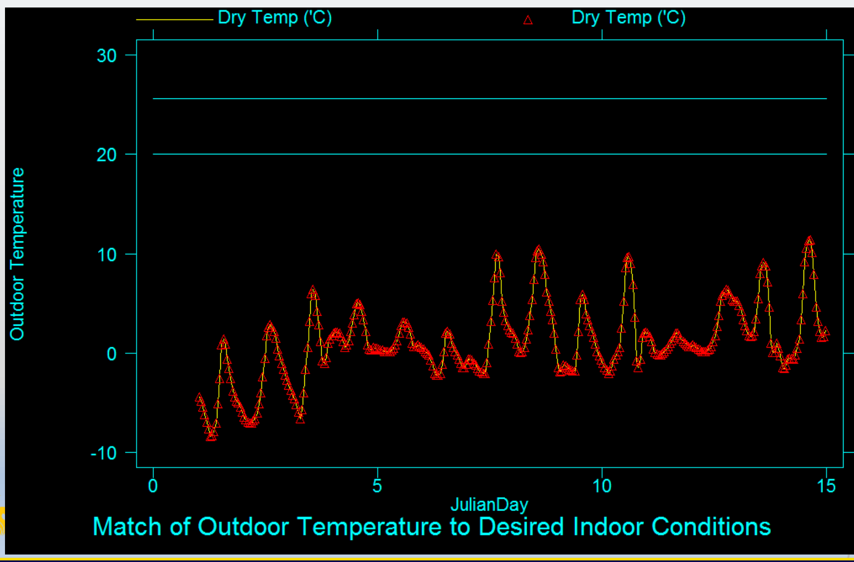
Heating/cooling flow targets: energy savings & relative exposure for multiple climates

Location	Heating/Cooling Flow Target (L/s)	Annual Average RE	Max Hourly RE	Annual Space Conditioning Energy Savings (kWh/%)	Annual Space Conditioning Energy + vent fan Savings (kWh/%)
Orlando, FL	31	1.0	3.6	211 / 8.0%	155 / 5.2%
Atlanta, GA	30	1.0	3.6	182 / 5.4%	117 / 3.2%
Minneapolis, MN	28	1.0	3.2	777 / 5.8%	753 / 5.5%
Chicago, IL	29	1.0	3.2	621 / 6.9%	592 / 6.3%
Phoenix, AZ	31	1.0	3.3	311 / 6.8%	229 / 4.6%

FSEC

Milan, First two weeks in January



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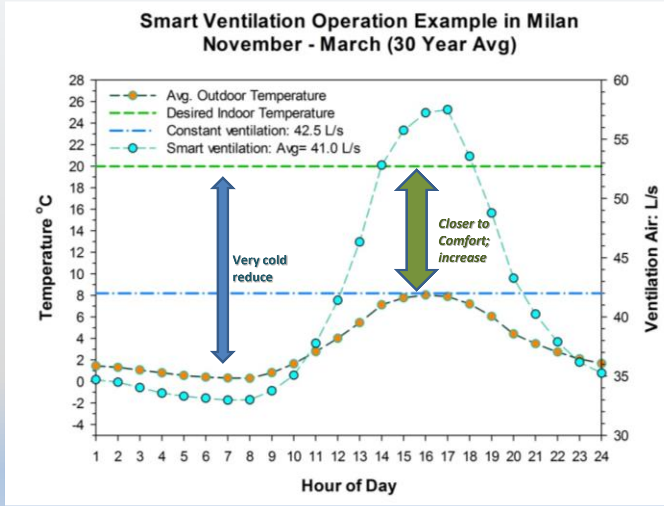
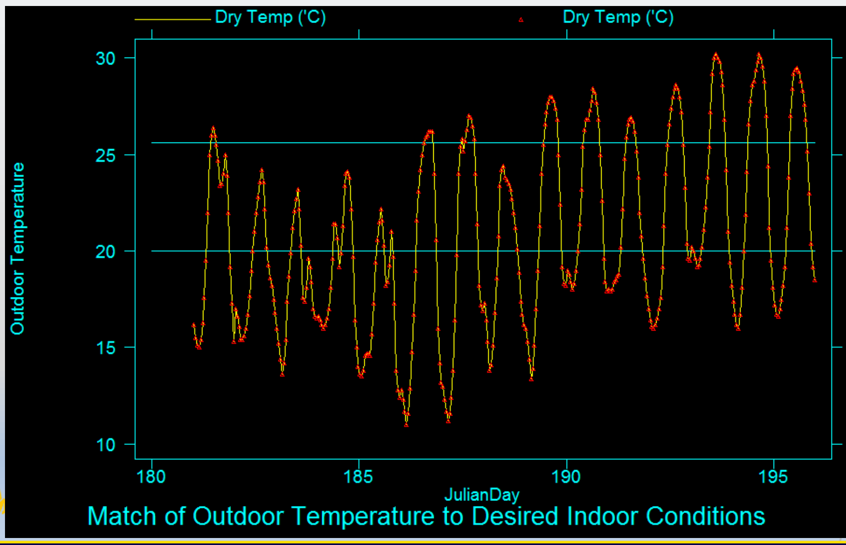
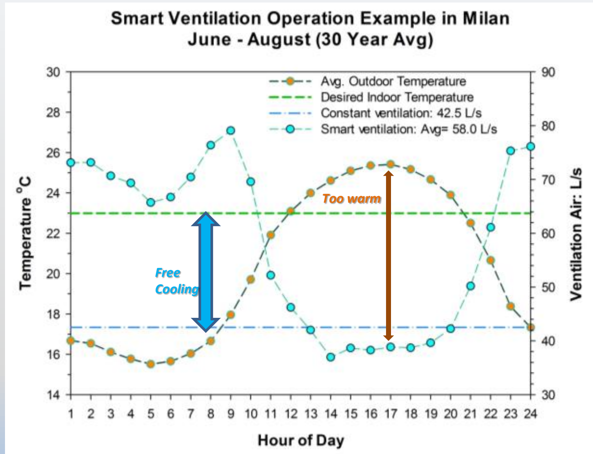
Avg Winter Smart Vent in Milan



Milan, First 2 Weeks in July



Avg Summer Smart Vent in Milan



Constant vent= 1.6 kWh/cooling/day; SmartVent: 3.2 kWh/day

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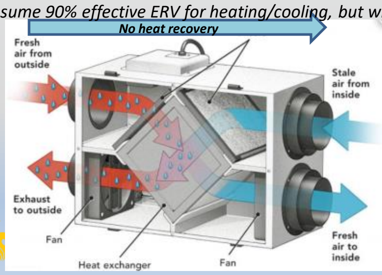
Heating/cooling flows, energy savings & relative exposure for European climates

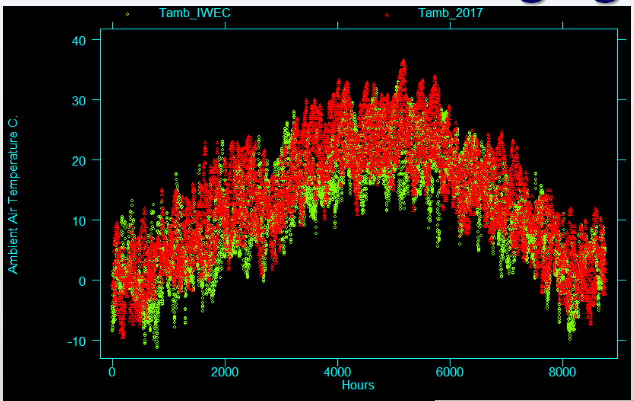
Location	Heating/Cooling Flow Target (L/s)	Annual Avg & Max RE	Temp Turndown Heat /Cool	Annual Space Heating Energy Savings (kWh/%)	Annual Space Cooling Energy Savings (kWh/%)
Frankfurt, DEU	40.3	1.0 / 4.9	-2.3°/27.8°	32 / 2.4%	26 / 16.1%
Lisbon, PRT	40.3	1.0 / 4.0	5.6°/27.8°	-9 / -75.0%	111 /17.6%
Milan, ITA	40.3	1.0 / 4.8	-6.1°/28.3°	37 / 2.9%	44 / 16.9%
Stockholm, SWE	40.3	1.0 / 4.8	-9.4°/26.1°	64 / 2.4%	44 / 35.8%
Seville, ESP	40.3	1.0 / 5.0	4.4°/32.2°	-9/ -100.0%	120 /12.1%

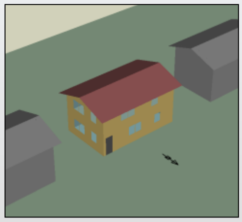
Assume 90% effective ERV for heating/cooling, but with bypass



MVHRs with summer bypass now available

Weather is Changing: Milan





IWEC Files 1982-1999 vs. 2017
Winter extremes about the same
Summer extremes higher
Nighttime lows becoming warmer
Cooling goes from 10% to 28% HVAC loads

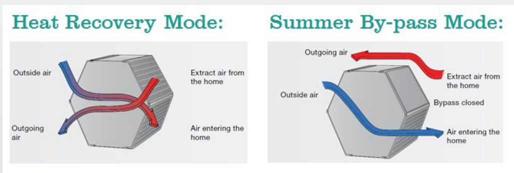
Milan's Changing Weather & Impact on Heating/Cooling Loads

Year of Weather	Avg Outdoor	Min Outdoor	Max Outdoor	Simulated Heating (kWh)	Simulated Cooling (kWh)
18 Yr IWEC	11.2	-11.2	33.0	3453	402
Last 10 Yrs	12.7	-11.0	32.7	2503	683
Yr 2016	13.2	-9.7	32.4	2298	777
Yr 2017	13.5	-9.4	36.7	2312	911
Yr 2018*	13.5	-10.6	34.3	2471	844

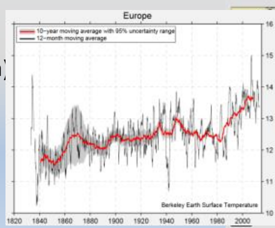
*Sep-Dec= 2017 data

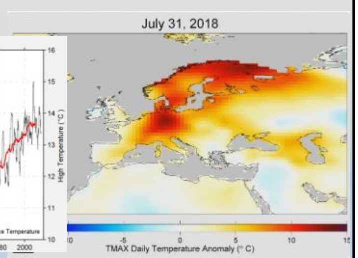
Preliminary Results: Smart Ventilation in Milan, Italy

- Comparison of smart vs. constant mechanical ventilation using weather sensitive algorithm; hourly data
- Standard mech vent: 42 L/s constant
- Smart ventilation: Avg. 53 L/s over yr
  - Range: 13–104 L/s; better rel exposure
  - 11% reduction in ventilation winter heating load
  - 52% reduction in summer ventilation cooling load
- With very efficient ERV:
  - 2% winter savings, but 17% cooling savings using "summer bypass"
- Can be operated with connected thermostat (internet weather data)
- <u>Cooling advantage important in warming world</u>
- <u>Weather files should emphasize recent years for analysis</u>



Important in cooling to be able to bypass Heat recovery for ambient cooling





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1

Markus Gwerder, Siemens Switzerland Ltd

Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates

siemens.com/buildingtechnologies

Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates

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1. **Introduction**
   - The project “3for2 – beyond efficiency”
   - The 3for2 concept
2. **Demonstrator Building**
   - HVAC system
   - Basic control
3. **Simulation model**
   - Overview
   - Validation/calibration
4. **Case Study**
   - Set-up
   - Base case
   - Results
5. **Conclusions**

1

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Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates – Introduction

The project “3for2 – beyond efficiency”

Duration	2014 - 2018
Partners	ETH Zurich, Institute of Technology in Architecture Prof. Dr. Arno Schlüter SEC FCL (Singapore ETH Centre, Future Cities Lab)
ETH	Bharath Sheshadri, Adam Rysanek, Jovan Pantelic, Yuzhen Peng, Lukas Lienhart, Clayton Miller, Portia Murray
Siemens BT	Bruno Illi, Markus Gwerder (Zug), Mark Mah, Prakash Padmanabhan, Noven Loh (Singapore), Anton Sokolov (Sofia)

CORE RESEARCH ORGANIZATION

PRINCIPAL SPONSOR

TECHNOLOGY PROVIDERS

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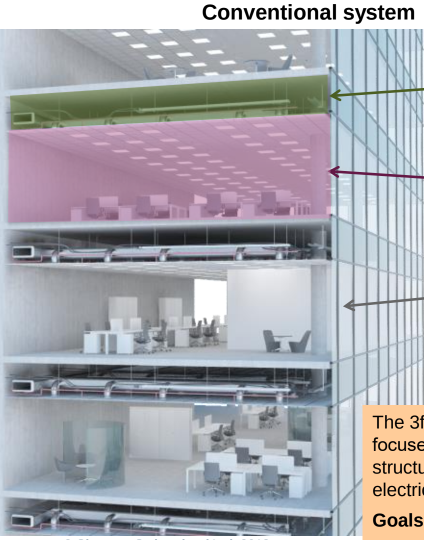
Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates – The 3for2 concept

Conventional system

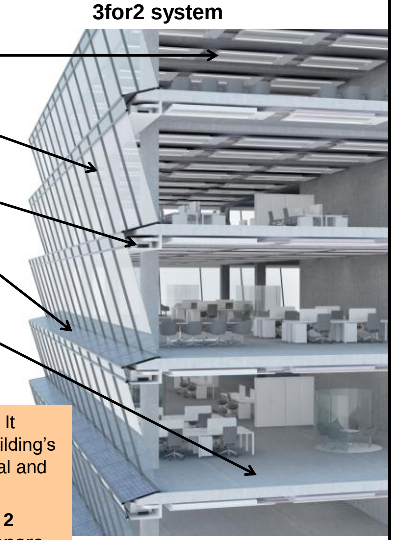


Air-conditioning systems require large amounts of volume and material to move air

Overly-cooled and ventilated systems lead to less-healthy indoor climates (cold air, draught)

Buildings are enclosed by badly insulated facades that are too large and too leaky

3for2 system



Radiant chilled ceiling (supplied at high chilled water temp. > 17 degC)

Sloped glazing panels for reduced solar gains

Facade-integrated ventilation units

Façade-integrated solar PV panels

Dedicated outdoor air systems (DOAS) through in-slab duct network and floor diffusers

The 3for2 concept is a systematic approach to building design. It focuses on the integration of building energy systems into a building’s structure so as to minimize volume requirements for mechanical and electrical systems.

Goals: – To build 3 floors where normally one could build 2
– Building the most energy-efficient office in Singapore

2

Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates – Demonstrator Building

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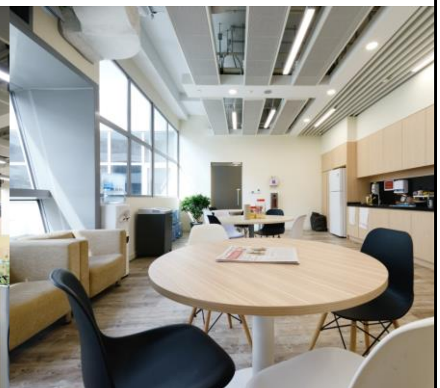
UWCSEA Dover Campus in Singapore
New High School building

- New 20’000 m² multipurpose building constructed by mid 2015
- 550 m² of office space for real world implementation of 3for2
- 13 rooms, 4 air distribution zones



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Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates – Demonstrator Building Floor Plan

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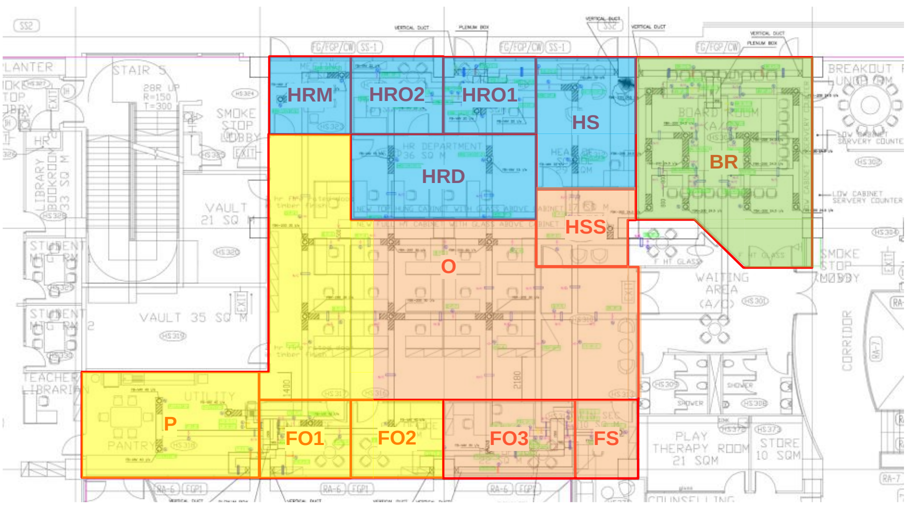


- Zone 1
- Zone 2
- Zone 3
- Zone 4

2

Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates – Demonstrator Building HVAC System

4

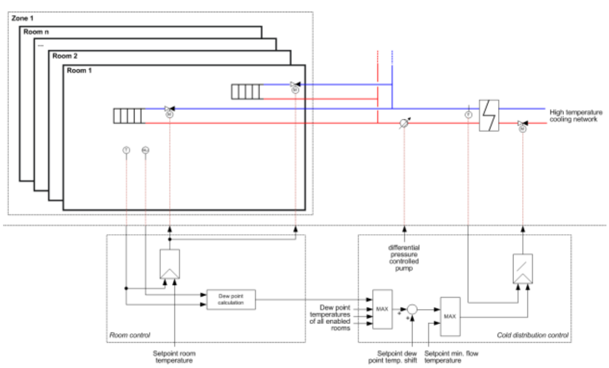
Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates – HVAC System & Basic Control

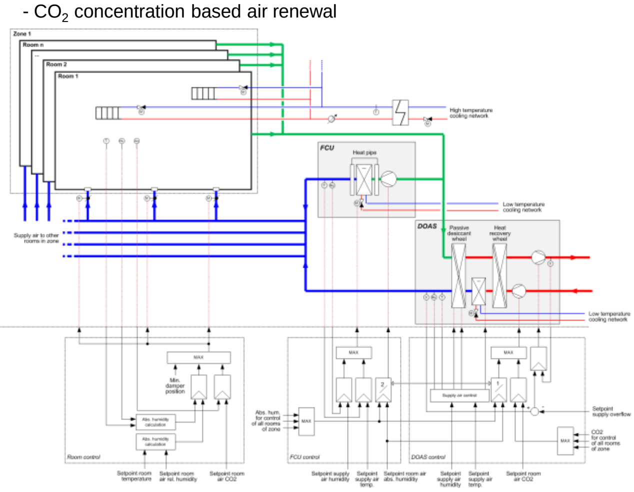
Room temperature control

- high-temperature cooling / condensation detection
- dew point temperature based flow temperature control

Room absolute humidity and CO_2 control

- room dehumidification including start-up dehumidification phase
- CO_2 concentration based air renewal





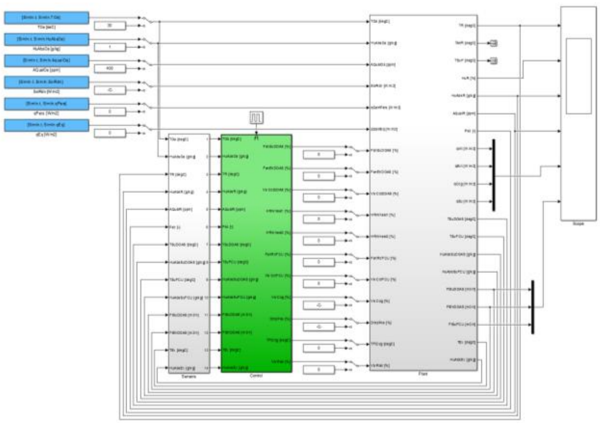
3 Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates – Simulation Model

SIEMENS

**The model is implemented in Matlab/Simulink based on existing components.
It represents zone 2 of the demonstrator building including 5 rooms.**

Core components

- Building
  - Multi zone model for temperature and humidity
  - Multi zone model for air quality
- HVAC system
  - Passive chilled beams PCB
  - Enthalpy wheel, passive desiccant wheel
  - Heat pipe
  - Fan
  - Cooling coil (cross flow)
  - Heat exchange supply air – underfloor air
- Control
  - Siemens control software
    (same logic as in demonstrator building controllers)



3 Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates – Simulation Model Validation/Calibration

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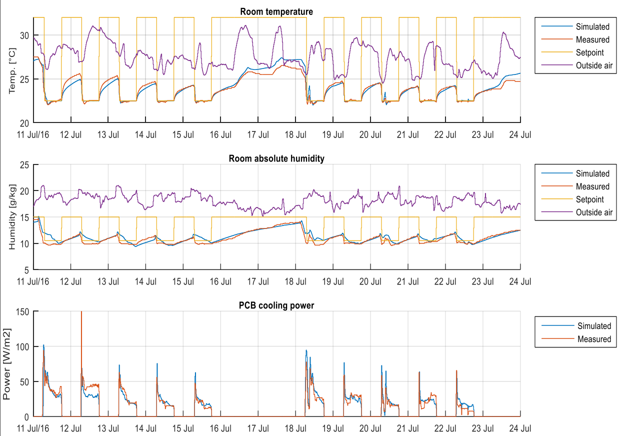
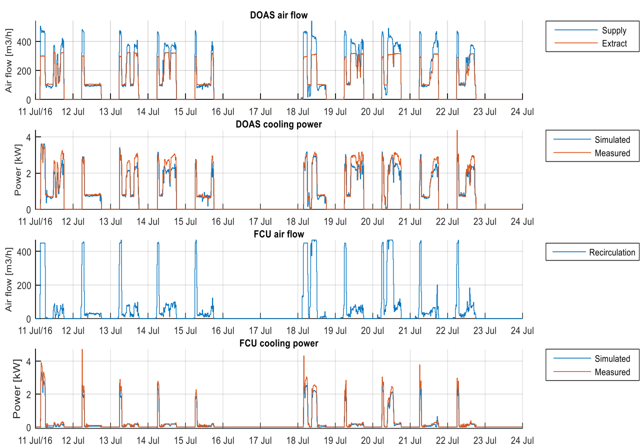
Example building validation results: two weeks during July 2016 base line

Room temperature, humidity and PCB cooling power (of one room)



Ventilation flow rates and cooling power by coils



4 Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates – Case Study

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Simulation Case Study Set-Up

Main goal:

- Assess performance of different control solutions such as presence and CO_2 based control, start-up regimes, air flow tracking for the demonstrator building and its HVAC system

For comparison:

- Comparison of performance with alternative HVAC systems and different comfort requirements

Performance criteria:

- HVAC electrical energy consumption
- Deviation from comfort requirements (temperature, humidity, CO_2)

Cases

Location
(Singapore, New Orleans)

Presence based control
(Requires presence detectors)

Alternative HVAC systems
(Conventional system, no energy recovery)

CO_2 based control
(Requires CO_2 sensors)

Comfort
(Reduced, enhanced, shifted)

Start-up control
(Lower fan speeds, optimum start)

Air flow tracking control
(Balanced, overpressured)

4 Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates – Case Study Results

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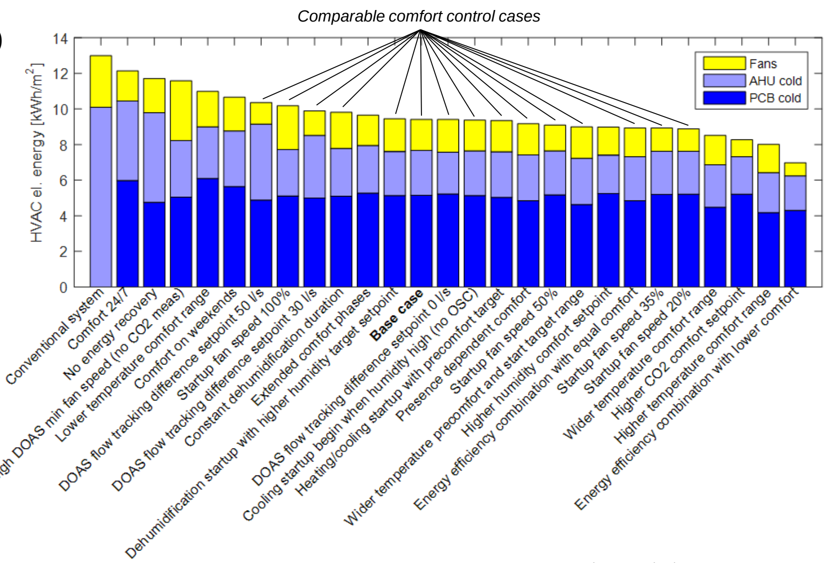
Electrical energy use (March – June)
Location Singapore

- Comfort regarding temperature, humidity and air quality, the according set points are maintained well for all cases
- Range relative total energy use all cases:
  Base case -26% – Base case +38%
- Range relative total energy for control cases that provide comparable comfort:
  Base case -5% – Base case +10%



4 Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates – Case Study Results

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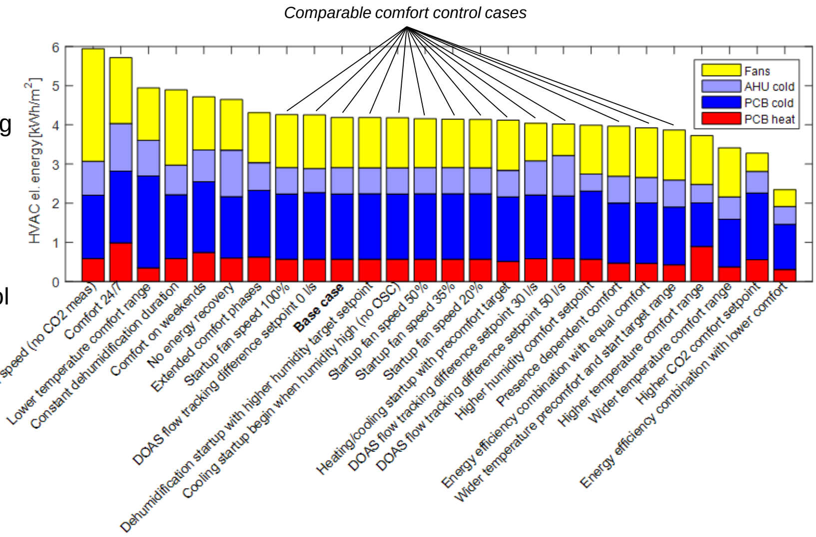
Electrical energy use (March – June)
Location New Orleans

- Comfort regarding temperature, humidity and air quality, the according set points are maintained well for all cases
- Range relative total energy use all cases:
  Base case -45% – Base case +40%
- Range relative total energy for control cases that provide comparable comfort:
  Base case -7% – Base case +2%



5 Control of Distributed Cooling and Ventilation Systems in Hot and Humid Climates – Conclusions

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- **Control is key** not just for comfort, but also for the overall energy efficiency of the investigated building and HVAC system
- Optimized HVAC system start-up, demand controlled ventilation and balanced outside air and exhaust air can **improve energy efficiency** significantly – in particular in locations with constantly hot and humid climate such as Singapore
- Most **results can be transferred** to central cooling and ventilation systems as well as conventional air-based only HVAC systems
- Control strategies that further reduce operation using **occupancy prediction** or adapt to **individual comfort requirements** can increase energy efficiency even more

KU LEUVEN

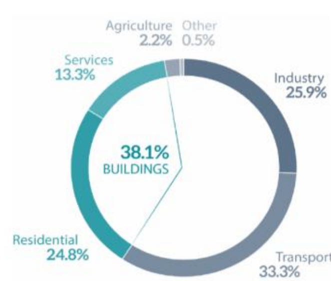
Simulation of control strategies for ventilation systems in commercial buildings

Bart Merema, Hilde Breesch, Dirk Saelens

Faculty of Engineering Technology

Context

- Control of HVAC important in nZEB buildings > IEQ and energy efficiency
- Why simulation tools?
  - Test control strategies
  - Predict energy use
  - Effect on indoor climate

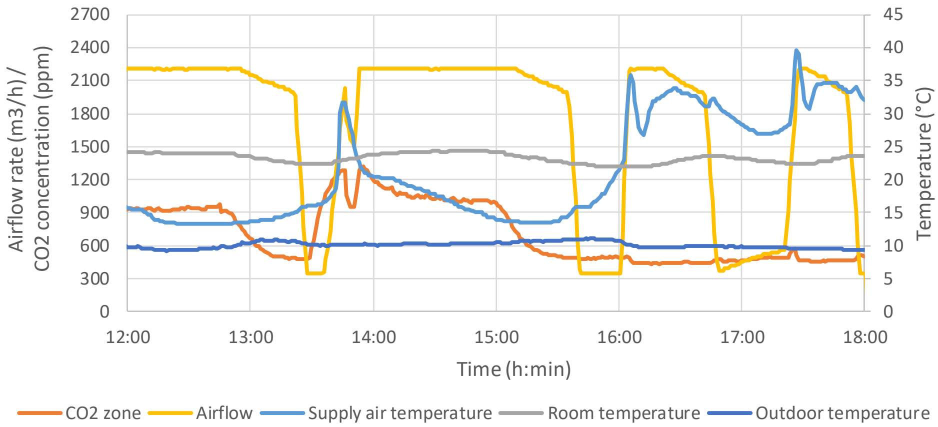


Data source: Eurostat, 2014.

- Goal: Study possibilities for implementation of control strategies and the possible effect in simulations

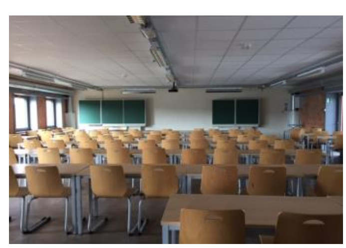
Operation AHU Test lecture rooms

- Example of challenging control
  - lecture, 50 persons (13:30 - 15:00h)



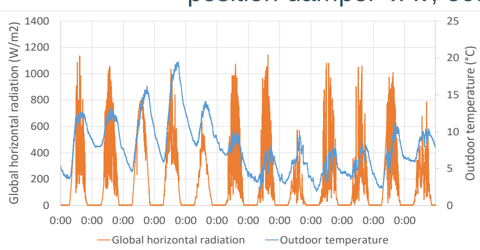
Case study

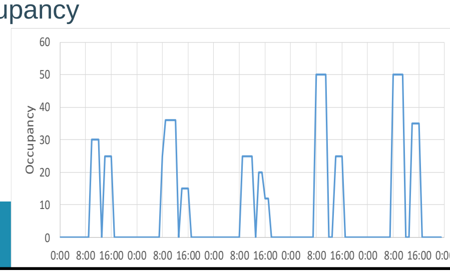
- Lecture room for 80 students
- Extensive building monitoring system > 100 sensors
- Control: DCV based on CO_2 and temperature
- All-air system with heat recovery



Method

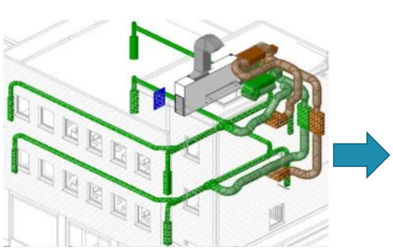
- BES in EnergyPlus and Modelica (validated models ASHRAE guideline 14, 2002)
- Measurement data input for simulations
  - Validation using 2 weeks data
- BMS data used for validation of models
  - e.g. CO_2 concentration, supply temperature, power use, position damper VAV, occupancy

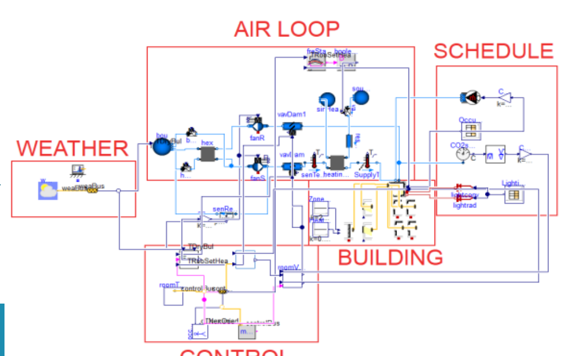




Method Simulation model Modelica

- Model created with IDEAS and Buildings library (Baetens et al., 2012; Baetens et al., 2015, Jorissen et al., 2018, Wetter, 2015)
- Validation period (18-29 April 2016), 1 minute timestep





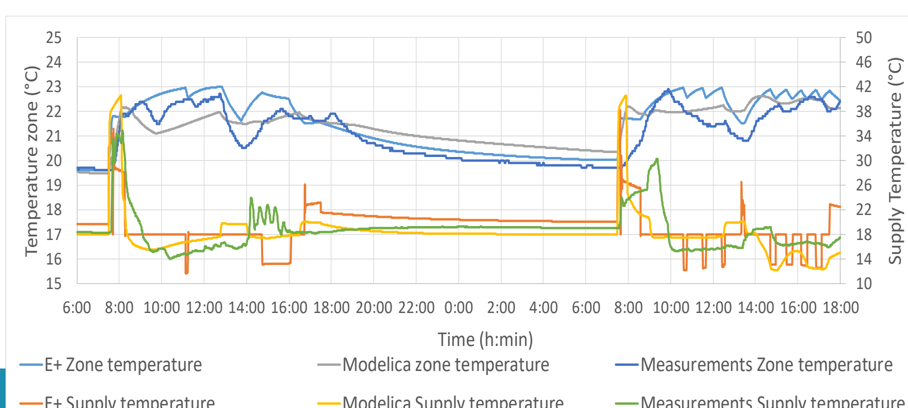
Overview comparison

The following parts are evaluated

- Ventilation network
- VAV control model
- CO_2 control model
- Fan control
- Effect on airflow
- Effect on IEQ
- Effect on energy use

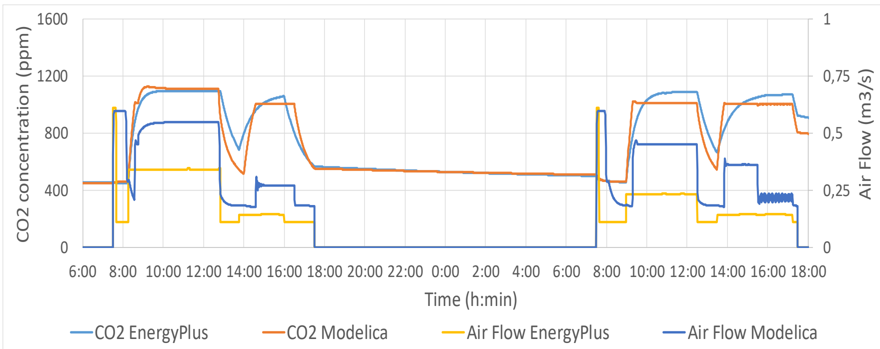
Operation VAV

- Modelica VAV (PI control)
- EnergyPlus VAV (idealized proportional controller)



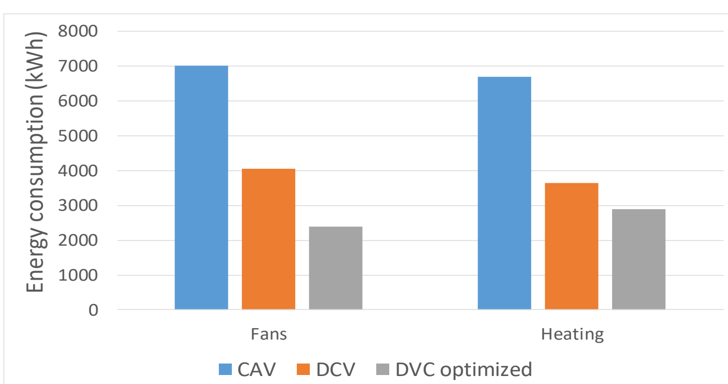
Effect airflow and CO_2

- Modelica: CO_2 source flow linked with air model
- EnergyPlus: CO_2 generation rate as input



Energy use

- Energy saving potential with respect to comfort



Discussion

- Smart control strategies are enabled
- CO_2 control model is different
- EnergyPlus allows proportional control but not detailed (gain factor, integration time)
- EnergyPlus smallest timestep 1 minute <> Modelica continuous time simulation
- Modelica allows detailed pressure modeling for ventilation network

Conclusion

- Simulations capable to control IAQ and thermal comfort
- Modelica > interaction system and building
  - Studies focus on detailed control for HVAC (implementation of MPC for HVAC)
  - Dynamics of the systems are included
  - Can be a bit complexer for first time users
- EnergyPlus > Good and accurate tool for BES
  - Powerful in BES
  - Easy accessible
  - Less detailed control for HVAC

Smart monitoring of ventilation system performance with IEQ sensornetworks

Atze Boerstra, Arjen Raue + Louis Cheng (PureLiving)
ab-bba@binnenmilieu.nl

bba building health & comfort binnenmilieu

bba binnenmilieu

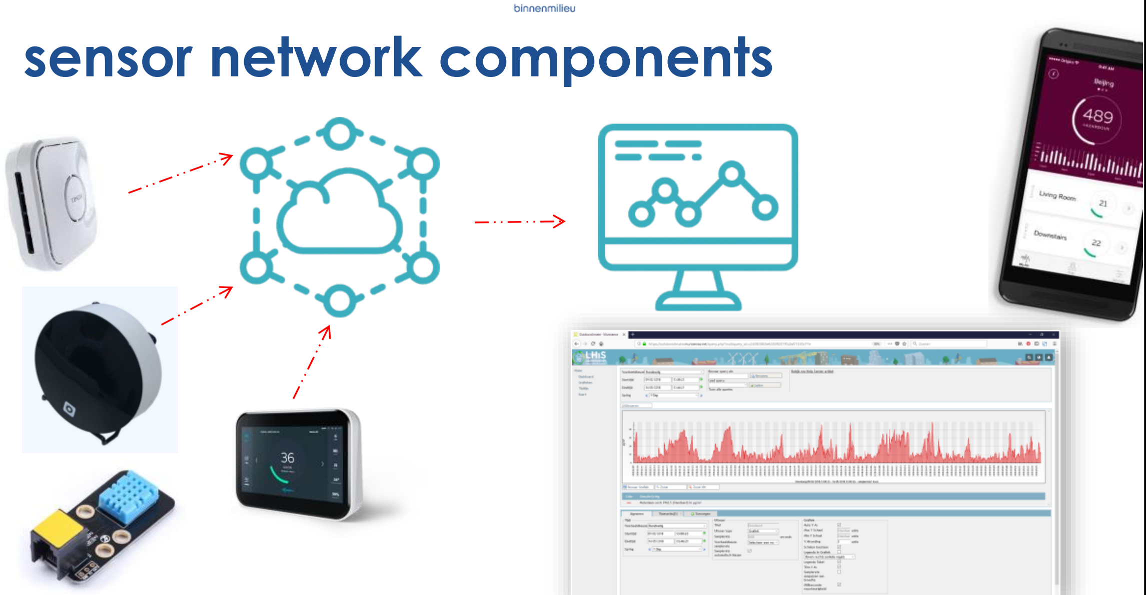
context

- temperature & IAQ sensors become smaller, more reliable, cheaper (Guyot et al., 2017)
- growing interest in continuous indoor climate monitoring
- in homes, schools, offices, ….

AIVC definition

‘A **smart ventilation** system adjusts ventilation rates in time or by location in a building to be responsive to one or more of the following: occupancy, outdoor **thermal and air quality** conditions, electricity grid needs, direct sensing of **contaminants**, operation of other air moving and air cleaning systems.’

sensor network components



many questions

- how to convince others to use sn?
- what to measure?
- what with?
- where?
- how to connect?
- how to gather data?
- how to interprete results?

> time for a position paper

explaining added value

- monitoring traditionally involves use of handheld equipment > often ineffective
- sn helps addressing health & comfort performance, not just financial / energy use
- sn results help to proof that contract requirements are met
- sn creates insight in real exposure + e.g. productivity risks,

parameters to measure

standard, e.g.:

- temperature
- humidity
- particulate matter (PM 2.5)
- CO2

Nice to haves:

- VOC's, CO, formaldehyde….

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sensor requirements

General guidance via RESET (www.reset.build):

- grade C/B/A
- range
- self-calibration
- accuracy

IAQ parameter	Common sensor technology used	Recommended measurement range (Grade B)	Selection notes
Particulate Matter (PM)	Optical particle counters (OPC)	0–300 μg/m³	Considerations: humidity compensation, long term accuracy. Measurement of PM 2.5 or 1 is preferred over PM 10.
Carbon Dioxide (CO2)	NDIRs	0–2000 ppm	CO2 is an indicator of bio-effluents in the air and allows one to assess the "quality" of the ventilation system.
Total Volatile Organic Compounds (TVOC)	Metal Oxide Sensors (MOS); Photo-ionization Detectors (PID)	0.15–2.00 mg/m³	Both MOS and PID sensors are indicative only. They will not usually match lab testing.
Temperature	Thermocouples; Resistive Temperature Devices (RTDs); Silicon diodes	0–50 °C	Many temp. sensors suffer from inaccuracy due to heat generated from nearby components.
Relative Humidity	Capacitive	20–90%	Esp. important to measure due to impact of humidity on measurements of e.g. PM.
Formaldehyde	Colormetric, electrochemical; chemical	0.03–0.3 mg/m³	Currently, there are no real-time technologies known that match RESET grade B requirements.

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accuracy is an issue!

limit values

As provided e.g. by:

- WHO
- EU/EC
- RESET >

IAQ parameter	Target level	
	Acceptable	**High performance**
Particulate Matter (PM 2.5)	< 35 µg/m3	< 12 µg/m3
Organic Compounds (TVOC)	< 500 µg/m3	< 400 µg/m3
Carbon Dioxide (CO2)	< 1000 ppm	< 600 ppm
Carbon Monoxide (CO)	< 9 ppm	-

intermezzo: how about perceptions?

device University Aalborg +
Green Me cube

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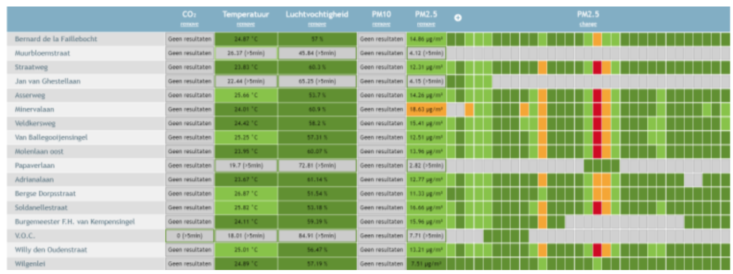
presenting results

Interfaces have to be informative to:

- ieq professionals + building managers
- end-users



	CO_2	Temperatuur	Luchtvochtigheid	PM10	PM2.5
Bernard de la Faillebocht	Geen resultaten	24.87 °C	57 %	Geen resultaten	14.86 µg/m³
Muurbloemstraat	Geen resultaten	26.37 (>5min)	45.84 (>5min)	Geen resultaten	4.12 (>5min)
Straatweg	Geen resultaten	23.83 °C	60.3 %	Geen resultaten	12.31 µg/m³
Jan van Ghestellaan	Geen resultaten	22.44 (>5min)	65.25 (>5min)	Geen resultaten	4.15 (>5min)
Asserweg	Geen resultaten	25.66 °C	53.7 %	Geen resultaten	14.26 µg/m³
Minervalaan	Geen resultaten	24.01 °C	60.9 %	Geen resultaten	18.63 µg/m³
Veldkersweg	Geen resultaten	24.42 °C	58.2 %	Geen resultaten	15.41 µg/m³
Van Ballegooijensingel	Geen resultaten	25.25 °C	57.31 %	Geen resultaten	12.51 µg/m³
Molenlaan oost	Geen resultaten	23.95 °C	60.07 %	Geen resultaten	13.96 µg/m³
Papaverlaan	Geen resultaten	19.7 (>5min)	72.81 (>5min)	Geen resultaten	2.82 (>5min)
Adrianalaan	Geen resultaten	23.67 °C	61.14 %	Geen resultaten	12.77 µg/m³
Bergse Dorpsstraat	Geen resultaten	26.87 °C	51.54 %	Geen resultaten	11.33 µg/m³
Soldanellestraat	Geen resultaten	25.82 °C	53.18 %	Geen resultaten	16.66 µg/m³
Burgemeester F.H. van Kempensingel	Geen resultaten	24.11 °C	59.39 %	Geen resultaten	15.96 µg/m³
V.O.C.	0 (>5min)	18.01 (>5min)	84.91 (>5min)	Geen resultaten	7.71 (>5min)
Willy den Oudenstraat	Geen resultaten	25.01 °C	56.47 %	Geen resultaten	13.21 µg/m³
Wilgenlei	Geen resultaten	24.89 °C	57.19 %	Geen resultaten	7.51 µg/m³

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outdoor (reference) measurements

- enable Indoor/Outdoor ratio (I/O) reporting
- better than relying on (only) outdoor climate measurements government
- rain, frost, fog, local air speed & vandalism can be challenging

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amount + location of sensors

- offices: 1 per 500 m2, min. 1 per room type
- at roomlevel: as close as possible to occupant

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connectivity + ict

- super important
- wifi, gprs, lora, ethernet
- clients often reluctant
- big issue is also physical location of server
- plus privacy / security aspect

conclusions

- great idea to use IEQ sensornetworks to objectivy ventilation system performance
- esp. IAQ + health/comfort aspect
- lot of practical issues to solve however
- e.g. accuracy, robustness, limit values, ergonomics interface, deployment strategy
- general consensus / standard is needed

Technical University of Denmark

HUNAN UNIVERSITY

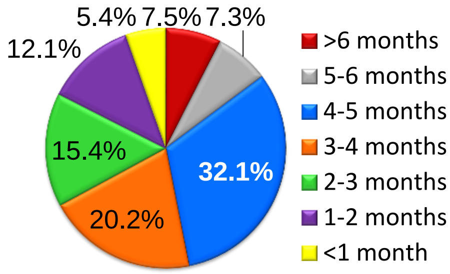
Short-term mechanical ventilation of air-conditioned residential buildings: case study and general design framework

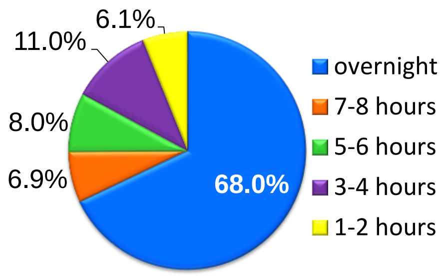
Zhengtao Ai[1] and Guoqiang Zhang[2]

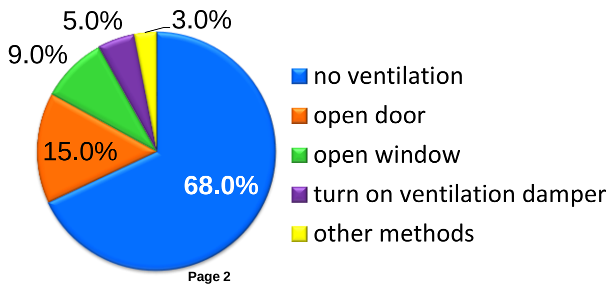
[1]Technical University of Denmark, Copenhagen, Denmark

[2]Hunan University, Changsha, China

Wide use of air-conditioners without ventilation

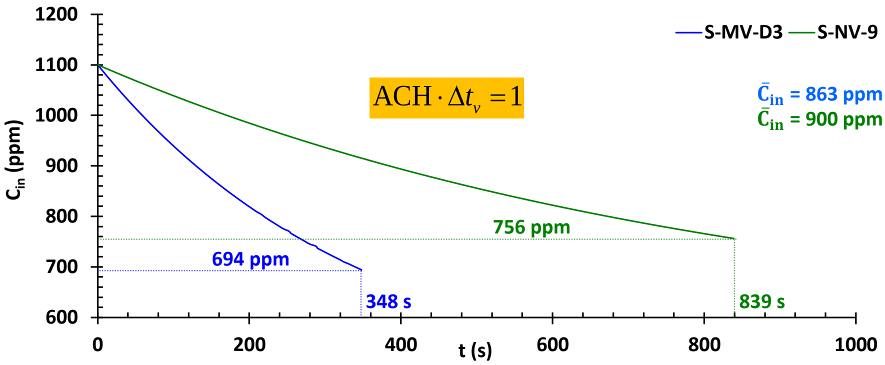


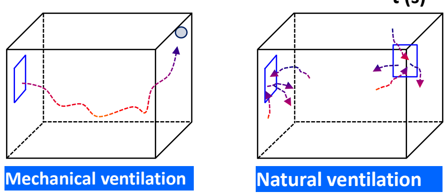




On-site evaluation of ventilation strategies

Long-term natural ventilation, short-term natural ventilation, short-term mechanical ventilation





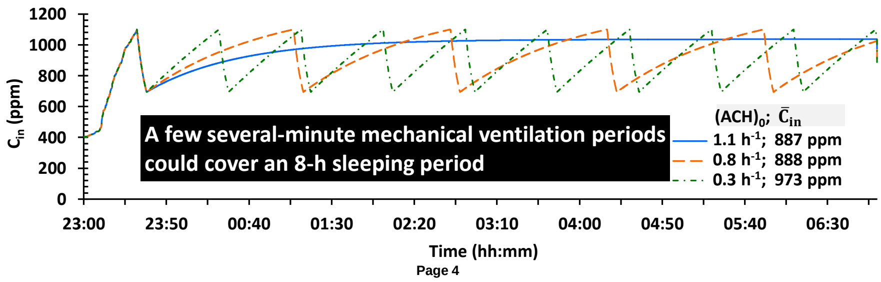
Recommend:
Mechanical ventilation

General design framework of short-term MV

Basic design and control parameters of short-term mechanical ventilation

Basic information	Mechanical ventilation	Control criterion	Optimization
❖ CO_2 generation rate per unit volume (G_r/V) ❖ Infiltration rate ($(ACH)_0$) ❖ Outdoor CO_2 concentration (C_{out})	❖ Start CO_2 concentration ($C_{in,ini}$) ❖ Ventilation rate (Q or ACH) ❖ Single ventilation period (t_{MV}) ❖ Number of ventilation period (N_{MV})	❖ $\bar{C}_{in,8h} \leq 1000$ ppm ❖ $\bar{C}_{in,8h}$ close to 1000 ppm	❖ MIN ($t_{MV} \cdot N_{MV}$) ❖ Feasibility (N_{MV})

Evolution of indoor CO_2 concentration within an 8-h sleeping period



Intelligent hybrid ventilation system enslaved by IAQ sensors

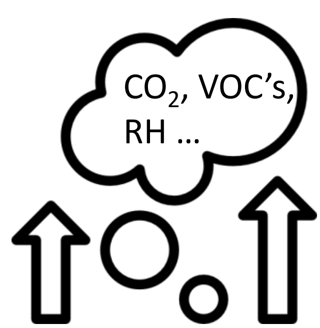
AICV 2018 – JUAN-LES-PINS

State of IAQ in France

90 % of lifetime in enclosed environment → **50%** at home

A disastrous record in France :

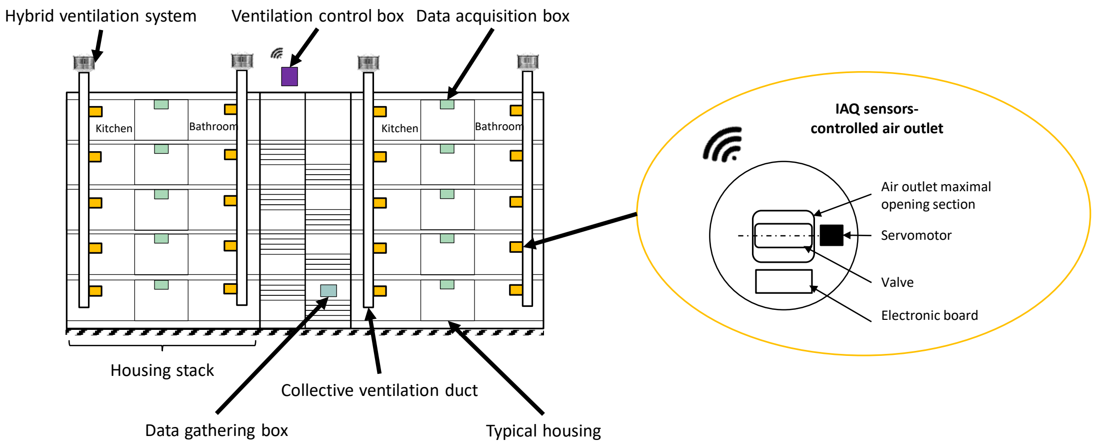
- **20 000** cases of death
- **28 000** new pathologic cases
- **€19 billion** to French social security



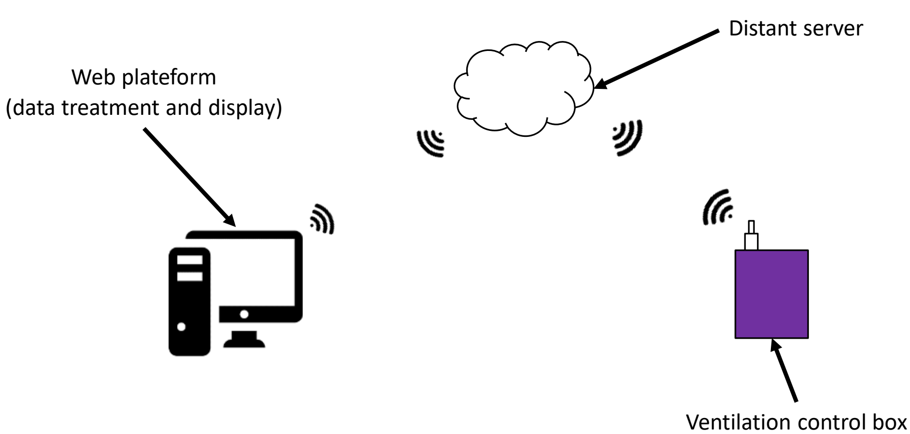
Ventilation systems based on flow rates → the means

Real IAQ data → the outcomes

Principle of the system



Data treatment and transmission



Thank you for your attention

ANDRÉ AMPHOUX – ALEXANDRE LUCET

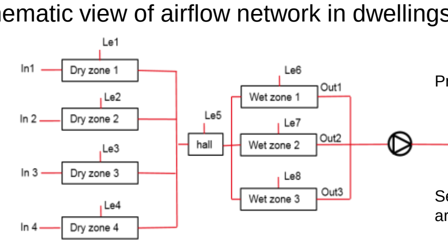
RESILIENT DEMAND CONTROL VENTILATION SYSTEM FOR DWELLINGS

X.Faure, F.Losfled, I.Pollet, O.Ouvrier-Bonnaz & E.Wurtz.

HOW DOES VENTILATION SYSTEMS WORK ?

Creating healthy spaces

Schematic view of airflow network in dwellings



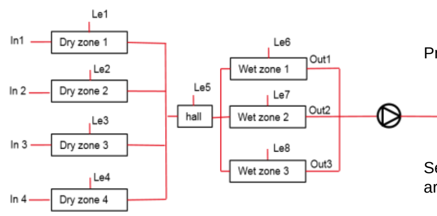
Primary components are : fan, ducts, outlets and inlets
→ guaranteed performances

Secondary components are : envelope local airtightness, free area of internal doors
→ non guaranteed components

HOW DOES VENTILATION SYSTEMS ARE DESIGNED ?

Creating healthy spaces

Schematic view of airflow network in dwellings



Primary components are : fan, ducts, outlets and inlets
→ guaranteed performances

Secondary components are : envelope local airtightness, free area of internal doors
→ non guaranteed components

The design process consist in multizone nodal modelling with fixed assumptions (occupancy, activities, humidity buffering effect, airtightness, climate).

→ DCV are quite efficient in terms of IAQ targets and Energy ! But…..

Since it is designed and optimized on specific conditions, does it has any chance to work on real cases?

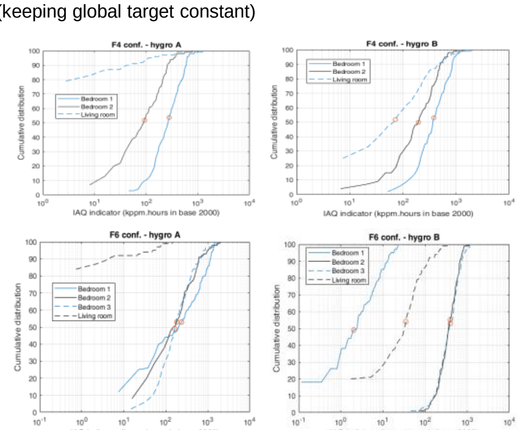
HOW DOES VENTILATION SYSTEMS ARE SENSITIVE ?

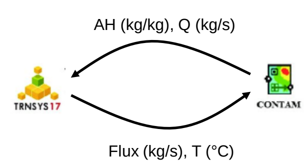
Creating healthy spaces

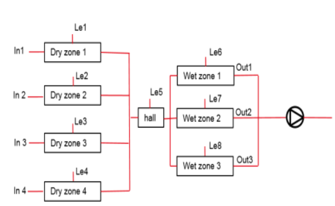
Test is realized on a single based sensor DCV strategy (humidity based)

2 types of dwellings and 2 types of DCV systems (*hygro A and B*)

Evenly versus randomly distributed leakage on 100 simulations (keeping global target constant)







Up to **60%** of the simulated cases wouldn't comply with the IAQ limit

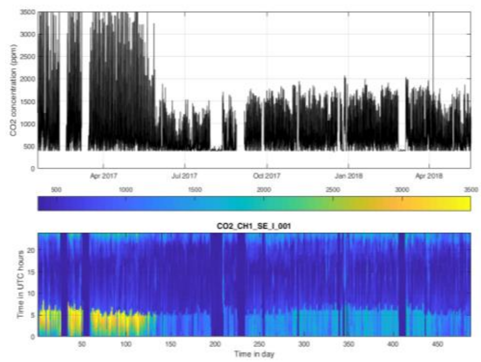
HOW DOES VENTILATION SYSTEMS COULD BE RESILIENT ?

RENSON Creating healthy spaces

Single based versus double based sensors DCV has been experimentally tested

Single family houses occupied by 2 adults and 2 children

Comparison of 2 ventilation systems :
- Simple wet rooms humidity based extractions
- Double wet and dry rooms humidity and CO2 based extractions

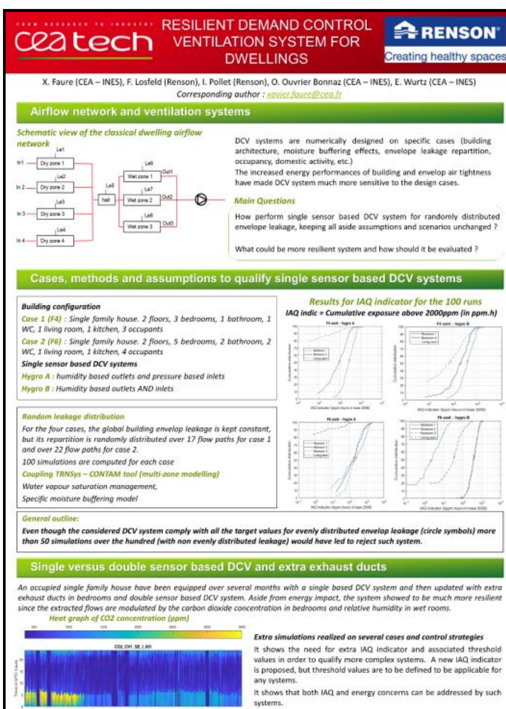


Resilient system should be a priority to make a step toward guaranteed system (and not component) performances

Energy should be an optimized output but with keeping it as a secondary objective of DCV systems !

Threshold values are needed but for any ventilation systems and not for specific ones.

Some are proposed for double sensors based DCV systems.



Thank you

KTH ROYAL INSTITUTE
OF TECHNOLOGY

Numerical Assessment of the Influence of Heat Loads on the Performance of Temperature-Controlled Airflow in an Operating Room

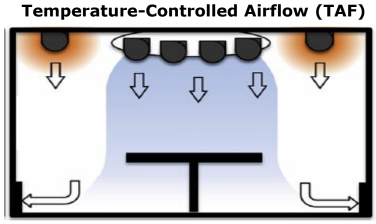
Cong Wang, Sasan Sadrizadeh and Sture Holmberg
ssad@kth.se

KTH Architectural Engineering

Background

- Airborne bacteria is the main cause of Surgical Site Infections (SSI), with the most relevant one being Staphylococci.
- Bacteria are carried on skin fragments, shed from the personnel and dispersed in the OR.
- OR ventilation aims to mitigate contamination.

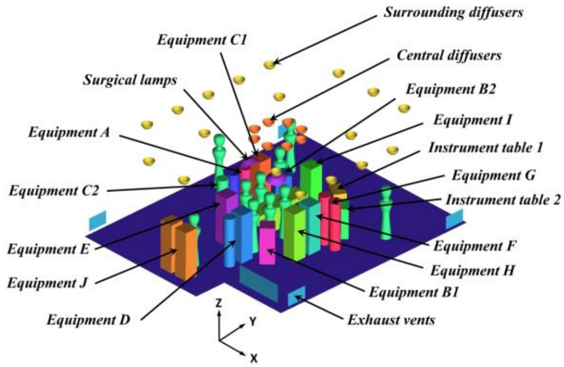
Temperature-Controlled Airflow (TAF)



Temperature-controlled airflow (TAF) ventilation

Objective

- The objective of this study is to investigate the influence of heat loads on the performance of TAF.
- 4 cases (Case 1-4) are defined with heat loads of 12 pieces of equipment gradually increasing.



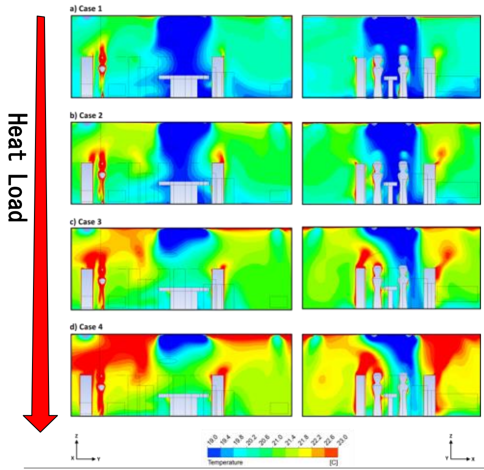
Methods

- ANSYS Fluent 18.2
- Steady RANS with Realizable $k - \varepsilon$ model
- Lagrangian Particle Tracking (LPT) with Discrete Random Walk (DRW) model
- Particle size 12 μm, average size of bacteria-carrying particles (BCPs)
- Case 1-4:

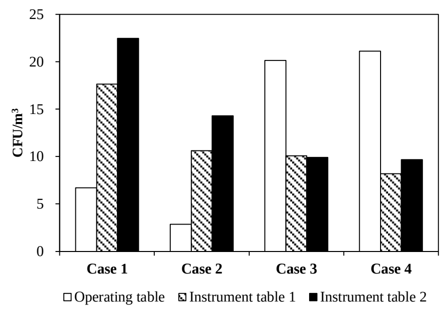
	Case 1	Case 2	Case 3	Case 4
Equipment [W]	936	1873	2809	3745
Surgical lamps [W]	215	215	215	215
General lighting [W]	2412	2412	2412	2412
Surgical staff [W]	810	810	810	810
Total [W]	4373	5310	6246	7182

Results

- Temperature field



- Airborne BCPs concentration



Conclusions

- TAF can tolerate moderately heavy heat loads and provide good protection for patients.
- Slightly higher heat loads can even help improve the performance.
- Very heavy heat loads degrade the performance of TAF.

Ventilative cooling and improved indoor air quality through the application of engineered Earth Tube systems, in a Canadian climate

Trevor Butler[1], Dr John Littlewood[2], and Dr Huw Millward[3]

1. PhD Candidate
Cardiff Metropolitan University, UK

2. Head of the Sustainable & Resilient
Built Environment Group
Cardiff Metropolitan University, UK

3. Academic Director
University of Wales Trinity Saint David, UK

Trevor Butler

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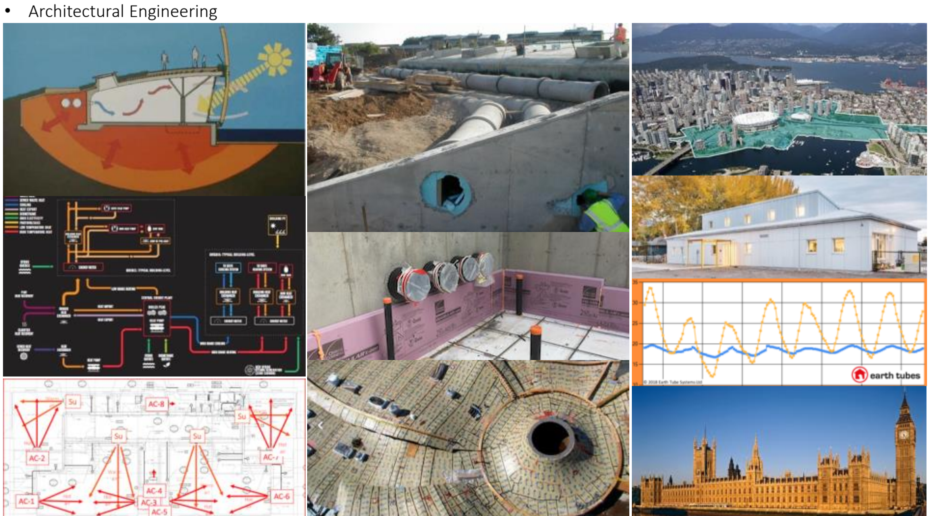
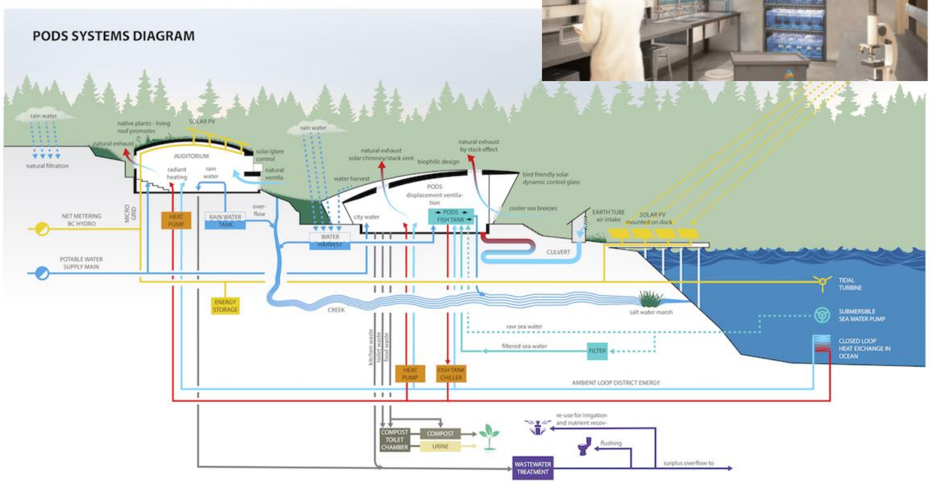
CEng PEng MEng MSt(cantab) MCIBSE MICE MASHRAE LEED AP BD+C

- Professional Engineer buildings and communities.
- 24 years experience, UK trained 14 years; Canadian Practice 10 years
- Architectural Engineering



Whole Systems Thinking

Working with serendipitous synergies
Pender Harbour Ocean Discovery Station, BC, Canada
Ocean Health, Occupant Health



The Indoor Life we lead

- Time spent indoors growing to 90% (Wargocki et al, 1999)
- Unnatural materials, off-gassing
- Better sealed envelopes

How do we improve the indoor environment?

- Daylight
- Sunlight
- Materials
- Plants / biophilia
- Connectedness
- Views
- Acoustics

Photo: George Hodan

VS

Stellaria NZ Ltd,

Red List Free

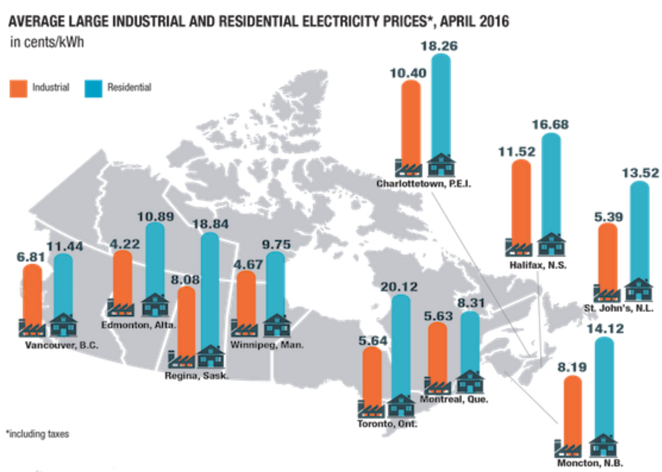
International Living Future Institute

BDP, York University

Fresh air – ventilation

Beat the: CO_2 concentrations Moisture Condensation Mould

Heating air in Canada can be expensive…



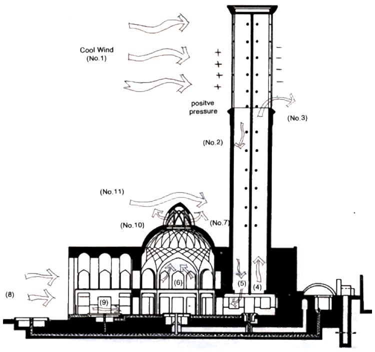
Average residential and large industrial electricity prices, including taxes, for one city per province in cents per kilowatt-hour for April 2016, (NRCan, 2017)

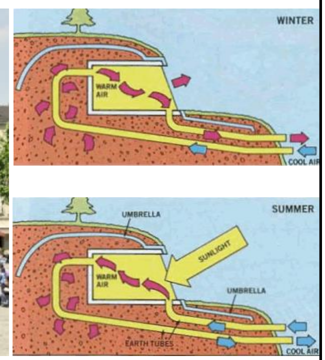
…so occupant health is particularly at risk due to cost of air treatment

This means that the indoor risk is doubled or even higher than that expected from existing levels of outdoor concentrations. This risk is increasingly associated with serious health problems for European citizens. IP/03/1278

Tree wallpaper does not improve air quality

Old technology reinvented





Persian Wind Towers (5000 BC) – with buried ducts for tempering outdoor air

Centre Pompidou (1971) tempering of outdoor air through plaza

Geodome 'umbrella' house, Missoula, Montana, 1981 Passive annual heat storage with earth tubes (Hait et al)

Earth Tube Systems

Draw air through buried pipes to capture the steady state thermal energy to offset active energy demand.

Must consider:

- Water table
- Soil properties
- Climate
- Air velocity
- Occupancy pattern

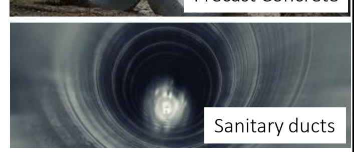
Potential and perceived issues:

- Condensation of humid air
- Mould-borne illness
- Improved indoor air quality, (Fluckiger et al, 1998)
- Contracts – cross-discipline design & installation
  - Mechanical engineer – ventilation system (HVAC)
  - Civil engineer – pipework system (tubes)
  - Electrical – (sensors and monitoring)
  - Contractor - general/mech/groundworks


Corrugated Steel Pipe


HDPE Tubing

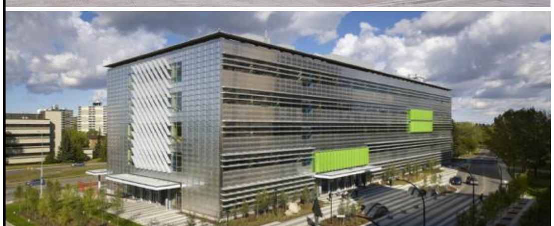

Precast Concrete


Sanitary ducts

Canadian examples

earth rangers

Dr. David Suzuki PUBLIC SCHOOL



UNIVERSITY OF CALGARY

ENERGY ENVIRONMENT EXPERIENTIAL LEARNING

Case Study House Retrofit and extension of 60-year old house

Building Size:

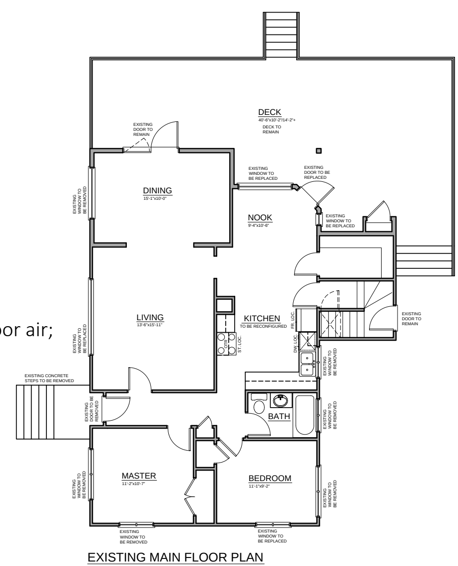
- Existing 105 m²
- Addition 35m²

Space Served by ETS:

- 48m² (34%);

System type:

- Single pass supply of outdoor air;



EXISTING PLAN

Case Study House Retrofit and extension of 60-year old house

Number of Pipes:

- 4 x 100mmØ

Pipe configuration:

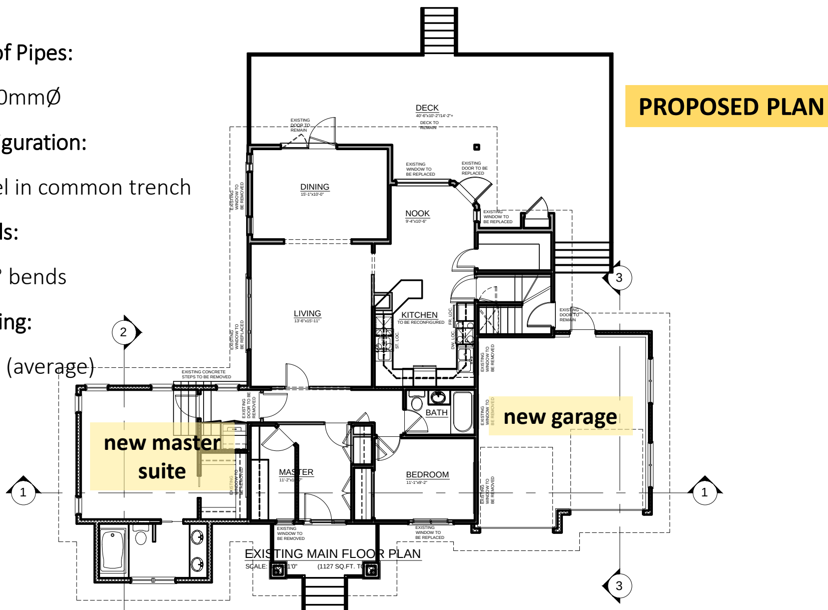
- parallel in common trench

Pipe bends:

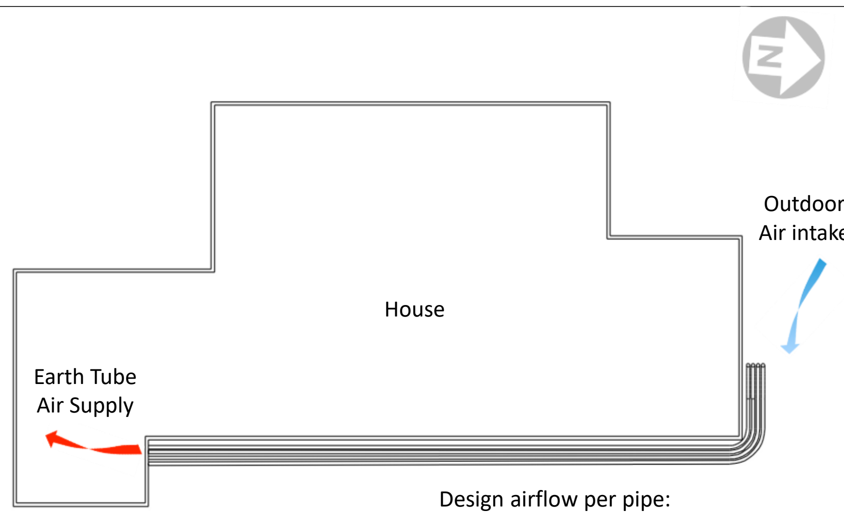
Two x 90° bends

Pipe spacing:

- 50mm (average)



Case Study House Retrofit and extension of 60-year old house



Design airflow per pipe:

- 18 litres per second per pipe;

Air velocity per pipe:

- 2.2 metres per second;

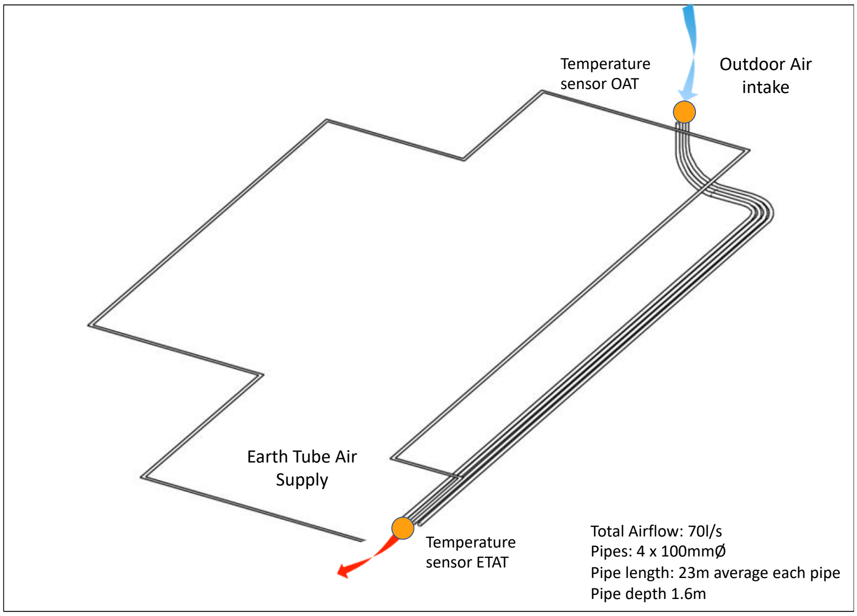
Total Airflow: 70l/s
Pipes: 4 x 100mmØ
Pipe length: 23m average each pipe
Pipe depth 1.6m

Trenching and laying earth tubes for case study project

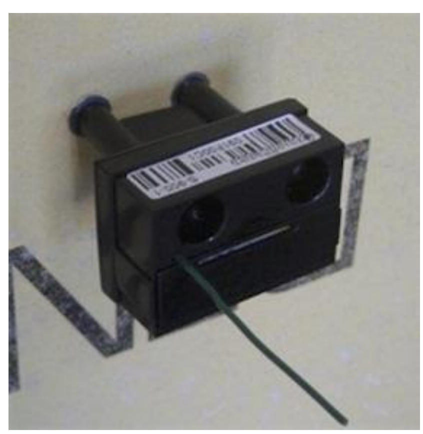
High Density Polyethylene (HDPE) solid, corrugated profile - 23 metres (m) per pipe

Outdoor air inlet box and filter housing (circled)

Isometric of ETS with Temperature Sensors shown



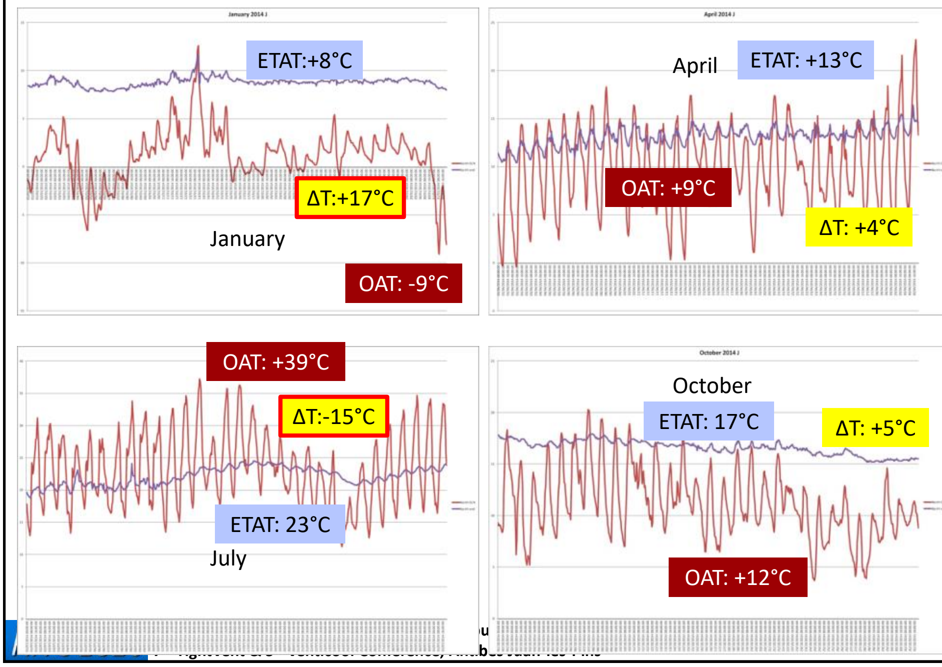
Monitoring of earth tubes



Omnisense, S-900-1, Wireless T, %RH, WME Sensor

AIVC 2018 39th AIVC Conference - Smart ventilation for buildings
7th TightVent & 5th venticool Conference, Antibes Juan-les-Pins

OAT and ETAT for case study house



Results

January:

Outside air:	-9°C
Supply air:	+8°C
ΔT +17°C	

July:

Outside air:	38°C
Earth tube air:	23°C
ΔT -15°C	

The annual savings in energy use in heating mode are: 46%

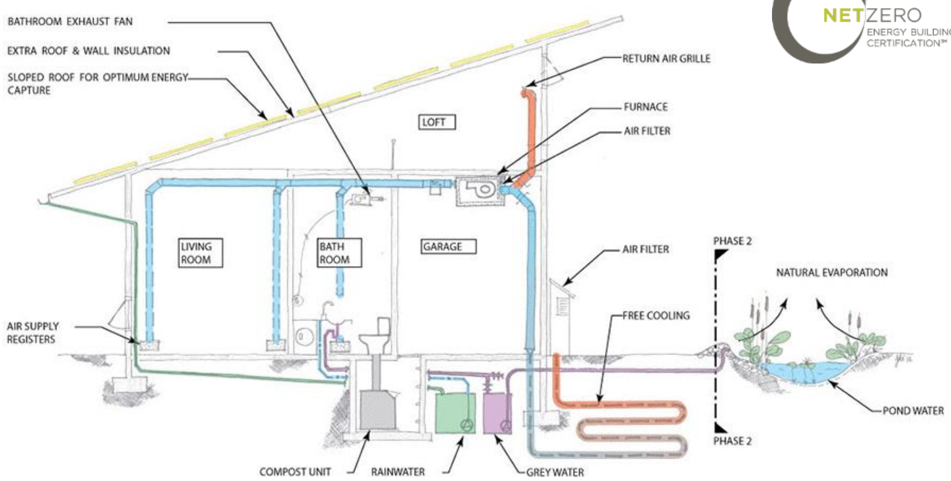
This means that an additional **46%** outdoor air can be supplied to the house in winter with zero energy penalty.

The annual savings in energy use in cooling mode are: **30%**

Free cooling is a new research option – potential for zero A/C loads, with better building envelope and bioclimatic design

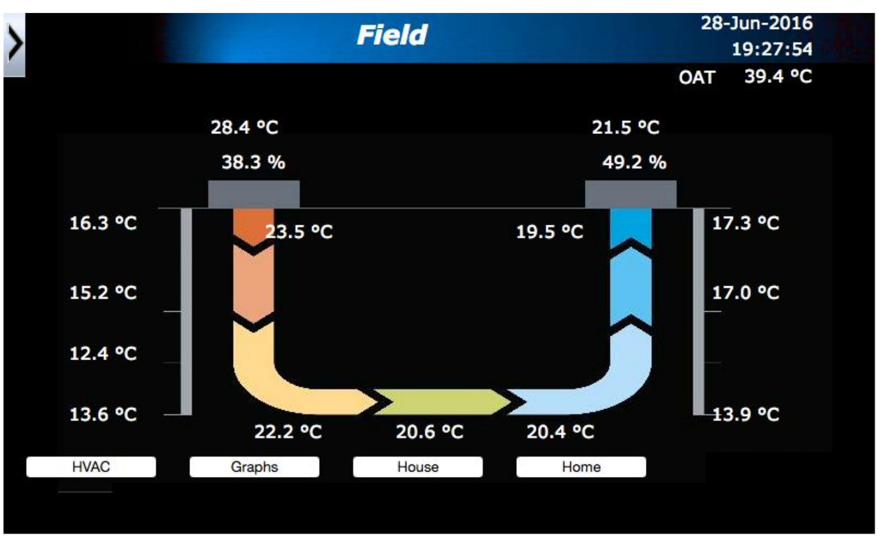
Ethel Lane House

Zero Air-Conditioned – 100% passive cooling by earth tubes



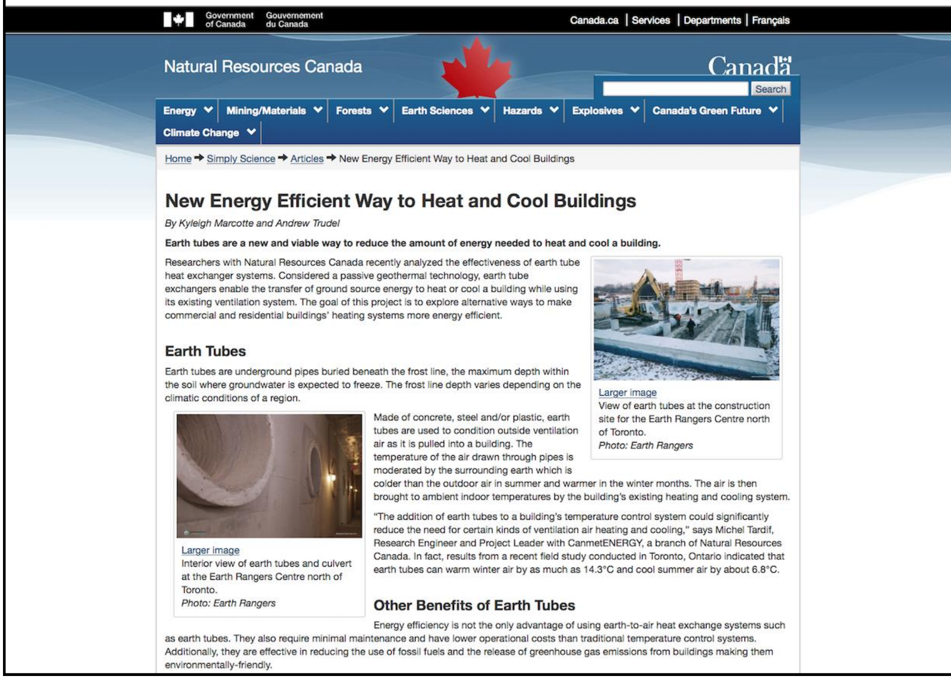
Ethel Lane House

Free cooling laneway house



Working with Government

https://www.nrcan.gc.ca/simply-science/20319



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Home → Simply Science → Articles → New Energy Efficient Way to Heat and Cool Buildings

New Energy Efficient Way to Heat and Cool Buildings

By Kyleigh Marcotte and Andrew Trudel

Earth tubes are a new and viable way to reduce the amount of energy needed to heat and cool a building.

Researchers with Natural Resources Canada recently analyzed the effectiveness of earth tube heat exchanger systems. Considered a passive geothermal technology, earth tube exchangers enable the transfer of ground source energy to heat or cool a building while using its existing ventilation system. The goal of this project is to explore alternative ways to make commercial and residential buildings' heating systems more energy efficient.

Larger image
View of earth tubes at the construction site for the Earth Rangers Centre north of Toronto.
Photo: Earth Rangers

Earth Tubes

Earth tubes are underground pipes buried beneath the frost line, the maximum depth within the soil where groundwater is expected to freeze. The frost line depth varies depending on the climatic conditions of a region.

Larger image
Interior view of earth tubes and culvert at the Earth Rangers Centre north of Toronto.
Photo: Earth Rangers

Made of concrete, steel and/or plastic, earth tubes are used to condition outside ventilation air as it is pulled into a building. The temperature of the air drawn through pipes is moderated by the surrounding earth which is colder than the outdoor air in summer and warmer in the winter months. The air is then brought to ambient indoor temperatures by the building's existing heating and cooling system.

"The addition of earth tubes to a building's temperature control system could significantly reduce the need for certain kinds of ventilation air heating and cooling," says Michel Tardif, Research Engineer and Project Leader with CanmetENERGY, a branch of Natural Resources Canada. In fact, results from a recent field study conducted in Toronto, Ontario indicated that earth tubes can warm winter air by as much as 14.3°C and cool summer air by about 6.8°C.

Other Benefits of Earth Tubes

Energy efficiency is not the only advantage of using earth-to-air heat exchange systems such as earth tubes. They also require minimal maintenance and have lower operational costs than traditional temperature control systems. Additionally, they are effective in reducing the use of fossil fuels and the release of greenhouse gas emissions from buildings making them environmentally-friendly.

Conclusions

Earth tubes are a simple technology – "well known", but not necessarily "known well"

Building Energy Codes primarily addressing heating reduction, but climate change showing growing need to provide **cooling to buildings**.

Earth tube technology can provide "compressor and refrigerant free" cooling

Improving IAQ in winter – as well as summer – with no operational costs.

Passive Survivability –

> *'A building's ability to maintain critical life-support conditions in the event of extended loss of power", (CBE Berkeley, 2008) are enhanced through less reliance on complex mechanical equipment.*

The earth tubes are a simple technology that can assist the passive operation for improving IAQ and Ventilative Cooling…

"If they are designed, installed and maintained correctly"

ACKNOWLEDGEMENTS

Dr John Littlewood, Head of the Sustainable & Resilient Built Environment Group
Cardiff Metropolitan University

Dr Huw Millward, Academic Director
University of Wales Trinity Saint David, UK

Confidential Client for engaging with the case study
Deren Sentesy, EnCircle Builders for building the system
Jamie Dabner, LEng for engineering the ventilation system
Dr Douglas MacLeod, Dean of Architecture, Athabasca University

My family for letting me travel miles from home

Merci

Further study

- Research, interviews and surveys with practitioners, academics and owners;
- Summertime cooling systems monitored range of 8-10°C;
- Data analysis to assess impact and possibilities of seasonal heat saturation;
- Design guidance based on climatic zones that address humidity and how condensation can be controlled or avoided;
- Production of Practical knowledge and recommendations for the design, installation and operational aspects of earth tube systems.

Glenmore Landfill Administration Building

City of Kelowna

THE UNIVERSITY OF BRITISH COLUMBIA

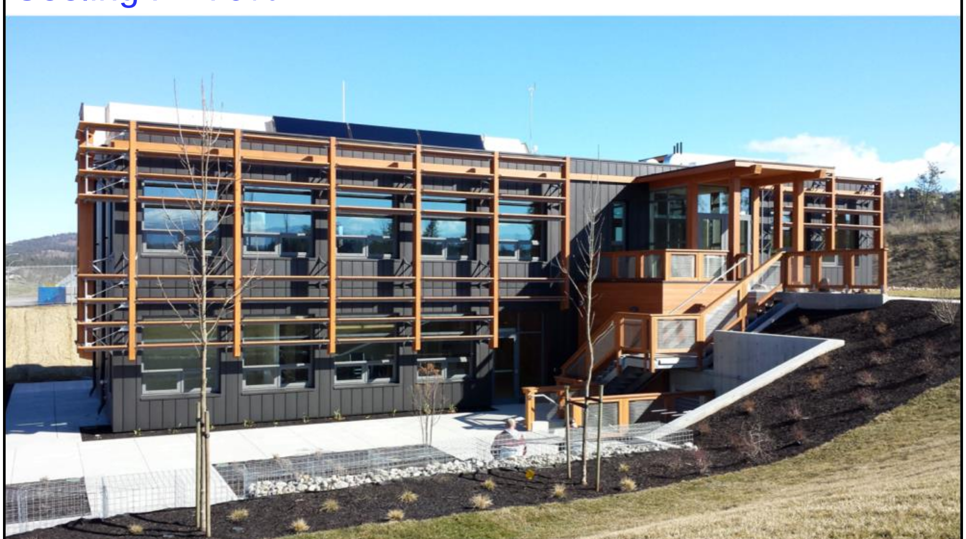
GLAB:
Earth Tube System provides 100% Make-Up Air for HVAC

GLAB – Energy Savings

City of Kelowna

Heating : 35%

Cooling : 70%



Passive House Daycare
Integrated DHW System

okanagan college

Thank you

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FREE COOLING OF LOW ENERGY BUILDINGS WITH GROUND SOURCE HEAT PUMP SYSTEM AND BIDIRECTIONAL VENTILATION

Ola Gustafsson*, Caroline Haglund Stignor, Huijuan Chen, Svein Ruud, and Jon Person

18-19, September 2018 (39th AIVC Conference)

Research Institutes of Sweden

Built Environment
Energy and circular economy

Background

- Why do we need this study?
  - Low-Energy buildings (or well-insulated houses) easily **over-heated** during summertime.
  - It has been shown in **earlier field measurements.**
  - It is possible to open window to lower the room temperature, but not always desirable (noise, insecurity and air pollution)
- Potential cost-efficient solution
  - If a **ground source heat pump** is used for heating
  - There is **bidirectional ventilation** (i.e., equipped with both exhaust and supply fans)
  - **Borehole** used for free cooling in summer time (by means of installing cooling coil placed after AHU)
  - Heat pump and cooling (by ventilation) should be **linked and controlled** together.
- Aim, scope and deliminations
  - Investigate the **potential** and increase the **knowledge** of how a heat pump system can be integrated with a bidirectional ventilation with heat recovery to enable free cooling.
  - Simulations (IDA) + followed-up field measurements in a research villa (performed during a part of one cooling season)
  - It has not been possible to predict the “cost” for the free cooling, in the form of additional pumping (circulation pump for brine) and fan power (pressure losses due to cooling coil).

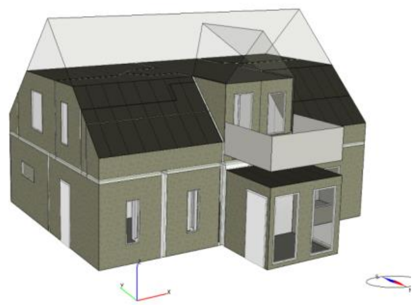
Studied house: The research villa (nZEB)

Technical information of the house

- **Single family house** (with simulated habitants)at RISE premises in Borås
- Size: 166 m² with two floor levels
- **Heating source**: ground source heat pump(4.5 kW, on/off control)
  - Storage tank: 150 l
  - Borehole: 90 m (81 m active)
- **Ventilation**: balanced (bidirectional) ventilation with heat recovery
  - Supply flow rate: **60 l/s**
  - Heat recovery efficiency: 82%

IDA Indoor Climate and Energy (ICE) simulation

- Simplified model (no ground source heat pump, cooling coil modelling)
  - Same construction and configuration (U-value)
  - Consider internal heat load, ventilation flow rate, solar gain, window opening, outdoor condition
  - Use IDA as a tool to What will happen to the room temperature if we change flow rate...... under certain outdoor conditions (study the impacts of different setting)



Field measurements (research villa)– system setup

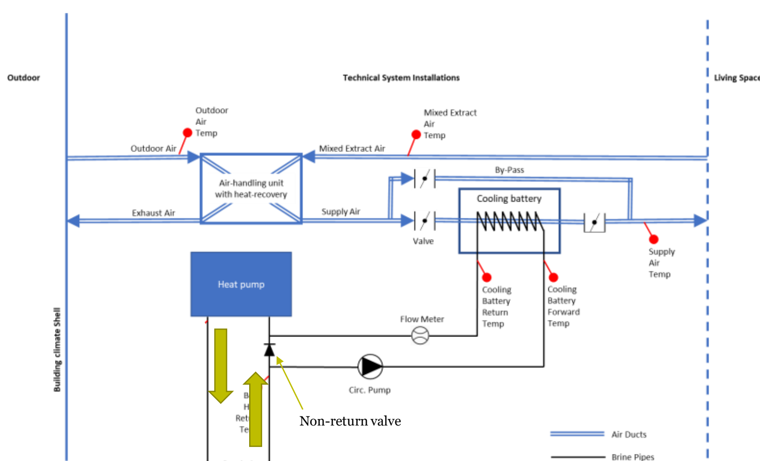
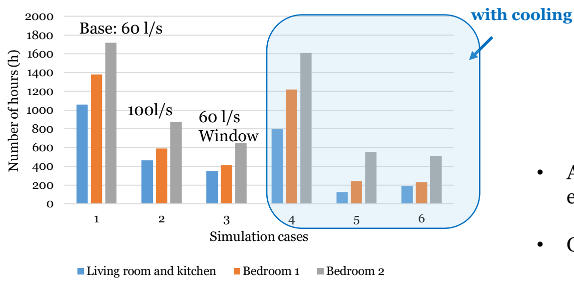


Figure 2. The system setup of the installation of the cooling battery in the Research Villa.

- Air-handing unit: deliver max flow of about **70 l/s** (no cooling coil)
- A cooling-battery installed at the supply air duct: 1kW
- By-pass: operated by manual values.
- Circulation pump: brine to cooling battery; variable speed control (by the supply air T)
  - The cooling was activated: Tout > 16°C
  - Turned off: Tout < 15°C
- Ground source heat pump: has its own internal pump

Modelled cases and results

Impact of increasing flow rate, opening window, add cooling on number of hours with room temperature exceeding **24 °C**



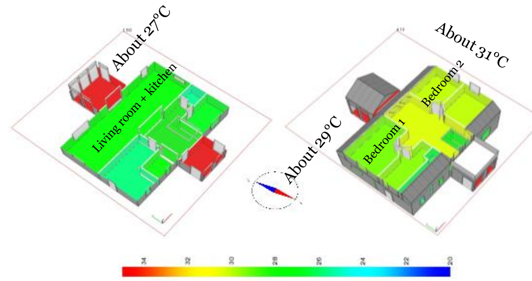


Figure 4. contour plot of room temperature of the modelled house for a sunny day in July at 16:00 (base case)

- As expected, an increase of ventilation and opening of windows can be efficient means to increase the thermal comfort.
- Opening windows: only available when someone is at home
- Free cooling reduces the number of hours with high temperature even more, especially for the case when the windows are not opened.

Field measurement results

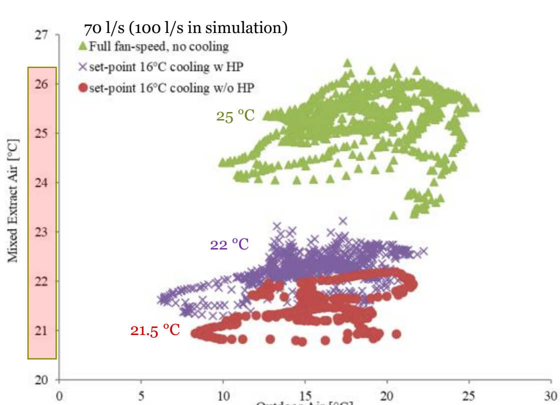


Figure 6. Temperature of the mixed extract air during different evaluation periods with and without free cooling and heat pump operation.

- Operation settings:
  - No cooling, HP on; 2018-06-19 to 2018-06-28.
  - Cooling, HP on; 08-22 to 08-31
  - Cooling, HP off; 08-11 to 08-22
- Mixed extract air T: represent average indoor T
  - No window opening (no people)
- Indicate big impact with and without cooling
  - No cooling: a large amount of time the room T over 24 degree although at moderate outdoor T.
  - Cooling on: reduced overheating significantly
    - With HP: default setting (heating during the night time if Toutdoor is below certain level)
    - HP off: get even lower room
- Note: short measuring period; no information about the weather (sunny or cloudy day)
  - Cant really compare the impact with simulation
  - Confirms that it is possible to reduce room temperature by use of the borehole and the supply air system, even through the cooling capacity is limited by the flow rate and supply air temperature.

Conclusions

- Important lessons learned from the measurements
  - The control should include **a summer and winter period** to prevent the heat pump to heat the house during night time when there is a cooling need in the daytime.
  - The system should have a value to shut-off the cooling coil when the heat pump is operating (for heating).
- Important conclusions
  - It is **possible** to lower room T significantly with a cooling connected to the borehole of a GSHP and bidirectional ventilation.
  - **Control of the cooling system** is crucial to achieve the full cooling potential and for the high system energy performance.

    e.g., start cooling before the actual cooling need
  - **Increasing ventilation flow rate** should be always considered first (efficient to reduce of the number of hours of overheating), if possible, before installing the cooling system.

THANK YOU!

Huijuan Chen

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Research Institutes of Sweden

Built Environment
Energy and circular economy

Energy analysis of balanced ventilation units from field studies

Heat recovery, cold recovery, ventilative cooling

Bart Cremers, Knowledge Consultant

Product Management, CC CSY, Zwolle

always the best climate

Article:
B.E. Cremers, Energy analysis for balanced ventilation units from field studies, AIVC Conference Proceedings (2018)

Presentation background

- Besides (or after) well-being and comfort, energy benefits are important
- Lack of understanding for ventilative cooling of balanced ventilation systems
- Shift from focus on heat recovery, to overall benefits for all seasons and climates
  - Global warming
  - Urbanization
  - Building characteristics and orientation

Presentation targets

1. How much does balanced ventilation save on the heating load of a house?
2. How much does balanced ventilation save on the cooling load of a house?
3. How much ventilative cooling is brought by a balanced ventilation system?
4. Can you prove that from the results of field studies?
5. How much electrical energy is needed for the above benefits?

Locations of field tests

Set-up

ComfoAir Q units with heat recovery or enthalpy recovery

Nulwoning and DE01: Units combined with ground heat exchange

Monitoring parameters

Set-up

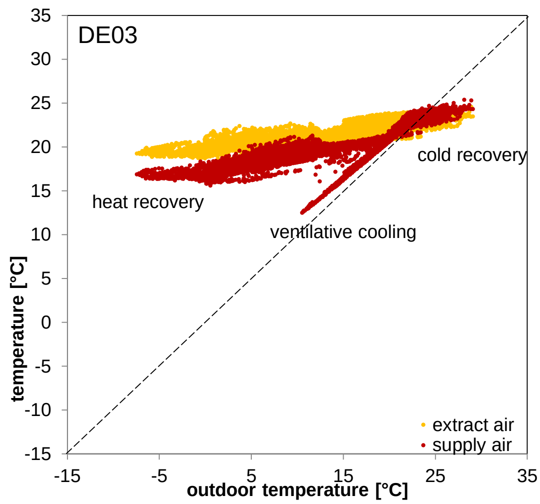
- Monitoring period:
  Jan 2017 – Dec 2017 (Nulwoning)
  Sep 2016 – Aug 2017 (Other field tests)
- Recording interval 5 min
- Analysis with hourly averaged data

Parameters

- Temperatures (outdoor, supply, extract, exhaust, preconditioned outdoor)
- Fan duty [%], fan rotational speed [rpm] (supply, extract)
- Air flow [m^3/h], total pressure [Pa] (supply, extract)
- Comfort settings
- Other control parameters …

Monitored temperatures without ground heat exchange

Control



Heat recovery:
- comfortably warm supply air
- saving on heating load

Cold recovery:
- comfortably cool supply air
- saving on cooling load

Ventilative cooling:
- comfortably cool supply air
- bringing coolness to the house

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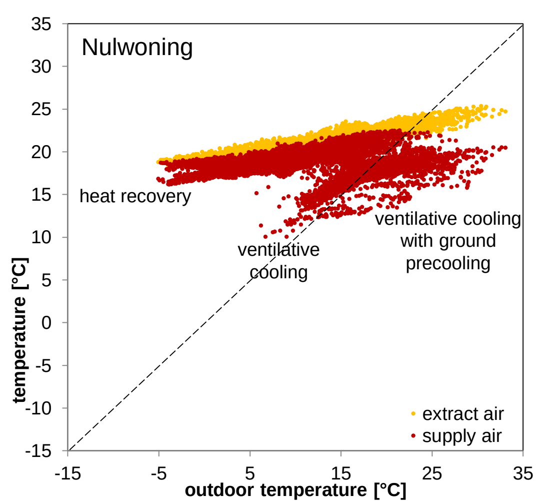
Monitored temperatures with ground heat exchange

Control



Heat recovery:
- comfortably warm supply air
- saving on heating load

Ventilative cooling:
- comfortably cool supply air
- bringing coolness to the house

Ventilative cooling with ground precooling:
- comfortably cool supply air
- bringing coolness to the house for the whole summer

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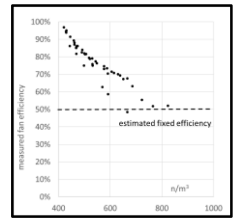
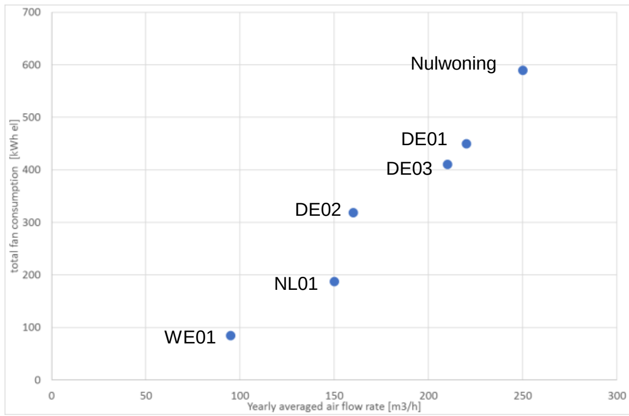
Annual electrical consumption for six field studies

Energy

Electrical consumption has been derived from total pressure, air flow rate, and average fan efficiency (estimated as 50%, on low side)





- The annual electrical consumption depends on the system duct resistance
- The annual electrical consumption varies quadratic with air flow rate

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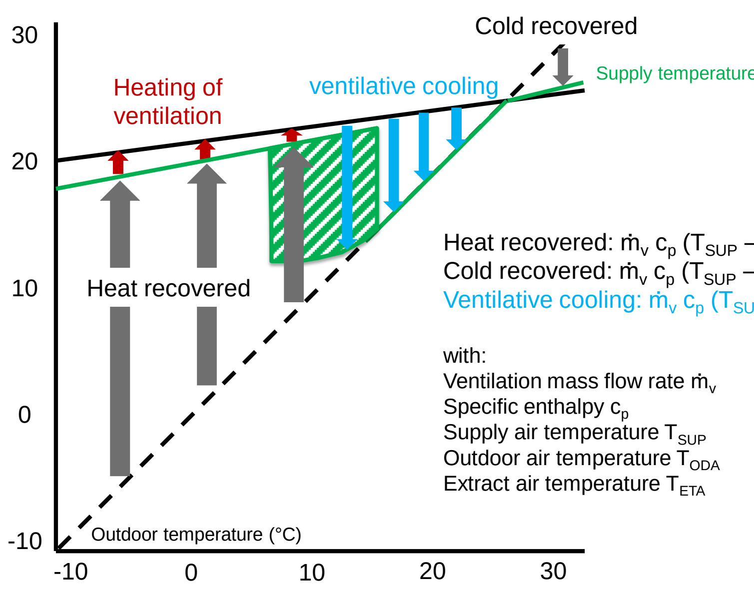
Energy calculation method

Energy



Heat recovered: $\dot{m}_v\, c_p\, (T_{SUP} - T_{ODA})$

Cold recovered: $\dot{m}_v\, c_p\, (T_{SUP} - T_{ODA})$

Ventilative cooling: $\dot{m}_v\, c_p\, (T_{SUP} - T_{ETA})$

with:

Ventilation mass flow rate $\dot{m}_v$

Specific enthalpy c_p

Supply air temperature T_{SUP}

Outdoor air temperature T_{ODA}

Extract air temperature T_{ETA}

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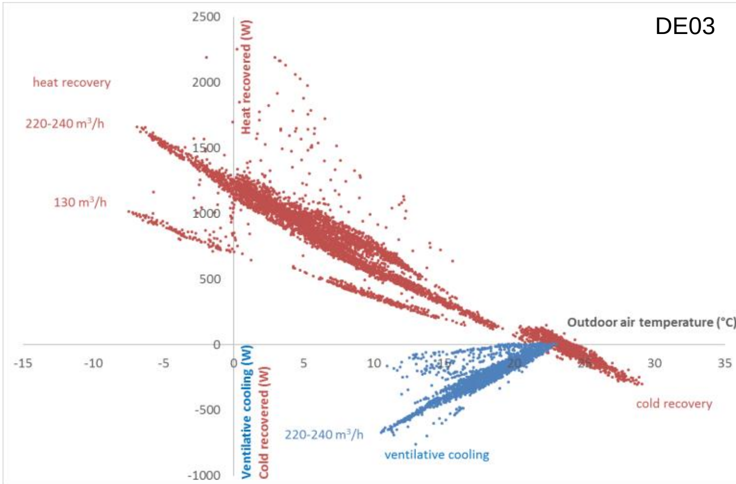
Monitored energy

Energy



- The recovered heat saves on the heating load for central heating system
- The recovered cold saves on the cooling load for central cooling system
- The ventilative cooling brings coolness to the house
- Numbers vary linearly with air flow rate

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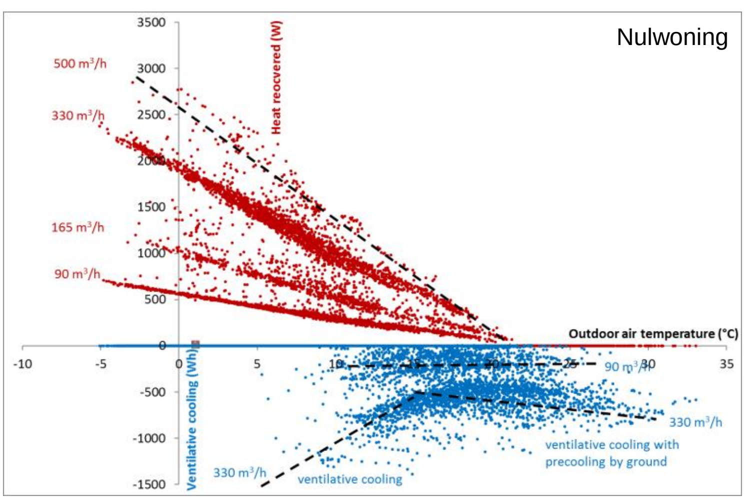
Monitored energy with ground heat exchange

Energy



- The recovered heat saves on the heating load for central heating system
- The ventilative cooling brings coolness to the house <u>for the whole summer</u>
- Numbers vary linearly with air flow rate

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Annual heat recovered

Energy

Seasonal performance factor for heat recovery (SPF HR) =
heat recovered divided by electricity consumed *in heat recovery season*

	Fan consumption [kWh el]	Heat recovered [kWh th]	SPF HR [-]
WE01 (ERV)	39	1850	47
NL01 (HRV)	130	2824	22
DE02 (HRV)	150	3404	23
DE03 (HRV)	251	4117	16
DE01 (ERV)	262	4449	17
Nulwoning (ERV)	290	4570	16

- Total heat recovered depends on outdoor climate, flow settings and comfort settings
- SPF HR is highest for low flow setting
- Monitored effectivity of heat recovery is between 47 and 16

Annual cold recovered

Energy

Seasonal performance factor for cold recovery (SPF CR) =
cold recovered divided by electricity consumed *in cold recovery season*

	Fan consumption [kWh el]	Cold recovered [kWh th]	SPF CR [-]
Nulwoning (ERV)	0	0	-
WE01 (ERV)	6	27	4.5
DE01 (ERV)	~~7~~	~~10~~	~~1.4~~
NL01 (HRV)	~~13~~	~~31~~	~~2.4~~
DE02 (HRV)	24	61	2.5
DE03 (HRV)	27	53	2.0

- Total cold recovered depends on outdoor climate, flow settings and comfort settings
- SPF CR is highest for low flow setting
- Monitored effectivity of cold recovery is between 4.5 and 2.0

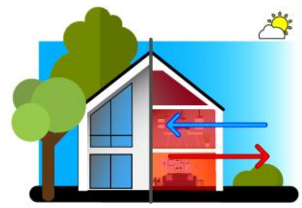
~~strike through numbers~~ not valid because of technical problems during this period

Annual ventilative cooling

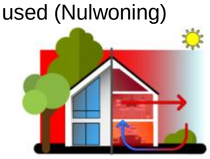
Energy

Seasonal performance factor for ventilative cooling (SPF cooling) =
ventilative cooling divided by electricity consumed *in ventilative cooling season*

	Fan consumption [kWh el]	Ventilative cooling [kWh th]	SPF cooling [-]
WE01 (ERV)	40	393	9.8
NL01 (HRV)	~~45~~	~~126~~	~~2.8~~
DE03 (HRV)	133	497	3.7
DE02 (HRV)	145	657	4.5
DE01 (ERV)	~~181~~	~~695~~	~~3.8~~
Nulwoning (ERV)	300	1480	4.9



- Total ventilative cooling depends on outdoor climate, flow settings and comfort settings
- Total ventilative cooling relatively high when ground precooling is used (Nulwoning)
- SPF cooling is highest for low flow setting
- Monitored effectivity of ventilative cooling is between 9.8 and 3.7



~~strike through numbers~~ not valid because of technical problems during this period

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Summary

Balanced ventilation systems are effective in saving on heating and cooling costs for residential buildings

Installed capacity of central heating/cooling systems can be reduced when combined with balanced ventilation systems

Balanced ventilation systems can provide ventilative cooling in an effective way for a comfortable supply of fresh air, especially when combined with ground heat exchange

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Characterising window opening behaviour of occupants using machine learning models

HANYANG UNIVERSITY
BUILDING & ENVIRONMENT DESIGN LAB

J.S. Park and Bongchang Jeong

Hanyang university

39th AIVC Conference, 19 September 2018

Purpose

- Occupant changes their indoor environment
- The behavior significantly influence on energy use
- There is big gab between the simulation / real buildings
- Modeling of the occupant behavior can help these gab

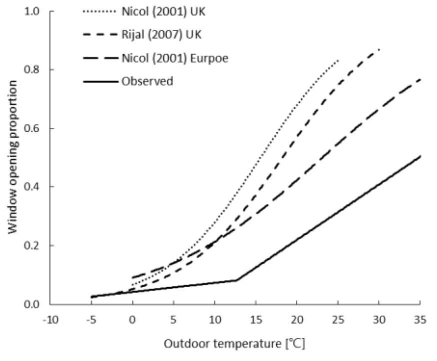
> Window opening/closing behavior in homes

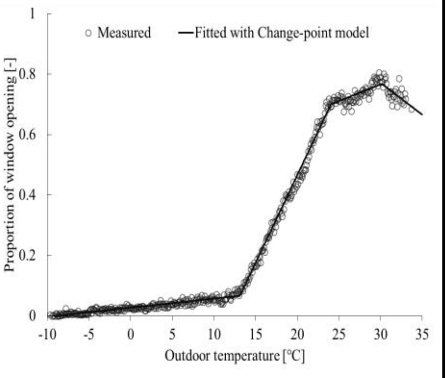
(thermal environment and IAQ, through ventilation)

- Developing the occupant behavior model

  using Machine learning algorithms

Previous models





Logistic models (linear)* Chang-point model (Non-linear)**

J.S.Park (2016), Occupant behavior regarding the manual control of windows in residential buildings, Energy and Buildings. 127, 206-216
J.S. Park (Reviewed), Modeling occupant behavior of the manual control of windows in residential buildings, Indoor Air

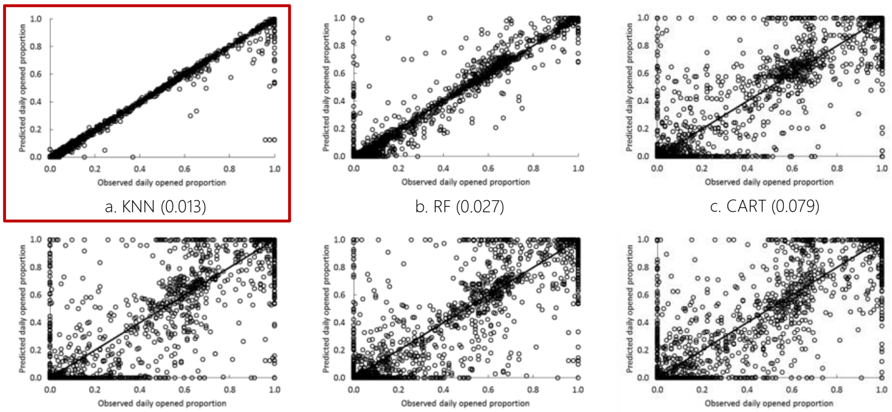
Monitoring

- Gathered data from 23 homes during three year

Sample ID	Floor area [m²]	Floor level[a]	Number of occupants[b]	Period of residence [year]	Smokers	Participated period[c]
a	109	4/20	3 (M, F, m)	6.5	0	H/NH/C
b	109	8/20	4 (M, F, f, f)	6.8	0	H/NH/C
c	171	8/20	4 (M, F, f, f)	6.6	1	H/NH/C
d	109	16/24	4 (M, F, f, f)	7.0	0	H/NH/C
e	109	5/24	3 (M, F, f)	6.6	0	NH
f	129	14/26	4 (M, F, m, f)	7.0	0	H/C
g	163	12/14	4 (M, F, m, f)	2.3	0	H/NH/C
h	163	4/15	4 (M, F, m, f)	2.0	0	H/NH/C
i	163	6/14	4 (M, F, m, f)	2.3	1	NH
j	163	10/15	4 (M, M, F, F)	2.0	0	NH
k	163	5/14	4 (M, F, m, f)	2.4	1	NH
l	136	2/19	4 (M, F, m, m)	2.8	0	H/C
m	145	4/19	4 (M, F, f, m)	3.0	0	H
n	145	13/19	4 (M, F, f, f)	1.2	0	H/C
o	163	1/19	5 (M, F, m, f, f)	2.8	0	C
p	72	14/21	4 (M, F, f, f)	6.7	0	H/NH
q	80	7/23	4 (M, F, m, f)	9.5	1	H/NH
r	72	14/21	3 (M, F, M)	7.8	0	C
s	108	9/25	4 (M, F, f, f)	4.5	0	H/NH/C
t	79	25/25	4 (M, F, m, f)	17.5	0	C
u	79	6/20	4 (M, F, m, m)	1.4	0	H/NH/C
v	163	15/25	4 (M, F, m, f)	2.0	0	NH
w	79	19/25	4 (M, F, m, m)	16	0	H/C

Results

- All algorithms predict the occupant behavior more precisely than previous models
- Among the algorithms, KNN showed the best fit with measured data

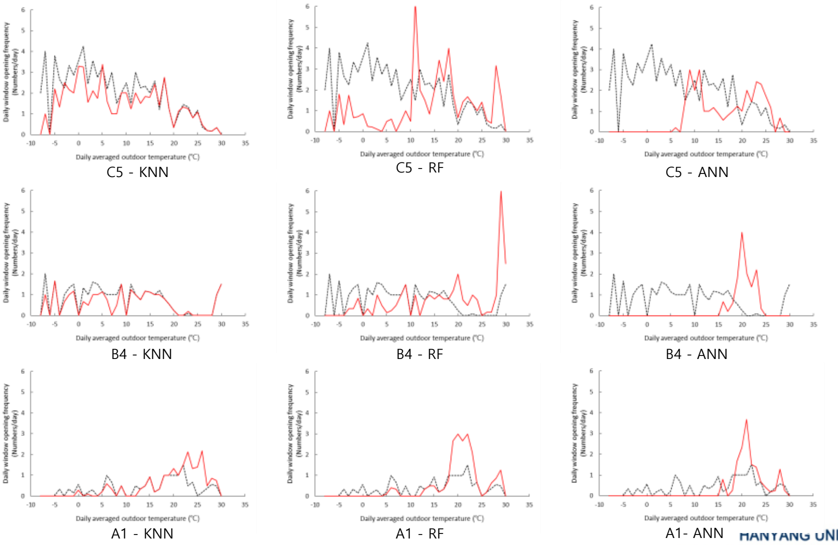


a. KNN (0.013) b. RF (0.027) c. CART (0.079)

d. SVM (0.087) e. ANN (0.096) f. CHAID (0.105)

Results

- Daily patterns predicted by the machine learning algorithms



C5 - KNN C5 - RF C5 - ANN

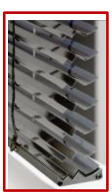
B4 - KNN B4 - RF B4 - ANN

A1 - KNN A1 - RF A1- ANN

EXPERIMENTAL AND NUMERICAL STUDY OF A BUILDING RETROFITTING SOLUTION COMBINING PHASE CHANGE MATERIAL WALLBOARDS AND NIGHT VENTILATION

Timea Béjat*[1] Emile Fulcheri[1], Didier Therme[1], Etienne Wurtz[1], Pierrick Péchambert[2]
19/09/2018

STUDIED SYSTEM AT CEA'S INCAS PLATFORM



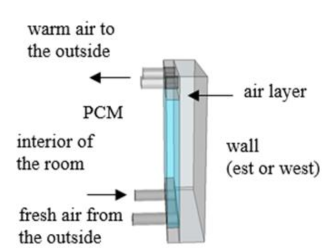

Added window

Prevent overheating from solar radiation with blinds

VIP (λ≈0,007 W.m^{-1}.K^{-1})

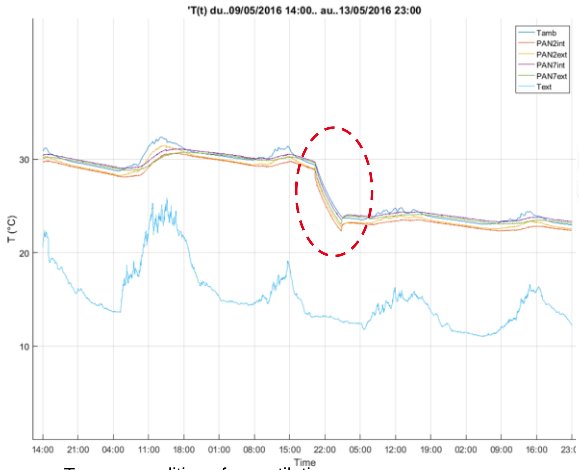
Box in the box concept

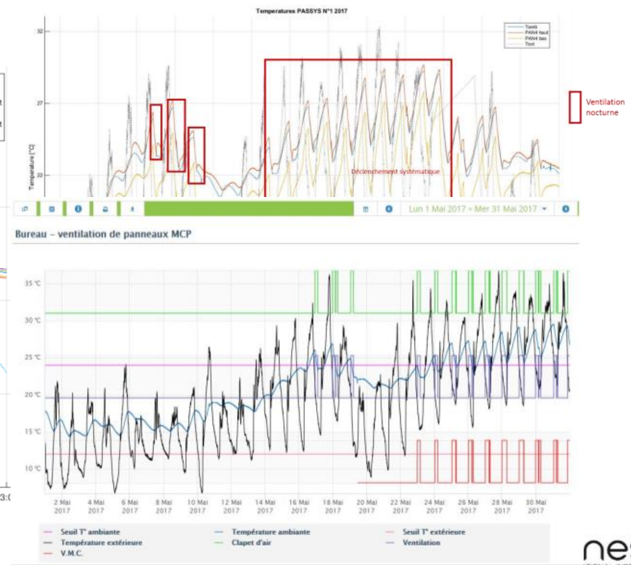
PCM containing ventilated wallboards



SYSTEM'S ACTIVATION

1st year: 09/2015
2nd year: 11/05/2016
3rd year: 17/05/2017



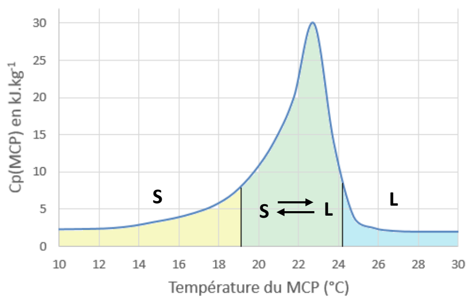


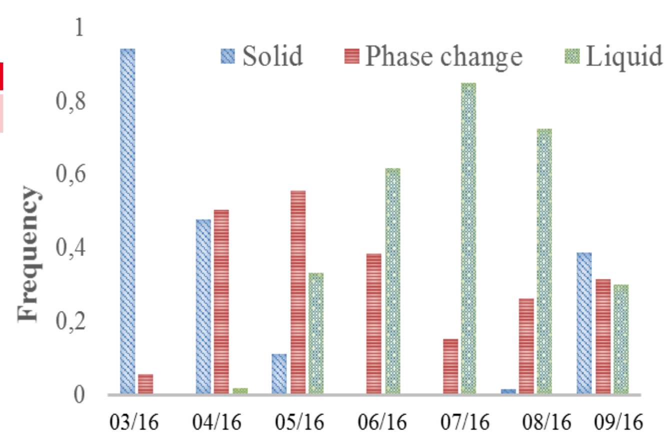
Turn on conditions for ventilation:

- non-occupied period (8PM – 7AM)
- $T_{int} > 24$ °C
- $T_{int} - T_{ext} > 5$ °C

ACTIVATION FREQUENCY OF PHASE CHANGE (WITHOUT ROOM VENTILATION)

Solid	Phase change	Liquid
T(PCM) <19,1°C	19,1°C < T(PCM) < 24,25 °C	T(PCM)>24,25 °C

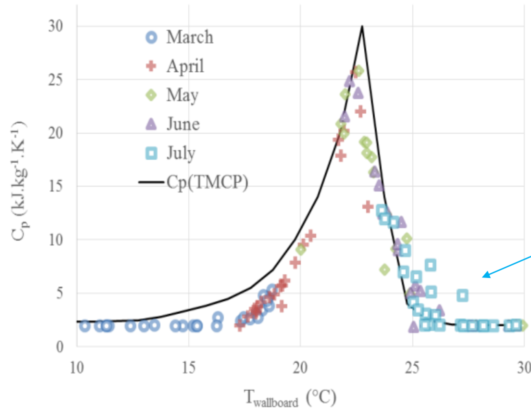




- During 2nd year latent heat is exploited mostly in April and May
- Overheating not avoided in June/July

→ System should be combined with room ventilation

Daily mean thermal capacity between March and July 2016



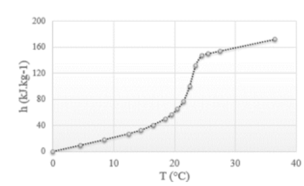
In July the phase change is not often exploited

Calcul method:

$T_{wallboard}$ measured at each minute → C_p (TPCM ≈ $T_{wallboard}$) → mean Cp during the day:

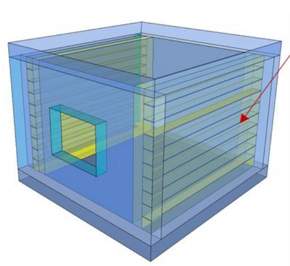
$$\frac{1}{1440}\sum_{m=0}^{1440} Cp(T) \approx \int_{day} Cp(t)dt$$

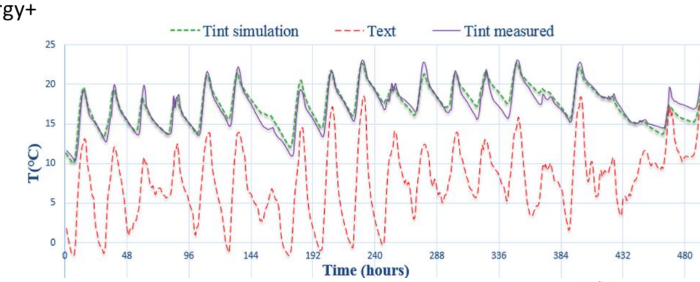
NUMERICAL STUDY



- **Test cell model in Energy+:**
  - - PCM wallboards are modeled as 10 thermal zones
  - - The enthalpy is determined by integrating the thermal capacity and entered in Energy+ in discretized form
- **Model validation shows good agreement between measured and simulated data.**

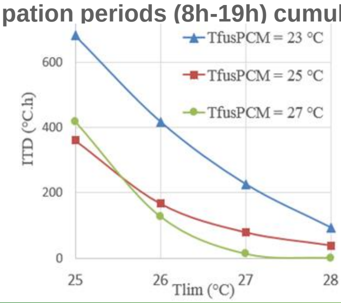
Convective exchange coefficients are input for Energy+

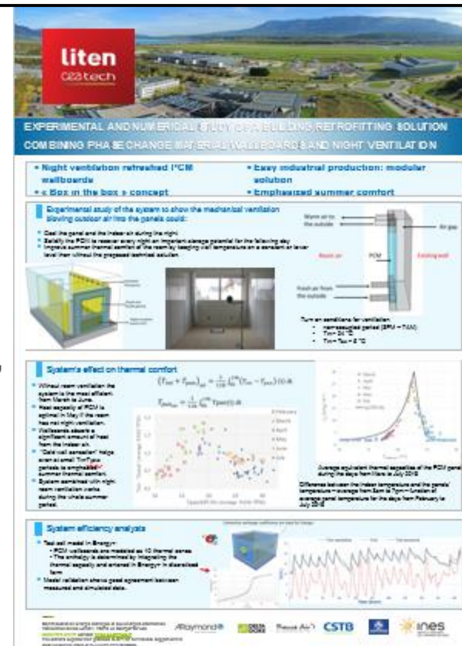




NUMERICAL STUDY

- The indicator used in this part is called integrated thermal discomfort level and is defined by:
- $\mathbf{ITDL_{Tlim}} = \frac{1}{T}\int_T e(t)\,dt$
- With:
- Tlim a limit indoor temperature of comfort (chosen here between 25 and 28 °C)
- e(t) = (Tint – Tlim) when Tint > Tlim and e(t) = 0 otherwise, with Tint(t) the indoor temperature
- T the occupation periods (8h-19h) cumulated from June to August





MERCI POUR VOTRE ATTENTION

THANKS FOR YOUR ATTENTION

Commissariat à l'énergie atomique et aux énergies alternatives
Alternative Energies and Atomic Energy Commission
17 av des martyrs 38000 GRENOBLE France
http://liten.cea.fr

Établissement public à caractère industriel et commercial
Public establishment with commercial and industrial character
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Potential of mechanical ventilation for reducing overheating risks in retrofitted Danish apartment buildings from the period 1850-1890 – A simulation-based study

Daria Zukowska, Jakub Kolarik, Myrto Ananida, Mandana Sarey Khanie and Toke Rammer Nielsen

Technical University of Denmark

Background:

- Energy efficient renovation of buildings necessitate adopting high-insulation and airtightness
- Overheating risk
- Negative effect of elevated indoor temperatures on occupants' health, wellbeing and productivity
- The Danish building regulations:

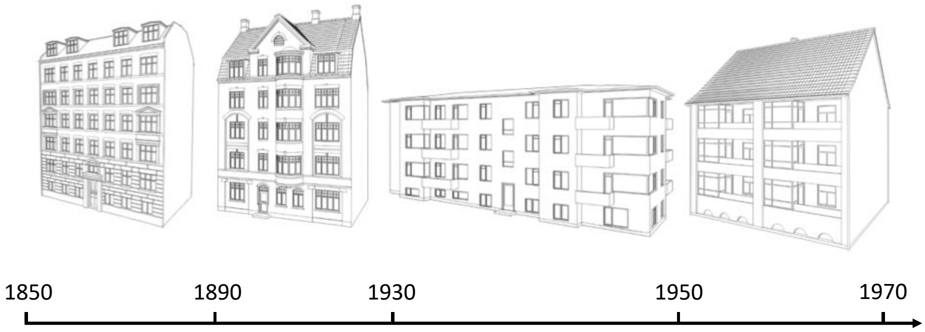
  $t_{operative}$ ≥ 27°C max. 100 h/year

  $t_{operative}$ ≥ 28°C max. 25 h/year

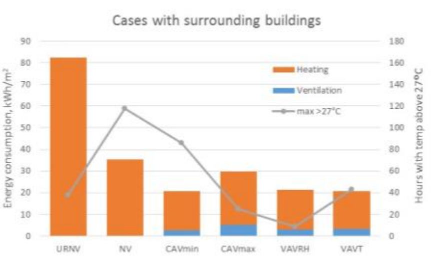
Part of research project:

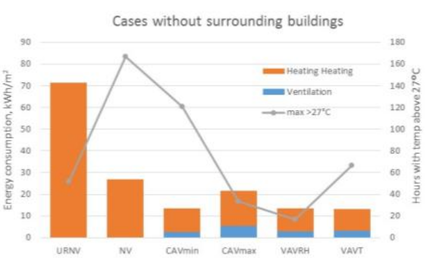
“Reduction of overheating in Danish dwellings by use of effective solar control without comprising visual comfort”

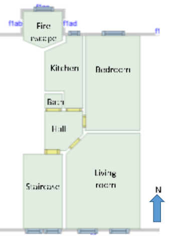
- which focuses on typical buildings from the period 1850-1970



The impact of different ventilation strategies on overheating risk and energy consumption







Development of an Indoor CO_2 Metric

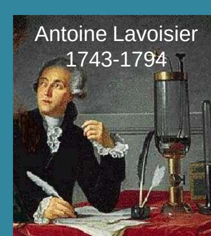
Andrew Persily
National Institute of Standards and Technology
Gaithersburg, Maryland USA

39th AIVC Conference
Antibes Juan-les-Pins, 19 September 2018

INTRODUCTION

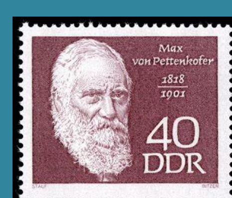
CO_2 part of ventilation & IAQ discussions since 18th century

- Many confused about indoor CO_2



IAQ Metrics

- Which contaminants? Levels?
- 1800 mg/m^3 (1000 ppm$_v$) CO_2



Background: Indoor CO_2

- **Studies of body odor perception**
  80 % acceptable: ~8 L/s•person,
  CO_2 1250 mg/m^3 > outdoor

- **1800 mg/m^3**
  Reflects acceptable body odor
  ASHRAE Standard 62-1989

- **Indoor CO2 levels < levels of health interest**
  Inconsistent evidence of effects on cognitive performance

Indoor CO_2 as an IAQ Metric?

Not a comprehensive indicator of IAQ

Indoor levels not health or comfort issue

Stop measuring?

Indicator of outdoor air ventilation per person

Analysis Approach

Calculate CO_2 vs. time

Space: Outdoor airflow rate: Floor area & volume

Occupants: Number, CO_2 generation (sex, age, body mass, met level)

Paper considers 10 commercial building spaces

Residential and on-line calculator to follow

CO_2 Concentration Calculations

	Occupancy (#/100 m^2)	**Outdoor air ventilation** (L/s•person)	**Occupants** (age, body mass in kg, met level)	**Avg. CO_2 per person** (L/s)
Classroom (>9 y)	35	6.7	17 males (15, 68, 1.7); 17 females (15, 61, 1.7); 1 male (30, 85, 2.5)	0.0059
Hotel bedroom	10	5.5	5 male (30, 85, 1); 5 female (30, 75, 1)	0.0033
Office space	5	8.5	2.5 male (30 85, 1.4); 2.5 female (30, 75, 1.4)	0.0047
Auditorium	150	2.7	75 males (30, 85, 1.3); 75 females (30, 75, 1.3)	0.0044
Lobby	150	2.7	75 males (30, 85, 2); 75 females (30, 75, 2)	0.0067
Retail/Sales	15	7.8	7.5 male (30, 85, 2); 7.5 female (3y, 75, 2)	0.0067

Occupancy and ventilation from Standard ASHRAE 62.1

Calculated CO_2 Concentrations

			CO_2 above outdoors (mg/m^3)		
Space Type	Time to steady-state (h)	t_{metric} (h)	Steady-state	1 h	t_{metric}
Classroom (>9 y)	1.1	2	1580	1490	1580
Hotel/motel bedroom	4.5	6	1080	520	1060
Office space	5.9	2	985	390	630
Auditorium	0.6	1	2900	2880	2880
Lobby	0.6	1	4467	4430	4430
Retail/Sales	2.1	2	1546	1170	1450

Repeated calculations for 25 % reduced ventilation rate

Potential CO_2 Metrics

Space Type	CO_2 above outdoors (mg/m^3)	Time (h after full occupancy)
Classroom (5 to 8 y)	1000	2
Classroom (>9 y)	1500	1
Lecture classroom	2000	1
Restaurant dining room	2000	1
Conference meeting room	2000	1
Hotel/motel bedroom	1000	6
Office space	600	2
Auditorium	3000	1
Lobby*	4500	1
Retail/Sales*	1500	2

*** Transient occupancy**

Discussion

CO_2 metric of ventilation per person

- **Must link to measurement time**
- **Must consider actual occupancy**
- **Spaces with transient occupancy**
- **Additional data:** Space type, occupant density; time of occupancy and concentration measurement; .

Future considerations

- **Residential building spaces**
- **Online calculator being developed**

ECONOMICS OF IAQ

Max Sherman, Benjamin Jones, Iain Walker

Lawrence Berkeley Laboratory; University of Nottingham

AIVC Conference; September 2018

Overview

- Economics drives decision making
  - Basic economics
  - What are the IAQ-related decisions
- How we can use economics
  - Monetizing costs
  - Monetizing benefits
- Examples
  - Smart Ventilation
  - IAQ Metrices

Economics

- ...is the branch of knowledge concerned with the production, consumption and transfer of wealth.
- *Economic decision-making* is the process of making decisions involving money.
- Every IAQ decision involves money: some directly, some indirectly.

Economic Tools

- Require identification of costs and benefits
  - Usually separately identified as a function of time
- Require *Monetization*
  - All costs and benefits must be turned into a currency
- Typical metrics
  - Benefit-cost ratio
  - Internal rate of return
  - Payback time
  - Net present value

Typical IAQ Decisions

- Put in (and size) ventilation and control system
- Use low-emitting building materials and appliances
- Install air cleaning or filtration
- Meet a standard, guideline or code

Factors in Decision

- FIRST COST OF CONSTRUCTION
- ONGOING COST OF OPERATIONS (ENERGY)
- STAFF AND SUPPLY MAINTENANCE COST
- HEALTH AND COMFORT IMPACT

Are those costs or benefits?

Could be either

- All are costs, if starting from a blank sheet
- Usually we compare alternatives from a base

↓

Some economics metrics are not always suited for this kind of problem

E.g. cost-benefit ratio, payback time, internal-rate of return.

↓

Net Present Value **(NPV) is immune to these issues**

But still requires economic inputs like interest rate

Key question: Can we monetize IAQ?

No
- No standard way to turn all IAQ factors into money

Maybe
- Standards can be used in some areas

Yes
- At least partially: We have ways monetize health

How do standards help?

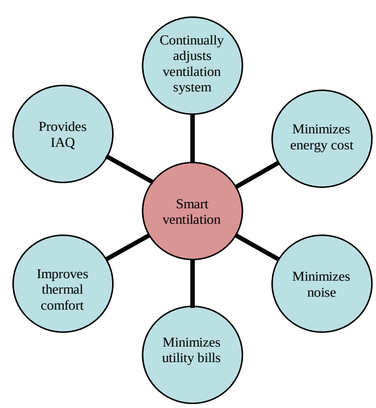
Replace monetization by minimum requirements
- Hopefully based on sound judgement
- ASHRAE Standard 62.2 is example of such a standard

Envable NPV-type calculation to optimize economic impact
- All other costs and benefits are monetized
- Other economic metrics may work depending on details.

Allow innovative approaches
- If standards are flexible enough
- "Smart Ventilation" is key example.

What is Smart Ventilation?

- Shift ventilation in time and still provide acceptable IAQ
  - Ventilate more when conditions are favorable, less when conditions are extreme
- Use operation of other air moving/cleaning/humidity control devices to reduce ventilation requirements
- Smart systems can use this flexibility to
  - Reduce energy consumption
  - Respond to electric grid needs & rate structures
  - Respond to outdoor air quality excursions
  - Improve IAQ cheaply
  - Reduce peak loads



Maintaining IAQ - Equivalence

Same (or lower) annual exposure to pollutants

Compared to current fixed ventilation rates in codes/standards

A low air change rate at one time offset by high flow at another

- NOT arithmetic average: concentration inversely proportional to ventilation rate
- Calculation procedures developed – included in ASHRAE 62.2

Smart Ventilation Examples

Simple Timer

System off for hottest (or coldest or most humid) 4 hours of the day. Same hours every day. Like a programmed thermostat

Sense weather

Use measured outdoor temperatures and humidity to control the ventilation system.

Shift within a day, a week, a season

Sense other fans

Kitchen, bathroom & clothes dryer exhaust – include them in exposure calculation so ventilation fan can be turned off

Smart Ventilation Examples

Respond to utility signal

System off/reduced at time of peak demand. Ventilate more later to "catch-up"

Respond to outdoor air quality

System off/reduced when outdoor air quality poor. Ventilate more later to "catch-up"

Respond to occupancy

Ventilate less when unoccupied

Keep track of pollutant build-up to avoid acute exposures

Smart Ventilation Controls

Use ventilation efficacy analysis to track dose and exposure
- Pre-calculated or Real-time

Pre-calculated
- Determine input "setpoints", e.g., outdoor temperature, at which to turn ventilation system on/off

Real-time
- Calculate dose and exposure for the airflows provided by the smart system (including other fans + infiltration if you want) relative to the non-smart system
- Decide to turn mechanical ventilation on or off depending on calculated dose and exposure
- Reasonable time periods are 10-15 minutes

Can be integrated into existing HVAC controls

Needs more fan capacity (25-50%)

Smart Ventilation is Limited

Improves upon dumb ventilation, but…
- Is blind to harm done by contaminants
- Does allow for time-varying emission rates
- Does not allow economic trade-off

Must monetize IAQ directly to go further
- Need to move from hazards to harm and put all kinds of harms on equal footing…and then but a monetary value on that.

Move from "smart ventilation" to "smart IAQ"
- Transition to *IAQ Metrics*

Four aspects of IAQ quantified & monetized

Health	Comfort	Moisture	Occupant/Activities

Economics takes over to find optimal allocation of resources

Maximize Net Present Value

IAQ Metrics Vision

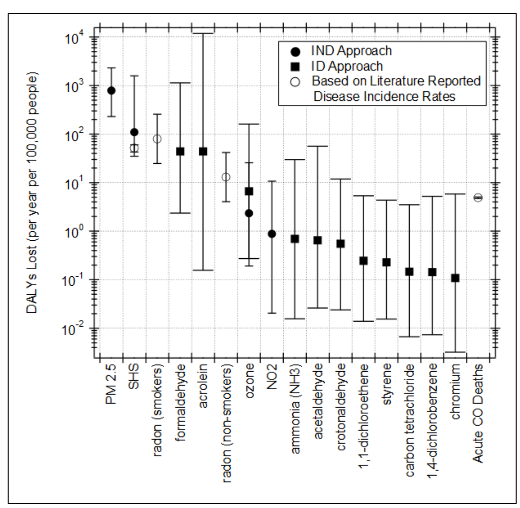
Disability Adjusted Life Years

- Existing concept used in medical economics
- Includes morbidity and mortality
- i.e. shortening of life and loss of quality of life
- Has had independent value, but varies
  £100k pre-Brexit
  €100k post-Brexit
- Works for health, but not for others

DALYs Identify Contaminants of Concern

1. Particles
2. Products of combustion
3. Formaldehyde

- Radon/Ozone locally



SUMMING UP

IAQ is resistant to economic analysis.

The more we can monetize IAQ, the easier it will be to have it incorporated in everyday decision making.

IAQ Metrics is the ultimate approach for monetization, but it just in its infancy.

Smart Ventilation is an intermediate step that can be implemented today.

Use Case of data analysis for assessing IAQ indicators

Xavier BOULANGER

AIVC - Juans les Pins *19.09.2018*

Use Case of data analysis for assessing IAQ indicators

#HealthyLiving

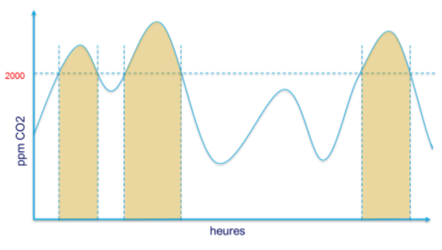
aldesgroupe

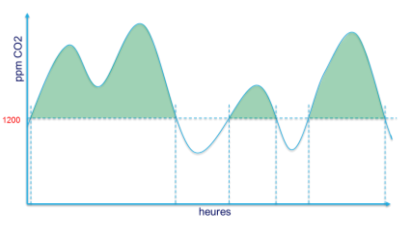
Use Case of data analysis for assessing IAQ indicators

4 dedicated indoor air quality sensors

#Healthy

IAQ indicators : focus on CO2





- Evaluation only with annual simulation
- Done with complex software (done by CSTB, TNO…),
- => not possible to be calculated on real time

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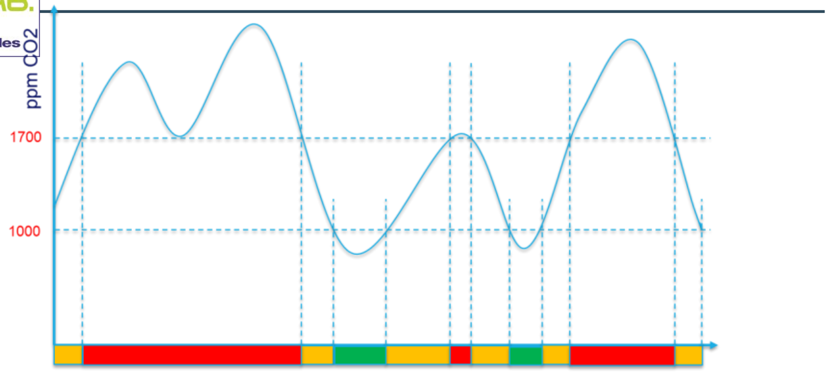
IAQ indicators CO2: ICONE



- a logarithmic law,

ICONE = 8,3 log (1 + % yellow + 3 x % red)

- a scale from 0 to 5, 0 being the best score and 5 the worst,
- 0 if CO_2 concentrations are below 1000 ppm,
- 5 if all CO_2 concentrations are above 1700 ppm,

The 0 to 5 scale is very easy to understand for a non-expert and the value is independent of the duration.

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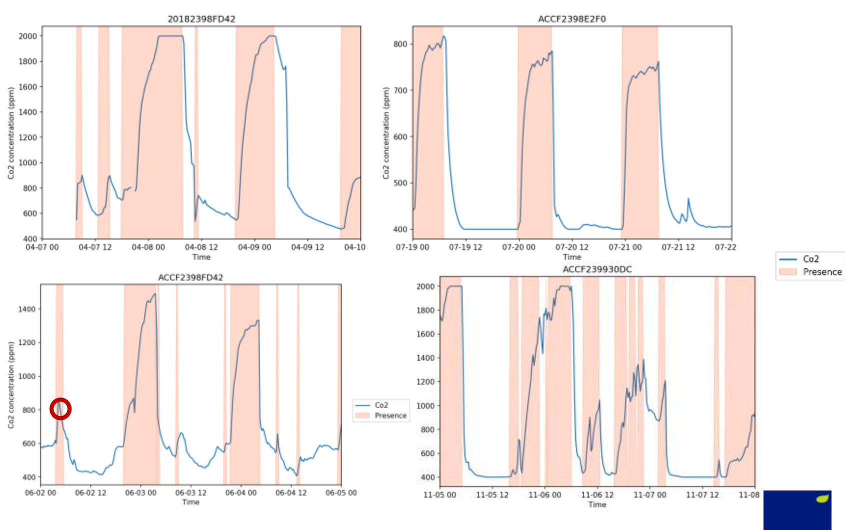
Presence detection: 4 analysis



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Simulations:

- Done with matis software

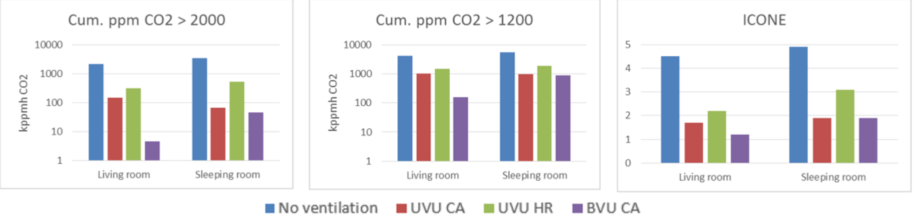

Figure 2: Comparison of stuffiness indicators in the living room and the main sleeping room of a dwelling equipped with either constant airflow extraction ventilation (UVU CA) or humidity control exhaust ventilation (UVU HB) or constant airflow bidirectional ventilation (BVU CA)

- Bidirectional ventilation is the best as attended
- ICONE more precise thanks to Log scale integrated in the indicator

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Comparison of Indicators

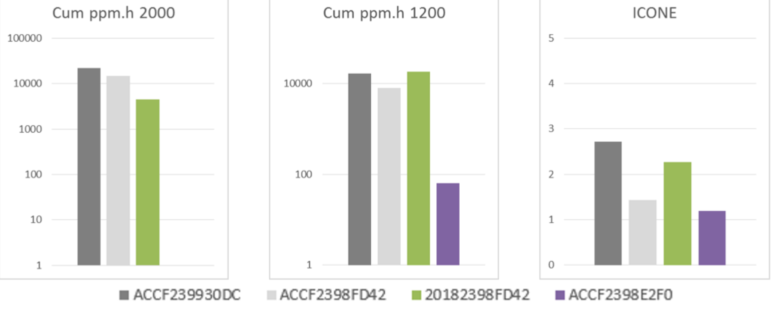

Figure 6 – Air stuffiness indicator value for 4 sensors in sleeping rooms

- Thanks to connected data and occupancy detection, able to be measured in real time – same results than simulation
- Scale of ICONE is easy to understand
- ICONE is independent of the length of the measurement period

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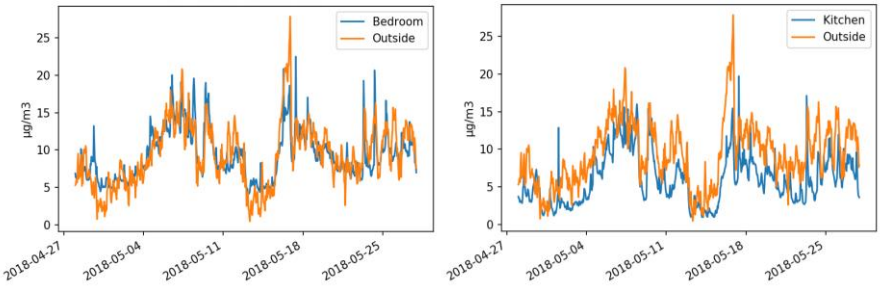
Correlation PM 2.5 Indoor/Outdoor



a) sleeping room and outside

b) kitchen and outside

Figure 8 - comparison of outside and inside PM2.5 concentration

- Very good indoor/outdoor correlation:
- Outside estimations are also precise
- Little influence of internal activity on PM 2.5
- Potential for improvement via high efficiency filtration

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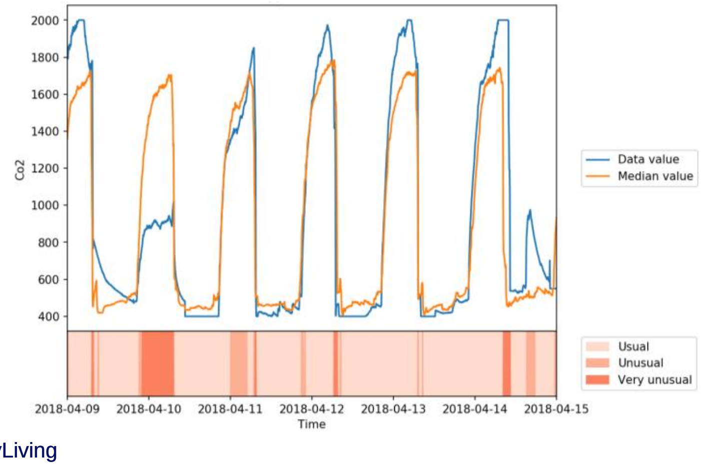
Detection of unusual events

- Algorithm based on comparing a given to each time step with a "median" type week.
-



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Conclusions

1. ICONE indicator based on CO2 is the best indicator for IAQ based on CO2
2. REAL TIME calculation are possible with connected product providing IAQ information (no more simulation …)
3. For exhaust ventilation system , air inlets should filter the air if we want to address PM2,5 issue
4. A lot to do with REAL DATA: usual and unusual scenarios, ….but also improvement of control, predictive maintenance and artificial intelligence

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Subjective Evaluation for Perceived Air Pollution Caused by Human Bioeffluents

AIVC 2018

Lisa YOSHIMOTO
Osaka University, Japan

1 Introduction

In Japan, there is a standard…

CO_2 concentration ≦ 1000 ppm

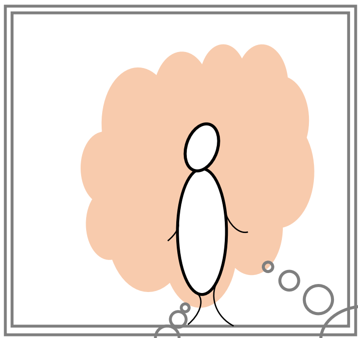
The problem is…

Adaptation Property of occupant is not taken into account.

To grasp how adaptation and property influence indoor air quality

1 Introduction

What is Adaptation?



Smell…

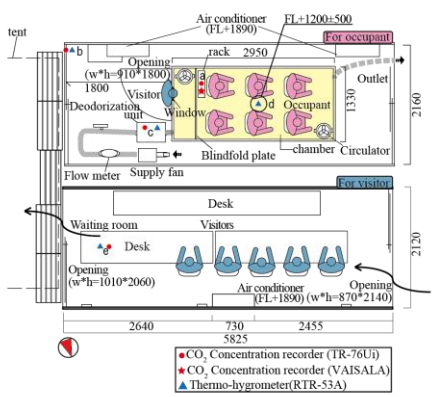
It got no smell…?

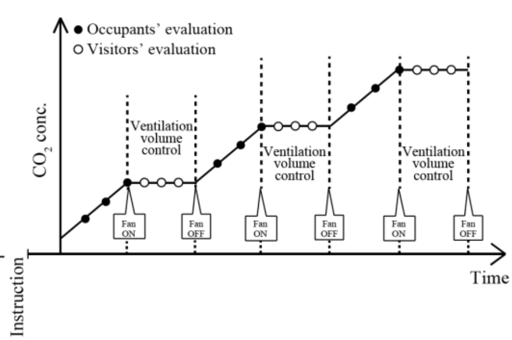
Adaptation

Ventilation air volume ↓

Energy saving!!

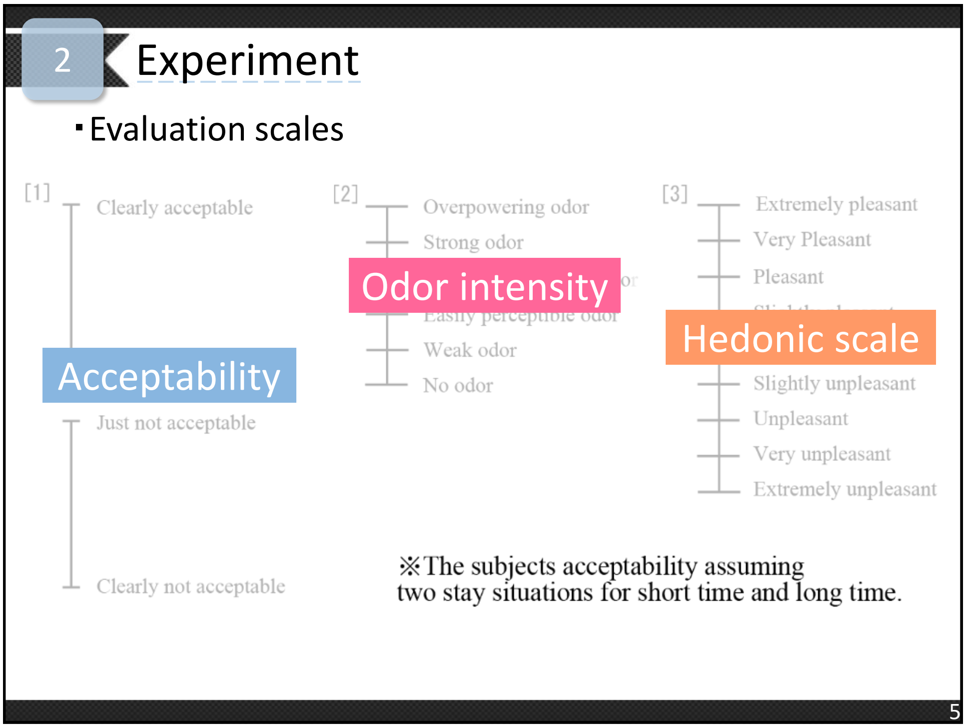
2 Experiment

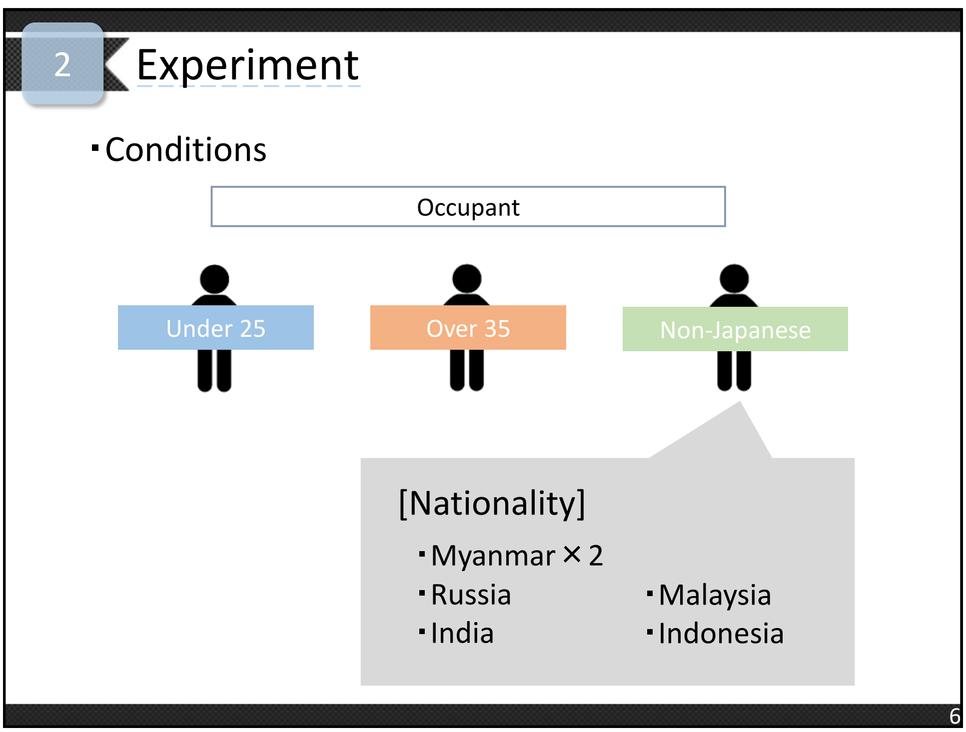




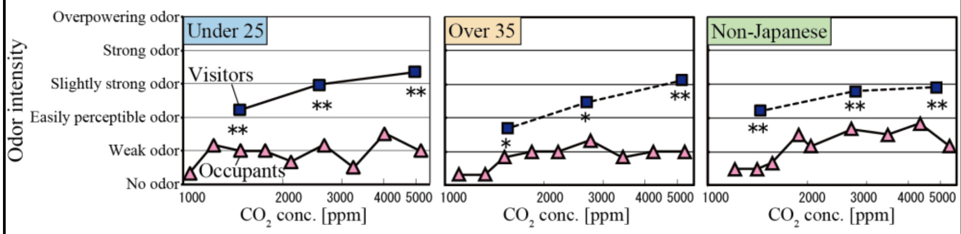
Occupants 1080, 1270, 1500, 1800, 2170, 2650, 3260, 4030, 5000 ppm

Visitors 1500, 2650, 5000 ppm


2
Experiment
・Evaluation scales
[1]
Clearly acceptable
Acceptability
Just not acceptable
Clearly not acceptable
[2]
Overpowering odor
Strong odor
Odor intensity
Easily perceptible odor
Weak odor
No odor
[3]
Extremely pleasant
Very Pleasant
Pleasant
Hedonic scale
Slightly unpleasant
Unpleasant
Very unpleasant
Extremely unpleasant
※The subjects acceptability assuming
two stay situations for short time and long time.
5


2
Experiment
・Conditions
Occupant
Under 25
Over 35
Non-Japanese
[Nationality]
・Myanmar × 2
・Russia
・India
・Malaysia
・Indonesia
6

3 Result



Visitors' Evaluation

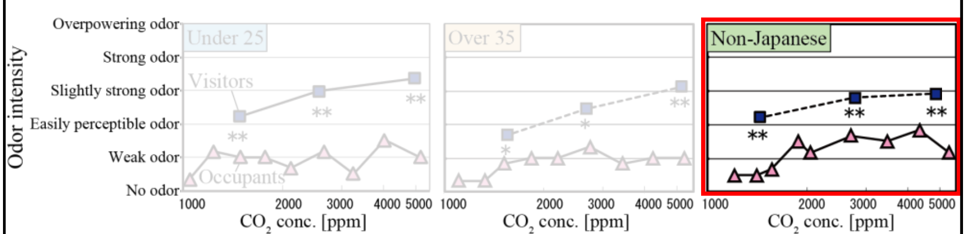
The positive correlation between odor intensity and CO_2 concentration can be seen in each condition.

Occupants' Evaluation

They evaluated almost flat through the environment.

Influence of adaptation

3 Result



Occupants' Evaluation

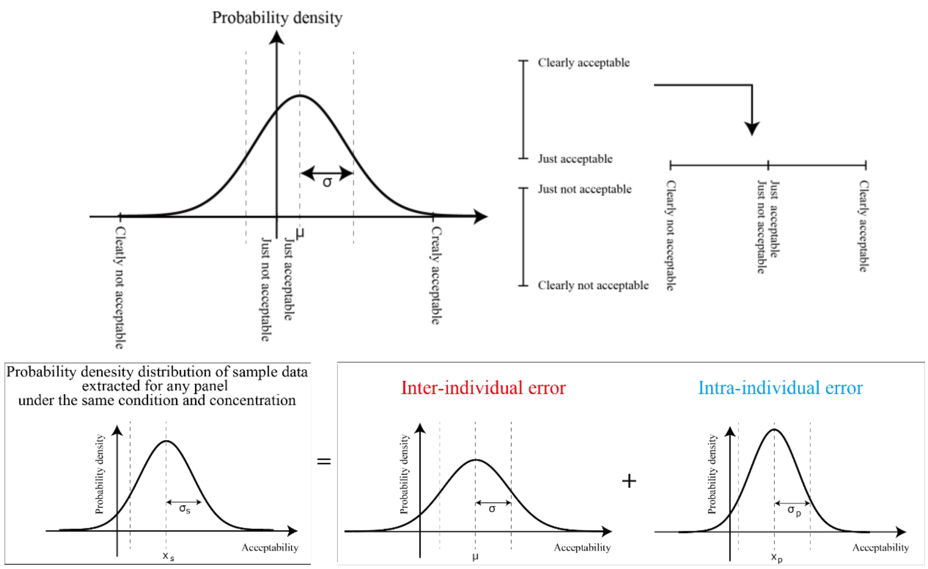
In Non-Japanese condition,

They evaluated more intense than other conditions after 1800 ppm.

Occupants with various nationalities were in same space.

4

Statistical Analysis



5

Conclusion

- The influence of adaptation was seen in occupants.
- Visitors' evaluation was correlated with CO_2 concentration.
- We analyzed statistically the reliability of data evaluated multiple times with a small number of panels.
- We proposed a probabilistic prediction method of PD.

PERFORMANCE OF CENTRAL HEAT RECOVERY SYSTEMS IN PRACTICE

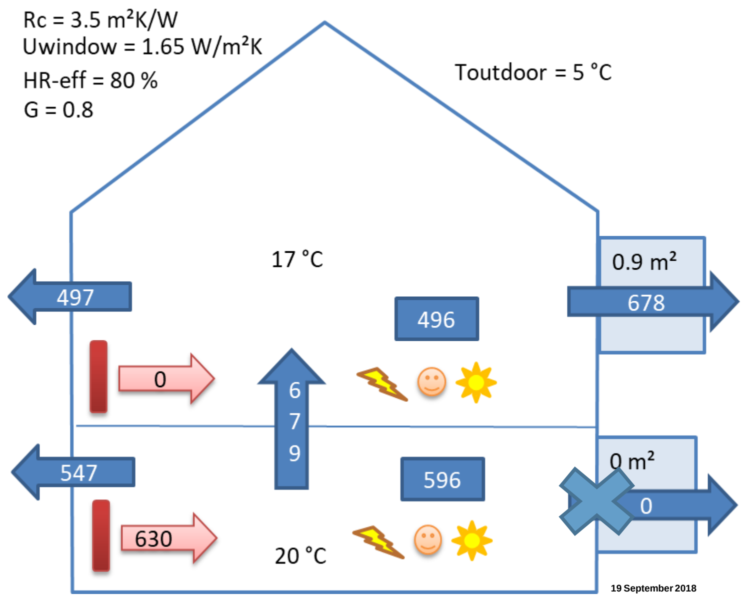
Bas Knoll and Wouter Borsboom

DEMANDS FOR THERMAL COMFORT

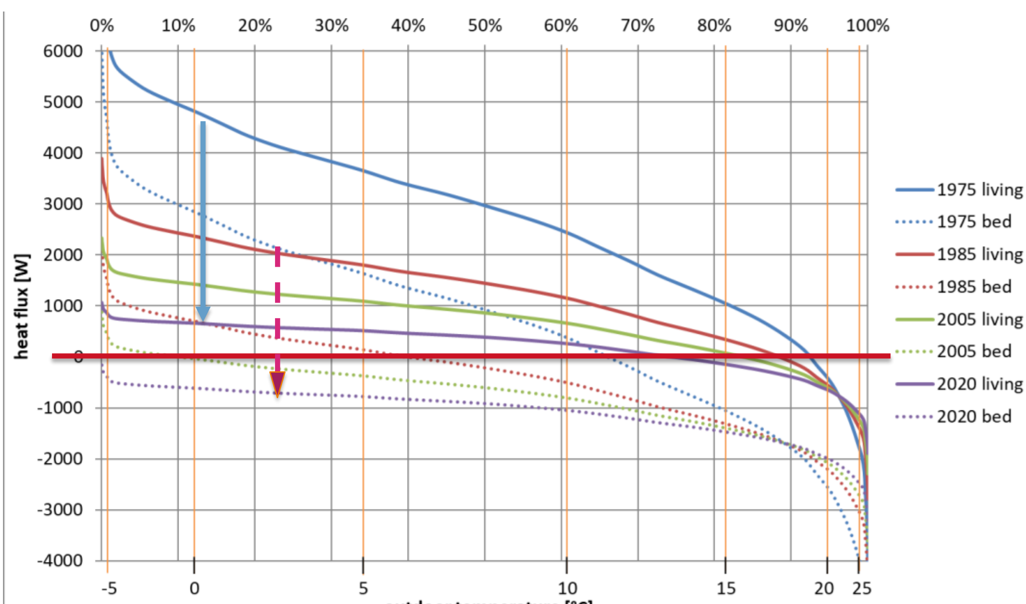
- Control indoor temperatures to comfortable values (at presence):
  - Heating season ~20°C living ~17°C bedroom
  - Summer season < ~24°C

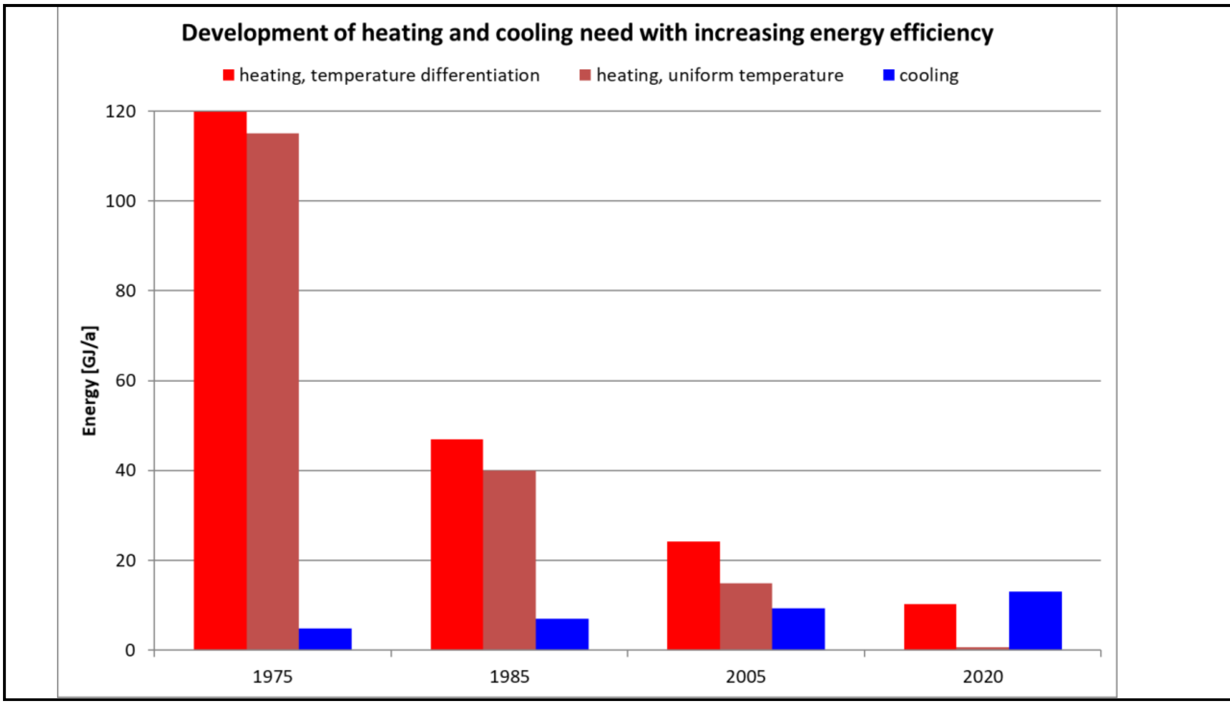
- Prevent draught:
  - Air velocities < 0.2 m/s (depending on inlet temperature)
  - Temperatures of room surfaces < 5 to 9 K below comfort temperature → insulation demand

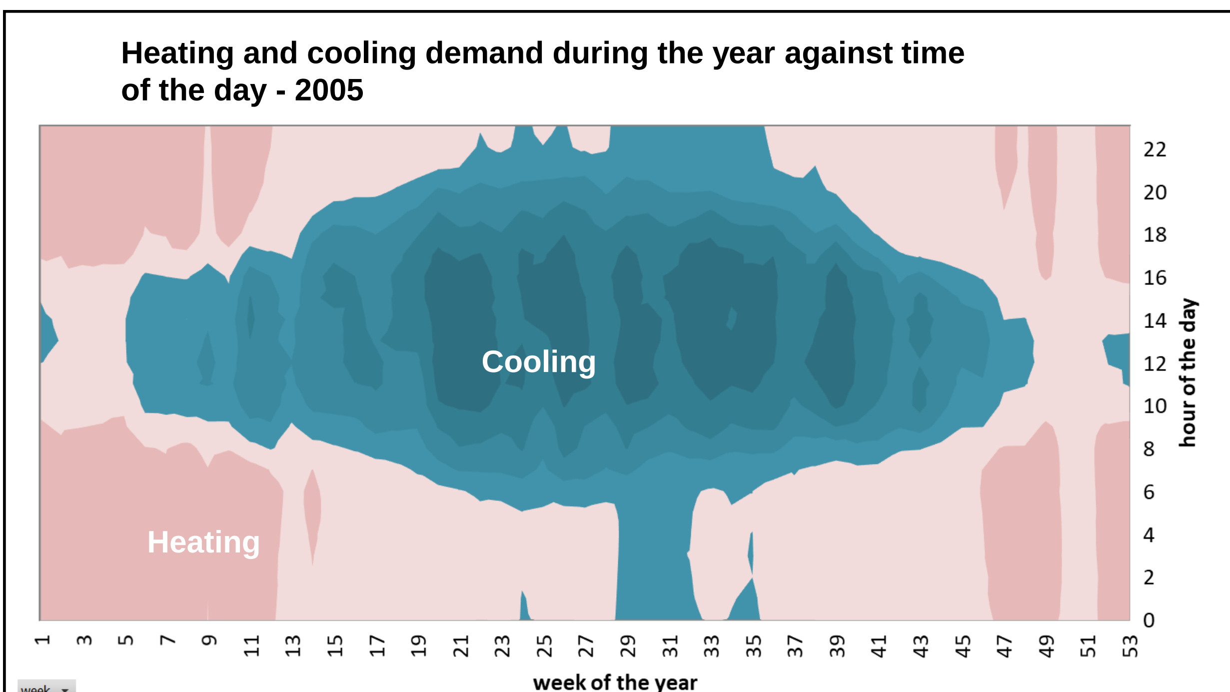
HEATING DEMAND LIVING, COOLING DEMAND BEDROOM



Change in heating and cooling demand from 1975 to 2020




Development of heating and cooling need with increasing energy efficiency
heating, temperature differentiation
heating, uniform temperature
cooling
Energy [GJ/a]
120
100
80
60
40
20
0
1975
1985
2005
2020

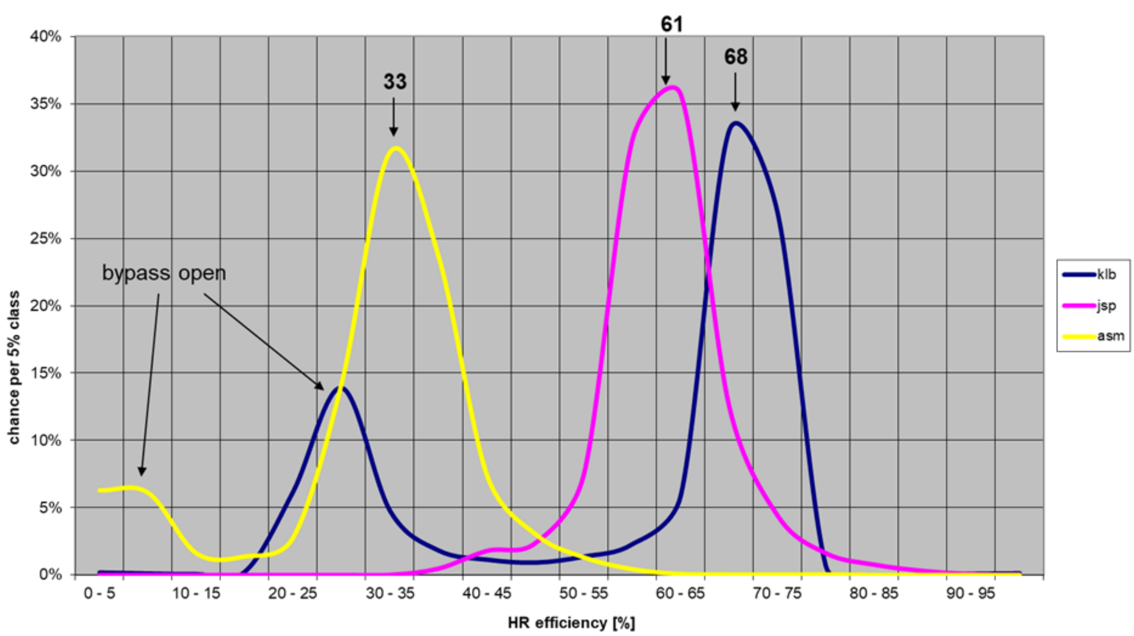

Heating and cooling demand during the year against time of the day - 2005
Cooling
Heating
22
20
18
16
14
12
10
8
6
4
2
0
hour of the day
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53
week of the year
week

DISADVANTAGES CENTRAL HR VENTILATION

- Current central HRV systems **do not distinguish different room** temperature demands:
  - There is no distinctive heat redistribution per room/zone, increased **risk of local overheating**

- Central HRV is common designed **for 'all heating' mode**, while this becomes les and less important. HRV is not fitted for 'combined heating/cooling' mode or 'cooling only' mode:
  - **Excess window use**, leading to an extra energy loss in the range of 7 GJ/a per dwelling
  - **Unnecessary high electricity use**, due to the extra pressure drop of the HR function all year

Measured HR recovery efficiency for three dwellings



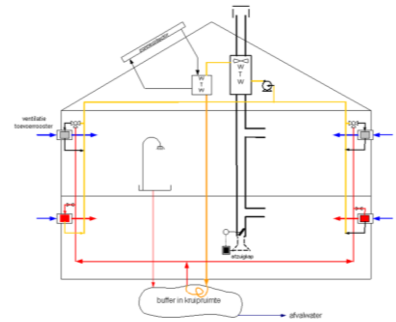
HOW ABOUT THE REAL HR PERFORMANCE?

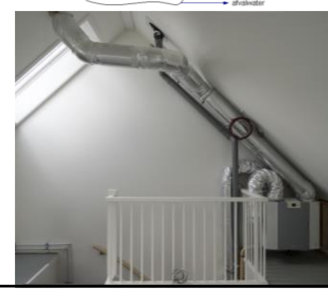
- Monitoring shows considerable lower heat recovery efficiency than specified, mainly due to:
  - **Partly blockage** of the small heat exchangers ducts by condensation moist
  - **Heat losses through ducts** to and from the unit to outside
  - **Internal leakage** and short-cut flows

- The primary energy saving is further reduced by:
  - Considerable **higher electricity** use than specified
  - No regain of **latent heat losses**

TOWARDS HRV 2.0

- Develop heat recovery differentiated per room and over time:
  - **Short term heat/cold storage** to deal with ventilation dynamics
  - Redistribute regained heat and cold only **on local room demand**
- Optimise heat exchangers to:
  - Extend to both sensible and **latent heat recovery**
  - Enable **low pressure** application
  - Enable **hybrid** ventilation possibilities
- Combine the new system with **other temperature heat sources**, solar collector, hot drain water, cooker hood, etc.
  Combine with heat pump to improve performance.
  Team up with the other heating/cooling systems present.





THANK YOU FOR YOUR ATTENTION

Take a look:
TIME.TNO.NL

FACULTY OF ENGINEERING
AND ARCHITECTURE

DEPARTMENT OF ARCHITECTURE AND URBAN PLANNING
BUILDING PHYSICS, CONSTRUCTION AND SERVICES RESEARCH GROUP

12 MONTHS OF IN SITU-MEASUREMENTS OND

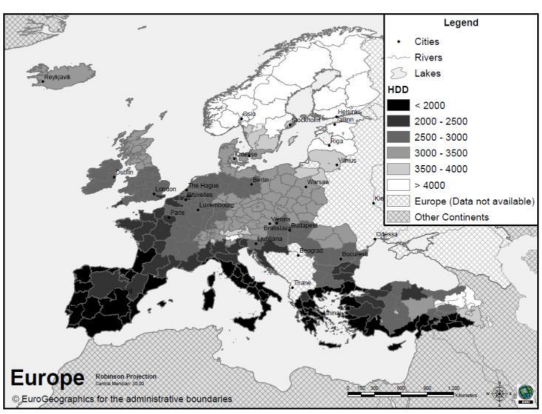
DCV AND MHRV

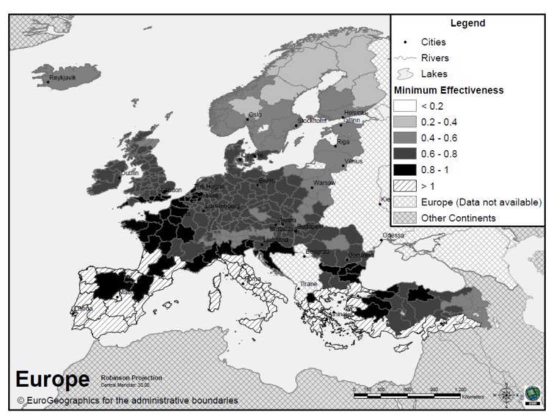
AIVC 2018

The Context: HRV in Belgium

GHENT UNIVERSITY

HRV POTENTIAL





Laverge, Jelle and A. Janssens, 2012, “Heat recovery ventilation operation traded off against natural and simple exhaust ventilation in Europe by primary energy factor, carbon dioxide emission, household consumer price and exergy”, Energy and Buildings

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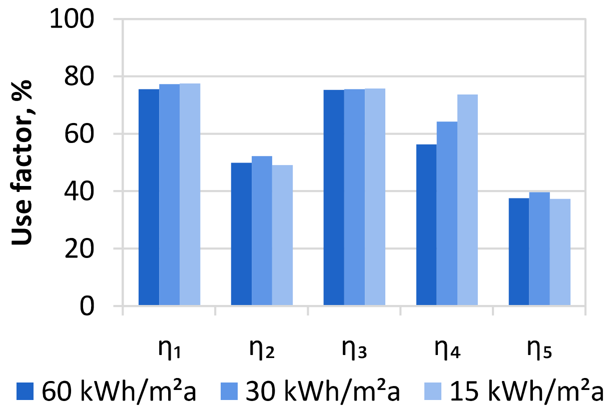
HRV POTENTIAL



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The Research Objective

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RESEARCH OBJECTIVE

Measure the impact of DCV and MHRV on heating energy demand in low energy (social) dwellings

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The Case Study

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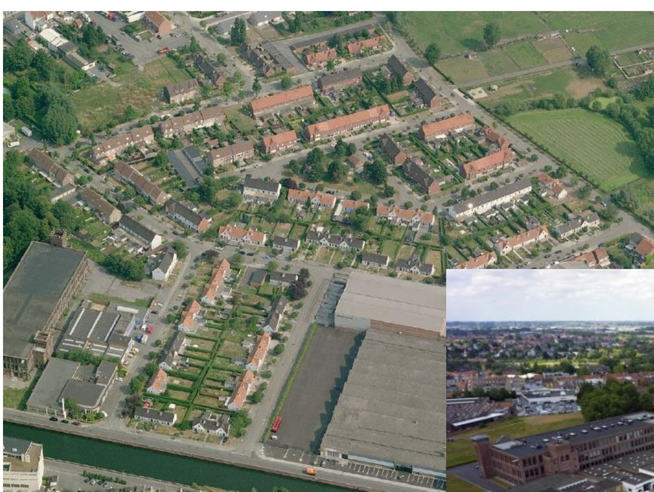
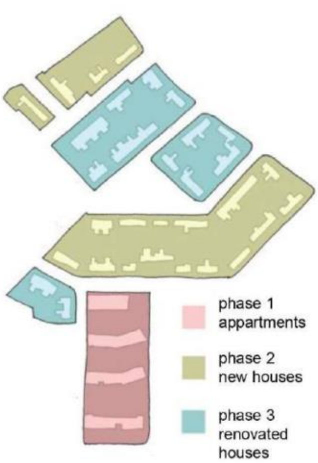
Demonstration Buildings	Gross floor area	Number of Dwellings	Start Occupancy	Start monitoring Manual			Stop Monitoring	Time (months)
				Manual	Auto Heat	Auto Elec		
Venning Phase1	7545	82	13/jul	13/sep	14/feb	15/jan	16/may	35
Venning Phase 2	7842	64	15/feb	15/feb	15/feb	15/feb	16/may	16
Venning Phase 3	7241	50	15/mar	15/mar	15/mar	15/mar	16/may	15
Pottenbakkershoek	2073	24	14/jul	15/jan	15/jan	15/jan	16/may	17
Gutenberg	1869	21	15/nov	15/nov			17/mar	17
Drie Hofsteden	2937	33	16/apr	16/apr			17/mar	12

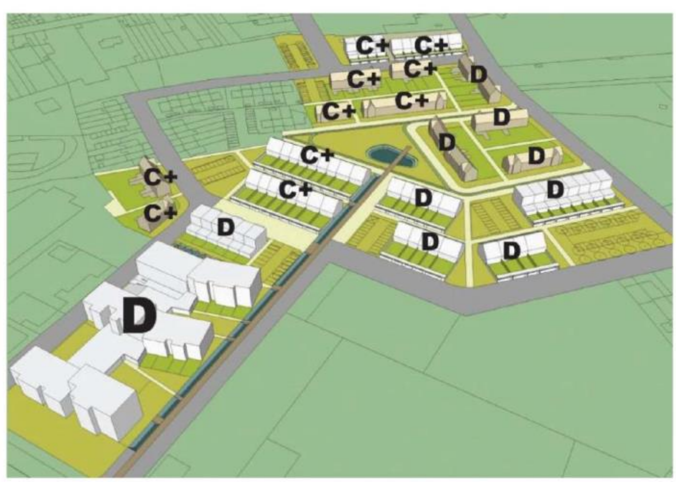


Social housing estate ‘Venning’
Kortrijk, Belgium

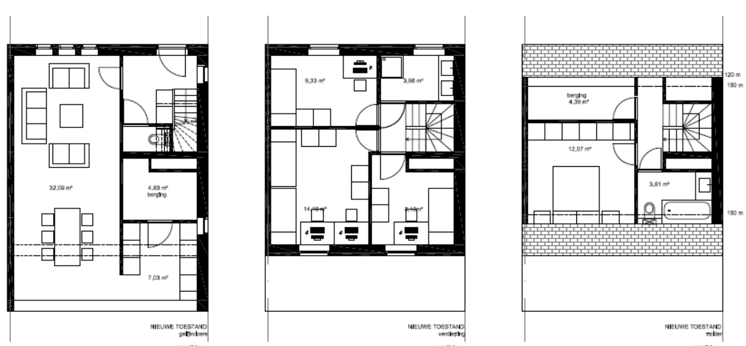
Renovation part of concerto ‘Eco-Life’

Focus on the individual dwellings






32,09 m²
4,83 m²
berging
7,03 m²
NIEUWE TOESTAND
gelijkvloers
WONING A
type 4/6
9,33 m²
3,96 m²
NIEUWE TOESTAND
verdieping
WONING A
type 4/6
berging
4,39 m²
12,07 m²
3,81 m²
120 m
150 m
150 m
NIEUWE TOESTAND
zolder
WONING A
type 4/6


32,09 m²
4,83 m²
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NIEUWE TOESTAND
gelijkvloers
WONING A
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12,07 m²
3,81 m²
120 m
150 m
150 m
NIEUWE TOESTAND
zolder
WONING A
type 4/6

‘Smartzone’

The Results

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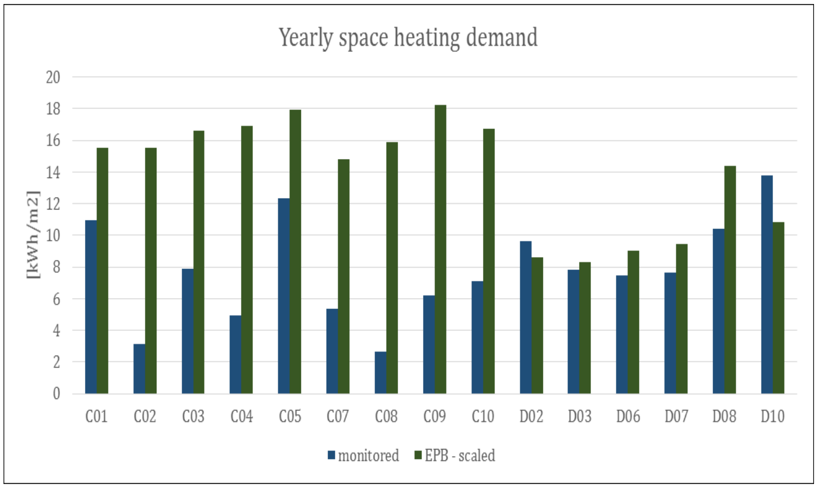
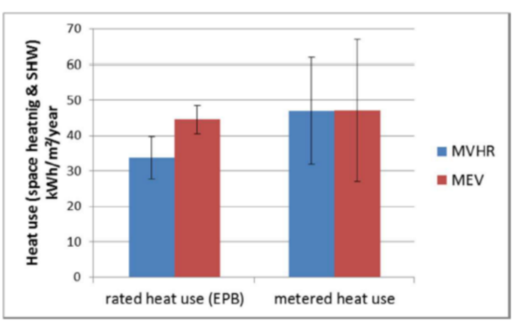
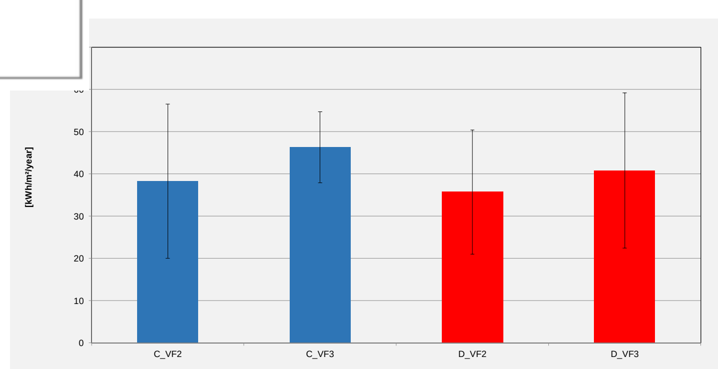
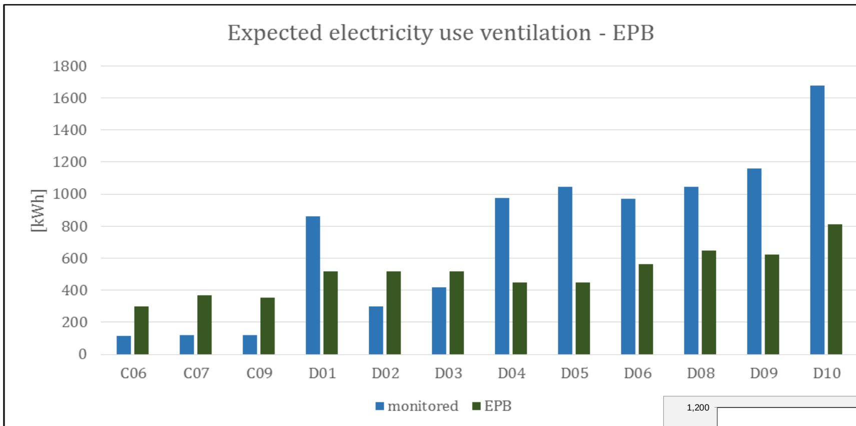

Yearly space heating demand
[kWh/m2]
0
2
4
6
8
10
12
14
16
18
20
C01
C02
C03
C04
C05
C07
C08
C09
C10
D02
D03
D06
D07
D08
D10
monitored
EPB - scaled

17

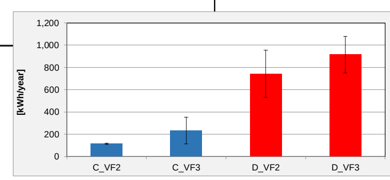

Heat use (space heatnig & SHW) kWh/m²/year
0
10
20
30
40
50
60
70
rated heat use (EPB)
metered heat use
MVHR
MEV


[kWh/m²/year]
0
10
20
30
40
50
C_VF2
C_VF3
D_VF2
D_VF3

18



	DCMEV	MVHR
Space heating consumption (kWh)	6592	5826
Fan consumption (kWh)	186	853
Total energy use (kWh)	6778	6679



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BUILDING PHYSICS, CONSTRUCTION AND SERVICES RESEARCH GROUP

12 MONTHS OF IN SITU-MEASUREMENTS OND

DCV AND MHRV

AIVC 2018

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AND ARCHITECTURE

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@Jlaverge
Jelle Laverge

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TEMPERATURE, DRAFT AND VENTILATION EFFICIENCY OF

ROOM BASED HRVS

AIVC 2018

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The Context:
Room based HRV

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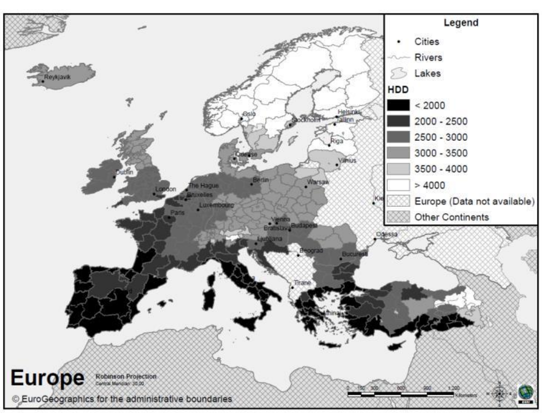
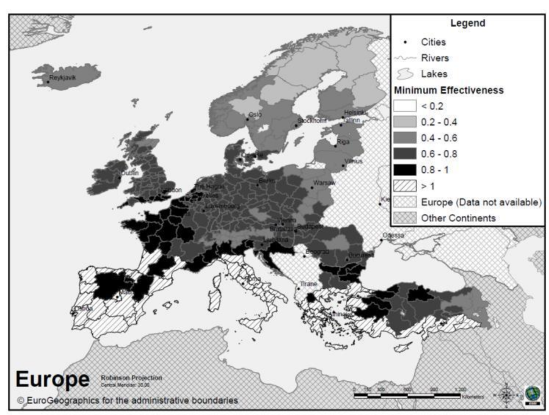
HRV POTENTIAL





Laverge, Jelle and A. Janssens, 2012, “Heat recovery ventilation operation traded off against natural and simple exhaust ventilation in Europe by primary energy factor, carbon dioxide emission, household consumer price and exergy”, Energy and Buildings

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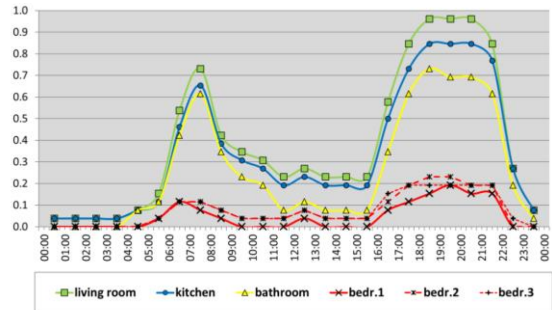
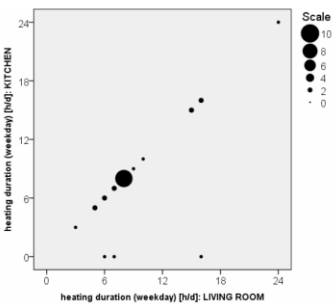
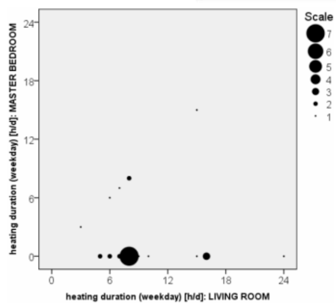
HRV POTENTIAL







Delghust, 2015

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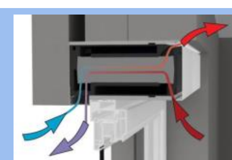
ROOM BASED HRV

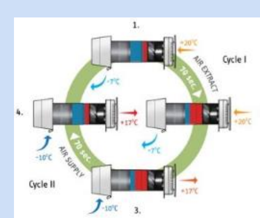
- Typically small and local (for minimal impact)
- In frame / In wall
- recuperation / regeneration
- focus on thermal effectivity



In frame, recuperation

In wall, recuperation

In frame, regeneration



In wall, regeneration

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The Research Objective

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RESEARCH OBJECTIVE

Test

- draft
- ventilation efficiency

of 3 room based HRV systems

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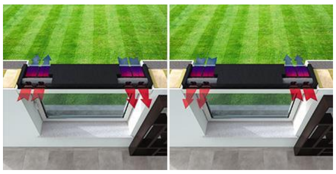
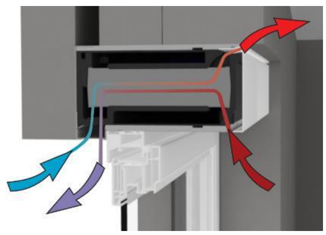
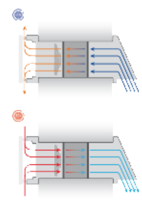
TESTED SYSTEMS

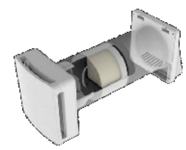


Endura Twist (Endura Twist, z.j.)



Provent D-luxe (raamtoestel) (Airria, 2014)

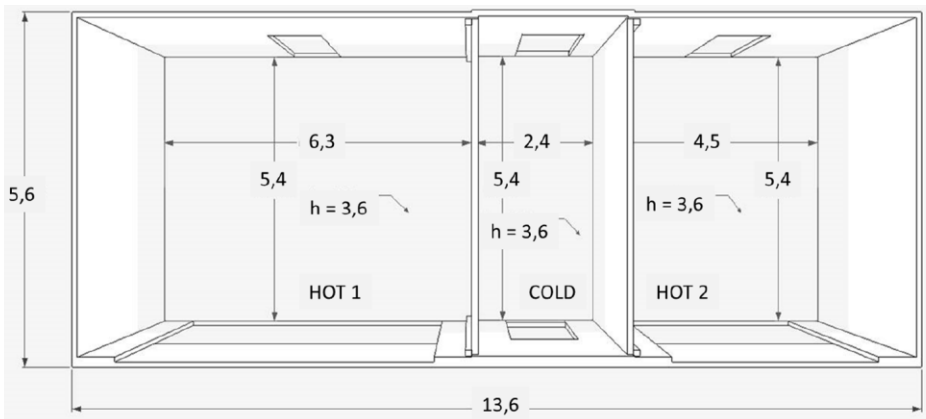




Tempero eco 150 ceram (Tempero eco 150 ceram, 2016)

The Test Setup

TEST ROOM



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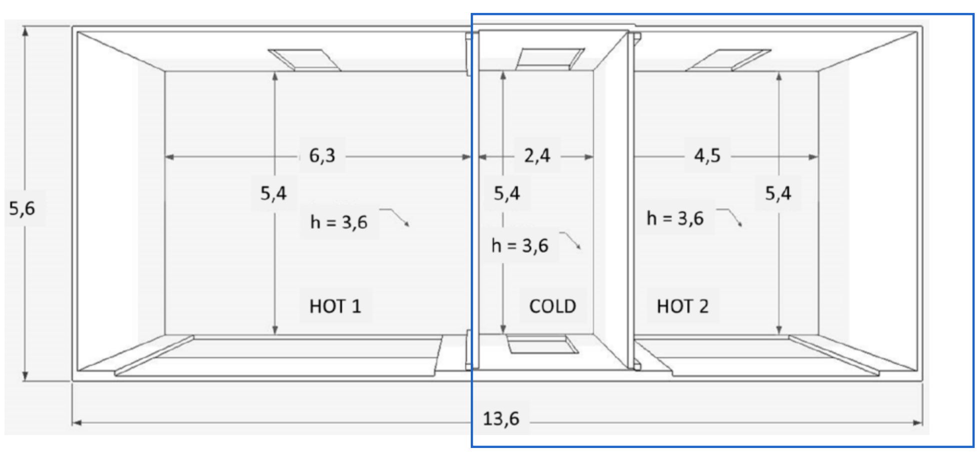
TEST ROOM



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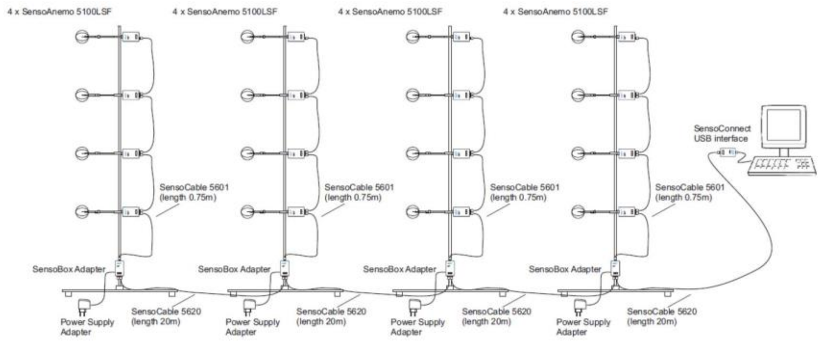

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The Results

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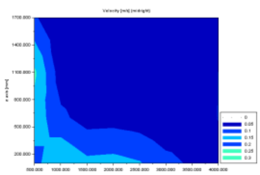
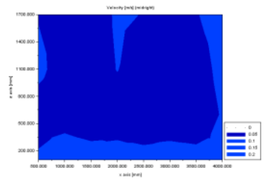
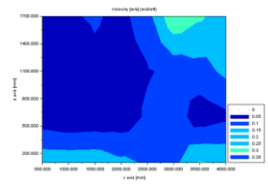
AIRSPEED AND DRAFT RATE



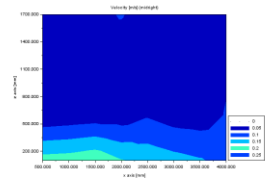
ET, 60 m3/h, 20 K, down



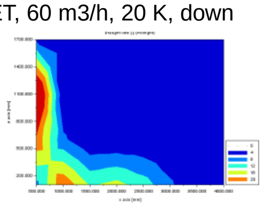
ET, 60 m3/h, 20 K, up

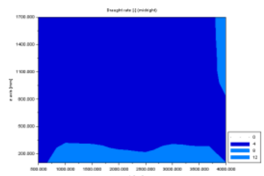


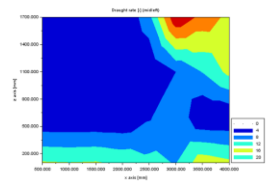
PD, 50 m3/h, 20 K

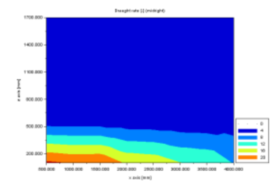


TE, 60 m3/h, 20 K

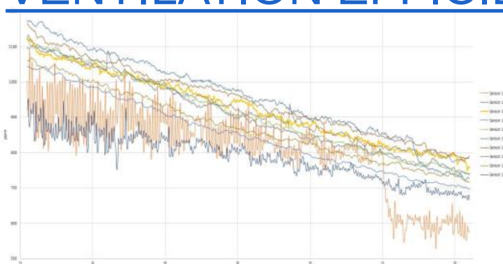




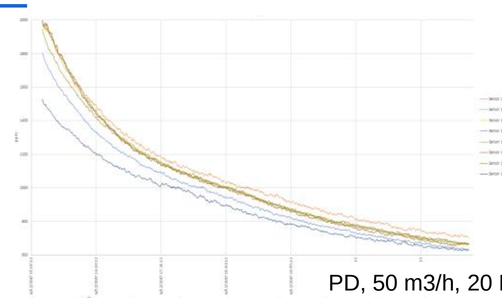




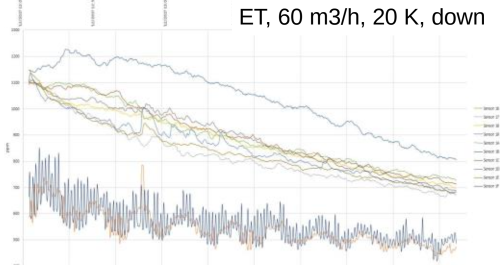
VENTILATION EFFICIENCY



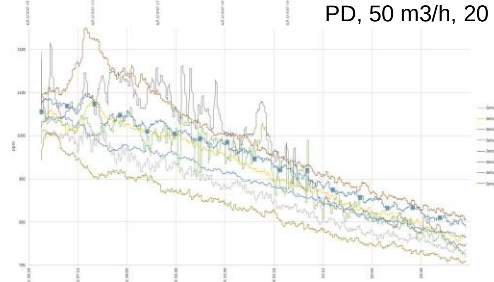
ET, 60 m3/h, 20 K, down



PD, 50 m3/h, 20 K



ET, 60 m3/h, 20 K, up



TE, 60 m3/h, 20 K

AIR CHANGE EFFICIENCY

Unit	Ventilation rate [m /h]	Average ε_a [%]
Endura Twist (downwards)	30	54
	60	49
Endura Twist (upwards)	30	52
	60	48
Provent D-luxe	36	50
	50	43
Tempero eco 150 ceram	30	51
	60	53

Flow pattern	Air change efficiency
Ideal piston flow	100%
Displacement flow	$50\% < \varepsilon_a < 100\%$
Fully mixed flow	50%
Short-circuit flow	< 50%

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The Conclusions

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CONCLUSIONS

For the tested room based HRV
- Jet direction has a large impact on draft
- All systems create draft at 'high' flow rate
- ventilation efficiency is relatively well mixed

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TEMPERATURE, DRAFT AND VENTILATION EFFICIENCY OF

ROOM BASED HRVS

AIVC 2018

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AND ARCHITECTURE

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Annex 80 - Resilient Cooling

Peter Holzer
Institute of Building Research & Innovation
Vienna, Austria

Topical Session at AIVC 2018

19th September 2018, 10:00

Background and Motivation

- There's a challenging increase in AC energy consumption.
- Further development and application of low energy and low carbon cooling solutions on a large scale are required to meet international climate goals.
  - *OECD/IEA global exchange platform report "The Future of Cooling" 2018*
  - *EU Mission Innovation Challenge Nr.7 "Affordable Heating and Cooling of Buildings"*
- A bundle of (passive) low carbon and low energy solutions are available and already regarded as mature but are in danger of loosing the race against AC.
- Promising new technologies/solutions are emerging.

Definition of Resilient Cooling

Affordable low energy and low carbon cooling solutions, strengthening the ability of individuals and community to withstand and prevent the thermal - and other - impacts of changes in global and local climates.

This includes technologies and solutions that:

- Reduce externally induced heat gains to indoor environments;
- Offer personal comfort apart from space cooling;
- Remove heat from indoor environments;
- Control the humidity of indoor environments.

Scope and Focus

- The Annex will focus on resilient cooling applications for new and existing buildings with typically no central BMS being available.
- Another focal point of the Annex will be resilient cooling applications for Nearly-Zero-Energy-Buildings (nZEBs).
- The scope of the Annex will be restricted to measures within the building itself. (No research on urban microclimate engineering, health, comfort nor social issues)
- The Annex will encompass both active and passive cooling technologies and systems.

Objectives

Our aim is to support a transition to an environment where affordable low energy and low carbon cooling systems are the mainstream and preferred solutions for cooling and overheating issues in buildings.

A Assess benefits, potentials and performance indicators. Identify limitations and bottlenecks. Provide guidance on design, performance calculation and system integration.

B Research towards implementation of emerging technologies. Extend boundaries of existing solutions, including user interaction and control strategies.

C Demonstrate the performance of resilient cooling solutions.

D Develop recommendations for regulatory context.

Technology Readiness Preliminary Assessment (TRPA)

answered by 13 experts from 10 countries

Numerous solutions of Resilient Cooling are fairly well developed at level of basic research and experimental application. Some might be regarded as mature.

Still, there's significant lack of application on a broad scale.

Thus, further research is needed for

- System Integration
- Design Guidance
- Guaranteed Performance Indicators (KPI)
- Recognition in Standards and Compliance Tools

Annex Scope – Technologies (including TRL)

Reducing external heat gains to indoor environments

- Advanced solar shading (TRL av. 7.3)
- Cool materials (TRL av. 6.2)
- Advanced Glazing Technologies (TRL av. 6.4)
- Ventilated Facades (TRL av. 7.0)

Increasing personal comfort apart from space cooling

- Ventilative Cooling / Comfort Ventilation (TRL av. 7.3)
- Micro-cooling and personal comfort control (TRL av. 5.3)

Annex Scope – Technologies (including TRL)

Removing heat from indoor environments

- Ventilative Cooling / Night flush Ventilation) (TRL av. 7.5)
- Thermal mass utilization, including PCM and off-peak ice storage (TRL av. 5.9)
- Adiabatic/evaporative cooling (TRL av. 6.5)
- High performance compression driven AC (TRL av. 8.1)
- High performance ab(ad)sorption based AC (TRL av. 6.8)
- Saisonally balanced use of natural heat sinks (boreholes, earth tubes, sky radiation, …) (TRL av. 7.1)

Removing humidity from indoor environments

- Desiccant dehumidification (TRL av. 6.7)

Annex Subtasks

The Annex will be structured in four subtasks:

A Impact Assessment

B Solutions

C Case Studies

D Regulatory Initiatives

Annex Subtasks A and B

A Impact Assessment

- Systematically assess existing technologies as regards potentials, limitations, performance indicators, levels of resilience, range of applicability, best practice of system design and system integration.
- Generate comprehensive 'Technology Profiles'

B Solutions

- Specifically develop emerging technologies.
- Improve functionality and efficiency.
  Widen the range of applicability.

Annex Subtasks C and D

C Case Studies

- Showcase the opportunities and benefits of resilient cooling through analysis and evaluation of well-documented case studies.

D Regulatory Initiatives

- Develop roadmaps and strategies for implementation of resilient cooling in regulatory initiatives.
  (on national, European and international level)

Results and Deliverables

A. Comprehensive Resilient Cooling 'Technology Profiles'

including instructions for successful system design, implementation and operation.

B. Specific Resilient Cooling R&D reports

C. Well documented case studies / success stories

D. Recommendations for the integration of resilient cooling in legislation and standards

Annex Preparation Phase (June 2018 – June 2019)

1. Preparative Web Meeting
   13th September 2018, 10:00-11:00 (MET)
2. **First Preparation Meeting, Juan-les-Pins, France**
   20th September 2018
3. Preparative Web Meeting
   4th April 2018
4. Second Preparation Meeting,
   Heriot-Watt University, Dubai
   11th April 2019, at CATE - Conference

Preparation Phase Programme

- 2 Preparation Meetings (September 2018, April 2019)
- Continuous Update of Annex Text (describing Annex's content)
- Definition of Subtask Leadership
- Definition of National Research Items
  - By participants according to subtasks
- Decision on participation in overarching research projects
  - Impact Assessment (STA)
  - Regulatory Initiatives (STD)
- Joint development of the State-of-the-Art-Review (SOTAR)
- Presentation of Results at ExCo Meeting June 2019

Annex Definition Workshop

M. Zinzi, G. Chiesa, P. Cooper, W. Miller, R. Bokel, C. Zhang, G. Hofer, G. Zhang, A. Zhengtao, O. Berk Kazanci (f.l.t.r.)

Expected Contributions

Country	Prename	Surname		Subtask			
				A	B	C	D
Austria	Peter	Holzer	Institute of Building Research & Innovation	X	X	X	X
	Philipp	Stern	Institute of Building Research & Innovation	X	X	X	X
	Gerhard	Hofer	e7 Energie Markt Analyse GmbH	X		X	
Australia	Paul	Cooper	University of Wollongong	X	X	X	
	Wendy	Miller	Queensland University of Technology	X	X		
Belgium	Peter	Wouters	BBRI				X
	Hilde	Breesch	K Leuven		X	X	
Canada	Liangzhu	Wang	Concordia U, Montreal	X	X	X	
China	Guoqiang	Zhang	Hunan University	X	X	X	X
	Yin	Wei	Hunan University	X	X	X	X
Denmark	Per	Heiselberg	Aalborg University	X	X		
	Chen	Zhang	Aalborg University	X	X		
	Bjarne	Olesen	Technical University of Denmark	X	X		X
	Ongun	Kazanci	Technical University of Denmark	X	X		X
	Zhengtao	Ai	Technical University of Denmark, Hunan University	X	X		X

Letter of National Participation received

Expected Contributions

Country	Prename	Surname		Subtask A	Subtask B	Subtask C	Subtask D
France	Emmanuel	Bozonnet	Univérsité de la Rochelle	X	X	X	
	Anais	Machard	Univérsité de la Rochelle	X	X	X	
	Francois	Gardé	ESIROI				
Italy	Michele	Zinzi	ENEA	X	X		
	Giacomo	Chiesa	Politecnico Torino	X	X		X
Netherlands	Jan	Hensen	Eindhoven University of Technology				
Ireland	Paul	O'Sullivan	CIT, Cork				
Japan	Toshihiro	Nonaka	LIXIL				
	Hom Bahadur	Rijal	Tokyo City University				
Switzerland	Flourentzos	Flourentzou	ESTIA				
UK	Maria	Kolokotroni	Brunel University	X	X	X	
	Anna	Mavrogianni	The Bartlett School of Environment, Energy and Resources (BSEER)	X	X	X	
	Rajat	Gupta	Oxford Brookes University		X	X	
	Behzad	Sodagar	School of Architecture and the Built Environment Lincoln	X	X		

Next Steps

- Constantly shape the research programme,
  according to research possibilities and interests of the participants
- Invite experts, research groups, companies
- Connect to IEA Cooling initiative and KIGALI cooling efficiency program
- Connect to EU Mission Innovation Challenge Nr. 7
  Affordable Heating and Cooling of Buildings Innovation Challenge
- 1st Annex preparation meeting at AIVC,
  Antibes Juan-Les-Pins, France, Sept 20th 2018
- 2nd Annex preparation workshop, April 11th 2019, at CATE, Dubai
- Team building, regarding Subtask Leaders
- Start Working Phase in June 2019

Find up do date information
at the Annex 80 website
http://annex80.iea-ebc.org

Possibly join 2nd preparation meeting
tomorrow in room Louis Armstrong

EBC Energy in Buildings and Communities Programme

Institute of Building Research & Innovation

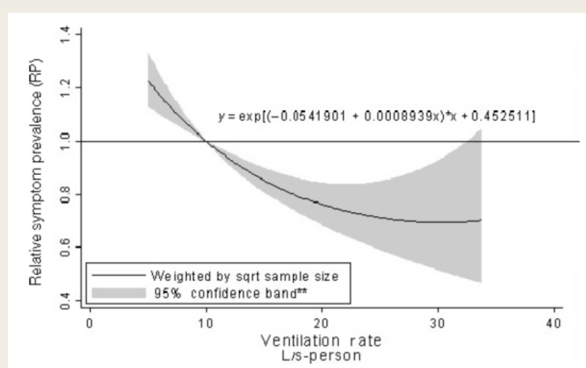
INDOOR ENVIRONMENTAL QUALITY GLOBAL ALLIANCE – HISTORY AND FUTURE

IEQ-GA HISTORY

William P. Bahnfleth, PhD, PE
Dept. of Architectural Engineering/Indoor Environment Center
The Pennsylvania State University
University Park, PA USA

Motivation

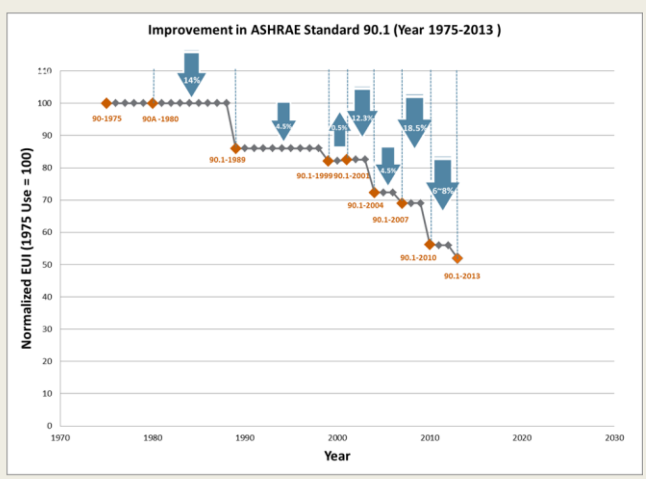
- Evidence for impact of air quality on people
  - *Health*
  - *Productivity*
  - *Learning*
- Potential for built environments to do much more to contribute to well-being
- Not much progress in realizing it



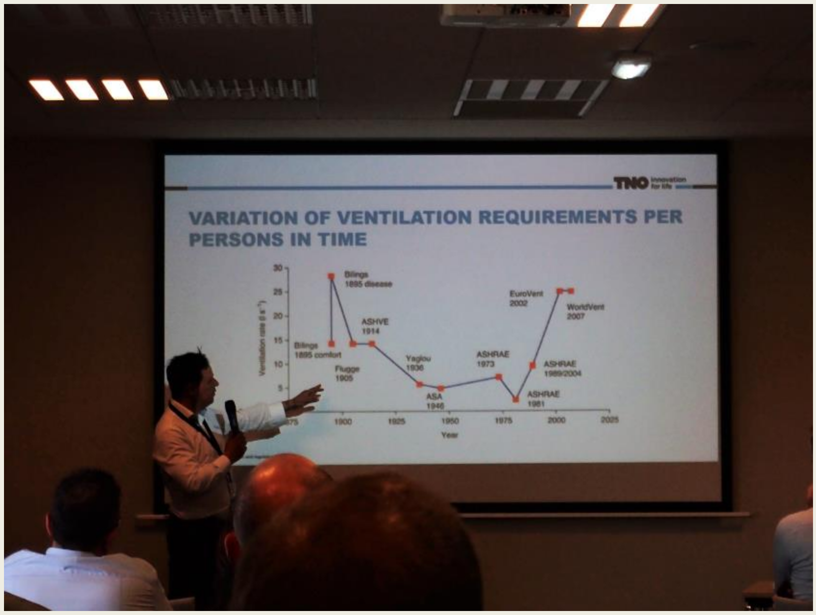
Source: W. Fisk, A Mirer, M. Mendell. 2009. Quantitative relationship of sick building syndrome symptoms with ventilation rates. Indoor Air

Issues

- Research – practice connection
  - *Translational research*
  - *Filling gaps*
- Workforce education
  - *Designer*
  - *Operator*
- Policy/advocacy
  - *Support for research*
  - *Support for regulations*



Source: Pacific Northwest National Laboratory

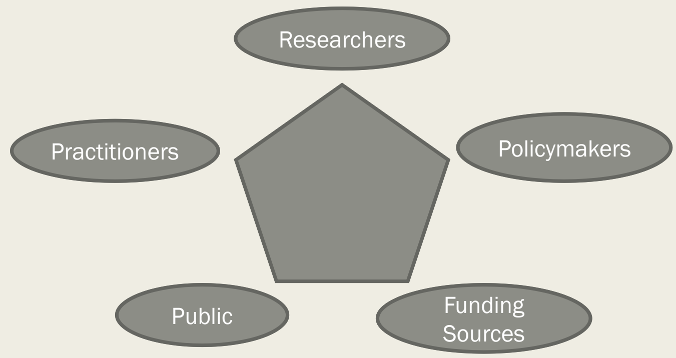


Professional and Scientific Organizations

- Organizational silos
  - *IAQ, lighting, acoustics*
  - *Science – practice - advocacy*
  - *Design – operation – remediation*
- Collectively, great potential
- Currently, fragmented, limited effectiveness

Concept

- Form a peer group of organizations whose scopes deal with aspects of IEQ
- “A broad, coordinated effort is needed to fill gaps in research, transfer the results of science to practice, advocate for higher standards and better educate both the built environment professions and the public.”



Inception – Indoor Environmental Quality Global Alliance

IEQ-GA

- ASHRAE presidential initiative of William Bahnfleth (2013-14), organizing ad hoc chaired by Bjarne Olesen
- MOU of founding partners signed in June 2014
  - *ASHRAE*
  - *AIVC*
  - *AWMA*
  - *AIHA*
  - *IAQA*
  - *REHVA*

Early Actions

- "Getting acquainted"
- Recruiting
  - *Acoustic and lighting partner organizations*
  - *Additional general interest organizations*
- Web site http://ieq-ga.net/
- Publications
  - *AIVC report review*
  - *Drafting review paper on standards*
- Programs
  - *Indoor Environmental Quality: A Holistic Perspective (ASHRAE 2015)*
  - *AIVC conferences*
- Conference co-organizer/supporter
  - *IAQ 2016*
  - *AIVC 2018*

Next Steps

- Incorporate or continue under an MOU?
- Fill out roster
- Higher profile
  - *More frequent communications*
  - *More diverse venues*
- Begin to address policy issues
- IEQ-GA conference?

- Communication/collaboration catalyze progress is the objective

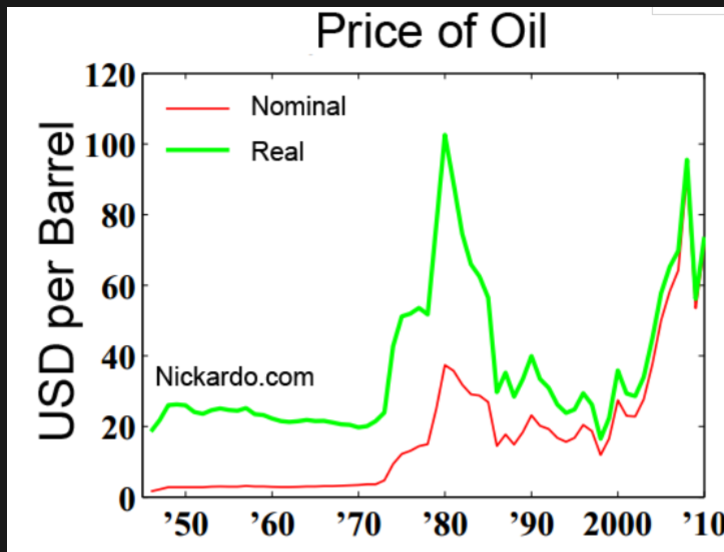
THANK YOU

wbahnfleth@psu.edu

Indoor Environmental Quality Global Alliance and the AIVC

Peter Wouters

Operating Agent AIVC



1975-1980

- Most countries: limited interest and almost no knowledge on ventilation, air infiltration and indoor air quality
- Few countries were ahead: SE, CAN, NL, …
- Start of IEA implementing agreement **ECBCS**: Energy conservation in Buildings and Community Systems

1975-1980

- ECBCS **AIC** (Air Infiltration Centre – Annex 5) running

  → Annex 1 had indicated that many questions existed regarding air infiltration
- Policy in several countries: Built tight!
- Airtightness was research topic in some countries
- IEA annex 8 Occupants' behaviour
- IEA Annex 18 Demand Controlled Ventilation
- In research and in some countries growing interest for health and comfort

1986

AIC became **AIVC**

The **'Air Infiltration and Ventilation Centre'**

Indoor Air conferences

1978 Indoor Climate, Copenhagen, Denmark

1981 Indoor Air Pollution, Health and Energy Conservation, Amherst

…

Healthy buildings conferences

1988 Healthy Buildings '88, Stockholm, Sweden

1991 Healthy Buildings/IAQ'91, Washington, DC

…

IBPSA
International Building Performance Simulation Association

1985: Seattle – USA

1989: Vancouver – Canada

…

…1990…

- European **Pascool** project

  … first time focus on summer comfort control…
- European project **NATVENT**

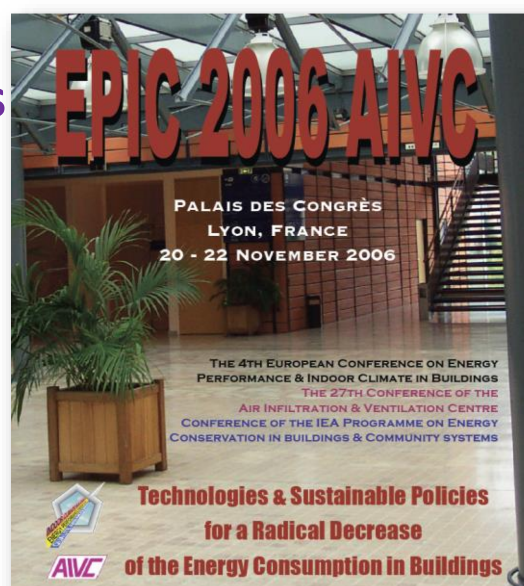
  … renewed attention for natural ventilation strategies…
- Annex 35 **Hybvent**

  … focus on hybrid ventilation
- **ISIAQ** created in 1992

INTERNATIONAL SOCIETY OF INDOOR AIR QUALITY AND CLIMATE

EPIC conferences in Lyon (1994 – 2006)

Energy Performance and Indoor Climate



Today (…2018…)

- **EPBD legislation**
  - Much more stringent requirements
  - Towards nearly-zero energy buildings
- Millions of airtightness measurements
  - Towards systematic testing…
- Concerns about quality of systems and workmanship
- More attention for 'smart'…

Multiple challenges

- Indoor air quality
- Thermal comfort
- Acoustics
- Visual quality

- Energy consumption
- Smart buildings (power)
- Life cycle analysis
- Sustainable development
- …

International collaboration
Collaboration between networks
…

Indoor environmental quality important

IEQ Global Alliance

For better indoor environment quality

HOME ADVOCACY EVENTS RESEARCH ABOUT CONTACT Search Site

IEQ-GA

Mission of the IEQ Global Alliance

The mission of IEQ-GA is to provide an acceptable indoor environmental quality (thermal environment-indoor air quality-lighting-acoustic) to occupants in buildings and places of work around the world and to make sure the knowledge from research on IEQ get to be implemented in practice. >> Read more...

Register now for AIVC 2018 Conference "Smart ventilation for buildings", 18-19 September 2018, Juan-les-Pins, France

AIVC

Registration is still open for the 39th AIVC – 7th TightVent – 5th venticool joint conference "Smart ventilation for buildings" to be held on 18 and 19 September 2018 in Antibes Juan-Les-Pins, France. The detailed programme is now available at: http://aivc2018conference.org/#FINAL-PROGRAMME There will be a total of 17 topical sessions: Rationale behind ventilation requirements and …
Continue reading →

New REHVA Dictionary App available!

IEQ-GA: THE NEXT DECADE

DONALD M. WEEKES, CIH, CSP, FAIHA
PRESIDENT, IEQ-GA

Indoor Environmental Quality-Global Alliance

www.ieq-ga.net

The founding organizations are:

- AIHA- American Industrial Hygiene Association
- AIVC-Air Infiltration and Ventilation Centre
- ASHRAE- American Society of Heating, Refrigerating and Air-Conditioning Engineers
- AWMA- Air and Waste Management Association
- IAQA-Indoor Air Quality Association
- REHVA- Federation of European Heating, Ventilation and Air Conditioning Associations

Current Activities

- Newest Member: ISHRAE (India)
- Contacting Societies for Light and Acoustics
- Seeking additional professional organizations as members of the Alliance – ABRAVA (Brazil)
- Meeting with ISIAQ to discuss future joint activities
- Set up the administration of the alliance
- Comparison of Position Documents

IEQ-GA: Future

- Legal Entity – Based in Brussels?
- New Opportunities for Sponsored Sessions at Conferences
- Endorsements of Position Statements by IEQ-GA and its members
- Joint Sponsorship of Conferences
- Advocacy for IAQ science and research on national and international standards and guidelines
- Technical review of proposed international standards
- New Potential Members

IEQ-GA: Future Activities

- Co-Sponsor – ASHRAE IAQ Conference – 2020
- Co-Organizer – ASHRAE IAQ Conference - 2023
- Research recommendations
- Proposals for publications and educational courses.
- Influencing and/or propose standards.
- Common position documents
- Combined conferences
- Quarterly Newsletter

IEQ-GA - Future

Thanks!

Questions?

Donald Weekes

don.weekes@inairenvironmental.ca

613-224-3863

International Centre for Indoor Environment and Energy

Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications. A proposed IEA-EBC Annex

Professor Bjarne W. Olesen, Ph.D

www.ie.dtu.dk

Technical University of Denmark

Workshop Program

	Topic	Proposed speaker(s)	Organisation
	Opening		
10 min	Background and Objective of the workshop	Bjarne W. Olesen	International Centre for Indoor Environment and Energy, Technical University of Denmark
5 min	Questions and discussion		
10 min	Standard measurement of perceived air quality (PAQ)	Pawel Wargocki	International Centre for Indoor Environment and Energy, Technical University of Denmark
5 min	Questions and discussion		
15 min	Example of testing of a gas phase air cleaner	Pawel Wargocki	Technical University of Denmark
45 min	Questions and discussion		

Background

- Worldwide an increasing number of publications related to air cleaning
- An increasing sales of gas phase air cleaning products.
- There is however a need for verifying the influence on the indoor air quality and health of using air cleaning.
- Can air cleaning supplement ventilation i.e. partly substitute for the required ventilation rates?
- What is the energy impact of using air cleaning as supplement of ventilation?

Air Cleaning

- Particle filtration
- **Gas phase pollutants removal**

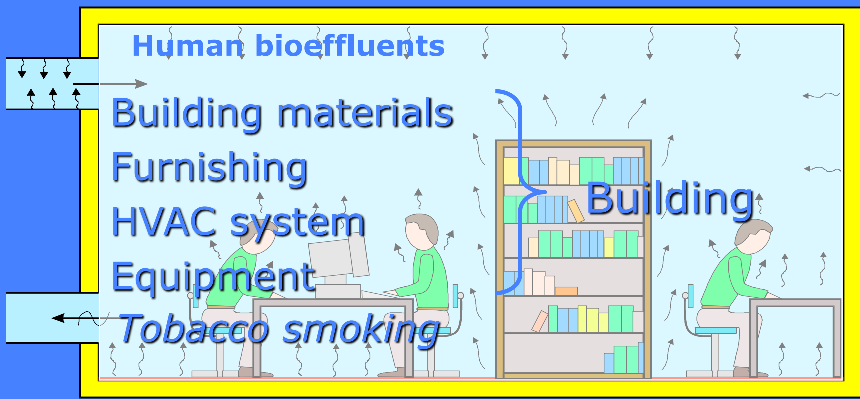
Background-Scope

- Outdoor air might be of such a bad air quality that it is better to avoid ventilation.
- An alternative could be the use of air cleaning of the indoor air.
- The use of air cleaning could reduce the amount of outside air and thereby save energy for heating/cooling the ventilation air and saving of fan energy.
- Air cleaning may improve the indoor air quality/health and reduce energy use for ventilation at the same time.
- There is however a need for better evaluation of the potential for energy savings and increased air quality
- There is also a need for developing acceptable testing methods.

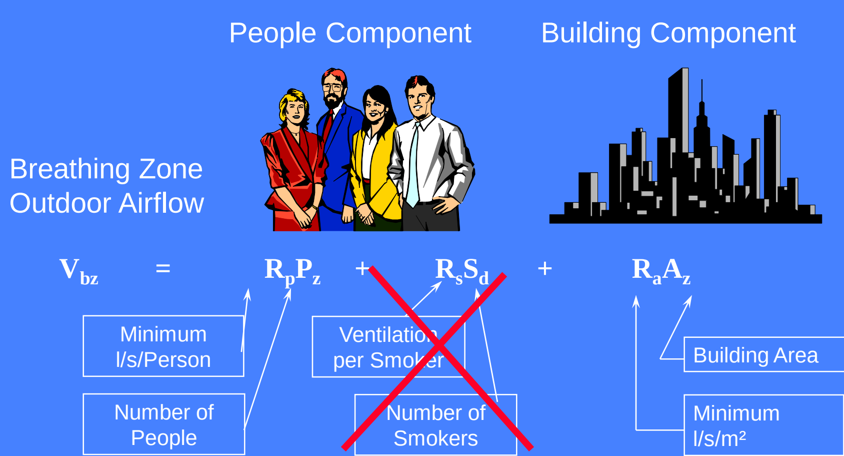
CRITERIA FOR INDOOR AIR QUALITY ~VENTILATION RATES

- COMFORT (Perceived Air Quality)
- HEALTH
- PRODUCTIVITY
- ENERGY

Indoor pollution sources



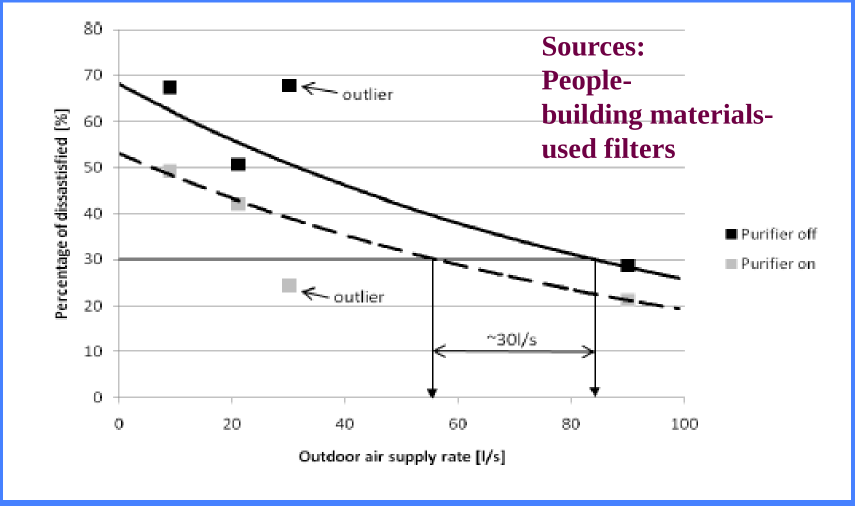
Concept for calculation of design ventilation rate



Background

- **Numerous studies have shown that air cleaners can reduce concentration of single chemicals, which can reduce the ventilation for the building component.**
- **Little is known regarding the influence of operation of air cleaners on the perceived air quality and with bioeffluent from people as a source**

Effect of air cleaning on perceived Air Quality



Purpose of a new annex

- The proposed Annex should bring researchers and industry together to investigate procedures for improving indoor air quality and/or reduced amount of ventilation by gas phase air cleaning.
- The project should quantify the potential for energy savings for ventilation i.e. 10-20%
- The project should also recommend a test method for air cleaners that considers the influence on the perceived air quality and substances in the indoor air.

ANNEX STRUCTURE

- Subtask A: Energy benefits using gas phase air cleaning
- Subtask B: How to partly substitute ventilation by air cleaning
- Subtask C: Selection and testing standards for air cleaners
- Subtask D: Long term field test of gas phase air cleaning

Subtask A: Energy benefits using gas phase air cleaning

- A.1. Energy reduction by cleaning indoor air (recirculation, no outside air) compared to cleaning outside air in areas where the outside air is not good enough for ventilation
- A.2. Energy reduction by decreasing the amount of outside air by use of air cleaning
- A.3. Energy reduction by using air cleaning together with personalized ventilation systems. Could be work place by work place; but could also be an air cleaner serving several workplaces
- A.4.Minimum performance of air cleaners (effectiveness). Establish a metric of assessing air cleaner efficiency in relation to energy: CADR/kWh where CADR is the clean air delivery rate

Subtask B: How to partly substitute ventilation by air cleaning

- B.1. Existing standards for IAQ-Ventilation
- B.2 Measure perceived IAQ for reducing people part
- B.3 Measure pollution chemical (voc, formaldehyde etc) for reducing the building part

Subtask C: Selection and testing standards for air cleaners

- C.1. Description of gas phase Air Cleaning Technologies
- C.2. Existing standards for testing gas phase air cleaning technologies
- C.3. Measurements of Perceived Air Quality (PAQ)
  - » People-bio effluents as source
  - » Individual substances (VOC, etc)
- C.4. Measure chemical concentrations
  - » Building materials i.e. VOCs as source
- C.5. Test space
  - » Test room for generation of bio effluent and for measuring PAQ
  - » Test channels for supplying and measuring individual substances

Subtask D: Long term field validation of gas phase air cleaning

- This subtask will perform long term field studies of the energy performance and indoor air quality in buildings using gas phase air cleaning

Outcomes

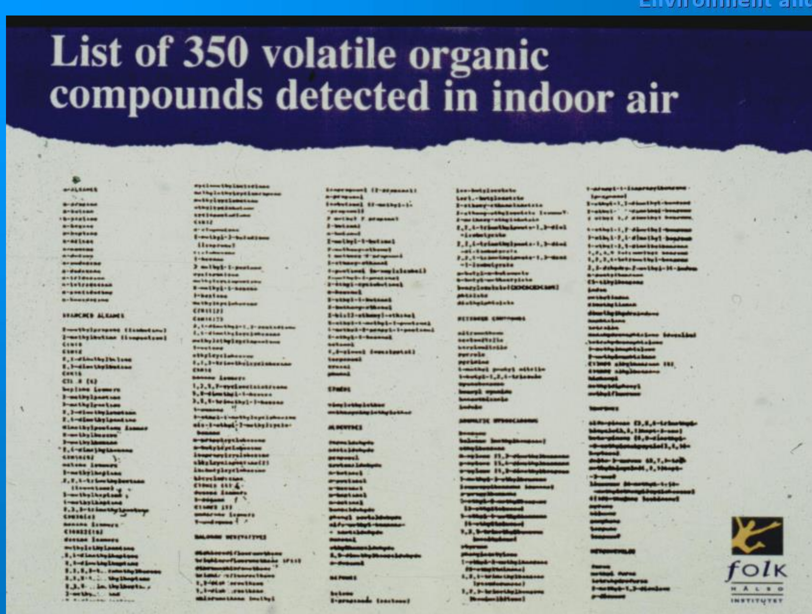
- **Subtask A: Energy benefits using gas phase air cleaning**
  - A method for predicting the energy performance of gas phase air cleaning technologies and the possible reduction of energy use for ventilation.
  - This will be of interest for consultants, manufacturers, government building codes in the goal to design and operate near zero energy buildings
- **Subtask B: How to partly substitute ventilation by air cleaning**
  - A validated procedure for supplementing (partly substituting) required ventilation rates with gas phase air cleaning.
  - This will be of interest for standards and guidelines setting requirements for indoor air quality and ventilation (CEN TC156/371, ISO TC 163/205, ASHRAE 62.1 and 62.2)
  - This will also be of significant interest for manufacturers of air cleaning technologies
- **Subtask C: Selection and testing standards for air cleaners**
  - A test method for air cleaning technologies that besides chemical measurements include perceived air quality as a measure of performance.
  - This will be of interest for standard bodies writing test standards (ISO TC142/ CEN TC 195 and ISO TC 146) and related certification bodies.
  - This will also be of significant interest for manufacturers of air cleaning technologies
- **Subtask D: Long term field test of gas phase air cleaning**
  - A report on the long term performance of air cleaning.
  - This will also be of significant interest for manufacturers, consultants, standard writing experts.

Expert list

- Karel Kabele Czech Technical University in Prague
- Alireza Afshari, Aalborg University Copenhagen
- Jeffrey Siegel, University of Toronto
- Sekhar, Chandra, Tham Kwok Wai, Cheong Kok Wai, David, National University Singapore
- Shin-ichi Tanabe, Waseda University
- Kosonen Risto, Aalto University
- Jianshun Zhang, Syracuse University
- Tronville Paolo, Politecnio Torino
- Pawel Wargocki, Lei Fang , Bjarne W. Olesen, ICIEE.DTU
- Jingjing Pei, Tianjing University

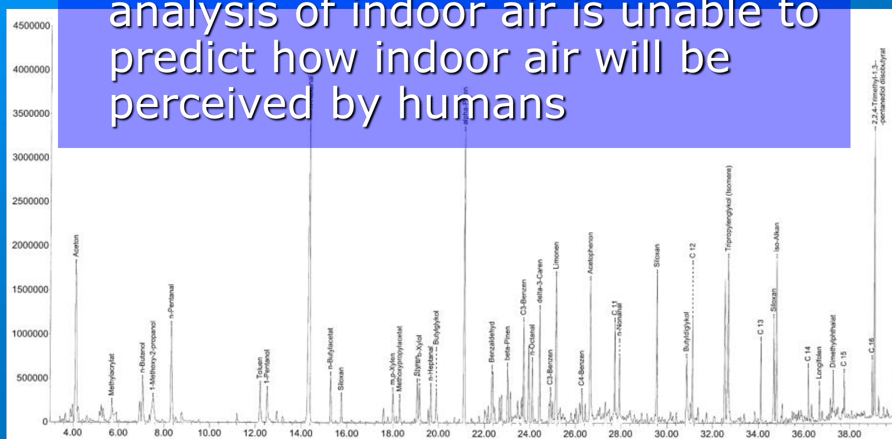
Measurements of Perceived Indoor Air Quality

Pawel Wargocki
International Centre for Indoor Environment and Energy
Technical University of Denmark
(www.ie.dtu.dk)



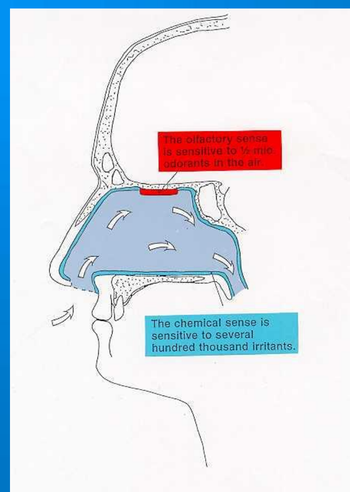
Chemical analysis of indoor air

- Detailed compound-by-compound analysis of indoor air is unable to predict how indoor air will be perceived by humans

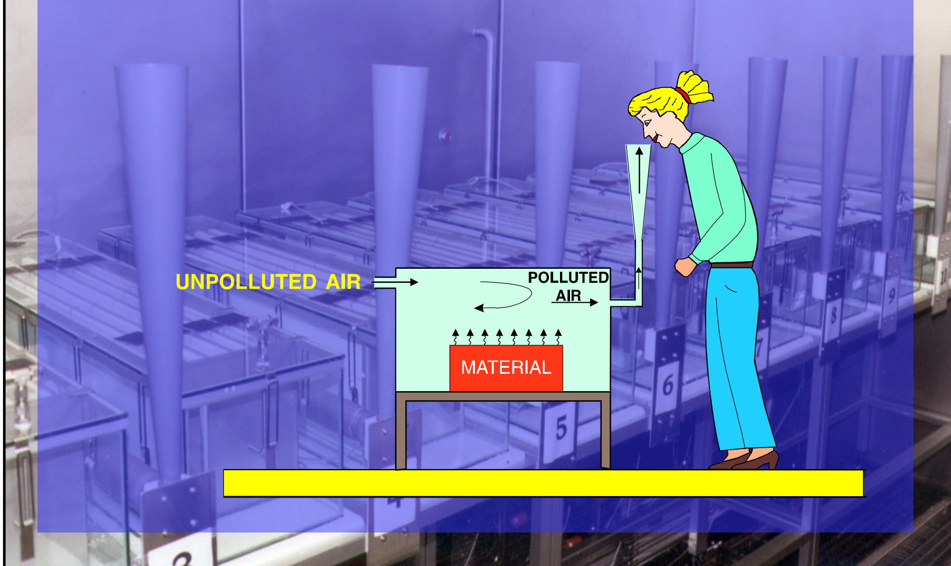


QUALITY = The extent to which human requirements are met

Using man as a meter



Measurements in chambers



Measurements in rooms

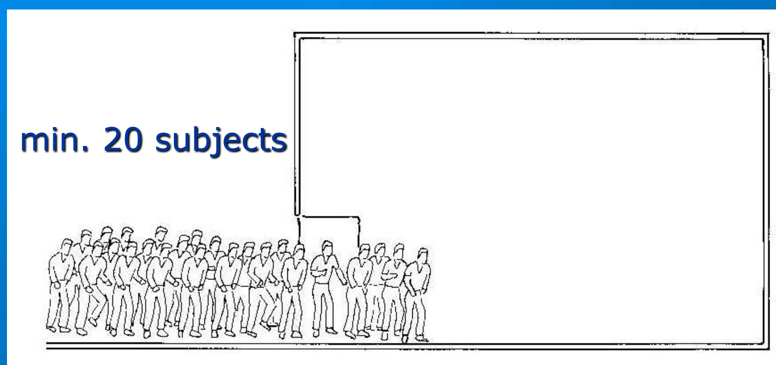
International Centre for Indoor
Environment and Energy

Measurements of perceived air quality

- Sensory panels of human subjects
  - Untrained panel
  - Trained panel
- Immediate response ("First impression")
- Impartial assessment

Untrained panel

"… a panel of at least 20 untrained observers (…) who render a judgement of acceptability…"

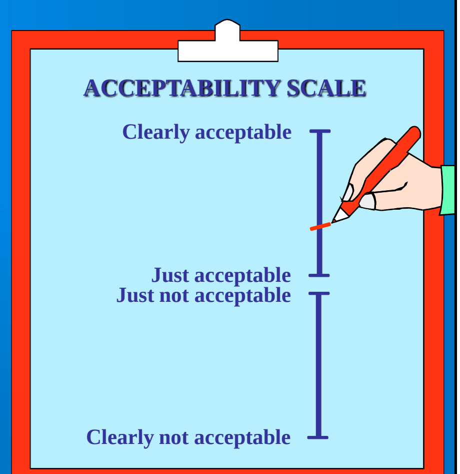


International Centre for Indoor
Environment and Energy

Continuous acceptability scale

How do you assess the air quality?

Pay attention to the dichotomy between acceptable and not acceptable.

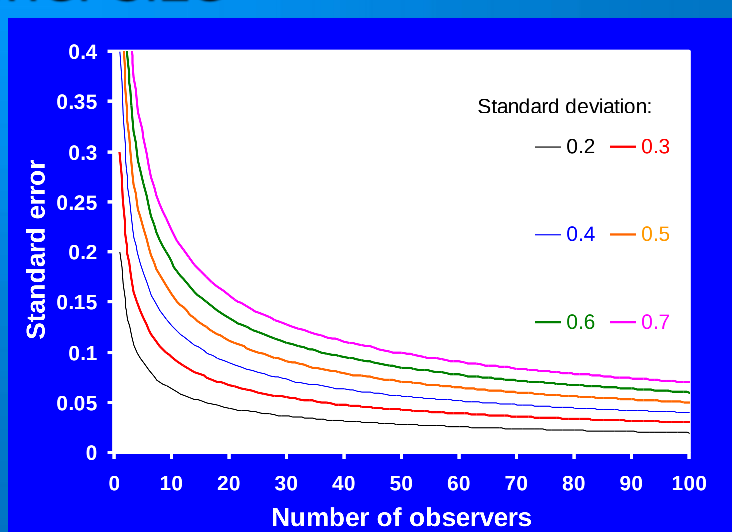


Dichotomous acceptability scale

Acceptable ☐

Not acceptable ☐

Panel size



Measuring metric

Acceptability

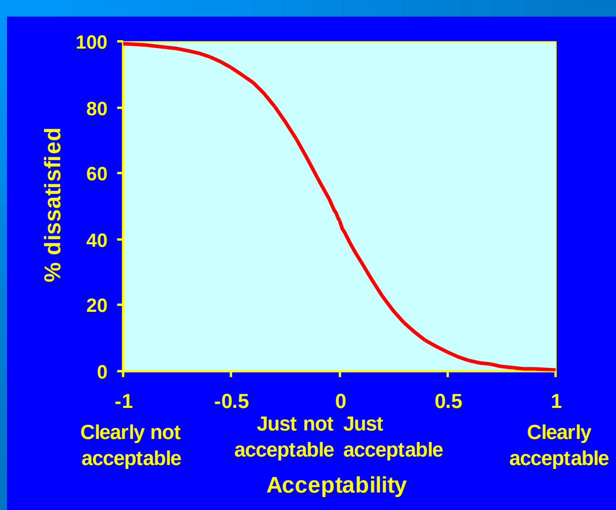
↓

% dissatisfied

↓

decipol

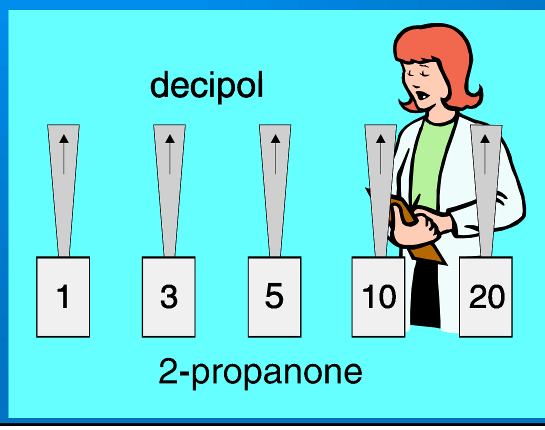
Estimation of % dissatisfied



International Centre for Indoor Environment and Energy

Trained panel

"… a panel of 10-15 subjects trained to assess the perceived air quality directly in decipol…"



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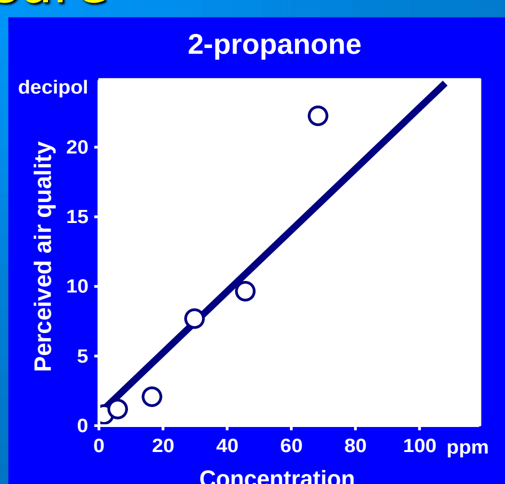
Trained panel - reference exposure

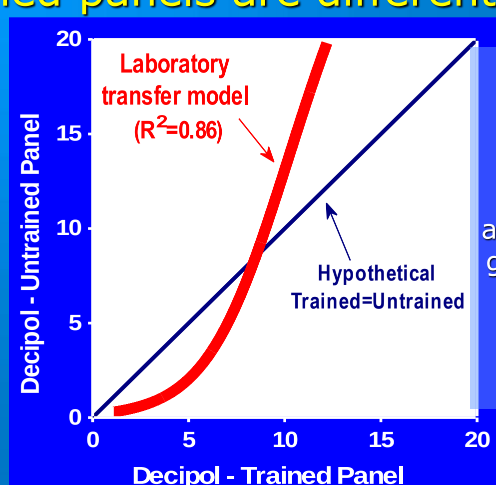


Untrained panel Trained panel

Untrained panel	Trained panel
☺ simple to use	☹ difficult to use
☺ no training	☹ training required
☹ large panels (>20-30 subjects)	☺ small panels (10-15 subjects)

International Centre for Indoor
Environment and Energy

Sensory assessments of trained and untrained panels are different

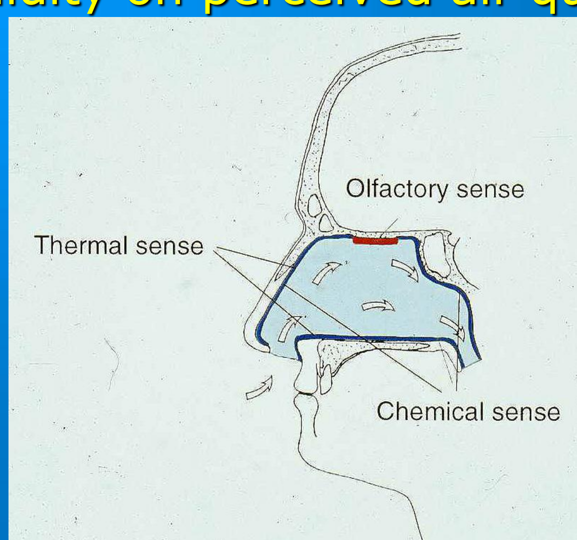


Sensory ratings made by panels trained with 2-propanone as a reference gas should be adjusted using the transfer model

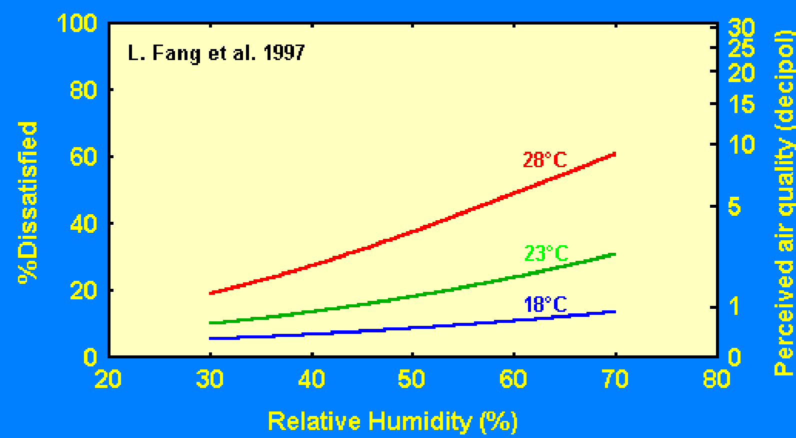
Factors influencing perception

- Temperature and relative humidity
- Adaptation

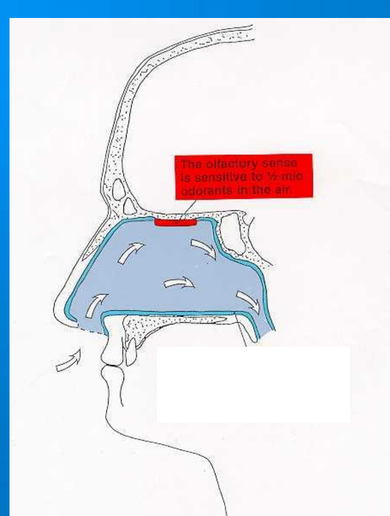
Impact of temperature and humidity on perceived air quality



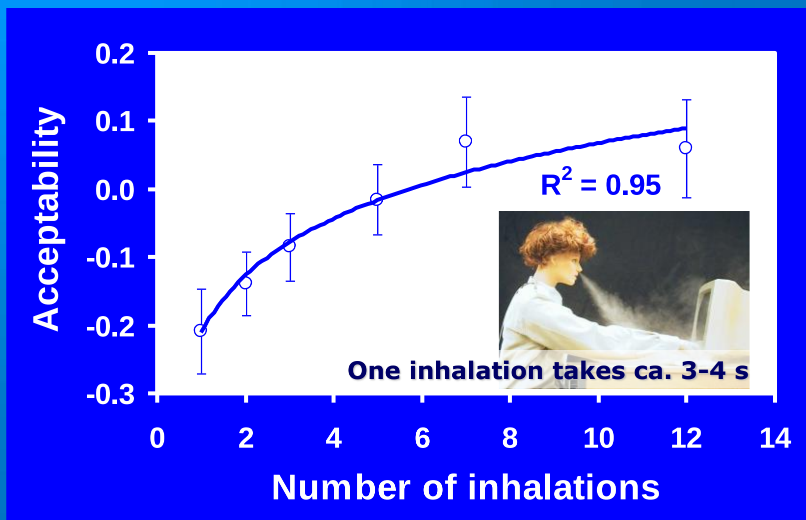
Impact of temperature and humidity on perceived air quality



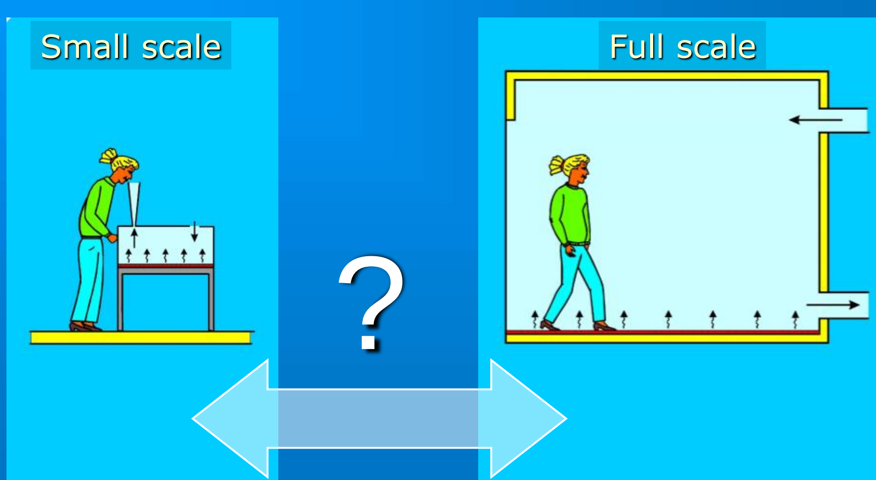
Impact of adaptation



Impact of adaptation



No reliable link between small-scale and full-scale sensory evaluations

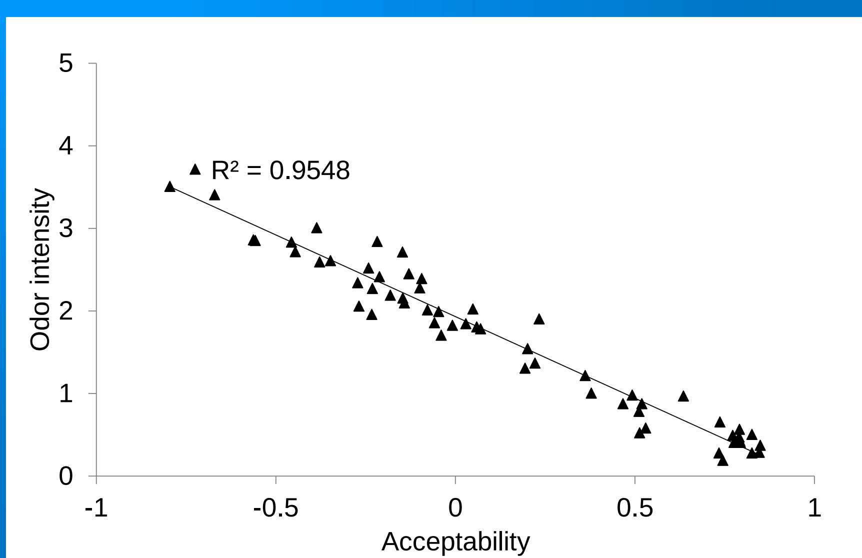


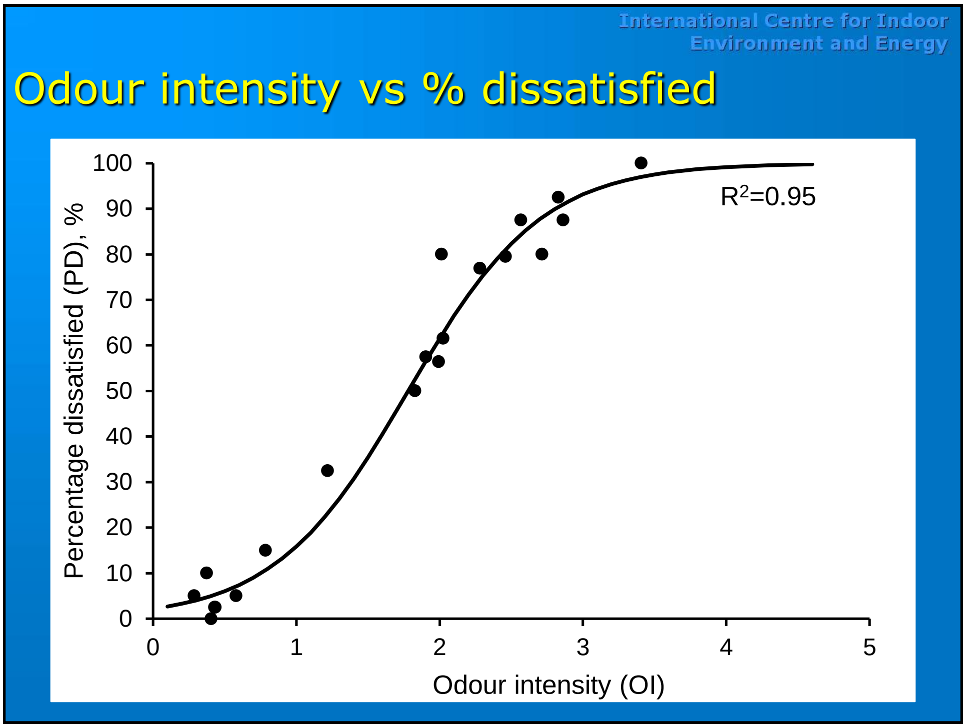
Odour intensity: category scale (Yaglou et al. 1936)

- No odour
- Slight odour
- Moderate odour
- Strong odour
- Very strong odour
- Overpowering odour

International Centre for Indoor Environment and Energy

Acceptability vs odour intensity




International Centre for Indoor
Environment and Energy
Odour intensity vs % dissatisfied
Percentage dissatisfied (PD), %
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
Odour intensity (OI)
R2=0.95

19/09/2018

Measurement accuracy of air flow

Isabelle CARE

Introduction

Building sector is the largest energy consumer in Europe

Union's target to reduce energy dependency and greenhouse gas emissions

Requirements with regard to energy performance of buildings

- more energy efficient
- more airtight

Ventilation: critical parameter

- Insufficient ventilation: impact on indoor air quality
- Excessive ventilation: impact on energy use

Introduction

Flow rate measurements on site

- Primary importance
- Not so trivial
  - Variety of ATD, diffusers (size/shape, flow pattern)
  - On site conditions

Objective of the session

A review of European standards

- Carl Welinder, SWEMA

Presentation of the issues related to flow measurement at ATD

- Samuel Caillou, BBRI

Discussion with the audience

CETIAT
ensemble, innover et valider

Domaine scientifique de la Doua
25 avenue des Arts – BP 52042
69003 VILLEURBANNE CEDEX - FRANCE

Mail : information@cetiat.fr
Tél : 04 72 44 49 00
Fax : 04 72 44 49 49

European Standards of air flow measurements on site

EN 12599 and EN 16211

Methods at air terminal devices, (ATDs) and ducts.

Exhaust and supply ATD.

Conditions, uncertainties

Carl Welinder, Stockholm, la Suède

European Standards of air flow measurements on site

EN 12599 and EN 16211

Methods at air terminal devices, (ATDs) and ducts.

Exhaust and supply ATD.

Conditions, uncertainties

Carl Welinder, Stockholm, la Suède

EN 12599:2012

”Ventilation for buildings - Test procedures and measurement methods to hand over air conditioning and ventilation systems”

EN 16211:2015

”Ventilation for buildings – Measurement of air flows on site – Methods”

EN 12599:2012

85 pages: 19 pages air flow.

What to check, extent of check and measurements, What to measure, (Electric current, air flow, air temperature, filter pressure drop, ductwork leakage, humidity, sound, air velocity) and special agreed measurements, uncertainty, Test reports, How to measure

EN 16211:2015

41 pages: Air Flow field measuring methods and their uncertainties

EN 12599 history

To assure that a good ventilation system is installed.

Originates from two reports. One is how to measure one is how much and what to measure.

First edition: EN 12599:2000 from TC 156 WG 8.

EN 16211 history

The climate in Denmark, Norway, Sweden and Finland implies a need for mechanical ventilation.

Nordic guide from the 1970s by Prof Anders Svensson: ”Methods of measuring air flow in ventilation installations”

In Sweden, since early 1990s law of obligatory ventilation check

In Sweden 1000 of technicians are certified to use the methods.

First edition: EN 16211:2015 from TC 156 WG4.

General

EN 12599

Prefers duct measurement:

If a defined cross section is available the measrurement should be performed in the duct.

EN 16211

Presents duct methods first

Air terminal methods

Air flow hoods (Flow funnels)

EN 16211: Two flow hood compensation methods

EN 12599 : Test chamber, Effective area

Reference pressure: K-factor

Bag

Flow hoods

EN 12599

Different Funnels exist.

If high requirements on accuracy

– use compensation method -

Large test chamber

EN 16211

Flow hood (Funnel)

Direct or compensated

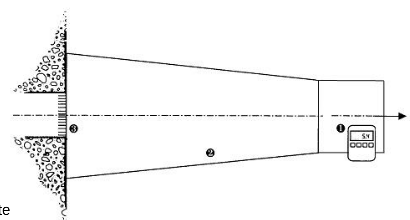
Equalize flow pattern

Minimum length $\geq 3\ D_h$ supply

Low pressure drop over hood

No leakage

If not uncertainties up to 100%



Comment: Supply valves: unstable air stream and different spread patte

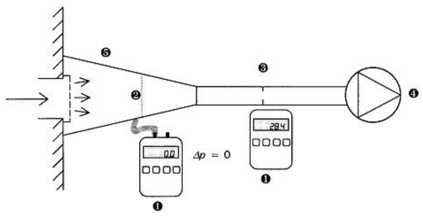
Funnel / Flow hood

Exhaust:

High pressure drop

Direct method - EN 16211

Funnel / Flow hood

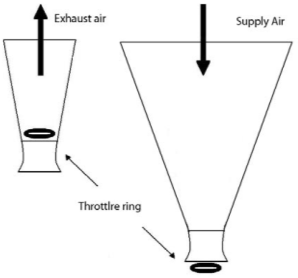


- EN 16211
- Flow hood (Funnel)
  Compensated with auxiliary fan

Funnel / Flow hood

EN 16211 compensation:

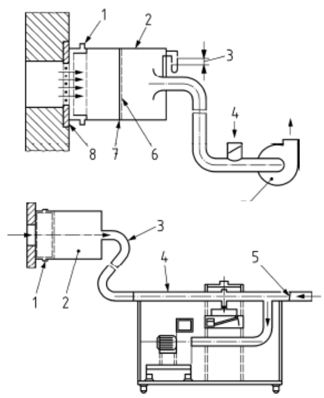
Flow hood compensating
with pressure increase



Test chamber method
EN 12599

- Compensation (zero) method

  compensation method should be used for high accuracy.



EN 12599:

At supply the cross-section of the measurement chamber should be at least 10 times larger than the cross section of the air terminal device (ATD).

Reference pressure
EN 12599, EN 16211

Reference pressure $q = k\,(p_u)^n$

Pressure drop - Throttle device heat exchangers, plenum boxes, (PrEN12599, E.2.4.1)

Flow = k-faktor x squar root of differential pressure

In duct - fixed device/valve (ex: orfice plates)

Exhaust air

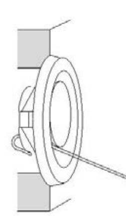
Measuring hook

Pressure connectors (Unusual)

Supply valve (Pressure connectors)

Plenum box supply (number of straights)

Inside plenum box



Bag method

- Bag with calibrated volume (V)
- Time to fill the bag (t)
- Stop at 3 Pa over pressure
- $q = V/t\ (m^3/s)$ = flow

Effective Area Ak - method

EN 12599 : The effective area method is given in EN 12238

$q = v_k \times A_k$

v_k is an avarage velocity value measured at a number of points described by the manufacturer.

A_k is the effective Area value given by the manufacturer.

Duct methods

Measurement by points in duct cross section:
Pito static pipe (EN 12599: equal area)
Thermo anemometer (EN 12599: equal area)

Flue gas analyse

Reference pressure: K-factor

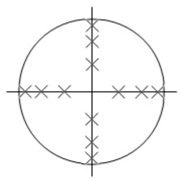
Air Flow in duct cross section

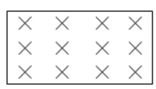
Air flow in duct cross section

EN 12599

Dsqroot(1-(2i-1)/2n)

0,0436D, 0,1464D, 0,2959D





A(2i-1)/2n

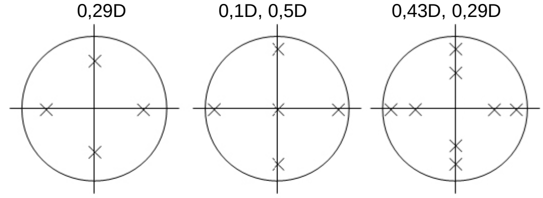
0,167A, 0,5A, 0,833A

0,125B, 0,375B, 0625B, 0875B

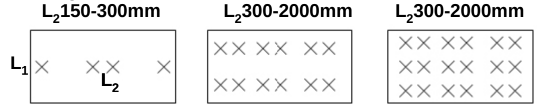
EN 16211

Ø100-160mm | **Ø200-400mm** | **Ø500-1250mm**

0,29D | 0,1D, 0,5D | 0,43D, 0,29D



Height 100-400 $L_2$150-300mm | **H 401-800 $L_2$300-2000mm** | **H 801-2000 $L_2$300-2000mm**



0,08, 0,43, 0,57, 0,92 L_2

0,06, 0,235, 0,43, 0,57, 0,765, 0,94 L_2

SWEMA

Reference pressure

EN 16211

Reference pressure $q = k\,(p_u)^n$

Pressure drop - Throttle device heat exchangers, plenum boxes, (EN12599, E.2.4.1)

Flow = k-faktor x square root of differential pressure

In duct - fixed device/valve (ex: orfice plates)

SWEMA

Tracer gas

EN 12599

Tracer gas E.2.4.1.3

Gas meter For tracer gas E.2.4.1.1

EN 16211

Tracer gas

$q = q_s / C_s$

Uncertainty 5 / 10%

EN 16211

Gross errors: *Human factor: stress, tiredness, lack of knowledge and understanding*

Systematic errors: *Measurements values deviates at same direction. Adjust instrument?*

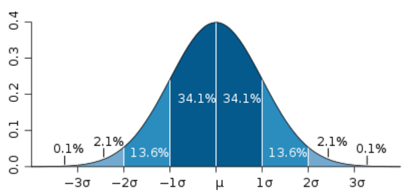
Random uncertainties: *Instrument uncertainty, method uncertainty and reading uncertainty*

Standard or Expanded Uncertainty

Standard measurement uncertainty covers 68% of all cases

Standard measurement uncertainty multiplied with 2 = expanded measurement uncertainty.

That means that with the expanded measurement uncertainty 95% of the measurements will be covered and 5% will not be.



EN 16211 Measurement uncertainty

- Standard Measurement uncertainty - 68%
  $u = ((u_1)^2 + (u_2)^2 + (u_3)^2)^{1/2}$
- u_1 = standard instrument uncertainty
- u_2 = standard method uncertainty
- u_3 = standard reading uncertainty
- Expanded Measurement uncertainty, U=2u (95%)
  - will cover approximately 95% of the measurements.

EN 16211 Standard Instrument uncertainty, u_1

should be stated by instrument manufacturer

Rectangular distributed:
value/(3) ^{½} is at 68% (Easy to think at 95% with 12599)

Correct by using corrections

Note: calibration uncertainty,uncertainty from the instrument itself such as hysteresis, temperature compensation, drift… can not be corrected.

EN 16211 Standard method uncertainty u_2 - 68%

Accurately specified method should be used

orientation of a probe,

distance between the probe and a grille

Influence of flow pattern

Flow pattern

EN 16211
Standard reading uncertainty
u_3 - 68%

Digital instrument - $1/(2(3)^{1/2})$ unit of last digit

Density compensation

EN 12599

- Density. Fans at 1,2 kg/m3 7.3.1.2

EN 16211

When presenting a measured air flow or velocity, it should be stated if it is the real air flow or the flow converted to standard conditions that is presented.

$$v_s = v_m \cdot \rho_m / \rho_s \ \text{m/s}$$

Revision of EN 14134:2004

Ventilation for buildings. Performance testing and installation checks of residential ventilation systems

Revision of EN 12599:2012

Ventilation for buildings. Test procedures and measurement methods to hand over air conditioning and ventilation systems

Revision of EN 16211:2015

Ventilation for buildings. Measurement of air flows on site – Methods

Merci beaucoup de votre attention

Carl Welinder, Stockholm, la Suède

Measurement of **airflow rates** at **air terminal devices**: an overview

Samuel Caillou (BBRI)
BBRI – Belgian Building Research Institute, Belgium

Overview of measurement methods at air terminal device

Vane anemometers

Small probe + specific cone

- Thermal or vane anemometer

Standard hoods

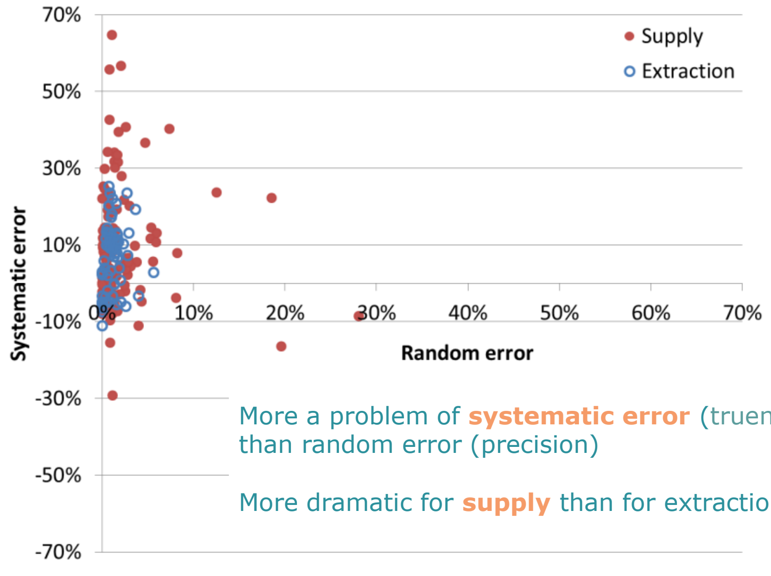
Compensation method

And more…

Overview presentation

- Integrating results from different teams
  - BBRI, Belgium
  - BSRIA, UK
  - Cetiat, France
  - LBNL, USA
- Different methodologies
  - Comparison with reference flow rate (in lab only)
  - Comparison with reference instrument (field study possible)
- Comparison of methods
  - But also trademarks… and calibration by the manufacturers

Overview of the problem

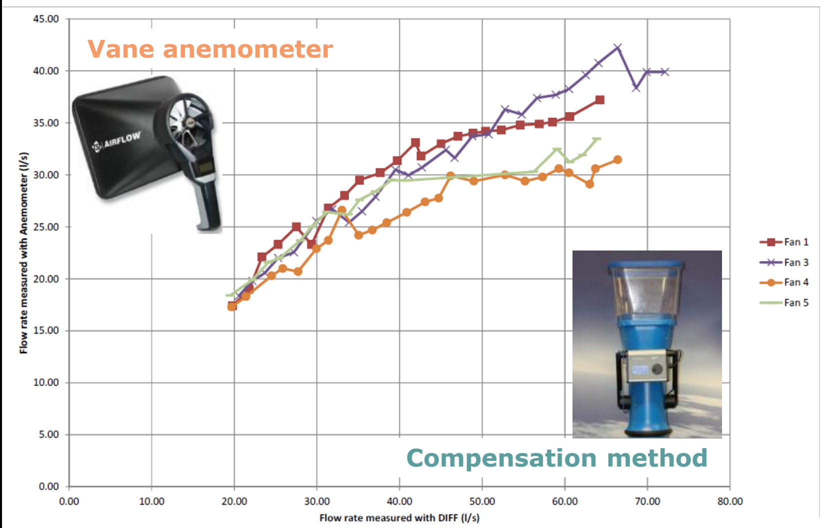


More a problem of **systematic error** (trueness) than random error (precision)

More dramatic for **supply** than for extraction

Caillou S. et al. (BBRI)

Problem n°1: Back pressure or insertion losses



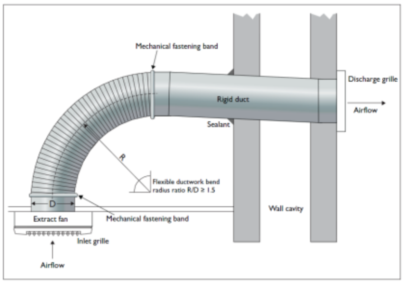
Roper M. et al. (BSRIA)

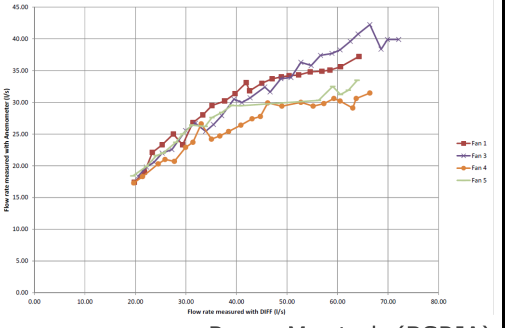
n°1: Back pressure or insertion losses

- The measurement instrument creates an **additional pressure drop**
  - Modifies ductwork characteristic and/or fan working point
  - Reduces the (apparent) measured flow rate
- For both **supply** and **extraction** ATD
- Depends on
  - Ductwork type: branched or not
  - Pressure drop of the ductwork: low vs. high
  - Fan characteristic: axial vs. centrifugal
- Solution? **Compensation method**

n°1: Back pressure or insertion losses - BSRIA study

- Decentralized ventilation systems
  - Axial fans + Wall- or ceiling-mounted
  - Low pressure, especially at higher flow rates





Roper M. et al. (BSRIA)

Problem n°2: Non-uniformity of the flow

- More problematic for supply than for extraction ATD
- Several causes of non-uniformity (ATD)
  - Flow pattern of the ATD
  - Swirl
  - Directional flow
  - High local velocities
  - Presence of a bend behind the ATD
  - Changed flow pattern after regulation of the ATD (too closed)
  - …

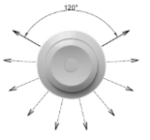
n°2: Non-uniformity of the flow - Examples of tested ATD (BBRI)

- Homogeneous
  - Classical ATD

    in normally opened position
- Non-homogeneous
  - ATD with lateral flow

    (high local velocity)
  - ATD with protected angle

    (directional flow pattern)
  - ATD particularly closed (10-50%)



Caillou S. et al. (BBRI)

n°2: Non-uniformity of the flow - Examples of tested ATD (Cetiat)

Caré I. et al. (Cetiat)

n°2: Non-uniformity of the flow - Examples of tested ATD (LBNL)

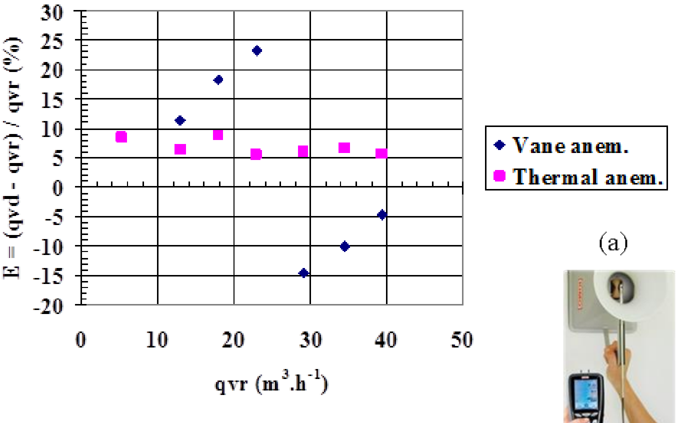
Directional flow

Swirl

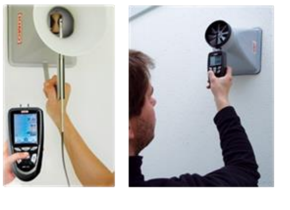
Walker I. et al. (LBNL)

Stratton J. et al. (LBNL)

n°2: Non-uniformity of the flow - Vane anemometer

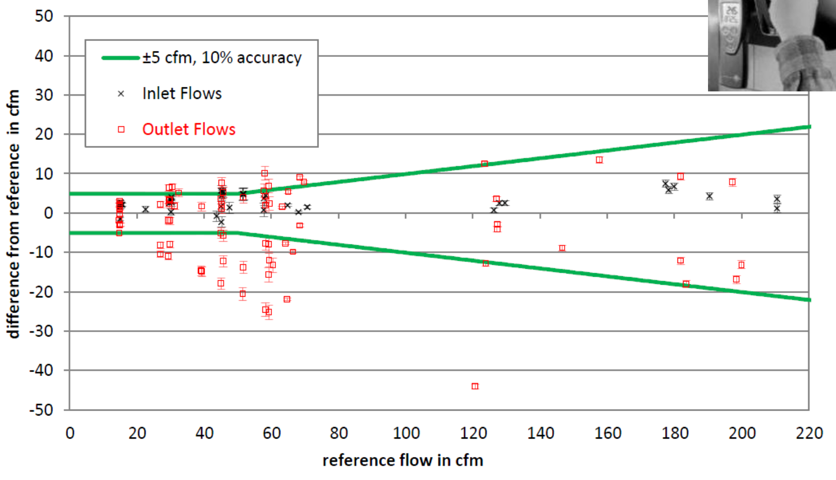


(a) (b)



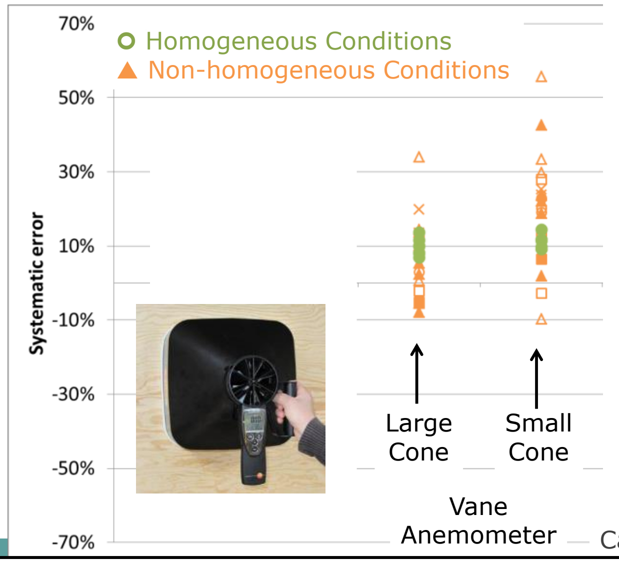
Caré I. et al. (Cetiat)

n°2: Non-uniformity of the flow - Vane anemometer



Stratton J. et al. (LBNL)

n°2: Non-uniformity of the flow - Vane anemometer



Caillou S. et al. (BBRI)

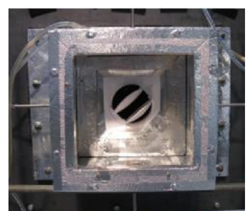
n°2: Non-uniformity of the flow
Vane anemometer (propeller)

- For extraction ok: < 10-15% error
- For supply
  - Very sensitive to flow pattern
  - Also very sensitive to swirl

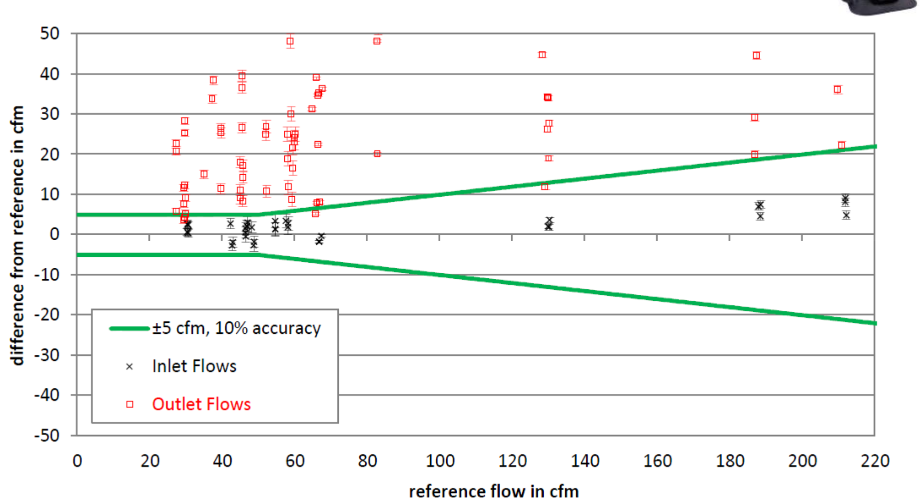
    Same direction as propeller → overestimated

    In opposition to propeller → underestimated

- Improvement
  - Larger cone
  - Longer hood
  - Or additional box (Cetiat)

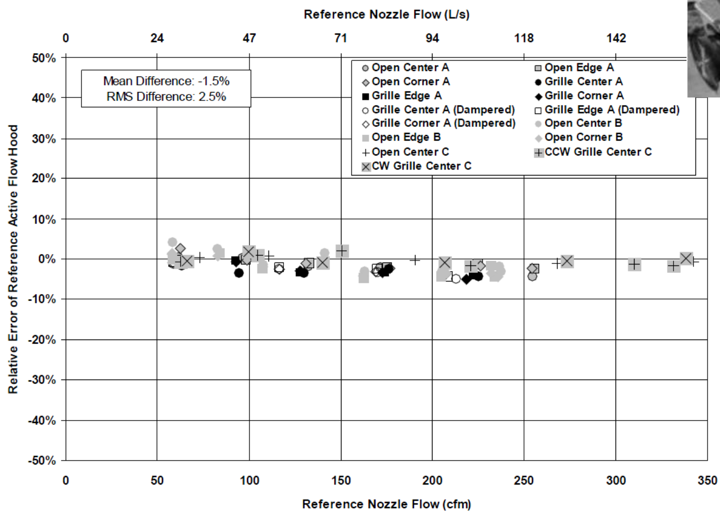


n°2: Non-uniformity of the flow – Standard hoods



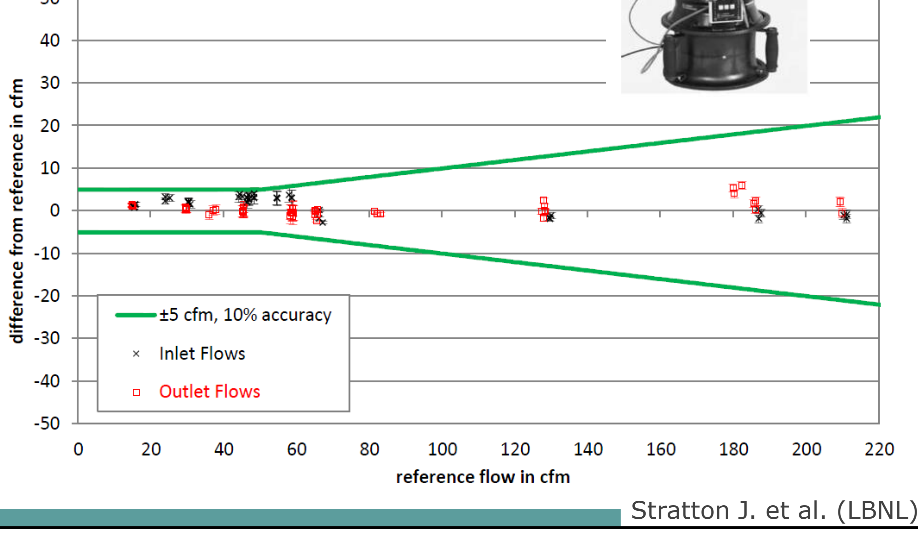
Stratton J. et al. (LBNL)

n°2: Non-uniformity of the flow - Compensation method



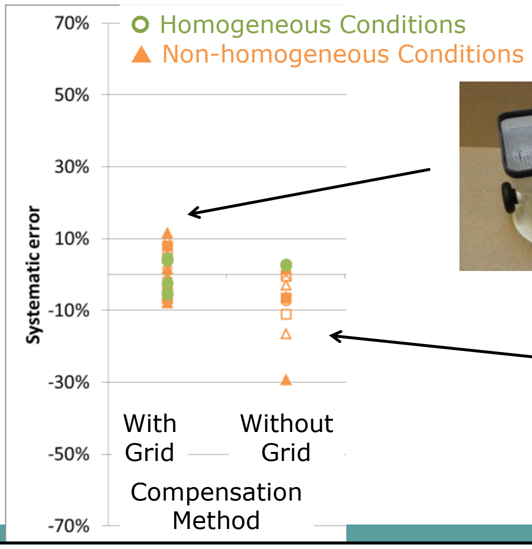
Walker I. et al. (LBNL)

n°2: Non-uniformity of the flow – Compensation method



Stratton J. et al. (LBNL)

n°2: Non-uniformity of the flow – Compensation method



Caillou S. et al. (BBRI)

n°2: Non-uniformity of the flow – Compensation method

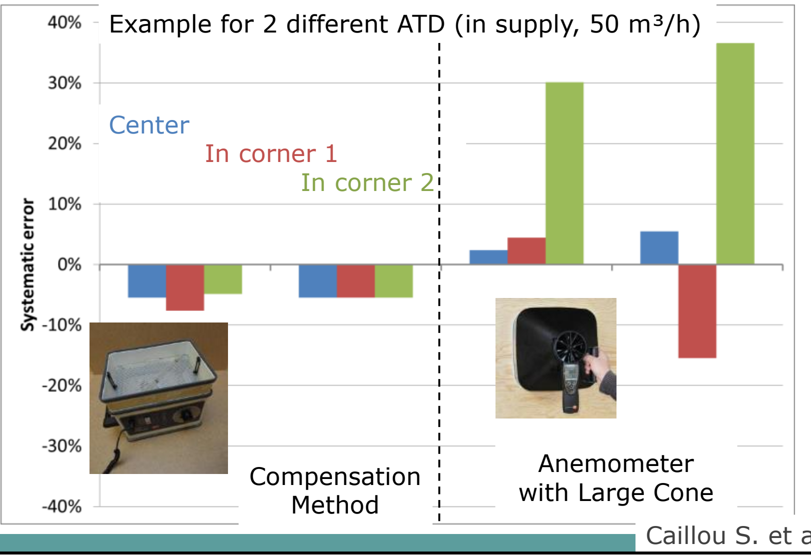
- Very good in all conditions: < 10% error
  - For both supply and extraction ATD
  - For all types of ATD and flow patterns
- **But the key point si flow stabilisation!**
  - Compensation as such is not enough
  - Stabilisation with a grid (compensation necessary to compensate the pressure drop)
  - Or stabilisation with longer hood?

Not enough stabilisation

n°2: Non-uniformity of the flow – Stabilisation using a duct piece

- Recent innovation
- Principle
  - Same as vane anemometer
  - But with additional duct piece
- Good in all conditions < 10-15% error
  - For both supply and extraction
  - For all types of ATD and flow patterns tested
- But
  - Pressure drop x 1.5 compared to without additional duct
  - See back pressure (problem 1)

Problem n°3: Non-centering of the instrument on the ATD



Solutions - recommandations

- **Compensation method**
  - But stabilisation is the key point: with grid vs. without grid

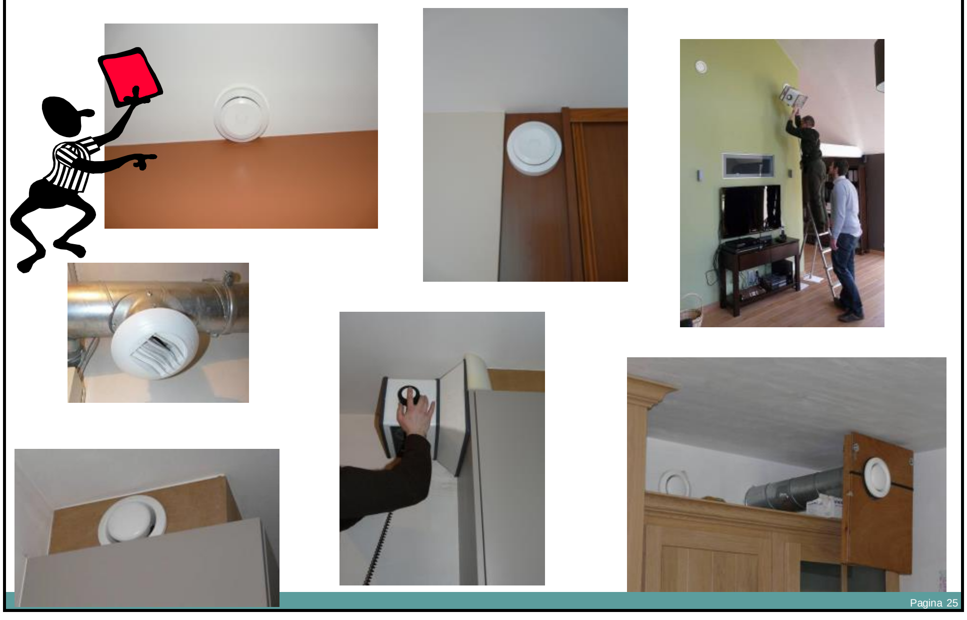
- For non-active methods (no compensation)
  - Ok for extraction ATD
  - But for supply, need additional stabilisation

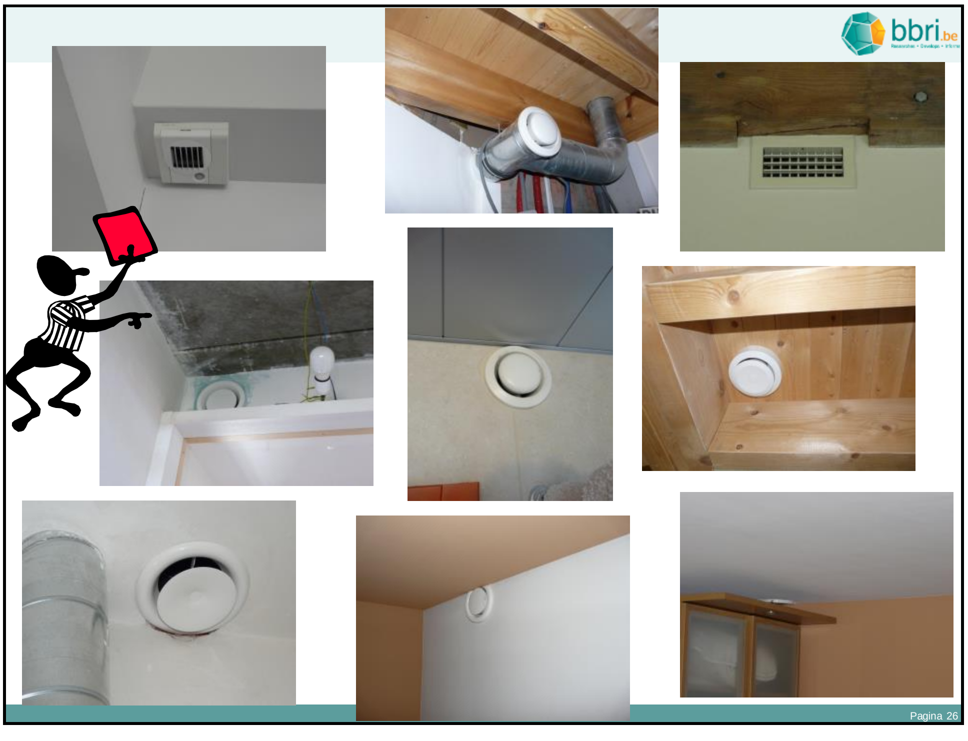
    Larger cone, longer hood

    Or additional duct section (! Back pressure)

Further thinking: Calibration vs. Field application

- Of course all these instruments have been calibrated
  - By the manufacturer (with good claimed accuracy…)
  - But for uniform/homogeneous flow patterns only
- Calibration is not enough…
- Selective description of « good » and « not good » methods is not a solution…
- Can we imagine a **standard test protocol** ?
  - Defining the main types of non-uniform patterns
  - Allowing to test instrument performances for these patterns
  - Leaving the way open to innovation!





Thank you for your attention

- References

  - NBN EN 12599:2012. *Ventilation for buildings - Test procedures and measurement methods to hand over air conditioning and ventilation systems*
  - prEN 16211 (to be published). *Ventilation for buildings - Measurement of air flows on site – methods*
  - G. Hawkins (2013). *Domestic ventilation systems – A guide to measure airflow rates.* A BSRIA Guide, BG 46/2013. www.bsria.co.uk
  - M. Roper (2013). *Flow Measurement for Domestic Ventilation Fans.* Final Report 57015/2. BSRIA. www.bsria.co.uk
  - A. Gilbert, Ch. Knights (2013). *Quality of ventilation systems in resiedential buildings : statut and perspectives in the UK*, AIVC International Workshop, Brussels, Belgium, 18-19 March 2013
  - J. C. Stratton, W.J.N Turner, C. P. Wray, I. S. Walker (2012). *Measuring Residential Ventilation System Airflows: Part 1 – Laboratory Evaluation of Airflow Meter Devices*. Lawrence Berkeley National Laboratory. http://homes.lbl.gov/sites/all/files/lbnl-5983e.pdf

- References (2)

  - J. Chris Stratton, Iain S. Walker, Craig P. Wray (2012). *Measuring Residential Ventilation System Airflows: Part 2 – Field Evaluation of Airflow Meter Devices and System Flow Verification.* Lawrence Berkeley National Laboratory. http://homes.lbl.gov/sites/all/files/lbnl-5982e.pdf
  - I.S. Walker, C.P. Wray, D.J. Dickerhoff, M.H. Sherman (2001). *Evaluation of flow hood measurements for residential register flows.* Lawrence Berkeley National Laboratory. http://epb.lbl.gov/publications/pdf/lbnl-47382.pdf
  - C.P. Wray, I.S. Walker, M.H. Sherman (2002). *Accuracy of flow hoods in residential applications.* Lawrence Berkeley National Laboratory. http://epb.lbl.gov/publications/pdf/lbnl-49697.pdf
  - I. Carré, P. Chaffois, P. Henry (2013). *Guide des bonnes pratiques des mesures de débit d'air sur site pour les installations de ventilation.* Cetiat, France. http://www.cetiat.fr/fr/chercher/index.cfm
  - I. Caré (2013). *Measurement of flow rate at air terminal device*, Congrès international de Métrologie, Paris, October 2013

Use of low cost IAQ sensors ?

Laure MOURADIAN

CETIAT ensemble, innover et valider

Low cost IAQ sensors

- Stand-alone sensors < 200 €
- Compact and internet-connected
- Measuring T, RH, CO_2, **PM, VOCs**
- Assessment of sensitivity, response time

C Grade of RESET ™

AERECO (PM)
LASER EGG (PM)
AWAIR (PM, VOCs, CO_2)
FOOBOT (PM, VOCs)
UNI-T (PM, VOCs)
SPECK (PM)

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Few / heterogeneous information on sensors characteristics

A
- Sensitivity: 0,3 – 10 µm
- **$PM_{2.5}$, PM_{10}**
- PM $_{2.5}$ ±10%
- Response time 10-100 ms

B
- Sensitivity: 0,3 - 2,5 µm
- ± 4 µg/m³ or ± 20 %
- Range: 0-1300 **µg/m³**

C
- Resolution 1µg/m³
- Range: 0- 500 **µg/m³**

D
- Range: 0-500 **µg/m³**

E
- Sensitivity: 0,5 - 3 µm
- Count of particles : **ppL**
- Transp. **µg/m³**

F
- **Count of particles** /size
- **$PM_{2,5}$, PM_{10}**

Information available on manufacturers ' technical specifications

for particles measurements

G
- Sensitivity: hydrogen gas, hydrogen sulfide, ammonia, ethanol, toluene, and formaldehyde
- Value in **ppb**

H
- Sensitivity: Formaldehyde, iso-butane, toluene, methane, ammoniac, benzene, etc. (*)
- Range:100-1000 **ppb**

I
- Range : 0-9,9 **mg/m³**
- Resolution 1mg/m³

And for VOCs

CETIAT
ensemble, innover et valider

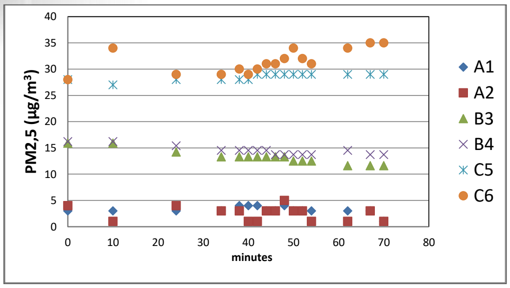
Tests at CETIAT

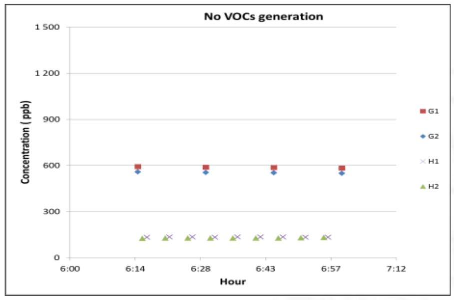
Testing room – 8 m³
- External supply fan + high efficiency filter
- Injection of pollutant + indoor comfort fan
- Sensors in central zone

Reference measurement/particles:
- Counter of Particules (COP) TSI 3330
- 7 channels 0,3 to 10 µm
- Transition from number to µg/m³ by calculation + hypothesis on particles density (2.8)

ensemble, innover et valider

Measurement with no generation of pollutants





Indoor concentration of PM2.5
No particle generation

Basic level : ~5 / 15 / 30 µg/m³

Indoor concentration of VOCs
No VOCs generation

Basic level : 130 / 600 ppb

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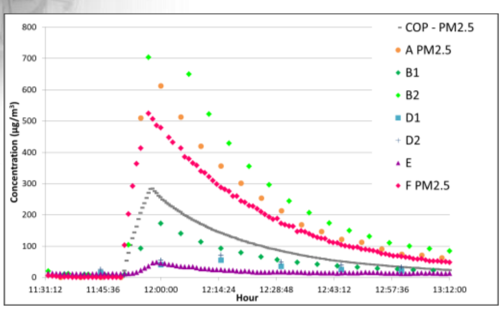
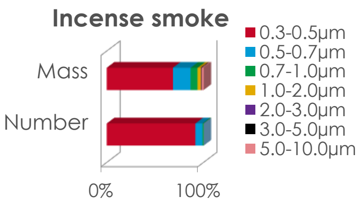
ensemble, innover et valider

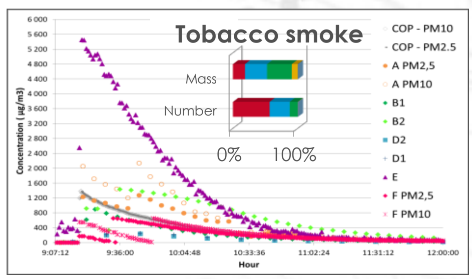
Sensor response to particulate matter

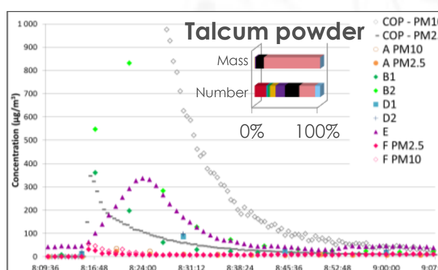




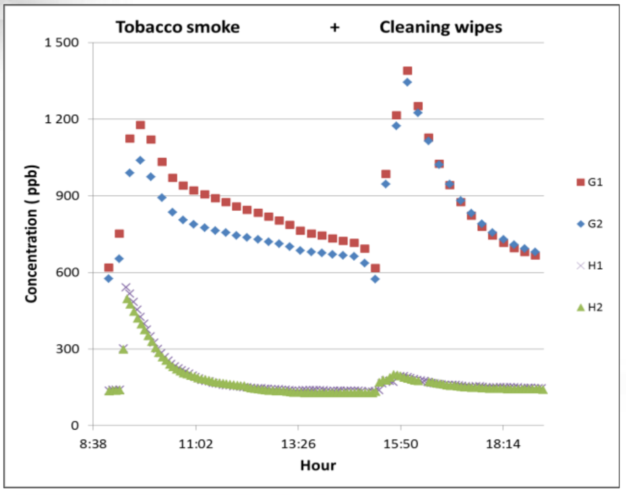
→ Differences due to:
- Sampling
- Average values
- Sensitivity

→ the orders of magnitude of the responses differ regarding particle composition





Sensor response to VOCs



Comparison of two sensors
With two different sources of VOCs

→ **Values differ between sensors G and H**

→ **the order of magnitude of the responses differ Tobacco/cleaning wipes**

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Conclusions

Measurement results

- High disparity between sensors
- Impact of data sampling and average: Time lag, Lower peak value
- Impact of the pollutant compositon
  - Sensor responses are different / nature of pollutant
  - Particles: incense, tobacco, talc
  - VOCs : tobacco, incense, cleaning wipes
- Few informations available
  - Sensitivity /selectivity
  - Data processing
  - Ambient conditions influence

Assessment of IAQ Sensors

- Need to characterize the generated pollutant
  - Nature and Composition
  - Properties (density, …)
- Initial and periodic calibration is needed
  - Complex pollutant
    - Not only one gas for VOCs
    - Several Particles generations (fine, very small, …)
  - On-site ?
  - Dedicated ISO standards
    - ISO 16000-29 (2014): VOC
    - ISO 16000-34 (2018): PM

CETIAT
ensemble, innover et valider

Which use of « low-cost » sensors (PM, VOCs) ?

Information on increasing or decreasing pollutant levels

- Impact of indoor activities (cooking, cleaning, DIY activities…) on some IAQ metrics
  - To detect need of higher air flow (boost, …)
- Increase end-user awarness, actor of its IAQ:
  - adjust its behaviour
  - understand the need of good ventilation system

Not ready for use as fine DCV sensor

(ventilation control around target value)

- Prob of reliability of data and connexion, durability, calibration, …

39th AIVC Conference

Thank you for your attention

Are low-cost sensors good enough for IAQ controls?

39th AIVC Conference 2018

Iain Walker, Woody Delp and Brett Singer
iswalker@lbl.gov

Introduction

Detecting health-related pollutant(s):

- Key health-related pollutant is PM2.5

Low cost – "consumer grade"

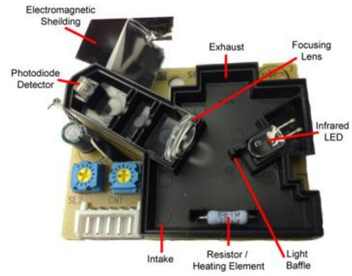
~ €250

Do sensors detect pollutants well enough for ventilation control?

- Lab tests of controlled emissions
- Home tests of events

Sensors: Mass produced €10-35

- Optical light scattering
  - 0.3 micron limit
- Several manufacturers
  - Sharp, Shinyei, Plantower, Syhightec + other proprietary units
  - Best ones (e.g., Plantower) packaged in rugged housing with a small fan & use good quality IR source
- **Monitors** include power supply, box, possibly a display, wireless data transfer, & CALIBRATION



Monitors Evaluated

AirBeam: AB

PM, T, RH

1 sec

Air Visual Node: AVN

$PM_{2.5}$, PM_{10}, CO_2, T, RH

10 sec – 15 min

Air Quality Egg: AQE

PM, T, RH

1 min

AWAIR: AWA

PM, CO_2, VOC, T, RH,

10 sec – 5 min

Foobot FOB

PM, CO_2, VOC, T, RH,

5 min

Purple Air PA

$PM_{1.0}$, $PM_{2.5}$, PM_{10}, T, RH

80 sec

Speck: SPK

PM, # particles T, RH

1 min

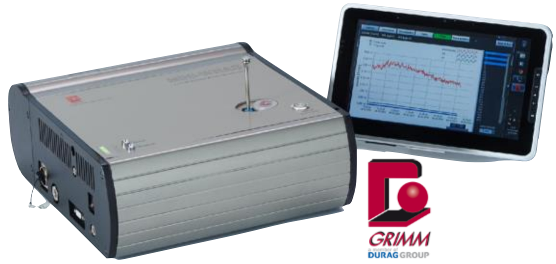
$PM_{2.5}$ Reference Instruments

Thermo-Scientific
TEOM-1405DF

ThermoFisher SCIENTIFIC

Direct Mass readings
$PM_{2.5}$, PM_{Coarse}

Grimm miniWRAS



Aerosol Spectrometer
Particle size distribution in 41 channels from 10nm up to 35μm

About €35,000

Building AMERICA U.S. Department of Energy
BERKELEY LAB

Research PM Monitors

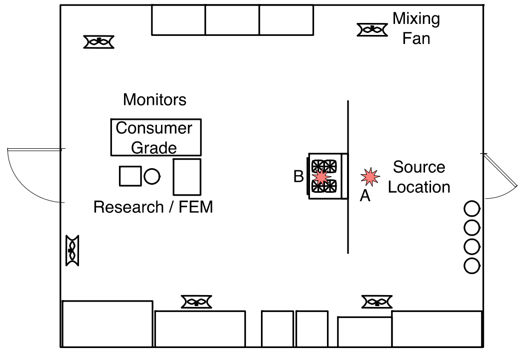
- Optical scattering devices developed for occupational health, used for residential research.
- Cost €4-10,000 for analyzer; €500 for sensor unit.

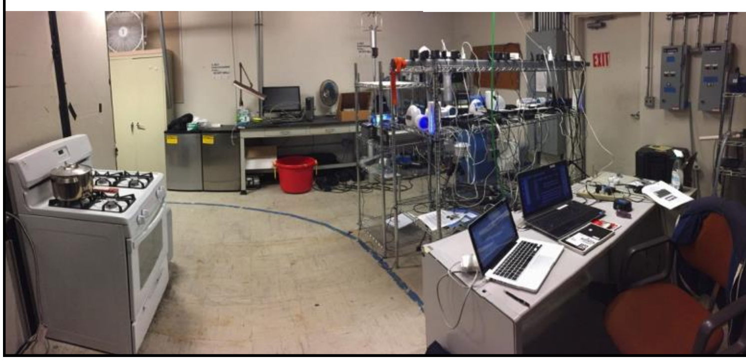
In this study: Thermoscientific **PDR** 1500 & MetOne **BT** 645

Building AMERICA U.S. Department of Energy
BERKELEY LAB

Test Lab

45 m^2
~120 m^3



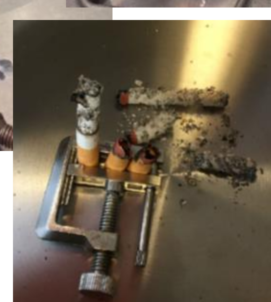


General
Particles:
AZ Road dust
Mop
Humidifier

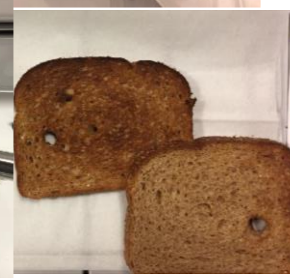
Hot surfaces:
- Hair Dryer
- Oven
- Electric Elements

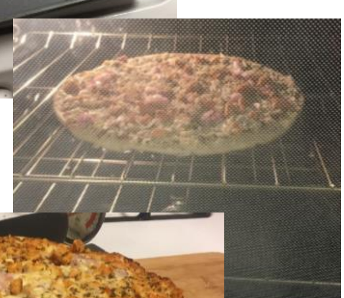


Combustion:
- Natural Gas
- Candles
- Cigarettes
- Incense

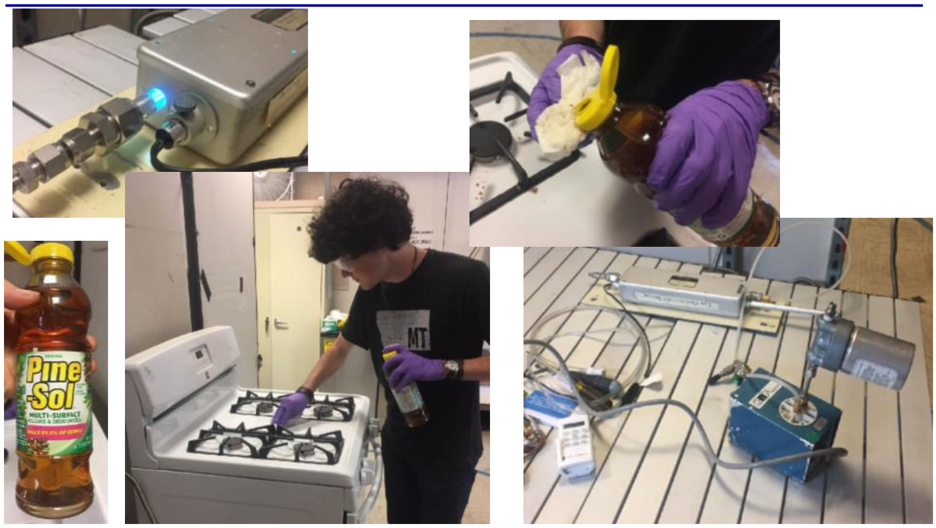
Cooking





Cooking

Chemistry – cleaning products and ozone



Lab Results

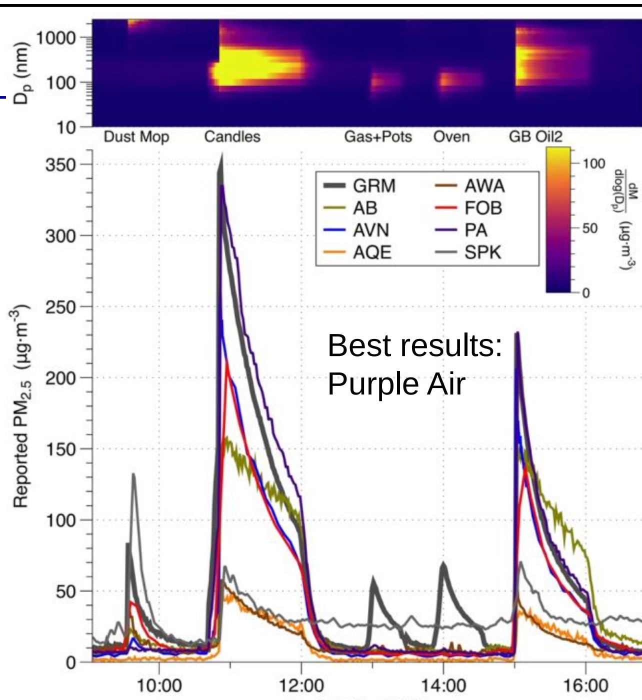
Event detection:

- Some better than others

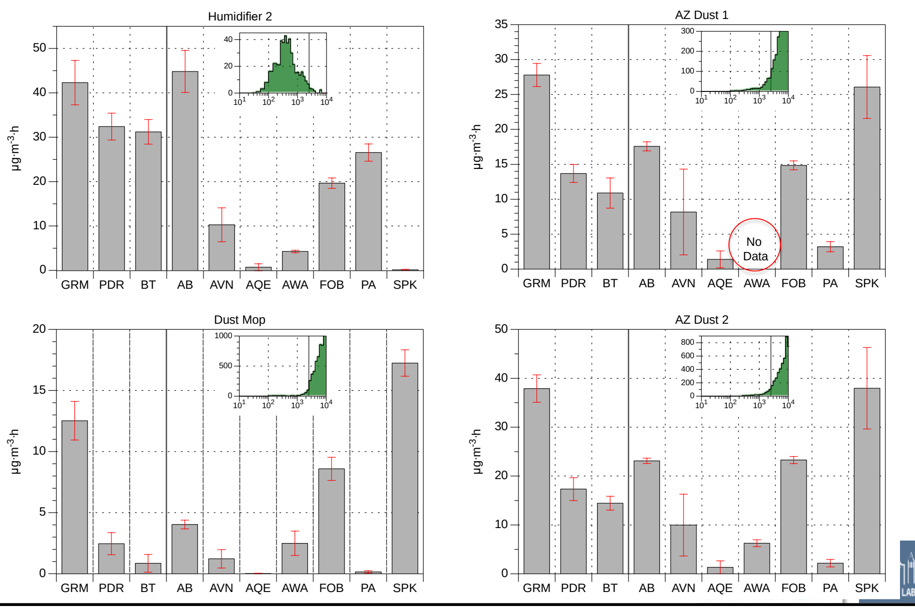
Magnitude

- Some better than others

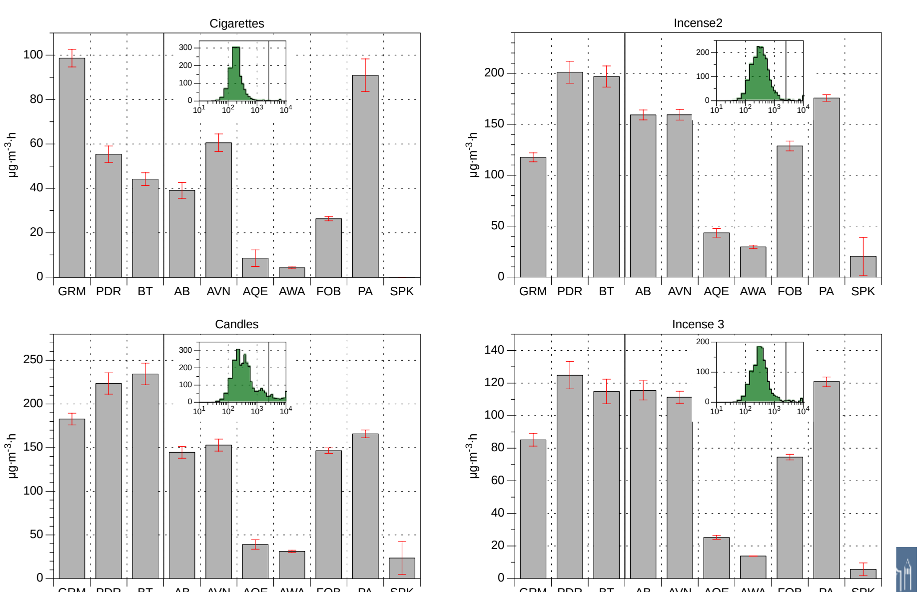
Depends on "event"
= depends on particle size distribution



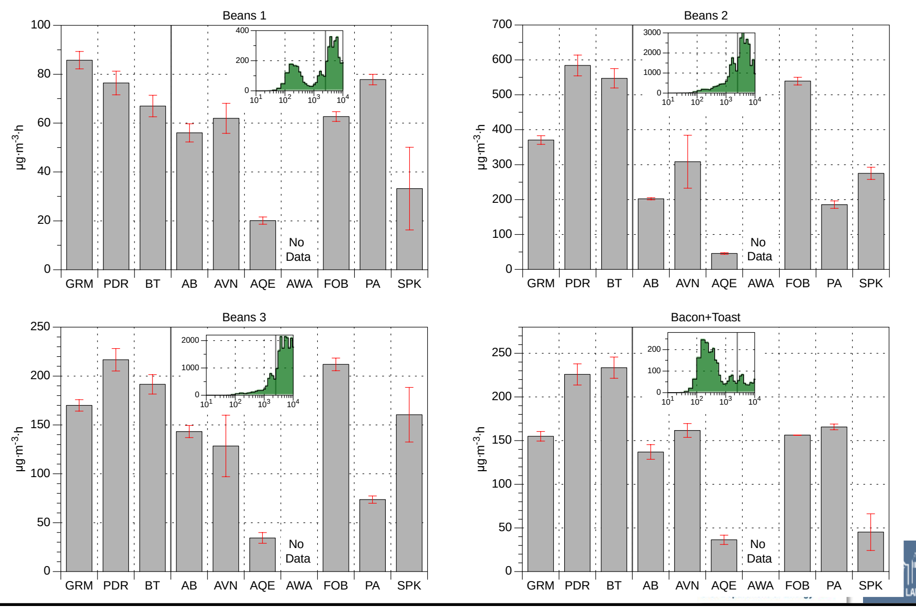
Humidifier and Dust



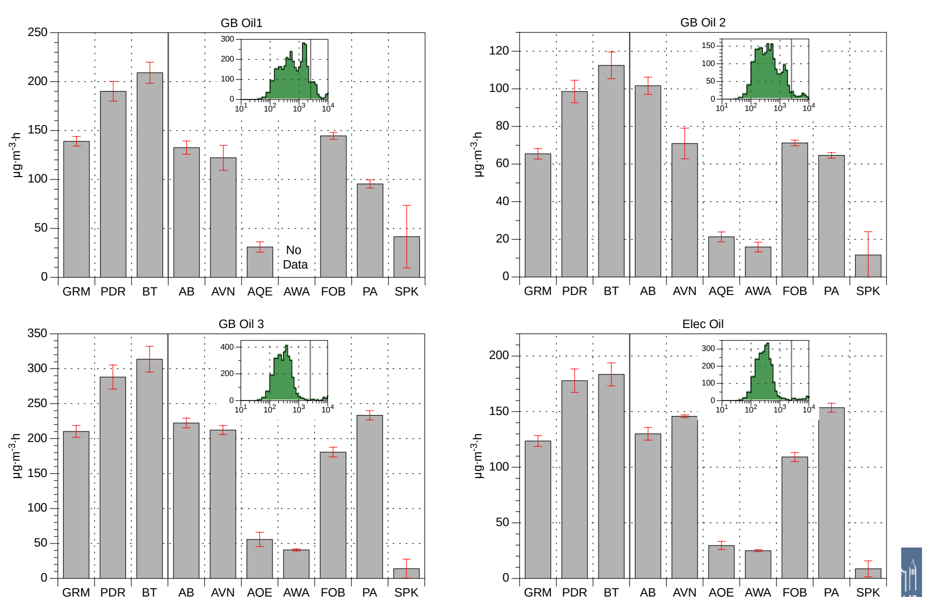
Recreational Combustion



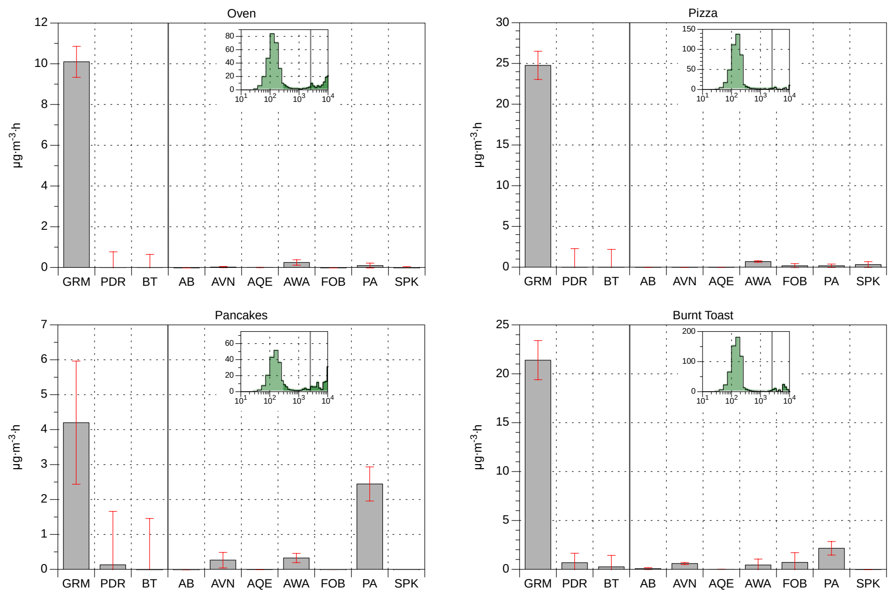
Stir-Frying and Frying + Toasting



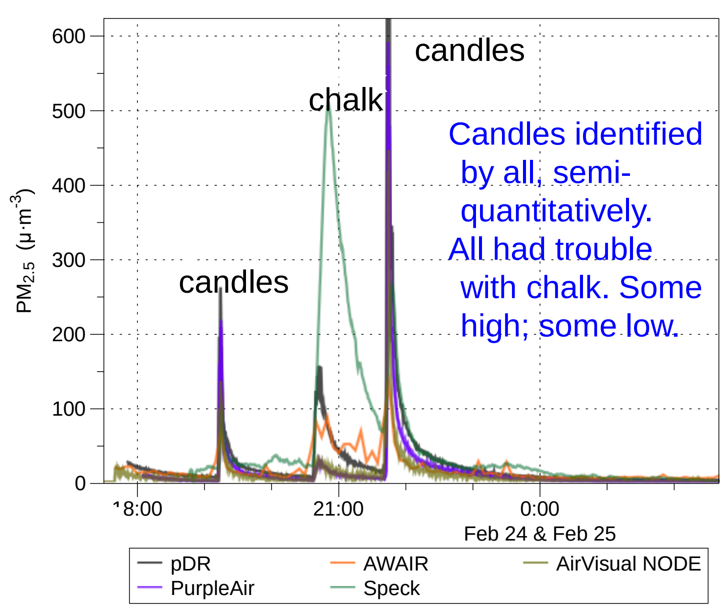
H Oil on Gas or Electric Burners



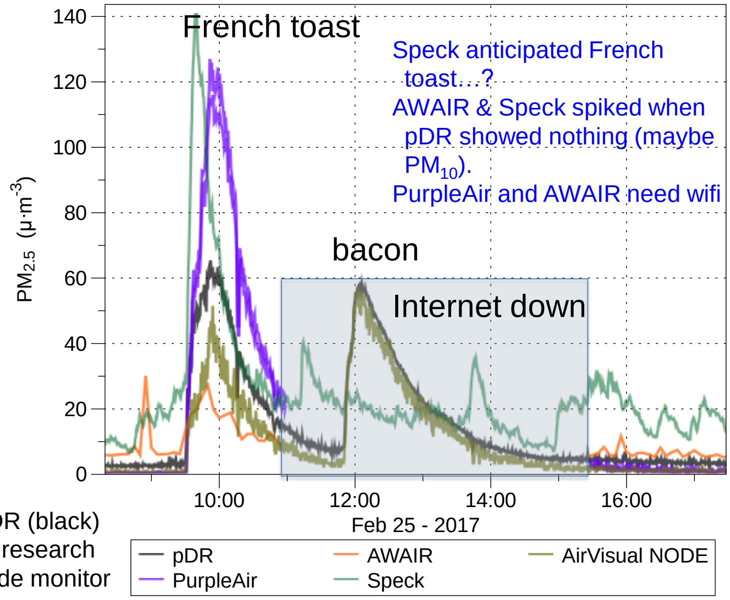
Cooking – Emits Mostly <0.3 um Particles



In-Home Test

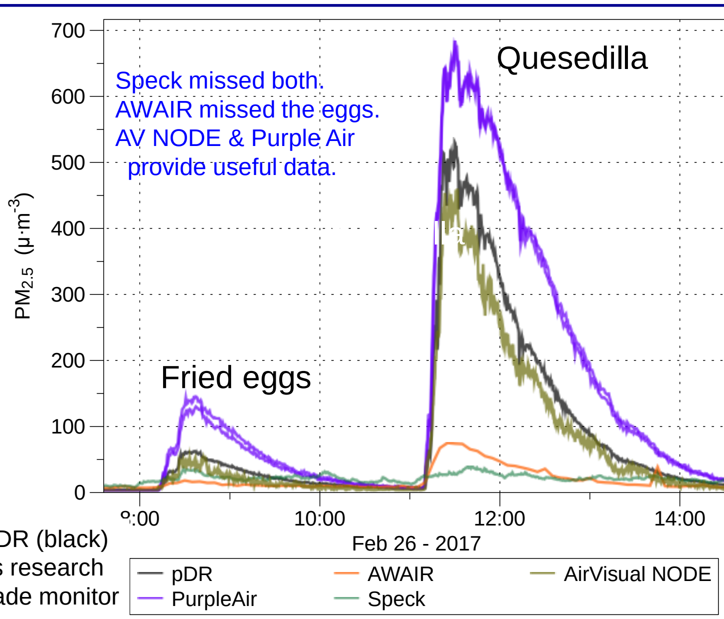


In-Home Test



pDR (black) is research grade monitor

In-Home Test



pDR (black) is research grade monitor

Conclusions

1. Four consumer monitors detected most sources and semi-quantitatively* measured all large sources of $PM_{2.5}$.
   - Appear suitable to indicate IAQ.
   - Could control a particle filter for most situations
   - PA could be used for health calculation for ventilation control

PA **FOB** **AB** **AVN**

2. Two consumer monitors detected many sources but not quantitatively.

AWA **AQE**

3. One monitor was not informative.

SPK

4. No consumer monitors suitable to detect & control ultrafine particles.

Purple Air quantitatively better than others – but no nice packaging/display

* Within a factor of 10 for AirBeam… is this good enough?

Other considerations

- Purple Air: Best performance, buy no nice packaging/display, no battery
- Foobot: Good performance, no direct display
- AirVisual Node: Good performance. Has battery power – will log w/o internet connection. Has better CO2 detection – looks at previous week for lowest reading and auto-calibrates. Has very good display.
- Air Beam: No display
- AWAIR: Stylish packaging
- Air Quality Egg: OK display
- Speck: Good Display

Remaining issues

Need to test for durability – are they still OK 5, 10 years from now?

What about other key pollutants: formaldehyde, NO_2, etc.?

Almost all require an internet connection for cloud storage or data retrieval but

- will restart automatically if internet down and then reconnected.
- ALWAYS confirm upload otherwise data overwritten and lost
- DYLOS only kept data in cloud for limit time – if not downloaded lost forever

Almost all have an app for data viewing – particularly if they have no built-in display

Build your own monitor (BYOM)

- **UPOD: Open source platform for mobile air quality monitoring**

  University of Colorado, Boulder

  http://mobilesensingtechnology.com/

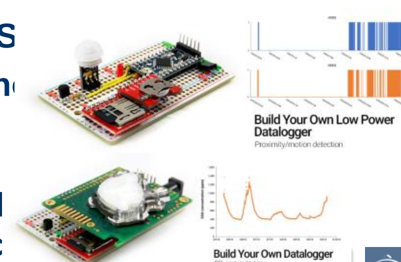
  T, RH, P, CO_2, O_3, NO_2; slots for 4 e2v MOx sensors

- **Open Source Building S**

  Illinois Institute of Techn

  http://www.osbss.com/

  T, RH, CO_2, Particles, δελτα–P, equilibrium RH, l state, proximity, occupanc



DIY / Maker offerings

- Perhaps a robust sensor, and the ability to do what you want
- A community is springing up offer parts lists and plans for devices
- ~$50

Other Studies

- EPA has done some work focusing on outdoors

  https://www.epa.gov/air-sensor-toolbox

- South Coast AQMD is working on outdoor and chamber tests

  http://www.aqmd.gov/aq-spec/home

- Carnegie Mellon has done some work and developed the SPECK

https://explorables.cmucreatelab.org/explorables/air-quality-monitor-tests/

- Air quality in China

  http://aqicn.org/sensor/

Indoor air quality (IAQ) investigation in a ventilated demonstrator building via a smart sensor

Loubna Qabbal, Zohir Younsi and Hassane Naji

18-19 September 2018, Conference, Juan-les-Pins, 39th AIVC conference

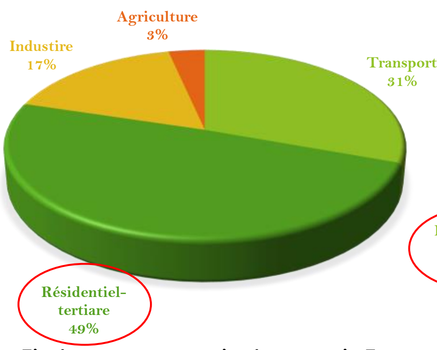
University of Artois
High School of Engineering Studies (HEI)
Laboratory Civil Engineering and Geo-Environment (EA 4515)
Doctoral School Sciences for the Engineer - Lille Nord University of France (EDSPI-72)

Plan

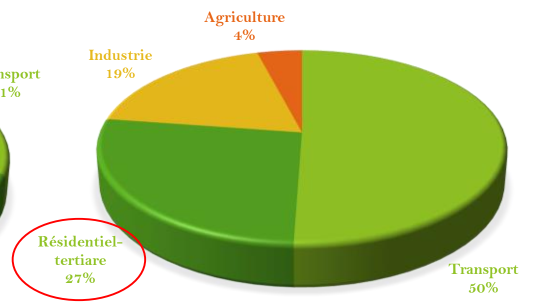
1. Introduction
2. Context and issues
3. Indoor air quality (IAQ) and the problems of poor IAQ
4. Synthesis and objectives of the study
5. Experimental approach description
6. Results : IAQ assessment and comfort parameters

1. INTRODUCTION

The building sector is the leading consumer of final energy in France, and the second in terms of greenhouse gas emissions.



Final energy consumption by sector in France



CO_2 emissions in the atmosphere by sector in France

2. CONTEXT AND ISSUES

Before
- The old buildings were permeable to air
- A lot of air infiltration through the leaks
- Therefore, the rate of air exchange was high

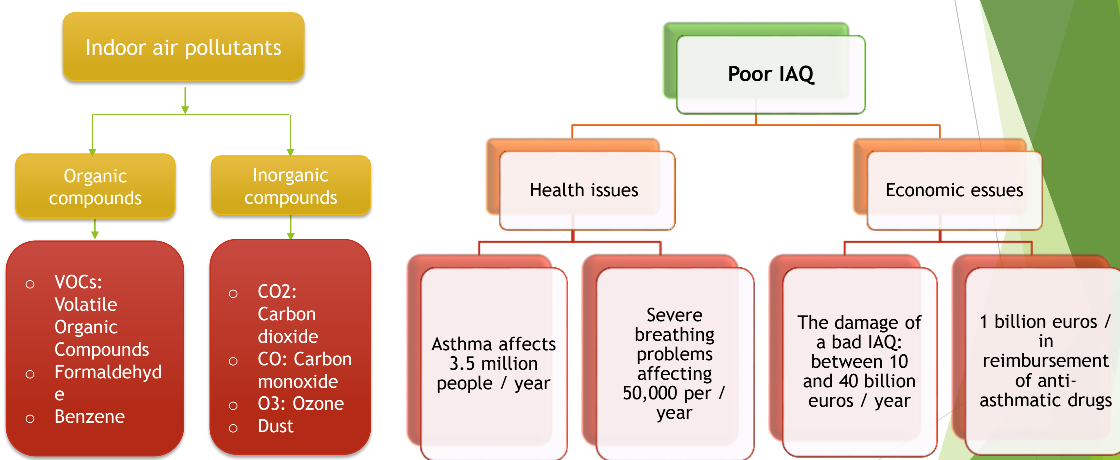
Thermal Regulation (TR 2012)
- Watertight building
- Suppression of air infiltration
- Insufficient air renewal rate

Problems
- Maintain a good level of IAQ
- Modulate and regulate airflow as needed
- Limit energy consumption

- **We spend 90% of our time in closed places**
- **12 million French people suffer from respiratory allergies**
- **Indoor air is 10 times more polluted than outside air***
- **We breathe 12000 liters of air a day**

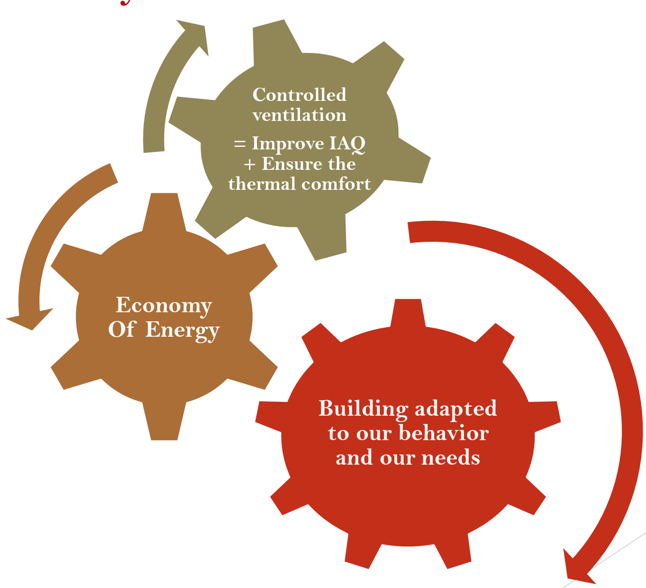
**World Health Organization (WHO)*

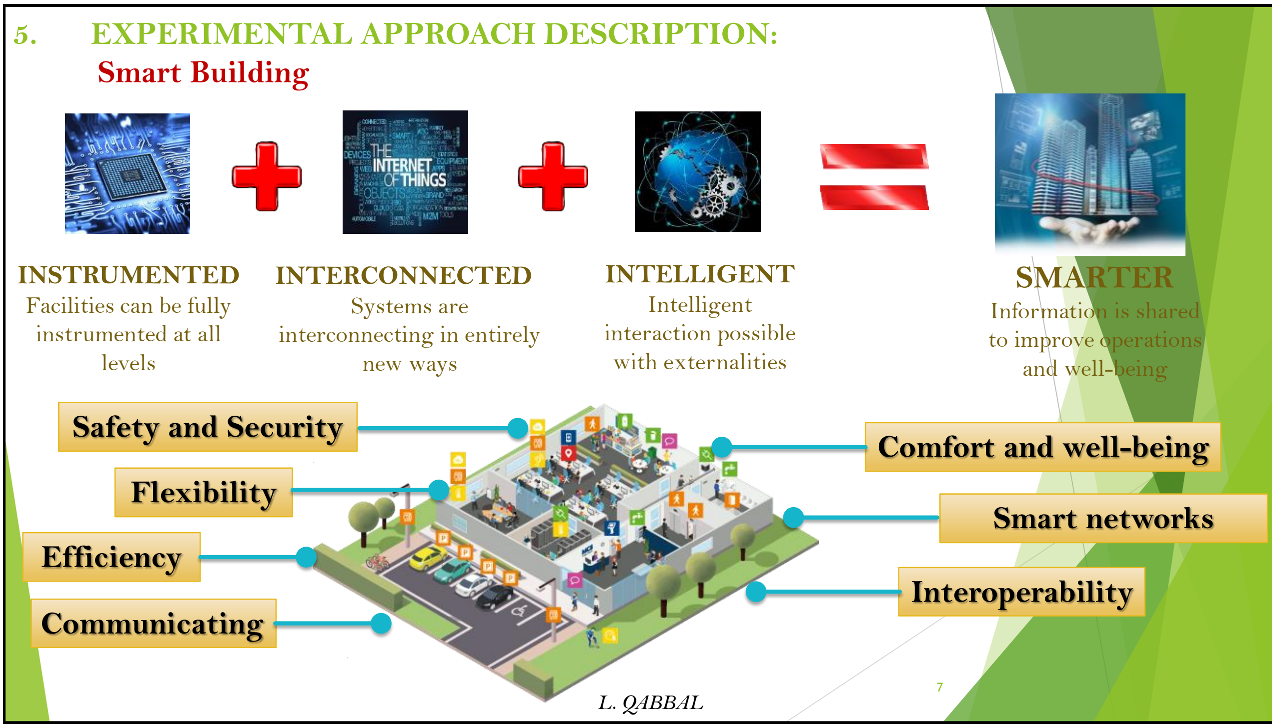
3. INDOOR AIR POLLUTANTS AND THE PROBLEMS OF POOR IAQ (Indoor Air Quality)

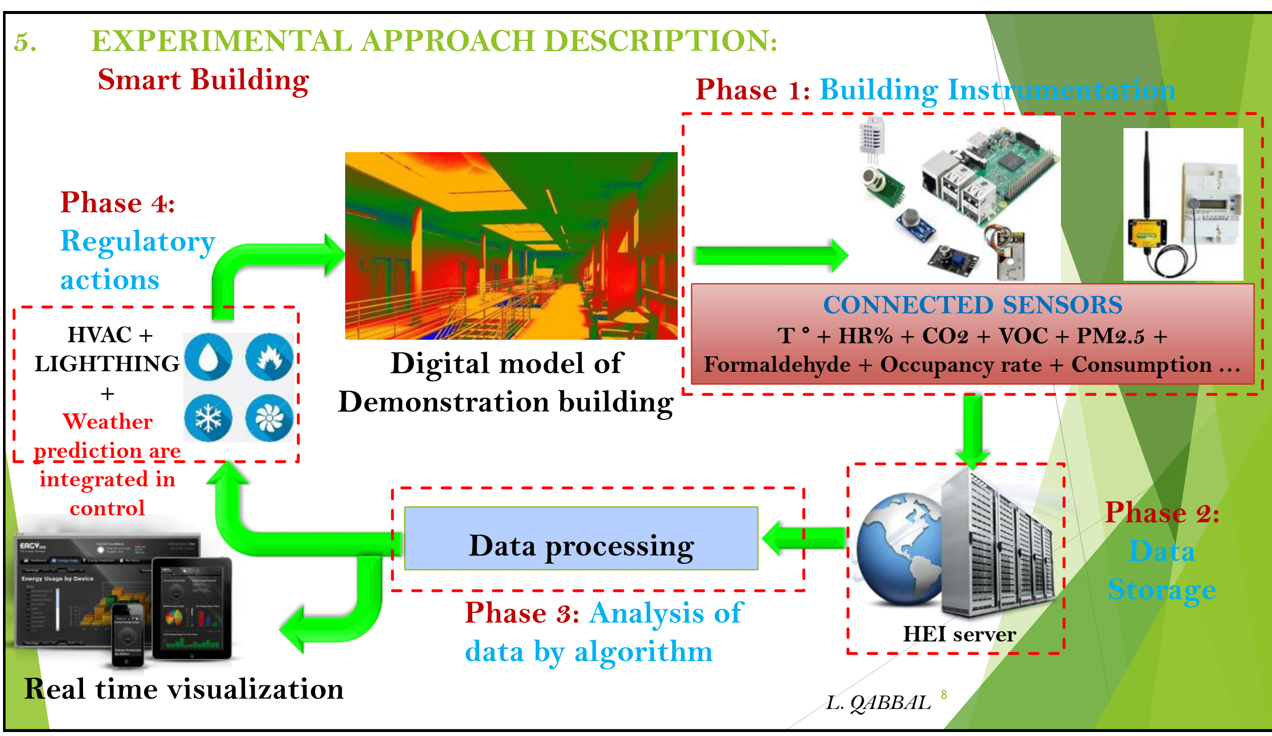


4. SYNTHESIS AND OBJECTIVES OF THE STUDY:

Multicriteria study



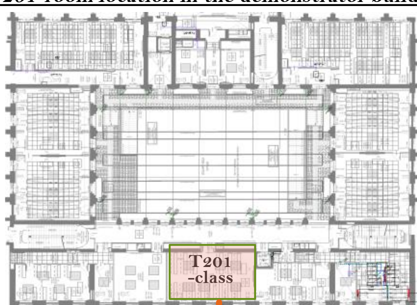

5. EXPERIMENTAL APPROACH DESCRIPTION:
Smart Building
INSTRUMENTED
Facilities can be fully instrumented at all levels
INTERCONNECTED
Systems are interconnecting in entirely new ways
INTELLIGENT
Intelligent interaction possible with externalities
SMARTER
Information is shared to improve operations and well-being
Safety and Security
Flexibility
Efficiency
Communicating
Comfort and well-being
Smart networks
Interoperability
L. QABBAL
7

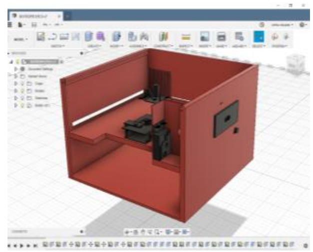

5. EXPERIMENTAL APPROACH DESCRIPTION:
Smart Building
Phase 1: Building Instrumentation
CONNECTED SENSORS
T ° + HR% + CO2 + VOC + PM2.5 +
Formaldehyde + Occupancy rate + Consumption …
Phase 4:
Regulatory actions
HVAC + LIGHTHING + Weather prediction are integrated in control
Digital model of Demonstration building
Phase 2: Data Storage
HEI server
Data processing
Phase 3: Analysis of data by algorithm
Real time visualization
L. QABBAL
8

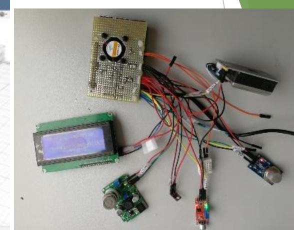
5. EXPERIMENTAL APPROACH DESCRIPTION:

Case study « T201-Classroom » and connected sensors

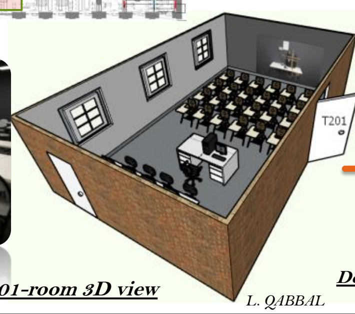
T201-room location in the demonstrator building



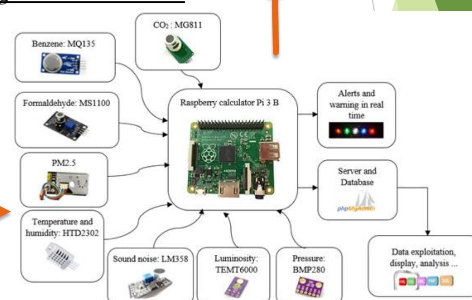




Design of the smart sensor



T201-room 3D view



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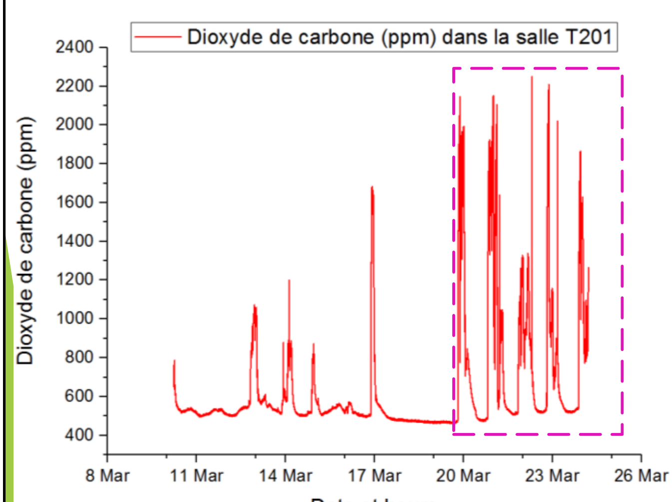
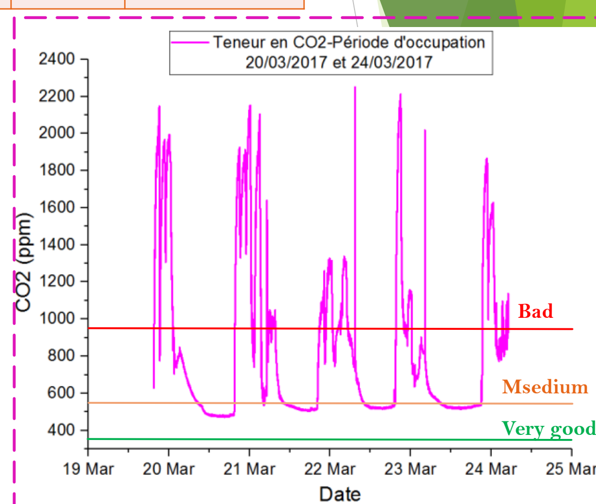
Development of the smart IAQ sensor and comfort parameters (CO_2, VOCs, CO, Formaldehyde, Benzene, PM2.5, humidity, temperature, etc...)

6. RESULTS : IAQ ASSESSMENT AND COMFORT PARAMETERS: CO_2 concentrations

Compound	Unit	Average	Minimum	Maximum	Limit value
CO_2	ppm	639	461	2250	1000





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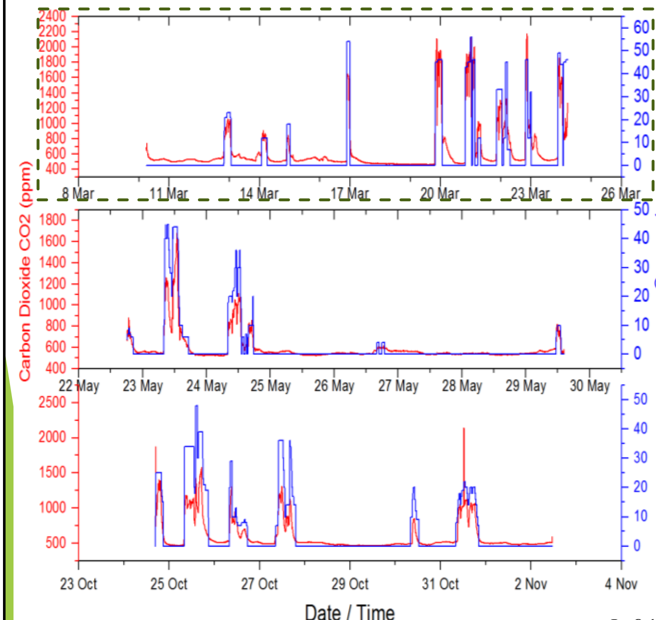
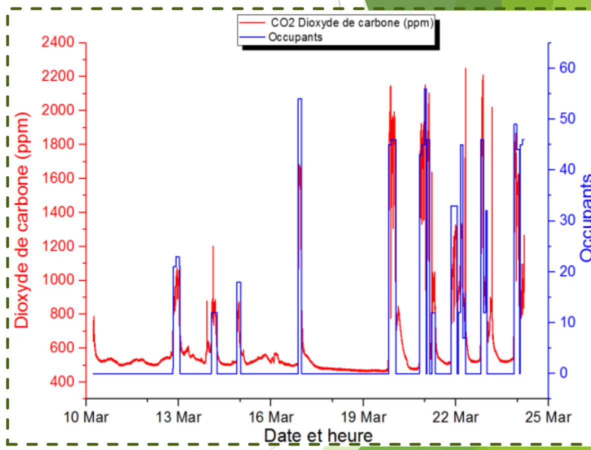
6. RESULTS : IAQ ASSESSMENT AND COMFORT PARAMETERS: CO2 concentrations and human occupation





Zoom on the CO2 measurements and occupants during the first measurement campaign

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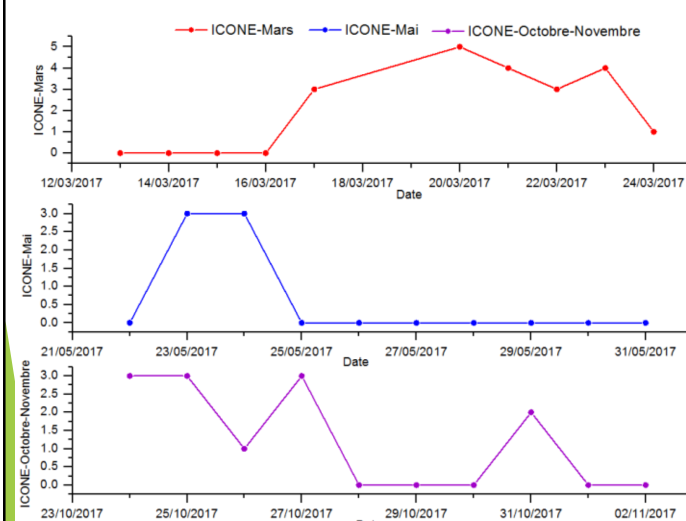
6. RESULTS : IAQ ASSESSMENT AND COMFORT PARAMETERS: Calculation of the ICON air containment index



Values of the ICONE index and nature of confinement

Value of the ICONE index	Selected value of the ICONE index	Nature of confinement
ICONE < 0.5	0	Null
0.5 ≤ ICONE < 1.5	1	Low
1.5 ≤ ICONE < 2.5	2	Way
2.5 ≤ ICONE < 3.5	3	High
3.5 ≤ ICONE < 4.5	4	Very high
ICONE ≥ 4.5	5	Extreme

The ICONE index is calculated according to the following formula

$$ICONE = \left(\frac{2.5}{\log_{10}(2)}\right)\log_{10}(1 + f_1 + f_2)$$

f_1 is the proportion of values between 10^3 and $1.7*10^3$ ppm $\left(f_1 = n_1 / (\sum_{i=0}^{2} n_i)\right)$ and f_2 is the proportion of values greater than $1.7*10^3$ ppm $\left(f_2 = n_2 / (\sum_{i=0}^{2} n_i)\right)$ avec

Coefficient n_i of the ICONE index (with i = 0; 1; 2)

n_0	Between 0 and 10^3 ppm
n_1	Between 10^3 and $1.7*10^3$ ppm
n_2	Greater than $1.7*10^3$ ppm

- ICONE is weak when the room is less busy.

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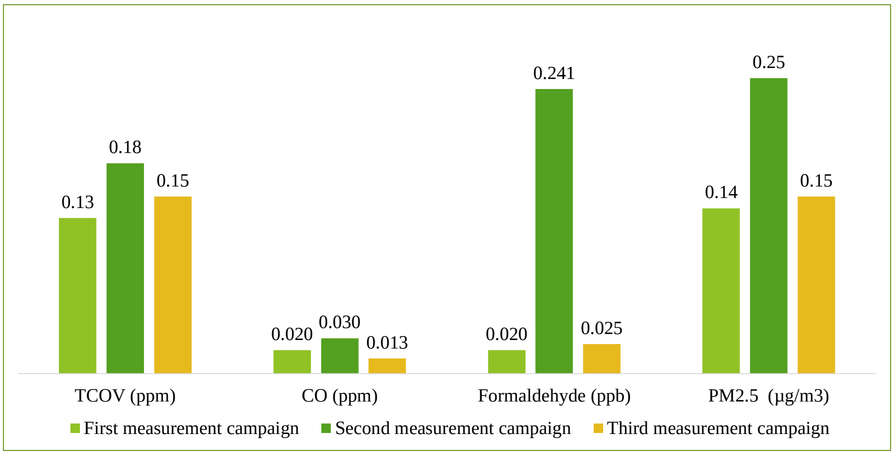
6. RESULTS : IAQ ASSESSMENT AND COMFORT PARAMETERS: Average values



Average values of IAQ in T201-room

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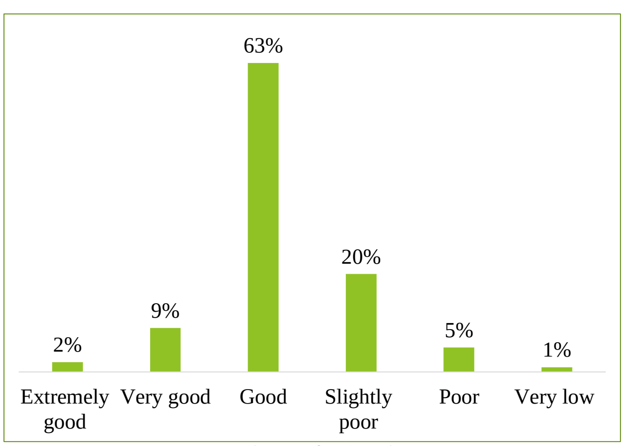
6. RESULTS : IAQ ASSESSMENT AND COMFORT PARAMETERS: Survey questionnaire of occupant perception



Occupant perception of IAQ in T201-room

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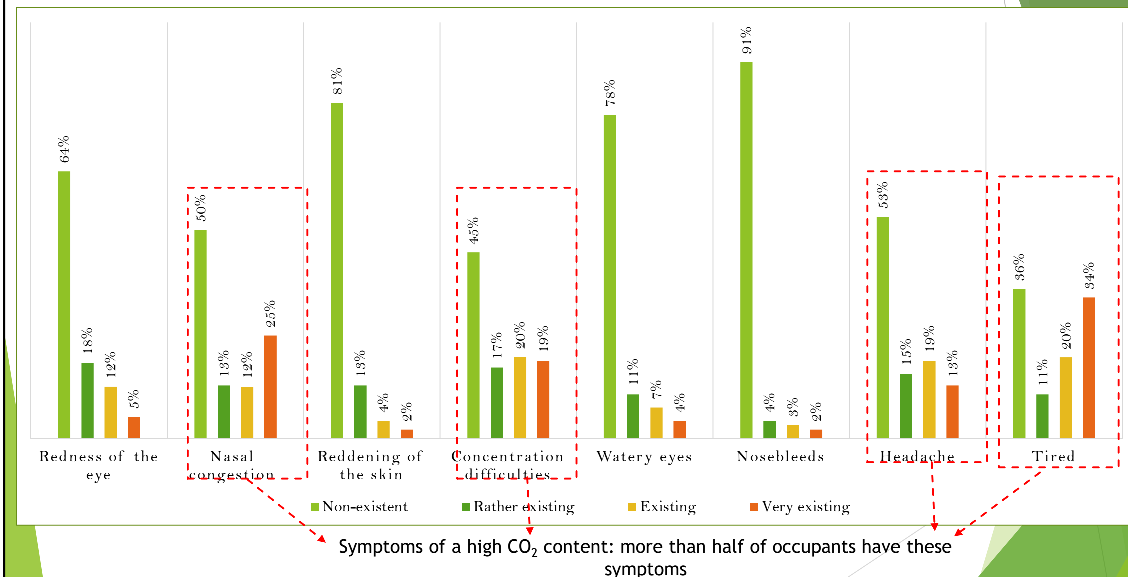
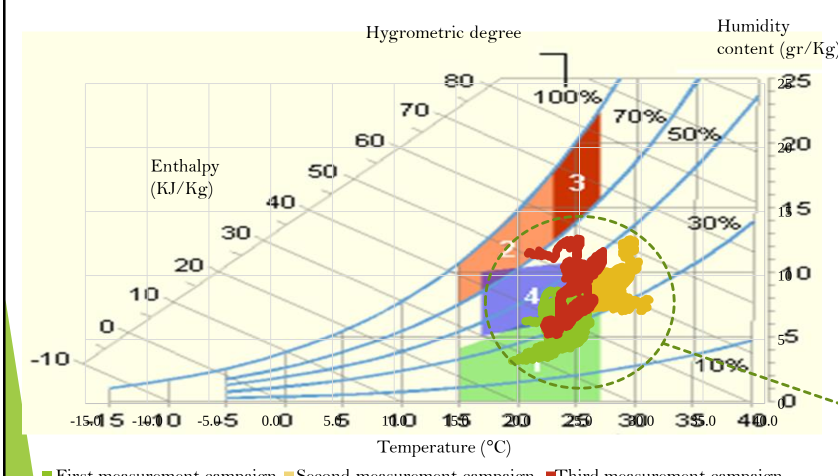
6. RESULTS : IAQ ASSESSMENT AND COMFORT PARAMETERS: Survey questionnaire of symptoms of poor IAQ



Distribution of responses based on symptoms of poor IAQ

6. RESULTS : IAQ ASSESSMENT AND COMFORT PARAMETERS: Hygrothermal comfort zone during the three campaigns of measures



1. Avoid area with regard to drought problems.
2. and 3: Areas to avoid in the development of bacteria and micro-fungi.
3. Zone to avoid vis-à-vis the development of mites.
4. Hygrothermal comfort polygon.

Comfort zone in T201 during the three campaigns:

- More than 80% of the points are located in the 1/3 zone 4 (hygrothermal comfort zone)
- Less than 20% of the points are located in comfort zone 1 (dry zone)

Comfort zone location in the T201-class (March 2017)

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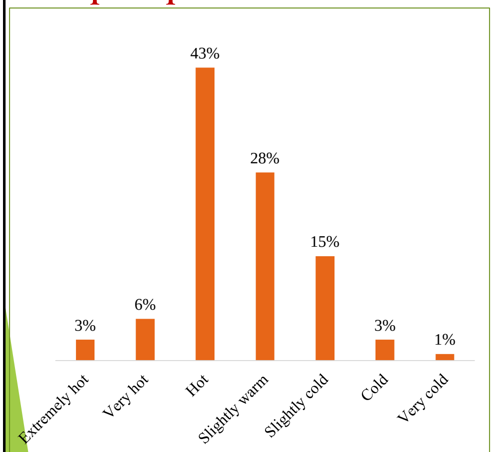
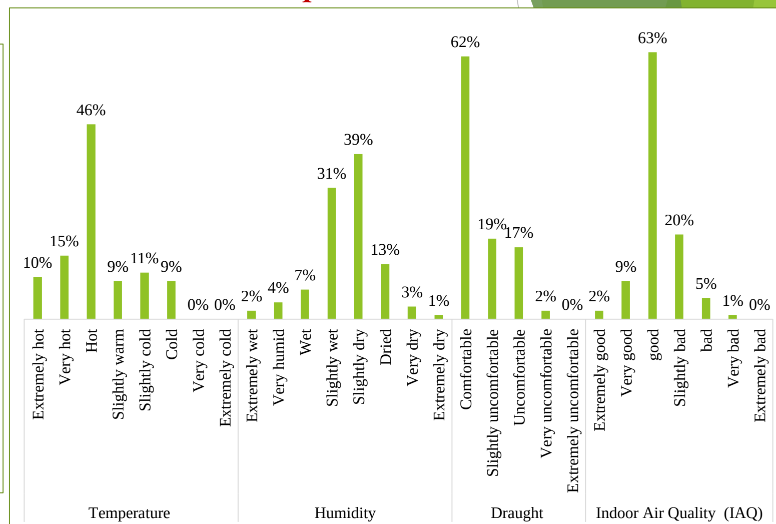
6. RESULTS : IAQ ASSESSMENT AND COMFORT PARAMETERS: Survey questionnaire of the occupants perception



Occupants perception of indoor temperature - March 2017



Occupants perception of IAQ and comfort- March 2017

Conclusion

- This study focuses on indoor air quality (IAQ) measurements and comfort parameters in a demonstrator building.
- The high CO_2-concentrations measured show that the current ventilation system is not adapted to the occupants needs
- A solution based on the development of an **intelligent sensor** that measures indoor air pollutants and comfort parameters in real time. Based on these measurements, the information is sent to the building managers
- The ultimate goal is: **Deployment** of a hundred smart sensors in the demonstrator building **to map the quality of indoor environments** to identify the most polluted parts. Subsequently, the stored measurements are analysed by algorithms and control actions are sent to the ventilation system to adjust the airflow to the actual needs dynamically.
- In this way, energy consumption is better controlled and comfort conditions are ensured.

Thank you for your attention !

Questions ?

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Dr. HDR. Zohir YOUNSI: zohir.younsi@yncrea.fr

Prf. Hassane Naji: hassane.naji@univ-artois.fr

Low-cost versatile sensor data platform

for monitoring and analysis of building services

39th AIVC – 7th Tightvent – 5th venticool Conference 18-19 Sept 2018
Antibes Juan-Les-Pins

Christian A. Hviid[1], Kevin Smith[1], Anders Struck[2]
[1]Dept. of Civil Engineering
[2]Dept. of Electrical Engineering
Technical University of Denmark
cah@byg.dtu.dk

Background

- Malfunctioning HVAC systems are expensive. Kim & Katipamula (2017) estimated in the USA, that 30% of energy consumption is due to inadequate monitoring and control
- The consequences are:
  - occupant complaints, discomfort and reduced productivity
  - reduced tenant retention and reduced asset value of the building

- It is unlikely that the building automation system is gathering the necessary forensic data to diagnose problems

- Wireless Sensor Networks (WSN's) that operate in parallel or integrate with building automation systems can make high-resolution temporal and spatial data abundantly available

- However, state-of -the-art platforms suffer from different weaknesses like:
  - too short range, limited sensors available, fixed sampling rate, proprietary protocols, requires power outlets, comes with excessive computing power,costly backend solutions and recurring fees

Objective

- Is it possible to create a generic battery-powered sensor platform that can measure different building related quantities, transmit data, store data, create metrics and display them at a minimum cost and with full control of the user?

- Development criterias
  - Measure different building related values accurately, i.e. use sensor data like temperature, relative humidity, luminosity, CO2, reed switches, 3D-axis magnetometers
  - Long-range data transmission in the signal-hostile built environment
  - Effective time-series data storage
  - Metrics easy to create and display
  - Several years of power on ordinary batteries
  - Minimal costs

Wirelessness in professional HVAC

- Libelium, ES
  - Generic and very versatile platform. Mature hardware
  - Expensive hardware at 230 euro per node
  - No HVAC competences. Data platform not in focus

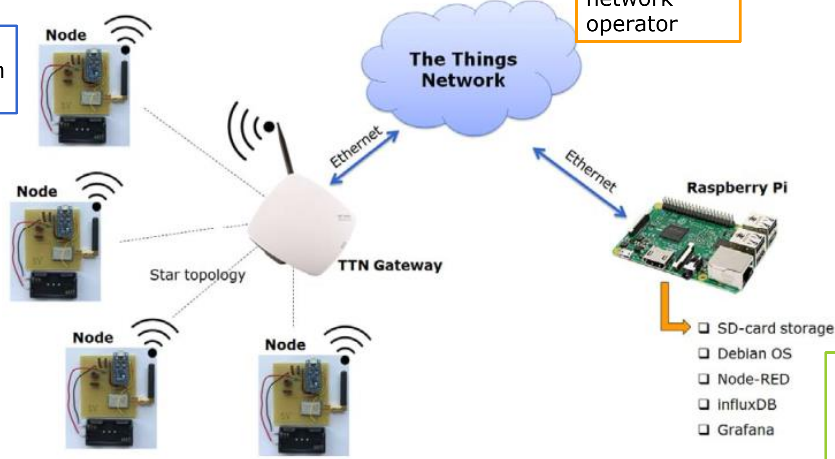
- Swegon WISE, SE
  - Mature wireless HVAC control and monitoring platform
  - Proprietary, only Swegon products

- Develco, DK
  - Strong focus on HW
  - No specific competences in HVAC
  - Development kit start fee 4000 euro

Platform schematic

Sensor nodes based on open source

Community-driven network operator



Digital sensors calibrated from factory

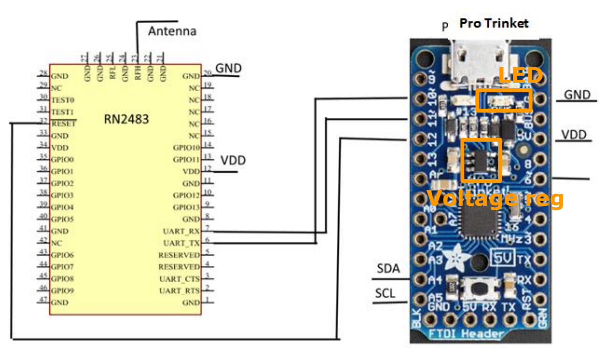
Open source software versions for storage and visualization

Sensor node

- Mini Arduino clone board optimized for size and computing power (70% of memory used)
- Removal of voltage regulator (5V->3.3 V) and LED-lights
- Now powered by only 2xAA batteries
- Lora-communication chip from Microchip RN2483 with external antenna
  - 868 Mhz transmission reaches much further than Wifi/Bluetooth at 2.4 Ghz

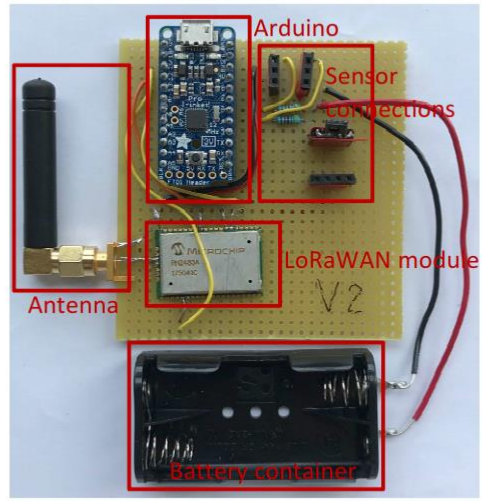
LoraWAN module

Mini Arduino clone



Sensor node

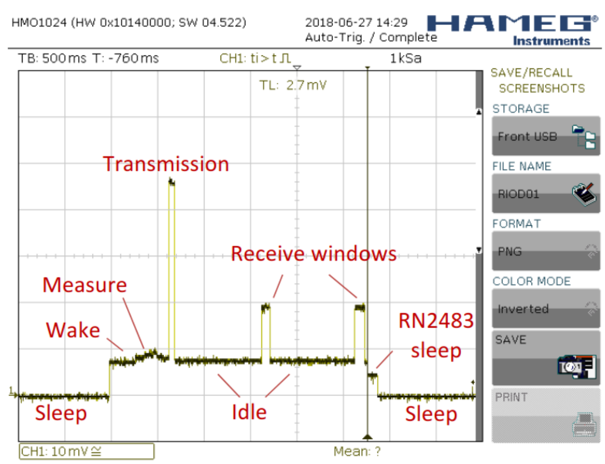
- Focus on digital sensors that come calibrated from factory
- Simple software written in Arduino Integrated Development Environment (IDE)
  - sets the sample rate and the determines the payload format
  - cycles through sensor ports upon startup to discover the connected sensor types
  - includes deviceID, sensor readings and battery voltage in the payload 'package'



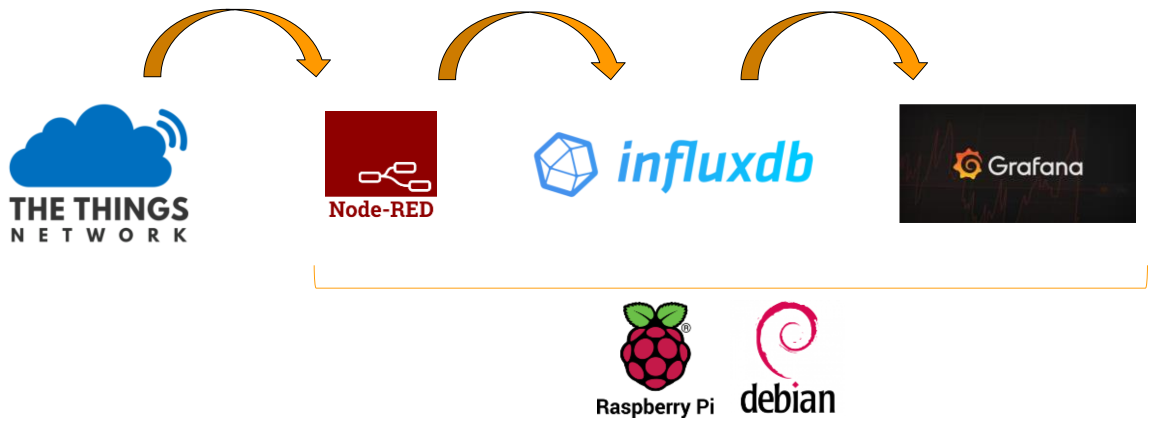
Battery life

- Estimated from two AA 1500 mAh alkaline batteries
- Battery life on sample rate 10 min: 3.7y

Sample rate	1min	10 min
Awake average	9.2 mA	9.2 mA
Total average	421 µA	45 µA
Battery life	148 days	1367 days



Data management



The Things Network

- Community-driven LoraWAN network operator. Free to use

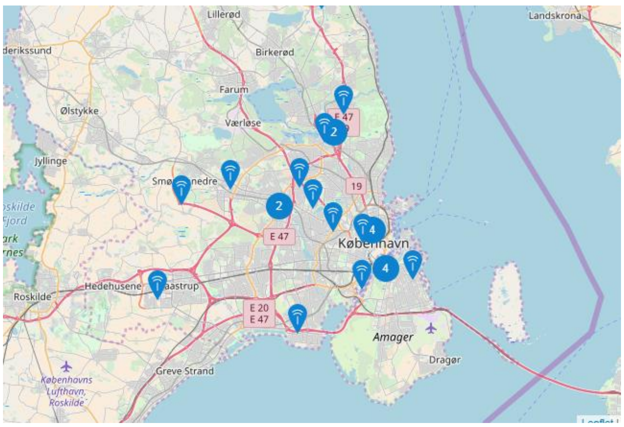
- Pools user gateways into data network that intercepts any Lora sensor data in the vicinity
- TTN servers provide backend, and relays data to the recipient. Employs AES128 encryption
- Data is never stored, only transported

- Limited by 'Fair usage' policy
  - High range, large payload (several sensor readings) and high sampling rate (<1 min) will violate the policy

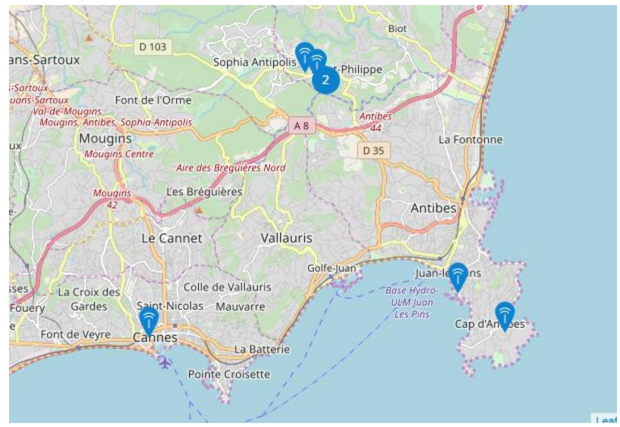
- Other commercial operators
  - Loriot.io
  - Teracom (in DK)
  - Sigfox (different protocol and business model)

The Things Network coverage

Copenhagen



Antibes



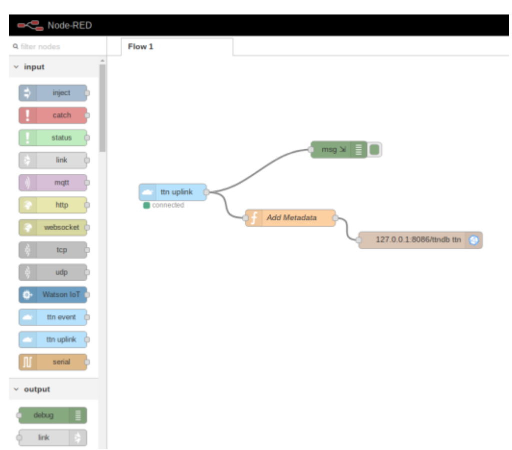
NodeRED & influxDB

- Programming tool for wiring data flows
- Open source

- Used to create link from TTN to influxDB

- Splits payload and adds meta-data before storage in influxDB
- Basic meta-data function: extract deviceID from payload, append and store values in influxDB under each deviceID

- Influx is open source database optimised for time-series data (as opposed to MySQL)
- Scalable, ready for large influx of data



Grafana

- Time series analytics
- Open source

- Appealing graphics
- Different metrics and KPI's can be created and monitored

- Integrates well with influxDB, just locate deviceID, then time-series and plot

- Customizable dashboard, drag'n'drop, zoom-in

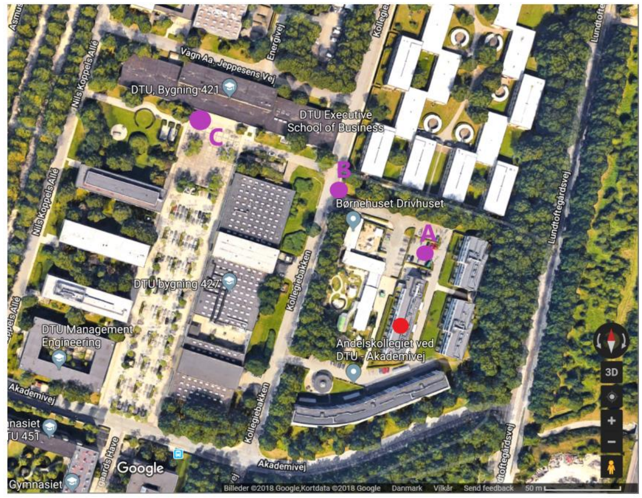
- Alerts and KPI's can be created

Costs

Component	Approx. price ex VAT (Euro)
Arduino	10
Radio chip	13
Antenna	7
Battery container	1
Temp + RH sensor	10
Node container	5
Sum Per Node	46
Raspberry Pi	35
SD-card 16 GB	14
RP container	6
Gateway (TTN)	300
Software	Open source

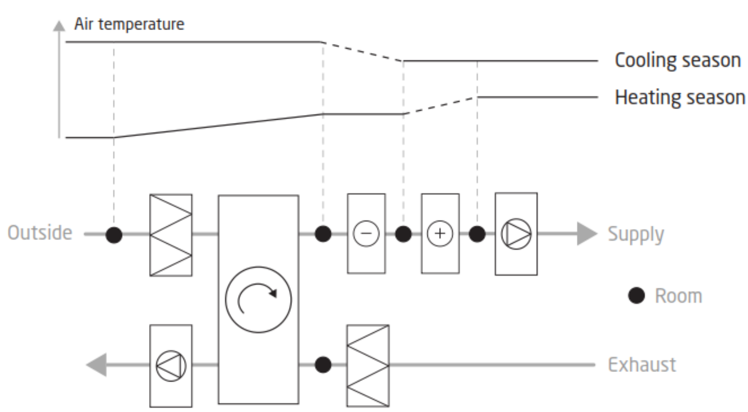
Range

- At maximum data transmission rate, i.e. shortest range
- Messages received:
  - Point A: all
  - Point B: some
  - Point C: none
- Distance to A: 50 m, approx. 8 concrete walls
- Antenna design and power should be optimized



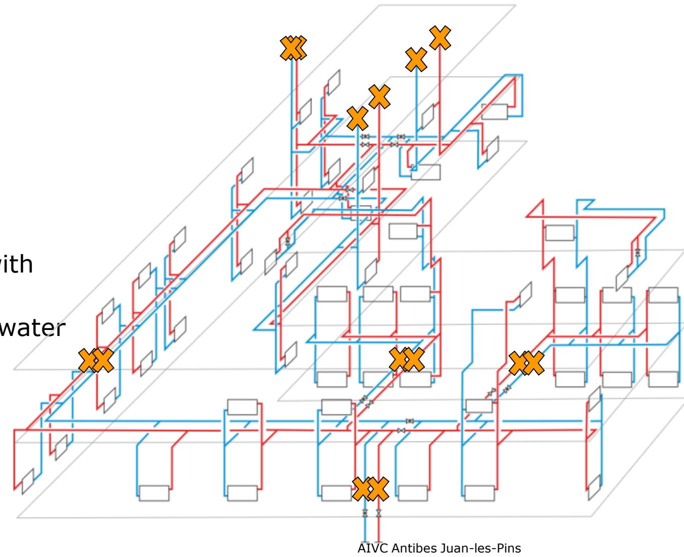
Envisioned deployment – AHU temperature measurements

- Diagnostics: operation and performance of fans, heat exchanger and h/c coils can be compared to expected performance and schedule



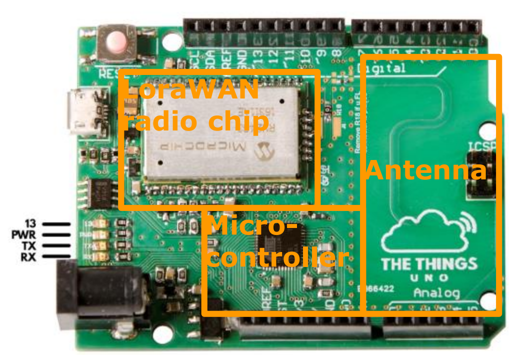
Envisioned deployment – heating/cooling system monitoring

- Fault diagnostics
- Monitoring supply and return temperature to disclose:
  - short-circuits
  - malfunctioning thermostats
  - under-dimensioned radiators with high mass flow
  - inadequate cooling of radiator water



Future developments

- Optimize data transmission rate vs. range
- Mount 2-5 sensors on one cord to one node
- Replace Raspberry Pi with Microsoft Azure or Amazon Web services and run influx/Grafana directly in cloud. Recurring fees will emerge but stability will increase
- Merge Arduino microcontroller, Lora chip and optimized antenna design into one printed circuit board like The Things Uno (which has too much computing power and requires power outlet)



Conclusion

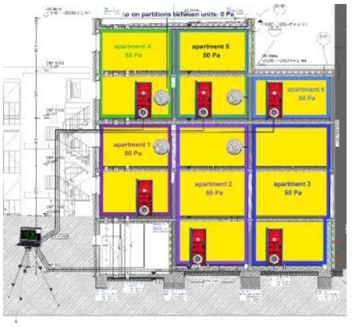
- For researchers (and facility managers) we have presented:

- Versatile nodes
  - a low-cost node that will accept many different sensors and probes
  - battery life of several years on ordinary AA alkaline batteries
  - all settings user customizable in node software

- Low-cost data management platform
  - free network operator
  - specialized time-series database
  - customizable dashboards and metrics

- Examples of deployment

INDIVIDUAL UNIT AND GUARD-ZONE AIR TIGHTNESS TESTS OF APARTMENT BUILDINGS

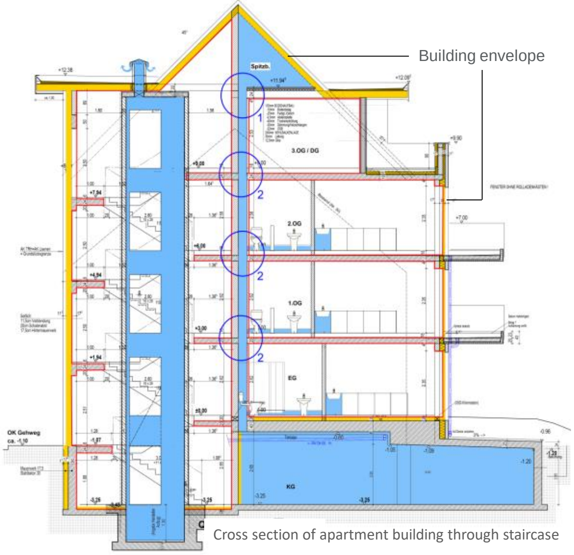


Angela Rohr, Andreas Holtgrave Stefanie Rolfsmeier and Oliver Solcher

with Tom Böttler, Till de Buhr, Siebelt Davids, Jan-Niklas Menke, Tobias Petzold, Christian Scholz and Svenja Wiemers

AIVC-Conference 19. September 2018

INTERNAL LEAKAGES



Cross section of apartment building through staircase

1 **Leakage to outside**
seal to avoid loss of heat and drafts

2 **Leakage to adjacent heated space**
seal to avoid odor, smoke or sound transmission

Airtight layer

Insulation

internal spaces connecting to outside, when leakages are sealed insufficiently

INTERNAL LEAKAGES - ISSUES

- Fire Protection
- Odor Transmission
- Sound Transmission
- Rodents, vermin, pests

Fig. 4: internal leakages – issues, AR

GERMAN LEGAL REQUIREMENTS AIRTIGHTNESS FOR NEW AND FULLY RENOVATED BUILDINGS

EnEV 2014 German Energy Savings Regulation

air change rate based on the **net volume** of the building
$n_{50} \leq$ **1.5 (1/h)** for buildings with **mechanical ventilation systems**
$n_{50} \leq$ **3.0 (1/h)** for all other buildings

buildings with a **net volume** of all heated or cooled areas beyond **1 500 m³**:

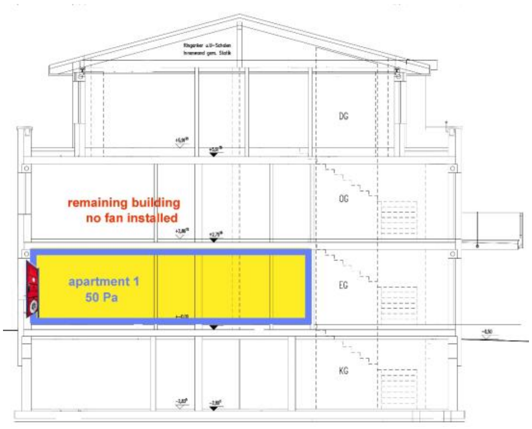
flow rate based on the **building envelope**
$q_{50} \leq$ **2,5 m³/(m²h)** for buildings with **mechanical ventilation systems**
$q_{50} \leq$ **4,5 m³/(m²h)** for all other buildings

- regulations apply to entire buildings or parts of buildings
- There are **no** building regulations for single unit compartmentalization tests or for guard zone tests - only recommendations by FLiB

source: EnEV

SINGLE UNIT COMPARTMENTALIZATION TESTS: PRINCIPAL SETUP

Single unit compartmentalization test per unit



- Airtightness tests unit by unit with no pressure in adjacent units
- Use of a single fan
- Internal leakages to adjacent units are included in the measured flow rate

Fig. 5: principal setup guard-zone test, AR

GUARD ZONE TEST: PRINCIPAL SETUP FOUR BUILDINGS AT OSNABRÜCK

Guard zone test using two Blower Doors

- Airtightness tests unit by unit building up equal pressure in adjacent units
- Border between units: zero pressure difference
- No air passing through leaks in internal partitions
- Only external leakages are recorded
- Use of at least two fans
- more extensive measurement technology, relatively simple setup
- **Limits of the method**
  - Large internal leakages
  - Strong wind

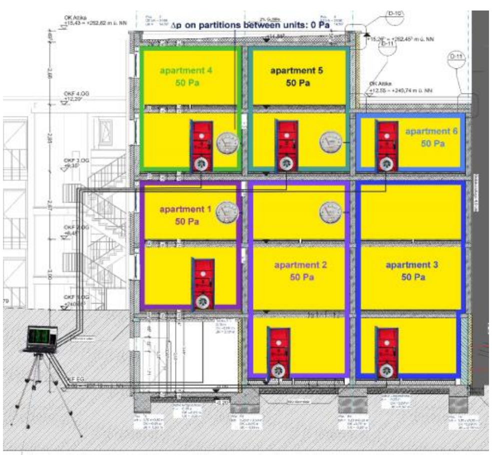
Fig. 6: principal setup guard-zone test, AR

FOUR BUILDINGS AT OSNABRÜCK

Fig. 8: buildings at Borsigstr. AR / AKH

GUARD-ZONE TEST: PRINCIPAL SETUP WITHOUT CENTRAL STAIRCASE. TWO BUILDINGS AT ISERLOHN

Guard-zone test using six blower doors



- six units / six units + one communal space without central staircase – access to units via access galleries
- Use of six fans simultaneously
- Use of extensive measurement technology
- Relatively simple setup, without internal staircase
- No doors between units - the natural pressure difference on internal partitions between units was recorded using capillary tubes inserted into adjacent windows.

Fig. 9: guard-zone test-setup Kluse: AR

TWO BUILDINGS AT ISERLOHN

Fig. 10: buildings at Kluse AR / AKH

GUARD-ZONE TEST:
SETUP IN TWO BUILDINGS AT ISERLOHN

Guard-zone test using eight blower doors

- eleven units
- four units without direct access to the stairwell
- Exceeding the limits of available equipment: the stairwell + four units have to share a fan
- Use of eight fans
- The pressure difference between units can be recorded on some doors to the staircase

Fig. 11: guard-zone test setup Rahmenstraße AR

TWO BUILDINGS AT ISERLOHN

Fig. 12: buildings at Rahmenstr. AR / AKH

PRACTICE: MEASURING EQUIPMENT

Fig. 13a: measuring equipment TdB

PRACTICE: WORKING CLIMATE

Fig. 14: working climate AR/AKH/SR/SD/CS

TECLOG 3 DATA LOGGER
GUARD-ZONE TEST WITH EIGHT FANS

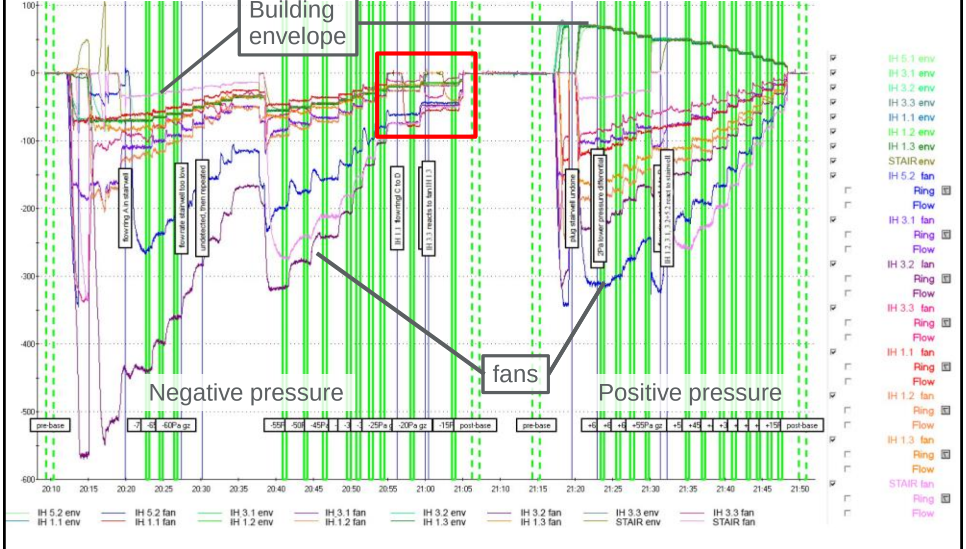


Fig. 20b: guard-zone test Rahmenstraße AR / AKH

TECLOG 3 DATA LOGGER
PROOF OF INTERNAL LEAKAGES BETWEEN APARTMENTS

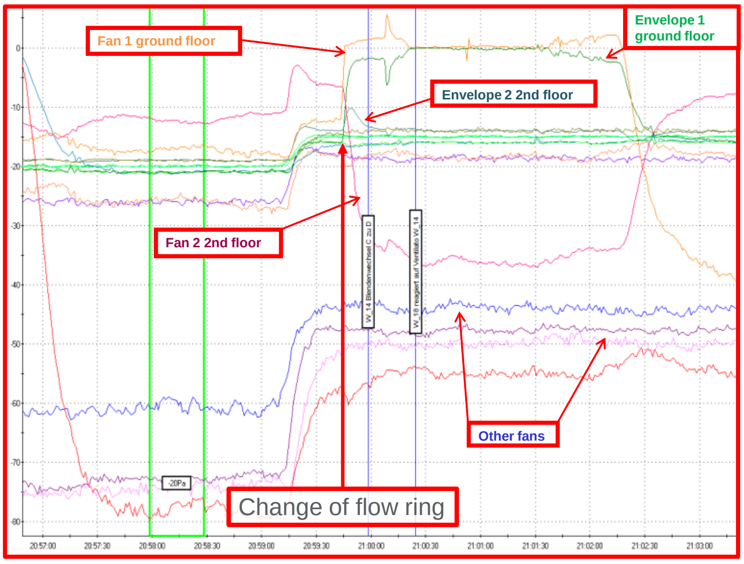


Fig. 21: guard-zone test Rahmenstraße AR / AKH

PRACTICE: TYPICAL LEAKS BETWEEN APARTMENTS

- Major internal leaks: distribution boxes for electric services and water in apartments above each other
- Mechanical ventilation systems

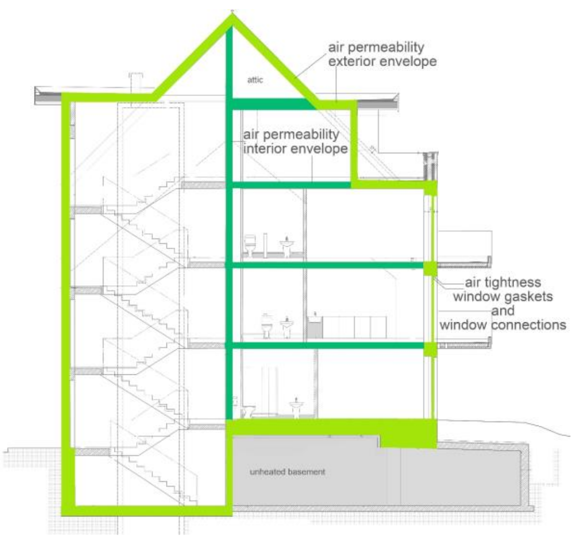


Fig. 19: leaks between apartments AR/AKH

GUARD-ZONE TEST AIRFLOW RATE n_{50} BUILDINGS OB / IG

	Building OB	Building IG
Weighted mean all apartments (without stairwell) **guard-zone test**	n_{50} = 0,64 1/h	n_{50} = 0,76 1/h
Weighted mean all apartments **compartmentalization tests**	n_{50} = 0,87 1/h	n_{50} = 1,10 1/h
Internal leakages:	**27%**	**32%**

MODEL DISTRIBUTION OF AIR FLOW

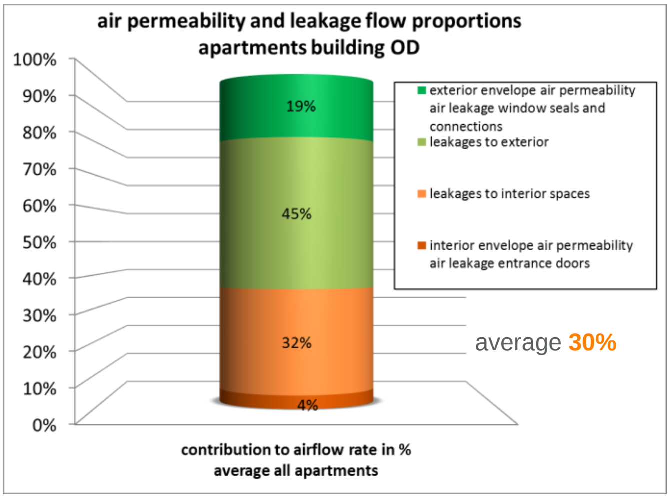


- the volume flow measured in a blower door test consists not only of a **leakage flow** but also of the air flow due to the **air permeability** of the building

Model defining

- air permeability of exterior envelope and interior partitions
- max. air leakage of window gaskets and window connections according to German regulations

MODEL DISTRIBUTION OF AIR FLOW FOR BUILDING OD



Building	q_{50} / n_{50}
OD	1,14 / **0,49**
IG	1,50 / **0,75**

- stairwells are disregarded
- Area-based weighted mean values

CONCLUSIONS AND PERSPECTIVE

- Internal leakages **are** relevant
- The average proportion of internal leakages approximates **30%**
- Internal leakages may impair the **fitness for use** as an apartment building

- We intend evaluation of this work in context with the findings of the FLiB research report „Evaluation of Flaws in Air Tightness Layers "
- Verification of air permeability values of building components by A-value-testing
- Detailed examination of internal leakages i.e. interdependent flow rates of adjacent units
- Detailed data analysis using statistical methods
- Recently published article in the American Journal of Building Physics

Thank you for listening

Angela Rohr AIVC-Conference 2018

19th of September 2018

University of Nottingham
UK | CHINA | MALAYSIA

AIVC 2018

An extended pressure range comparison of the blower door and novel pulse method for measuring the airtightness of two outdoor chambers with different levels of airtightness

Chris Wood

University of Nottingham
UK | CHINA | MALAYSIA

Background to Pulse / Introduction

Testing Methodology

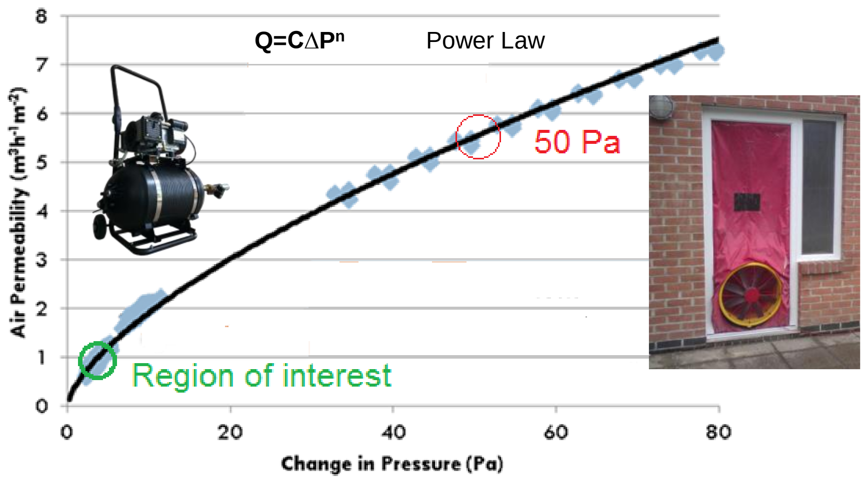
Equipment and setup

Test results

Conclusions

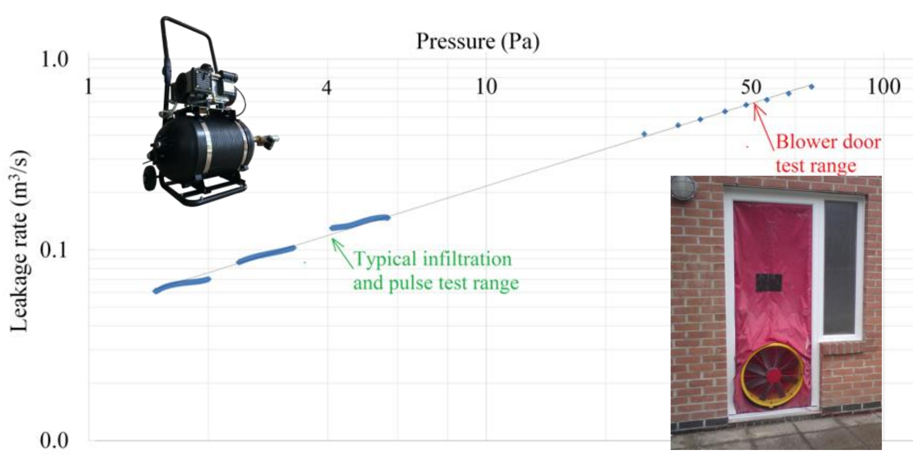
Buildings, Energy and Environment Research Group
Faculty of Engineering
University of Nottingham, United Kingdom

Introduction



BUILD TEST SOLUTIONS EPSRC Engineering and Physical Sciences Research Council Innovate UK Technology Strategy Board BUILT2SPEC Tools for the 21st Century Construction Worksite University of Nottingham UK | CHINA | MALAYSIA

Introduction



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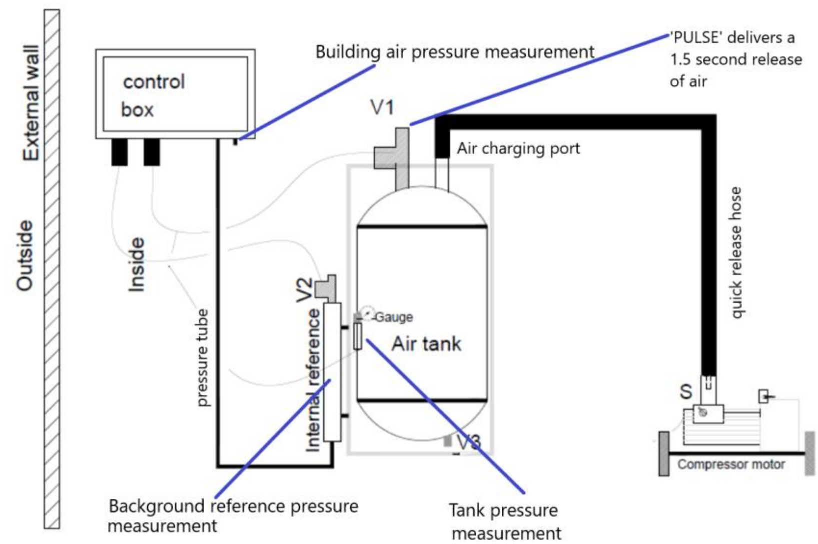
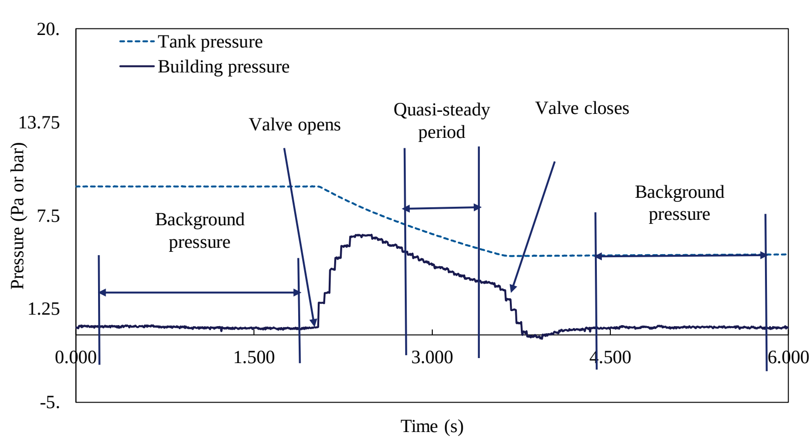
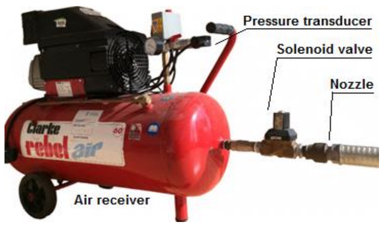
Principle



Principle



Pulse unit development



Test chamber

Pod	2: Passivhaus	1: Standard
Volume (m^3)	22	21
Envelope area (m^2)	48	47
Approximate ACH @50Pa	1.65	6

Equipment

BD-4

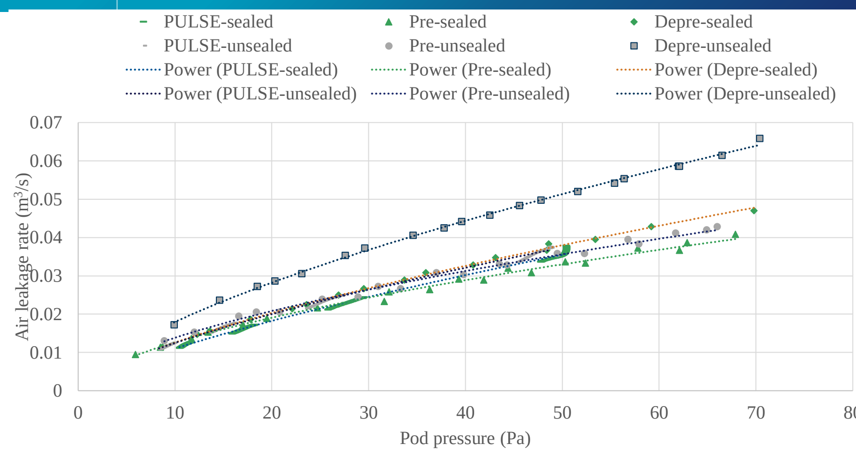
PULSE-20

Testing scenarios

Unsealed

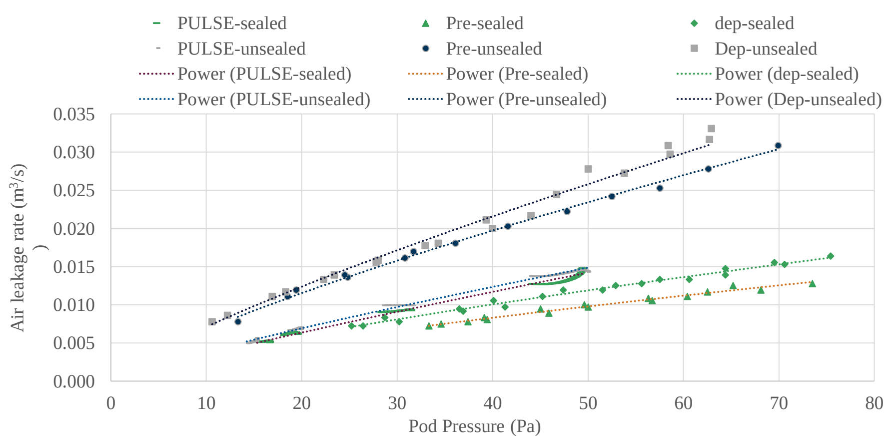
Sealed

Results-Standard



Pod 1 (standard)	BD-4 against PULSE-20				Impact of sealing on the leakage		
	Pressure (Pa)	10	50		Pressure (Pa)	10	50
Sealed	Pre	13.2%	-8.0%		PULSE-20	-10.4%	-3.4%
	Depre	12.6%	5.4%		BD-4-Pre	-8.9%	-7.4%
Unsealed	Pre	11.5%	-4.1%		BD-4-Depre	-29.9%	-26.0%
	Depre	44.1%	37.6%				

Results-Passive



Pod 2 (passive)	BD-4 against PULSE-20				Impact of sealing on the leakage		
	Pressure (Pa)	15	50		Pressure (Pa)	15	50
Sealed	Pre	-31.7%	-42.4%		PULSE-20	-6.4%	-1.4%
	Depre	-15.1%	-27.2%		BD-4-Pre	-58.8%	-60.5%
Unsealed	Pre	55.1%	44.0%		BD-4-Depre	-52.5%	-55.3%
	Depre	67.3%	60.7%				

Results-Passive

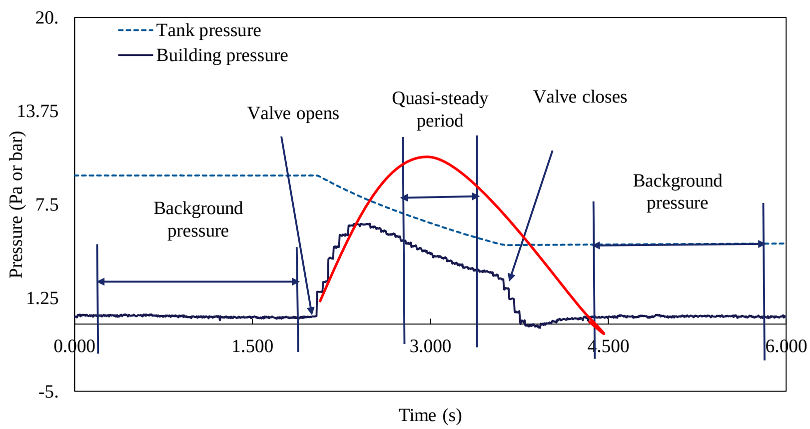


Illustration only – not real data

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Conclusions

- The gaps between the blower door and door frame: significant proportion of the overall air leakage for the pod tests. (up to 30% for Pod 1 and up to 60% for Pod 2). Hence, need for sealing for comparative tests.
- For door sealed tests Pod 1 (typical UK new build airtightness) shown good agreement for pulse vs blower methods, circa <13% across the range.
- For door sealed tests Pod 2 (towards Passivhaus airtightness) gave less agreement than in Pod 1; circa <42% maximum. (but much better than the scenario where the door frames were unsealed.)
- New observation: Pulse created in Pod 2 unlike that seen in average dwellings. (Line gradients non-typical)
- New observation: In highly airtight pod the pressure pulse takes longer time period to reach peak. Set valve opening times mean range of data for analysis is closer to the peak. i.e. the elevated pressure persisted for a prolonged period following the cessation of air from the pulse unit.
- Further testing required to investigate behaviour of pulse in highly airtight environments.

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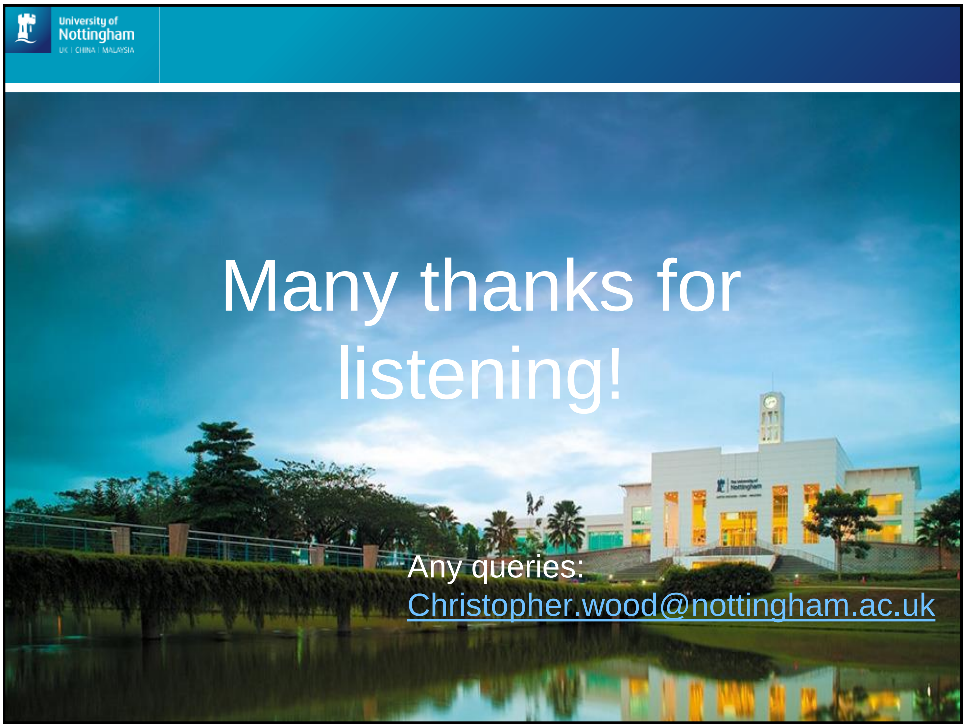
University of Nottingham
UK | CHINA | MALAYSIA
Many thanks for listening!
Any queries:
Christopher.wood@nottingham.ac.uk

Non-intrusive experimental assessment of air renovations in buildings and comparison to tracer gas measurements

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GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Motivation

- The building sector has significant potential to save energy and reduce CO_2 emissions.
- Implementation of related regulations, highlighting the need to increase knowledge about energy performance of buildings and pushing research activities in this field.
- Most compliance checks and labelling of the energy performances of buildings are based on theoretical calculations and design values.
- Performance of a building may deviate significantly from this theoretical performance.
- **Intense research activity to address this performance gap** (ej.: IEA-EBC Annex 71, etc)
- The **building envelope** is one of the key elements influencing the energy behavior of buildings.
- Procedures for energy performance assessment from in-situ tests are based on the **dynamic energy balance** of the volume confined by the building envelope.

Motivation

- Procedures for energy performance assessment from in-situ tests are based on the **dynamic energy balance** of the volume confined by the building envelope.
  - One of the contributions to this dynamic energy balance is which is due to the air renovation either by natural or mechanical ventilation.
- Thermal performance indicators of the building envelope are obtained from data series (ej.: **sampling frequency** 10 minutes, and **no pressurisation**).
  - PROBLEM: Air renovation rate can't be considered a constant parameter in these approaches
- Well known procedures for the experimental assessment the air renovation rate in rooms are available
  - Don't fit the objectives of this particular application
  - Complex, expensive and intrusive for the building users and inhabitants

Objective

Investigate alternatives to extract the information of air renovation rate required to enhance procedures of thermal performance assessment of building envelope

- Options considered:
  - Decay of CO_2 concentration produced by metabolic activity
  - Expression of ACH as function of boundary variables (wind speed, delta T, etc).

Case studies

1. Single-zone building. Natural ventilation

2. Office building prototype. Natural and mechanical ventilation

Research carried out

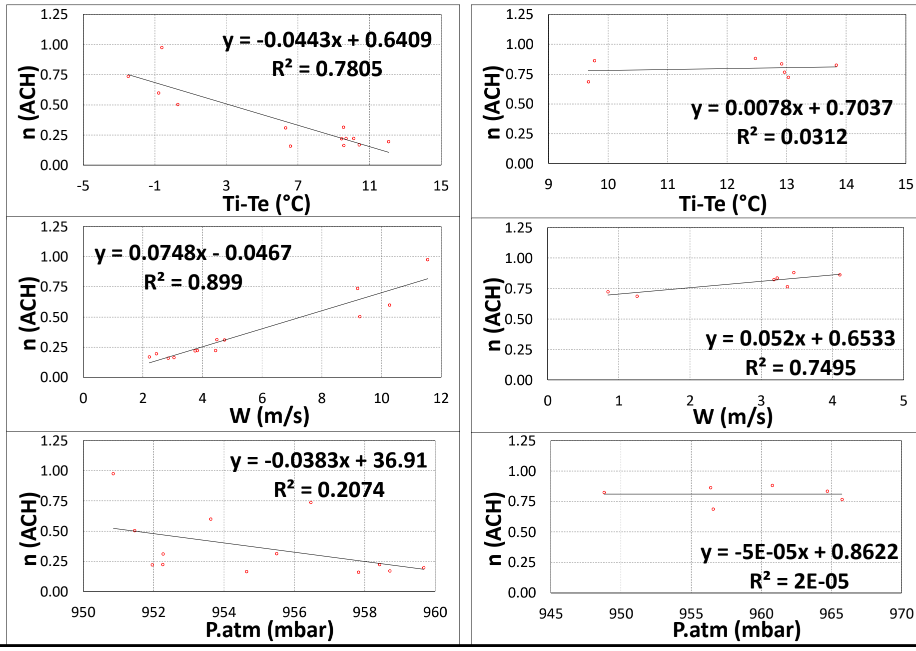
For both buildings, in natural and mechanical ventilation:

- Tracer gas measurements based on **N_2O have been used as reference**.
- The air renovation rate has been obtained using the Decay method.

1. **Relations between the ACH and the following variables** have been analysed.
   - Difference between indoor and outdoor air temperatures (T_i-T_e).
   - Wind speed (W)
   - $W(T_i-T_e)$
   - $W^2(T_i-T_e)$
   - Atmospheric pressure
2. The reliability of an alternative method based on the **evolution of metabolic CO_2 i**s evaluated in a room of the office building.
   - Two different types of CO_2 transmitters have been evaluated
   - Error obtained as the deviation regarding the reference value (based on N_2O) represented as function of the maximum value of the CO_2 concentration at the beginning of the decay method curve.

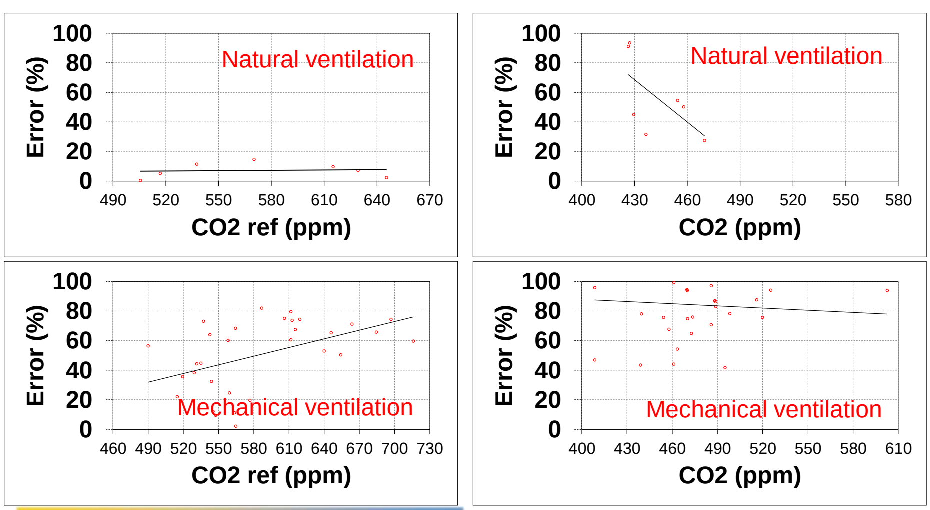
Results. Correlations to boundary variables. Natural Ventilation

Single-zone building | **Office building**



Results. CO_2 analysis. Deviations from reference values

Office building



Conclusions

When mechanical ventilation is not active:

- **Significant correlation** between air renovation rate and wind speed has been observed in both buildings.
- The **agreement between** the values obtained using **N_2O and the metabolic CO_2** increases when the starting value of CO_2 concentration increases

When mechanical ventilation is active:

- **Large variations** have been observed among the different values obtained along the test campaign using N_2O tracer gas.
- These values don't show any correlation with any of the boundary conditions.
- The observed spread has been used to estimate an uncertainty of the ACH.
- The measurements based on CO_2 concentrations don't show good agreement to the values obtained using N_2O tracer gas.
  - This issue will be further investigated. In principle it is attributed to the low level of CO_2 when the mechanical ventilation is active.
  - This explanation is in agreement with previous works in the same building.

Thank you for the attention

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Airflow measurements at supply air terminal devices on residential balanced ventilation

Valérie Leprince (PLEIAQ)
Anne-Marie Bernard (ALLIE'AIR)
annemarie.bernard@allieair.fr

Objective

- Taking over balanced systems
- Accurate measurement of small airflows at ATD
- Cones with one central hot wire are not accurate enough for supply ATD (PROMEVENT study)

METHOD

- **On site measurement :**
  - Real connection conditions
  - Maximum difference of airflow reported at 15, 30, 45 and 90 m3/h (4 to 25 l/s)

- **Lab measurement :**
  - Calibration exhaust and supply; with and without ATD
  - Comparison / on site
  - At 30 m3/h, with Promevent protocol

RESULTS

- Average uncertainty 15 – 20%
- 3 types of anemometers are acceptable :

Powered hood – propellers – hot wire grills

- Hot wire grills (low pressure drop) are more sensible to flow direction at ATD or prior

Recommendations

- Check minimum airflow of device (velocity in measuring plane)
- Avoid large hoods on small ATD

- Pressure drop of propellers acceptable on small flowrate (beware of boost flowrate) :
  - 2 Pa at 30 m3/h - 20 Pa at 100 m3/h

Thanks for your attention

The future of passive techniques for for air change rate measurement

PhD project: Developing a passive air change rate measurement technique

Sarah L. Paralovo

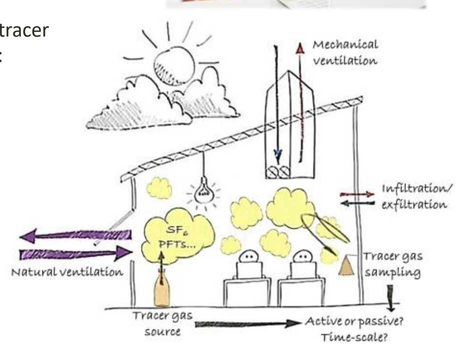
VITO promoter: dr. Marianne Stranger
UGent promoter: prof. dr. Jelle Laverge

Introduction

Motivation:

- IAQ, health and ventilation;
- Ventilation is often ignored;
- Need for a reliable, reproducible and accessible ventilation rate measurement method.

Most ventilation assessments use tracer gas dilution/dispersion tests (TGT):



Objective:

New **passive tracer gas test (TGT) for air change rates measurement:**

- Tracer is co-captured and co-analyzed with IAQ pollutants;
- Measure internal and external flows;
- Accurate, affordable, safe for occupants;
- Well-known, predictable indoor behavior.

Development

Methods:

- Selection of tracer candidate:
  - Literature review: Definition of criteria; evaluation of candidates; selection of best option.
- Test behavior of tracer candidate:
  - Ongoing work: Preliminary field test; chamber test.
- Next steps:
  - Further chamber tests; modeling; field tests.

Results:

- Definition of 6 determining criteria for a good tracer:
  1. Quantification via passive sampling used in IAQ surveys;
  2. Typically insignificant background concentrations;
  3. Safe for occupants;
  4. Can be co-analyzed with common IAQ pollutants;
  5. Not susceptible to physical or chemical parameters of the indoor environment;
  6. Financially adequate.
- Current option: 2-butoxyethyl acetate (EGBEA)
  - Sampled by Radiello samplers;
  - Low toxicity, not linked to chronic effects;
  - Low background concentration: Literature and past VITO studies.

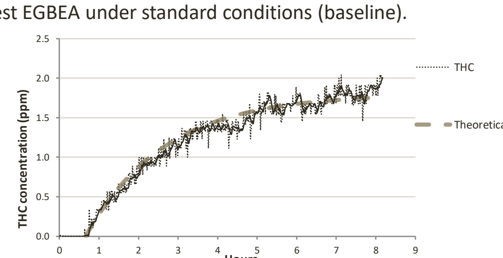
Development

Preliminary test: Check measurability amongst common indoor VOCs.

Sample	Sampling start	Sampling finish	EGBEA mass (µg)
Lab blank	-	-	0.067
Background	15/01 – 17h25	19/01 – 17h39	0.059
With EGBEA source	19/01 – 17h40	23/01 – 17h34	3.32

- Negligible background concentration;
- Concentration after 4 days: 14 µg m^{-3} (< LCI);
- Measurable and not affected by other VOCs.

Test Chamber, Phase 1 (TCP1): Test EGBEA under standard conditions (baseline).



- Radiellos and Tenax were oversaturted.

Conclusions

Achieved results:

- Literature review:
  - Definition of the 6 determining criteria;
  - Selection of most prominent candidate: EGBEA.
- Preliminary test;
- Chamber tests were initiated.

Future steps:

- Further chamber tests to evaluate:
  - Response to varying parameters;
  - Presence of other VOCs;
  - Sink effects;
  - Different designs/setups.
- Modelling tests;
- Validation: Field tests.

Thank you!

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Cerema

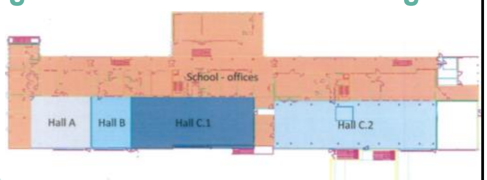
AIVC TightVent Europe venticool

Airtightness measurement of large buildings by using multi-zonal techniques: a case study

Lucille Labat[1], Sylvain Berthault

Cerema - Centre-Est, France

French context, problem and objective: Airtightness measurement of large buildings by using multi-zonal techniques



- **Standard measurement airtightness :**
  - International standard ISO 9972;
  - Special requirements for the large buildings:
    - measuring whole building (single zonal techniques),
    - <u>or</u> dividing the building into smaller elements (multi-zonal techniques);

- **Problem using the multi-zonal techniques :**
  - Two methods can be used:
    - measuring each zone separately, which includes inter-zonal airflows,
    - or providing an identical pressure in adjacent zones, which allows to measure only airflows between the pressurized zone and outdoors;
  - Literature:
    - these two methods give significantly different results: about 30% (Szymanski, Gorka & Gorzenski, 2014)

- **Objective:**
  - Specifying the conditions for airtightness test in large buildings by using multi-zonal techniques

Airtightness measurement of large buildings by using multi-zonal techniques: a case study

- **Method :**
  - Preparing the building in order to isolate four independent zones

  - Detecting many significant inter-zonal leaks
  - Measuring each zone with different protocols
    - separately from the other zones,
    - and simultaneously with adjacent zones (guarded test method);
  - Evaluating inter-zonal airflows by mean of calculation according to a simplified method (inspired from Hult & Scherman, 2014)

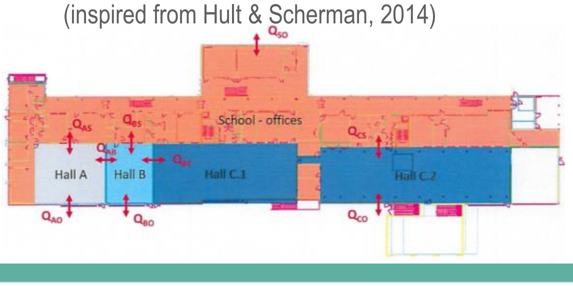


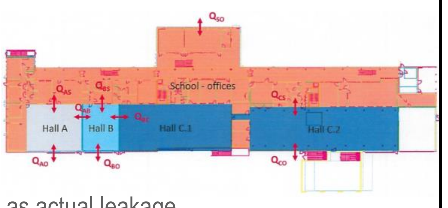
Table 3: Airtightness tests notations

Measurement	q_{50} notation	Equation
Hall A alone	Q_1	$Q_1 = Q_{AO} + Q_{AS} + Q_{AB}$
Hall A, Hall B depressurized	Q_2	$Q_2 = Q_{AO} + Q_{AS}$
Hall A, guarded test method	Q_3	$\mathbf{Q_3 = Q_{AO}}$
Hall B alone	Q_4	$Q_4 = Q_{BO} + Q_{BS} + Q_{AB} + Q_{BC}$
Hall B, Hall A and Hall C depressurized	Q_5	$Q_5 = Q_{BO} + Q_{BS}$
Hall B, guarded test method	Q_6	$\mathbf{Q_6 = Q_{BO}}$
Hall C alone	Q_7	$Q_7 = Q_{CO} + Q_{CS} + Q_{BC}$
Hall C, Hall B depressurized	Q_8	$Q_8 = Q_{CO} + Q_{CS}$
Hall C, guarded test method	Q_9	$\mathbf{Q_9 = Q_{CO}}$
School – offices alone	Q_{10}	$Q_{10} = Q_{SO} + Q_{AS} + Q_{BS} + Q_{CS}$
School – offices, guarded test method	Q_{11}	$\mathbf{Q_{11} = Q_{SO}}$

Table 4: Inter-zonal airflows notations

Interzonal leakage	q_{50} notation	Equation
Between Hall A and Hall B	Q_{AB}	$Q_{AB} = Q_1 - Q_2$
Between Hall A and School - offices	Q_{AS}	$Q_{AS} = Q_2 - Q_3$
Between Hall B and Hall C	Q_{BC}	$Q_{BC} = Q_4 - Q_5 - Q_1 + Q_2$
Between Hall B and School - offices	Q_{BS}	$Q_{BS} = Q_5 - Q_6$
Between Hall C and School - offices	Q_{CS}	$Q_{CS} = Q_8 - Q_9$

Airtightness measurement of large buildings by using multi-zonal techniques: a case study



- **Main results and conclusion :**
  - The inter-zonal airflows were successful estimated
  - For each zone, inter-zonal airflows are almost as important as actual leakage
    - => the inter-zonal airflows do not be neglected when measuring airtightness
    - => the n50 value is overestimated from about 70% to 100%
  - The uncertainty on calculated inter-zonal airflows can be significant, which indicates that results should be considered with caution
    - => Uncertainties are even higher if calculating at lower pressure differences.

	Hall A	Hall B	Hall C	School-offices
Actual leakage (between the zone and the outdoors) (m^3/h)	7071	6640	24412	31328
Uncertainty (%)	3%	3%	3%	3%
Inter-zonal airflow (m^3/h)	4935	4982	22674	24989
Uncertainty (%)	14%	5%	3%	4%
Inter-zonal airflow compared with actual leakage (%)	70%	75%	93%	80%

Inter-zonal leakage	q_{50} (m^3/h)	Uncertainty in q_{50} (%)
Between Hall A and Hall B	$Q_{AB} = 2525$	27%
Between Hall A and School - offices	$Q_{AS} = 2410$	10%
Between Hall B and Hall C	$Q_{BC} = 1792$	40%
Between Hall B and School - offices	$Q_{BS} = 665$	40%
Between Hall C and School - offices	$Q_{CS} = 16080$	6%

Thanks

Lucille Labat – Sylvain Berthault

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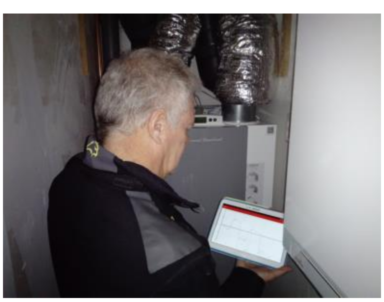
A new method to measure building airtightness

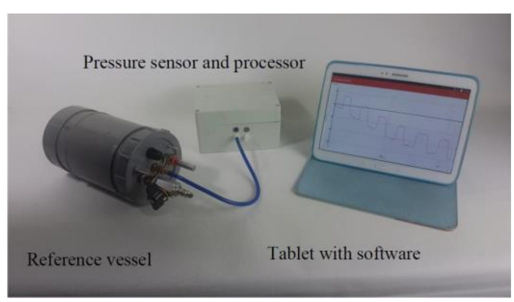
Timothy Lanooy, Wim Kornaat, Niek-Jan Bink, and Wouter Borsboom

ACIN instrumenten

TNO innovation for life

What do you need?





❖The ATT system is unique in that it uses an indoor pressure reference (less sensitive to wind !) and the building ventilaton system.

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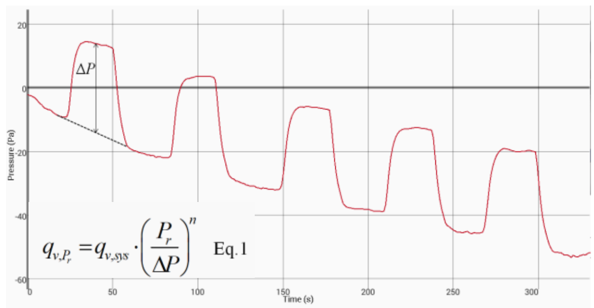
Getting an airtightness value



$q_{v,Pr}$: airtightness at the referenced building pressure [l/s]
$q_{v,sys}$: volumetric flow of the ventilation system [l/s]
P_r : specified reference building pressure [Pa]
ΔP : measured differential pressure [Pa]
n : flow exponent. [-]

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Comparisons to the blowerdoor

Column 1 : Building number.
Column 2 : Blowerdoor measurement.
Column 3 : ATT measurement with the measured flow exponent.
Column 4 : ATT measurement with an average flow exponent of 0.66.

Building no.	q_{blower} (l/s)	$q_{new,nmeas}$ (l/s)	$q_{new,nfixed}$ (l/s)
18	9.9±1.2	10.3±0.4	12.0±1.6
19	10.6±1.5	11.0±0.5	10.8±1.4
20	14.8±1.2	17.7±1.4	18.0±1.6
21	20.0±1.2	19.6±0.5	21.2±2.9
22	17.5±1.1	18.9±0.4	20.0±2.9
23	12.2±2.3	14.1±0.5	17.1±2.8
24	10.9±0.7	12.3±0.3	14.8±2.5
25	12.5±1.3	14.3±0.6	16.8±2.0
26	14.0±1.7	14.9±0.5	14.9±1.6
27	10.8±1.4	11.2±0.4	13.4±2.0
28	9.8±1.6	11.2±0.6	12.1±1.5

Green : The building meets the requirement.
Blue : The building only meets the requirement without considering the uncertainty.
Red : The building does not meet the requirement.

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Discussion and conclusion

❖The ATT gives a very good indication whether a building passes the airtightness requirement or not. When taking into account the uncertainties, the ATT method and the blowerdoor pass and fail nearly all the same buildings.

❖All measurements done with the ATT are single point measurements, making it necessary to assume a flow exponent. It is possible to do a multi-point measurement with this method if the fan system can be set to different flows.

❖With the ATT it is possible to measure the entire building envelope, including the front door as no exterior fan is needed.

❖It almost goes without saying that one has to take the measuring uncertainties of both methods into account for a good comparison.

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AIVC 2018

SABINA

Comparison of experimental methodologies to estimate the air infiltration rate in a residential case study for calibration purposes

Paolo Taddeo

Juan Les Pins, 19/09/2018

Objective

- **To compare different air infiltration rate estimation methodologies and evaluate in a simple way an *n50* input value for buildings dynamic energy simulations**
- Case study: residential building in Catalunya

Methodology and results

Tracer gas decay methods

- CO_2 generated by building occupants used as tracer gas
- Two point decay method and regression analysis implementation
- ACH values range from 0.08 [1/h] to 0.49 [1/h]

Blower Door tests

- European standard UNE-EN 13829:2002

Average results at 50 Pascals		All dwelling	Main Bedroom
n50	1/h (Air Change Rate)	2.89	2.92

IREC Institut de Recerca en Energia de Catalunya Catalonia Institute for Energy Research

Conclusions

- Good airtightness of the envelope especially considering the construction period of the building ('90)

- Good agreement between decay methods results and Blower Door results

- A methodology has been suggested as simplified way to estimate the air infiltration rate value *n50* without performing intrusive operations such as Blower Door tests

	Average of regression results n_1 [h^{-1}]	Average n_{50} [h^{-1}]
Simplified approach [ACH_{av}]	0.22	2.92

Empirical Correlations

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Thanks for your attention.

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Experimental study on the measurement of Building Infiltration and Air Leakage Rates (at 4 and 50 Pa) by means of Tracer Gas methods, Blower Door and the novel Pulse technique in a Detached UK Home

Alan Vega Pasos, Xiaofeng Zheng, Vasileios Sougkakis, Mark Gillott, Johann Meulemans, Olivier Samin, Florent Alzetto, Luke Smith, Stephen Jackson, Christopher Wood

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Introduction

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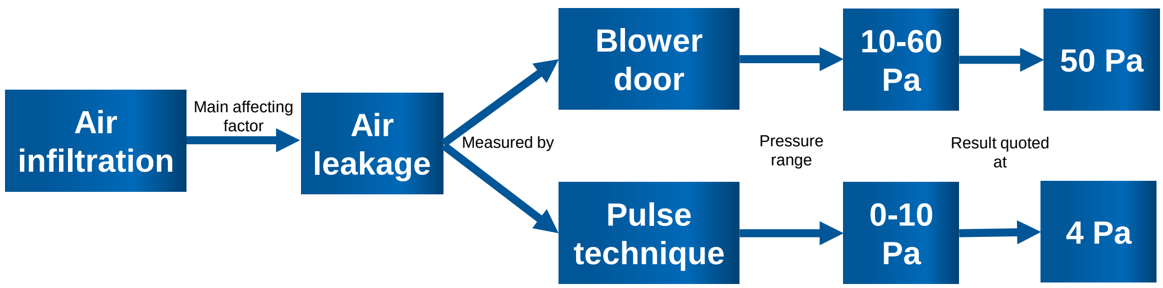
Introduction



Objective: start understanding the correlation between air infiltration and the air leakage measurements taken at 4 Pa by the pulse technique and how it compares with the correlation between air infiltration and air leakage measured at 50 Pa by the blower door.

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Method & Test house

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Method

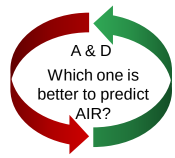
Testing Period: January and February 2018

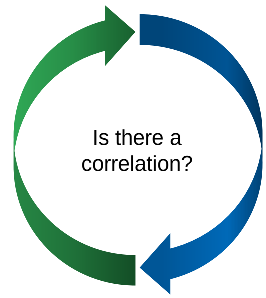
Tracer gas → Constant Concentration → Long tests (days) → 15 tests
Tracer gas → Decay Method → Short tests (hours) → 19 tests

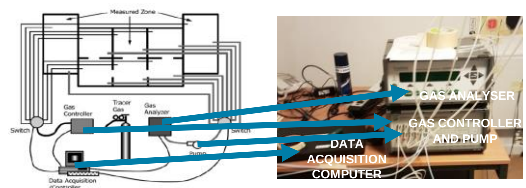
- INNOVA 1412I gas analyser.
- LumaSense 1303 multipoint gas sampler and doser.
- Tracer gas, CO2.

Blower door → Pressurisation / Depressurisation → Before and after every TG test → 10 tests

Pulse method → Tests every day → At least 3 valid tests per day → 29 testing days







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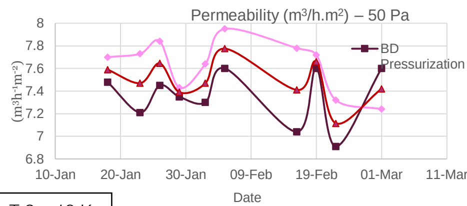
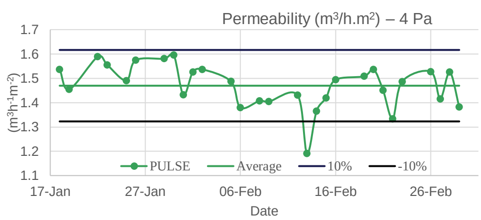
Results

Results

Pulse and Blower Door

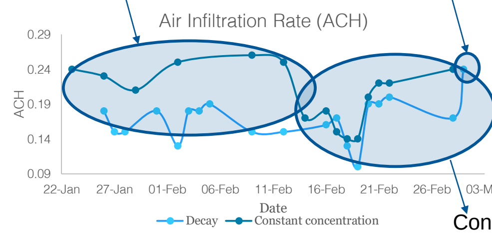


Wind speed 0-3 m/s, ΔT 3 – 18 K



Wind speed 0-12 m/s, ΔT 3 – 23 K

Changing weather, mild during day, cold at night



Constant weather

Wind speed 0-15 m/s, ΔT 1 – 28 K

Results

Ratio:

$$Q_{\Delta P}/Q_1 = N$$

Used by Standard Assessment Procedure (SAP) in the UK
For ***ΔP = 50 Pa*, *N*** normally takes the value of **20**

But in this study:

For Q_{50}
31<N<50*
≈20% Uncertainty

For Q_4
6.5<N<10*
≈20% Uncertainty

*. Excluding extreme results

Conclusions

Conclusions

- Several measurements of Air Infiltration Rates and Permeability Rates (at 50 and 4 Pa of ΔP). Using tracer gas constant concentration and decay methods and; Blower door and Pulse methods.
- Both Blower Door (±6%) and Pulse (±10%) showed good reproducibility
- Blower door: Good reproducibility and widely developed method, however, difficult to predict AIR due to extrapolation to lower pressure
- Pulse: Good duration of test and portability, however, sometimes more than one test is needed because of the invalidity of some tests.
- Pulse presented a good potential to predict AIR because it measures ALR at lower pressure differences.

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THANK YOU

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AN EXPERIMENTAL INVESTIGATION INTO THE VENTILATION EFFECTIVENESS OF DIFFUSE CEILING VENTILATION

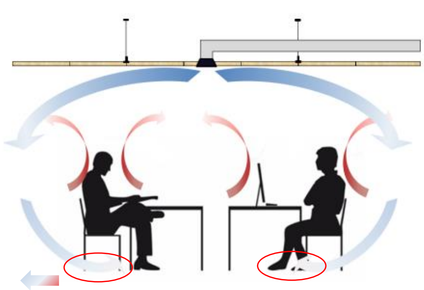
- 39th AIVC Conference Smart Ventilation for Buildings

CHEN ZHANG*, RUNE ANDERSEN, GEORGIOS CHRISTODOULOU, MARIUS KUBILIUS, PER KVOLS HEISELBERG

DEPARTMENT OF CIVIL ENGINEERING, AALBORG UNIVERISTY

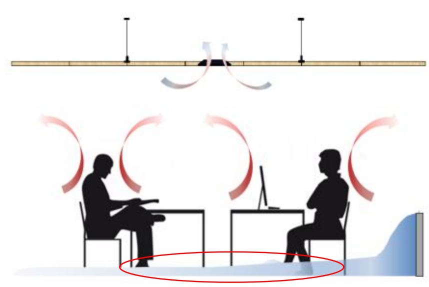
AALBORG UNIVERSITY
DENMARK

Problems by using conventional ventilation systems



Mixing ventilation

$$Q = 3.5 \cdot 10^3 K_{sp}^{1.5} \left(\frac{L}{x_s}\right)^{1.5} \frac{u_{rm}^3}{L}$$



Displacement ventilation

$$T_i - T_{oz} : 2\text{~}4\ oC$$
$$u_i < 0.25\ m/s$$

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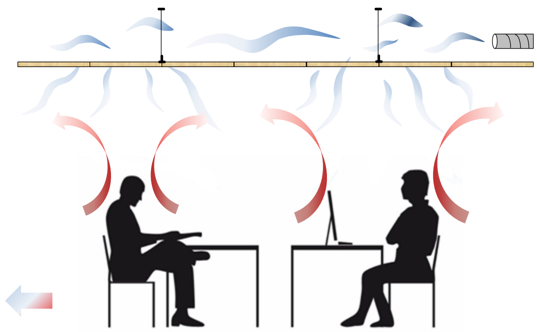
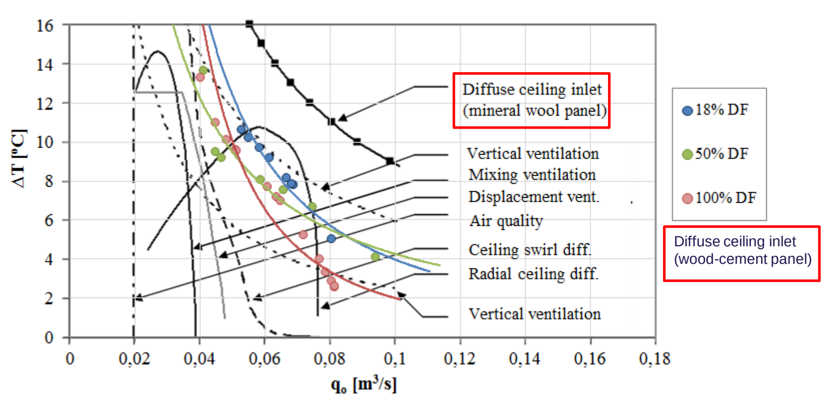
Diffuse ceiling ventilation



Thermal comfort

Energy saving

Compare with other air distribution systems



Ref: C.Zhang, Phd thesis, 2016

Research questions

- How is the air quality in the room with diffuse ceiling ventilation?
- What are the influences of different contaminant sources (heated/unheated and location)?

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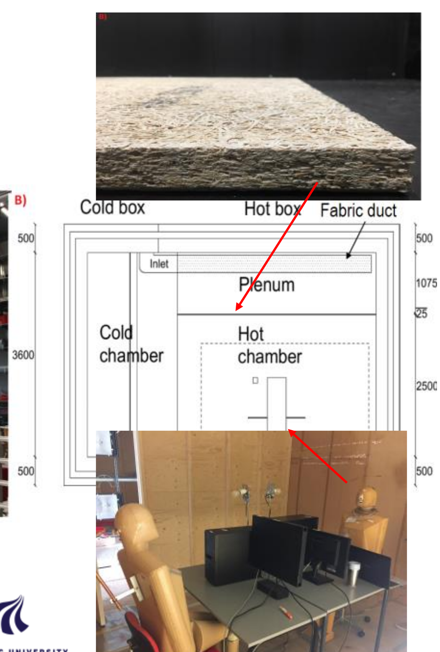
Measurement facility



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Measurement positions

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Measurement cases

Case	Supply temp. °C	ACH h^{-1}	Internal heat load W	Contaminant source
1	14,2	3	451	2 persons
2	14,4	6	861	2 persons
3	14,4	6	861	point source on the floor
4	14,2	3	451	point source on the floor
5	17,3	3	275	point source at 1.1 m
6	17,3	3	275	1 person

Variables:

- Supply temperature
- ACH
- Heat load
- Contaminant source: heated/unheated and location

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Ventilation effectiveness

Case	Supply temp.	ACH	Internal heat load	Contaminant source
	°C	h⁻¹	W	
1	14,2	3	451	2 persons
2	14,4	6	861	2 persons
3	14,4	6	861	point source on the floor
4	14,2	3	451	point source on the floor
5	17,3	3	275	point source at 1.1 m
6	17,3	3	275	1 person

Contaminant removal effectiven

$$CRE = \frac{C_e - C_s}{C_i - C_s}$$

where C_e is the concentration in the exhaust air; C_s is the concentration of the supplied air, and C_i is the concentration in the occupied zone.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
CRE_{avg}	0,93	0,97	2,24	0,99	1,21	0,88

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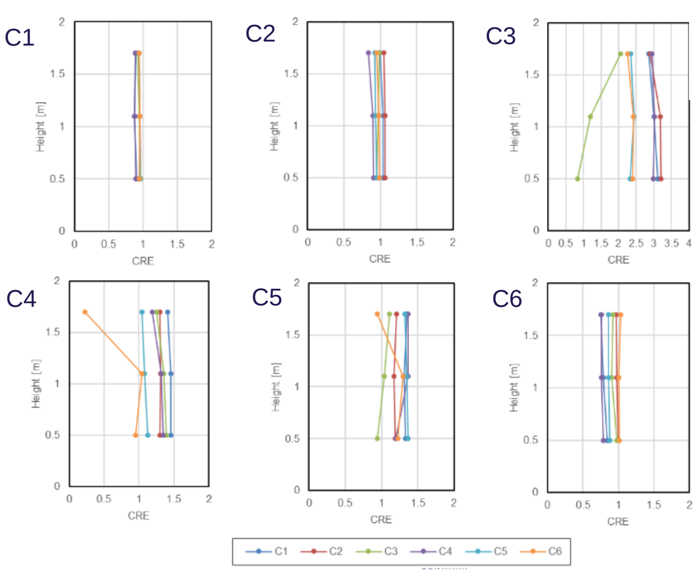
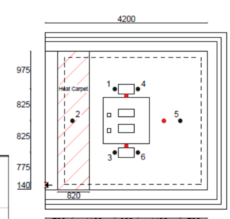
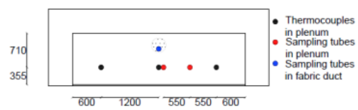
Local air quality index



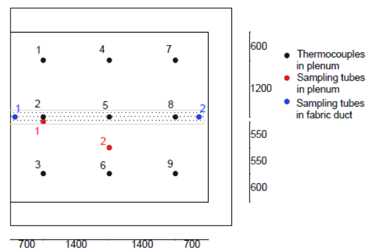


Concentration in the plenum

Concentration [ppm]	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Inlet	1,00	0,68	0,49	4,81	1,02	0,40
Plenum	0,59	0,52	0,49	3,03	0,57	0,38
Room	223	119	61	252	191	121



No reverse flow to the plenum



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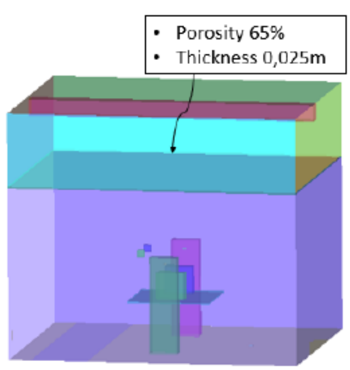
Numerical model



Porous media model is used to simulate diffuse ceiling panel

Ref: C. Zhang, IBPSA 2015

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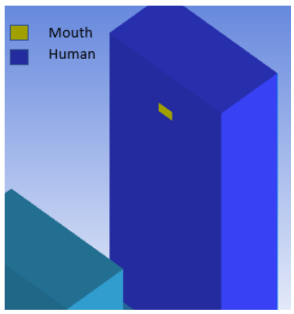
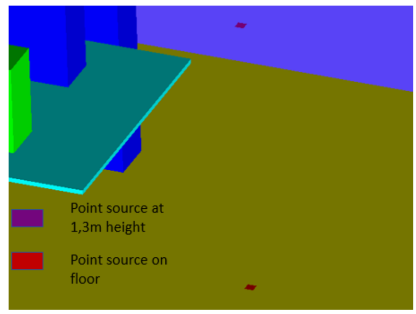
Contaminant sources



Active: velocity inlet



Passive: wall species boundary condition

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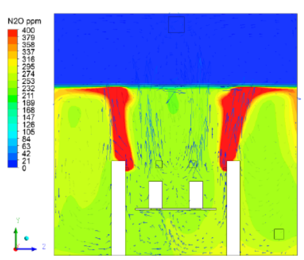
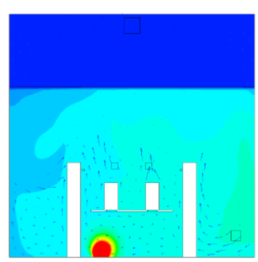
Numerical results

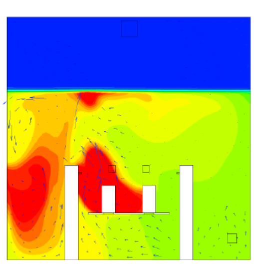
Case 1



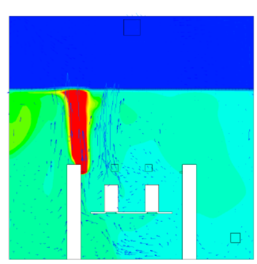
Case 3



Case 5



Case 6



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Conclusions

- The ventilation effectiveness strongly influenced by contaminant source and its location
- When contaminant source is also heat source, CRE≈1 comparable to mixing ventilaiton
- When contminant source is passive source (unheated), the CRE depends on the location of the source

Future work

- Different location of exhaust
- Operate in the heating mode

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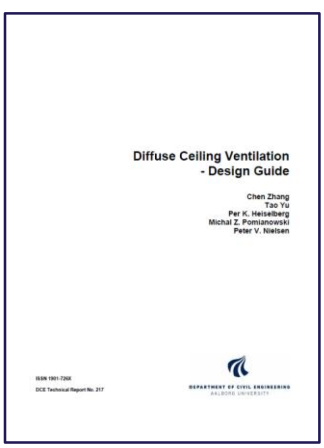
Diffuse Ceiling Ventilation
- Design Guide

Chen Zhang
Tao Yu
Per K. Heiselberg
Michal Z. Pomianowski
Peter V. Nielsen

ISSN 1901-726X
DCE Technical Report No. 217

DEPARTMENT OF CIVIL ENGINEERING
AALBORG UNIVERSITY

http://vbn.aau.dk/files/243057526/Diffuse_ceiling_ventilation_Design_guide.pdf

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A HOLISTIC EVALUATION METHOD FOR DECENTRALIZED VENTILATION SYSTEMS

39th AIVC - 7th TightVent & 5th venticool Conference Smart ventilation for buildings

Sven Auerswald

Fraunhofer Institute for Solar Energy Systems ISE

39th AIVC - 7th TightVent & 5th venticool

Antibes Juan-Les-Pins, 19th Sep. '18

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AGENDA

- Introduction
- Available technical regulations and certification methods
- Multi-criteria approach
- Test chamber
- Next steps

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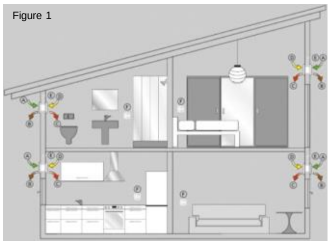
Introduction
Decentralised supply and exhaust air systems' – SEA-D

Continuous devices

Figure 1



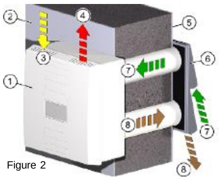


Figure 2

- Exhaust air indoor
- Supply air indoor
- Ambient air outdoor
- Exhaust air outdoor

Alternating devices

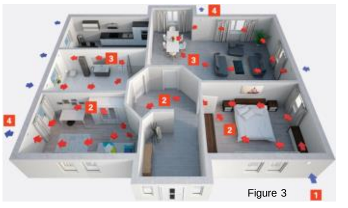


Figure 3

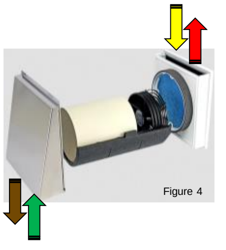


Figure 4

Figure 1: https://www.viessmann.de/content/dam/vi-brands/DE/Produkte/Wohnungslueftung/wohnungslueftung-dezentral.jpg/_jcr_content/renditions/original.image_file.310.174.file/wohnungslueftung-dezentral.jpg, 12.09.2018

Figure 2: https://www.meltem.com/fileadmin/user_upload/5302_00_Meltem_Betriebsanleitung_M-WRG-S_KW37-2017.pdf, 12.09.2018

Figure 3: https://www.viessmann.de/content/dam/vi-brands/DE/Produkte/Wohnungslueftung/Vitovent-100-D/Systemdarstellung.png/_jcr_content/renditions/original.image_file.420.236.file/Systemdarstellung.png, 12.09.2018

Figure 4: https://dezentrale-lueftung.com/wp-content/uploads/dezentrale-lueftung-sevi-160-mit-wetterschutzhaube-blank-seventilation.png, 12.09.2018

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Introduction
Why a new evaluation method?

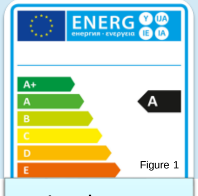
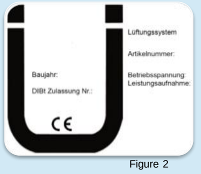
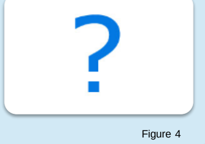
EU 1254/2014	DIBt Lü-A. 22-2	DIN EN 13141-8	?
 Figure 1	 Figure 2	 Figure 3	 Figure 4
Leakages	Leakages	Leakages	Leakages
EE	EE	EE	EE
Acoustic		Acoustic	Acoustic
	Filter	Filter	Filter
			Thermal Comfort
			IAQ

Figure 1: https://www.derinstallateur.at/fileadmin/_processed_/csm_12_54_PL_EU_Label_2015_DR-1_82334fa5e9.jpg, 13.09.2018

Figure 2: Mirring, Busler 17.12.2014 – Bericht WRG 375 DIBt

Figure 3: http://bm-land.de/sicherheit/wp-content/uploads/2014/04/DIN-EN.jpg, 13.09.2018

Figure 4: https://www.computerhope.com/jargon/q/questionmark.jpg, 13.09.2018

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Available technical regulations and certification methods

SEA-D and ventilation assessment

Energy efficiency + leakages	Thermal comfort	IAQ + air exchange efficiency
■ EU 1254/2014 ■ EN 13141-8 ■ DIBt LÜ-A. Nr. 22-2 ■ PHI requirements for DRV < 600 m³/h	■ ISO 7730 ■ DIN 4108-2 ■ EN 15251 ■ ASHRAE 55	■ EN 13779 ■ ISO 16000 ■ ISO 12569


Figure 1

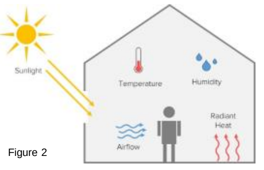

Figure 2

Figure 3

Figure 1: https://www.munters.com/globalassets/images/about/electricity-plugged-to-the-globe_shutterstock_89738425-color-print_1200x600.jpg, 11.09.2018
Figure 2: http://ggbec.co.uk/wp-content/uploads/2017/02/Internal-Gains_3.jpg, 11.09.2018
Figure 3: http://www.forbixindia.com/electronics/wp-content/uploads/2015/02/Air-Quality-Monitor.png, 11.09.2018

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Available evaluation methods

Energy efficiency

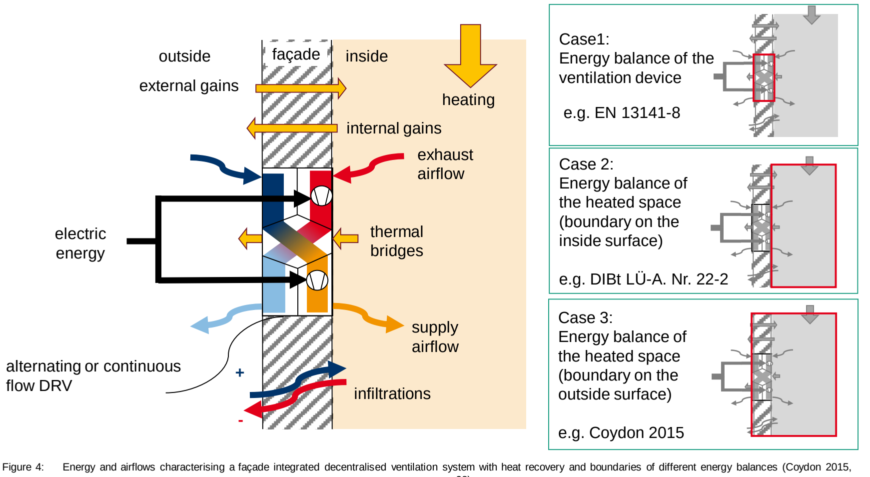

Figure 4: Energy and airflows characterising a façade integrated decentralised ventilation system with heat recovery and boundaries of different energy balances (Coydon 2015, p. 38)

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Available evaluation methods

Thermal comfort: adaptive comfort models

EN 15251 + ASHRAE 55

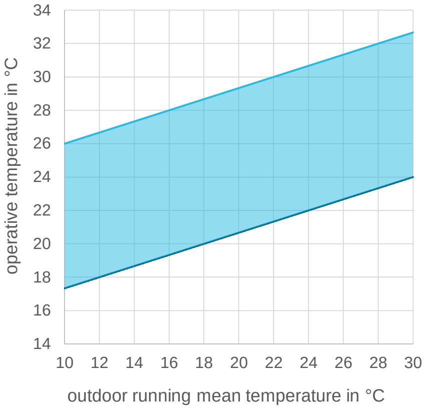


Figure 1: Adaptive comfort diagrams according to EN 15251 and ASHRAE 55,

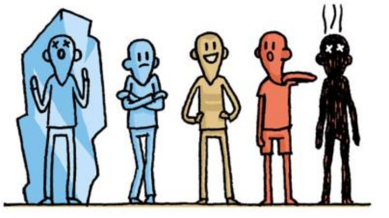


Figure 2: http://multicomfort.saint-gobain.com/wp-content/themes/mc250216/images/human_factor/thermal-comfort/thermal_engines.jpg, 13.09.2018

Available evaluation methods

IAQ + air exchange efficiency

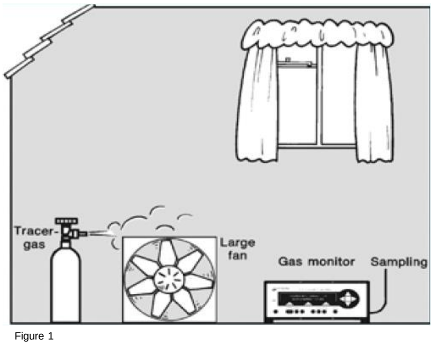


Figure 1

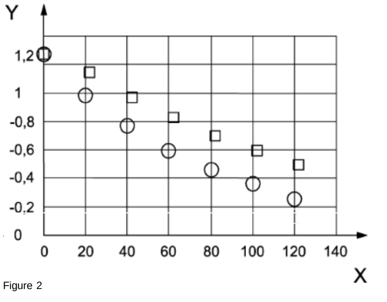
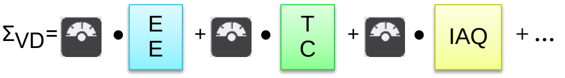


Figure 2

X time, in min
Y φ tracer gas concentration, in $cm^3 \cdot m^{-3}$
○ results 1
□ results 2

Figure 1: https://www.aiha.org/aihce06/handouts/po129simmons.pdf, 14.09.2018
Figure 2: Example DIN ISO 16000-8:2008-12, p. 39

Multicriteria approach



(4-1)

- Σ_{VD} total score achieved by the ventilation device
- Standardisation functions for indicators e.g.
  - η_{ϑ} mean seasonal heat recovery ratio
  - PPD percentage persons dissatisfied
  - DR draft rate
  - $PD_{\Delta T}$ percentage dissatisfied in terms of vertical temp. gradients
  - ε_V ventilation efficiency in a representative horizontal plane PD_{CO_2} percentage dissatisfied with respect to the CO_2-concentration
-  weighting factor for indicators

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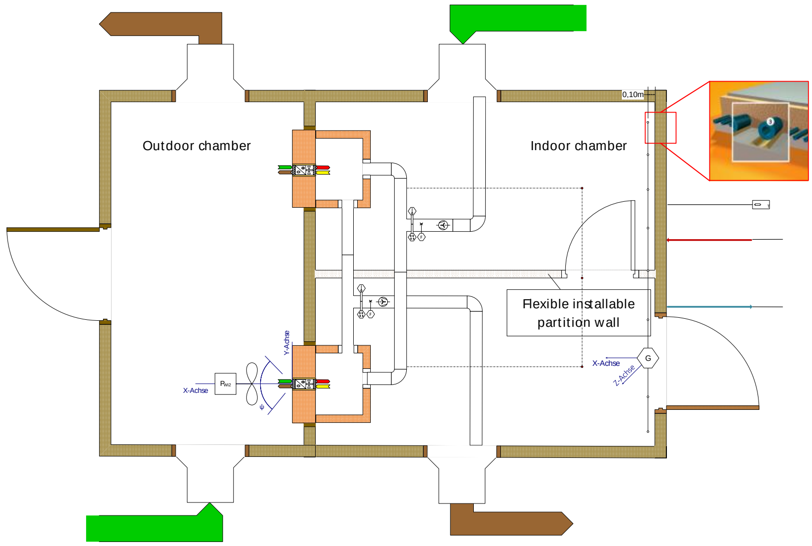
Test facility



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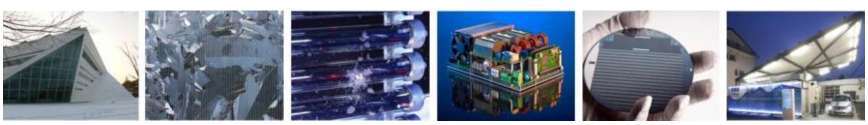
Next steps

- Decisions which evaluation methods should be combined for the multi-criteria method in terms of:
  - EE + leakages
  - Thermal comfort
  - IAQ + air exchange effectiveness
- Construction of the test facility + Definition of the test conditions
- How to implement the acoustic into the evaluation procedure?

Thank you for your attention!



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Sven Auerswald

www.ise.fraunhofer.de
sven.auerswald@ise.fraunhofer.de

Pool of assessment criteria’s and objective

figure reference: http://canaves.com/wp-content/uploads/2016/10/Infinity-Pool-Suite-Caldera-Sea-View-5.jpg, 10.11.2018
IAQ = indoor air quality
EE = energy efficiency

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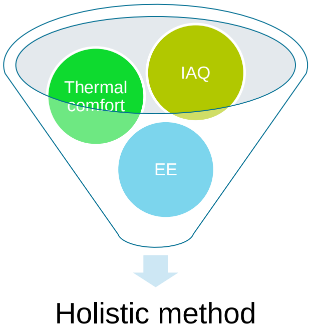
Pool of assessment criteria’s and objective



Holistic method

figure reference: http://canaves.com/wp-content/uploads/2016/10/Infinity-Pool-Suite-Caldera-Sea-View-5.jpg, 10.11.2018
IAQ = indoor air quality
EE = energy efficiency

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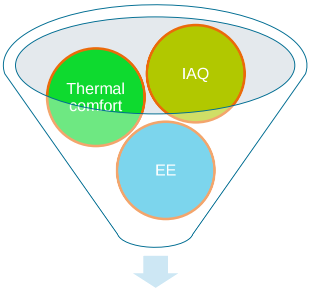
Pool of assessment criteria's and objective

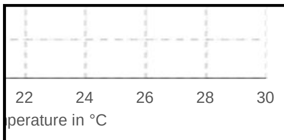


Modular Holistic method

Figure 1: http://canaves.com/wp-content/uploads/2016/10/Infinity-Pool-Suite-Caldera-Sea-View-5.jpg, 10.11.2018

IAQ = indoor air quality

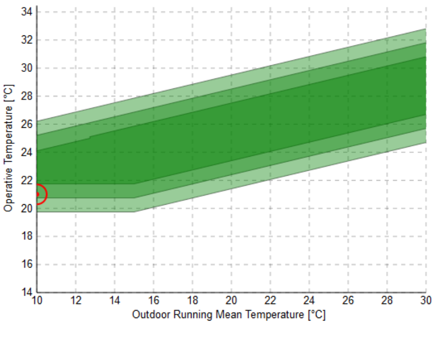
EE = energy efficiency



ation methods

rt: selected models

EN 15251



ASHRAE 55

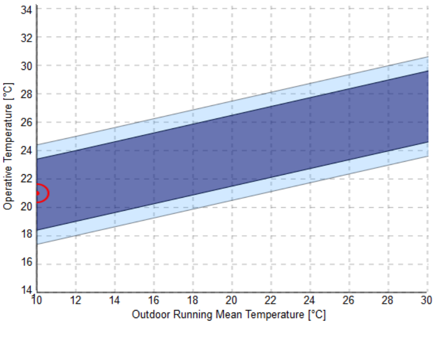


Figure 5: Adaptive comfort diagrams according to EN 15251 and ASHRAE 55, http://smap.cbe.berkeley.edu/EN, 11.09.2018

Introduction

Why a new evaluation method?

EU 1254/2014

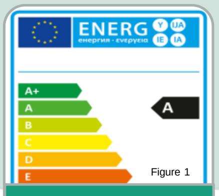


Figure 1

DIBt Lü-A. 22-2

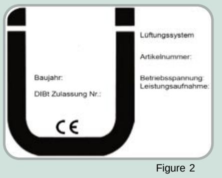


Figure 2

DIN EN 13141-8

Figure 3

EU 1254/2014	DIBt Lü-A. 22-2	DIN EN 13141-8
Leakages	Leakages	Leakages
EE	EE	EE
Acoustic		Acoustic
	Filter	

Figure 1: https://www.derinstallateur.at/fileadmin/_processed_/csm_12_54_PL_EU_Label_2015_DR-1_82334fa5e9.jpg, 13.09.2018
Figure 2: Mirring, Busler 17.12.2014 – Bericht WRG 375 DIBt
Figure 3: http://bm-land.de/sicherheit/wp-content/uploads/2014/04/DIN-EN.jpg, 13.09.2018
https://www.computerhope.com/jargon/q/questionmark.jpg, 13.09.2018

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Influence of multizone airleakage on IAQ performance in low-energy residential buildings

Gaëlle Guyot[1,2], Hugo Geoffroy[2], Michel Ondarts[2], Evelyne Gonze[2], Monika Woloszyn[2],

[1] Cerema Centre-Est 46, rue St Théobald, F-38080, L'Isle d'Abeau, France ;

[2] Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, LOCIE, 73000 Chambéry, France

Outline

- Introduction and research problem
- Method
- Results and discussion
- Conclusion and perspectives

Research problem

- **Envelope airtightness, an unavoidable parameter in the European context with the generalization of nearly zero energy building (NZEB) in 2020 (European EPBD Directive)**

- **More and more included in EP-regulatory calculations**
  - At best 1 zone models
  - Air leakage is evenly distributed on building envelope
  - Energy performance / IAQ : no matter about air transfers between rooms

- **Impacts on ventilation performance in low energy houses of :**
  - Multizone modelling …
  - Taking into account an uneven distribution of envelope airleakage …
  - And an uneven distribution of internal partition walls airleakage

?

Why airleakage distribution is an issue of interest

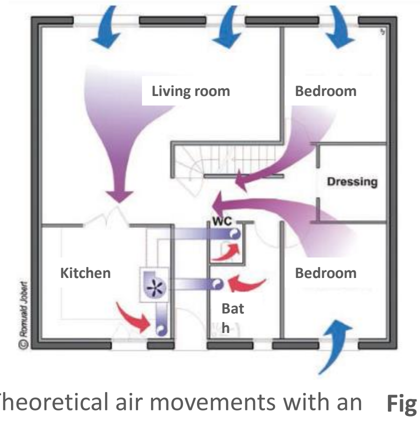


Fig 1 : Theoretical air movements with an exhaust-only ventilation system
Source : R. Jobert, Cerema, FR

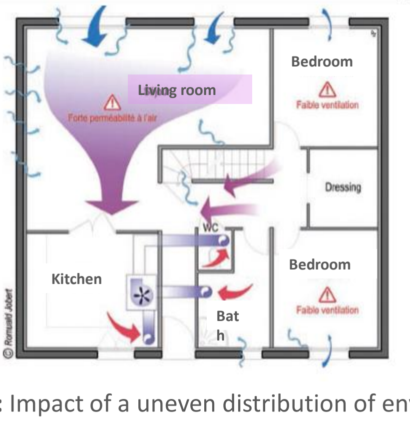


Fig 2 : Impact of a uneven distribution of envelope airleage, short-circuiting theoretical air movements
Source : R. Jobert, Cerema, FR

Introduction

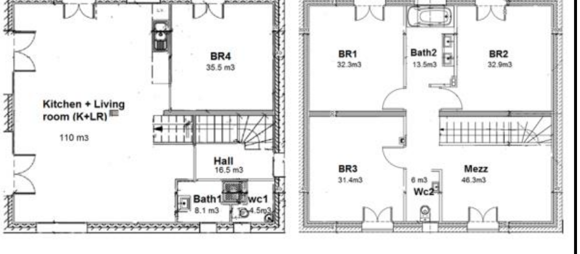
- **In a former campaign on 23 houses, we observed that airleakage distributions were uneven, and that internal airleakage was non negligible compared to a door undercut (Guyot et al., 2016) and proposed input values for IAQ models**

- **Now, it's time to quantify the impacts on IAQ in a low-energy house !**

Guyot, G., Ferlay, J., Gonze, E., Woloszyn, M., Planet, P., Bello, T., 2016. Multizone air leakage measurements and interactions with ventilation flows in low-energy homes. Building and Environment 107, 52–63. https://doi.org/10.1016/j.buildenv.2016.07.014

Method

- **Case study**
  - A low-energy house (50 kWep/year/m²)
    - 2 stories, 4 bedrooms, …
    - 337 m³ and 135 m²
    - Measured airleakage:
      - Envelope: $n_{50}=1.5\ h^{-1}$
      - Internal partition walls, median value of: $q_{50}=0.8\ m^3.h^{-1}.m^{-2}$



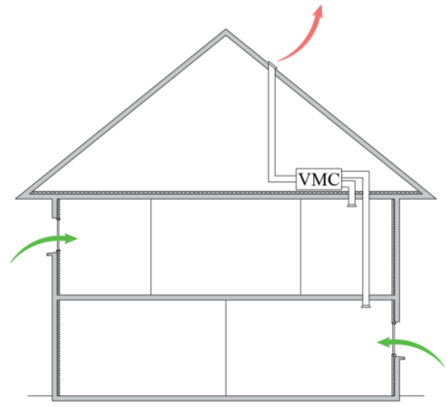
  - Multizone modelling
    - with CONTAM + R
    - Δt=10 minutes
    - Over the heating period (from October 15th 00:00 to April 14th 24:00, 4366 h)

CONTAM
Multizone Airflow and Contaminant Transport Analysis Software

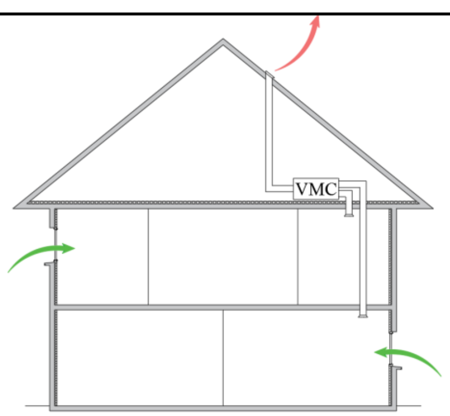
Method

- **Two types of ventilation systems**
  - Balanced
  - Exhaust-only with constant airflow
  - Both providing: Q=135 m^3/h (ACR=0.4 h^{-1})

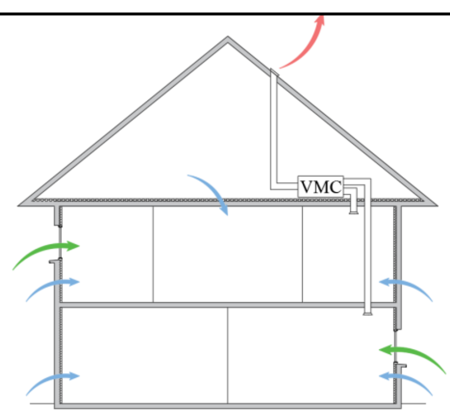
- **Seven cases of airleakage distributions**
  - From very simple : case a = no
  - To very detailed : cases d, d2, d3, d4



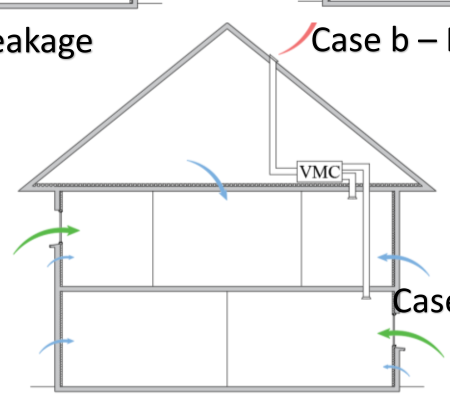
Case a – No airleakage



Case a – No airleakage



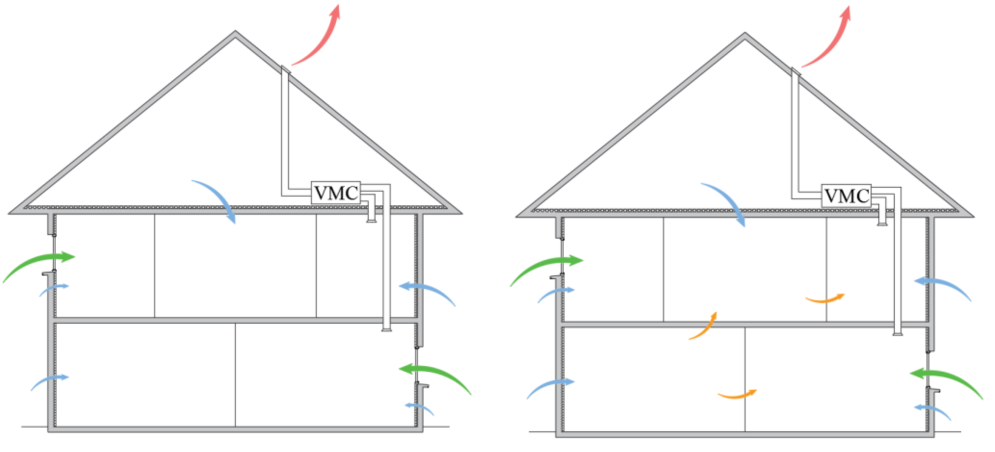
Case b – Evenly distributed



Case c – Unevenly distributed

Case c – Unevenly distributed

Cases d, d2 / d3, d4
+ Uneven internal distribution
Heavy structure / Wooden structure
Measured / Calculated from Guyot et al. 201



Occupancy schedules

- **From the French national campaign on IAQ of dwellings from 2005 (Zeghnoun, Dor, et Grégoire 2010) :**

1. A unique schedule for each day of the week all the yearlong,
2. A time spent in the house divided for each occupant by 9h20 spent in its bedroom, 2h50 spent in the living room, 2h40 spent in the kitchen (5h30 in case of open kitchen on living room) divided in three periods for breakfast, lunch and dinner, 40 minutes spent in the bathroom.
3. A ventilation high-speed in the kitchen switched-on for 1 hour twice a day at the beginning of lunch and dinner periods.

Zeghnoun, Abdelkrim, Frédéric Dor, et A. Grégoire. 2010. « Description du budget espace-temps et estimation de l'exposition de la population française dans son logement »

Pollutants emissions

g_{low}= 4.5 µg.h^{-1}.m^{-2}
g_{ed}= 12.0 µg.h^{-1}.m^{-2}
g_{high}= 23.6 µg.h^{-1}.m^{-2}

- **Formaldehyde emitted continuously**
  - Low / Medium / High – emission class
    - calculated from unpublished literature about IAQ and Q measurements on ten low-energy houses
- **Calculated IAQ performance indicators (per room):**
  - Compared to the ELV of 9 µg/m^3 (USA-California) as proposed by (Cony Renaud Salis et al. 2017)
  - Average concentration
  - Percentage of time exceeding the ELV
  - Occupant exposure

$$E_{max} = \max_j \left(\sum_i C_j(t_i) * t_i \right)$$

Cony Renaud Salis, L., Abadie, M., Wargocki, P., Rode, C., 2017. Towards the definition of indicators for assessment of indoor air quality and energy performance in low-energy residential buildings. Energy and Buildings 152, 492–502. https://doi.org/10.1016/j.enbuild.2017.07.054

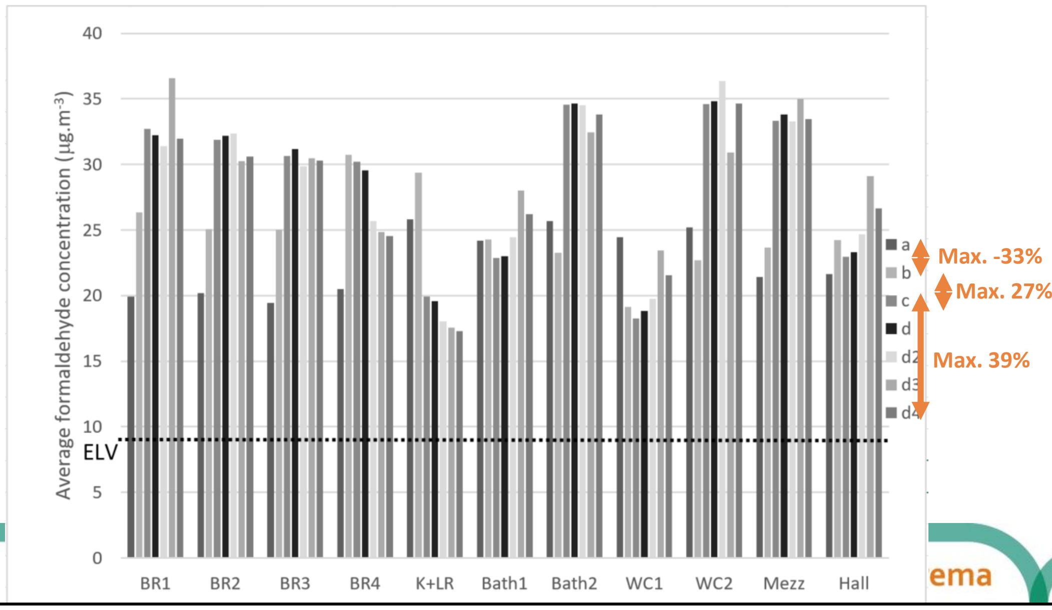
Description of the model and assumptions

- **Building model**
  - 1 room = 1 zone = 1 pollutant concentration
  - Indoor temperature : 20°C (heating period)
  - Closed doors
- **Boundary conditions**
  - Typical meteorological data of a typical year in Lyon, France (ASHRAE IWEC Weather file, 2001)
    - Wind at the building: power-law with 0.3287 modifier factor, suburban area and a 8.5 m-hig
    - Pressure coefficients from the EN 15242 (CEN 2007), i.e +0.5 (upwind) and -0.7 (downwind)
  - Constant outdoor formaldehyde concentration of 3 µg/m^3

Results and discussion

Impact of detailed airleakage data on average formaldehyde concentration
High-emission scenario, exhaust-only ventilation.

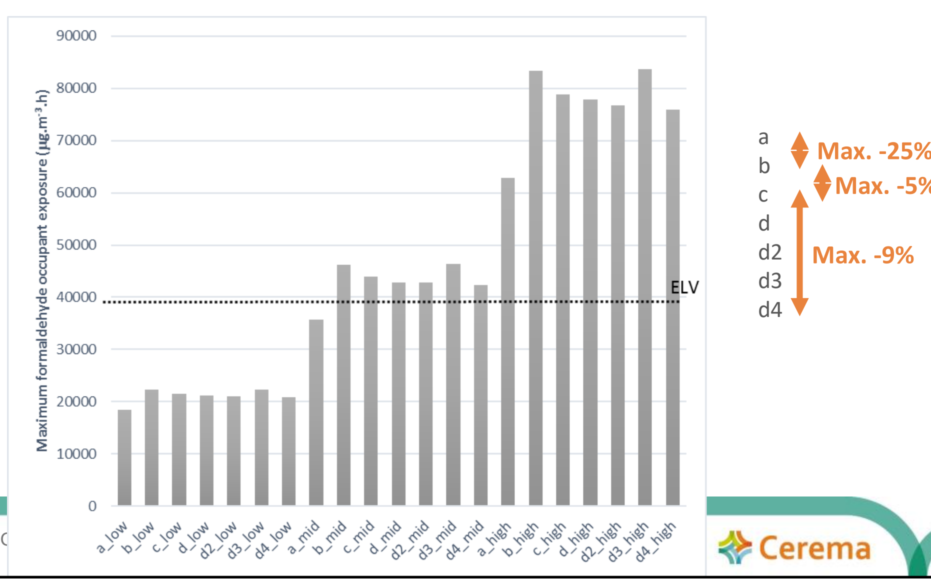
[0.9-4.1] ELV, 99.9%.



Results and discussion

Impact of airleakage distribution on maximum exposed occupant to formaldehyde
Three levels of emissions, exhaust-only ventilation.

High: [1.6-2.1] ELV-exposure, Medium: [0.9-1.2] ELV-exp., Low: [0.5-0.6] ELV-exp.



Conclusions

- **IAQ performance indicators based on formaldehyde are rarely under the ELV, except for the lower emission scenario with the balanced ventilation system**
- **Relevance of using detailed data on envelope airleakage**
  - gaps on average formaldehyde concentrations can reach 52% with exhaust-only ventilation and 18% with the equivalent balanced ventilation.
- **Relevance of using detailed data on internal partition walls airleakage**
  - worthwhile with an exhaust-only ventilation system (can reach 20%) but non useful with balanced ventilation systems.
- **Such results must be confirmed**
  - On other metrics based on other parameters ($PM_{2,5}$, humidity, CO_2)
  - With other house geometries
  - With lower envelope airleakage
  - With smart ventilation strategies
- **As a general perspective: the need of data on pollutant emission rates, at a house scale.**

Cerema

AIVC TightVent Europe venticool

Thank you for your attention !

Gaelle.guyot@cerema.fr

Further information available soon with:
- The PhD manuscript
- A journal paper

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Residential Balanced Ventilation and its Impact on Indoor Pressure and Air Quality

Boualem Ouazia Ph.D.

Daniel Aubin, Doyun Won, Wenping Yang, Stephanie So, Chantal Arsenault, Yunyi Li and Jacqueline Yakobi-Hancock

The Construction Research Centre

The 39th AIVC Conference

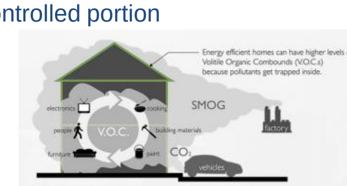
Juan Les Pins September 18-19, 2018

National Research Council Canada | Conseil national de recherches Canada

Canada

Background

- Rational and predictable ventilation is a prerequisite to establish and maintain IAQ
- Air entering a house is usually a mixture of
  - ✓ Ventilation supply air – desired and controlled portion
  - ✓ Infiltration air – uncontrolled portion



- Difference of few Pascals are enough to generate airflows between zones (room, attic, garage, outdoor, etc.)
- Airflows can transport contaminants between these zones
- Canadians homes are often at negative pressure than their attached garages and outdoor, particularly in winter (Graham 1999)
- Contaminants present there will find their way into the occupied spaces

Project Motivation

Problem Statement - Ventilation Standards ASHRAE 62.2 and CSA F326-M91

- ✓ *Entire house is a single, well mixed zone,*
- ✓ *No difference between different whole-building ventilation systems in providing effective ventilation*
- ✓ *Ventilation rates are set to be high enough to accommodate the worst performing system (which is single point exhaust)*

Research questions

- ✓ *Do different whole-building ventilation systems perform significantly differently in terms of their ability to deliver uncontaminated ventilation air to occupants?*
- ✓ *What is the overall IAQ impact of operating an unbalanced whole-building ventilation systems (exhaust-only) versus balanced ventilation system?*

Hypothesis

- ✓ *Balanced ventilation reduces infiltration by creating indoor positive pressure*
- ✓ *Positive pressure between indoor and outdoors can be used for decreasing the concentration of contaminants in indoor air*

Methodology

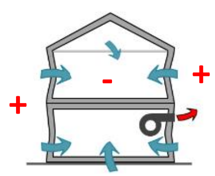
Side-by-side Testing using NRC's CCHT Twin Houses

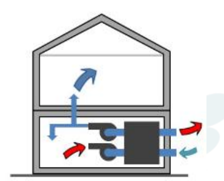
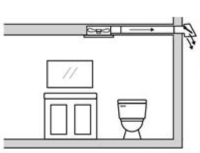
Reference House

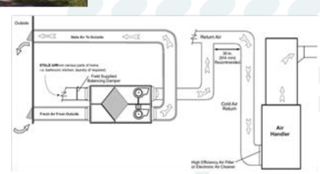
- Exhaust fan from master bathroom
- Furnace

Test House

- ERV
- Exhaust from kitchen and bathrooms
- Furnace






Methodology

Experimental Design and Performance Measurements

Test #	Type	House 1 (M24-B)	House 2 (M24-C)
1	Baseline	No mechanical ventilation	No mechanical ventilation
2	Partial mixing	Exhaust ON / ERV OFF	ERV ON / Exhaust OFF
3	Partial mixing	ERV ON / Exhaust OFF	Exhaust ON / ERV OFF
4	No mixing	ERV ON / Exhaust OFF	Exhaust ON / ERV OFF
5	No mixing	Exhaust ON / ERV OFF	ERV ON / Exhaust OFF

- Air leakage characterization – fan depressurization tests
- HVAC characterization - central air distribution system airflows and ventilation systems airflows.
- Differential pressure in designated zones with respect to outdoor, attic and garage
- Perfluorocarbon tracer gas (PFT) testing to determine zone air change rates.
- Multi-zone sampling of volatile organic compounds (VOCs), formaldehyde.
- Energy consumption

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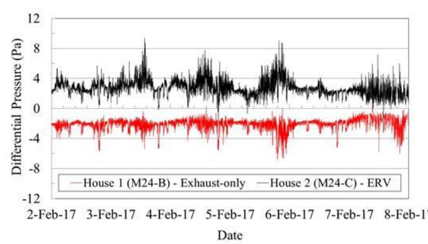
Results

Pressure between Indoors and Outdoors

Location of envelope differential pressure measurements

Floor	Zone / Facade	Differential Pressure
Basement	North Façade	Indoor to Outdoor
Main Floor	Living Room / North Façade	Indoor to Outdoor
	Dining Room / South Façade	Indoor to Outdoor
	Hallway / Entry	Indoor to Garage
Second Floor	Master Bedroom / North Façade	Indoor to Outdoor
	Bedroom 2 / North Façade	Indoor to Outdoor
	Bedroom 3 / South Facade	Indoor to Outdoor
	Hallway	Indoor to Attic



Average measured indoor pressures to outdoor (including adjacent zones)

House	Test 1	Test 2	Test 3	Test 4	Test 5
M24-B	+0.6 (Baseline)	-1.5 (Exhaust)	+0.7 (ERV)	+0.8 (ERV)	-1.8 (Exhaust)
M24-C	+0.7 (Baseline)	+2.8 (ERV)	-1.3 (Exhaust)	-0.9 (Exhaust)	+2.8 (ERV)

Average measured indoor pressures to outdoor (excluding adjacent zones)

House	Test 1	Test 2	Test 3	Test 4	Test 5
M24-B	+0.5 (Baseline)	-2.9 (Exhaust)	+1.0 (ERV)	+1.2 (ERV)	-2.4 (Exhaust)
M24-C	+0.3 (Baseline)	+2.2 (ERV)	-1.7 (Exhaust)	-1.4 (Exhaust)	+2.8 (ERV)

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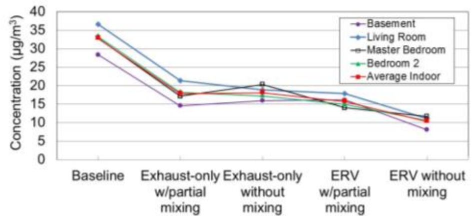
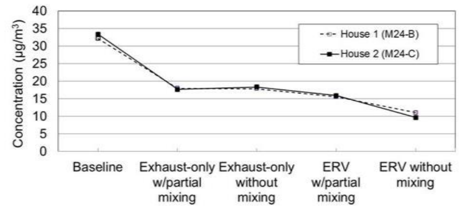
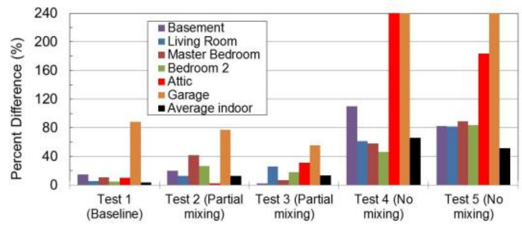
Results

Formaldehyde – Whole-house Percent difference







House Average Indoor Concentration of Formaldehyde significantly reduced

Heating Season)

ERV over Exhaust-only

↓37% to ↓70%

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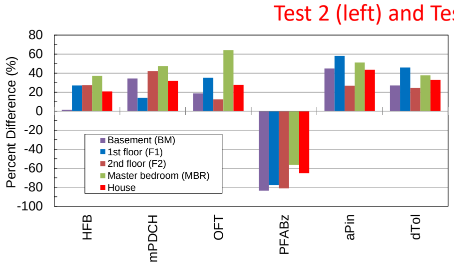
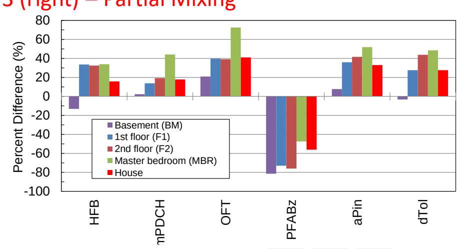
Results

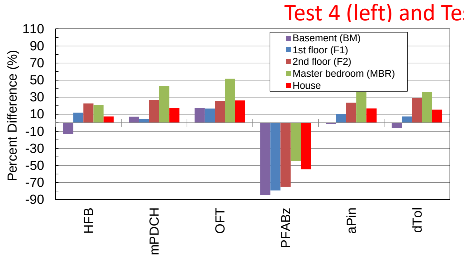
Indoor Air Concentration of PFTs and VOCs

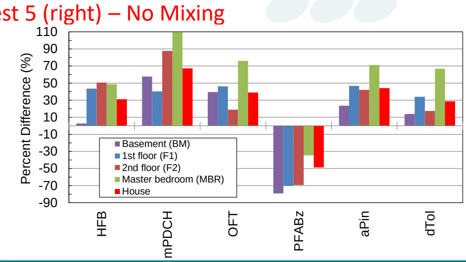
Test 2 (left) and Test 3 (right) – Partial Mixing





Test 4 (left) and Test 5 (right) – No Mixing





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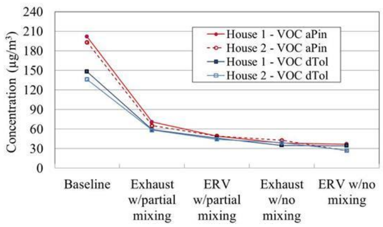
Results - VOCs Concentration Reduction

Whole-house VOCs Concentration Reduction

Deployed VOCs

α-pinene and Toluene-d8



α-pinene

Test #	House 1		House 2		% difference Over exhaust
	Ventilation System	aPin [μg/m³]	Ventilation System	aPin [μg/m³]	
1	Baseline	201.7	Baseline	193.1	-
2	Exhaust	70.8	ERV	49.3	-30.4%
3	ERV	49.0	Exhaust	65.2	-24.8%
4	ERV	36.7	Exhaust	42.8	-14.3%
5	Exhaust	38.4	ERV	26.7	-30.5%

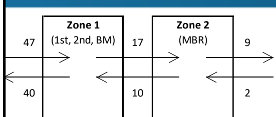
House average indoor concentration of deployed VOCs significantly reduced

Toluene-d8

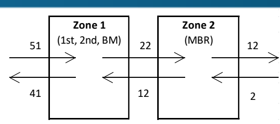
Test #	House 1		House 2		% difference over exhaust
	Ventilation System	dTol [μg/m³]	Ventilation System	dTol [μg/m³]	
1	Baseline	148.1	Baseline	136.1	-
2	Exhaust	58.9	ERV	44.4	-24.6%
3	ERV	45.9	Exhaust	58.5	-21.5%
4	ERV	34.2	Exhaust	39.5	-13.4%
5	Exhaust	35.1	ERV	27.3	-28.6%

Results

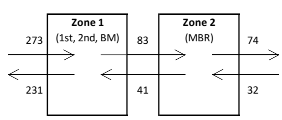
Whole-house Air Change Rate



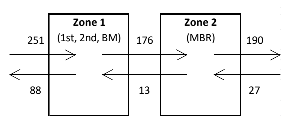
M24-B (no mechanical ventilation)



M24-C (no mechanical ventilation)



M24-B (ERV)



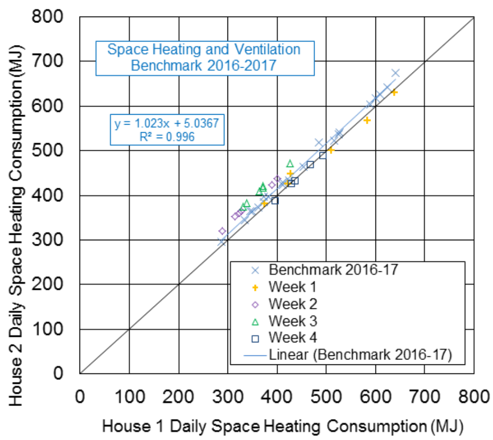
M24-C (exhaust only)

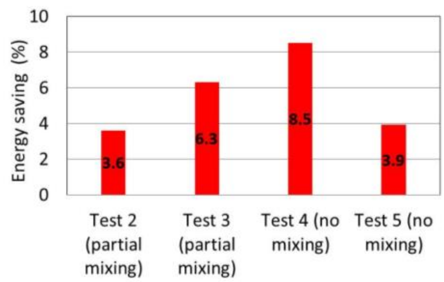
Ventilation Type	No ventilation	Partial mixing		No mixing	
House/Test #	Test 1	Test 2	Test 3	Test 4	Test 5
M24-B	0.06	0.28	0.34	0.38	0.38
	Baseline	Exhaust	ERV	ERV	Exhaust
M24-C	0.07	0.33	0.29	0.36	0.49
	Baseline	ERV	Exhaust	Exhaust	ERV

Percent difference (%) over exhaust-only				
Test 1	Test 2	Test 3	Test 4	Test 5
9	15	16	6	28

Space Heating and Ventilation

Weekly Average Energy Saving





Conclusions

- Balanced ventilation (ERV) was superior as a whole-house ventilation strategy,
- Superior because of the created indoor positive pressure (1-3 Pa),
- House operated with a balanced ventilation had higher whole-house air change rate regardless of the mixing,
- Baseline test (no ventilation) showed little and similar inter-zonal airflows - both houses had similar patterns of air exchanges between zones.
- All cases showed that inter-zonal flows were better balanced in the house with balanced ventilation,
- Significantly reduced indoor VOCs/Formaldehyde concentrations,
- As a further positive side, house operated with ERV showed energy savings of 4 to 8% in winter.


Thank you
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Isolation Rooms - CFD Simulations of Airborne Contamination Through Doors During Passage

Associate Professor Trond Thorgeir Harsem
Dr.ing Bård Venås
M.Sc. Andreas Welde Vikan
M.Sc. Merethe Lind
M.Sc. Petri Kalliomäki
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TURKU AMK TURKU UNIVERSITY OF APPLIED SCIENCES
OSLO METROPOLITAN UNIVERSITY

Introduction

- Risk of spreading airborne infectious diseases such as influenza A/H1N1 or SARS is increasing
- The Norwegian National Influenza Pandemic Preparedness Plan states that Norway must be able to face a possible pandemic with an attack rate of 25%
- This means that hospitals must be able to take up to 14-16500 admissions (0.025-0.03% of the population in Norway)
- There is only a limited number of Airborne Infection Isolation Rooms (AIIRs) in each hospital in Norway
- The rooms are expensive to build and airflow control to avoid contamination is often complicated

Goal of the Research Project

Is it possible to build a 90% solution using only 10% of the costs compared to an ordinary AIIR?

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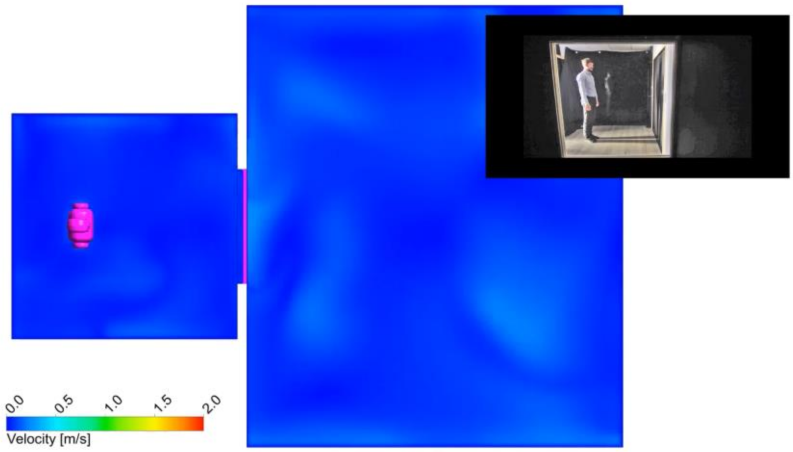
Method

Using a Patient Room as a Reference Case

- Computational Fluid Dynamics (CFD) simulations
- Laboratory measurements to verify the CFD simulations

Presented at the 39th AIVC Conference 2018 in Antibes Juan-les-Pins, France

Entering the Patient Room



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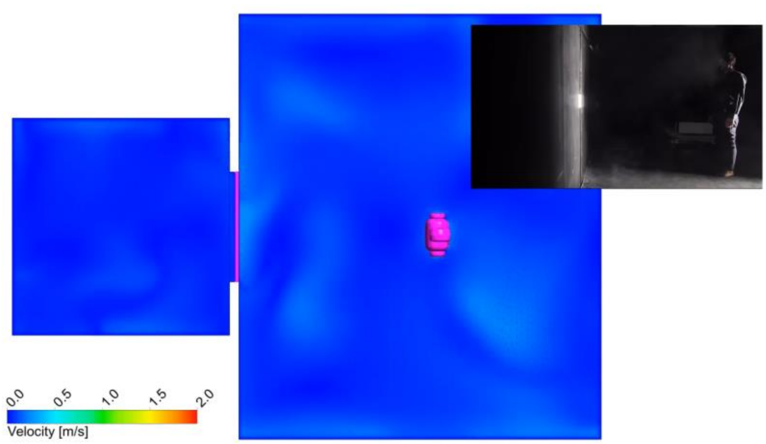
Exiting the Patient Room



Presented at the 39th AIVC Conference 2018 in Antibes Juan-les-Pins, France

Results and Conclusions

Simulation no.		1	2	3	4
Description		Door only	Exit	Entry	Entry (alt.)
CFD model		755 litres	781 litres	1098 litres	682 litres
Experiments	Average	765 litres	729 litres	802 litres	
	Max	810 litres	751 litres	843 litres	
	Min	720 litres	684 litres	770 litres	
Difference (exp. vs. CFD)		1 %	- 7 %	-27 %	+ 18 %

- Yes, we find that our hypothesis is possible and our further research shows that with changing the ventilation flow it is possible to reach our goal

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Thank you for your attention

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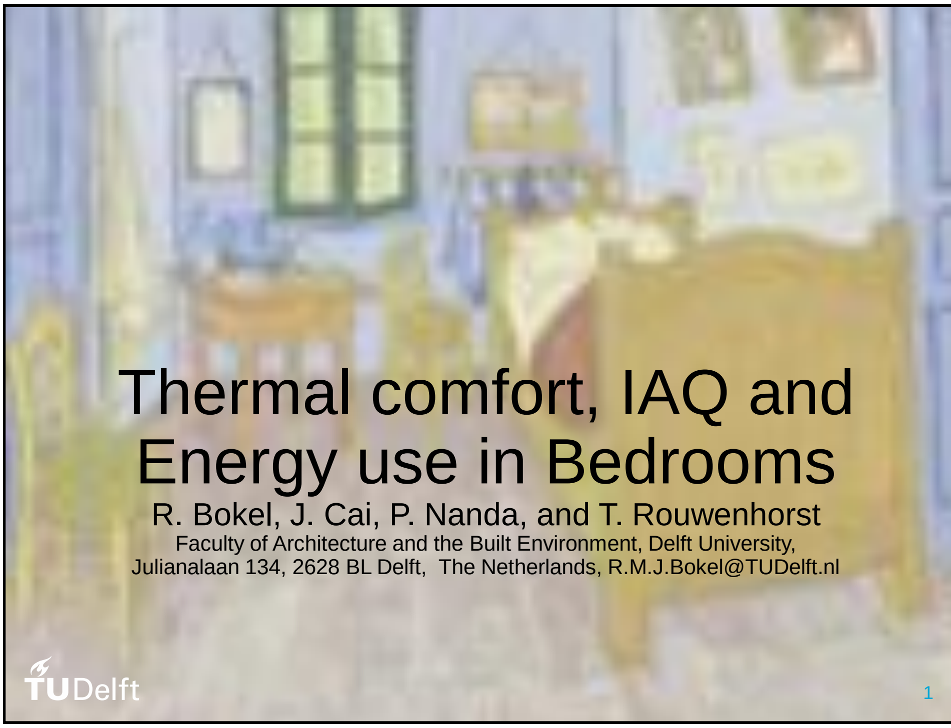

Thermal comfort, IAQ and Energy use in Bedrooms

R. Bokel, J. Cai, P. Nanda, and T. Rouwenhorst
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TUDelft

Is it possible to save energy by lowering the bedroom temperatures in winter?

And not compromise air quality!

Method

Questionnaire

- 1. Occupant info
- 2. Built environment
- 3. Thermal comfort sensation, quality of sleep

Measurements

- 16 bedrooms of Master students
- Two week temperature measurements at bedside table
- Cold March 2018.
- CO_2 measurements 1-2 nights

TU Delft

Results

Questionnaire

- Energy label A-G
- Majority of students do not easily wake up in the morning
- More students feel slightly warm to warm than cool and slightly cool

Measurements

- High temperatures at night (20-25 °C)
- CO_2 only in 2 cases > 1100 ppm
- increase in CO_2 at night 400 ppm- 700 ppm.

TU Delft

Conclusion

Is it possible to save energy by lowering the bedroom temperatures in winter?

First results indicate:

Yes, due to very high measured temperatures and generally no IAQ problems

(but students are not entirely representative)

See poster and paper for details

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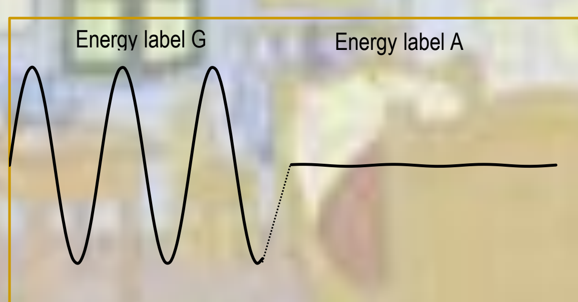

TU Delft

An intervention study of $PM_{2.5}$ concentrations measured in domestic kitchens

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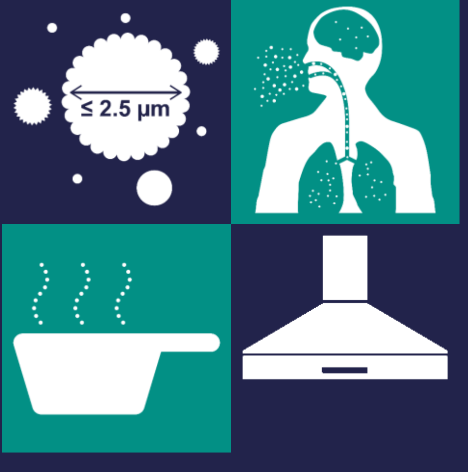
Aims



- Simple intervention study to investigate:
  - What $PM_{2.5}$ concentrations are found in student kitchens?
  - Can concentrations be reduced using installed equipment and changing behaviour?

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The Houses

A	B	C	D	E
FAULTY		UNKNOWN	RECIRCULATING	VENTING

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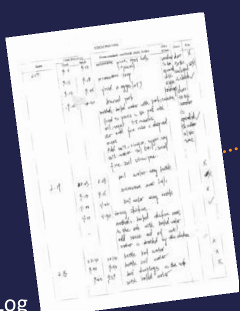
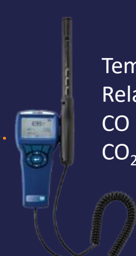
Test Set Up



Cooking Log

$PM_{2.5}$



Temperature
Relative Humidity
CO
CO_2

A

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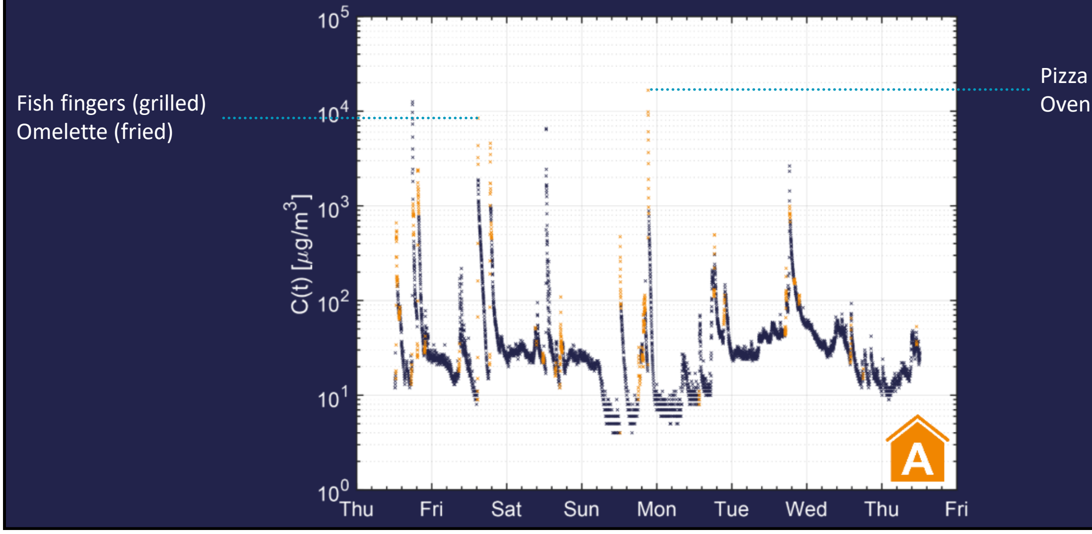
Results: Influence of Cooking



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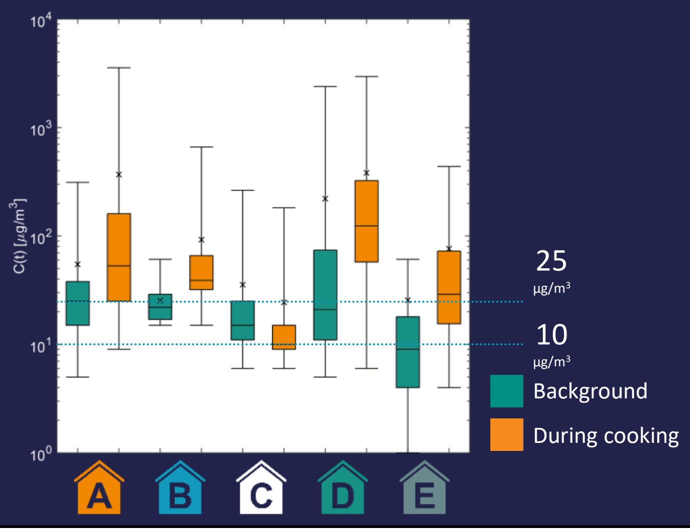
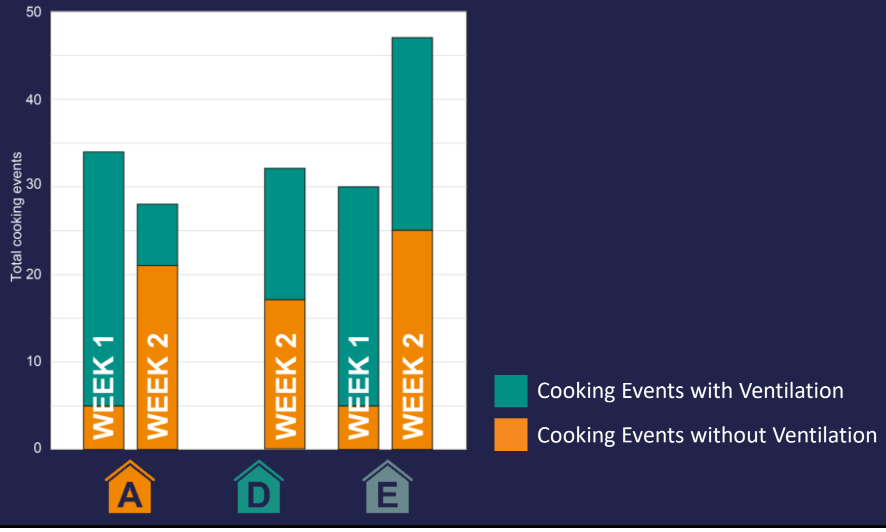
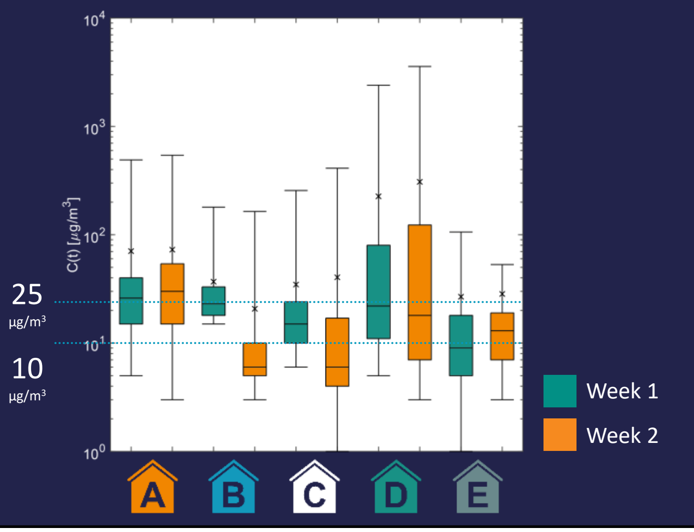
Results: Influence of Cooking



Results: Behaviour



Results: $PM_{2.5}$ Concentrations



Summary

- Simple intervention study
- Student houses
- Only observed reduction in 1 of 5 houses
- Design and maintenance of cooker hoods may be important
- Effectiveness limited by users

Thank you

Catherine O'Leary

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Measured Pollutant Performance of Island Overhead Kitchen Exhaust

39th AIVC Conference 2018

Iain Walker, Gabriel Rojas and Jordan Clark
iswalker@lbl.gov

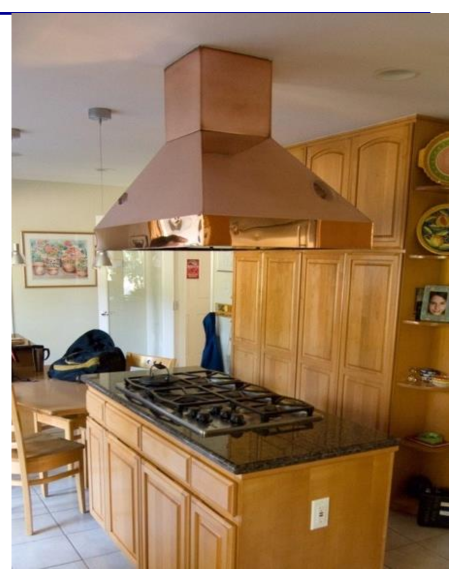
Introduction

Objectives:

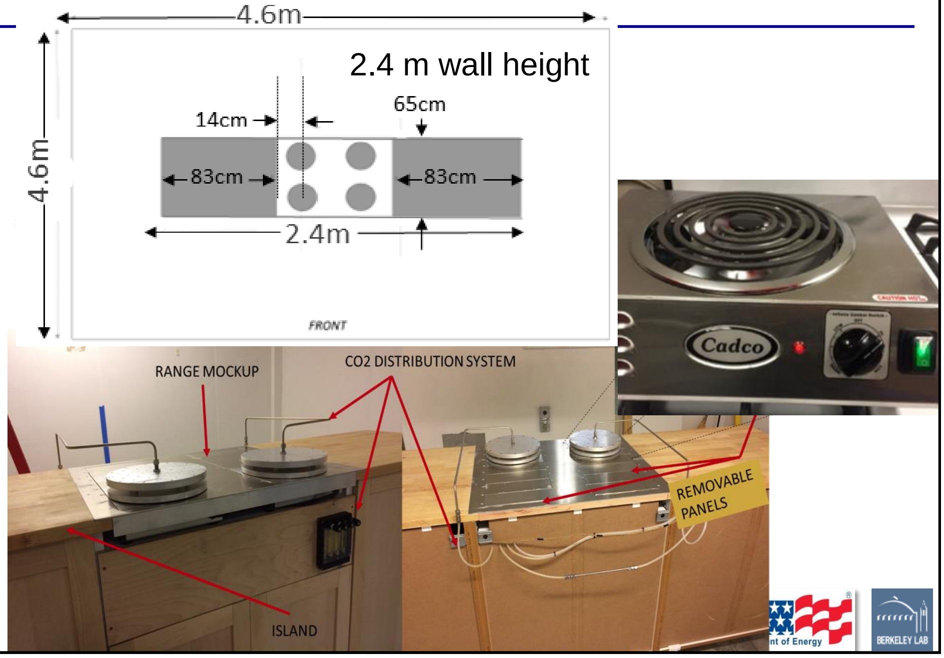
1. Develop a test procedure suitable for use in ratings
2. Demonstrate test procedure

Based on existing ASTM E 3087 Standard for wall-mount hoods

- Uses tracer gas + standardized emitters, burner temperatures, etc.
- Measures Capture Efficiency: CE

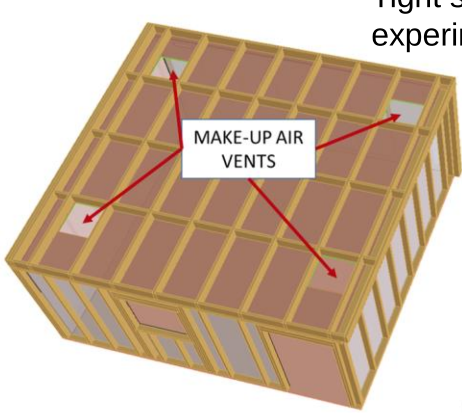


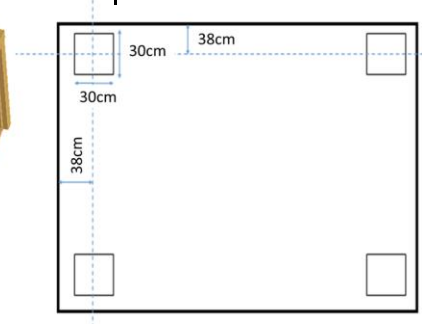
Test Chamber



Make Up Air- MUA

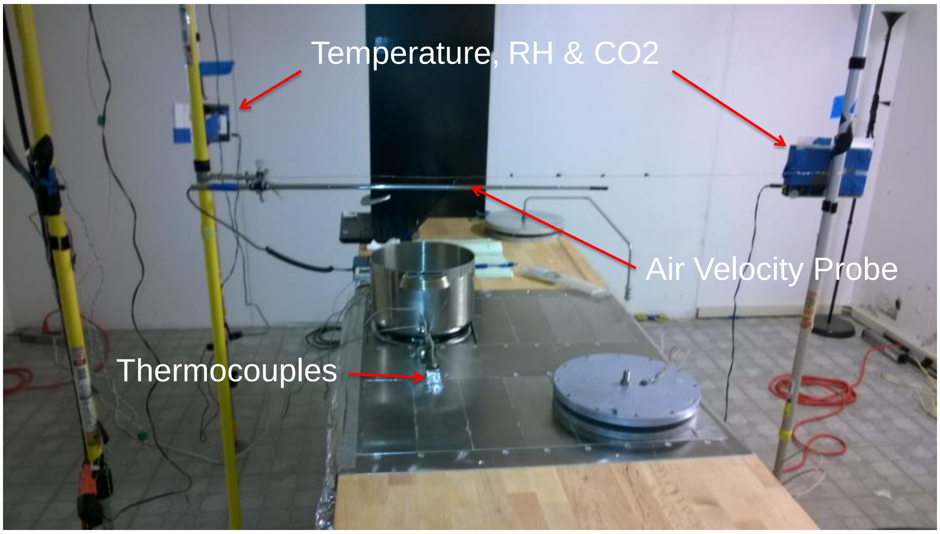
Tight structure: <0.5L/s at typical experimental pressures



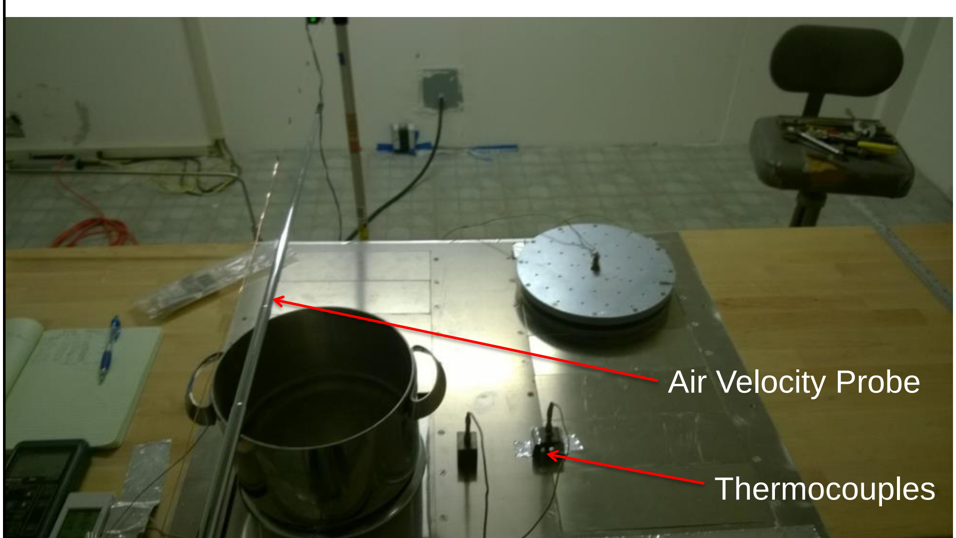


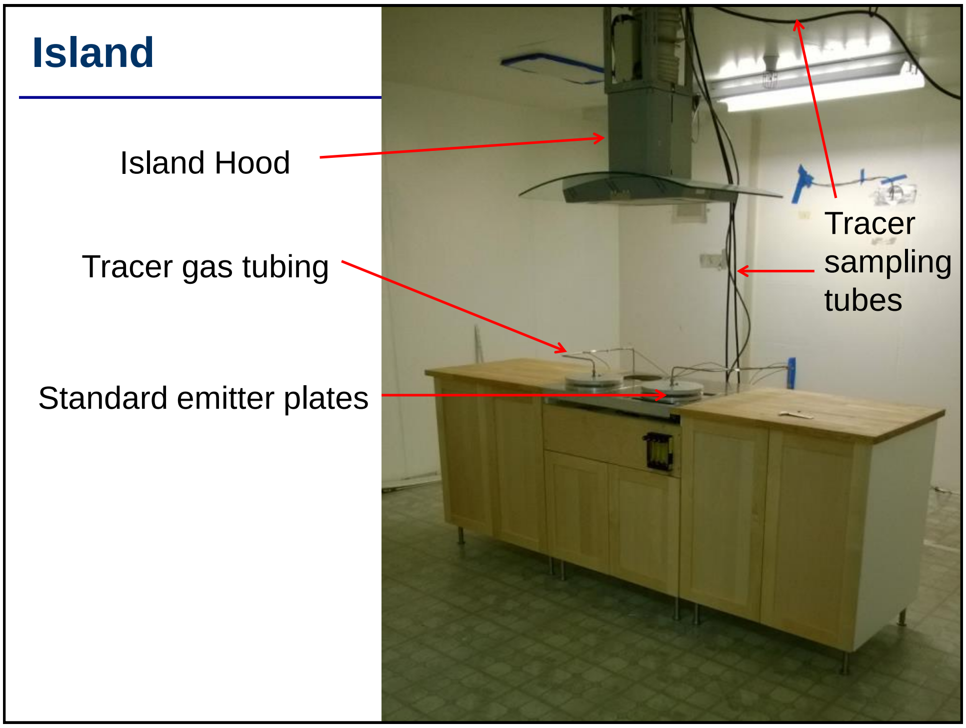
MUA - Far away from hood/cooktop to minimize interference
Minimize entering air velocity:
- Less than 0.4 m/s at diffuser face
- Less than 0.1 m/s 0.5 m from face

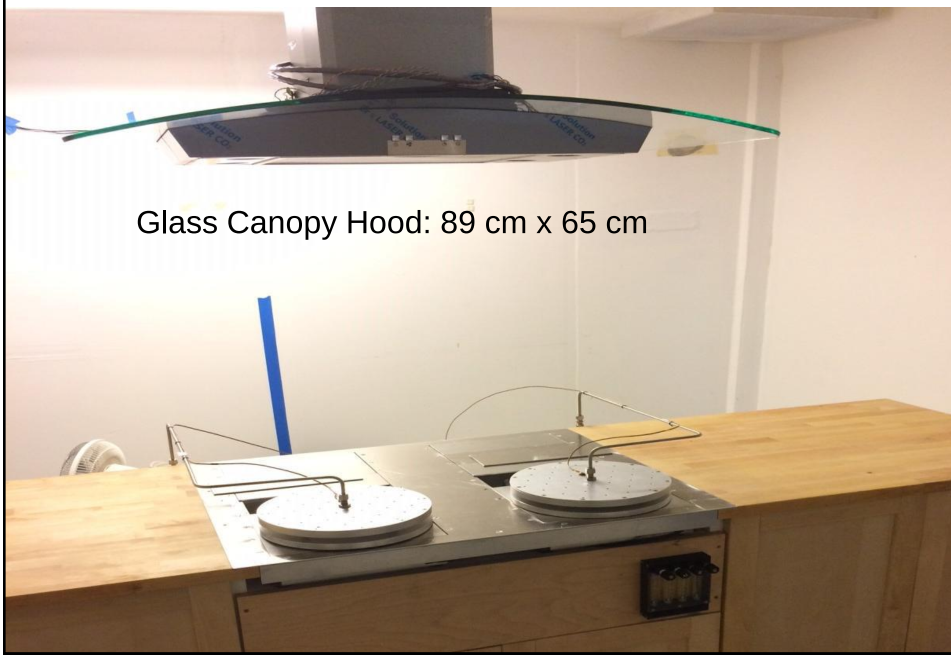
Apparatus



Apparatus




Island
Island Hood
Tracer gas tubing
Standard emitter plates
Tracer
sampling
tubes

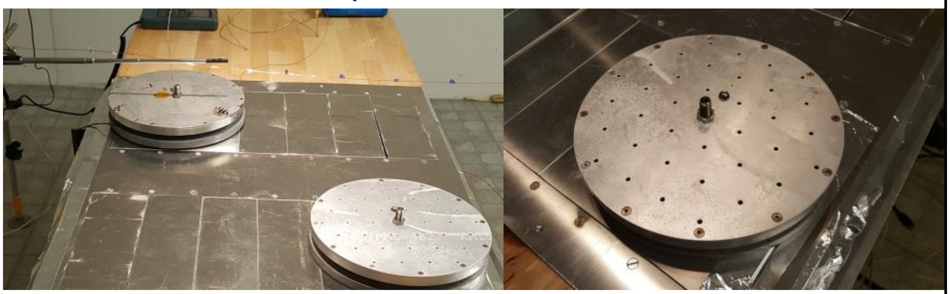


Glass Canopy Hood: 89 cm x 65 cm

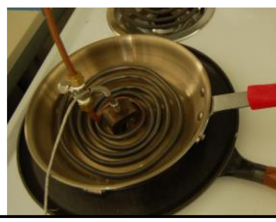
Underside of hood

Tracer Gas Injection – CO_2 @ 2000ppm in exhaust

- Standard emitter plate



- Perforated tube submerged in boiling water in a pot



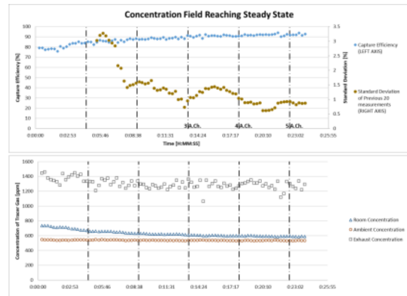
Tends to give higher CE
- Tall pot –emits closer to hood
- 500-750W to boil water
- Above 100 L/s very similar to standard plate

Tracer Gas Sampling

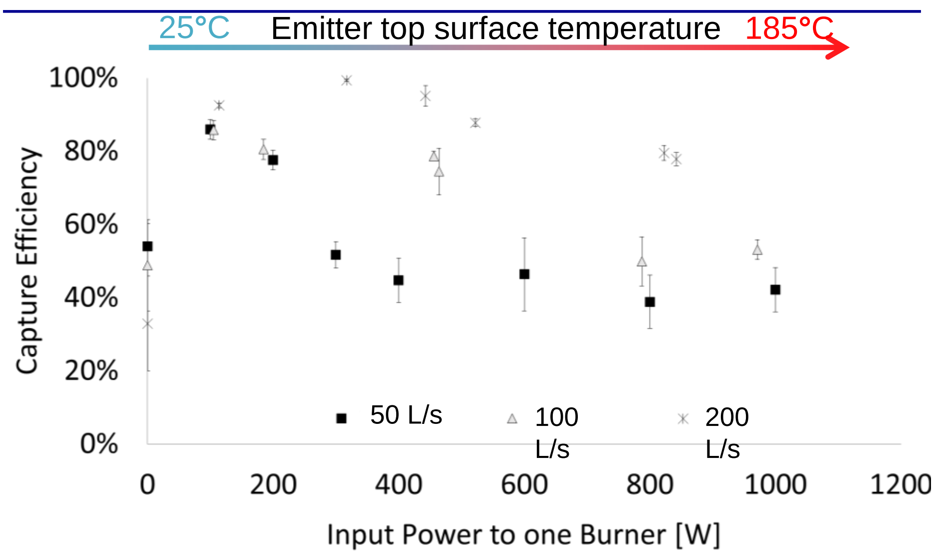
- Sample locations;
  - Half height between the counter top and bottom of the hood, 0.5m into room
  - Entering air
  - Exhaust air

Test procedure notes

- Large room means:
  - Two to four hours for steady-state thermal conditions
  - One to two hours for CO_2 equilibrium
- High power = high temp
  1000W = 550°C burner
  - Dangerous and led to high surface temps on cooktop that interfered with getting consistent results
- Standard deviation of measurements reduced if instantaneous CE averaged rather than CE calculated from averaged concentrations

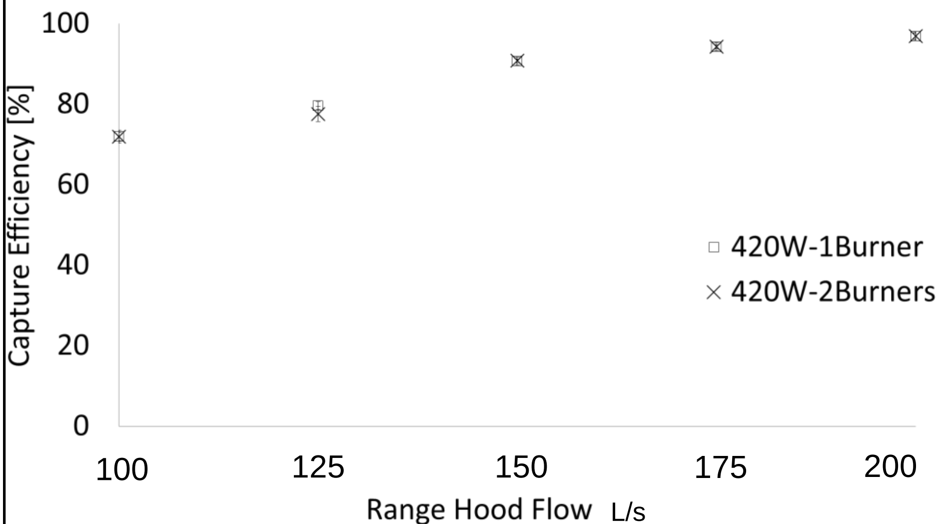


Results – Power and Airflow

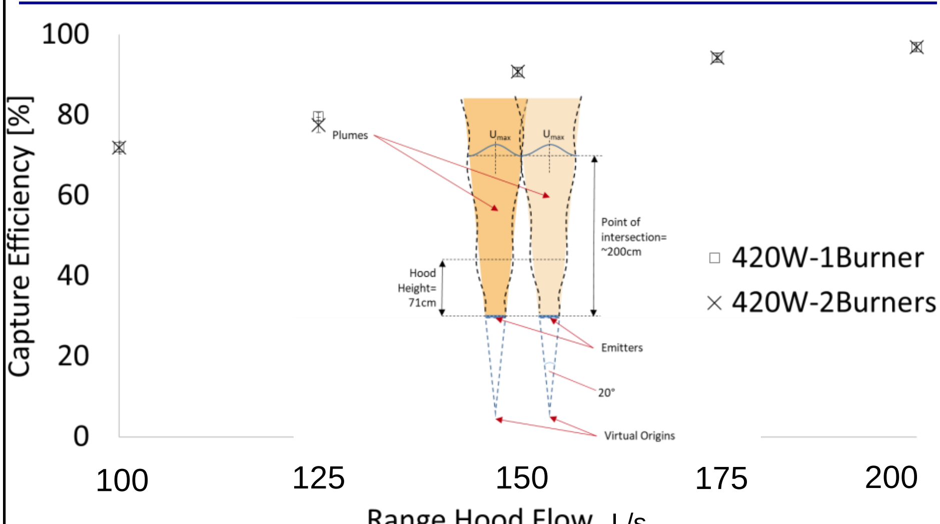


More flow = better capture
Less variability above 400W

Results – One or Two Burners: Doesn’t Matter



Results – One or Two Burners



200
L/s

Results – Capture Efficiency changes with burner location

Mean
Standard Deviation
over 15 minures

Back Left **77%** **+/-1.6%**	**Back Right** **76%** **+/-2.6%**
Middle Left 91% +/-0.4%	Middle Right 88% +/-0.6%
Front Left 80% +/-2.0%	Front Right 76% +/-2.4%

At 435W & 106 L/s exhaust & 61 cm mounting height

Summary

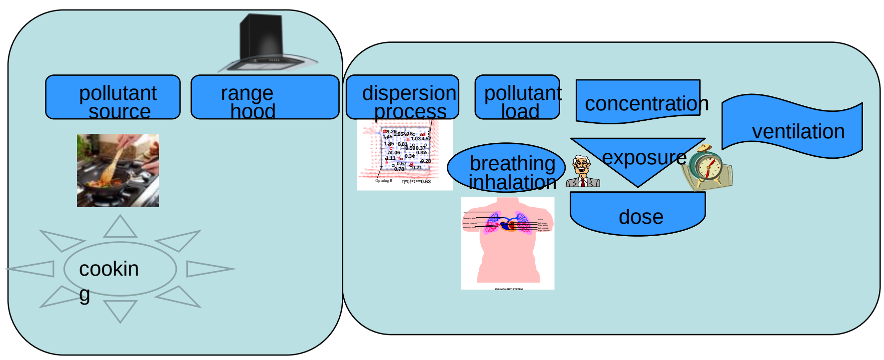
- OK to test a single burner
- Important to specify burner location on cooktop
- High sensitivity to flow at low air flows
- Calculate CE from average of each sample rather than from average concentrations – about 2% CE uncertainty
- Important to specify emitter power (or surface temperature) and don't test at full power!
- Takes several hours to perform a test

ASSESSMENT OF RANGE HOODS BASED ON EXPOSURE

Wouter Borsboom, Willem de Gids, Iain Walker, and Piet Jacobs

RANGE HOOD EFFICIENCY? IT'S EXPOSURE THAT MATTERS !

POLLUTANT PROCESS DURING COOKING



range hood efficiency

human exposure

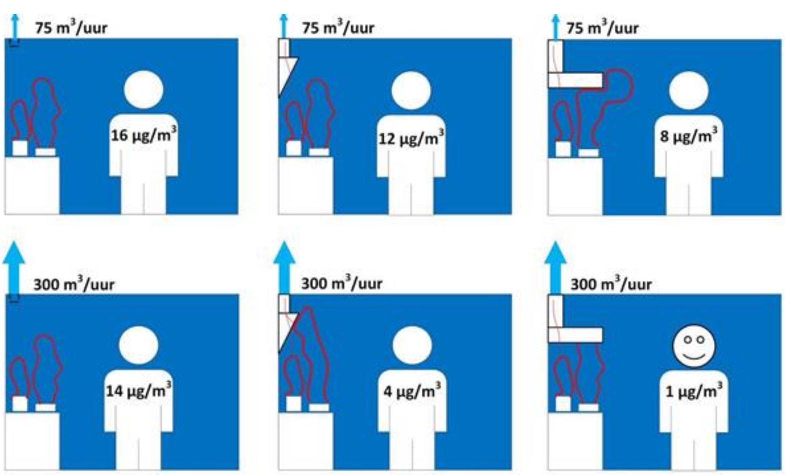
INFLUENCING FACTORS ON THE HOOD EFFICIENCY

- Hood design
- Flowrate(s)
- Height above hob
- Adjacent cupboards
- Source strength
- Position of source
- Type of the source
- Gas/ceramic/induction

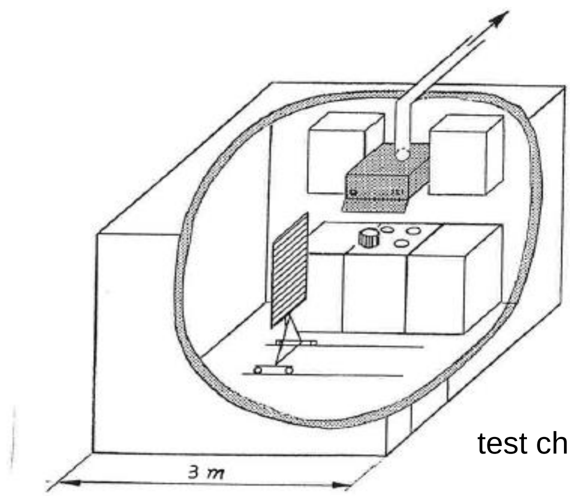
EXPOSURE STUDY

- Cooking a full Dutch meal for 2,2 persons causes an emission of 35 mg PM2,5
- Dutch people: a meal is cooked on average 5 times a week
- An open kitchen/living with a volume of 96 m^3
- Cooking 10 minute emission constant emission rate of 41,6 µg/s
- Dilution flow of 28 dm^3/s for the kitchen/living

RESULTS OF EXPOSURE STUDY

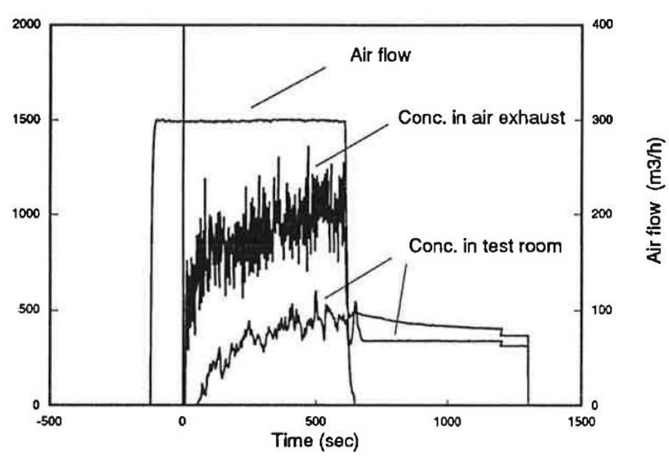


DISTURBANCE



test chamber of Geerinckx and Wouters (1991)

EFFICIENCY INCLUDING INTERFERENCE

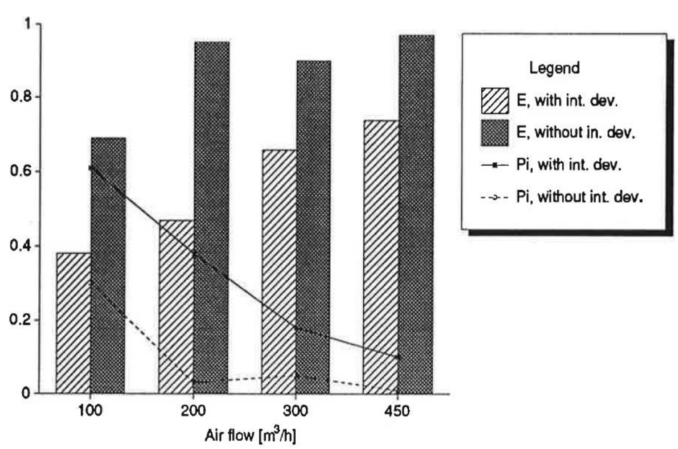


POLLUTANT INDEX ACCORDING GEERINCKX AND WOUTERS

$$P_i = \frac{C * 10^{-6}}{\frac{q}{100}(1 - e^{-\frac{100}{V}t})}$$

- Whereby P_i : pollution index of the kitchen hood
- C: concentration of tracer gas (PPM)
- q : tracer gas injection flow (m^3/h)
- t : injection time (h)
- V : volume of the room without cupboards (m3)

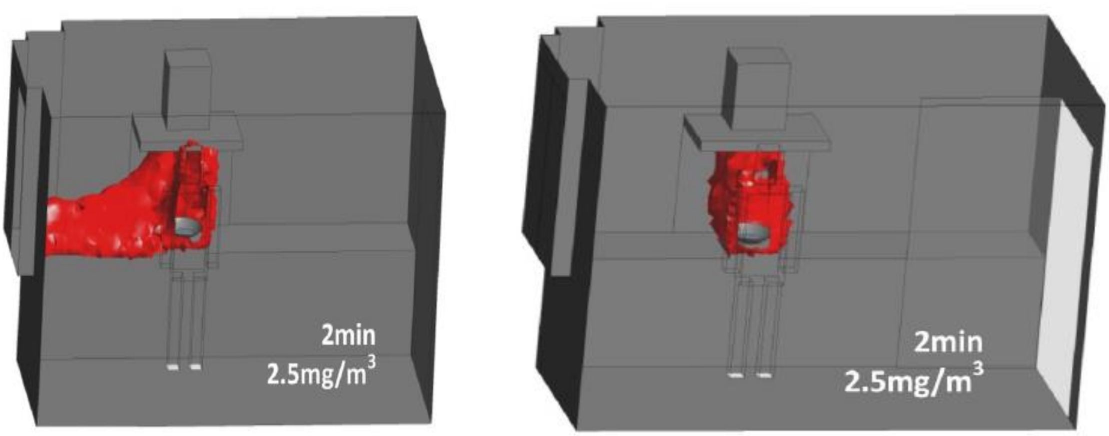
EFFICIENCY, E, AND POLLUTANT INDEX, PI, WITH AND WITHOUT DISTURBANCE



EFFECT OF DISTURBANCE, POLLUTANT INDEX

Air flow (m3/h)	With interference device	Without interference device
450	0.1	0.01
300	0.18, 018	0.06, 0.05
200	0.39, 0.37	0.03,0.03
100	0.61,0.61	0.32,0.29
‘optimal’ 300	0.03	

EFFECT OF OPEN WINDOW (L) AND DOOR (R)

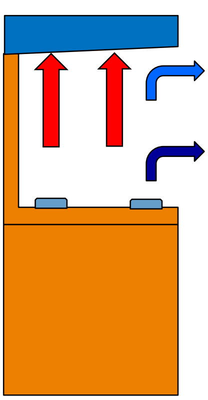


Gao et all (2013)

MODEL DEVELOPMENT OF DISTURBANCE ASSUMPTIONS

- The model is based on mimicking the motions of a cook in the following way:
  - When stir frying the cook moves twice to and from the cook plate
  - The cook moves with a velocity of 0.5 m/s
  - The cooks arm blocks an effective area of 0.075 m2
  - The flowrate of the hood is 50 dm3/s with an efficiency of 80 %
    - Average velocity towards the rangehood is 0.25 m/s
  - A PM2,5 source strength under the hood on the cook plate of 10 µg/s
  - A general kitchen exhaust rate of 21 dm3/s in addition to the hood

INTERFERENCE/DISTURBANCE DUE TO COOKING INCREASING THE EXPOSURE

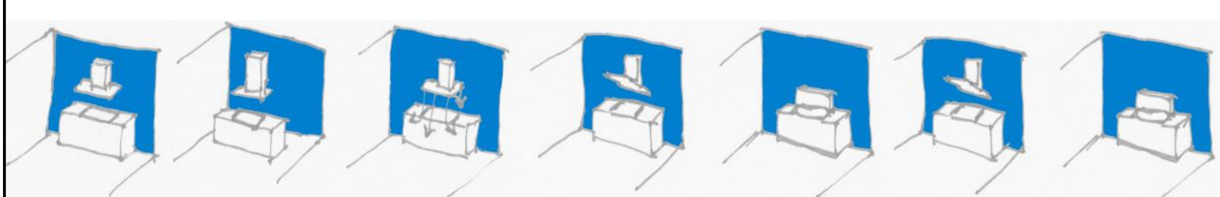


- inefficient exhaust
- smelling
- body movements
- arm movements

CALCULATIONS OF THE DISTURBANCE

- **$q_{\text{dist flow}}$** = $A_{\text{dist cook}} * v_{\text{cook}}$ = **0.075 * 0.5**
- $q_{\text{dist flow}}$ = **37.5 dm^3/s**
- **$C_{\text{av hood}}$** = $q_{\text{source}}/q_{\text{vent hood}}$
- q_{source} = 10 µg/s
- $q_{\text{vent hood}}$ = 50 dm^3/s
- $C_{\text{av hood}}$ = 10/0.050 = **200 $\mu g/m^3$**
- $\Delta C_{\text{dist}} = (q_{\text{re ent}} * C_{\text{av hood}}) / q_{\text{vent kitchen}}$ = (0.00375 *200)/ 0,071 = **10.6 $\mu g/m^3$**.
- **$C_{\text{av kitchen without dist}}$** $= q_{\text{source}}/q_{\text{vent kitchen}}$ =2 / 0,071 = **28.2 $\mu g/m^3$**
- the calculated effect of the disturbance is about **38 %.**

EFFECT OF DIFFERENT TYPES OF RANGE HOOD CONFIGURATIONS



CONCLUSIONS

- The disturbance due to cooks is important for their exposure
- Simple calculations can estimate the reduction of efficiency of range hoods due to disturbance by the cook
- More research on this topic is needed:
  - Measurements of exposure
  - Measurements of disturbances
  - The effect on differences range hoods types

Estimated distributions of PM2.5 concentrations in the kitchens of the English housing stock for infiltration and mechanical ventilation scenarios

Catherine O’Leary

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Department of Architecture and Built Environment
University of Nottingham
@colearyIEQ
Catherine.O’Leary@nottingham.ac.uk

Aims

Predict concentrations in kitchens
Test UK Building Regulations

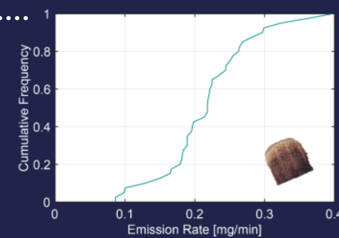
University of Nottingham
UK | CHINA | MALAYSIA

Methods

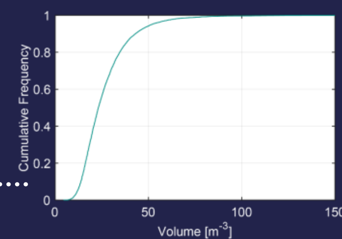
SS   B

$$C_{ss} = C_b + \frac{(1-\eta)G}{(\lambda + k)V}$$

Predict steady state concentrations
Inputs selected stochastically



μ = 0.22 mg/min
σ = 0.065 mg/min

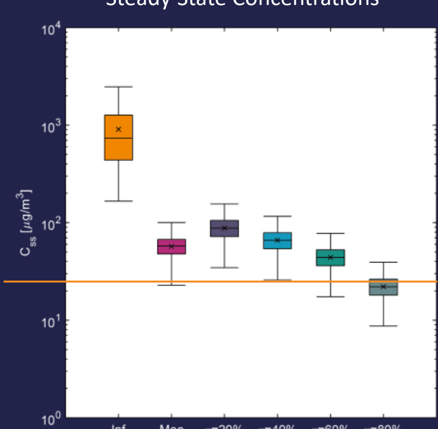


μ = 26.5 m^3
σ = 13.8 m^3

University of Nottingham
UK | CHINA | MALAYSIA

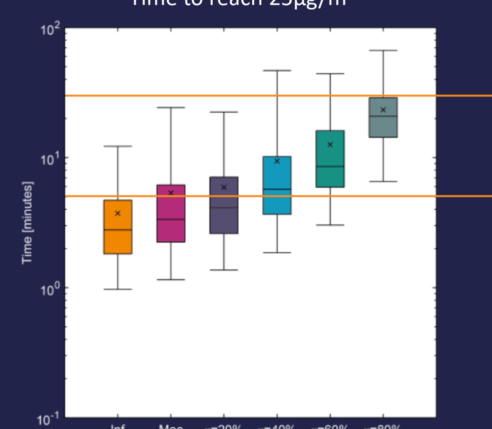
Results

Steady State Concentrations



25
μg/m³

Time to reach 25μg/m³



30
minutes

5
minutes

Conclusions

Thank you

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European Commission

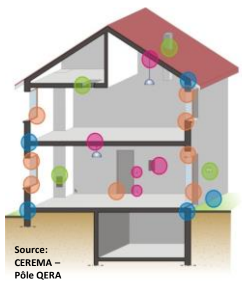
EU support for BIM in energy efficient buildings

Philippe Moseley
Project Advisor
EASME Unit B1 Horizon 2020 Energy

39th AIVC Conference
Smart ventilation for buildings

Juan-les-Pins, 19 September2018

Energy efficient buildings – the skills challenge



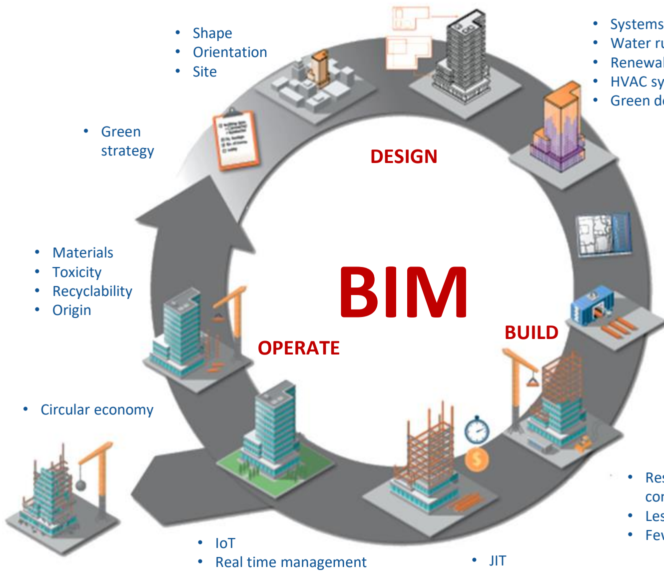
Higher standards

Technological change

Collaboration

European Commission

BIM contributes to sustainable, energy efficient buildings



- Shape
- Orientation
- Site

- Systems & materials
- Water runoff & collection
- Renewable energy systems
- HVAC system
- Green design decisions

- Green strategy

- Simulations
- Daylighting
- Energy-analysis software
- Energy use/m^2
- Energy cost

- Materials
- Toxicity
- Recyclability
- Origin

- Sustainable sourcing
- Recyclability
- Sustainable manufacturing
- Dangerous substances

- Circular economy

- Resource & Energy efficient construction
- Less waste
- Fewer errors

- IoT
- Real time management
- Big data
- Connection to energy grid

- JIT

BIM cycle basis: Lloyd's Register

European Commission

Commission initiatives & support

EUBIM TASKGROUP

- PPD

Support public sector take-up

www.eubim.eu

Support Research & Innovation

- H2020
- Horizon Europe

Support construction value chain and SMEs

- Study "support digitalisation of construction and its SMEs"
- Smart CE marking

Create momentum

- Thematic Group 1: High level Group on Construction
- Conferences/speeches
- LinkedIn: Construction 4.0 Europe

Support horizontal activities

- BIM standardisation
- Digital industrial platform for construction

European Commission

Scope of H2020 efforts on BIM for energy efficiency

Technologies & processes

Research & innovation
(Energy efficient Buildings PPP)

Knoweldge & skills

The BUILD UP Skills initiative

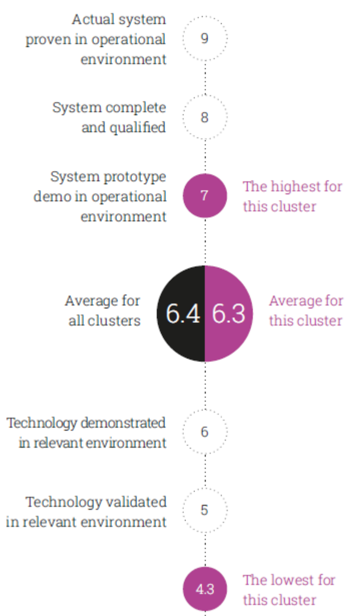
EeB PPP
Project review
2018

May 2018

www.ectp.org

www.buildup.eu

Technology Readiness Level for this cluster



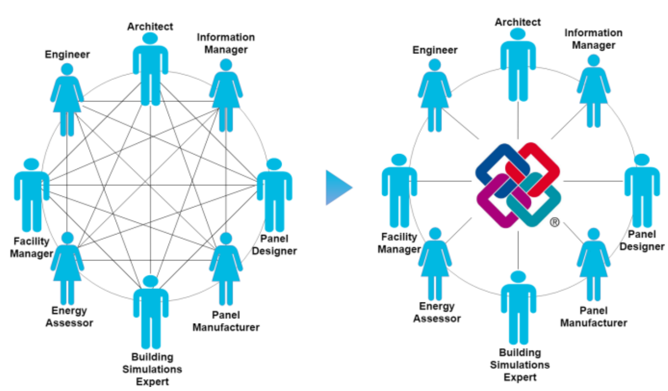
6 EeB PPP Impact
10 Design
12 Technology building blocks
14 Advanced materials and nanotechnology
16 Construction process, end of life, cross-cutting information
18 Energy performance monitoring and management
20 ICT
22 BIM/ Data/ Interoperability

14 CASCADE
22 COOPERATE
36 eeEmbedded
39 EFFESUS
49 FASUDIR
57 HESMOS
60 HOLISTEEC
63 INDICATE
85 PROFICIENT
103 STREAMER
123 Eebers
145 MORE-CONNE
147 OptEEmAL
148 P2Endure
150 Pro-Get-One
156 RESPOND
157 REZBUILD
161 SWIMing

IMPRESS

Interoperable Data Exchange Server (IDES)

IDES main concept

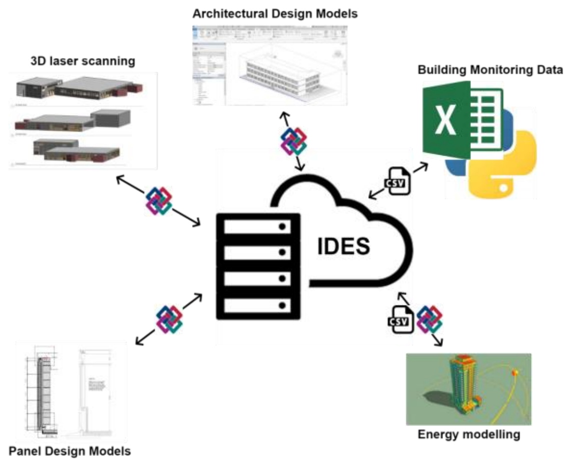


IDES facilitates Interoperable Building Information Data Exchange within building design teams

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 636717

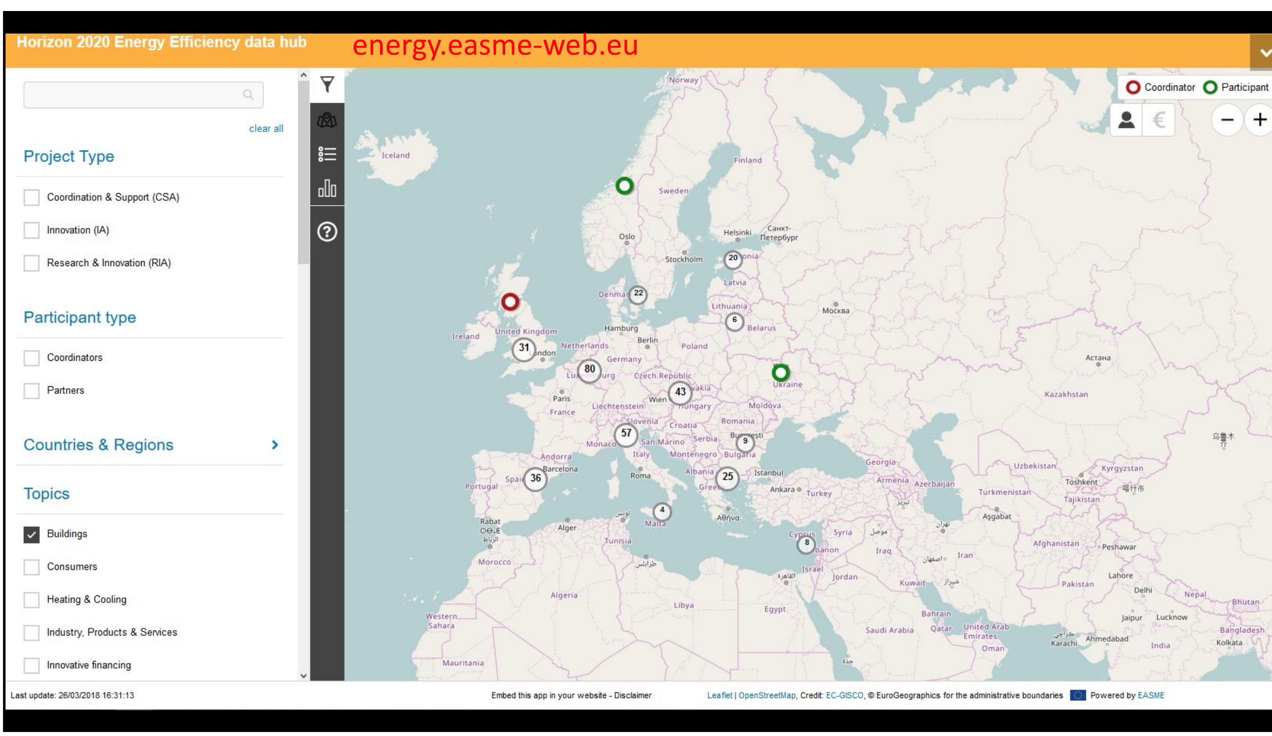
Interoperable Data Exchange Server (IDES)

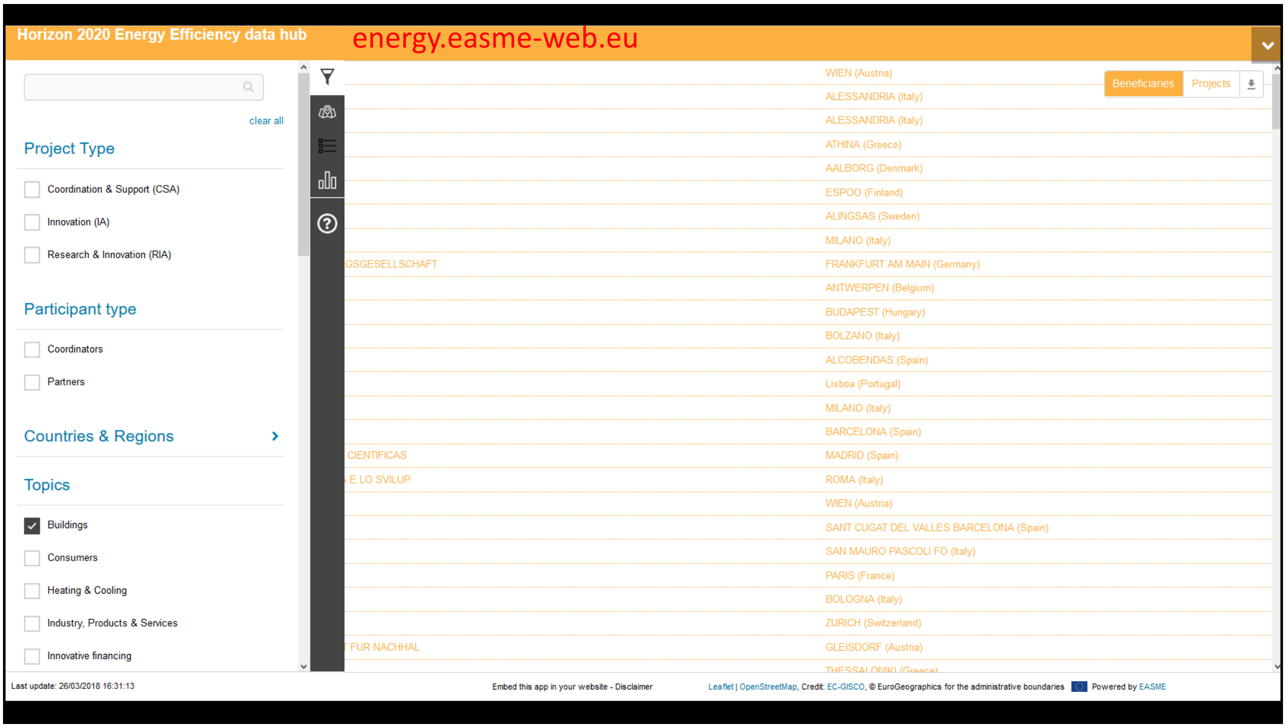
IDES main concept



IDES accepts and validates BIM data in open source format

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 636717




Horizon 2020 Energy Efficiency data hub
energy.easme-web.eu
clear all
Project Type
Coordination & Support (CSA)
Innovation (IA)
Research & Innovation (RIA)
Participant type
Coordinators
Partners
Countries & Regions
Topics
Buildings
Consumers
Heating & Cooling
Industry, Products & Services
Innovative financing
Beneficiaries
Projects
WIEN (Austria)
ALESSANDRIA (Italy)
ALESSANDRIA (Italy)
ATHINA (Greece)
AALBORG (Denmark)
ESPOO (Finland)
ALINGSAS (Sweden)
MILANO (Italy)
GSGESELLSCHAFT
FRANKFURT AM MAIN (Germany)
ANTWERPEN (Belgium)
BUDAPEST (Hungary)
BOLZANO (Italy)
ALCOBENDAS (Spain)
Lisboa (Portugal)
MILANO (Italy)
BARCELONA (Spain)
CIENTIFICAS
MADRID (Spain)
E LO SVILUP
ROMA (Italy)
WIEN (Austria)
SANT CUGAT DEL VALLES BARCELONA (Spain)
SAN MAURO PASCOLI FO (Italy)
PARIS (France)
BOLOGNA (Italy)
ZURICH (Switzerland)
FUR NACHHAL
GLEISDORF (Austria)
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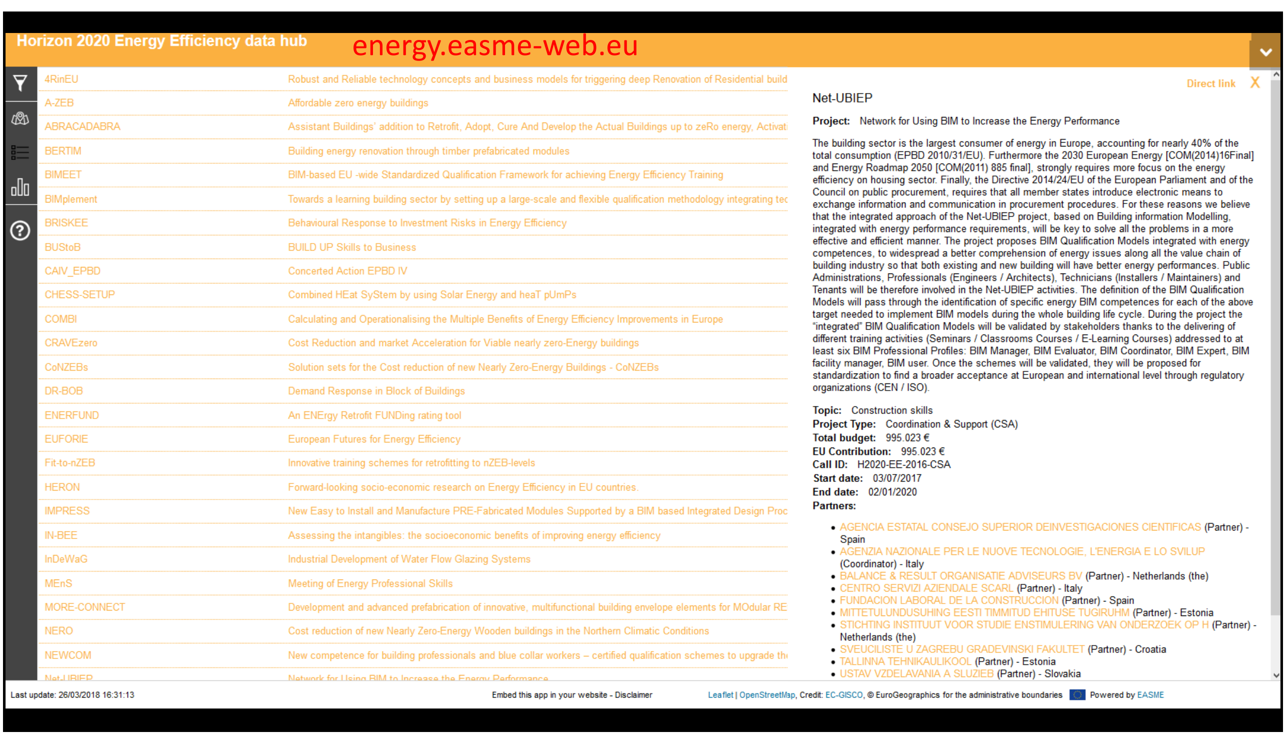
Powered by EASME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4RinEU Robust and Reliable technology concepts and business models for triggering deep Renovation of Residential build
A-ZEB Affordable zero energy buildings
ABRACADABRA Assistant Buildings' addition to Retrofit, Adopt, Cure And Develop the Actual Buildings up to zeRo energy, Activat
BERTIM Building energy renovation through timber prefabricated modules
BIMEET BIM-based EU -wide Standardized Qualification Framework for achieving Energy Efficiency Training
BIMplement Towards a learning building sector by setting up a large-scale and flexible qualification methodology integrating tec
BRISKEE Behavioural Response to Investment Risks in Energy Efficiency
BUStoB BUILD UP Skills to Business
CA IV_EPBD Concerted Action EPBD IV
CHESS-SETUP Combined HEat SyStem by using Solar Energy and heaT pUmPs
COMBI Calculating and Operationalising the Multiple Benefits of Energy Efficiency Improvements in Europe
CRAVEzero Cost Reduction and market Acceleration for Viable nearly zero-Energy buildings
CoNZEBs Solution sets for the Cost reduction of new Nearly Zero-Energy Buildings - CoNZEBs
DR-BOB Demand Response in Block of Buildings
ENERFUND An ENErgy Retrofit FUNDing rating tool
EUFORIE European Futures for Energy Efficiency
Fit-to-nZEB Innovative training schemes for retrofitting to nZEB-levels
HERON Forward-looking socio-economic research on Energy Efficiency in EU countries.
IMPRESS New Easy to Install and Manufacture PRE-Fabricated Modules Supported by a BIM based Integrated Design Proc
IN-BEE Assessing the intangibles: the socioeconomic benefits of improving energy efficiency
InDeWaG Industrial Development of Water Flow Glazing Systems
MEnS Meeting of Energy Professional Skills
MORE-CONNECT Development and advanced prefabrication of innovative, multifunctional building envelope elements for MOdular RE
NERO Cost reduction of new Nearly Zero-Energy Wooden buildings in the Northern Climatic Conditions
NEWCOM New competence for building professionals and blue collar workers – certified qualification schemes to upgrade the
Direct link X
Net-UBIEP
Project: Network for Using BIM to Increase the Energy Performance
The building sector is the largest consumer of energy in Europe, accounting for nearly 40% of the total consumption (EPBD 2010/31/EU). Furthermore the 2030 European Energy [COM(2014)16Final] and Energy Roadmap 2050 [COM(2011) 885 final], strongly requires more focus on the energy efficiency on housing sector. Finally, the Directive 2014/24/EU of the European Parliament and of the Council on public procurement, requires that all member states introduce electronic means to exchange information and communication in procurement procedures. For these reasons we believe that the integrated approach of the Net-UBIEP project, based on Building information Modelling, integrated with energy performance requirements, will be key to solve all the problems in a more effective and efficient manner. The project proposes BIM Qualification Models integrated with energy competences, to widespread a better comprehension of energy issues along all the value chain of building industry so that both existing and new building will have better energy performances. Public Administrations, Professionals (Engineers / Architects), Technicians (Installers / Maintainers) and Tenants will be therefore involved in the Net-UBIEP activities. The definition of the BIM Qualification Models will pass through the identification of specific energy BIM competences for each of the above target needed to implement BIM models during the whole building life cycle. During the project the "integrated" BIM Qualification Models will be validated by stakeholders thanks to the delivering of different training activities (Seminars / Classrooms Courses / E-Learning Courses) addressed to at least six BIM Professional Profiles: BIM Manager, BIM Evaluator, BIM Coordinator, BIM Expert, BIM facility manager, BIM user. Once the schemes will be validated, they will be proposed for standardization to find a broader acceptance at European and international level through regulatory organizations (CEN / ISO).
Topic: Construction skills
Project Type: Coordination & Support (CSA)
Total budget: 995.023 €
EU Contribution: 995.023 €
Call ID: H2020-EE-2016-CSA
Start date: 03/07/2017
End date: 02/01/2020
Partners:
AGENCIA ESTATAL CONSEJO SUPERIOR DEINVESTIGACIONES CIENTIFICAS (Partner) - Spain
AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPP (Coordinator) - Italy
BALANCE & RESULT ORGANISATIE ADVISEURS BV (Partner) - Netherlands (the)
CENTRO SERVIZI AZIENDALE SCARL (Partner) - Italy
FUNDACION LABORAL DE LA CONSTRUCCION (Partner) - Spain
MITTETULUNDUSUHING EESTI TIMMITUD EHITUSE TUGIRUHM (Partner) - Estonia
STICHTING INSTITUUT VOOR STUDIE ENSTIMULERING VAN ONDERZOEK OP H (Partner) - Netherlands (the)
SVEUCILISTE U ZAGREBU GRADEVINSKI FAKULTET (Partner) - Croatia
TALLINNA TEHNIKAULIKOOL (Partner) - Estonia
USTAV VZDELAVANIA A SLUZIEB (Partner) - Slovakia
Last update: 26/03/2018 16:31:13
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BIM projects supported by EASME

Technologies & processes

BERTIM
Pro-GET-OnE
IMPRESS
MORE-CONNECT
P2Endure

Knoweldge & skills

BIMEET
BIMcert
BIMplement
Net-UBIEP

European Commission

Funding from Horizon 2020

Horizon 2020 call: Energy-efficient Buildings (EEB)

- LC-EEB-02-2018: Building information modelling adapted to efficient renovation (RIA)
  4-5 projects being funded

Horizon 2020 call: Energy efficiency (EE)

- LC-SC3-EE-1-2018-2019-2020: Decarbonisation of the EU building stock
- LC-SC3-EE-3-2019-2020: Stimulating demand for sustainable energy skills in the construction sector
- LC-SC3-EE-5-2018-2019-2020: Next-generation of Energy Performance Assessment and Certification
  2018 Call closed: proposals to be assessed

European Commission

Sources of information

Horizon 2020 Participant Portal
http://ec.europa.eu/research/participants/portal/desktop/en/home.html

European Commission

39th AIVC Conference
Smart ventilation for buildings

EASME

Executive Agency for Small and Medium-sized Enterprises

THANK YOU
FOR YOUR ATTENTION

Philippe MOSELEY
Unit B.1 Horizon 2020 Energy
https://ec.europa.eu/easme/en/energy

Follow EASME on Twitter @H2020EE @philippemoseley

European Commission

SINTEF

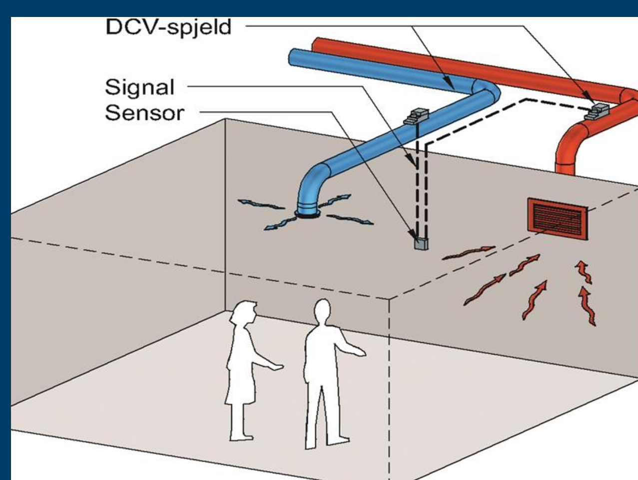
BIM-INTEGRATED DESIGN TOOL FOR IN-LINE RECOMMENDED VENTILATION RATES WITH DEMAND CONTROLLED VENTILATION STRATEGY

Kari Thunshelle, SINTE

, Thea Marie Danielsen[2], Sverre Holøs[1], Mads Mysen[1]

Demand Controlled Ventilatin - DCV

- An efficient measure for energy efficient ventilation
- Potential not always met



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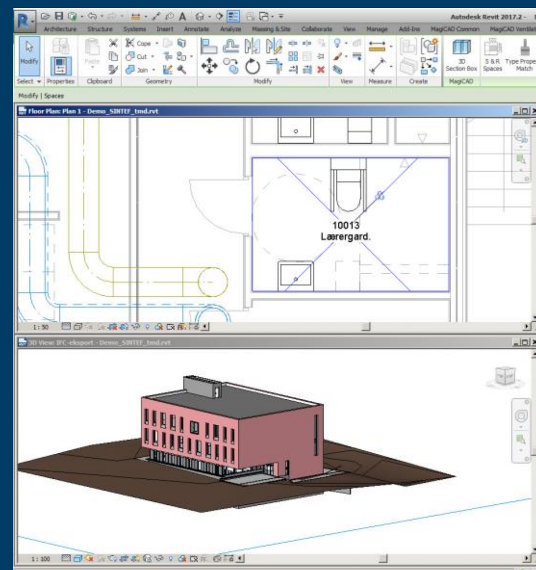
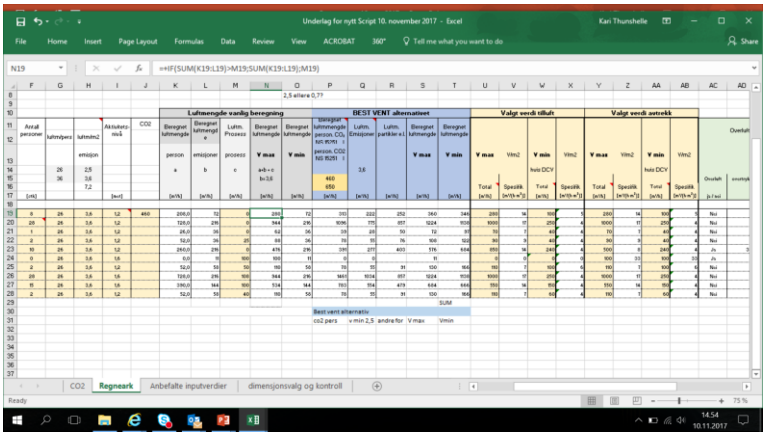
Norway
– a BIM frontrunner



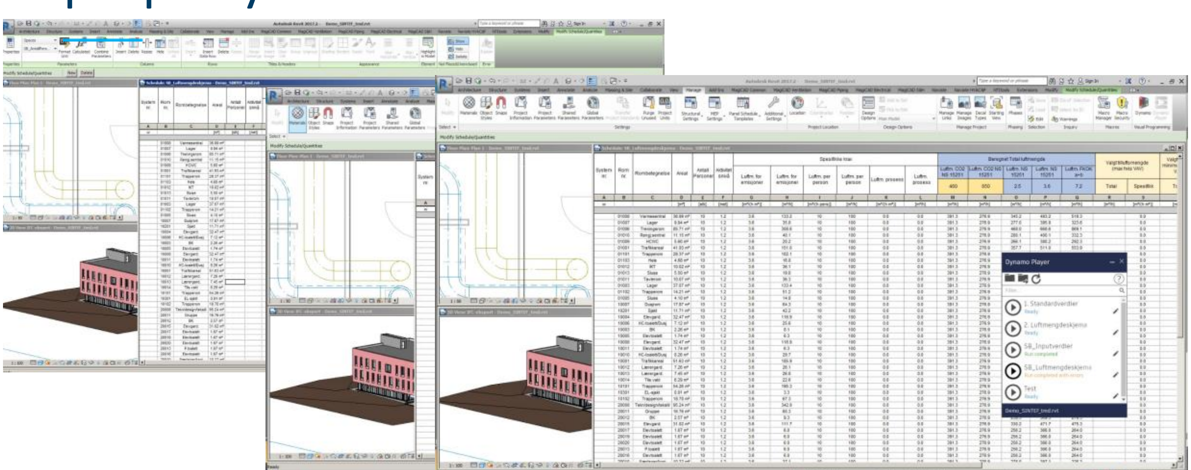
Today's situation	Desired change
Use of separate calculation tools	Calculations within the BIM model
Based on drawing details early design phase	Based on in-line model spaces
Time consuming - hours	Quick – within seconds
Transfer on information manually	No manual transfer of data. Based on data within the BIM model (spaces)
High risk of errors in transfer	Low error risk
Information divided in several tools	All information in one tool – from 3D to 4D
Calculating maximum values Minimum values lacking or missing	Calculating both max and min values Conscious choice
No control of suitable choice of damper dimension Poor regulation and design caused by wrong damper dimension	Control of suitable damper dimension

Modeling of output and input criteria

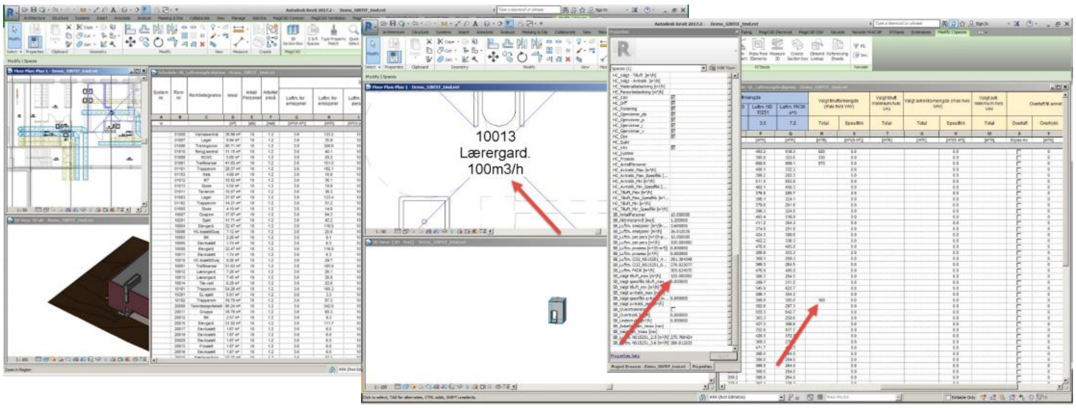


- Advanced version
- Recognisable
- Focus on both Vmax and Vmin
- Standard calculation and BEST VENT alternative – compare and select values
- Control of damper suitability

Calclulating air flow rate based on space property



Air flow rates returned to "properties" and drawing



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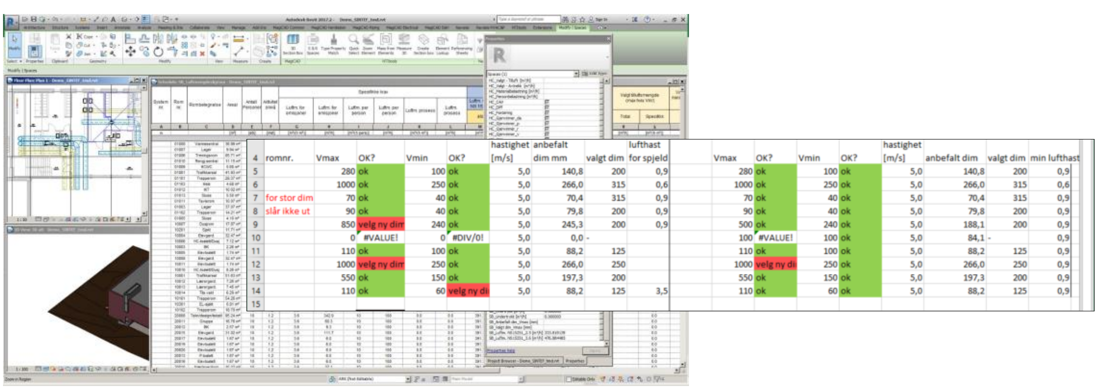
Control of damper suitability



4	romnr.	Vmax	OK?	Vmin	OK?	hastighet [m/s]	anbefalt dim mm	valgt dim	lufthast for spjeld
5		280	ok	100	ok	5,0	140,8	200	0,9
6		1000	ok	250	ok	5,0	266,0	315	0,6
7	for stor dim	70	ok	40	ok	5,0	70,4	315	0,9
8	slår ikke ut	90	ok	40	ok	5,0	79,8	200	0,9
9		850	velg ny dim	240	ok	5,0	245,3	200	0,9
10		0	#VALUE!	0	#DIV/0!	5,0	0,0	-	
11		110	ok	100	ok	5,0	88,2	125	
12		1000	velg ny dim	250	ok	5,0	266,0	250	
13		550	ok	150	ok	5,0	197,3	200	
14		110	ok	60	velg ny di	5,0	88,2	125	3,5
15									

Vmax	OK?	Vmin	OK?	hastighet [m/s]	anbefalt dim	valgt dim	min lufthast
280	ok	100	ok	5,0	140,8	200	0,9
1000	ok	250	ok	5,0	266,0	315	0,6
70	ok	40	ok	5,0	70,4	315	0,9
90	ok	40	ok	5,0	79,8	200	0,9
500	ok	240	ok	5,0	188,1	200	0,9
100	#VALUE!	100	ok	5,0	84,1	-	0,9
110	ok	100	ok	5,0	88,2	125	0,9
1000	velg ny di	250	ok	5,0	266,0	250	0,9
550	ok	150	ok	5,0	197,3	200	0,9
110	ok	60	ok	5,0	88,2	125	0,9

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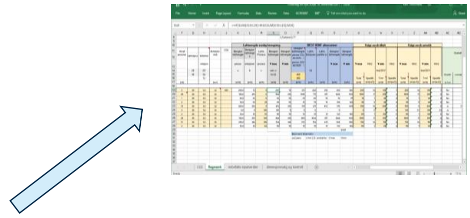
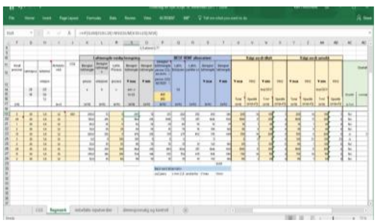
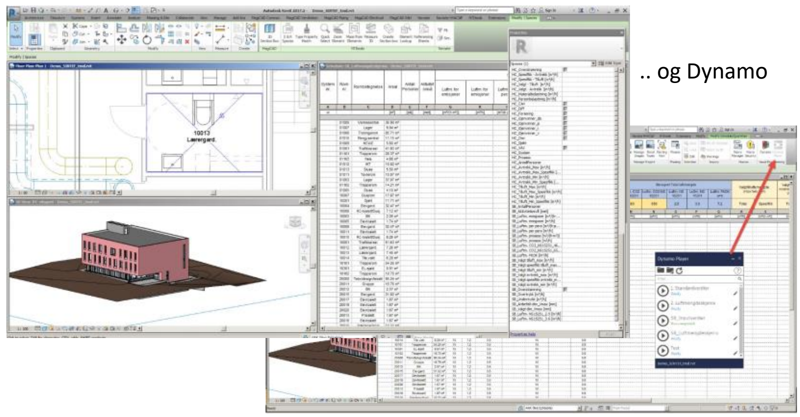
Fra dagens excel til modell



Revit

Dagens Excel





.. og Dynamo

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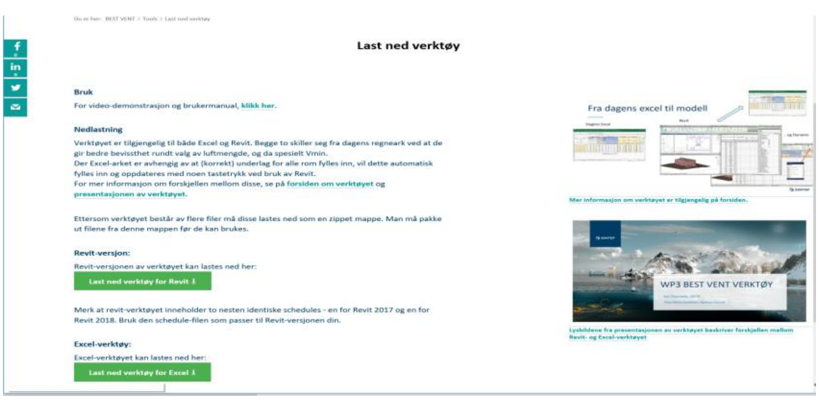
Online available tool and support

www.sintef.no/projectweb/best-vent/tools/



Du er her: BEST VENT > Tools > Last ned verktøy

Last ned verktøy

Bruk

For video-demonstrasjon og brukermanual, klikk her.

Nedlastning

Verktøyet er tilgjengelig til både Excel og Revit. Begge to skiller seg fra dagens regneark ved at de gir bedre bevissthet rundt valg av luftmengde, og da spesielt Vmin.
Der Excel-arket er avhengig av at (korrekt) underlag for alle rom fylles inn, vil dette automatisk fylles inn og oppdateres med noen tastetrykk ved bruk av Revit.
For mer informasjon om forskjellen mellom disse, se på forsiden om verktøyet og presentasjonen av verktøyet.

Ettersom verktøyet består av flere filer må disse lastes ned som en zippet mappe. Man må pakke ut filene fra denne mappen før de kan brukes.

Revit-versjon:

Revit-versjonen av verktøyet kan lastes ned her:

Last ned verktøy for Revit

Merk at revit-verktøyet inneholder to nesten identiske schedules - en for Revit 2017 og en for Revit 2018. Bruk den schedule-filen som passer til Revit-versjonen din.

Excel-verktøy:

Excel-verktøyet kan lastes ned her:

Last ned verktøy for Excel

Fra dagens excel til modell

Mer informasjon om verktøyet er tilgjengelig på forsiden.

WP3 BEST VENT VERKTØY

Lysbildene fra presentasjonen av verktøyet beskriver forskjellen mellom Revit- og Excel-verktøyet

SINTEF

SINTEF

Teknologi for et bedre samfunn

Ventilation Planning for Mid-sized Japanese Commercial Kitchens and Calculation Method of Ventilation Rate Using Building Information Modeling

Osamu Nagase [*, 1, 2],
Yasushi Kondo [2],
Hajime Yoshino [3, 2],
Miwako Fujita [4] and
Shunsuke Ogita [5]

1 NIKKEN SEKKEI LTD
2 Tokyo City University
3 Nippon Institute of Technology
4 Chubu Electric Power Company
5 TONETS CORPORATION

OVERVIEW

For
healthy and comfortable environment
with moderate **ventilation rate.**

In this study, surveys were conducted on commercial kitchen ventilation.

The results of surveys were used in Japanese standards of test method and ventilation rate.

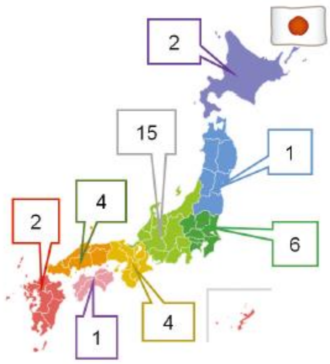
Calculation system of ventilation rate using BIM is also demonstrated in this study.

Survey 1	Kitchen specification and ventilation system
Survey 2	Load factor of cooking appliances
Create 1	Standard test method 【JTCCM V6201:2015】
Create 2	Standard ventilation rate 【JSTM V 6271 : 2017】
Calculation	Ventilation tool using BIM • High efficiency design • Remove of human errors

SURVEYED KITCHEN'S LOCATION

Survey 1 — Kitchen specification and ventilation system
- **35 kitchens**

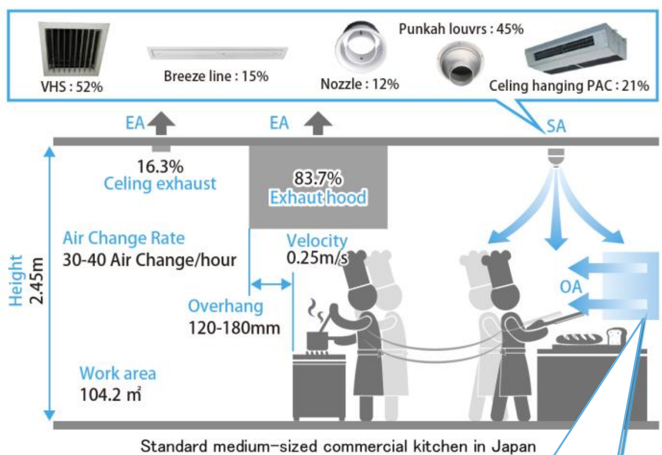
Survey 2 — Load factor of cooking appliances
- **10 kitchens**



Medium size kitchen :

A kitchen that can serve 200 to 800 meals at lunch time

RESULTS OF SURVEY 1 **THE VENTILATION SYSTEM**



In 20 kitchens, which is about 60% of the total, outside air was supplied without temperature control.

Outside air was supplied without temperature control in many kitchen

Average Mid-sized Japanese Commercial Kitchen

RESULTS OF SURVEY 2 **LOAD FACTOR**

Design load factor calculation procedure

(1) The one-hour average load factor for each cooking appliance was calculated and **the peak period of one hour was determined**.

(2) The percentile value for all the **5-min average load factor** data was calculated. **The design load factor can be selected** from the 90th percentile value, the 95th percentile value, or the 100th percentile value.

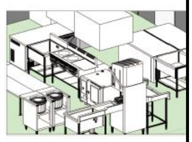
Cooking appliances		Noodle boiler	Flyer	Rice cooker	IH cooktop	Low range
Image photo						
Cumulative value	90%	104	66	93	72	98
	95%	105	75	94	94	100
	100%	106	103	111	112	105
Cooking appliances		**Tilting pan**	**Steam ceonvection**	**Warmer table**	**Dish wash**	**Kitchens (A-J)**
Image photo						
Cumulative value	90%	101	80	110	98	38
	95%	101	92	111	100	43
	100%	104	106	111	108	60

CALCULATION TOOL FOR VENTILATION RATE USING BIM

BIM software is Revit and Dynamo

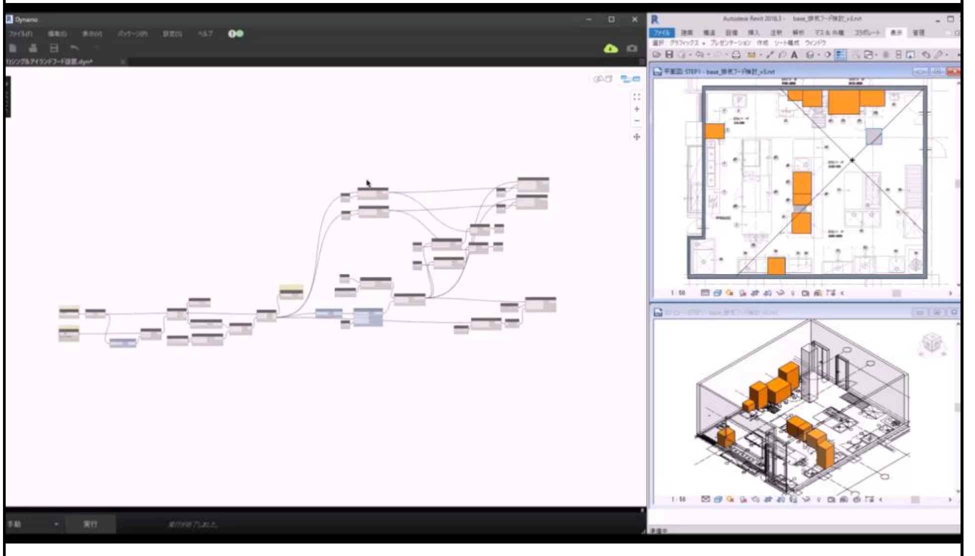
AUTODESK REVIT

Dynamo



Operation video

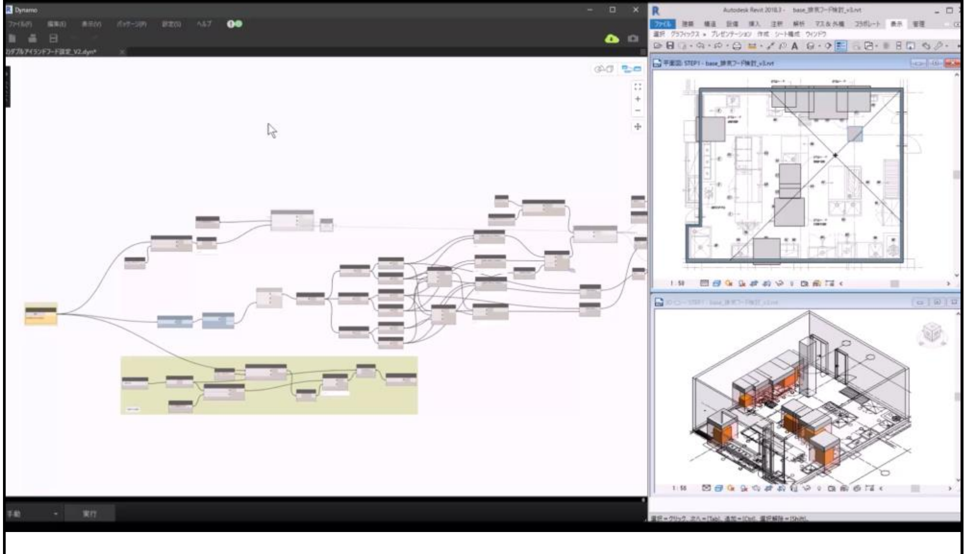
This shows an operation video
→**Draw exhaust hood** on cooking appliance



video 1

Operation video

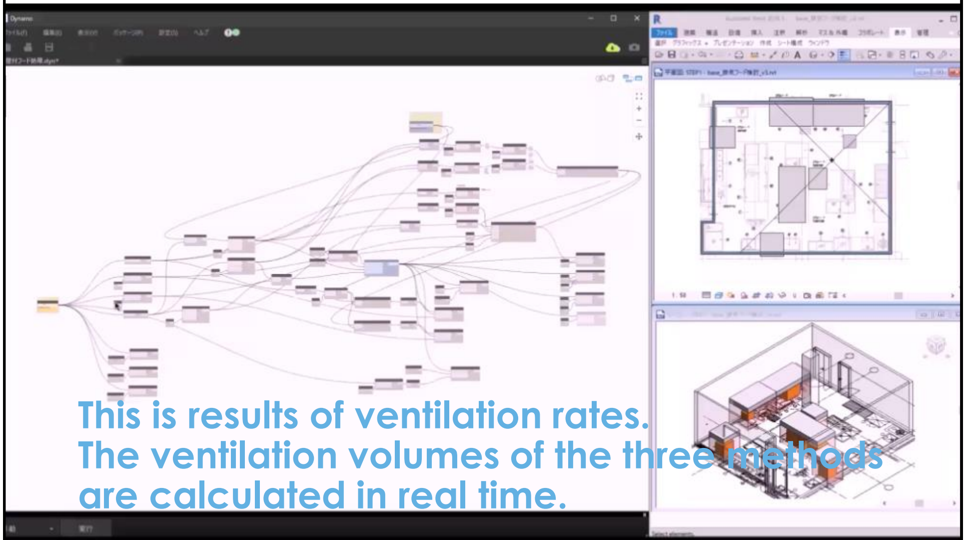
→ **Unify the exhaust hood**[Change the shape]



Video 2

Operation video

→ **Attach to the wall** [Change the shape]



Video 3

CONCLUSIONS

This paper shows
results of surveys 1 and 2,

Calculation tool is prototype stage.

⇩

I would like to use it as designed as soon as possible

and
Calculation tool using BIM

- improve the design efficiency
- remove human error.

FLOW OF VENTILATION PLANNING

Survey 1	Kitchen specification and ventilation system
Survey 2	Load factor of cooking appliances
Create 1	Standard test method 【JTCCM V6201:2015】
Create 2	Standard ventilation rate 【JSTM V 6271 : 2017】
Calculation	Ventilation tool using BIM • High efficiency design • Remove of human errors

Thank you very much

for your attention.

Observatoire de la qualité de l'air intérieur

CSTB le futur en construction

39th AIVC Conference
Smart ventilation for buildings

Topical Session French initiatives

An update on the French indoor air quality observatory recent results

Focus on ventilation

Corinne Mandin
University of Paris Est / Scientific and Technical Building Centre (CSTB) /
French Observatory of Indoor Air Quality (OQAI)

Observatoire de la qualité de l'air intérieur

The IAQ observatory in brief

- **IAQ Observatory: created in 2001**
- **Objective: To coordinate and develop indoor air research activities at a national scale**
  - To improve knowledge on IAQ in buildings
  - To provide support for public policies
  - To publish recommendations for professionals and general public
- **Funding from 3 ministries (environment, housing and health), ADEME and Anses**

Observatoire de la qualité de l'air intérieur

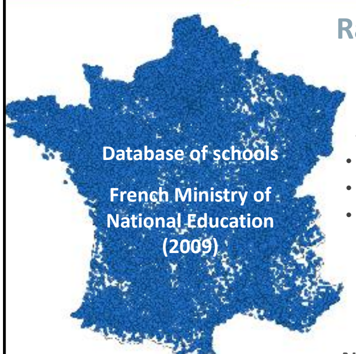
Outline

- School nationwide survey (2013-2017)
- Office building nationwide survey (2013-2017)
- IAQ and comfort in energy-efficient dwellings (on-going program)

With a focus on ventilation

Observatoire de la qualité de l'air intérieur

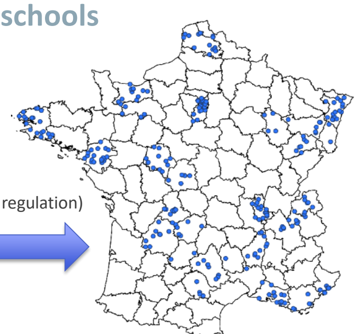
School survey: sampling design



52,582 schools

Randomly selected schools

Stratified on:
- **Schools** (nursery/primary)
- **Environment** (urban/rural)
- **Climatic zones** (French thermal regulation)



301 schools
(600 classrooms)

Number of schools calculated on the basis of the target precision on the VOC concentrations

Raking ratio adjustment (Deming and Stephan)

Observatoire de la qualité de l'air intérieur

Parameters (1)

One week: from Monday to Friday

On-line measurements

- ⇨ Carbon dioxide (CO_2)
- ⇨ Temperature and relative humidity
- ⇨ Particle counting (0,3 to 20 µm)
- ⇨ Noise level (7 days, starting the Friday before the monitoring week)

Air samples

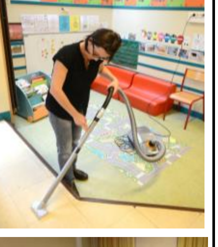
- ⇨ **With pumps**: $PM_{2,5}$ and SVOCs
- ⇨ **With passive samplers**:
  - VOCs and aldehydes
  - Nitrogen dioxide (NO_2)

Observatoire de la qualité de l'air intérieur

Parameters (2)

Dust sampling

- ⇨ **With a wipe** for lead
- ⇨ **With a specific vacuum cleaner**: metals and SVOCs



Punctual measurements

- ⇨ Illuminance on tables and boards (illuminance meter)
- ⇨ Lead in paint by X-Ray fluorescence
- ⇨ Electromagnetic fields

Questionnaires

- ⇨ Description of the classrooms and the buildings
- ⇨ Description of classroom activities
- ⇨ Teachers' and children's perception (noise, light, thermal comfort)

Results at a glance

Positive aspects

- Low NO_2 concentrations
- Lower VOC concentrations compared to dwellings

Critical issues

- $PM_{2,5}$
- Semi-volatile organic compounds
- **Lack of ventilation, air stuffiness**
- Lead in paint

The indoor air stuffiness index

Easy to understand and communicate

$$ICONE = \left(\frac{2{,}5}{\log_{10}(2)}\right)\log_{10}(1 + f_1 + 3f_2)$$

f_1 :proportion of values between 1000 and 1700 ppm $\left(f_1 = \frac{n_1}{n_0 + n_1 + n_2}\right)$

f_2 :proportion of values above 1700 ppm $\left(f_2 = \frac{n_2}{n_0 + n_1 + n_2}\right)$

ICONE score	Frequency of CO_2 values	Air stuffiness
0	100% CO_2 values < 1000 ppm	Fresh air (no air stuffiness)
1	~1/3 values > 1000 but < 1700 ppm	Low air stuffiness
2	~2/3 values > 1000 but < 1700 ppm	Average air stuffiness
3	~2/3 values > 1000 with 1/3 > 1700 ppm	High air stuffiness
4	~2/3 values > 1700 ppm	Very high air stuffiness
5	~100% CO_2 values > 1700 ppm	Extreme air stuffiness

(Ramalho et al, International Journal of Ventilation 2013)

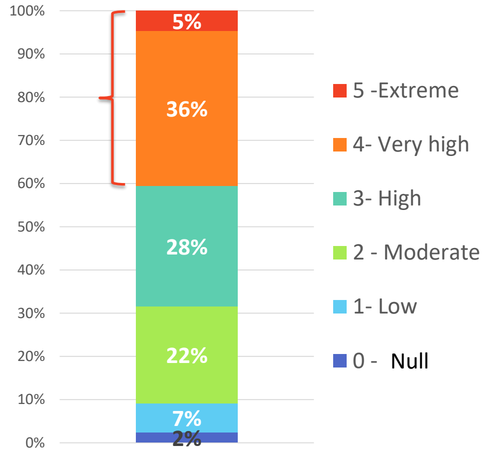
Observatoire de la qualité de l'air intérieur

In the French schools

25% of schools have a mechanical ventilation system

41% of schools have at least one classroom with a very high ICONE index (≥ 4)

Air stuffiness index (ICONE)



Highest value per school among the instrumented classrooms

Observatoire de la qualité de l'air intérieur

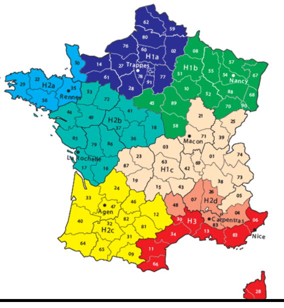
School survey: next steps

Data analysis still in process…

- Indoor pollution:
  - electromagnetic fields
  - metals and SVOCs in settled dust
  - comfort parameters: thermal comfort, noise, light
- Determinants of indoor pollutants and discomfort
- Cumulative exposure: noise and indoor air pollution

Office building survey: sample of buildings

- We identified **13,709 office buildings** with > 50 persons in mainland France
- We calculated the **number of buildings** needed on the basis of the target precision on the VOC concentrations: **300**
- We **randomly selected** these 300 buildings stratifying on the climatic zones



Difficulty for the recruitment
Volunteers were included

Office building survey: survey design

- **1 day per building / 3 field operators**
- **3 types of data**:
  - Health and comfort reported by the occupants (self-administered questionnaire)
  - Description of the building characteristics: systems, equipment, materials, etc.
  - Measurements of IAQ and comfort parameters

First results for 129 office buildings

IAQ and comfort measurements (1/2)

Observatoire de la qualité de l'air intérieur

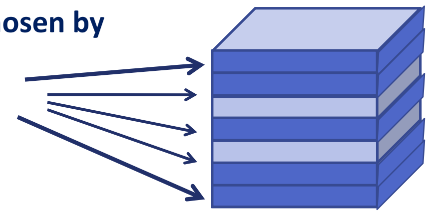
Representativity
Feasability

→

5 indoor locations
+ 1 outdoor

The 5 indoor locations were chosen by the operators

- Spatial variability



- Different orientations
- Typical of the office spaces: cellular offices and open spaces
- Occupied offices
- Occupants agree with the measurements

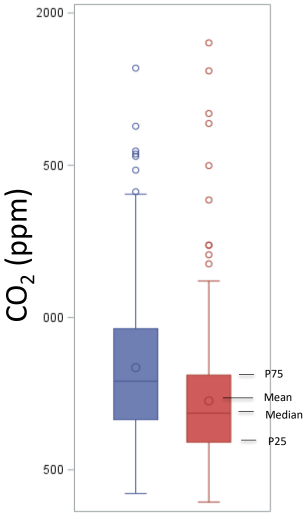
IAQ and comfort measurements (2/2)

Observatoire de la qualité de l'air intérieur

- During **6 hours**:
  - On-line measurement (10 min) of **temperature**, **relative humidity and CO_2**
  - On-line measurement (1 min) of **ultrafine particles** (∅ 10 nm-1 µm), 1h/office
  - Active sampling of **VOCs** on Tenax TA 60/80 tubes; airflow rate: 20 mL/min
    ↳ GC/MS analysis
  - Active sampling of **aldehydes** on SKC cartridges; airflow rate: 300 mL/min
    ↳ HPLC/UV analysis

Observatoire de la qualité de l'air intérieur

CO_2 concentrations



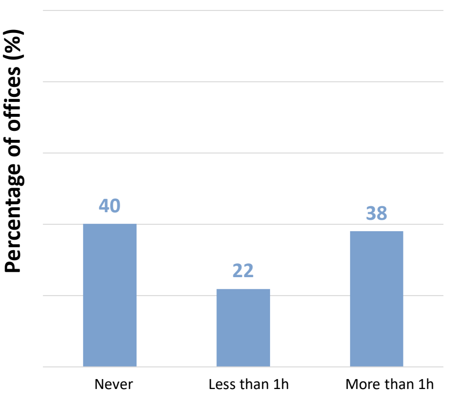
WINTER

SUMMER

Observatoire de la qualité de l'air intérieur

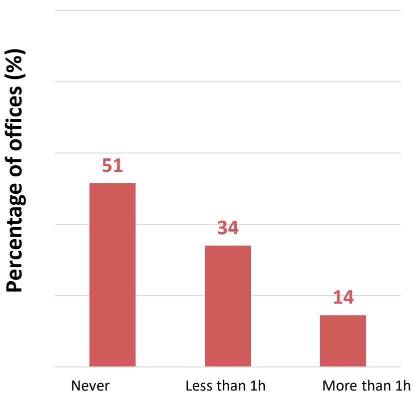
CO_2 concentrations: % of values exceeding 1000 ppm

WINTER



Fraction of time with $[CO_2]$ > 1000 ppm

SUMMER



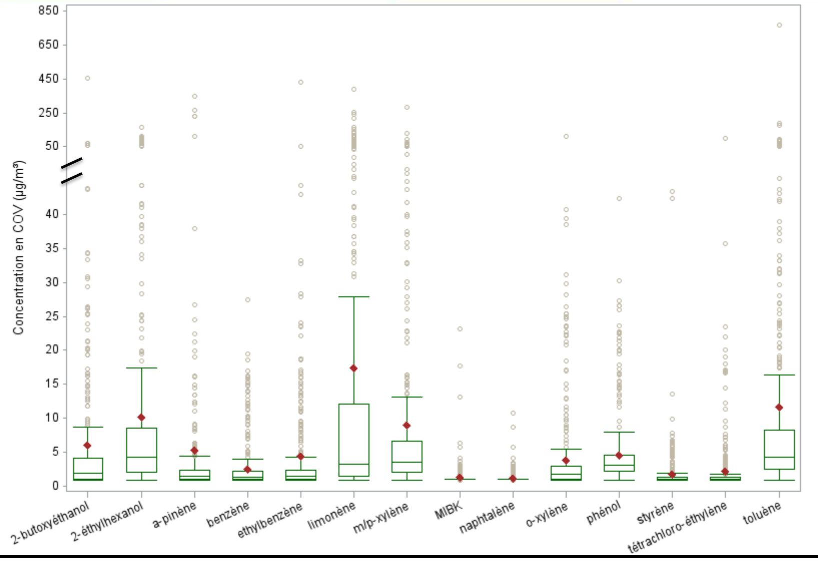
Fraction of time with $[CO_2]$ > 1000 ppm

CO_2 concentration in winter > CO_2 concentration in summer ($p < 5$ %)

Observatoire de la qualité de l'air intérieur

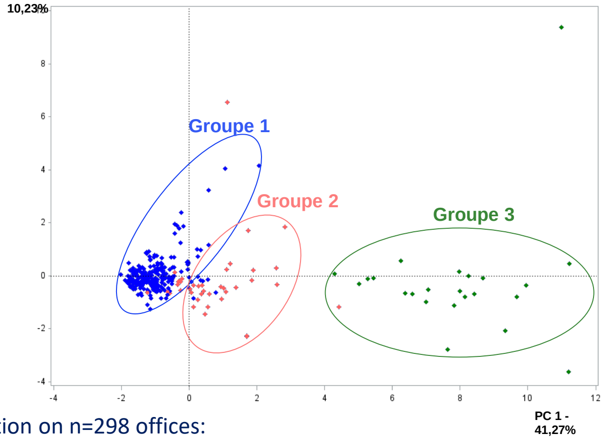
Indoor VOC concentrations

n=423 offices



Observatoire de la qualité de l'air intérieur

Typologies of indoor pollution in offices



Classification on n=298 offices:

- Group 1: n = 232 (78%) offices with the lowest concentrations
- Group 2: n = 41 (14%) offices with concentrations close to the medians
- **Group 3: n = 25 (8%) offices with the highest concentrations**

Office building survey: next steps

- **Low concentrations overall**. However:
  - All the target compounds are detected
  - Some offices show very high concentrations for several pollutants
  - The IAQ guidelines are sometimes exceeded and the alert value for benzene is exceeded in 6% of offices.
- **Next steps:**
  - Factors relative to buildings and occupants explaining the indoor air high concentrations
  - Health and comfort perceived by the occupants

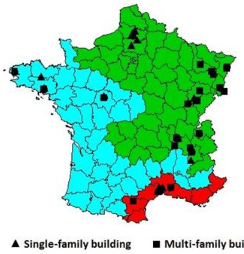
IAQ MONITORING IN ENERGY-EFFICIENT BUILDINGS

- **The concern**: to save energy, the air tightness of buildings is improved to reduce air infiltration. Meanwhile, we know that:
  - Occupants do not open regularly the windows
  - Mechanical ventilation systems are not always functioning correctly

  → What about IAQ and comfort in these energy-efficient buildings?
- The OQAI has set **a permanent monitoring program** in new and retrofitted buildings: dwellings, schools and office buildings
- **Data are analyzed every year**

SAMPLE TO DATE: 72 DWELLINGS

	17 houses (16 new and 1 retroffited)	28 new apartments	27 retrofitted apartments
Ventilation system	65% balanced ventilation 35% mechanical exhaust ventilation	39% balanced ventilation 61% mechanical exhaust ventilation	37% balanced ventilation 30% mechanical exhaust ventilation 33% hybrid ventilation (fan-assisted stack)



WHAT DO WE OBSERVE TO DATE?

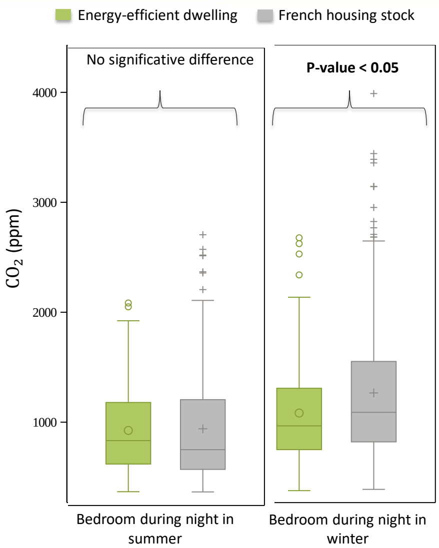
(Derbez et al, Indoor Air 2018)

- **Regarding VOCs and aldehydes:**
  - Overall lower indoor concentrations compared to the housing survey (2003-2005)
  - **Except for hexanal, limonene and α-pinene**

- **Regarding mold:**
  - Lower % of visible mold: 0% versus 15%
  - But **higher % of dwellings with fungal development** (mVOC based evaluation): 50% versus 37%

- **Regarding indoor temperature:**
  - Higher temperatures at both seasons
  - But most occupants are satisfied with thermal comfort

REGARDING VENTILATION



- From 20 to 30% respect the mandatory value for air flow rate in the kitchen
- From 30 to 40% respect the minimum value for air flow rate in the kitchen
- From 30 to 50% respect the minimum value for air flow rate in the whole dwelling

DETERMINANTS OF THE INDOOR CONCENTRATION OF α-PINENE

		β (SD)	P-value
Constant		3.04 (0.37)	0.08
DWELLING CHARACTERISTICS	Building envelope (reference: Masonry facades: concrete/concrete blocks)		
	Masonry facades: Terracotta brick Monomur©	-1.50 (1.19)	0.21
	Mixed facades (wooden frame + other material)	1.08 (1.45)	0.46
	Lightweight facades (49 wooden frame, 2 steel frame)	**7.95 (1.62)**	**<0.05**
	Masonry façades: Brick	**-2.70 (1.16)**	**<0.05**
	Above the investigated dwelling, there is a/an (reference : Another dwelling)		
	Attic insulated with made-made materials	1.10 (1.56)	0.49
	Attic insulated with natural fibre materials (cellulose or wood fibre)	**2.47 (1.45)**	**<0.05**
	Flat roof insulated with made-made material	-0.67 (1.24)	0.59
	Flat roof insulated with natural fibre materials (cellulose or wood fibre)	-0.76 (1.36)	0.58
BEDROOM CHARACTERISTICS	**Presence of only wood or wood-based furniture in the bedroom (reference: No)**	**3.74 (1.20)**	**<0.05**
OCCUPANT BEHAVIOUR	**Duration of bedroom window opening during day-time (reference: less than 30 min/day)**	**-4.25 (1.21)**	**<0.05**

Factors ↑ the alpha-pinene concentration

- wooden frame buildings
- Attic insulated with natural fiber materials (cellulose fiber, wood fiber) just above the dwelling
- Wood or wood-based furniture

Factors ↓ the alpha-pinene concentration

- Masonry brick
- Duration of window opening more than 30 min per day

Observatoire de la qualité de l'air intérieur

Thank you for your attention!

Acknowledgements:

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE ET SOLIDAIRE
MINISTÈRE DE LA COHÉSION DES TERRITOIRES
MINISTÈRE DES SOLIDARITÉS ET DE LA SANTÉ
ADEME Agence de l'Environnement et de la Maîtrise de l'Énergie
anses

Observatoire de la qualité de l'air intérieur

Some questions OQAI in general

What are aspects that future OQAI studies should focus upon?

Any specific building types/topics that we have missed so far?

Observatoire de la qualité de l'air intérieur

Some questions
IAQ and energy-efficiency program

Are there research opportunities related to the energy transition?

Observatoire de la qualité de l'air intérieur

Some questions
Ventilation

Can we identify specific research questions related to SMART ventilation and IOT developments?

Any ideas how to further develop & apply the air stuffiness index?

Some questions
Future housing survey

How can we keep building occupants motivated to stay actively involved in our studies?

Are there existing databases that we can tune into with relevant data?

REHVA

AIVC conference Juan les Pins, sept. 18/19, 2018

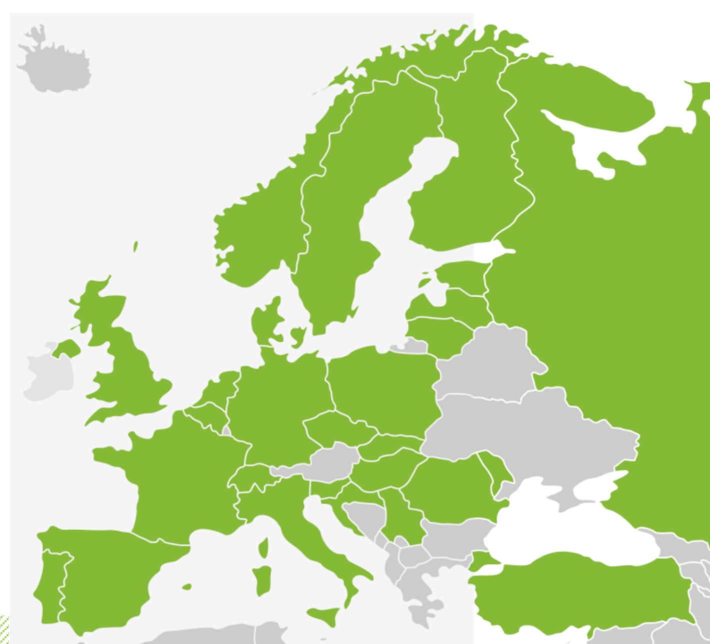
Ventilation, energy transition, indoor air quality and health: EU/REHVA perspective

Dr. Eng. Atze Boerstra, REHVA vice-president

REHVA

28 member associations like AICVF

ca. 100.000 HVAC professionals



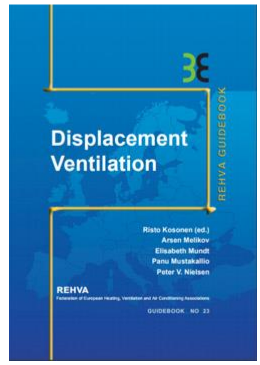
REHVA Federation of European Heating, Ventilation and Air Conditioning Associations

REHVA publications

- REHVA Journal –
  European HVAC Journal
- Guidebooks and reports (>25)

More information:

- www.rehva.eu



03/2017

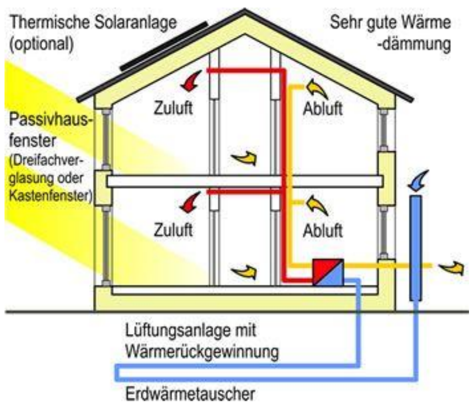
REHVA events

- Yearly Brussels Summit
  (next: November 11+12)
- CLIMA conferences
  (next: may 26-29th, 2019; see www.clima2019.org)

REHVA BRUSSELS SUMMIT
12-13 November 2018

CLIMA 2019
Built environment facing climate change
REHVA 13th HVAC World Congress
26 - 29 May, Bucharest, Romania

Energy transition is here to stay…

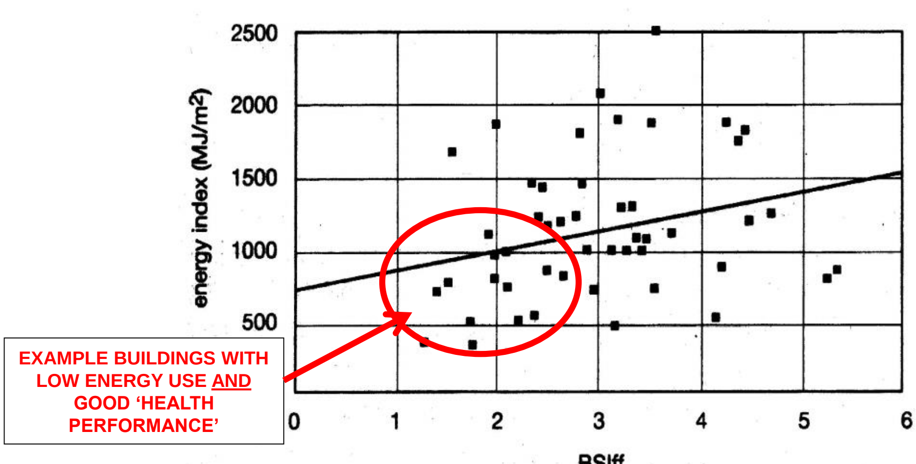


Does it arrive with side-effects?

Health/comfort risks of energy retrofitting

- IAQ / inadequate ventilation
- Mould & moisture issues (esp. renovations)
- Overheating
- Personal control issues (e.g. temperature winter)
- Inadequate daylighting
- Noise from installations
- ….

Energy efficient & healthy CAN go together



Source: EU Audit Project, Bluyssen et al, 1995

Let’s tune in with large body of knowledge on Indoor Environmental Quality & Health…

CLIMA
Built environment facing
REHVA 13th HVAC W
26 - 29 May, Bucha

WINDSOR CON
RETHINKING COMF

Indoor Air 2011
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INDOOR AIR
doi:10.1111/j.1600-0668.2010.00703.x

Commemorating 20 Years of *Indoor Air*

Ventilation rates and health: multidisciplinary review of the scientific literature

Abstract The scientific literature through 2005 on the effects of ventilation rates on health in indoor environments has been reviewed by a multidisciplinary group. The group judged 27 papers published in peer-reviewed scientific journals as providing sufficient information on both ventilation rates and health effects to inform the relationship. Consistency was found across multiple investigations and different epidemiologic designs for different populations. Multiple health endpoints show similar relationships with ventilation rate. There is biological plausibility for an association of health outcomes with ventilation rates, although the literature does not provide clear evidence on particular agent(s) for the effects. Higher ventilation rates in offices, up to about 25 l/s per person, are associated with reduced prevalence of sick building syndrome (SBS) symptoms. The limited available data suggest that inflammation, respiratory infections, asthma symptoms and short-term sick leave increase with lower ventilation rates. Home ventilation rates above 0.5 air changes per hour (h^{-1}) have been associated with a reduced risk of allergic manifestations among children in a Nordic climate. The need remains for more studies of the relationship between ventilation rates and health, especially in diverse climates, in locations with polluted outdoor air and in buildings other than offices.

J. Sundell[1,2,*], H. Levin[3,*], W. W. Nazaroff[4], W. S. Cain[5], W. J. Fisk[6], D. T. Grimsrud[7], F. Gyntelberg[8], Y. Li[9], A. K. Persily[10], A. C. Pickering[11], J. M. Samet[12], J. D. Spengler[13], S. T. Taylor[14], C. J. Weschler[1,15]

[1]Technical University of Denmark, Lyngby, Denmark, [2]Tsinghua University, Beijing, China, [3]Building Ecology Research Group, Santa Cruz, CA, USA, [4]University of California, Berkeley, CA, USA, [5]University of California, San Diego, CA, USA, [6]Lawrence Berkeley National Laboratory, Berkeley, CA, USA, [7]University of Minnesota, MN, USA, [8]Bispebjerg Hospital, Copenhagen, Denmark, [9]The University of Hong Kong, Hong Kong SAR, China, [10]National Institute of Standards and Technology, Gaithersburg, MD, USA, [11]Wythenshawe Hospital, Manchester, UK, [12]University

12th REHVA World Congress
CLIMA2016
22-25 May | Aalborg | Denmark

ISIAQ
INTERNATIONAL SOCIETY OF INDOOR AIR QUALITY AND CLIMATE

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

EPBD recast - REHVA position

‘The (energy perfo
requirements shall
general indoor clin
order to avoid pos
such as inadequate
as local conditions
function and the a

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

DRAFT
prEN 16798-1

May 2015

ICS 91.120.10; 91.140.01

Will supersede EN 15251:2007

English Version

Energy performance of buildings - Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics - Module M1-6

Performance énergétique des bâtiments - Partie 1 : Critères d'ambiance intérieure pour la conception et l'évaluation de la performance énergétique des bâtiments couvrant la qualité de l'air intérieur, l'ambiance thermique, l'éclairage et l'acoustique - Module M1-6

Energieeffizienz von Gebäuden - Teil 1: Eingangsparameter für das Raumklima zur Auslegung und Bewertung der Energieeffizienz von Gebäuden Raumluftqualität, Temperatur, Licht und Akustik - Modul M1-6)

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 156.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Warning : This document is not a European Standard. It is distributed for review and comments. It is subject to change without notice and shall not be referred to as a European Standard.

cen
EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

aper on the European Commission proposal of the revised
RGY PERFORMANCE OF BUILDINGS DIRECTIVE
COM(2016)0765

ites the principles of EPBD aiming both at the improvement of energy with cost optimal minimum requirements, as well as at the improvement of buildings with incentives. REHVA welcomes the binding 30% energy efficiency d is confident that the building sector can and should contribute more to ack with highly ambitious nZEB targets for new buildings, **the EPBD must put urbishment of the existing building stock**, including the **replacement and cal building systems that waste energy and don't deliver good indoor** sed EPBD shall better tackle this challenge and aim at **strengthening the ement.**

oor environmental quality and
ficiency at the same time

trofit projects. To achieve this, REHVA advocates for indoor environment nts in the EPBD. REHVA welcomes that Annex I of the legislative proposal sure minimum environment quality levels. However, to provide and maintain e, IEQ aspects should be further strengthened in the directive.

ld set a clear mandate for Member States to **define indoor environmental hat are monitored and reported in a harmonised way** in building regulations

part of the inspection of heating and cooling systems, and continuously

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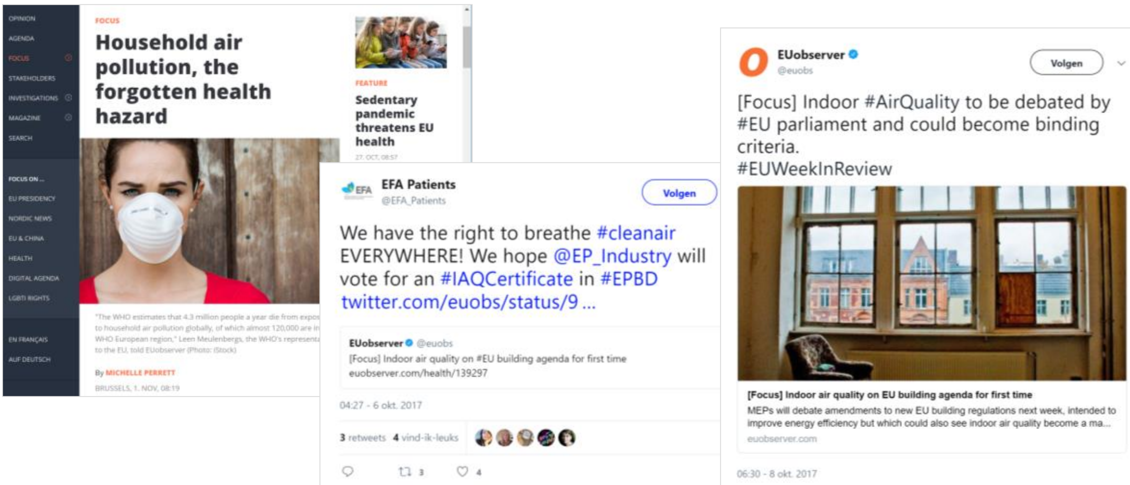
On the radar of the EU parliament…



EN 16798-1 (before: EN 15251)

Performance requirements (category A/B/C) for:

- Indoor Air Quality / ventilation
- Thermal environment / heating & cooling
- Light / lighting & daylight penetration
- Noise / spec. installation noise

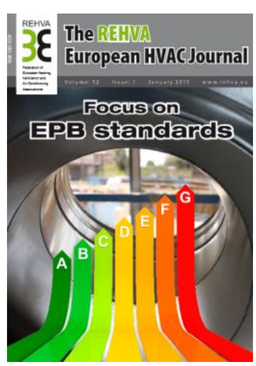
Seperate requirements for residential and non-residential buildings

example IAQ requirements in EN 16798-1

Table B2.1.3-1. Default design CO_2 concentrations above outdoor concentration assuming a standard CO_2 emission of 20 L/(h per person).

Category	Corresponding CO_2 concentration above outdoors in PPM for non-adapted persons
I	550 (10)
II	800 (7)
III	1350 (4)
IV	1350 (4)

Fore more general information about EPBD recast, see: www.rehva.eu & www.EPB.center



EPB CENTER

http://www.rehva.eu/publications-and-resources/rehva-journal

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Forget about (just) nZEB….

WHAT WE NEED IS INTEGRAL APPROACH, ALSO TAKING INTO ACCOUNT THAT PEOPLE WANT/NEED/EXPECT **HEALTH AND COMFORT** IN BUILDINGS

Integrating HEA aspects

BREEAM®

Code for a Sustainable Built Environment
www.breeam.org

BREEAM New Construction

Non-Domestic Buildings

Technical Manual
SD5073 - 5.0:2011

Hea 02 Indoor air quality

Number of credits available	Minimum standards
Building type dependent	No

Aim

To recognise and encourage a healthy internal environment through the specification and installation of appropriate ventilation, equipment and finishes.

Assessment criteria

This issue is split into two parts:

- Minimising sources of air pollution (4 credits)
- Adaptability - potential for natural ventilation (1 credit)

Note:

- The potential for natural ventilation credit does not apply to buildings on a prison development.

The following is required to demonstrate compliance:

Minimising sources of air pollution

One credit - Indoor air quality (IAQ) plan

1. An indoor air quality plan has been produced , with the objective of facilitating a process that leads to design, specification and installation decisions and actions that minimise indoor air pollution during occupation of the building. The indoor air quality plan must consider the following:
   a. Removal of contaminant sources
   b. Dilution and control of contaminant sources
   c. Procedures for pre-occupancy flush out
   d. Third party testing and analysis
   e. Maintaining indoor air quality in-use

INTERNATIONAL WELL BUILDING INSTITUTE™
WELL
PLATINUM 2017

HEA + nZEB =

Health ↑

Energy ↓

HEAnZEB

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

More information…

Editorial

Towards HEAnZEBs!

Recently, I was invited by a group of civil servants engaged in the update of the current Dutch EPB regulation based of the expected EPBD revision. My contact person asked me, beforehand, to focus my presentation on health and comfort of building occupants in nearly Zero Energy Buildings (nZEBs).

I started my presentation saying: 'I'm worried about this and I truly believe that it is high time that you start worrying about this too.' That maybe wasn't what they wanted to hear, but they asked for my honest and professional opinion which I was happy to share.

Which are my worries? Since the Paris Agreement, everybody seems to be interested in nothing but the energy performance of both existing and new buildings. I do see the need to fight global warming and drastically cut back on CO_2 emissions. There is no time to lose. However, during the last couple of years I have seen (and investigated) a lot of transformed and new buildings, (re)designed with an energy agenda that had unwanted and serious side effects.

For example, some problems that I have come upon in class A (A+) energy performing dwellings, schools and offices include: overheating in summer, underventilation in winter, severely limited daylight penetration, too noisy HVAC systems and overcomplicated climate controls. These are important issues, as a suboptimal

designed to improve the energy performance of (new or existing) buildings should consider indoor climate conditions in order to avoid possible negative effects 'such as inadequate ventilation'. It, furthermore, states that aspects like indoor air quality, adequate natural light and shading should be taken into account when (re)designing energy-efficient buildings.

The good news is that countries that want to ensure that the Indoor Environmental Quality of our future nearly Zero Energy Buildings is adequate can now find examples of IEQ performance criteria in FprEN 16798-1 (the upgraded version of EN 15251). This CEN standard presents requirements that can be used when one wants to avoid problems with overheating, underventilation, installation noise, etc.

Several articles in this special issue of REHVA Journal support the hypothesis that the health and comfort performance of buildings is as important as the energy performance. Authors from Europe, South-America, China and India explain that aspects like fine particle exposure, personal control options and sensor technology aimed at local IEQ improvement should be addressed too.

I ended my presentation with the Dutch EPBD recast group saying that, in my opinion, we should start to systematically create buildings that are *both* healthy and

REHVA journal 3/2017, *www.rehva.eu*

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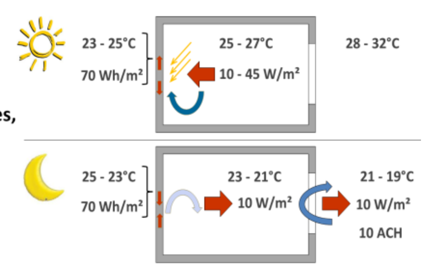
Summing up of the Ventilative Cooling – Resilient Cooling track

Session 2C – Ventilative Cooling
Philipp Stern: Key findings from Annex 62

- Favour airflow through architectural apertures
- Enhance airflow by powerless ventilators
- Design for very low pressure drop
- Make the most of available temperature differences, limit VC to periods which physically make sense
- Strictly emphasise Operability and Reliability of VC components
- Recognise the importance of post occupancy optimisation



venticool.eu/annex-62-home

Session 2C – Ventilative Cooling
Christoffer Plesner: Status and recommendations for better implementation of Ventilative cooling into Danish standards, legislation and compliance tools

Conclusion #1

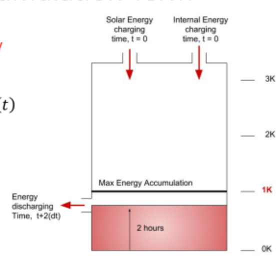
- Generally, ventilative cooling is not very well included in standards, legislation and compliance tools across the evaluated countries , ranging from very simplified to detailed methods, e.g. from pure monthly average models to more dynamic hourly-based models.
- Most European compliance tools, uses the monthly average models that could underestimate the cooling potential of ventilative cooling, where there in Denmark has been made an improvement:
  - The implementation to the official compliance tool of a "Summer comfort" module that performs **hourly calculations** of thermal comfort in summer in residential buildings only
- Legislation should include or refer to guidelines, standards or compliance tools on how to calculate the cooling effect, resulting temperatures and the energy performance

Session 2C – Ventilative Cooling
Paul O´Sullivan: The influence of thermal mass on the predicted climate cooling potential in low energy buildings

Methodology – Energy Accumulation Term

$$\overbrace{\hat{Q}_{acc}(t)}^{\text{hourly heat acc. rate}} = \overbrace{Q_s\boldsymbol{\alpha}(t)}^{\text{Solar Energy Charging}} - \overbrace{Q_s\alpha(t-\boldsymbol{\tau})}^{\text{Solar Energy discharging}} + \overbrace{\boldsymbol{h}A(T_{sp}-\boldsymbol{T_{tm}})(t)}^{\text{Convective Energy Charging}}$$

- Set the terms α, τ, h above to ensure charging does not exceed daily maximum limit
- Evaluate these terms at each occupancy period to Identify numerical values
- 3K temp difference set between thermal mass and indoor air



seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND | Brunel UNIVERSITY LONDON | CIT CORK INSTITUTE OF TECHNOLOGY

www.nbert.xyz/home

Session 2C – Ventilative Cooling
Michal Pomianowski: Validation of Dynamic Model BSim to Predict the Performance of Ventilative Cooling in a Single Sided Ventilated Room

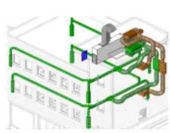
Conclusions

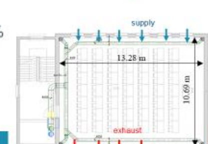
1. Good understanding of indoor air distribution is required!
2. Good understanding of software used is required!
3. Reliability of simulation results of natural (single sided) ventilation are comparable to results for mechanical ventilation strategy.
4. Good estimation of natural ventilation performance was obtained in presented study.
5. Validation against EN 15255 is recommended but non compliance in some tests can be reasoned by discrepancy between input from standard and input possibilities of particular software.
6. Check the robustness of the model for one parameter at the time and for combined parameters!

Session 2C – Ventilative Cooling
Hilde Breesch: Ventilative cooling in a school building: evaluation of the measured performances

Ventilative cooling

- Indirect evaporative cooling in AHU
  - Max 4400 m³/h
  - Max cooling capacity 13.1 kW
  - Activated: $T_i > 26°C$ or $T_e > 22°C$
- Natural night ventilation
  - Cross ventilation
  - Effective opening area = 4%





Lessons Learned

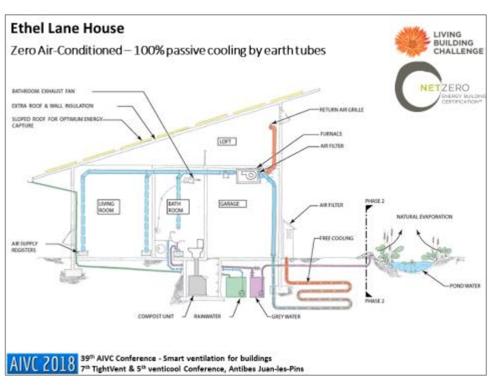
- Extensive data monitoring system
  - To detect malfunctions
  - To improve control of systems
  - To optimize building performance
- Do not forget the users
  - Inform them about automated systems
  - Educate them

Session 2C – Ventilative Cooling

Andrés Litvak: Ventilative Cooling and Summer Comfort in 9 buildings in France

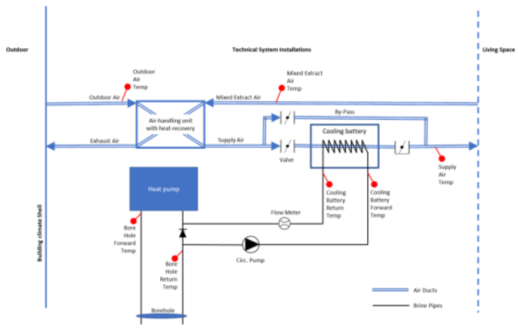
Session 5C – Improving the efficiency of VC

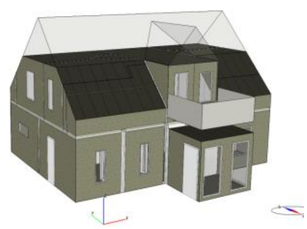
Trevor Butler: Ventilative cooling and improved indoor air quality through the application of engineered Earth Tube systems, in a Canadian climate



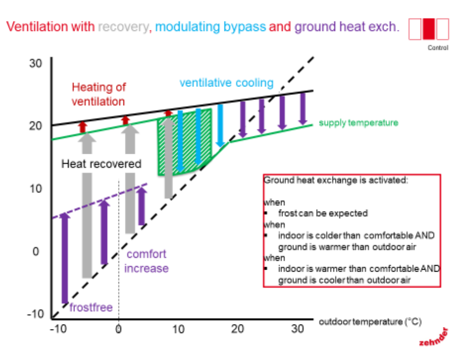
Design Guidance: https://www.nrcan.gc.ca/simply-science/20319

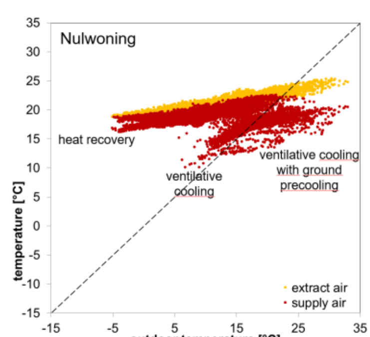
Session 5C – Improving the efficiency of VC
Huijuan Chen: Free cooling of low energy buildings with ground source heat pump system and bidirectional ventilation



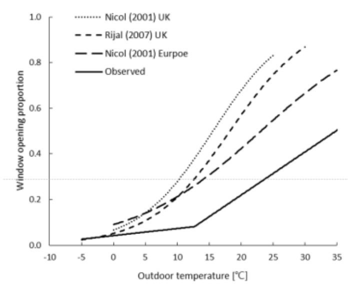


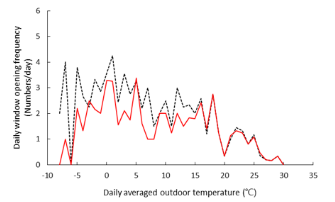
Session 5C – Improving the efficiency of VC
Bart Cremers: Energy analysis of balanced ventilation units from field studies



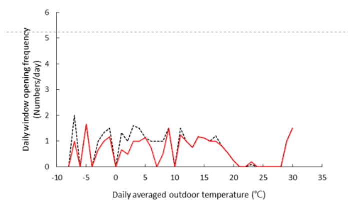


Session 5C – Improving the efficiency of VC
Junseok Park: Characterising window opening behaviour of occupants using machine learning models



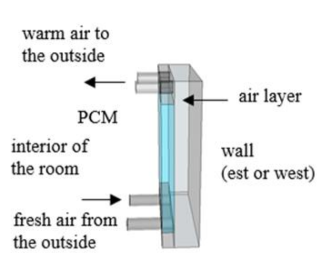


C5 - KNN

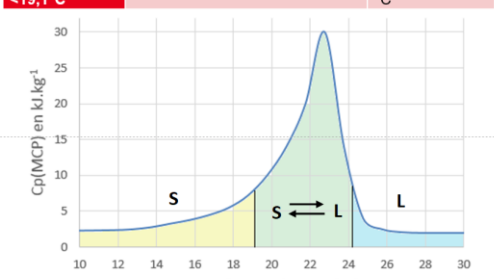


B4 - KNN

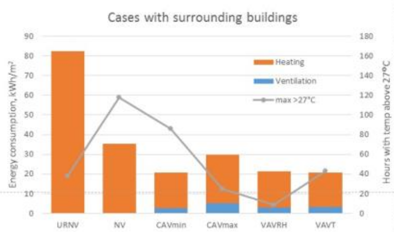
Session 5C – Improving the efficiency of VC
Timea Bejat: Experimental and Numerical Study of a Building Retrofitting Solution Combining Phase Change Material Wallboards and Night Ventilation

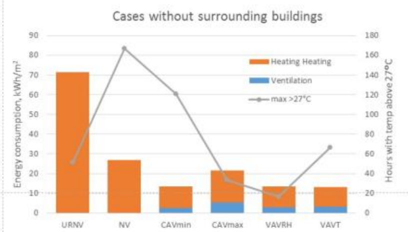


Solid	Phase change	Liquid
T(PCM) <19,1°C	19,1°C < T(PCM) < 24,25 °C	T(PCM)>24,25 °C



Session 5C – Improving the efficiency of VC
Daria Zukowska: Potential of mech. Vent. for reducing overheating risks in retrofitted Danish apartment buildings from 1850-1890 – A simulation-based study





Session 6C – Annex 80 Resilient Cooling
Peter Holzer, Hilde Breesch

1. Preparation phase of Annex 80 Resilient Cooling open until June 2018
2. Preparation workshop Nr.1
   taking place tomorrow, 09:00,
   Room Louis Armstrong
3. Further information
   http://annex80.iea-ebc.org

EBC
Energy in Buildings and Communities Programme

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AIVC 2018

Smart Ventilation, IAQ & Health

Benjamin Jones

University of Nottingham
UK | CHINA | MALAYSIA

Context

AIVC Projects and Workshops

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On-Going AIVC Projects

1. Smart Ventilation
2. Air cleaning as an alternative to ventilation
3. Utilization of heat recovery
4. Rational behind ventilation requirements and regulations
5. Integrating uncertainties dues to wind and stack effect in declared airtightness results
6. Indoor Air Quality-IAQ Metrics
7. Residential cooker hoods
8. Competent tester schemes for building airtightness testing

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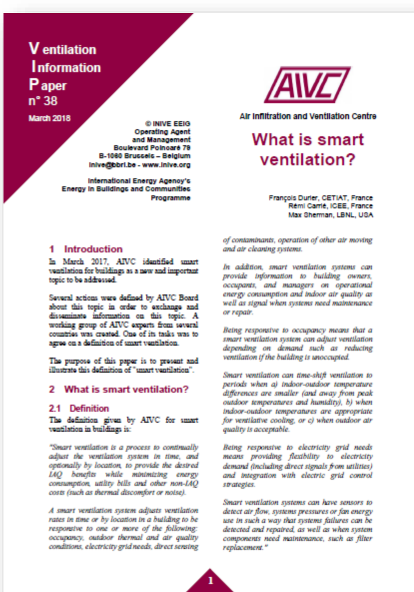
Smart Ventilation and Health Metrics



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Smart ventilation

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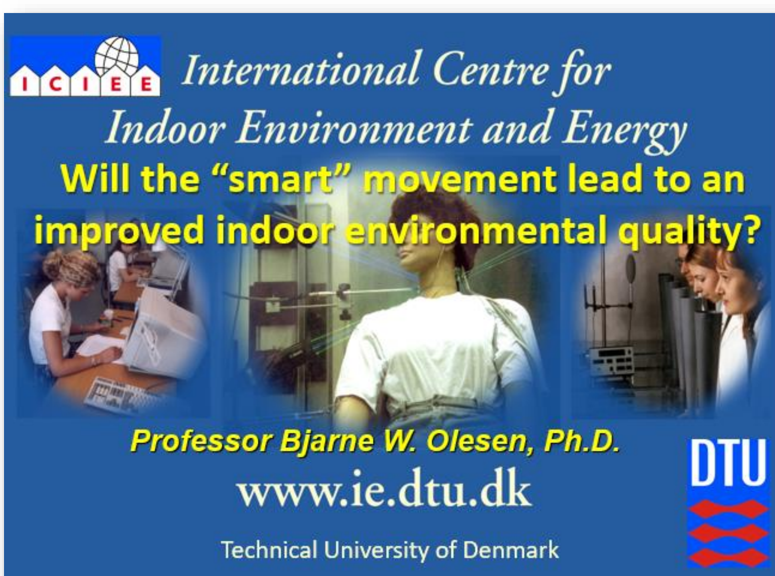
A question



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Panel of experts!

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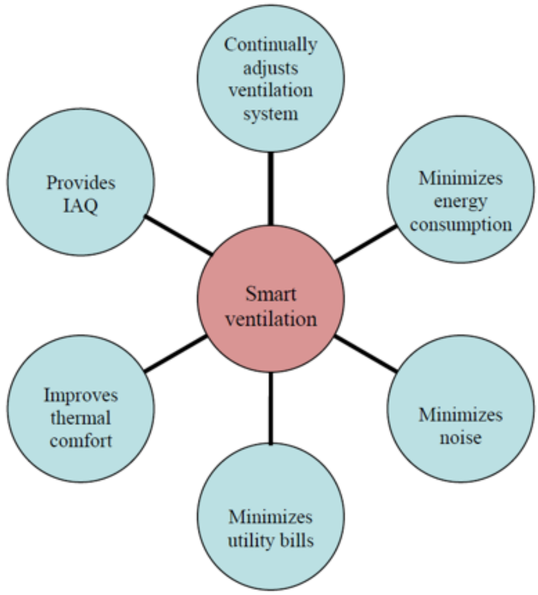
Filters

*Smart ventilation is a process to **continually adjust the ventilation** system in time, and optionally by location, to provide the **desired IAQ** benefits while **minimizing energy consumption,** utility bills and other non-IAQ costs (such as thermal discomfort or noise).*

Parameters to which a smart system *can* respond



Further clarification

" A smart ventilation system adjusts ventilation rates in time or by location in a building to be responsive to one or more of the following:
occupancy, outdoor thermal and air quality conditions, electricity grid needs, direct sensing of contaminants, operation of other air moving and air cleaning systems

Further information:

1. AIVC VIP 38
2. Guyot, G., Sherman, M.H., Walker, I.S., 2018. Smart ventilation energy and indoor air quality performance in residential buildings: A review. Energy and Buildings 165, 416–430. https://doi.org/10.1016/j.enbuild.2017.12.051

Panel of experts!

Control of contaminants

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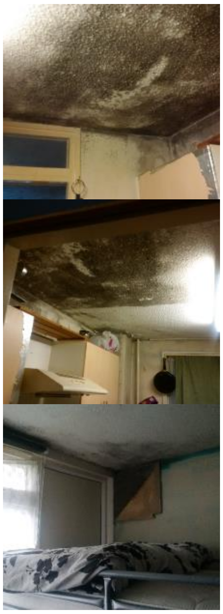
Problems in houses



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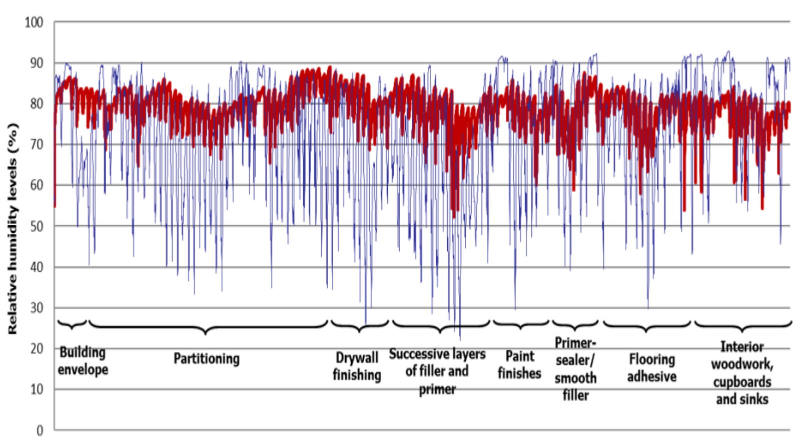
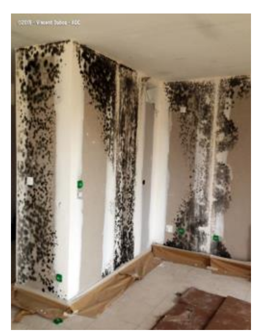
Problems in houses



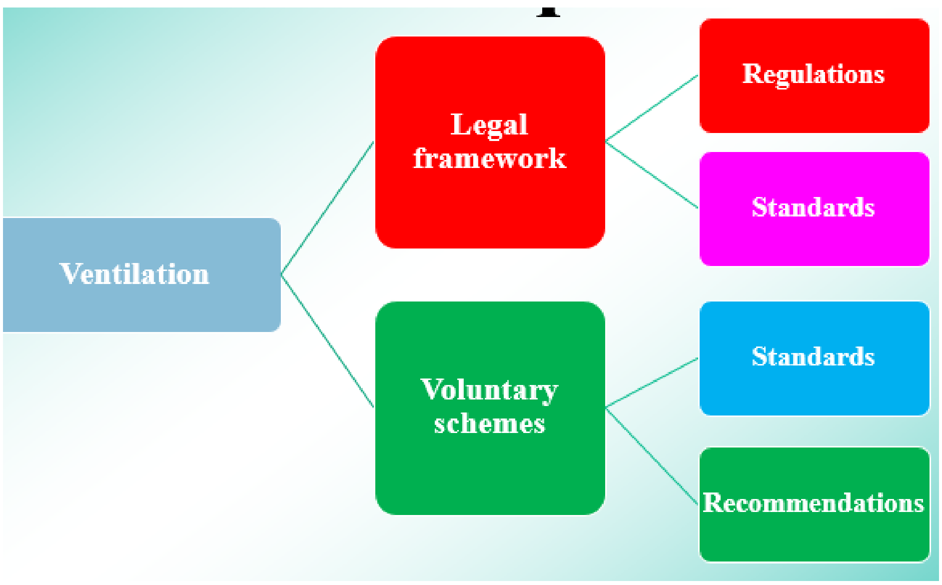


Domestic Kitchens

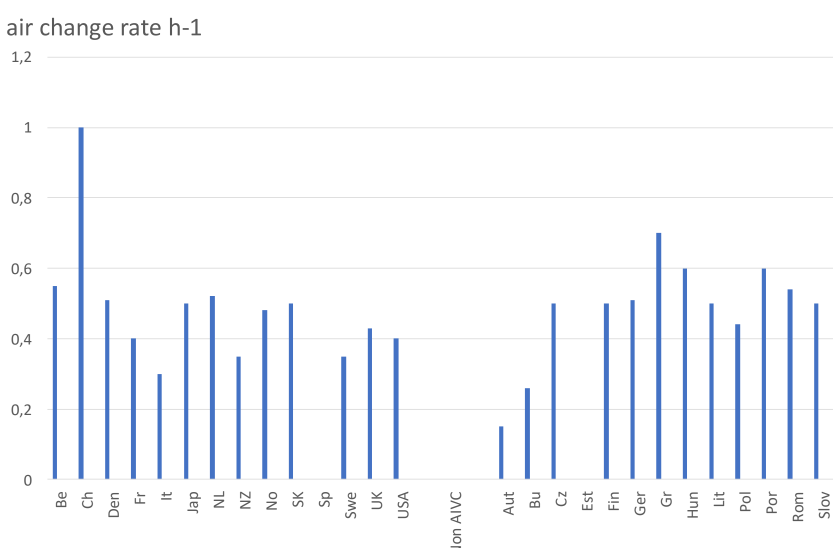
- An intervention study in UK student housing (where the intervention was health information based on the measured concentrations) showed now effect despite the efforts of the occupants to control their ventilation.
- A need to consider both extraction flow rate and the capture efficiency of a cooker hood in building regulations and standards. It suggests that most UK kitchens are currently under-ventilated if trying to stay below WHO thresholds. But is this an appropriate threshold?
- However, exposure is key to those cooking or standing nearby! Could assume perfect mixing but in reality the movement of the cook significantly affects exposure.
- More research on this topic is needed on measurements of exposure and disturbances, and on the effect of differences range hoods types.
- Cooker hood capture efficiency can be affected by airflow rate, emitter power and location. These must be specified by a standard test procedure. A test requires time, because a steady-state concentration must be achieved.

Requirements and regulations

Boundaries



Surprising differences



average 0,48
min. 0,15
max. 1,0
ratio H/L ≈ 6
without outlyers:
ratio h/l ≈ 3

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And the rationale?

- It seems that:
  - experts studied literature and made best guesses for the ventilation levels
  - No solid scientific reports are found as background
- New studies show a need for other solutions for cooking fumes (PM, NOx)
- **Can AIVC play a role in an more universal approach for ventilation requirements based on exposure, taking into account national circumstances?**
- **It thinks it can!**

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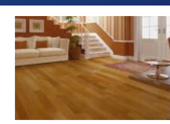
New contaminants and diagnostic techniques

- **Volatile organic compounds (VOCs)**
  - Vapor pressure $\geq$10 Pa at 20 °C
  - Examples: formaldehyde, benzene, butanol, etc.
  - Sources: paints, adhesives, carpets, pressed-wood products, floorings, etc.
  - Effects: reduced worker productivity, eye and respiratory irritations, headaches, fatigue, asthmatic symptoms, and cancers
- **Semivolatile organic compounds (SVOCs)**
  - Vapor pressure in range of 10^{-9} to 10 Pa
  - Examples: phthalate plasticizers, brominated flame retardants, and organophosphate pesticides
  - Sources: polyvinyl chloride (PVC) products, lotions, nail polish, cling film, shampoo, computers, televisions, foams, shower curtains, etc.
  - Effects: endocrine disrupting to neurodevelopment and reproductive development

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IAQ Metrics

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Metrics

- New values of CO_2 concentration to be used as an indicator of per capita ventilation rates
- There is a need to turn IAQ metrics into a monetized value
  - Using medical economics
  - Consider morbidity and mortality (i.e. account from shortening of life and loss of quality of life)
  - Smart ventilation is an intermediary step that can be implemented today
- Diagnostic techniques to enforce metrics
  - Discussions on the measurements of CO_2 and PM2.5
    - Where? What with? Sampling frequency? How long? Acceptable uncertainty. Data presentation.

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Sensors

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PM2.5

- Two studies of low-cost light scattering sensors (<€250)
  - Arizona road dust, mop, hair dryer, cooking element, cooking cigarettes, incense, cooking, cleaning products
- Problems
  - All calibrated to different particles and so their reading are relative the refractive indexes of the calibrating particles. Calibration factors are required.
  - Devices are sensitive to PM of different diameters and so give different readings even when measuring PM from the same source
- Outcomes
  - Cheap devices without calibration factors are probably OK to switch ventilation devices
  - However, they are probably not good enough to inform calibrated health models
  - Still need to investigate durability & deal with internet downtime


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The End

39th AIVC Conference
7th TightVent Conference
5th venticool Conference

Smart Ventilation for buildings

Summing up of airtightness track

Arnold Janssens

Ghent University, Belgium

Track ‘ventilation and (building) airtightness’: Topics in call for papers

- Durability of building and ductwork airtightness
- Energy and IAQ impact of envelope and ductwork leakage
- Risks related to building airtightness
- Field data and case studies
- Infiltration measurement techniques and IR thermography
- Compliance schemes and barriers to innovation
- Energy rating of ventilation product and systems
- Innovative ventilation concepts and combined systems
- Fan energy demand
- Heat recovery issues (freezing, natural ventilation)
- Ventilation in renovated buildings

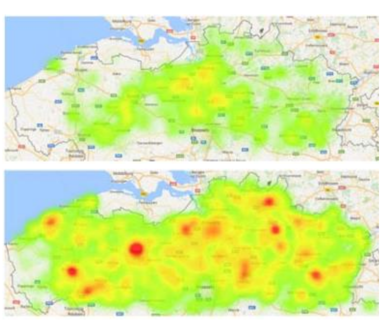
Overview airtightness track

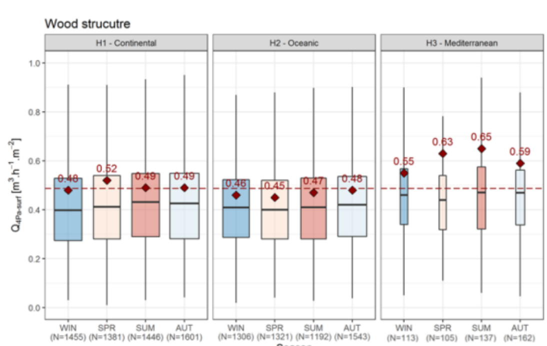
18 September	19 September
1A Analysing airtightness measurements	5B Demand controlled ventilation
2B Topical session: Ductwork airtightness	6B Topical session: Performance of heat recovery ventilation in practice
3B Topical session: Integrating uncertainties in declared airtightness results	
	8B New methodologies and improvements for airtightness

34 presentations

Big data on airtightness

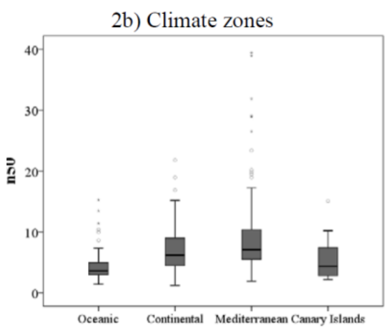
- Part of qualified tester schemes to support compliance of EP-regulations of new houses:
  - Belgium: 22 600 test results [De Strycker et al.]
  - France: 215 000 test results [Moujalled et al.]

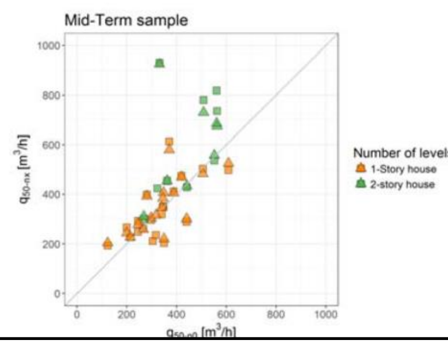




Smaller data on airtightness

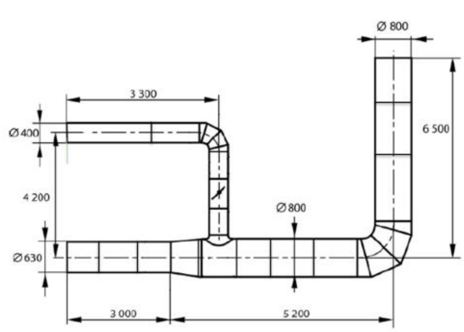
- Ductwork airtightness
  - France: 1300 measurements since 2017
- Existing houses
  - Spain: 400 houses tested for national baseline [Poza-Casado et al.]
  - France: 61 houses to investigate durability
  - Czech Rep.: 4 houses to investigate durability [Novàk]





Solutions for ductwork airtightness

- DUCT: Eurovent Certified Performance for airtightness of ductwork systems
- Aeroseal technology for sealing existing duct systems

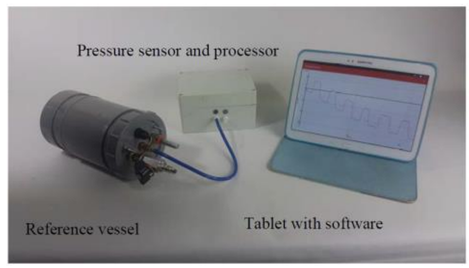


Alternative methods for building airtightness testing

Figure 10 Setup of blower door (SW test)

Figure 11 Setup of PULSE unit (SW test)

- Pulse test [Zheng et al., Wood et al., Vega Pasos et al.]
- Pressurization using mechanical ventilation system [Lanooy et al.]



Design of residential ventilation systems

- Airtight NZEB presents challenges and opportunities for ventilation [Kurnitski]
- Improve designs of MEV and MVHR ventilation systems to improve performance and better reflect user needs [Knoll et al., Laverge et al., Fauré]

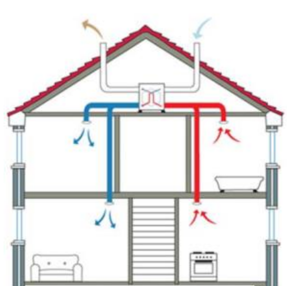


Figure 4: Mechanical ventilation with heat recovery

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7th TightVent Conference

5th venticool Conference

Smart Ventilation for buildings

Summing up of airtightness track

Thank you for your attention!

French R&D activities related to ventilation, indoor air Quality and airtightness of buildings

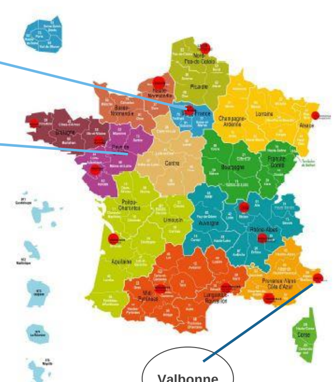
Nicolas Doré
Deputy Head of Building Department at ADEME
French "EBC" ExCo member

ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

INVESTISSEMENTS D'AVENIR

ADEME : French Environnement and Energy Management Agency

- waste management,
- soil conservation,
- Energy efficiency and renewable energy,
- raw materials savings,
- air quality,
- noise abatement,
- circular economy transition
- food wastage abatement.



~900 people

180 PhD's

3 national locations

17 regional directions

Budget incitatif

600 M€ in 2018

IAQ and ventilation context in France

- New building market : Thermal Regulation "RT2012" : improvement of thermal insulation and building air-tightness with "on site controls".
- The retrofit market : None particular efficient regulation, none control
- 1 building over 2 show non conformity rates on residential ventilation systems

Challenges :

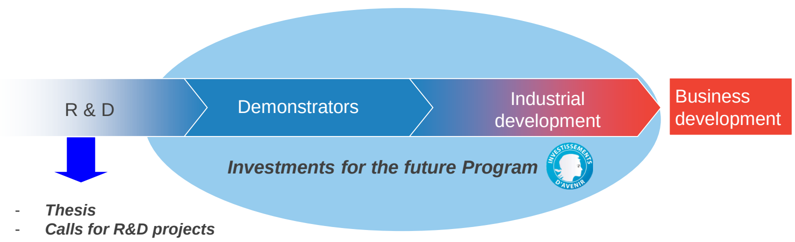
1. Conciliate energy performance and IAQ
2. Consider the ventilation sector as a key sector
3. Create the job of "ventilation specialist"

Ademe intervention on the ventilation sector

1. Innovation
2. Quality of the installations and skills of the installers
3. Regulations Evolutions
4. Public and professional communication

ADEME: tools for financing innovation at different stages

- **R&D phase:** ADEME thesis, calls for R&D projects, contribution to European calls
- **"Investments for the future" program**
  - Demonstrators and industrial development
  - A ten-years program
  - Budget of € 2.9 bn operated by ADEME
  - Two ways of funding: State aid according to the European framework (subsidies and refundable grants) and capital investment



- *Thesis*
- *Calls for R&D projects*
- *European calls for projects*

THESIS

Funding of more than 50 PhD's every year for more than 25 years (including 3 to 4 thesis per year on IAQ and ventilation)

Some Examples of thesis helped by ADEME

- Time monitoring on residual exposition to biocides substances
- Modelisation of air transfers and their impact on hygro-thermal reaction of building envelope
- Heat – Humidity - Air in wooden houses : experiments and models
- Study on microorganisms developments on biosource insulation materials
- Study of ventilation strategies to improve IAQ and comfort in schools
- Performance assessment of a bio process to reduce indoor pollution

calls for R&D projects

The call for **projets "Sustainable building by 2020" or "Cortea"** to help reseach and development of industrial products for new and retrofitted buildings as well as framework projects which are presented during this conference.

VIA QUALITE project (2013-2016) aims at developing quality management of ventilation systems complementing the existing quality management of building air-tightness of our energy regulation.

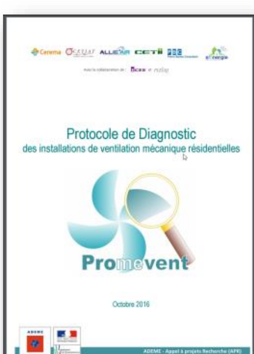
PROMEVENT (2014-2016) aims at improving measurements for the inspection of residential ventilation systems, proposes a control process for mechanical ventilation systems including airflow measurement at ATD and duct air tightness measurement.

ICHAQAI : The objective of the ICHAQAI scientific project was twofold: firstly, to identify and characterize the different elements that can have a detrimental impact on the indoor air quality during construction; secondly, to propose solutions that will enable professionals to reduce the negative impacts of construction on the indoor air quality of the future constructed building 'in-use'.

FOCUS on PROMEVENT results

Protocol and technical guide for airflow measurement at ATD and duct air tightness measurement

- Our objective : make the protocol compulsory for the next new buildings regulation 2020



PRAXIBAT « Improving the skills of the installers »

Implementation of PRAXIBAT a training tool for practitioners to improve their skills and fitting needed for sustainable buildings, energy efficients.

For ventilation : 50 technical fully equipped centers and more than 200 trainers.
For building air-tightness, : 62 equipped centers and more than 350 trainners.

Different Publications

Translation in progress

Thank you

Nicolas Doré

Modern History of Indoor Air Quality (1973-Present)

DONALD M. WEEKES, CIH, CSP, FAIHA

INAIR ENVIRONMENTAL LTD.

OTTAWA, ON, CANADA

1970'S - Ventilation

ASHRAE 62-73

62-73

ANSI B 194.1-1977

ASHRAE STANDARD

Standards for NATURAL AND MECHANICAL VENTILATION

Approved by the American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc. Standards Committee January 28, 1973, and Board of Directors by Letter Ballot February 16, 1973.

ASHRAE Standards are updated on a five-year cycle; the date following the Standard number is the year of approval. The latest copies may be purchased from the ASHRAE Circulation Sales Department, 345 East 47th Street, New York NY 10017.

Copyright 1973

ASHRAE LIBRARY

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

Highlights

- Definition – Acceptable Ventilation Air Quality
- Maximum Allowable Contaminant Concentrations – CO, Particulates, Sulfur Dioxide, etc. – NO CO_2.
- Unacceptable Outdoor Air – 1/10 of the ACGIH TLV's.
- Ventilation Requirements – Minimum in offices – 15 CFM; Recommended – 15-25 CFM.
- Industrial – Ventilation Requirements

1970's – Indoor Air Quality

Professional Meetings

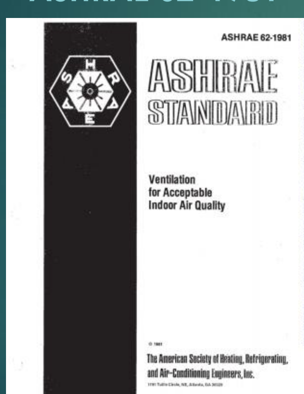
- REHVA – First Meeting – 1970 - Brussels
- AIVC – First Conference – 1979
- Indoor Climate – First Conference – 1978 – Stockholm (focus – Thermal Comfort)

Other IAQ Issues

- Legionella – Philadelphia – 1976
- Asbestos – 1972
- Lead Paint – 1979
- Sick Building Syndrome

1980's - Indoor Air Quality

ASHRAE 62-1981



Highlights

- Title – Ventilation for Acceptable Indoor Air Quality
- Definition – Acceptable Air Quality – 80% of occupants – no 'dissatisfaction'.
- Two Procedures
  - Ventilation Rate Procedure
  - IAQ Procedure
- 1/10 of OSHA Standards
- Minimum Ventilation Rate – Offices – 5 CFM (non-smoking)

ASHRAE Standard 62.1
What is its History?

1970 | 1980 | 1990 | 2000 | 2010

62-1973
first issued

62-1981
Alternative Air Quality Proc.

62-1989
- Removed Thermal Comfort
- Ventilation Rate Proc.
- IAQ Proc.

62-1999
- IAQ-Health disclaimers
- Smoking disclaimers
- Clarified CO_2 as ventilation metric

62-2001
- Prescriptive
- Commissioning
- O&M
- Combustion air
- Filtration

62.1-2004
- Commercial and High Rise Res.
- Enforceable code language
- ETS vent. rates not covered
- Vent. Rate. Proc. Modified
- Occupant and area vent. rates

62.1-2007
Updated

Indoor Air Quality Procedure

Table 4 – Air Contaminants

- First mention of CO_2 – 4.5 g/m^3
- Formaldehyde – 120 μg/m^3
- Asbestos – Known carcinogen – Best available control technology
- Also: Radon; Chlordane; Ozone

IAQ Procedure

- Subjective rather than objective evaluation
- 80% of a panel of at least 20 untrained observers find the air to be 'not objectionable'.
- 15 seconds - judgment of acceptability

1980's - Indoor Air Quality

Other Organizations

- AIHA – Indoor Environmental Quality (IEQ) Committee – First meeting – 1983
- Healthy Buildings Conference – First in 1988 – Stockholm
- AIHA – International Symposium on IAQ – 1988 – St. Louis, MO
- ASHRAE IAQ Conference - 1986

Growth and Changes

- Indoor Air Conferences – Amherst – 1981; Stockholm – 1984; Berlin – 1987
- IAQ Practitioners – Involved with MCS, asbestos, lead paint, radon, etc.
- Research – Focus on Microbial Contamination, VOC's, ETS, MCS
- ASHRAE 62-1989 – Ventilation for Acceptable Indoor Air Quality

1990's - Indoor Air Quality

New Organizations

- ISIAQ Founded – 1992
- IAQA Founded – 1995
- USGBC Founded – 1993

New Directions

- Microbial Contamination
- Environmental Tobacco Smoke
- Perceived Indoor Air Quality (Fanger – 1992)
- IAQ in Developing Nations

2000's - Indoor Air Quality

IAQ Interests

- Microbial Contamination and Damp Buildings
- Allergies and allergic reactions
- VOC's
- Particles
- COPD and acute respiratory infections
- Asthma

Green Buildings

- LEED Requirements – Post-Construction, pre-occupancy IAQ Sampling
- Energy Savings – Tight Buildings
- Increase in IAQ complaints in office buildings
- Growth of Remediation activities
- Emissions from Building Materials

2010's - Indoor Air Quality

IAQ Interests

- Residential issues with IAQ and health effects (allergies)
- Multi-disciplined Approach to IAQ issues
- Multi-national issues (PM_{10} and $PM_{2.5}$)
- Indoor Environmental Quality (IEQ) (lighting; sound, vibration, electromagnetic radiation)

Emerging Issues

- Biomass Burning for Cooking – Prime IAQ Killer in World
- Ventilation in Hot, Humid Climates
- Ventilation in Bad Ambient Air
- SVOC's and Health
- Indoor Air Chemistry
- Microbiome

Modern History of IAQ

Thanks!

Questions?

Donald Weekes

don.weekes@inairenvironmental.ca

613-224-3863

Upcoming

Hide upcoming

15-16 October 2019, Conference, Ghent, 40th AIVC conference

Ghent, Belgium 15/10/2019

The 40th AIVC conference will be held on 15 and 16 October 2019 in Ghent, Belgium. It will also be the 8th TightVent conference and the 6th venticool conference. More information on the title, topics etc. will be available soon.

View More

18-19 September 2018, Conference, Juan-les-Pins, 39th AIVC conference

Juan-les-Pins, France 18/09/2018

View More

13-14 September 2017, Conference, Nottingham, 38th AIVC conference

Nottingham, United Kingdom 13/09/2017

View More

12-14 September 2016, Conference, Alexandria, VA –37th AIVC - ASHRAE- IAQ joint Conference

Alexandria, VA, United States of America 12/09/2016

View More

23-24 September 2015, Conference, Madrid – 36th AIVC conference

Madrid, Spain 23/09/2015

View More

24-25 September 2014, Conference, Poznan - 35th AIVC conference

Poznan, Poland 24/09/2014

View More

25-26 September 2013, Conference, Athens - 34th AIVC Conference

Athens, Greece 25/09/2013

View More

40TH AIVC CONFERENCE

- October 15-16, 2019, Ghent, Belgium
- **From Energy Crisis to Sustainable Indoor Climate: 40 years of AIVC**
  - Smart ventilation, IAQ and health
  - Ventilation an airtightness
  - Ventilative and resilient cooling
  - Historical evolutions in ventilation and infiltration

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WHAT IS NEW IN 2019?

- Two possibilities for submission of papers:
  - Abstract review
  - … + full paper review
- Possibility to propose topical sessions
- Short industry presentations

… while maintaining classic ingredients of AIVC conferences:

- 3 parallel sessions
- Summing up tracks
- Best paper and poster
- Social programme:
  - Welcome reception
  - Walking dinner in the city

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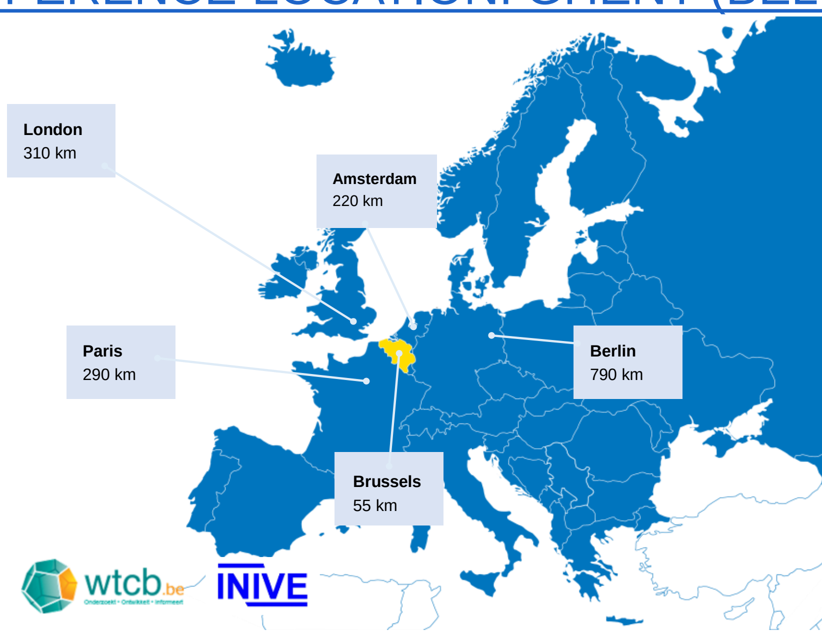
CONFERENCE LOCATION: GHENT (BELGIUM)



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GHENT (BELGIUM)

- City of culture with 250.000 inhabitants
- Student city with +70,000 students

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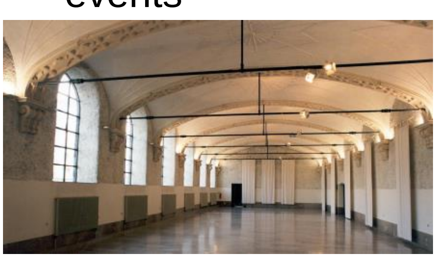
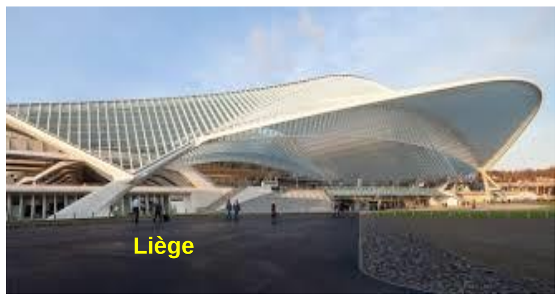
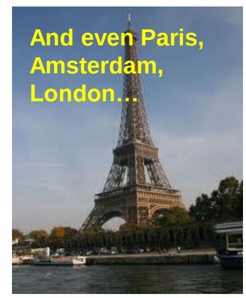
CONFERENCE VENUE 'HET PAND'

- Former Domenican monastry (13th cent.) in heart of the city
- Now used for scientific and cultural events



SIGHTSEEING





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HOW TO TRAVEL?

- By plane
  - From Brussels airport: 1 hour by train
  - From Schiphol airport, Amsterdam: 2 hours by train
  - From Charles De Gaulle Paris airport: 2h15 by train
- Travelling in Belgium
  - Brussels: 30 minutes by train
  - Bruges: 20 minutes by train
  - Antwerp: 50 minutes by train

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‘Ghent: Belgium's best kept secret’

‘Once medieval Europe's second largest city, over the past century this unsung treasure of a town has developed a strong artistic bent, and is now one of the best places in Europe for culture’

https://youtu.be/BWY8vIF5gls