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PRESENTATIONS

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Wednesday 24 September 2014

08:00 Registration

ROOM A

09:00-10:45 Opening – Plenary Session *(part 1)*

Chairpersons: ***Peter Wouters, Tomasz Mroz***

- **Welcome on behalf of AIVC, venticool, TightVent** (p.17)
  Peter Wouters, Manager of INIVE EEIG, Belgium
- **Ventilation and airtightness in Poland. Status and perspectives** (p.30)
  Tomasz Mróz, Professor, Poznań University of Technology, Poland
- **Recent advances on factors influencing human responses and performance in buildings and their potential impact on ventilation requirements** (p.49)
  Pawel Wargocki, Associate Professor, Technical University of Denmark, Denmark (Invited Speaker)

11:15-12:45 Plenary Session *(part 2)*

Chairpersons: ***Tomasz Mróz, Max Sherman***

- **Outcome of Annex 55 "Reliability of energy efficient building retrofitting-Probability assessment of performance & cost (RAP-RETRO)** (p.69)
  Carl-Eric Hagentoft, Professor, Chalmers, Sweden (Invited Speaker)
- **The French Indoor Air Quality Observatory-Outcomes of a decade of research and perspectives** (p.84)
  Séverine Kirchner, Health and Comfort Division CSTB, France (Invited Speaker)
- **Potential and limitation to ventilative cooling** (p.102)
  Per Heiselberg, Professor, Aalborg University, Denmark (Invited Speaker)

13:45-15:15 Parallel Session 1A: Topical Session – Quality issues in airtightness testing

Chairpersons: ***Max Sherman, Masaki Tajima***

- **Comparison of building preparation rules for airtightness testing in 11 European countries** (p.117)
  Valérie Leprince, France
- **Belgian framework for reliable fan pressurization tests for buildings** (p.130)
  Clarisse Mees, Belgium
- **Large buildings airtightness measurements using ventilation systems** (p.137)
  Michał Szymański, Poland

- **Model error due to steady wind in building pressurization tests** (p.147)
  François Rémi Carrié, France

ROOM B

13:45-15:15 Parallel Session 1B: Topical Session – Ventilative cooling and Annex 62
Chairpersons: ***Per Heiselberg, Peter Holzer***

- **IEA EBC Annex 62 ventilative cooling** (p.157)
  Per Heiselberg, Denmark (Invited Speaker)
- **Design and analysis methods for ventilative cooling** (p.167)
  Annamaria Belleri, Italy
- **Experiences with ventilative cooling in practical application based on experiences with completed active houses** (p.179)
  Peter Foldbjerg, Denmark
- **Residential ventilative cooling in national energy performance regulations: requirements and sensitivity analysis** (p.191)
  Ivan Pollet, Belgium
- **Experimental characterization of dominant driving forces and fluctuating ventilation rates for a single sided slot louver ventilation system** (p.202)
  Paul D O' Sullivan, UK

ROOM C

13:45-15:15 Parallel Session 1C: Topical Session – Demand - controlled ventilation strategies for residential / commercial buildings
Chairpersons: ***Tomasz Mroz, Jelle Laverge***

- **Requirements and hand-over documentation for energy-optimal Demand-Controlled Ventilation**(p.210)
  Mads Mysen, Norway
- **Monitoring of an innovative room-by-room demand controlled heat recovery system on four locations** (p.216)
  Madeline Colette, France
- **Evaluation methodology to quantify the energy potential of DCV strategies** (p.223)
  Samuel Caillou, Belgium
- **Multi-zone demand-controlled ventilation in residential buildings: An experimental case study** (p.236)
  Arefeh Hesaraki, Sweden

ROOM A

15:15-16:45 Parallel Session 2A – Topical Session: Durability of airtightness
Chairpersons: ***Arnold Janssens, Paula Wahlgren***

- **Durable airtightness in single-family dwellings: field measurements and analysis** (p.244)
  Wanyu Chan, USA
- **Durability of building airtightness** (p.252)
  Magnus Hansén, Sweden
- **Assessment of the durability of the airtightness of building elements via laboratory tests** (p.260)
  Clarisse Mees, Belgium
- **Airtightness of building penetrations: Air sealing solutions, durability effects and measurement uncertainty** (p.274)
  Wolf Bracke, Belgium
- **Airtightness variation over the year** (p.288)
  Paula Wahlgren, Sweden

ROOM C

15:15-16:45 Parallel Session 2C – Topical Session: EPBD Ventilation standards and regulations Revision Status
Chairpersons: ***Jaap Hogeling, Gerhard Zweifel***

- **The second generation CEN-EPBD standards** (p.300)
  Jaap Hogeling, The Netherlands (Invited Speaker)
- **Indoor enviromental parameters: Revision of EN 15251** (p.316)
  Bjarne Olesen, Denmark (Invited Speaker)
- **Calculations methods: Revision of EN 15241-15242-15243** (p.334)
  Gerhard Zweifel, Switzerland (Invited Speaker)
- **Inspection of ventilation systems and air conditioning systems** (p.341)
  François Rémi Carrié, France

ROOM A

17:10-18:40 **Parallel Session 3A- Short oral presentation session – Building Airtightness:field characterization, energy and IAQ impacts**

Chairpersons: ***Wouter Borsboom, Michal Szymański***

- **Estimating the impact of incomplete tracer gas mixing on infiltration rate measurements** (p.349)
  Peter McDowall, New Zealand
- **The 10 steps to conceive and build airtight buildings** (p.351)
  Clarisse Mees, Belgium
- **ACH and air tightness test results in the Croatian and Hungarian border region** (p.354)
  György Polics, Hungary

ROOM B

17:10-18:40 **Parallel Session 3B- Short oral presentation session – Ventilative cooling**

Chairpersons: ***Peter Holzer, Ivan Pollet***

- **Summer performance of residential heat recovery ventilation with an air-to-air heat pump cooling system** (p.360)
  Bart Cremers, Poland
- **Indoor climate in a Danish kindergarten built according to active house principles: measured thermal comfort and use of electrical light** (p.363)
  Peter Foldbjerg, Denmark
- **Strategies for exploiting climate potential through ventilative cooling in a renovated historic market** (p.368)
  Annamaria Belleri, Italy
- **Passive Cooling Through Ventilation Shafts in High-Density Zero Energy Buildings: A Design Strategy to Integrate Natural and Mechanical Ventilation in Temperate Climates** (p.372)
  Luca Guardigli, Italy
- **Optimization of data center chilled water cooling system according to annual power consumption criterion** (p.375)
  Piotr Kowalski, Poland

- **Simulation analysis for indoor temperature increase and reduction of heating load in the detached house with buoyancy ventilated wall in winter** (p.378)
  Kan Lin, Japan
- **Reducing cooling energy needs through an innovative daily storage based facade solution** (p.381)
  Javier García Ramos, Spain
- **Monitoring results and optimization of a facade integrated ventilation concept for building retrofit** (p.384)
  Fabien Coydon, Germany
- **PROMEVENT: Improvement of protocols measurements used to characterize ventilation systems performance** (p.387)
  Adeline Bailly, France
- **Impact of a poor quality of ventilation systems on the energy efficiency for energy-efficient houses** (p.390)
  Adeline Bailly, France
- **Exergy evaluation of mechanical ventilation systems** (p.393)
  Anna Dutka, Poland
- **Multi-pipe earth-to-air heat exchanger (EAHE) geometry influence on the specific fan power (SFP) and fan energy demand in mechanical ventilation systems** (p.396)
  Lukasz Amanowicz, Poland
- **Implementation and performance of ventilation systems: first review of voluntary certification controls in France** (p.401)
  Sarah Juricic, France
- **Energy saving and thermal comfort in residential buildings with dynamic insulation windows** (p.403)
  Daisuke Kawahara, Japan
- **Development of a decentralized and compact comfort ventilation system with highly efficient heat recovery for the minimal invasive refurbishment of buildings** (p.406)
  Janez Zgaga, Italy

17:10-18:40 Parallel Session 3C- Short oral presentation session – Ventilation, indoor air quality, health and comfort

Chairpersons: ***François Durier, Mads Mysen***

- **Derivation of equation for personal carbon dioxide in exhaled breath intended to estimation of building ventilation** (p.409)
  Masaki Tajima, Japan
- **Impact of a photocatalytic oxidation layer covering the interior surfaces of a real test room: volatile organic compound mineralisation, risk assessment of by-product and nanoparticle emissions** (p.412)
  Franck Alessi, France
- **Use of DCV for heating and the influence on IAQ in passive house buildings** (p.416)
  Vegard Aslaksen, Norway
- **A Study of Carbon Dioxide Concentrations in Elementary Schools** (p.418)
  John Sifnaios, Greece
- **The effect of enthalpy recovery ventilation on the residential indoor climate** (p.423)
  Bart Cremers, Poland
- **Air renewal effectiveness of decentralized ventilation devices with heat recovery** (p.426)
  Fabien Coydon, Germany
- **Demand-Controlled Ventilation- 20 years of in-situ monitoring in the residential field** (p.429)
  Jean-Luc Savin, France
- **Heating "passive house" offices in cold climate using only the ventilation system – comparison of two ventilation strategies** (p.435)
  Hugo Lewi Hammer, Norway
- **Cleanliness of air filters in the experimental passive house** (p.441)
  Malgorzata Basinska, Poland
- **Air heating of passive house office buildings in cold climates – how high supply temperature is acceptable?** (p.435)
  Axel Cable, Norway
- **Energy-optimal ventilation strategy outside of the operating time for passive house office buildings in cold climates** (p.444)
  Per Magnus Holth, Norway
- **Can air heating alone be used in passive house office building in cold climates? Review of the obtained results** (p.446)
  Kari Thunshelle, Norway

- **Impact of the use of a front door on thermal comfort in a classroom in a passive school** (p.449)
  Hilde Breesch, Belgium
- **Development of a Unique Thermal and Indoor Air Quality Probabilistic Modelling Tool for Assessing the Impact of Lowering Building Ventilation Rates** (p.452)
  James McGrath, Ireland
- **A protocol for assessing Indoor Air Quality in retrofitted energy efficient homes in Ireland** (p.455)
  Aine Broderick, Ireland
- **CFD simulation of an office heated by a ceiling mounted diffuser** (p.457)
  Bård Venås, Norway
- **Optimal positioning of air-exhaust openings in an operating room based on recovery test: a numerical study** (p.465)
  Sasan Sadrizadeh, Sweden
- **The influence of traffic emissions on IAQ, especially in street canyons** (p.470)
  Zbigniew Bagieński, Poland

Thursday 25 September 2014

ROOM A

08:45-09:45 **Parallel Session 4A: Topical Session – Characterization of airtightness products**

Chairpersons: ***Tormod Aurlien, Targo Kalamees***

- **Temperature and pressure corrections for power-law coefficients of airflow through ventilation system components and leaks** (p.473)
  François Rémi Carrié, France
- **Testing for building components contribution to airtightness assessment** (p.480)
  Nuno M. M. Ramos, Portugal
- **Performance of airtightness products: characterization of sealants and expanding foams** (p.493)
  Filip Van Mieghem, Belgium

ROOM B

08:45-09:45 **Parallel Session 4B: Long Oral Presentation Session – Ventilative cooling**

Chairpersons: ***Gerhard Zweifel, Jarek Kurnitski***

- **Do existing international standards support ventilative cooling?** (p.517)
  Bjarne Olesen, Denmark (Invited Speaker)
- **Perception of a cooling jet from ceiling - a laboratory study** (p.529)
  Henna Maula, Finland
- **Coupling hygrothermal whole building simulation and air-flow modelling to determine strategies for optimized natural ventilation** (p.536)
  Matthias Pazold, Germany

ROOM A

10:05-11:35 **Parallel Session 5A: Long oral presentation Session – Airtightness improvements in existing buildings**

Chairpersons: ***Paula Wahlgren, Benjamin Jones***

- **Air leakages in a retrofitted building from 1930: measurements and numerical simulations** (p.553)
  Par Johansson, Sweden
- **Airtightness improvement of structures to improve indoor air quality** (p.566)
  Katariina Laine, Finland

- **Experiences in the airtightness of renovated tertiary Exemplary Building in the Brussels Capital Region**(p.570)
  Bram De Meester, Belgium
- **Strategies for the planning and implementation of airtightness on existing sloped roofs**(p.584)
  Wilfried Walther, Germany

ROOM B

10:05-11:35 Parallel Session 5B: Topical Session – Comfort in sustainable buildings

Chairpersons: ***Hannu Koskela, Karsten Duer***

- **Self-evaluated thermal comfort compared to measured temperatures during summer in three active houses where ventilative cooling is applied** (p.604)
  Peter Foldbjerg, Denmark
- **Control of indoor climate systems in Active Houses** (p.611)
  Peter Holzer, Austria
- **Comfort in naturally ventilated offices** (p.629)
  Ivan Pollet, Belgium
- **Human comfort in Active House,learning's from ModelHome2020** (p.644)
  Moritz Fedkenheur, Germany

ROOM C

10:05-11:35 Parallel Session 5D: Topical Session – Residential cooker hoods and kitchen ventilation

Chairpersons: ***Peter Wouters, Wouter Borsboom***

- **Boundary conditions and challenges for cooker hoods in low energy buildings** (p.658)
  Peter Wouters, Belgium
- **Cooker hoods in the American context-Standardized method for Capture Effiency**(p.665)
  Max Sherman, USA
- **Cooker hoods in the European standardization and legislative context** (p.675)
  Willem de Gids, The Netherlands
- **Strategies for efficient kitchen ventilation** (p.690)
  Wouter Borsboom, The Netherlands

ROOM A

11:50-12:50 Parallel Session 6A: Topical Session – Ductwork airtightness in new and renovated buildings

Chairpersons: ***Arnold Janssens, Jarek Kurnitski***

- **Demand controlled Ventilation in renovated buildings with reuse of existing ductwork** (p.704)
  Mads Mysen, Norway
- **Ductwork airtightness: reliability of measurements and impact on ventilation flowrate and fan energy consumption** (p.711)
  Sylvain Berthault, France
- **Practical solutions for airtight ductwork** (p.721)
  Lars-Åke Mattsson, Sweden

ROOM B

11:50-12:50 Parallel Session 6C: Long oral presentation session – Field performance of demand controlled ventilation

Chairpersons: ***Pilar Linares Alemparte, Hannu Koskela***

- **Comparison of two ventilation control strategies in the first Norwegian school with passive house standard** (p.730)
  Axel Cable, Norway
- **Monitoring the energy & IAQ performance of ventilation systems in Dutch residential dwellings** (p.739)
  Rob Van Holsteijn, The Netherlands

ROOM A

13:50-15:25 Parallel Session 7A: Long oral presentation session – Building airtightness: Test methods, optimum levels
Chairpersons: ***Max Sherman, Andrzej Gorka***

- **Predicting the optimum air permeability of a stock of detached English dwellings** (p.755)
  Benjamin Jones, UK
- **Measurement of infiltration rates from daily cycle of ambient CO2** (p.766)
  Joao Dias Carrilho, Portugal
- **The impact of air-tightness in the retrofitting practice of low temperature heating** (p.773)
  Qian Wang, Sweden
- **A nozzle pulse pressurisation technique for measurement of building leakage at low pressure** (p.780)
  Edward Cooper, UK
- **Tips for Improving Repeatability of Air Leakage Tests to EN and ISO Standards** (p.785)
  Colin Genge, Canada

ROOM B

13:50-15:25 Parallel Session 7C: Long oral presentation session – Ventilation, indoor air quality, health and comfort
Chairpersons: ***Pawel Wargocki, Samuel Caillou***

- **Proposed change in Spanish regulations relating to indoor air quality with the aim of reducing energy consumption of ventilation systems** (p.794)
  Pilar Linares-Alemparte, Spain
- **Simulation of static pressure reset control in comfort ventilation** (p.801)
  Chrysanthi Sofia Koulani, Denmark
- **Numerical simulation of Indoor Air Quality - Mechanical ventilation system supplied periodically vs. natural ventilation** (p.808)
  Ewelina Kubacka, Poland
- **Measured moisture buffering and latent heat capacities in CLT test houses** (p.818)
  Ivana Katavic, Norway

ROOM C

13:50-15:25 Parallel Session 7D: Long oral presentation session – Integrated design, MaTrID project

Chairpersons: ***Klemens Leutgöb***

- **The IED tool-kit, lessons learned and policy recommendations**
  Klemens Leutgöb, Austria (Invited Speaker) (p.824)
- **Simulation of night ventilation performance as a support for an integrated design of buildings** (p.840)
  Jerzy Sowa, Poland
- **Integrated approach as a prerequisite for nearly zero energy schools in Mediterranean region- ZEMedS project** (p.848)
  Elzbieta D. Ryńska, Poland (Invited Speaker)

ROOM A

15:40-17:10 Closing Session

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

- **Summing up of "ventilative cooling" track** (p.856)
  Per Heiselberg, Professor, Aalborg University, Denmark (Invited Speaker)
- **Summing up of "ventilation, indoor air quality health and comfort" track** (p.862)
  Willem de Gids, VentGuide, The Netherlands (Invited Speaker)
- **Summing up of "airtightness" track** (p.867)
  Arnold Janssens, Professor, University of Ghent, Belgium (Invited Speaker)
- **Indoor Environmental Quality-Global Alliance: The value chain of IEQ** (p.874)
  Bjarne Olesen, Professor, Technical University of Denmark, Denmark (Invited Speaker)

CONFERENCE Venue

IBB Andersia Hotel
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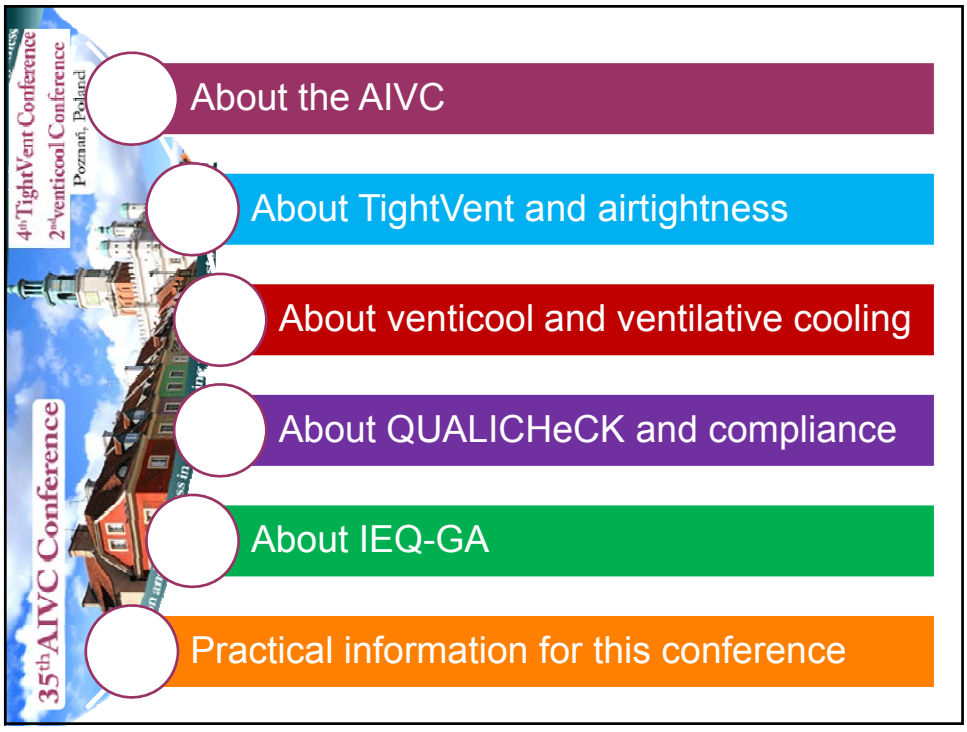
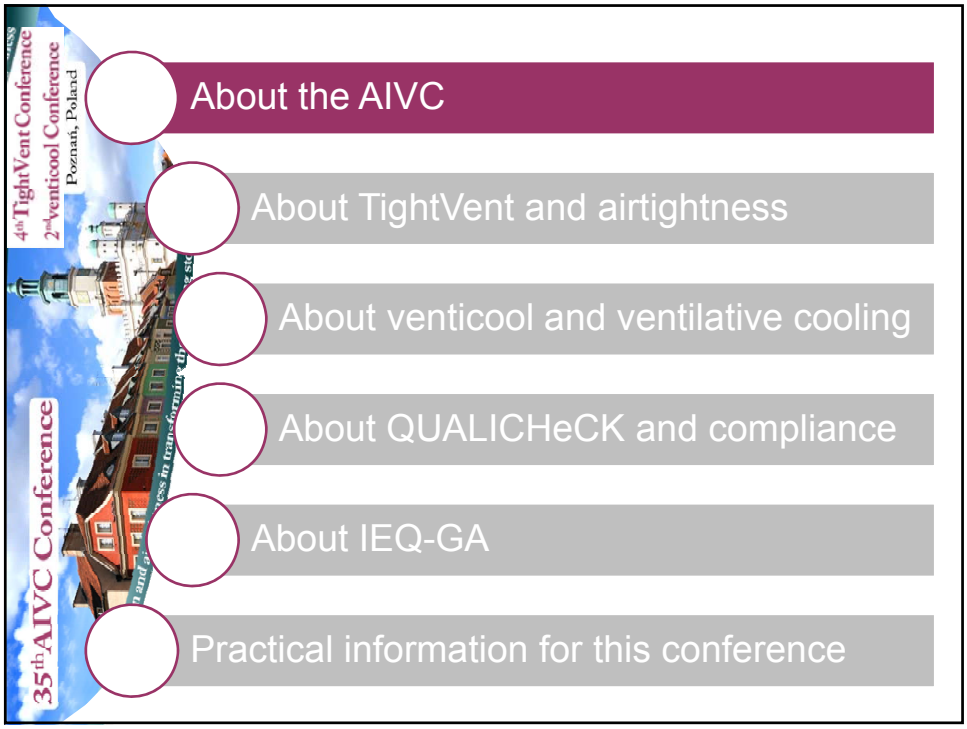
Manager INIVE EEIG

AIVC – TightVent - venticool

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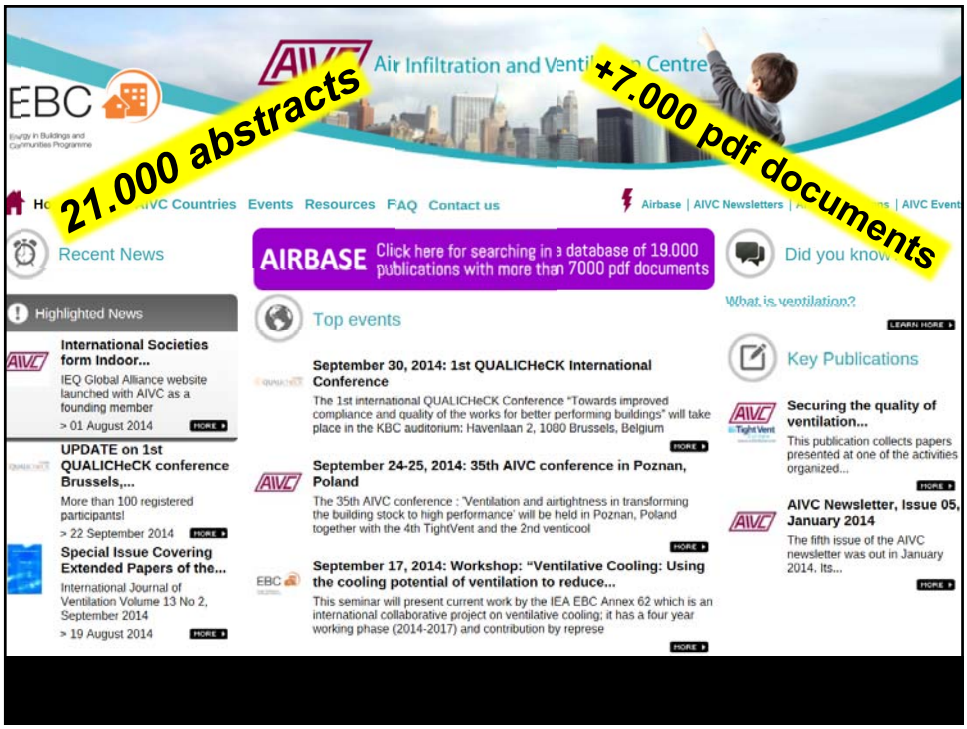
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Special Issue Covering Extended Papers of the...
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Top events
September 30, 2014: 1st QUALICHeCK International Conference
The 1st international QUALICHeCK Conference "Towards improved compliance and quality of the works for better performing buildings" will take place in the KBC auditorium: Havenlaan 2, 1080 Brussels, Belgium
September 24-25, 2014: 35th AIVC conference in Poznan, Poland
The 35th AIVC conference : 'Ventilation and airtightness in transforming the building stock to high performance' will be held in Poznan, Poland together with the 4th TightVent and the 2nd venticool
September 17, 2014: Workshop: "Ventilative Cooling: Using the cooling potential of ventilation to reduce...
This seminar will present current work by the IEA EBC Annex 62 which is an international collaborative project on ventilative cooling; it has a four year working phase (2014-2017) and contribution by represe
Key Publications
Securing the quality of ventilation...
This publication collects papers presented at one of the activities organized...
AIVC Newsletter, Issue 05, January 2014
The fifth issue of the AIVC newsletter was out in January 2014. Its...

70 participants

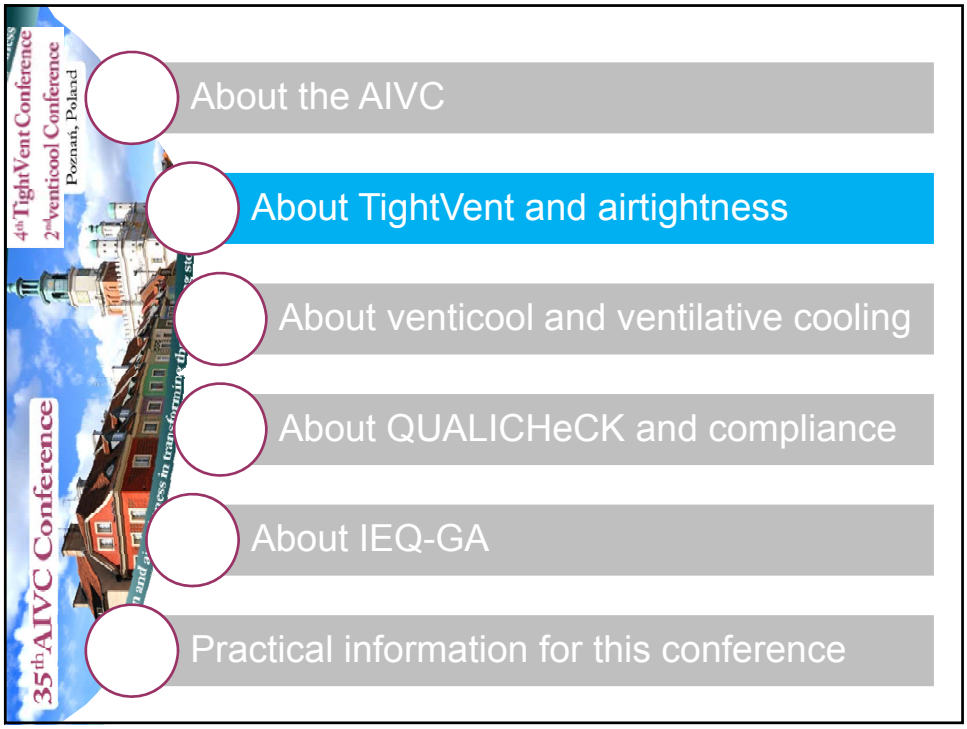
Proceedings available in February 2015

Brussels, Belgium

18-19 March 2014

AIVC Workshop

Quality of Methods for Measuring Ventilation and Air Infiltration in Buildings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Energy efficient ventilation systems will have to be used
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UPDATE: 1st QUALICHeCK conference Brussels, September 30
1st QUALICHeCK conference Brussels, September 30: registration open!
International Journal of Ventilation Special Issue Covering Extended Papers of the 34th AIVC Conference
Reasons behind and lessons learnt with the development of airtightness testers schemes in 11 European countries
Archives
September 2014
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TightVent Europe

BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM

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TightVent Airtightness Associations Committee – TAAC

The TightVent Airtightness Associations Committee (TightVent TAAC committee) was launched on September 26, 2012. Its primary goal is to promote reliable testing and reporting procedures. Since September 2012, the committee had a physical meeting in Hannover before the BUILDAIR symposium and has met eight times (via internet).

At present, the participants are from Belgium, Canada, Croatia, Czech Republic, Denmark, Estonia, France, Germany, Hungary, Ireland, Latvia, Norway, Poland, Sweden, UK and the US (list of TAAC members, list of TAAC guests).

TightVent® Europe

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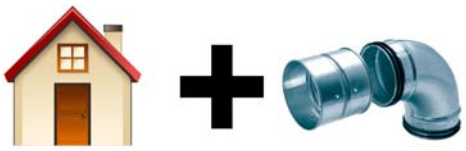

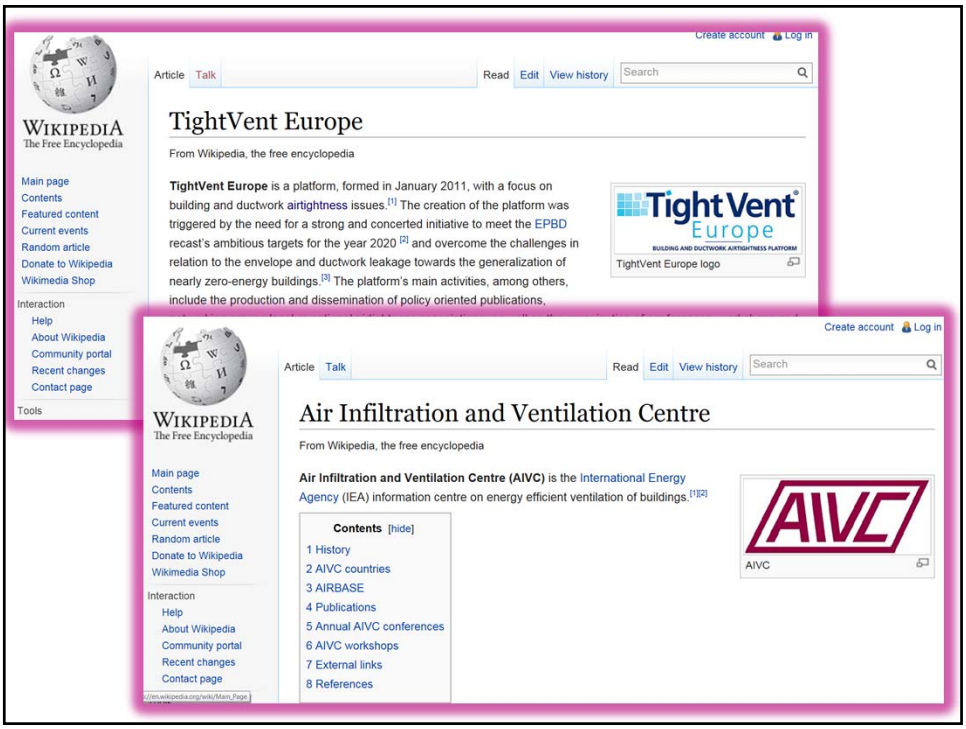

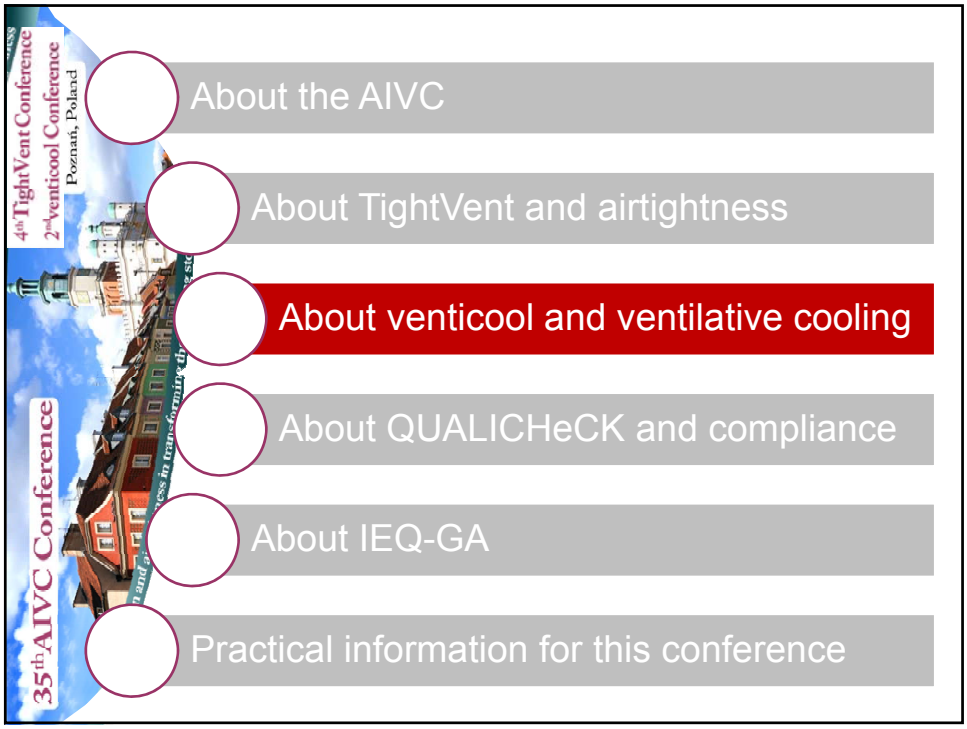
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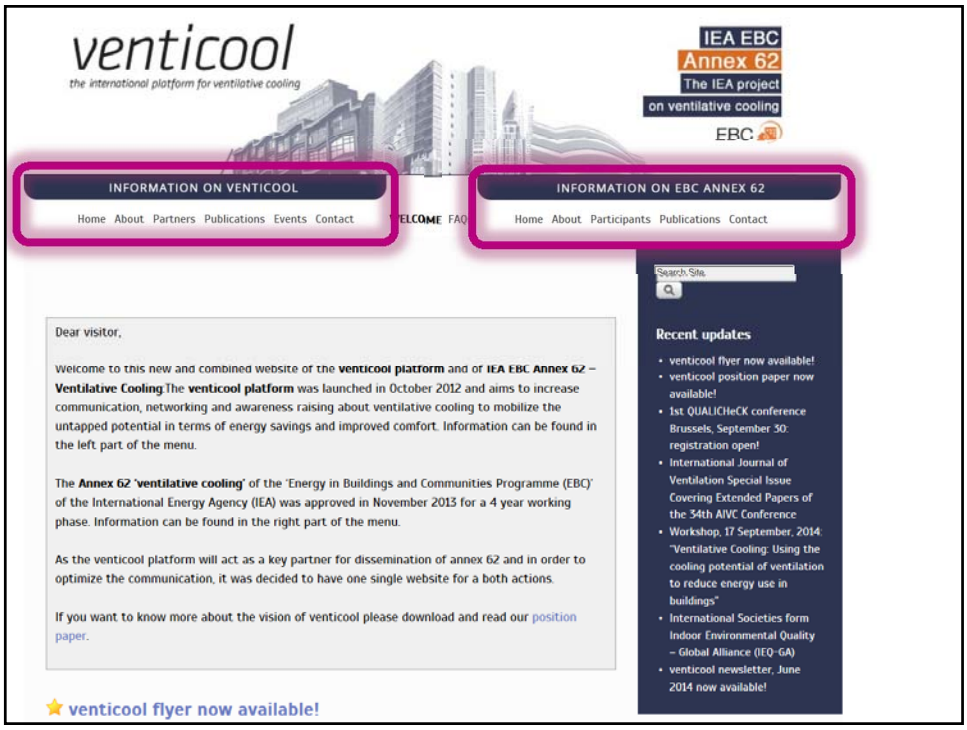
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Search Site
Dear visitor,
Welcome to this new and combined website of the venticool platform and of IEA EBC Annex 62 – Ventilative Cooling.The venticool platform was launched in October 2012 and aims to increase communication, networking and awareness raising about ventilative cooling to mobilize the untapped potential in terms of energy savings and improved comfort. Information can be found in the left part of the menu.
The Annex 62 'ventilative cooling' of the 'Energy in Buildings and Communities Programme (EBC)' of the International Energy Agency (IEA) was approved in November 2013 for a 4 year working phase. Information can be found in the right part of the menu.
As the venticool platform will act as a key partner for dissemination of annex 62 and in order to optimize the communication, it was decided to have one single website for a both actions.
If you want to know more about the vision of venticool please download and read our position paper.
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1st QUALICHeCK conference Brussels, September 30: registration open!
International Journal of Ventilation Special Issue Covering Extended Papers of the 34th AIVC Conference
Workshop, 17 September, 2014: "Ventilative Cooling: Using the cooling potential of ventilation to reduce energy use in buildings"
International Societies form Indoor Environmental Quality – Global Alliance (IEQ-GA)
venticool newsletter, June 2014 now available!

venticool

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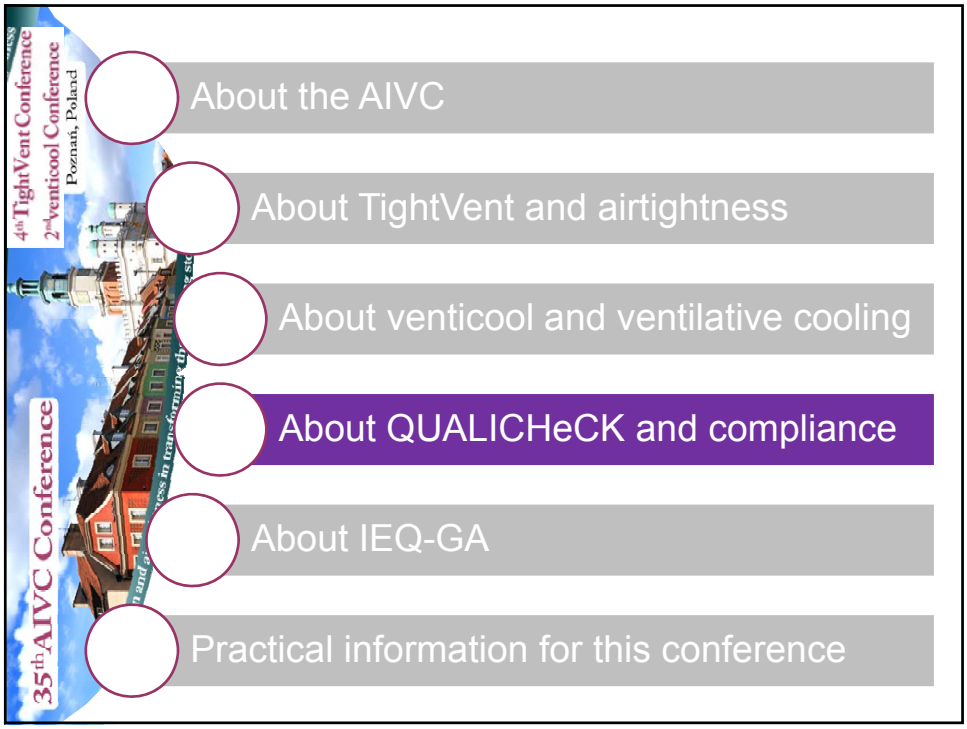
- Raise awareness about the potential of ventilative cooling
- Raise awareness about existing bottlenecks
- Raise awareness about interesting approaches
- (Support to) Planning of priority actions

venticool



QUALICHeCK Issues of concern…

- **Is the efficiency of the heat exchanger as used in the certificate the right one? The fan power?**
- **Are demand controlled ventilation systems correctly taken into account?**
- **Are the reported air flow rates correct?**
- **Are the declared airtightness levels of the building envelope correct? What about the ductwork?**
- **What about the acoustical performances?**
- **Are there sanctions if not OK? If so, what type?**

QUALICHeCK
Towards better quality and compliance
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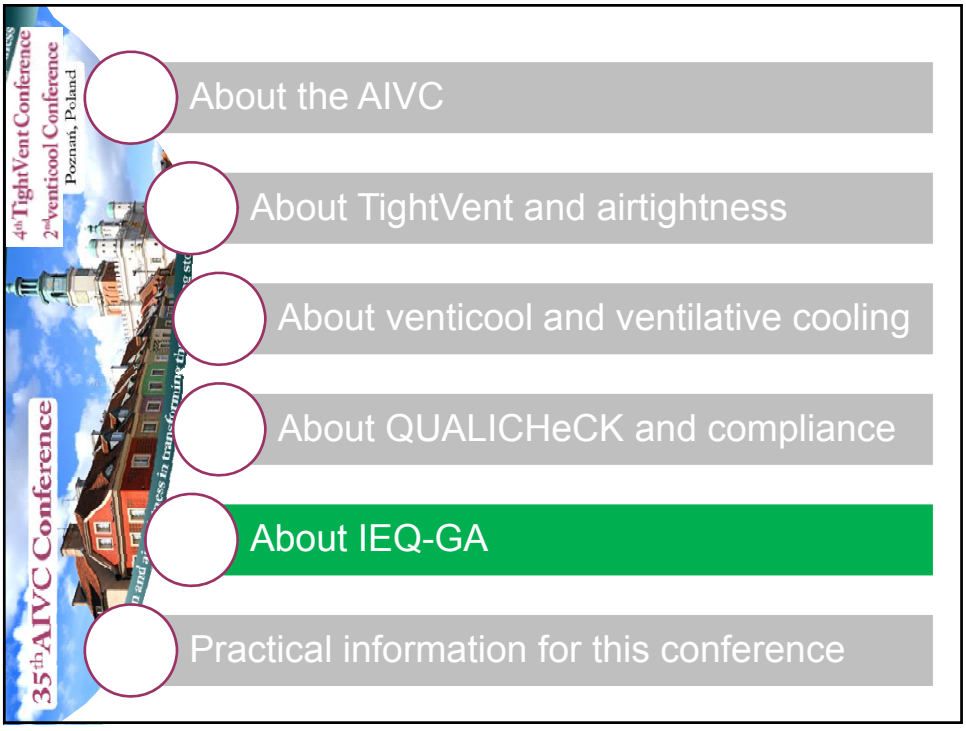
Quality of the Works
Compliance and Effective Penalties
1st QUALICHeCK International Conference
Posted on 2014/08/21 by Alexander Deliyannis
Brussels, 30 September 2014
KBC auditorium: Havenlaan 2, 1080 Brussels, Belgium

QUALICHeCK
Towards better quality and compliance
1st conference
2014.09.30 | KBC Auditorium | Brussels
Views from the airtightness industry
Views from the ventilation industry
Views from the solar shading industry
Views from the ventilative cooling industry
on quality and compliance issues
improved compliance and
rming buildings

QUALICHeCK workshops on reliable input data, quality of the works & compliance

March 2015 - Sweden	March 2016 - Athens
Ventilation and airtightness	**Sustainable summer comfort technologies**
Partners: AIVC TightVent	**Partners:** AIVC venticool

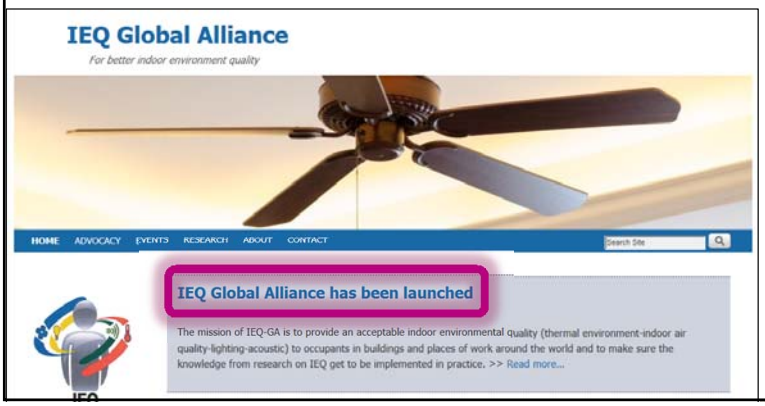
QUALICHeCK
Towards better quality and compliance

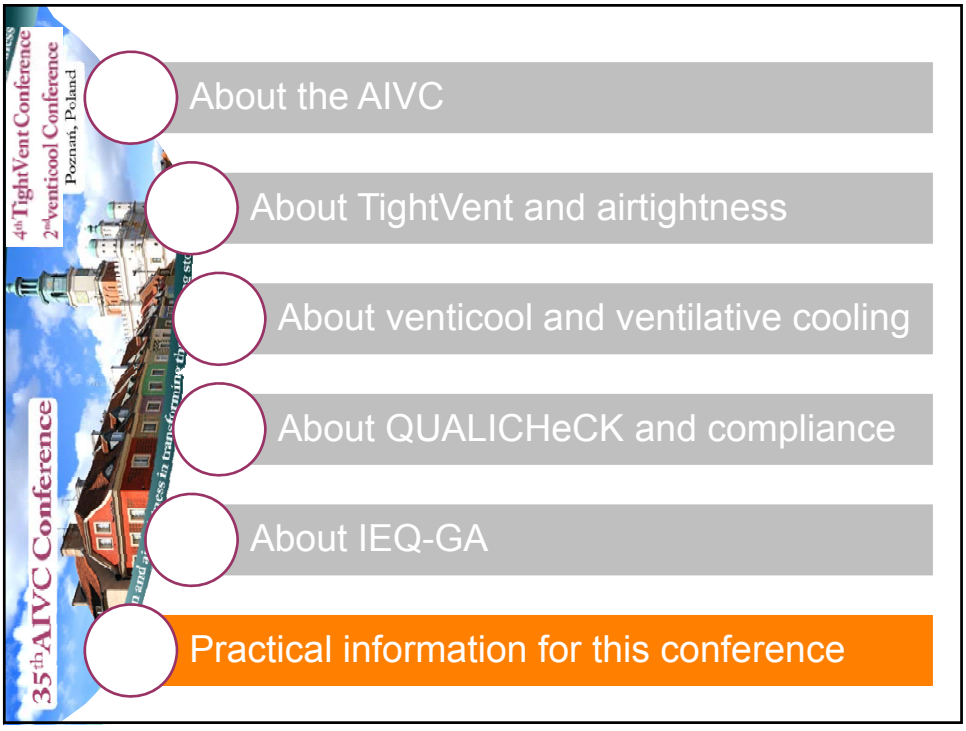


- About the AIVC
- About TightVent and airtightness
- About venticool and ventilative cooling
- About QUALICHeCK and compliance
- **About IEQ-GA**
- Practical information for this conference

IEQ-GA

Presentation by Prof. Bjarne Olesen in closing session





- About the AIVC
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THANK YOU
INIVE
International Network for Information on Ventilation and Energy Performance
GRUPOTERMOTECNIA
CETIAT
TNO innovation for life
Fraunhofer IBP
SINTEF
CSTB
ENTPE

THANK YOU
AERECO
AEROSEAL
Duct Sealing From The Inside
AGORIA
BlowerDoor GmbH
MessSysteme für Luftdichtheit
eurima
Halton
Lindab
retrotec
SOUDAL
Swegon
tremco illbruck
VELUX
Wienerberger
Window Master
Natural Ventilation

35th AIVC Conference, 24th-25th September 2014 Poznań, Poland

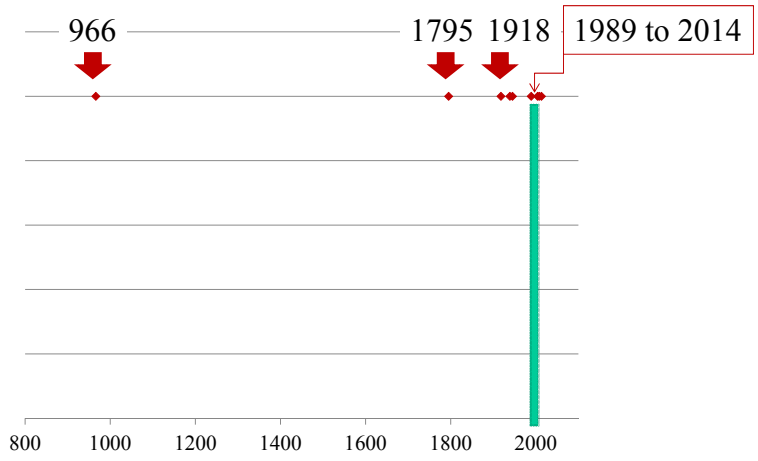
VENTILATION AND AIRTIGHTNESS IN POLAND
STATUS AND PERSPECTIVES

Tomasz M. Mróz
Institute of Environmental Engineering
Poznań University of Technology

SCOPE OF PRESENTATION

(i) Poland in EUROPE/EU/IEA/AIVC,
(ii) Sustainable built environment,
(iii) Current status of ventilation and airtightness in Poland,
(iv) R&D in the field of ventilation and airtightness,
(v) Perspectives,
(vi) Conclusions.

POLAND IN EUROPE/EU/IEA/AIVC



POLAND IN EUROPE/EU/IEA/AIVC

- 06/1989 Poland starts political and economical reforms,
- 11/1996 Poland enters OECD (formerly OEEC – est. in 1948 to run the Marshall Plan):
  - IEA Northern Home Project,
  - IEA Annex 36,
  - ….
- 05/2004 Poland joins EU (est. 1957),
- 09/2008 Poland enters IEA (est. 1974),
- 06/2013 Poland joins AIVC (est. 1979);

AIVC MISSION

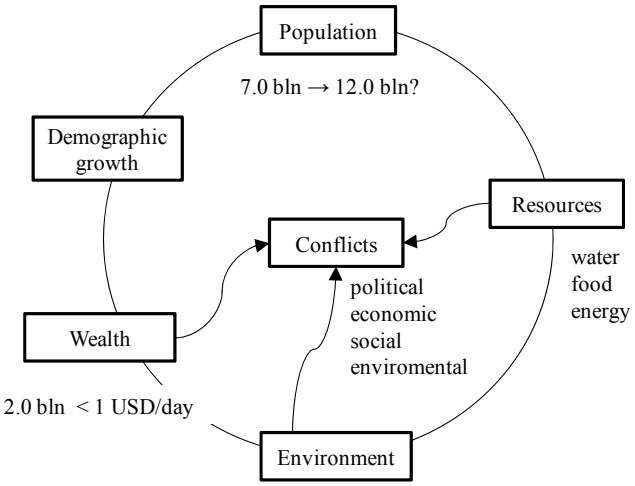
- Ventilation and air infiltration into buildings represent a substantial energy demand which can account for between 25% to over 50% of a building's total space heating (or cooling) needs,
- Unnecessary or excessive air change can therefore have an important impact on global energy use. On the other hand insufficient ventilation may result in poor indoor air quality and consequential health problems,
- Designing for optimum ventilation performance is hence a vital part of building design – it leeds to **SUSTAINABLE BUILT ENVIRONMENT**.

SUSTAINABLE DEVELOPMENT

There are three main pillars of sustainable development: **(i) economic growth, (ii) environmental protection and (iii) social equality**. Those pillars refer directly to the definition of sustainable development that was proposed by Gro Harlem Brundlant in the Report: "Our common future" in 1987:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

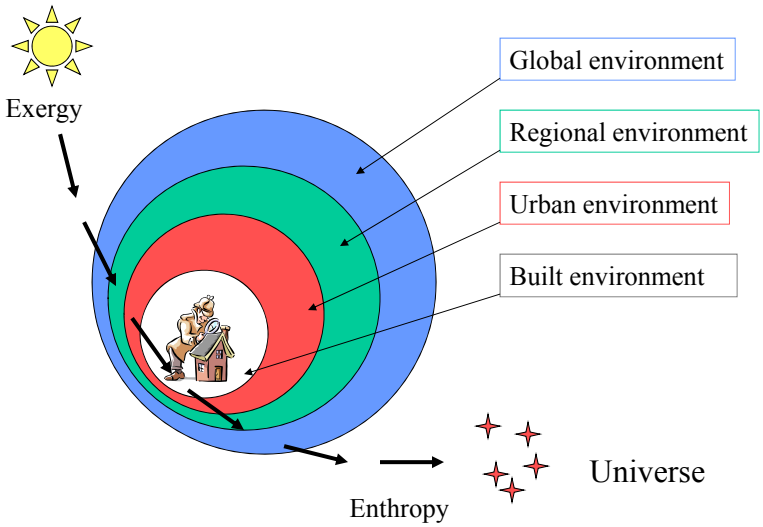
NON-SUSTAINABLE DEVELOPMENT VS. GLOBAL CONFLICTS



SUSTAINABLE BUILT ENVIRONMENT

NEST STRUCTURE OF ENVIRONMENT

The 2005 World Sustainable Building Conference in Tokyo



SUSTAINABLE DEVELOPMENT IN BUILT ENVIRONMENT

The need of fossil fuels exergy conservation in built environment refers to:

- The improvement of the exergy efficiency of fossil fuels utilization in buildings (building envelope, HVAC systems, lighting, …),
- The increase of exploitation of alternative, waste and renewable (e.g. wind, solar, bio, geothermal or hydro) exergy sources.

THE REDUCTION OF GREENHOUSE GASES (GHG) EMISSION

THE INDICATOR OF SUSTAINABLE DEVELOPMENT – KAYA EQUATION

$$GHG = \frac{GHG}{TOE} \cdot \frac{TOE}{GDP} \cdot \frac{GDP}{POP} \cdot POP$$

GHG – green house gases (carbon dioxide) emission in national economy, Mg a^{-1},

$\frac{GHG}{TOE}$ – carbon dioxide emission factor for the fossil fuels used in the national economy, Mg CO_2 $(Mg_{OE})^{-1}$,

$\frac{TOE}{GDP}$ – energy intensity of national economy, Mg_{OE} (thous.\$)$^{-1}$,

$\frac{GDP}{POP}$ – gross domestic product per capita, thous.\$ cap^{-1}.

POP – population, cap.

POLISH LEGISLATION IN THE FIELD OF AIRTIGHTNESS AND VENTILATION

- Building Construction Law (Building Code): National Act Nr 243/2010, dated 7th July 1994 (pos. 1623),
- Directive of the Ministry of Transportation, Construction and Maritime Economy on the technical conditions, which have to be fulfilled by buildings and their positioning, National Act Nr 75/2002, dated 5th July 2013 (pos. 690),
- Directive of the Ministry of Infrastructure and Development on the methodology of calculation of energy performance of buildings …, dated 2nd July 2014 (pos. 888);

POLISH LEGISLATION IN THE FIELD OF AIRTIGHTNESS AND VENTILATION

- „Exhaust or inlet-exhaust mechanical ventilation has to be applied in high raised buildings and other buildings, in which proper indoor air quality cannot be provided by natural ventilation. Other buildings can be equipped in natural or hybrid ventilation",
- „In the room, which is equipped in mechanical ventilation or air conditioning, no natural ventilation can be installed",
- „Hybrid, exhaust and inlet-exhaust mechanical ventilation installations have to be equipped in ventilators with controlled capacity";

Directive of the Ministry of Transportation, Construction and Maritime Economy on the technical conditions, which have to be fulfilled by buildings and their positioning, National Act Nr 75/2002, dated 5th July 2013 (pos. 690);

POLISH LEGISLATION IN THE FIELD OF AIRTIGHTNESS AND VENTILATION

- „Inlet-exhaust mechanical ventilation and air conditioning installations of the capacity over 500 m^3/h have to be equipped in heat recovery devices with temperature efficiency over 50% or recirculation. In the case of recirculation the flow of fresh air cannot be smaller than that required by hygienic conditions. In the case of technological ventilation the usage of heat recovery has to be considered with respect to the existing technological conditions and economical evaluation";

Directive of the Ministry of Transportation, Construction and Maritime Economy on the technical conditions, which have to be fulfilled by buildings and their positioning, National Act Nr 75/2002, dated 5th July 2013 (pos. 690);

POLISH LEGISLATION IN THE FIELD OF AIRTIGHTNESS AND VENTILATION

- „Specific power of ventilators installed in ventilation and air conditioning installations has to be as follows:"

Pos.	Type and usage profile of ventilator	Specific power of ventilator [$kW/(m^3/s)$]
1	2	3
1	Inlet ventilator	
	a) Air conditioning and inlet-exhaust ventilation installations with heat recovery	1,60
	b) Inlet-exhaust ventilation installations without heat recovery and inlet ventilation	1,25
2	Exhaust ventilator	
	a) Air conditioning and inlet-exhaust ventilation installations with heat recovery	1,00
	b) Inlet-exhaust ventilation installations without heat recovery and inlet ventilation	1,00
	c) Exhaust ventilation	0,80

POLISH LEGISLATION IN THE FIELD OF AIRTIGHTNESS AND VENTILATION

- „In small, medium and high (up to 50 m height) buildings air permeability of windows and balcony doors @ 100 Pa cannot exceed 2,25 $m^3/(m\ h)$ or 9,0 $m^3/(m^2\ h)$ – class nr 3 according to the Polish code. In high raise buildings air permeability of windows and balcony doors @ 100 Pa cannot exceed 0,75 $m^3/(m\ h)$ or 3,0 $m^3/(m^2\ h)$ – class 4 according to the Polish code."

Directive of the Ministry of Transportation, Construction and Maritime Economy on the technical conditions, which have to be fulfilled by buildings and their positioning, National Act Nr 75/2002, dated 5th July 2013 (pos. 690):

POLISH LEGISLATION IN THE FIELD OF AIRTIGHTNESS AND VENTILATION

- „Recommended airtightness of buildings is as follows:
  - Buildings with natural ventilation and hybrid ventilation – $n_{50} < 3{,}0\ h^{-1}$,
  - Buildings with mechanical ventilation and air conditioning – $n_{50} < 1{,}5\ h^{-1}$."

Directive of the Ministry of Transportation, Construction and Maritime Economy on the technical conditions, which have to be fulfilled by buildings and their positioning, National Act Nr 75/2002, dated 5th July 2013 (pos. 690);

POLISH LEGISLATION IN THE FIELD OF AIRTIGHTNESS AND VENTILATION

- Average flow of the fresh air infiltrating through the building envelope due to the wind and thermal forces is calculated as follows:
  - Buildings with airtightness test:

$$\dot{V}_{\text{inf}} = 0{,}05 \cdot \frac{n_{50} \cdot V}{3600}$$

  - Buildings without airtightness test:

$$\dot{V}_{\text{inf}} = \frac{n \cdot V}{3600} \qquad n = 0{,}2 \div 0{,}3$$

Directive of the Ministry of Infrastructure and Development on the methodology of calculation of energy performance of buildings …, dated 2nd July 2014 (pos. 888);

R&D IN THE FIELD OF VENTILATION AND AIRTGHTNESS IN POLAND

- R&D centers and groups located in Technical Universities (6) and Research Institutes (3),
- Polish Academy of Sciences – Division of District Heating and Air Conditioning,
- Main funds for R&D come from:
  - Ministry of Science and Higher Education (MNiSW),
  - National Center for Research and Development (NCBiR),
  - National Center for Science (NCN);

NCBiR STRATEGIC RESEARCH PROJECT

INTEGRATED SYSTEM FOR REDUCING ENERGY CONSUMPTION IN THE MAINTENANCE OF BUILDINGS

The project includes 7 research tasks:

- Study of socioeconomic possibilities and effects of raise in energy efficiency in civil engineering,
- Structure/materials and installations energetically optimal for buildings,
- Increase in the use of renewable energy in civil engineering,
- Development of thermal diagnostics of buildings,
- Optimization of energy consumption in buildings,
- Analysis of technical and operational constraints for buildings supplied with power from centralized energy sources,
- Energy saving conditions and possibilities created by municipal policy instruments.

STRATEGIC R&D PROJECTS

- The influence of occupants behavior on the performance of ventilation systems,
- Indoor climate comfort analysis (TC + IAQ),
- Optimization of the structure of ventilation and air conditioning systems,
- Simulation of ventilation effectiveness in buildings: ANSYS CFD, TRNSYS 17, Math LAB, Energy +,
- New control algorithms of ventilation and air conditioning systems: neuron networks, FLC, …
- Energy, exergy, economy and multicriteria optimization of ventilation systems – new tools of evaluation,
- Renewable energy usage: ground heat exchangers, heat pumps, solar systems, … - minimization of energy/exergy demand for space heating/cooling/ventilation.

AIRTHGHTNESS IN POLAND

GENERAL SITUATION

Commissioning companies:

- the situation in the field of airtightness on the Polish construction market looks like at the beginning of the whole long quality-improvement process,
- for now no requirements imposed for commissioning companies: their competencies, experience, references, equipment and certification,
- it results in measurement inaccuracies leading to not precise n_{50} evaluation,
- about 30 commissioning companies in Poland (100% of annual growth – ref. 2013),
- few of them have experience in large buildings testing,
- only several large buildings tested in Poland.

AIRTHGHTNESS IN POLAND

GENERAL SITUATION

Equipment:

- the most popular are Minneapolis Blower Door units,
- no XXL trailer fans,
- large building measured with multi Blower Door sets,
- attempts to measure large building with AHUs (low test price),
- AHU producers cannot guarantee the accuracy of flow measurement - PN-EN 13829 fulfillment?
- hard to estimate how many test-devices necessary for testing (poor n_{50} database).

AIRTHGHTNESS IN POLAND

GENERAL SITUATION

Public/institutional investors:

- subject to provisions of public procurement law (PPL),
- focused only on initial cost – the most popular tender criteria is the lowest investment price,
- as the result poor quality of workmanship and technical solutions,
- running cost and therefore n_{50} are neglected,

Private investors:

- more conscious (but not always) in the field of energy efficiency (operating cost),

General remarks:

- problems in investor's and contractor's budget planning, lack of awareness, knowledge and experience,
- problems in offering (both sides investors and test companies).

AIRTIGHTNESS VS. ENERGY DEMAND

- Heat transfer coefficient joined with ventilation:

$$H_{ve} = \rho_a \cdot c_a \cdot \sum_k \left(b_{ve,k} \cdot V_{ve,k,mn} \right) \quad [W/K]$$

  - Exhaust mechanical ventilation:

$$b_{ve,1} = 1;\ V_{ve,1,mn} = V_{ex}$$
$$b_{ve,2} = 1;\ V_{ve,2,mn} = V_x$$

  - Inlet-exhaust mechanical ventilation:

$$b_{ve,1} = 1 - \eta_{oc};\ V_{ve,1,mn} = V_{su}$$
$$b_{ve,2} = 1;\ V_{ve,2,mn} = V_x$$

AIRTIGHTNESS VS. ENERGY DEMAND

- Air infiltration:

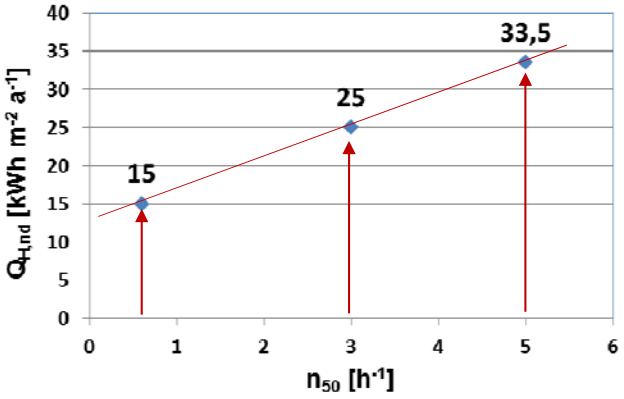
$$V_x = \frac{e \cdot n_{50} \cdot V}{1 + \left(\frac{f}{e} \cdot \left(\frac{V_N - V_W}{V_i \cdot n_{50}}\right)\right)^2} \cong e \cdot n_{50} \cdot V$$

$\left(\frac{f}{e} \cdot \left(\frac{V_N - V_W}{V_i \cdot n_{50}}\right)\right) \rightarrow 0$

$$n_{\text{inf}} = e \cdot n_{50} \approx 0{,}05 \cdot n_{50} \approx \frac{n_{50}}{20}$$

AIRTIGHTNESS VS. ENERGY DEMAND

- Case study: annual useable energy needs for heat transfer and ventilation for low energy building $A_f = 150\ m^2$ with inlet exhaust mechanical ventilation system $\eta_{HR} = 80\%$



AIRTHGHTNESS IN POLAND

MEASUREMENTS – SINGLE FAMILY HOUSES

Old buildings recently retrofitted:

- natural ventilation (sealed air outlets),
- masonry walls,
- wooden structure pitched and flat roof,
- small windows and walls leakages,
- strong pitched roof influence.

A_f 72 m^2
n_{50} **8.4** ACH

A_f 115 m^2
n_{50} **7.0** ACH

A_f 385 m^2
n_{50} **5.9** ACH

A_f 134 m^2
n_{50} **2.2** ACH

AIRTHGHTNESS IN POLAND

MEASUREMENTS – SINGLE FAMILY HOUSES

New buildings recently constructed:

- left: timber wall construction, open combustion chamber furnace, piping shaft leakages connected to cold roof attic,
- right: typical masonry brick walls construction, low windows and walls leakages.

A_f 188 m^2
n_{50} **4.6** ACH

A_f 177 m^2
n_{50} **2.6** ACH

A_f 134 m^2
n_{50} **1.7** ACH

AIRTHGHTNESS IN POLAND

MEASUREMENTS – SINGLE FAMILY HOUSES

Low energy buildings:

- left: timber constructions, passive standard retrofitting,
- right: masonry walls, low energy building,
- roof-wall joint – the most leaky area.

A_f 73 m^2
n_{50} **0.49** ACH

A_f 108 m^2
n_{50} **0.65** ACH

AIRTHGHTNESS IN POLAND

MEASUREMENTS – LARGE BUILDINGS

OFFICE BUILDING IN SZCZECIN

- Private Investor, IKEA Development
- Floor area 5.100 $m^2 \approx$ **55 000 ft^2**
- Volume 16.100 $m^3 \approx$ **570 000 ft^3**
- 8-storey (incl. 2 underground)
- Construction:
  - Envelope → reinforced concrete
  - Typical windows + sealings
  - No special airtightness concerns during design and construction process

AIRTHGHTNESS IN POLAND

MEASUREMENTS – LARGE BUILDINGS

OFFICE BUILDING IN SZCZECIN

- double-fan Blower Door used,
- n_{50} = 0.49 ACH,
- examples of leaky points.

AIRTHGHTNESS IN POLAND

MEASUREMENTS – LARGE BUILDINGS

MECHATRONICS, BIOMECHANICS AND NANOENG. CENTER

- Public Investor - Poznan University of Technology
- Purpose: laboratories, lecture halls, staff offices,
- Floor area 14.000 m^2 ≈ **151 000 ft^2**
- Int. volume 50.700 m^3 ≈ **1 790 000 ft^3**
- Special airtightness concerns during design and construction,
- Contract's n_{50} demand of maximum **1.5 ACH.**

AIRTHGHTNESS IN POLAND

MEASUREMENTS – LARGE BUILDINGS

MECHATRONICS, BIOMECHANICS AND NANOENG. CENTER

Important details:

- Filling wall-slab joints (EPDM sealing),
- Window-wall connection,
- Walls plastered from inside,
- Electricity – ext. wall installed (inner plaster broken),
- VAC Shut-off dampers installed close to the envelope (part-time operation)

PERSPECTIVES

Reduction of GHG emission caused by ventilation systems:

$$GHG = \frac{GHG}{TOE} \cdot \frac{TOE}{GDP} \cdot \frac{GDP}{POP} \cdot POP$$

$$\left.\begin{array}{l} \frac{GDP}{POP} \uparrow \\ POP \uparrow \end{array}\right\} \Rightarrow \begin{array}{l} \frac{TOE}{GDP} \downarrow \\ \frac{GHG}{TOE} \downarrow \end{array}$$

PERSPECTIVES

IEA Annual Report on energy indicators - 2010

Country	$\frac{TOE}{GDP}$	$\frac{GDP}{POP}$	$\frac{GHG}{TOE}$
	[Mg_{OE} (thous.$)^{-1}$]	[thous.$ cap^{-1}]	[Mg CO_2 $(Mg_{OE})^{-1}$]
France	0.174	22.837	1.38
Germany	0.159	24.410	2.36
Poland	**0.389**	**6.335**	**3.05**
USA	0.190	36.936	2.40

CONCLUSIONS

- The need of reduction of GHG emission requires improvement of energy performance of ventilation systems,
- Two major measures have to be considered: (i) improvement of exergy efficiency of ventilation systems and (ii) increase of renewable energy use,
- The improvement of exergy efficiency is joined with the improvement of airtightness of buildings (especially existing stock) and application of efficient ventilation systems, which enables creation of proper IAQ,
- The increase of renewable energy use refers to the development and application of specific technologies, e.g. ground heat exchangers, heat pumps, solar chimneys, solar walls, PVs, …

THANK YOU FOR YOUR ATTENTION

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Recent advances on factors influencing human responses and human performance in buildings, and their potential impact on ventilation requirements

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International Centre for Indoor Environment and Energy
Department of Civil Engineering
Technical University of Denmark

MOTIVATION

- Building sector under transformation
- Focus on energy
- Focus should be an humans in buildings
- Define and address new challenges
- Reuse plenty of good research that has been performed to date

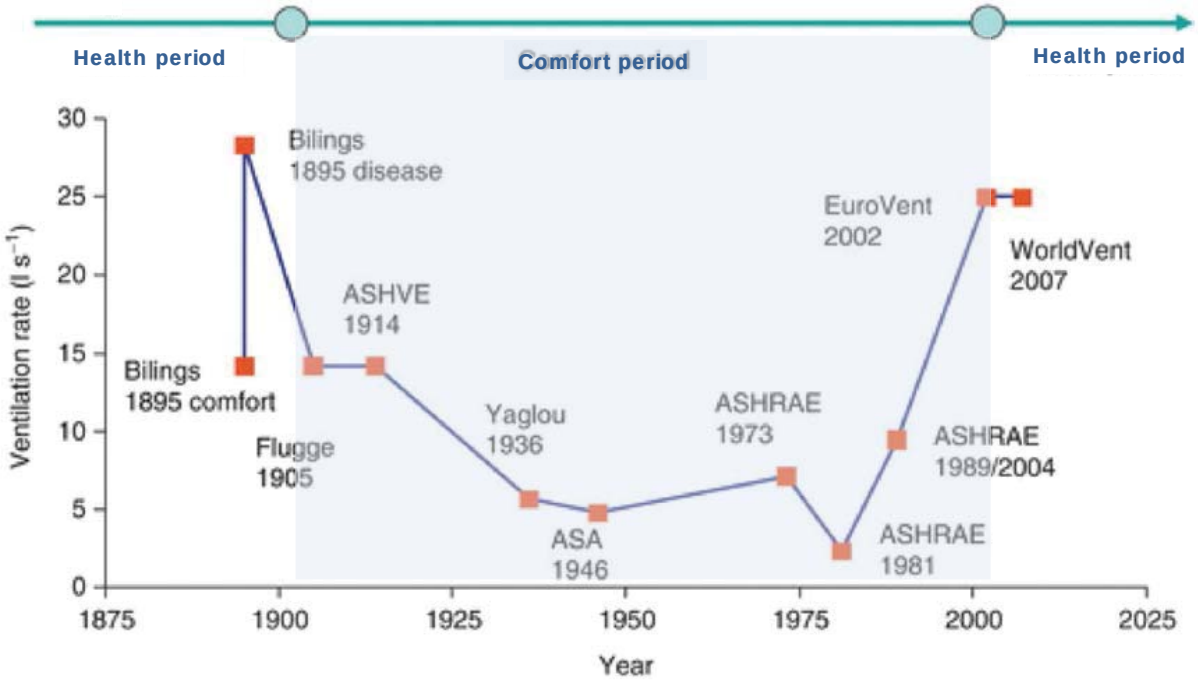
FIVE QUESTIONS

- Q1: How can health-based ventilation guidelines be developed?
- Q2: Should CO_2 be considered as a pollutant or as an “innocent” compound?
- Q3: Is sleep quality affected by poor air quality?
- Q4: Are there any seasonal differences in human responses to increasing temperature?
- Q5: Which criteria should be used for designing IEQ?

Question 1: HOW CAN HEALTH-BASED VENTILATION GUIDELINES BE DEVELOPED?

Source: Wargocki et al. (2013)

VENTILATION RATES THROUGH HISTORY



Adapted from Li (2013)

RATIONALE, MOTIVATION

- Current ventilation standards do not adequately address the health-relevant aspects of IAQ
- Ventilation rates based on sensory comfort (different classes of comfort), not based on "hard" health evidence
- Requirements are defined for different classes of building users (visitors and occupants) and modified based on the strength of pollution sources (classes of building materials)
- Ventilation rates are not defined on target values for exposures
- There are no (formal) requirements for the quality of air used for ventilation (ambient air assumed to be clean) and there are no requirements for compliance with the requirements in the standard

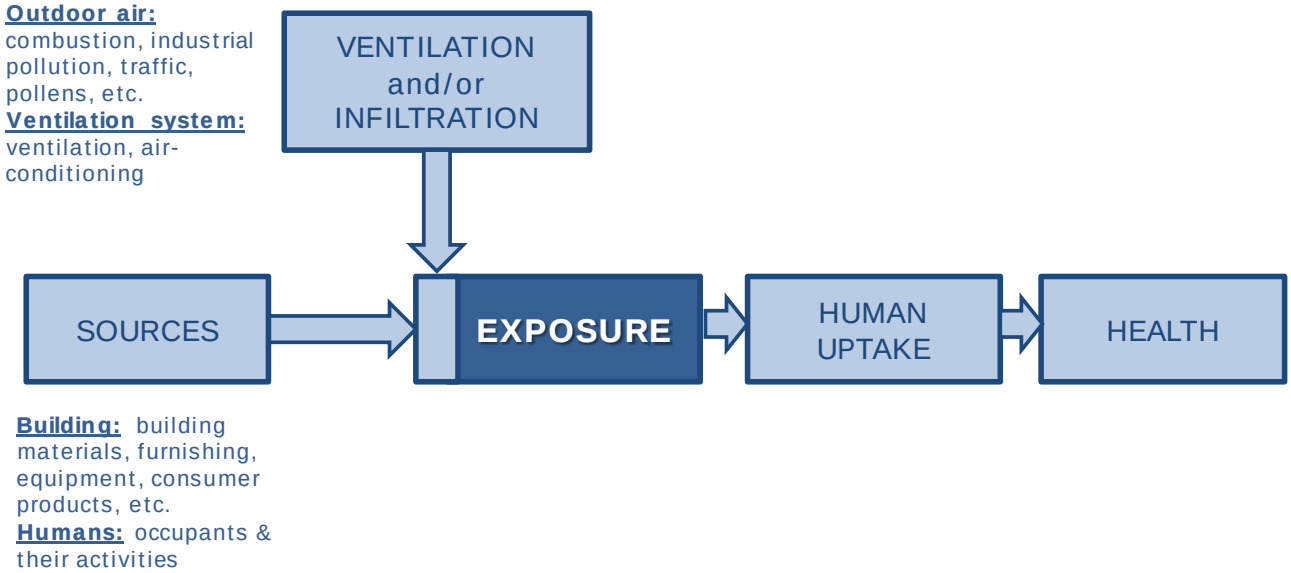
EPIDEMIOLOGICAL DATA ON VENTILATION AND HEALTH

- No agreement on which rate should be used as a guideline value: from 10 to 25 L/s per person
- The lowest ventilation rates with no observed adverse effect for health reported in the published literature from field studies were 7 L/s per person in homes, 8 L/s per person in offices and 9 L/s per person in schools.

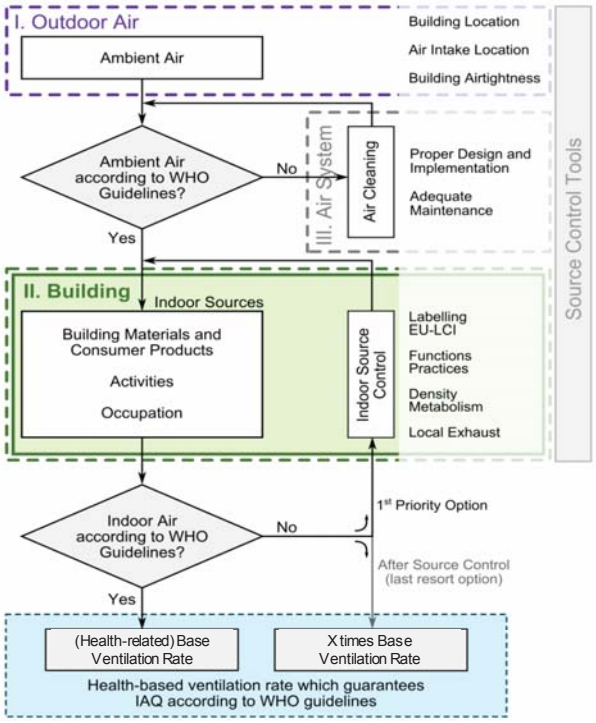
- Do not provide proper characterization of exposures
- No clear causality due to numerous factors: intensity and strength of pollution sources affecting the exposures, sensitivity of populations exposed and type of the outcome.
- There is no proper characterization of actual exposures incl. outdoor air quality, inadequate quality of ventilation measurements (method, duration), maintenance of HVAC, no data on chronic health outcomes, poor characterization of acute health outcomes, cross-sectional, etc.

Source: Carrer et al. (2012)

HEALTH-EXPOSURE-VENTILATION



DECISION DIAGRAM FOR DEFINING HEALTH-BASED VENTILATION RATES



- Air supplied must always meet WHO Air Quality Guidelines

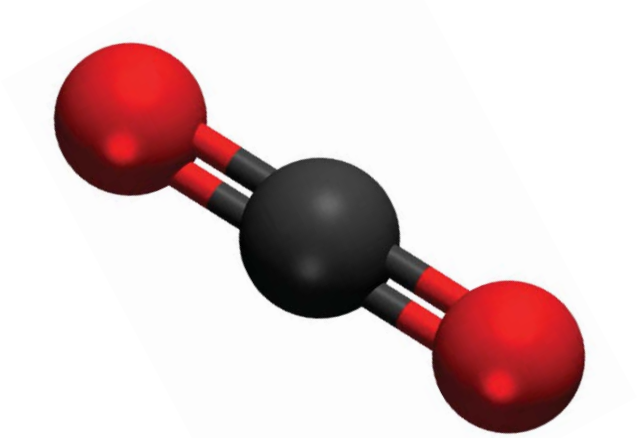
- When WHO Air Quality Guidelines are met through control of sources then health-based ventilation rate equals base rate
- When WHO Air Quality Guidelines cannot be met through control of sources then health-based ventilation rate is a multiply of base rate

Source: ECA 30 (2014); in the Press

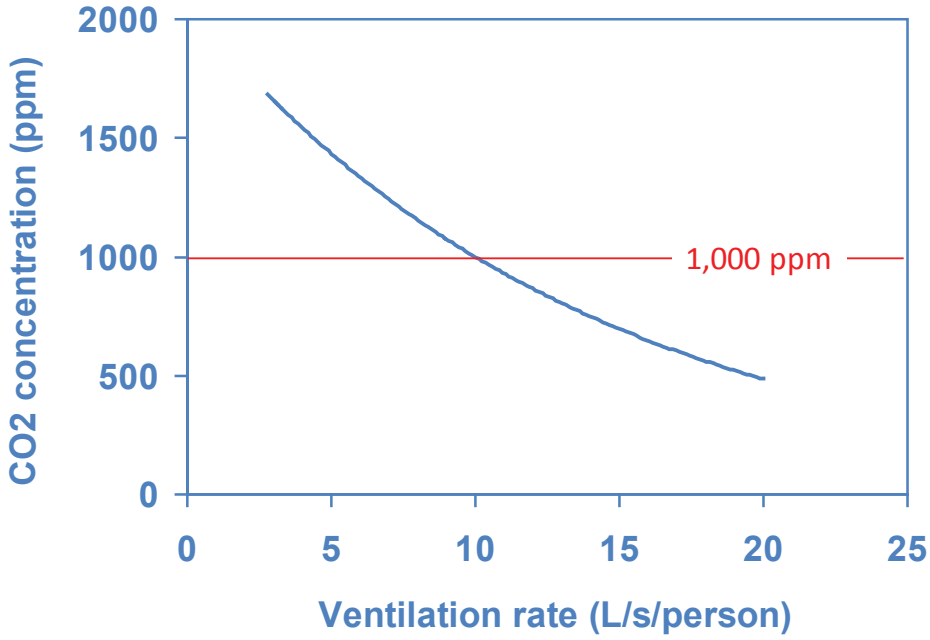
DEFINITION OF THE BASE RATE

- The base ventilation rate is the rate intended to dilute and exhaust occupant bioeffluents.
- It is a basic requirement that should always be satisfied when people are present indoors.
- The health-based ventilation rate cannot be lower than the base rate.
- 4 L/s per person is **PROPOSED** based on CO_2/RH modeling.

Question 2:
SHOULD CO_2 BE CONSIDERED AS A POLLUTANT OR AS AN "INNOCENT" COMPOUND?

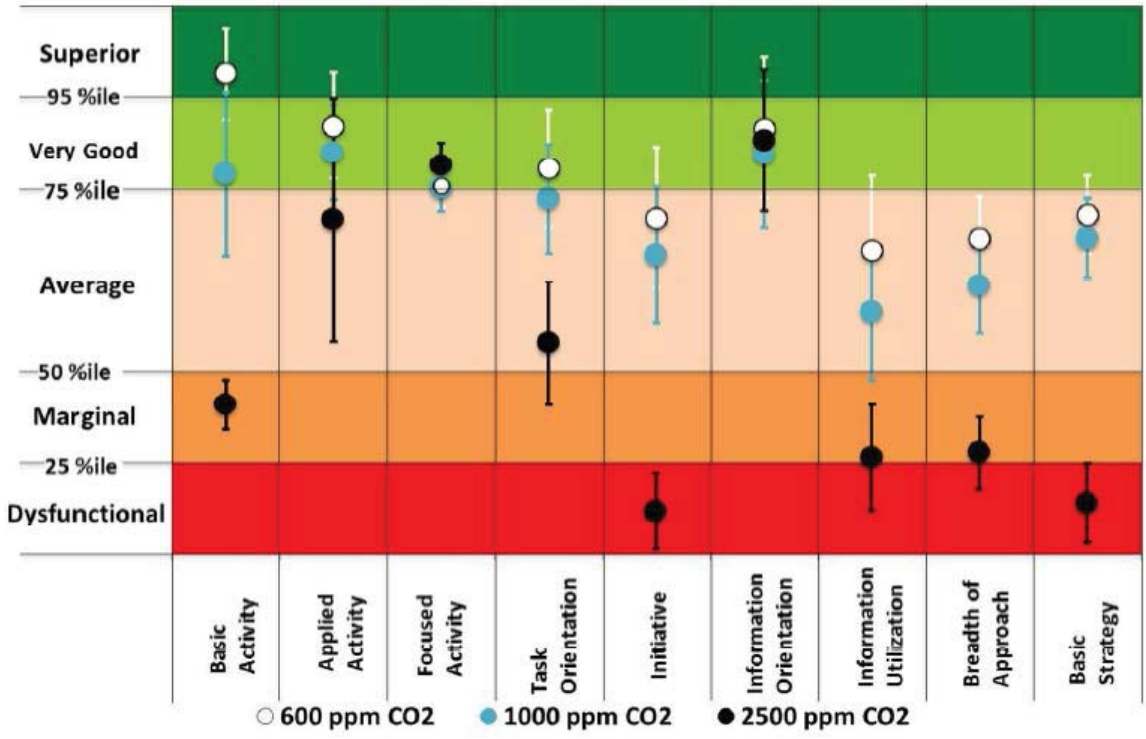


SINCE PETTEKOFER (1858) CO_2 IS CONSIDERED TO BE "INNOCENT" AND TO BE AN EXCELLENT INDICATOR OF HUMAN BODY ODOR AND VENTILATION



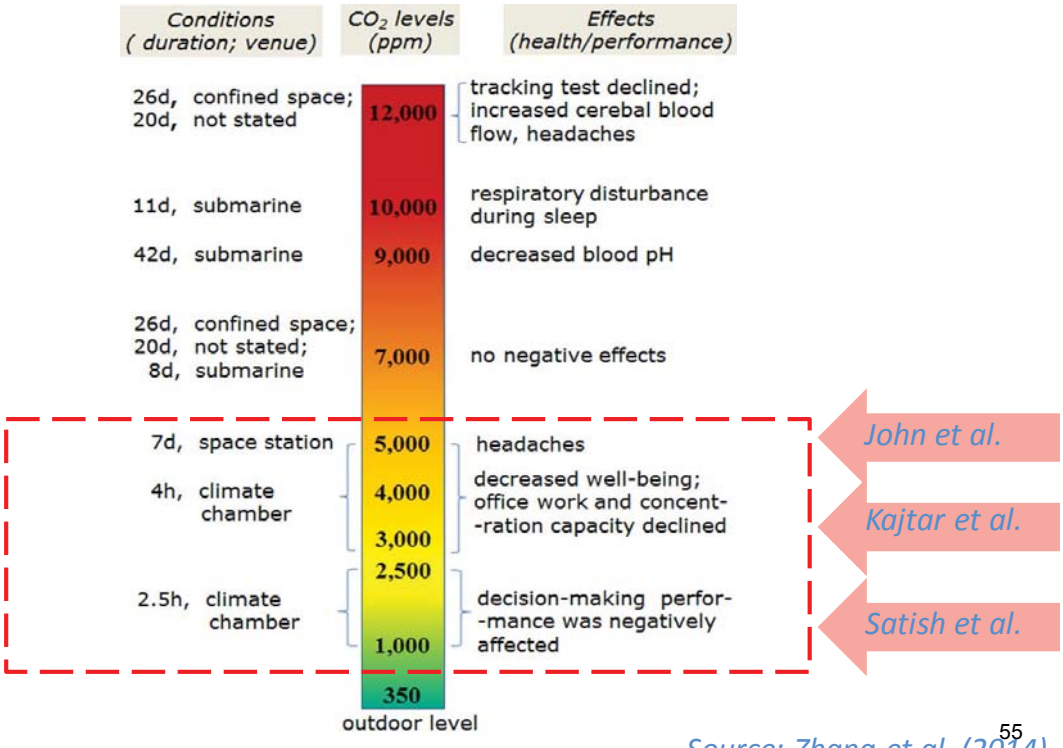
Source: Fanger (1988)

NEGATIVE EFFECTS OF CO_2 ON DECISION-MAKING PERFORMANCE



Source: Satish et al. (2012)

EFFECTS OF CO_2 ON HEALTH AND COGNITIVE PERFORMANCE

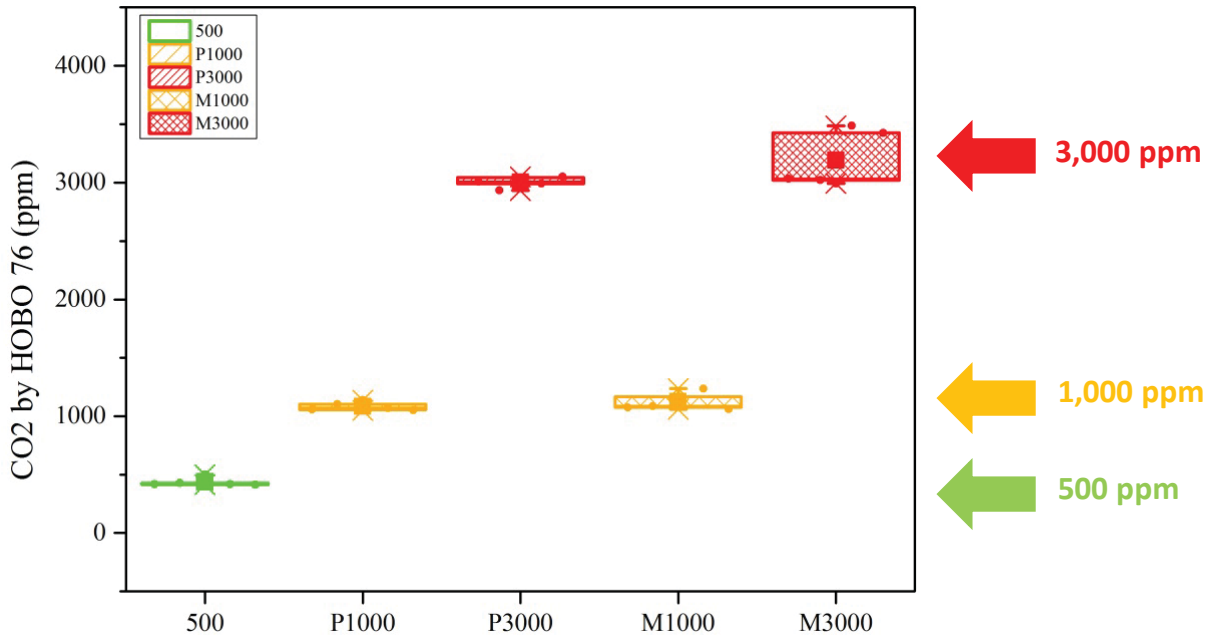


Source: Zhang et al. (2014)

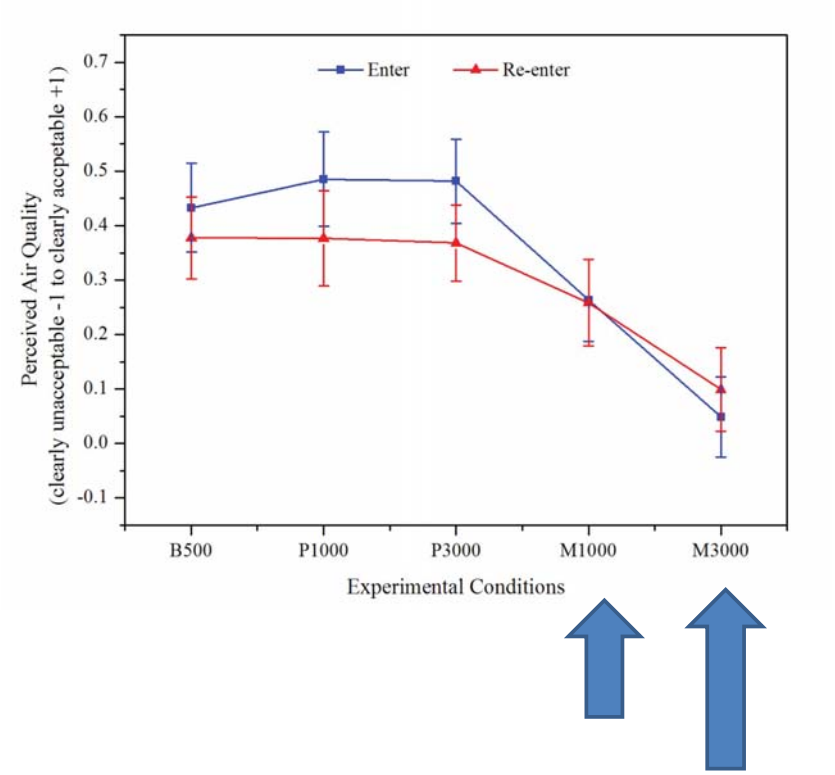
SUBJECTS & EXPOSURES

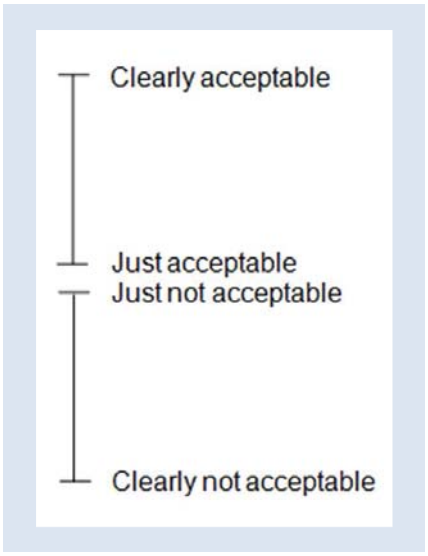
- 25 subjects (10 males & 15 females)
- 5 conditions with pure and metabolic CO_2
- 5 hour exposure in chamber
- Physical measurements
- Subjective measurements (symptoms, comfort, performance)
- Measurements of cognitive performance
- Physiological measurements

MEASURED CONDITIONS IN THE CHAMBER DURING EXPOSURES

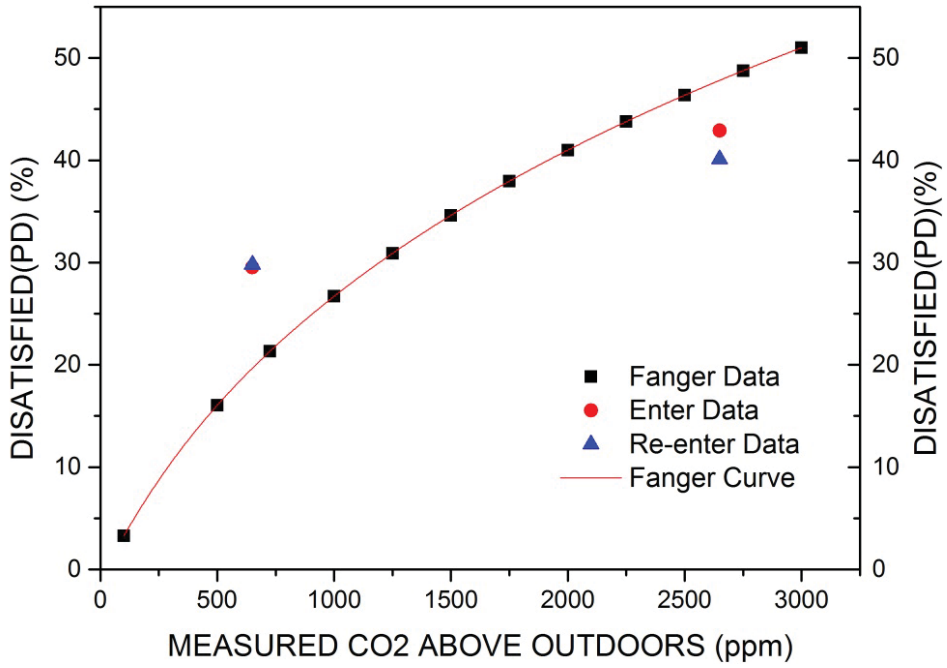


SUBJECTIVELY REPORTED ACCEPTABILITY OF AIR QUALITY

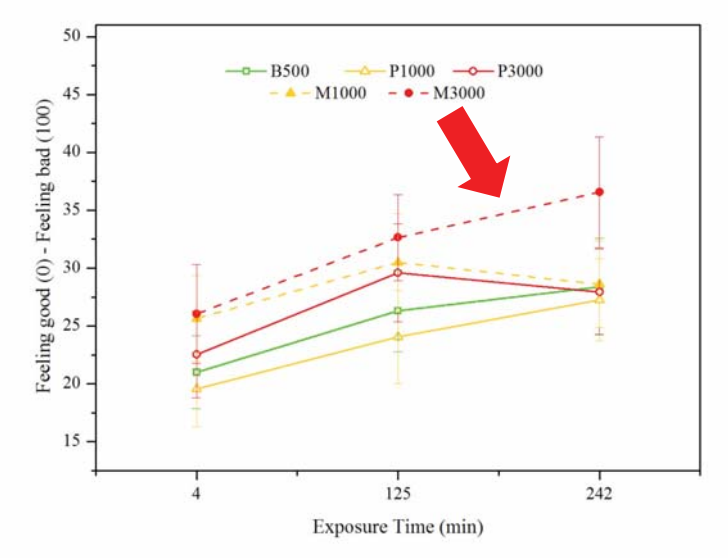




% DISSATISFIED WITH AIR QUALITY



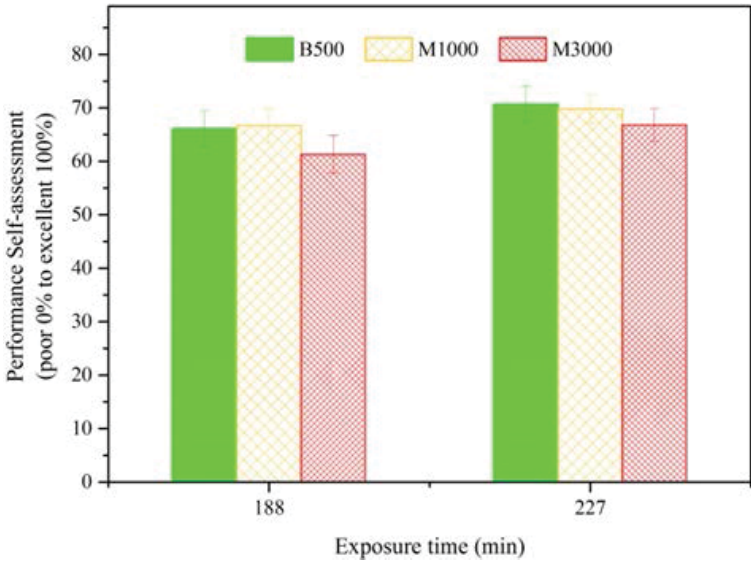
SUBJECTIVELY REPORTED SYMPTOMS AND PERCEPTIONS



- Dizziness
- Fatigue
- Sleepiness
- Depression
- Difficulty to concentrate
- Difficulty to think
- Headache

Feeling good (0) ——— Feeling bad (100)

SELF-ESTIMATED PERFORMANCE



I can work

0% ——— 100%

Question 3: IS SLEEP QUALITY AFFECTED BY POOR AIR QUALITY?

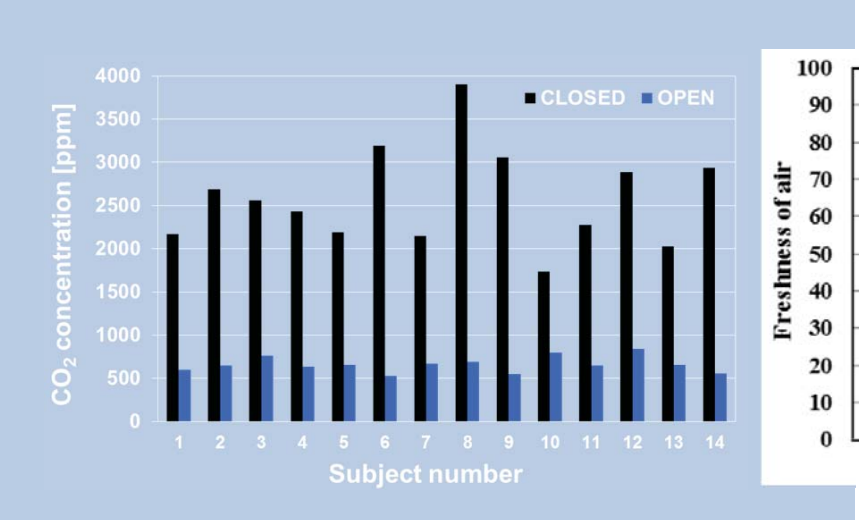
Source: Strøm-Tejsen et al. (2014)

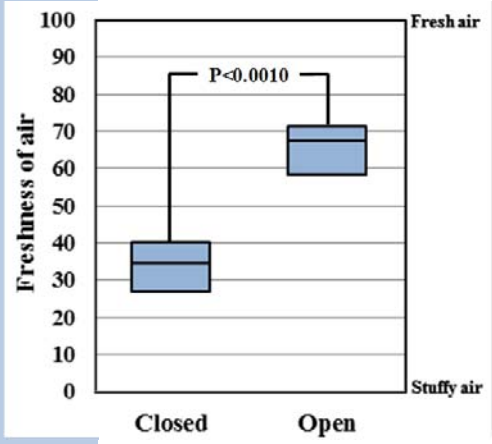
OBJECTIVE

- To investigate the effect of open windows on indoor air quality, sleep quality and next-day well-being

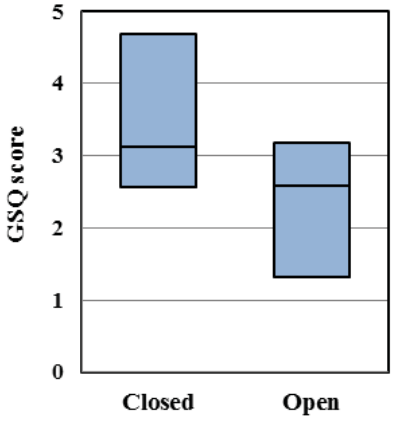
- 7 female + 7 male students in the Campus Village
- A simple intervention, one that can be made in most bedrooms, namely opening a window
- Each condition lasting 1 week
- Normal life style except for limitations for caffeine and alcohol

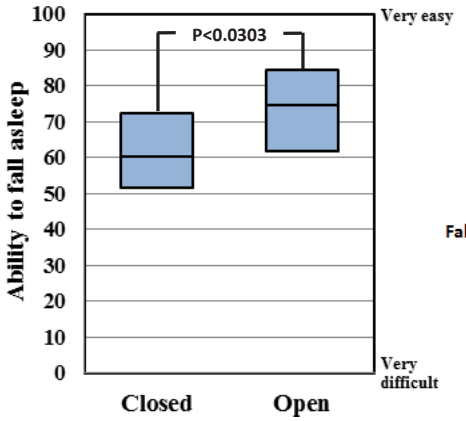
AIR QUALITY MEASUREMENTS





SUBJECTIVE ASSESSMENTS





How did you sleep last night?

1. I had a deep sleep last night	☐ True	☐ False
2. I feel that I slept poorly last night	☐ True	☐ False
3. It took me more than half an hour to fall asleep last night	☐ True	☐ False
4. I woke up several times last night	☐ True	☐ False
5. I felt tired after waking up this morning	☐ True	☐ False
6. I feel that I did not get enough sleep last night	☐ True	☐ False
7. I got up in the middle of the night	☐ True	☐ False
8. I felt rested after waking up this morning	☐ True	☐ False
9. I feel that I only had a couple of hours' sleep last night	☐ True	☐ False
10. I feel that I slept well last night	☐ True	☐ False
11. I did not sleep a wink (at all) last night	☐ True	☐ False
12. I did not have trouble falling asleep last night	☐ True	☐ False
13. After I woke up last night, I had trouble falling asleep again	☐ True	☐ False
14. I tossed and turned all night last night	☐ True	☐ False
15. I did not get more than 5 hours' sleep last night	☐ True	☐ False

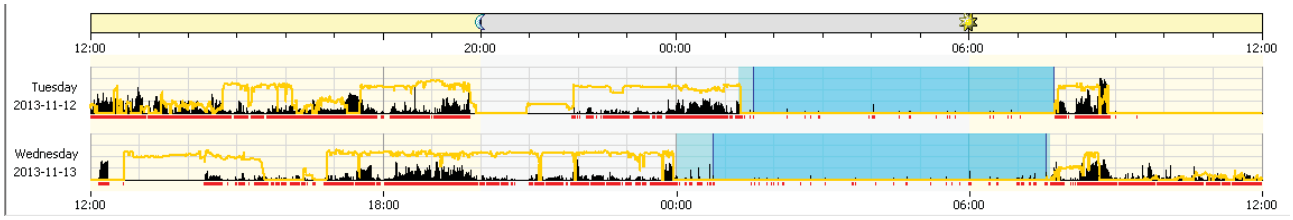
Falling asleep last night was:

Very easy ——— Very difficult

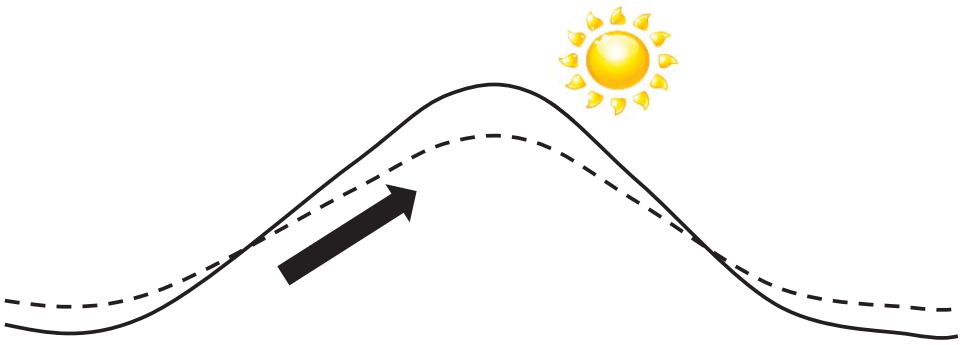
ACTIGRAPH DATA

- Significant improvement in Sleep latency (P<0.048) with open window
- A positive tedency for Sleep efficiency (P<0.074)

Sleep efficiency ● Sleep duration ● Sleep latency ● Snooze time ● No. of awakenings

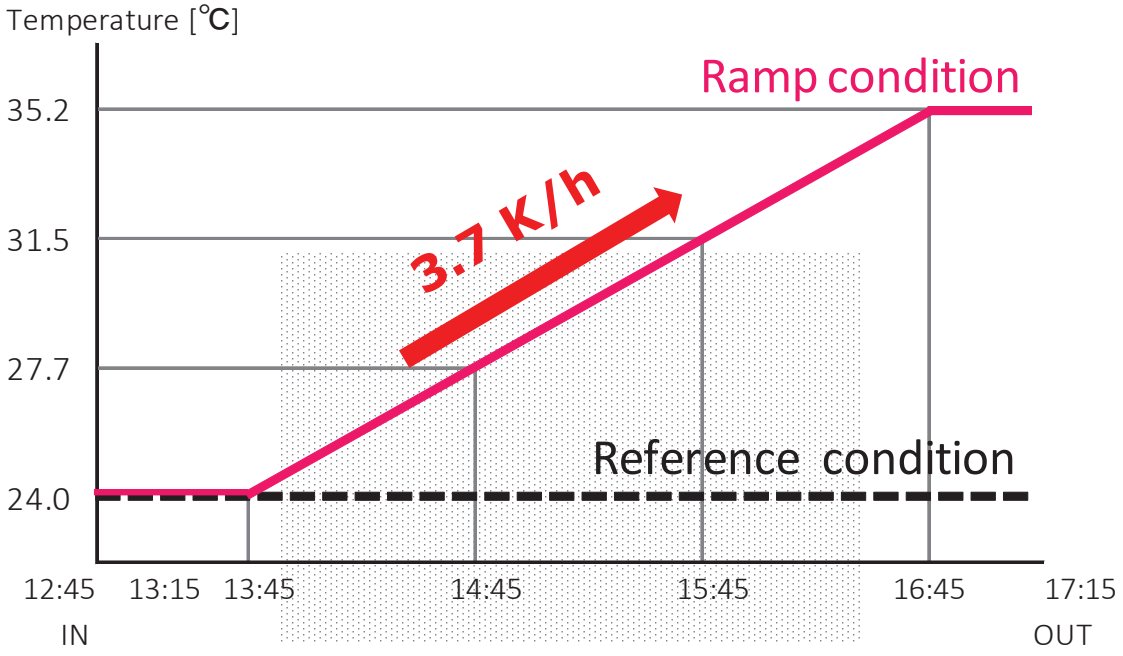


Question 4: ARE THERE ANY SEASONAL DIFFERENCES IN HUMAN RESPONSES TO INCREASING TEMPERATURE?

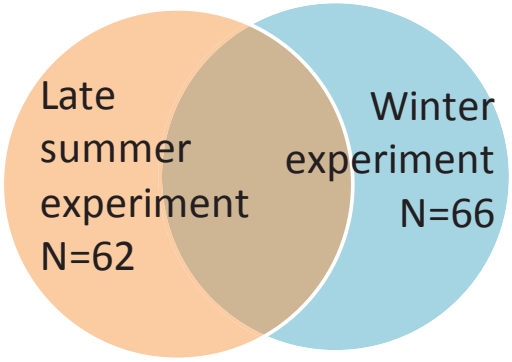


Source: Kitazawa et al. (2014)

TEMPERATURE RAMP: 24=>35.2ºC (late summer & winter)

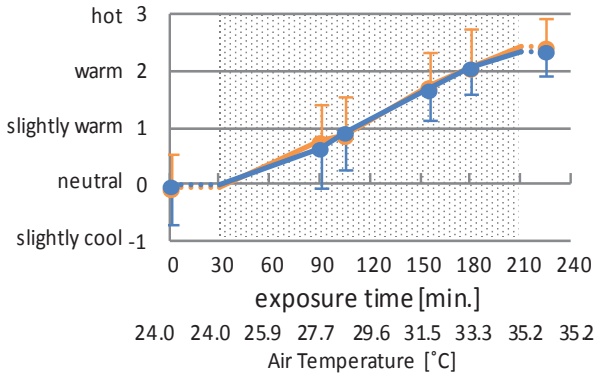


EXPOSURES, SUBJECTS, MEASUREMENTS

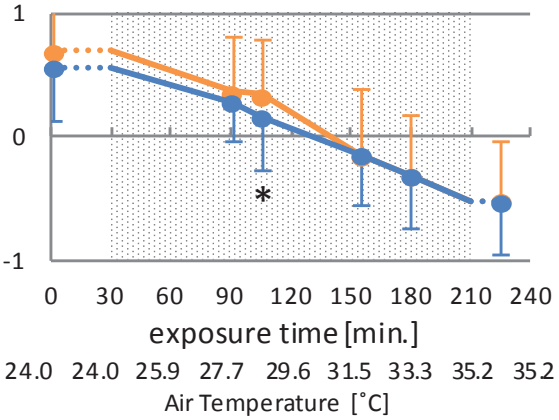


- Physical measurements
  - Subjective assessments
  - Thermal sensation
  - Acute health symptoms
  - Self estimated performance
- Physiological measurements
  - Skin temperature
  - $ETCO_2$
- Work performance
  - Simple cognitive tests (addition, attention (cue-utilization))

SUBJECTIVELY REPORTED THERMAL SENSATION AND ACCEPTABILITY



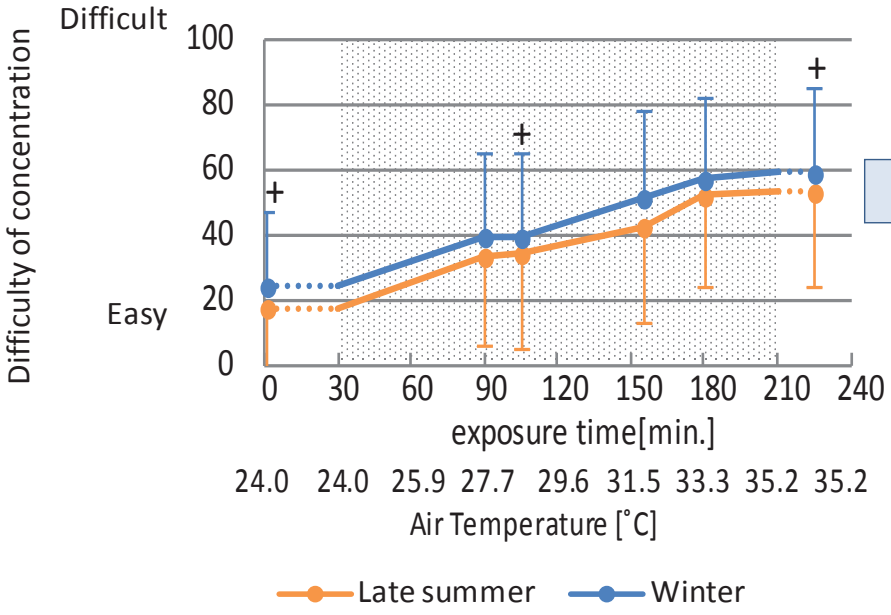
NO SEASONAL DIFFERENCES



MORE FORGIVING IN SUMMER

Late summer Winter

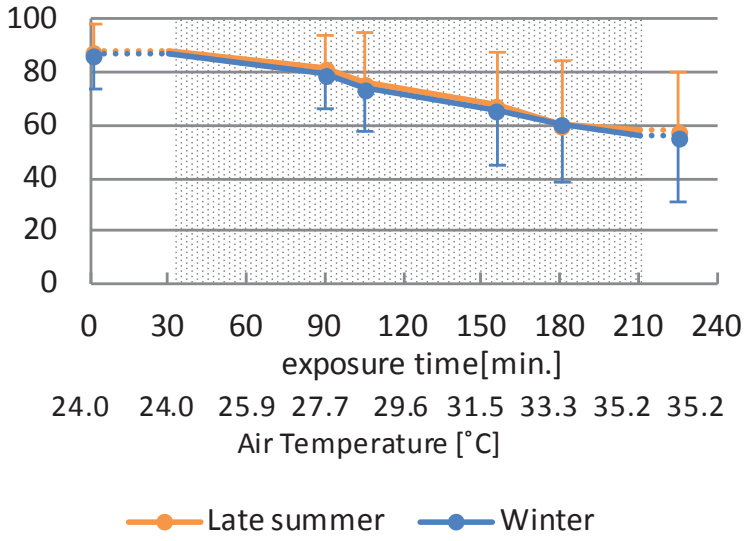
SUBJECTIVELY REPORTED ACUTE HEALTH SYMPTOMS



SMALL SEASONAL DIFFERENCES EFFECTS LESS INTENSE IN SUMMER ….and MORE INTENSE SYMPTOMS WITH INCREASING TEMPERATURE

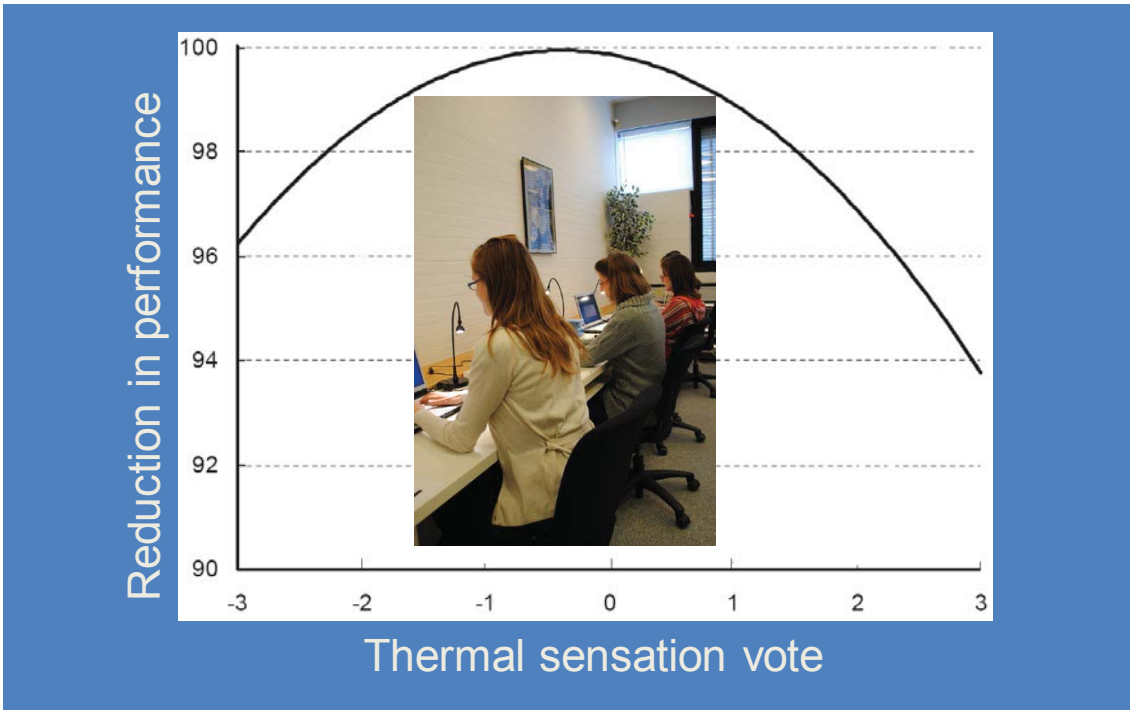
Late summer Winter

SELF-ESTIMATED ABILITY TO PERFORM WORK



NO SEASONAL DIFFERENCES
But….
ABILITY REDUCED WITH INCREASING TEMPERATURE

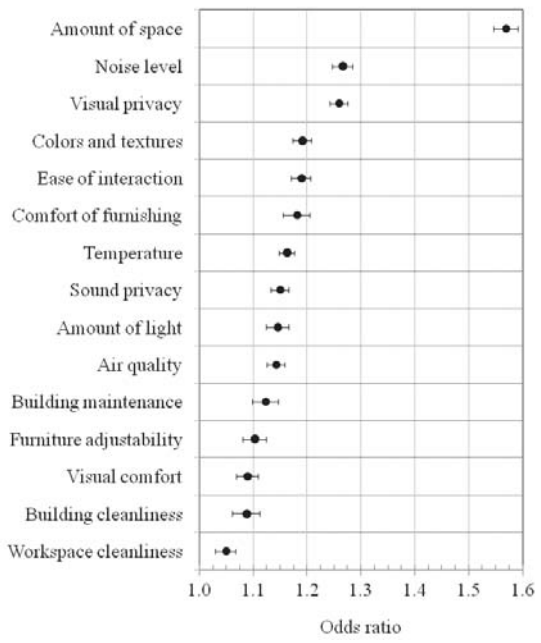
THERMAL DISCOMFORT AND PERFORMANCE OF OFFICE WORK



Source: Lan et al. (2011)

Question 5: WHICH CRITERIA SHOULD BE USED FOR DESIGNING IEQ?

IEQ AND BUILDING FEATURES IMPORTANT FOR SATISFACTION/COMFORT

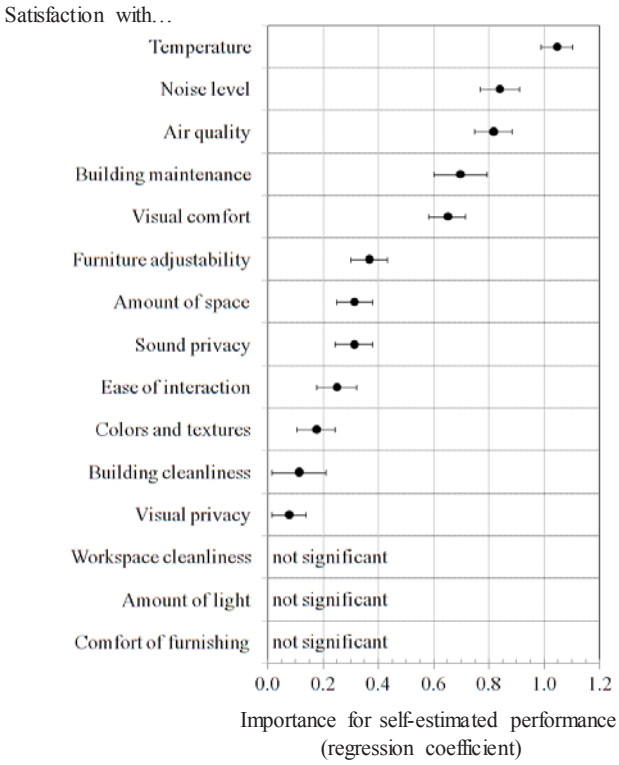


Importance for satisfaction/comfort (odds ratio)

- All important ($p<0.05$)
- The most important is satisfaction with amount of space the most important regardless occupants' gender and age, type of office (single office, shared office, cubicles) and distance from a window
- Other important parameters include satisfaction with, noise level, visual privacy, colors and textures, etc.
- IEQ is not the most important

Source: Frontczak et al. (2011)

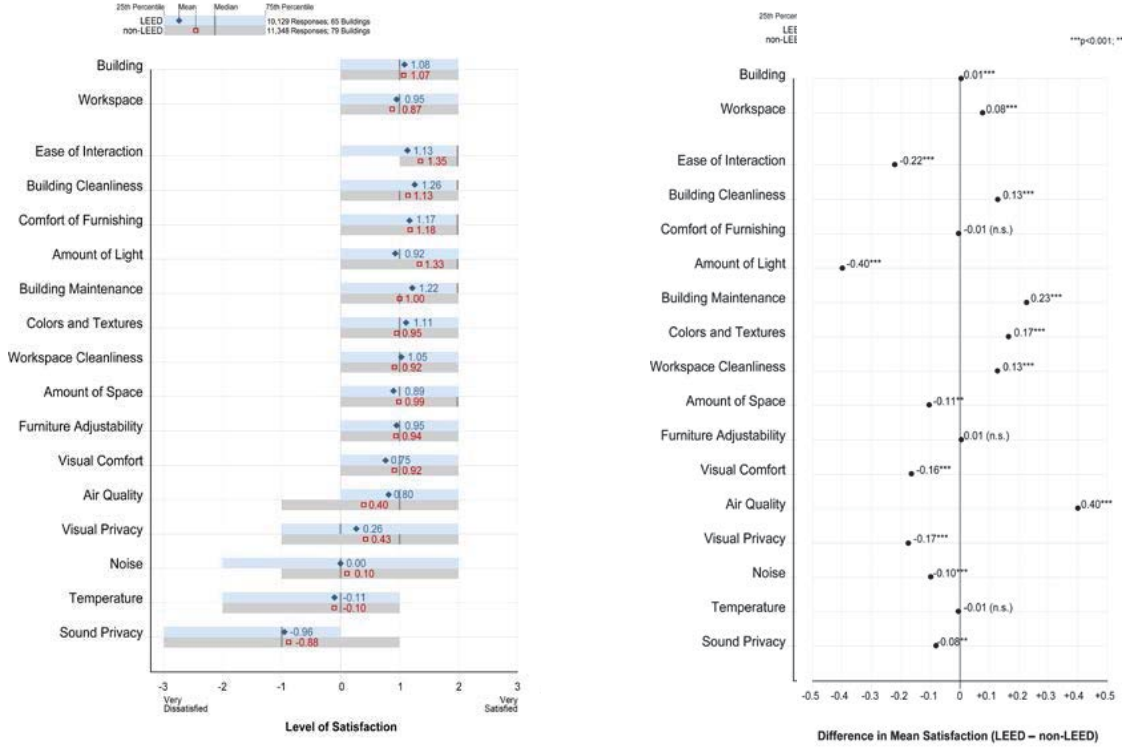
PARAMETERS IMPORTANT FOR (SELF-ESTIMATED) PERFORMANCE



- Satisfaction with temperature, noise level and air quality = satisfaction with IEQ
- For example, ~15% increase in satisfaction with temperature would increase self-estimated job performance by ~1%

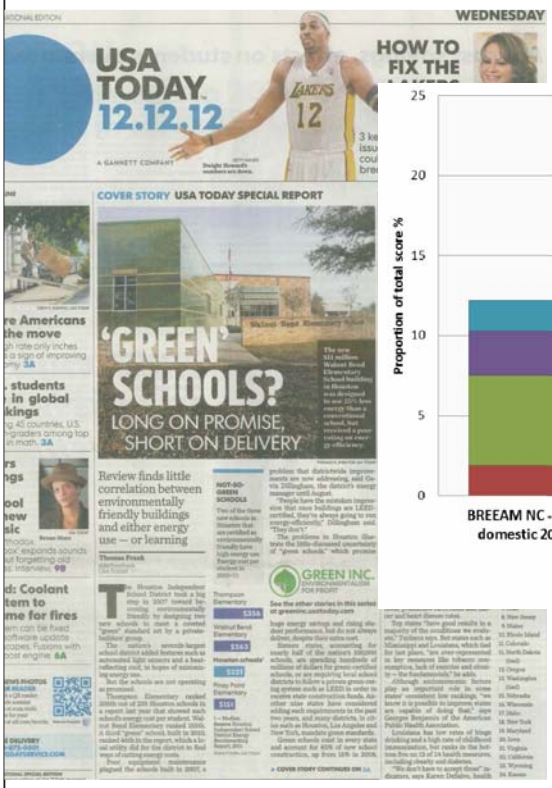
Source: Wargocki et al. (2012)

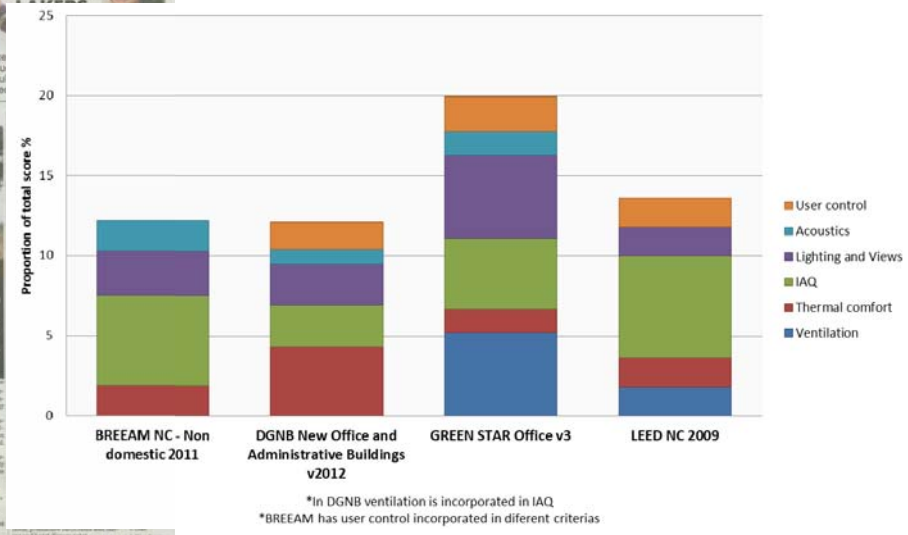
SATISFACTION AND LEED CERTIFICATION



Altomonte and Schaivon (2013)

ADAPTATION OF THE ENVIRONMENTAL ASSESSMENT SCHEMES





SUMMARY

- Definition of health-based ventilation requirements must consider all exposures (indoors and outdoors) and source control (indoors and outdoors) as a primary method to reduce exposures
- There is inconsistent evidence on whether pure CO_2 is to be considered as a pollutant with regard to cognitive performance; pure CO_2 is most likely harmless for the acute and chronic health and benign for perceived air quality <5,000 ppm
- Metabolic CO_2, a proxy of human bioeffluents, corelates well with the perceived air quality and acute health symptoms; effects on cognitive performance are likely (tbc)
- Improved bedroom ventilation may have positive effects on sleep quality (tbc)
- Allowing temperatures to slowly increase in an attempt to reduce energy may have detrimental effects on health and performance
- Investments to upgrade indoor environmental quality and building design should consider whether comfort or working morale are expected to be improved

(SOME) CHALLENGES FOR FUTURE

- Stronger acknowledgment that buildings are for people
- Stronger acknowledgment of importance of human behavior => Performance based buildings with more adaptive systems: occupants - ”passive recipients” becoming real users – ”inhabitants”
- Stronger acknowledgment of importance of interactions especially for comfort but also for health risks
- Much higher attention to human requirements (considering i.a. sleep quality, aging population, hypersensitive groups, children)
- Differences in traditional and modern (energy-efficient) buildings
- Air conditioning-educational buildings-exposures-role of air cleaning- source control

“In many respects today we submit ourselves to dramatic sudden changes in climate several times a day without giving it a second’s thought”

Source: Proctor (1982); Google Pictures

EBC

Energy in Buildings and Communities Programme

Reliability of Energy Efficient Building Retrofitting-Probability Assessment of Performance and Cost Annex 55 (RAP-RETRO)

Carl-Eric Hagentoft
Operating agent (OA)

Start : April 2010
Ends: 2014

Chalmers University of Technology, Sweden

Outline of presentation

- Background
- Annex 55 RAP-RETRO
- Risk management/assessment
- Framework
- Probabilistic analysis – Cold Attics

Subtask leaders:

Subtask 1: Gathering of stochastic data
Nuno Ramos, University of Porto, Portugal
John Grunewald, Technische Universität Dresden, Germany

Subtask 2: Probabilistic tools
Staf Roels, KUL, Belgium
Hans Jansen, KUL, Denmark

Subtask 3: Framework and Case studies
Carsten Rode, DTU, Denmark
Angela Sasic, Chalmers, Sweden

Subtask 4: Practice and Guidelines
Andreas Holm, Germany
Achilles Karagiozis, Oak Ridge National Laboratory, USA

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- → United States

+Brazil and Estonia

Background

Improving the energy efficiency is often the main focus.

Adding insulation and changing the air and vapor tightness results in a different building envelope.

Complex interaction between building envelope, building services, external climate and the users.

As a result retrofitting measures not only often do not meet the energy targets; they also result in performance failures.

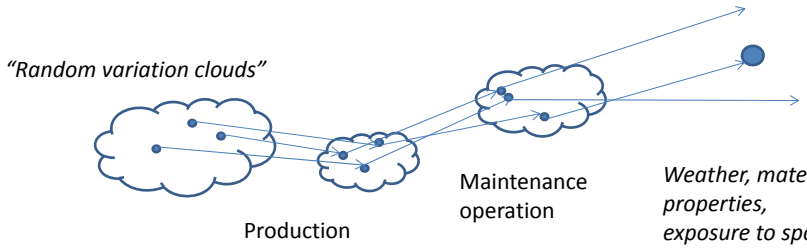
The *scope* of the work:

To develop and provide decision support data and tools for energy retrofitting measures leading to substantial upgrading.

The tools will be based on probabilistic methodologies for prediction of energy use, life cycle cost and functional performances.

- Energy
- Thermal comfort
- Performances:
  - U-values, Airtightness
  - Durability (frost, rot, mould and algae growth)
- Cost

Probabilistic approach



Examples of random variations in:

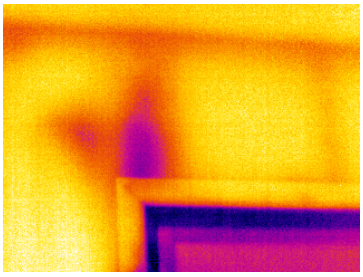
Indoor moisture sources, internal gains airing, aging of material, cracks in façades,…

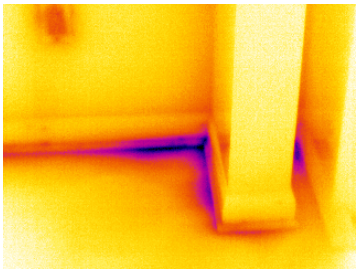
Workmanship initial conditions of material,…

Example: Airtightness:

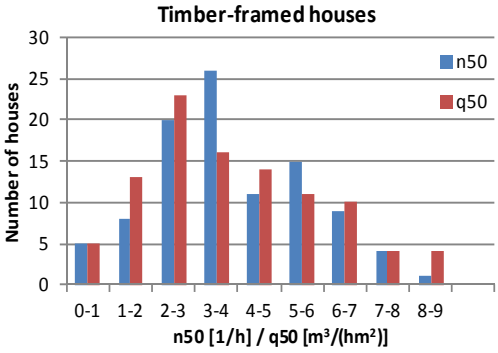
Design
Workmanship

A crucial quality!





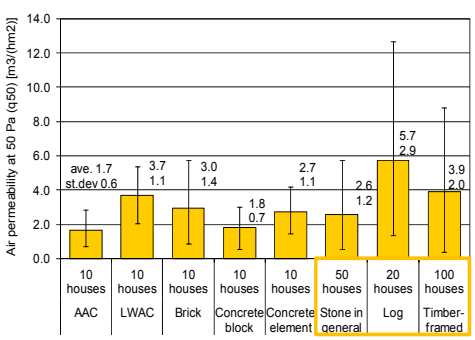
Performance -Air tightness at 50 Pa of 100 timber-framed Finnish buildings built after year 2000

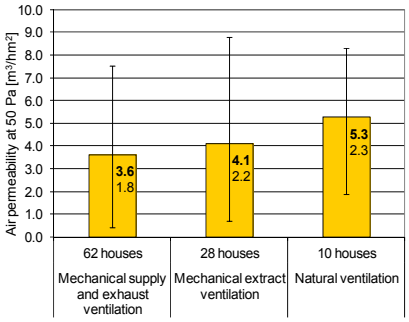


Impact of airtightness:

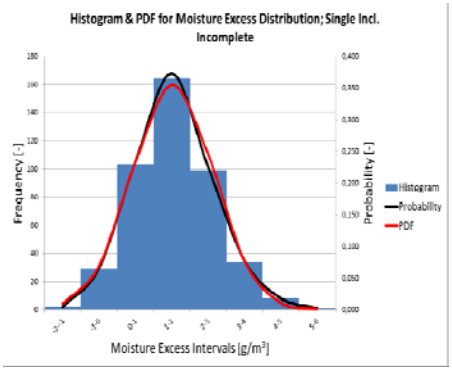
- Energy
- Thermal comfort
- Durability -Moisture safety
- Indoor air quality
- …

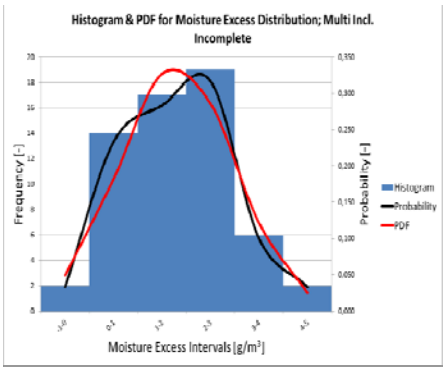
Airtightness – The spread!





Moisture loads





Envelope - Material properties statistical description

Minimum input information

Hygrothermal basic parameters

Parameter	Symbol	Unit	Mean	StdDev	Min	Max	Remarks
Bulk density	ρ	[kg/m³]	1741.0	44.0	1667.2	1787.5	
Specific heat capacity	c	[J/kgK]	939	72.7	868	1092	
Thermal conductivity	λ_{dry}	[W/mK]	0.650	0.117	0.543	0.871	
Open Porosity	θ_{por}	[m³/m³]	0.362	0.011	0.336	0.376	
Capillary saturation	θ_{cap}	[m³/m³]	0.264	0.011	0.231	0.266	
Dry cup value	μ_{dry}	[--]	18.0	06.8	08.6	24.5	
Water absorption coefficient	A_w	[kg/m²s$^{0.5}$]	0.178	0.047	0.107	0.227	

Water Retention (Desorption)

Arguments pc [hPa]	Mean θ [m³/m³]	StdDev	Min	Max	Remarks
0	0.332	0.016	0.313	0.357	
30	0.320	0.017	0.297	0.351	
60	0.318	0.016	0.296	0.345	
150	0.309	0.016	0.289	0.335	
300	0.295	0.032	0.232	0.334	
600	0.282	0.038	0.212	0.334	
900	0.262	0.042	0.206	0.316	
2000	0.163	0.047	0.100	0.221	
4000	0.093	0.037	0.047	0.146	
6000	0.075	0.034	0.041	0.137	
14000	0.062	0.028	0.030	0.120	

Sorption Isotherm (Desorption)

Arguments φ [%]	Mean θ [m³/m³]	StdDev	Min	Max	Remarks
97.4	0.0250	0.0130	0.0037	0.0427	
96.0	0.0182	0.0112	0.0033	0.0380	
90.0	0.0122	0.0060	0.0028	0.0185	
84.7	0.0097	0.0049	0.0025	0.0164	
78.4	0.0062	0.0032	0.0024	0.0111	
58.2	0.0043	0.0010	0.0019	0.0060	
43.2	0.0032	0.0016	0.0013	0.0053	
32.9	0.0026	0.0015	0.0008	0.0051	

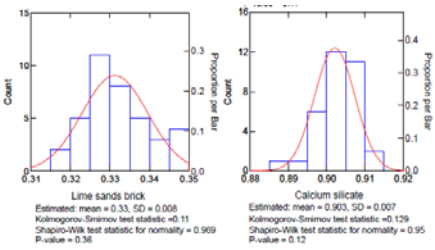
Additional input information

Water vapour permeability

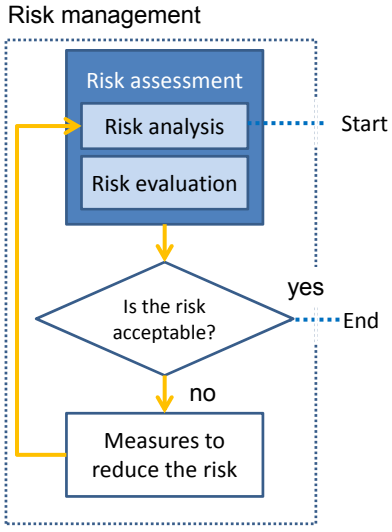
Arguments φ inside [%]	φ outside [%]	Mean μ [-]	StdDev	Min	Max	Remarks
5.0	30.0	18.0	6.8	8.6	24.5	DryCup
90.0	82.0	13.7	4.6	8.5	20.8	WetCup

Liquid water conductivity

Arguments θ [m³/m³]	mean pc [Pa]	Mean K_l [s]	StdDev	Min	Max	Remarks
0.33		3.1E-09	3.4E-09	8.0E-10	1.1E-08	

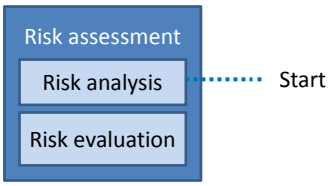


Risk management and Risk assessment



- Risk assessment should be preferably performed by experts.
- Renovation projects may involve risks for which expert knowledge is lacking.
- We can build-up knowledge while performing risk assessment.
- A framework helps in performing the assessment methodically and transparently (well documented)

Framework includes questions and actions that guide you through the assessment



Start

- What is to be retrofitted?
- What is the aim of the retrofit?
- Desired values and consequences?
- What are the renovation strategies?

Risk analysis

- What is known about the chosen renovation strategies?
- What causes deviations?
- Qualify and quantify the deviations

Risk evaluation

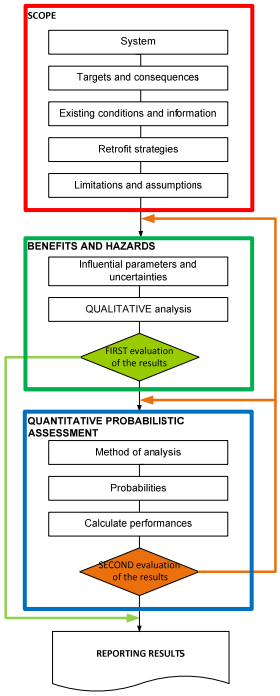
- How well does the renovation strategy meet the purpose of the renovation?
- Any limitations with the recommended renovation?

The Framework as a flow chart

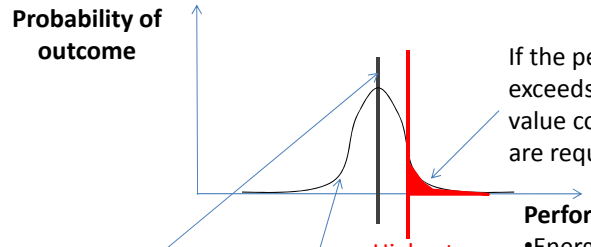
Different sections and loops.

Outgoing loops mean quick 'exit' , i.e. when the assessment shows too high or very low risk.

Backward loops – that's usually a trouble, i.e. mistake made in the assessment process



Probability assessment of performance



Conventional analysis gives a single value.

Probabilistic analyses gives a range of values and the probability of exceeding a certain value (critical value or required value) can be assessed.

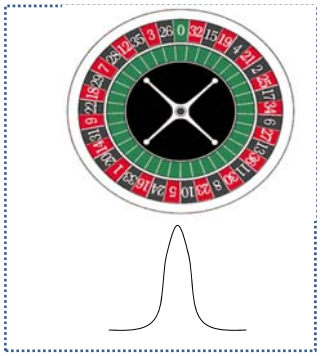
Using knowledge in the building process – What improves the desired performance? Example: Cold Attics

- Available expert knowledge
- Measurements and in-situ tests
- Simulations

In this example – an expert can list a number of influential parameters

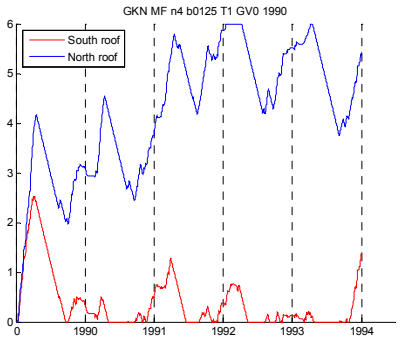
1. Building height
2. Area of the attic
3. Leakage area in the attic floor
4. Insulation thickness in the attic floor
5. Insulation thickness in the roof
6. Attic ventilation
7. Indoor moisture excess
8. Indoor air temperature
9. Initial moisture content in the wooden underlay
10. Climate year…

Example: Probabilistic analysis Monte Carlo simulations

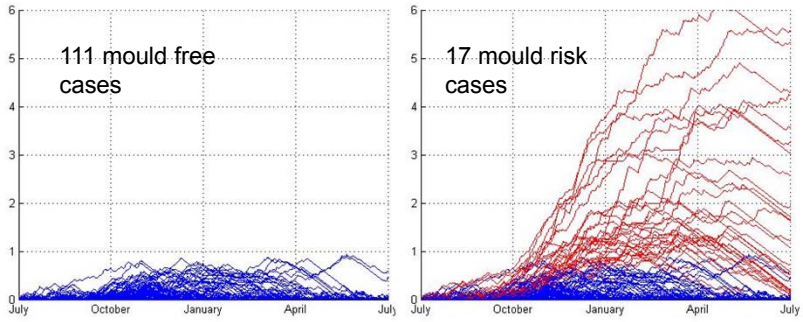


Index	Growth rate	
0	No growth	Spores not activated
1	Some growth detected only with microscopy	Initial stages of hyphae growth
2	Moderate growth detected with microscopy	Coverage more than 10 %
3	Some growth detected visually	New spores produced
4	Clear visually detected growth	Coverage more than 10 %
5	Plenty of visually detected growth	Coverage more than 50 %
6	Very heavy and tight growth	Coverage around 100 %

Performance criteria –
Mould Growth Index (MGI)
(Viitanen)

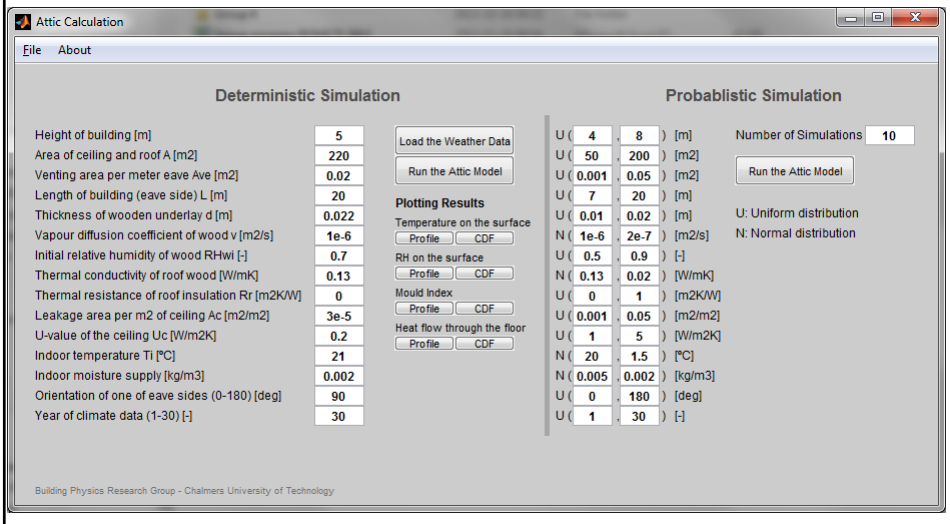


MGI above 1 (once) – The attic is considered damaged!



- Risk = 17/128=13% (reliability is 87 %)

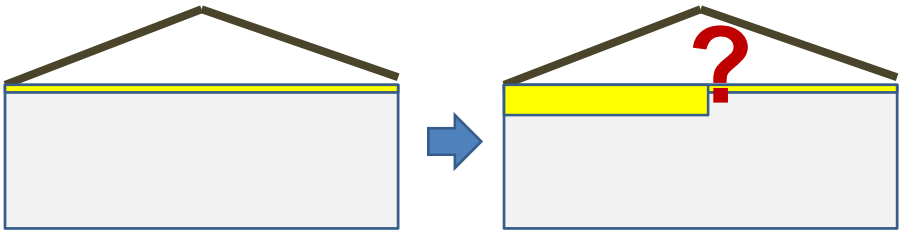
Ready-to-use cacluation tool
SimpleColdAttic (Hagentoft,Nik)
Free sofware: www.byggnadsteknologi.se/downloads.html



Looking at economics!
Advise an ESCO (Energy Saving Company) in a retrofitting project of 237 dwellings – 10 years outcome

Target: minimise the risks, maximise the benefits

Example: Retrofitting of attic insulation

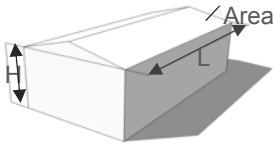


Different possible scenarios for retrofitting, but of course each renovation measure corresponds to a certain cost, will result in certain benefits (energy savings) and may result in hygrothermal risks (mould growth)

What is the renovation measure (applicable to all dwellings) that results in the largest overall profit ?

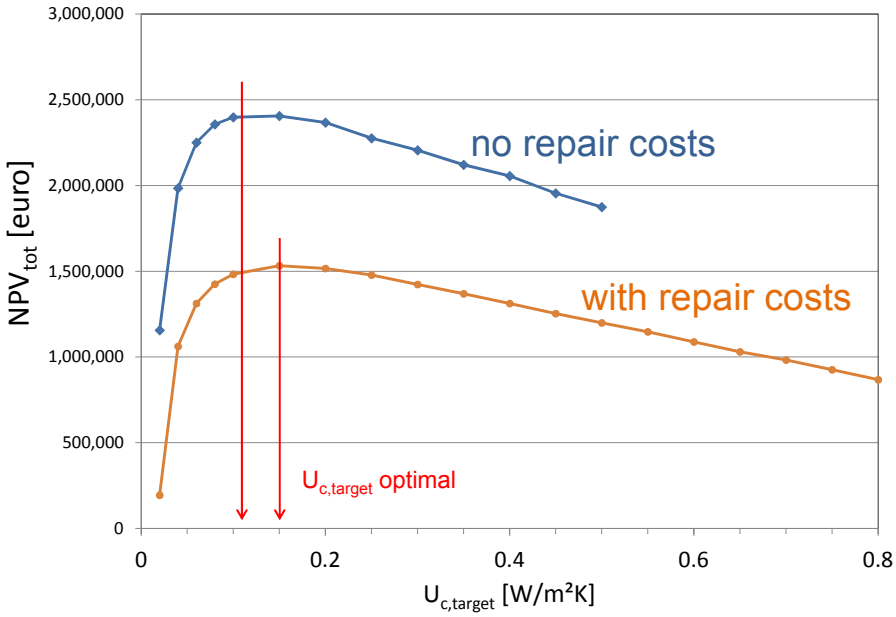
Variations taken into account

1. variation on existing structure, loads, orientation of dwellings,.

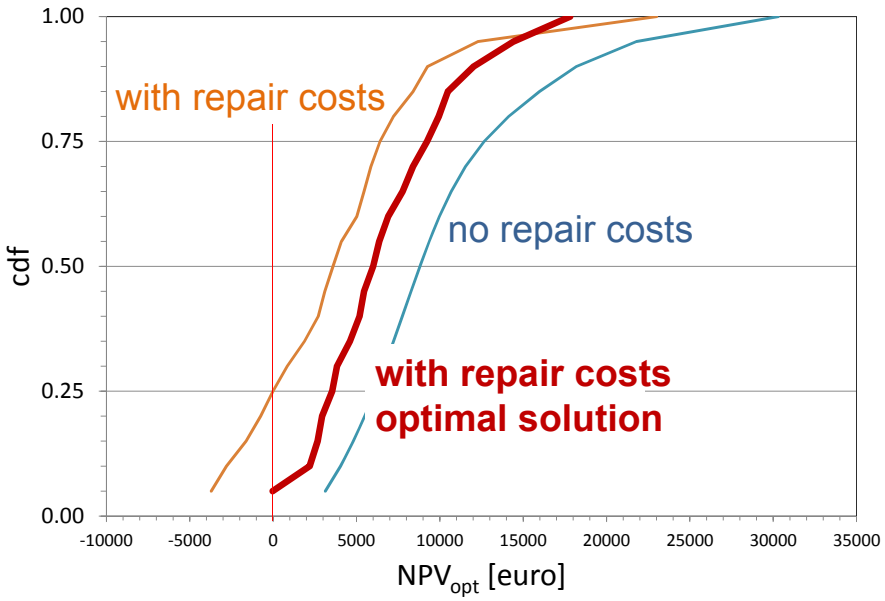


input parameter	symbol	distribution
Height of building H (m)	H	U(4,8)
Area of ceiling and roof A (m^2)	Area	U(50,200)
Orientation of one of eave sides (-)	BSangle	U(0,180)
Venting area per meter eave A_e (m^2/m)	Ae	U(0.01,0.05)
Length of building (eave side) L (m)	Length	U(7,20)
Thickness of wooden underlay d (m)	d	U(0.01,0.02)
Vapour diffusivity of wood δ_v (m^2/s)	deltav	N(10^{-6},2 10^{-7})
Initial relative humidity of wood φ_0 (-)	startRH	U(0.5,0.9)
Thermal conductivity of wood λ_{roof} (W/mK)	lambda	N(0.13,0.02)
Resistance of roof insulation R_r (m^2K/W)	Rr	U(0,1)
Effective leakage area per m^2 of ceiling A_c (m^2/m^2)	Ac	U(10^{-5},10^{-4})
U-value of the ceiling U_c (W/m^2K)	Uc	U(1,3)
Indoor temperature T_i (°C)	Ti	N(20,1.5)
Indoor moisture supply (kg/m^3)	MS	N(0.005,0.002)

Outcome of analysis:
Total Net Present Value for all 237 dwellings

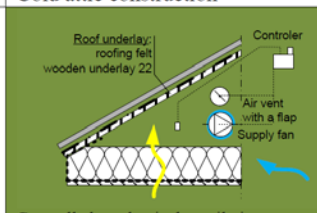
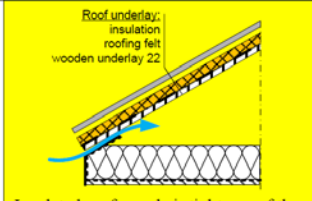


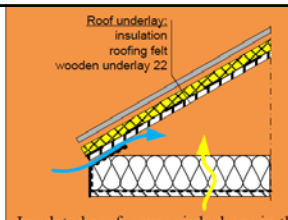
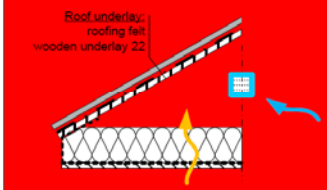
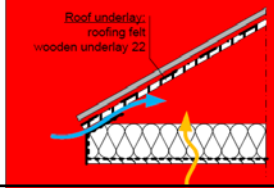
CDF of Net Present Value for optimal solution



Risk free (green)
Low risk (yellow)
Semi high risk (orange)
High risk (red)

Method is used to get conclusions in a nutshell for Swedish conditions
To communicate the risk

	Cold attic construction	Requirements and sensitivity
Risk free	 Controlled mechanical ventilation	• The airtightness of the attic should be at least 10 1/h@50Pa • Ventilation should start directly after completeness of attic construction • Requires alarm function for failure of mechanical devices • Lowest total life cycle cost
Low risk	 Insulated roof, good air tightness of the attic floor	• Requires durable solution for the airtightness of the attic floor. • Works better at low moisture excess in the building (well ventilated housing - preferably exhaust only mechanical ventilation system). • Sensitive to the building orientation. • Some sensitivity to the local and future climate. • Should be supplemented with dehumidifiers in the construction phase to eliminate built-in moisture.

Semi-high risk	 Insulated roof, some air leakage in the attic floor	• Works better at low moisture excess in the building (well ventilated housing - preferably exhaust only mechanical ventilation system). • Sensitive to the local and future climate. • Should be supplemented with dehumidifiers in the construction phase to eliminate built-in moisture.
High risk	 Reduced ventilation – only through gable vents; air tight roof eaves.	• Extra sensitive to the lack of air-tightness in the attic floor and high moisture excess in the home. • Should be supplemented with dehumidifiers in the construction phase to eliminate built-in moisture. • Sensitive to future climate.
High risk		• Extra sensitive to the lack of air-tightness in the attic floor and high moisture excess in the home. • Sensitive to future climate. • The most expensive technical solution when lifecycle cost is assessed. • Should be supplemented with dehumidifiers in the construction phase to eliminate built-in moisture.

A better building process is needed in general!

Reliability/Risk assessment can contribute to this!

Thanks!

Figure 8 Left: appearance of MBG on retrofitted façade. Right: MBG removed from the façade by water.

Performance criteria

- U-values for construction parts
- Heat loss through thermal bridges
- Indoor temperature and relative humidity
- Minimum / maximum air change rates
- Critical moisture in the construction materials
- Mould growth index
- Number of freezing/thawing cycles

Source of image: internet

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le futur en construction

The French Indoor Air Quality Observatory
Outcomes of a decade of research and perspectives

Séverine Kirchner

24 septembre 2014
www.cstb.fr / www.oqai.fr

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le futur en construction

Towards good health and well-being indoors …

Light
Noise
Vibration
Electro magnetic fields
Radon
Moulds
Bacteria
Virus
Allergens : dust mites, cats, dogs, ...

Robert and Shana Parkeharrison
Study of Nest, 1994/2010

Indoor Smoke
particulate matter
Asbestos, MMMF
aldehydes (ex formaldehyde)
VOCs : benzene, ...
NOx
Lead, Arsenic, Mercury, lead, ...
Phtalates
POPs
Pesticides
Flame retardant
Endocrine disuptors

AIR WATER SOIL

Tracability of substances?

Next ?

Nano materials

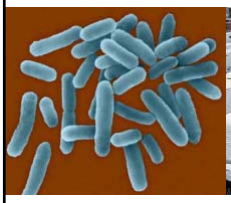
PCB

Asbestos

Lead

How to manage ?

1976 : Légionella



1980s : Formaldehyde

1990s : killer carpets

1995 : Asbestos

2004 : cleaning products

2006 : furnishing

2013 : Cellulose wadding

Observatoire de la qualité de l'air intérieur

Observatory on indoor air quality

Created in 2001

- To coordinate and develop **scientific knowledge on indoor environment on a national scale supporting public policies**
  - Building and equipments
  - Occupants behaviors
  - Indoor air quality (chemical, physical, microbio)
  - Comfort (acoustic, thermal, light)

- **Public funding**: between 1.8 – 2.5 million €/year
  3 ministries (Construction, Environment and Health),
  2 national Agencies in charge of Energy & Environment (ADEME) and Environmental Health and safety (ANSES)
  CSTB
- **Multidiciplinary scientific partner network coordinated by CSTB**

Observatoire de la qualité de l'air intérieur

How to choose target parameters to measure?

Periodic health-ranking (2001, 2005, 2010)
Score based on inventory of pollutants, concentrations and toxicological reference values for acute and chronic exposure
More than 1000 chemical substances and particules:

Dwellings

15 priority substances
formaldehyde,
benzene
Carbon monoxide,
di-2-éthylhexylphtalate (DEHP),
acrolein,
lead,
acetaldehyde,
particules matters (PM_{10} et $PM_{2.5}$),
cadmium,
arsenic,
benzo[a]pyrène,
benzo[a]anthracène,
1,4-dichlorobenzène
chloroforme.

Schools

6 priority substances
formaldehyde,
benzene,
acetaldehyde,
PM_{10} et $PM_{2.5}$
chrome.

Office buildings

5 priority substances
benzene,
$PM_{2.5}$,
Mix of PCB,
ethylbenzene,
formaldehyde.

Sources : *Almeras et al, 2010*

PAGE 6

Observatoire de la qualité de l'air intérieur

2.How much of pollutants are people exposed to ?
3. How many people are exposed ?

7

Observatoire de la qualité de l'air intérieur

Inside the real-life …

8

Observatoire de la qualité de l'air intérieur

OQAI's National surveys

Dwellings 2003-2005
(n = 567) IAQ

Schools (n=300) 2013-2017
IAQ, acoustic, light, thermal and perceived comfort

Office buildings (n=300) 2013-2017
IAQ, acoustic, light, thermal and perceived comfort, SBS

Low energy buildings 2013...
IAQ, acoustic, light, thermal and perceived comfort

PAGE 9

Observatoire de la qualité de l'air intérieur

1. Indoor air quality in housing stock

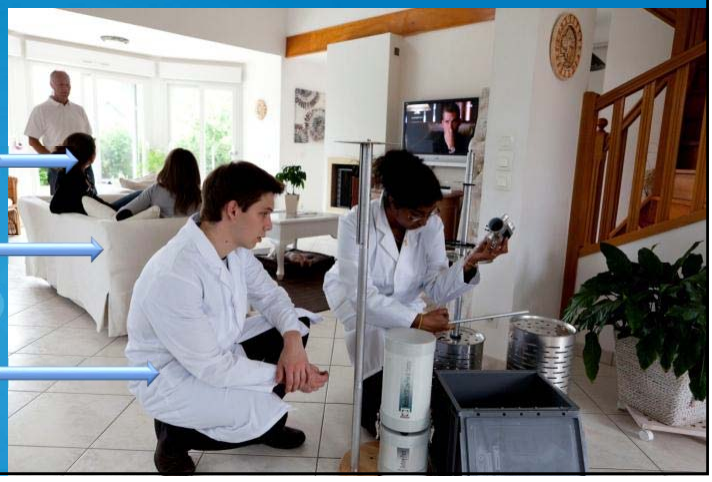
National survey (oct 2003- dec 2005)

567 dwellings
1 612 people
4 691 rooms
One week survey

Data on household (socio-economical statut, activities, …)

Building audit (materials, products, equipments, etc.)

Measurements CO, VOCs, radon, PM, moulds, cats and dogs allergens, dust mites, CO_2,T, RH, airflowrate



2. National survey on indoor environment in schools :

Observatoire de la qualité de l'air intérieur

300 buildings
600 classrooms
from monday to friday

Building audit : building products, ventilation, heating appliances, …

- **NO_2**
- **13 VOC , 3 aldehydes**
- **46 COsV** in air, **46 COsV** in dust
- **6 metals in dust**
- **Lead** in paint and dust
- **$PM_{2,5}$** mass concentration and number
- **Allergens dogs, cats, dust mites** on mattress
- **Electro magnetic fields**

– **Acoustic and light levels**
– **Temperature and relative humidity**
– **CO_2 (ventilation indicator)**

Occupants : activities, time activity paterns, cleaning activities, …
Perceived comfort

3. National survey in office buidlings

Observatoire de la qu
l'air intérieur

- Buildings and use
- Population exposure to pollutants
- Comfort in office room: light, thermal, acoustic
- Perceived health (SBS)
- Energy performance

What are the links between IAQ, comfort, perceived health and energy efficiency ?

Observatoire de la qualité de l'air intérieur

3. National survey in office buildings
300 buildings

Phase 1 : 1 day

- **Building audit**
- **Perceived comfort and health**
- **IAQ monitoring** (COV, aldehydes, ultrafine PM, T, RH, CO_2)
- **Energy performance**

2012-2017

Phase 2 : 1 week

- **IAQ and comfort monitoring**
  - VOCs, aldehydes, O_3
  - Particles
  - Biocontaminants
  - Thermal comfort, light, noise
  - Ventilation (air flow rate)
- **Energy performance – detailed**

2017

Observatoire de la qualité de l'air intérieur

4. Indoor air quality and comfort in energy efficient buildings

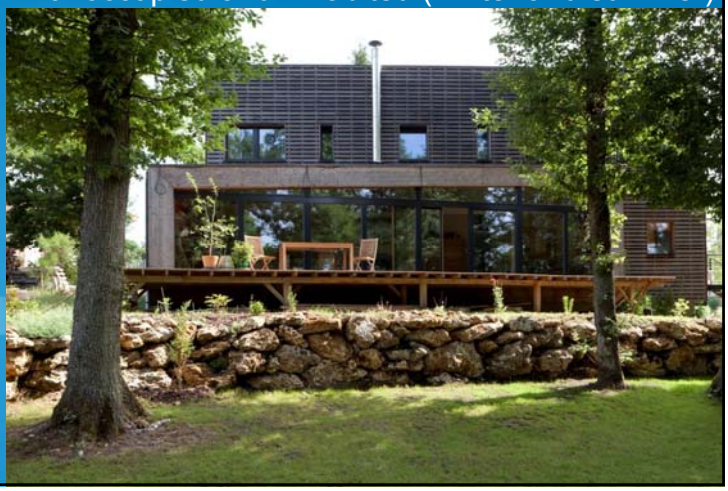
Survey in 7 houses
unoccupied and inhabited (winter and summer)

Indoor air quality: CO, VOC, TVOC, $PM_{2.5}$, UFP, radon

Comfort : T, RH, air speed, acoustic, questionnaires on occupation and perceived comfort

Energy consumption: bills, measurement for each end use of energy (2 houses)

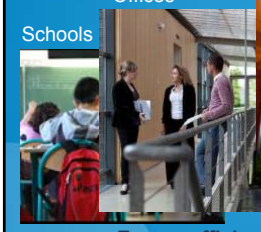
Qualification of building: air tightness, air exchange rate, building materials, systems, etc.



Observatoire de la qualité de l'air intérieur

4. Indoor air quality and comfort in energy efficient buildings

Schools



Offices

Dwellings

Energy efficient buildings

National database On IAQ and comfort In energy efficient buildings

Agreement with private and public operators

Harmonised protocoles

IAQ | Ventilation | Comfort | Energie

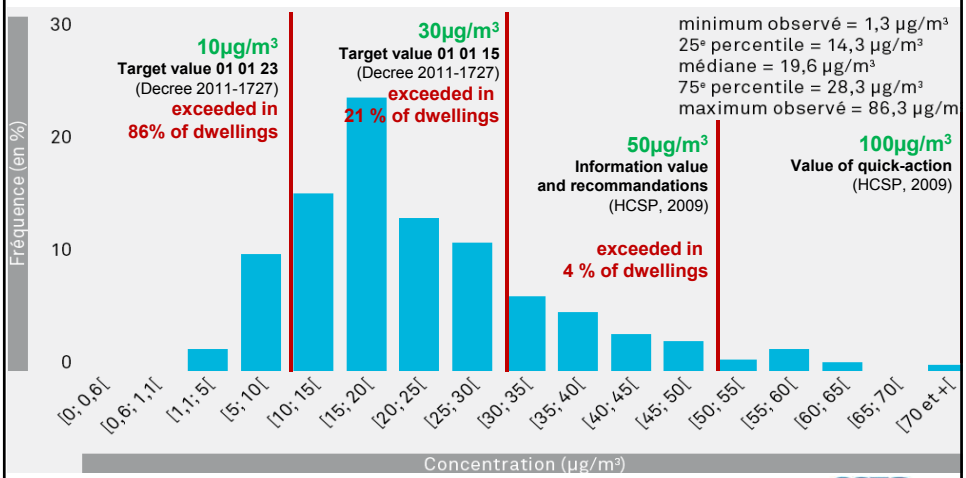
One week repeted at different seasons

Observatoire de la qualité de l'air intérieur

Results: global overview

Dwellings: distribution of pollutants
From scientific results to public policies

Formaldehyde : distribution of concentrations in French dwellings



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Dwellings: comparison with WHO IAQ-G (2010)

- **Carbon monoxide:**

Exposure duration	WHO guideline values	Exceeded in x% of dwellings
15 minutes	100 mg/m³	0.7% - 3.7%
1 hour	35 mg/m³	2.2% - 5.8%
8 hours	10 mg/m³	**4.4% - 9.4%**

- **Formaldehyde:** 100 µg/m³ never exceeded
- **Trichloroethylene:** the concentration associated with an excess lifetime cancer risk of 10^{-5} (23 µg/m³) is exceeded in **1.7% - 5.0%** of dwellings
- **Tetrachloroethylene**: 250 µg/m³ is exceeded in **0.07%** of the dwellings (only one dwelling in the sample)
- **Radon**: **0.1% – 1.5%** > 400 Bq/m³ (mandatory remediation value in France)
- **Particles**:
  [PM_{10}] exceeds WHO air quality guideline (20 µg/m³) in around **80%** of dwellings;
  [$PM_{2.5}$] exceeds AQG (10 µg/m³) in around **90%**

Dwellings: key determinants of IAQ

Emission sources

Building

attached garage
materials / decoration products
water damage
heating systems

Occupants & activities

density of occupation
smoking,
Diy
candles, incense
dry cleaning, …

Air management

Air management

ACH
design and maintenance of ventilation systems
opening windows

Outdoor environment

Outdoor environnent

Air
Soil
T and RH

Association between pollutants and household incomes

Dwellings: type of ventilation

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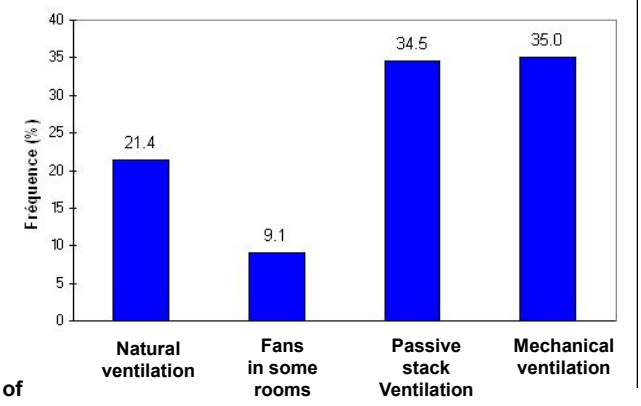
le futur en construction

Half of the dwellings was built
before 1967
before ventilation regulation (1969)

Type of ventilation in the housing stock



Balanced ventilation in dwellings represent 1.1% of housing stock

Dwellings: air management

ACH = air leakage **+ doors and windows opening +** air flow rate from ventilation system

ACH weekly average for the dwellings (h^{-1}) Calculated with CO_2 levels	
450 observations	**ACH (h^{-1})**
P5	**0,15**
P10	**0,19**
P25	0,31
Median (P50)	**0,54**
P75	0,92
P90	1,45
P95	2,02

Half of the French dwellings have air changes rates < 0,54 h^{-1}

1982 Regulation : 0.5 h^{-1}

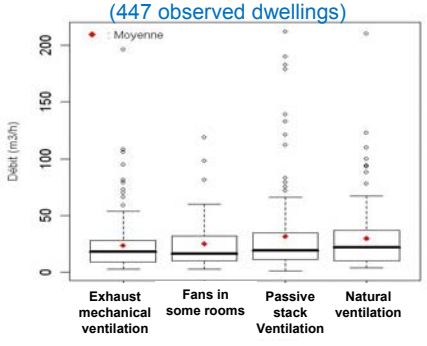
1969 Regulation : 1 h^{-1}

CSTB

Dwellings: air management

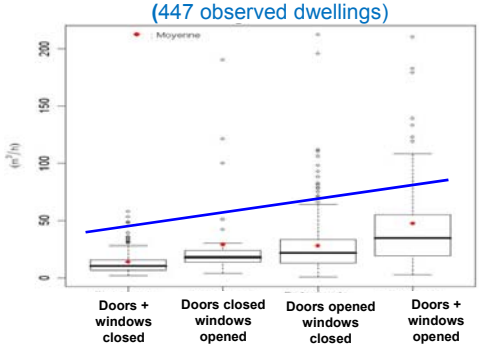
- In the overall housing stock, **the ventilation is not dependent to the installed systems**

Air change rate (m^3/h) distribution according ventilation systems
(447 observed dwellings)



- **The occupant** (behaviors, habits, living conditions, circumstances) **plays a role as important as technical performance of systems**

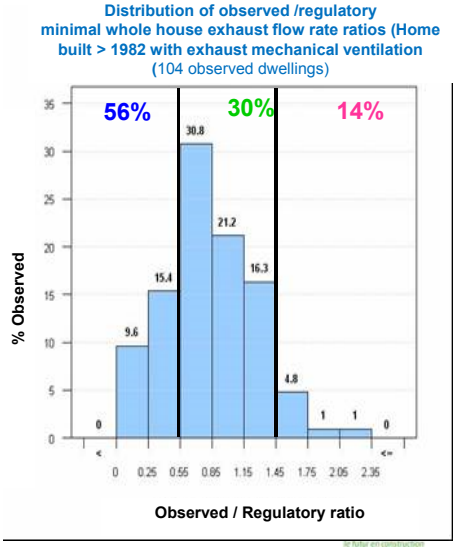
Air change rate (m^3/h) distribution according doors and windows opening condition
(447 observed dwellings)



Dwellings: air management

- The **newer dwellings** show a **better control of ventilation** conditions thanks to mechanical systems

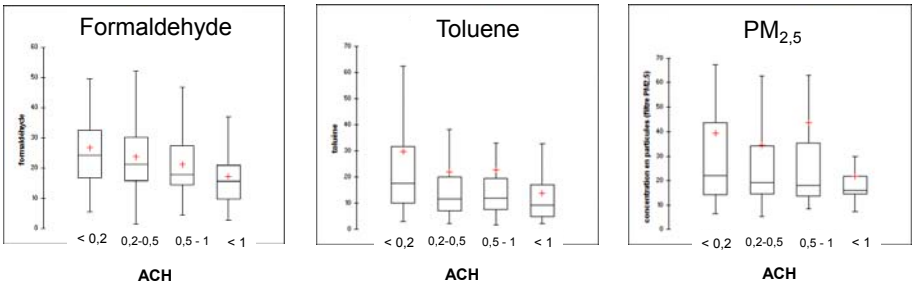
- **These systems frequently show malfunctions**, which severely limits their reliability: nearly **56% of homes** have a minimum exhaust flowrate that does not comply the standards



Ventilation and IAQ relationship

Relationship between air change rate and pollutant concentration depend on pollutant sources, operative conditions of systems, occupant's behavior, type of dwellings …

Air change rate : calculated on the basis of CO_2 concentration



Observatoire de la qualité de l'air intérieur

IEQ in 7 low energy houses

equiped with balanced ventilation systems

- Very airtight buildings
- Low energy consumption
- Indoor pollution levels similar to housing stocks for radon and PM but higher for VOC (new buildings)
- Ventilation conditions satisfactory…when it works (ACH : 0.1 to 1 h^{-1} depending of the fan speed)

- Malfunctioning ventilation systems
- Not friendly used systems
- Difficulty of maintenance (filters, ducts, ..)
- Modulation rates not always relevant or discriminant (2- 4 fan speeds)
- Annoyances due to the systems: noise, especially at night

Strong pollution observed

in case of malfunction of the ventilation system

Observatoire de la qualité de l'air intérieur

IAQ indicators

LUM'AIR® : **integrated tool for assessment and management of air stuffiness in schools and kindergarten based on CO_2 levels**

- Index ICONE : rating from 0 to 5
- Trafic light

ICONE index 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	Medium 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

Observatoire de la qualité de l'air intérieur

ICONE levels during occupancy in 310 schools and day-care centers (weekly-based)

ICONE index score	Schools	Day-care centres
0	14%	25%
1	16%	**31%**
2	22%	22%
3	**26%**	17%
4	20%	2.7%
5	0.9%	0.5%
Invalid data	1.3%	2.1%
N (rooms)	896	187

- **High intra-school spatial variability**: typical differences of 2-3 index scores (up to 4) between 8 to 14 classrooms within a school
- **Low intra-classroom temporal variability**: typical differences of 0-1 index scores between 16 weeks within a given classroom (up to 2-3 in nursery classrooms)

Observatoire de la qualité de l'air intérieur

Socio-Economic Costs due to IAQ: a tentative estimation for France

1. EXTERNAL COSTS	2. IMPACT ON PUBLIC FINANCES
1.1 Mortality cost (life year value = €115,000, Quinet, 2013) 1.2 Morbidity costs 1.3 Loss of productivity	2.1 Health care 2.2 Research 2.3 Pensions not paid ("benefits")

More than 28 000 new cases of illness every year
Around 20 000 deaths annually
Annual costs in millions euros for 6 target pollutants

Benzene	TCE	Radon	CO	Particles	ETS
883	39	2 694	308	14 331	1 279

Total indoor pollution costs in France

estimated at around **€20 billions per year** = 1% of GDP, 28% of energy bill

Particles generated the highest burden, with €14 billions per year.

Observatoire de la qualité de l'air intérieur

Conclusions

From scientific results to actions

Observatoire de la qualité de l'air intérieur

1. Source control

- Smoking ban
- Ban of compounds : ex CMR category 1 and 2 in decoration products (trichloroethylene, benzene, dibutyle phthalate, bis(2-ethylhexyle)phthalate)
- Voluntary or mandatory labelling systems
- Maintenance of building and equipments : combustion appliance, repair leaks and water damage
- Avoid intensive use of pesticides, air fresheners, candles or incense sticks, etc..

2. Air management

Improve design, sizing, implementation and maintenance of systems

Validate on site performance and safety of new technological options (ventilation, filtration)

Protect all indoor environments from outdoor pollution, especially particles

3. Take into account the people involved

… especially those who live indoors

- The occupant has a significant role on the final performance of the building

✓ Choose robust and easy to handle systems

✓ Help the occupant to effectively manage his environment

✓ Inform and train

Think in a more integrated way

✓ **Energy efficiency**

✓ **Indoor air quality**

✓ Noise

✓ Light

✓Water quality

✓Control of natural hazards and accidental risks

✓Quality of use and accessibility

✓Preservation the environmnent

✓Waste management

✓Costs

Yang Yongliand
Heavenly City by Yang Yongliang Untitled 4

CSTB
le futur en construction

Séverine Kirchner
www.oqai.fr

VENTILATIVE COOLING
- POTENTIAL AND LIMITATIONS

PER HEISELBERG
DEPARTMENT OF CIVIL ENGINEERING

AALBORG UNIVERSITY
DENMARK

DEFINITION OF VENTILATIVE COOLING

VENTILATIVE COOLING IS APPLICATION (DISTRIBUTION IN TIME AND SPACE) OF VENTILATION AIR FLOW TO REDUCE COOLING LOADS IN BUILDINGS

VENTILATIVE COOLING UTILIZES THE COOLING AND THERMAL PERCEPTION POTENTIAL (HIGHER AIR VELOCITIES) OF OUTDOOR AIR

IN VENTILATIVE COOLING THE AIR DRIVING FORCE CAN BE NATURAL, MECHANICAL OR A COMBINATION

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VENTILATIVE COOLING IS A SOLUTION

THE DEVELOPMENT TOWARDS "NEAR ZERO ENERGY BUILDINGS" HAS RESULTED IN AN INCREASED NEED FOR COOLING – NOT ONLY IN SUMMER BUT MOST OF THE YEAR!

VENTILATIVE COOLING CAN BE AN ATTRACTIVE AND ENERGY EFFICIENT PASSIVE SOLUTION TO REDUCE COOLING AND AVOID OVERHEATING.

- Ventilation is already present in most buildings through mechanical and/or natural systems using opening of windows
- Ventilative cooling can both remove excess heat gains as well as increase air velocities and thereby widen the thermal comfort range.
- The possibilities of utilizing the free cooling potential of low temperature outdoor air increases considerably as cooling becomes a need not only in the summer period.

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POTENTIAL AND LIMITATIONS

OUTDOOR CLIMATE POTENTIAL

- Outdoor temperature lower than the thermal comfort limit in large part of the year in many locations
- Especially night temperatures are below comfort limits
- Natural systems can provide "zero" energy cooling in many buildings

LIMITATIONS

- Temperature increase due to climate change might reduce potential
- Peak summer conditions and periods with high humidity reduce the potential

- An Urban location might reduce cooling potential (heat island) as well as natural driving forces (higher temperature and lower wind speed). Elevated noise and pollutions levels are also present in urban environments

- Building design, fire regulations, security are issues that might decrease the use of natural systems
- High energy use for air transport limit the potential for use of mechanical systems

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Climate Potential

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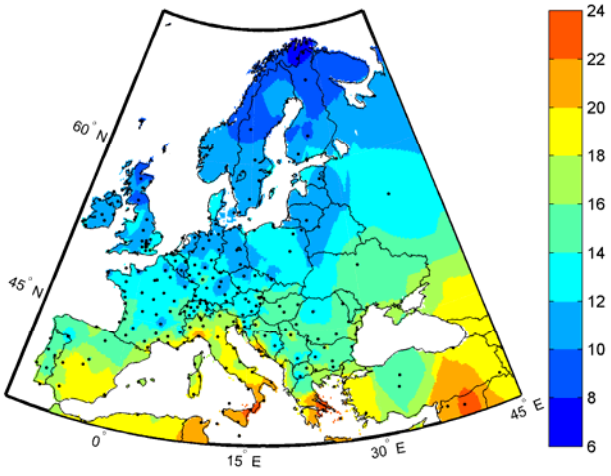
DAILY MINIMUM TEMPERATURE JULY



Meteonorm Data

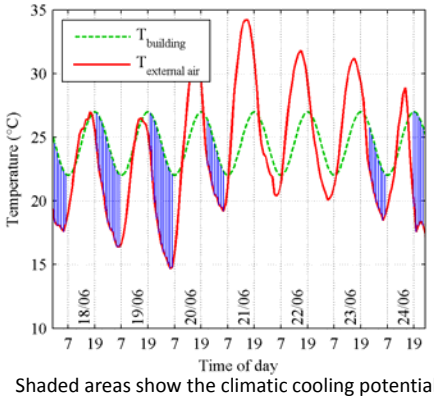
CLIMATIC POTENTIAL FOR NIGHT-TIME COOLING

DEGREE HOURS METHOD TO QUANTIFY THE CLIMATIC COOLING POTENTIAL (CCP)
HARMONICALLY OSCILLATING BUILDING TEMPERATURE WITHIN A RANGE OF THERMAL COMFORT:

$$T_b = 24.5°C \pm 2.5°C$$

VENTILATION PERIOD: 7PM – 7 AM

MINIMUM TEMPERATURE DIFFERENCE: $\Delta T_{crit} = 3K$



Shaded areas show the climatic cooling potential during one exceptionally hot week in summer 2003 for Zurich SMA (ANETZ data)

CCP (KH)

$$CCP_d = \sum_{t=t_i}^{t_f} m_{d,t} \left(T_{b(d,t)} - T_{e(d,t)}\right) \quad \begin{cases} m = 1\,h & \text{if } T_b - T_e \geq \Delta T_{crit} \\ m = 0 & \text{if } T_b - T_e < \Delta T_{crit} \end{cases}$$

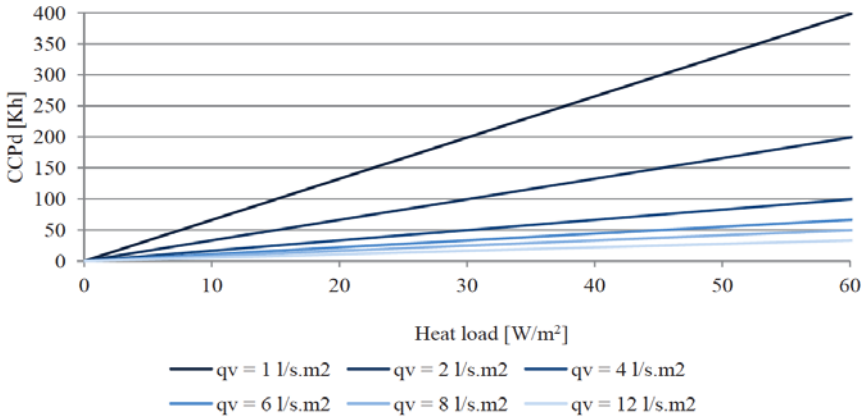
PRACTICAL SIGNIFICANCE OF CCP

Example:

- **Internal and solar heat gains:** $\dot{Q} = 20W/m^2 + 30W/m^2 = 50W/m^2$
- **Occupancy time:** $t_{occ} = 8h$
- **Effective air change rate:** $ACR\,\eta = 6\,h^{-1}; \quad \left(\eta = \frac{T_{out} - T_e}{T_b - T_e}\right)$
- **Room height:** $H = 2.5m$
- **Air properties:** $\rho = 1.2\,kg/m^3; c_p = 1000\,J/(kgK)$

Climatic cooling potential: $CCP = \frac{\dot{q} \cdot t_{occ}}{H\,ACR\,\eta\,\rho\,c_p} = 80\,Kh$

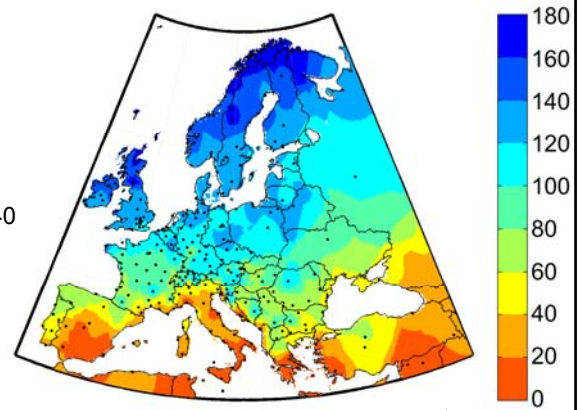
NECESSARY CCP
AS A FUNCTION OF HEAT LOAD AND VENTILATION AIR FLOW RATE



LOCAL VARIABILITY

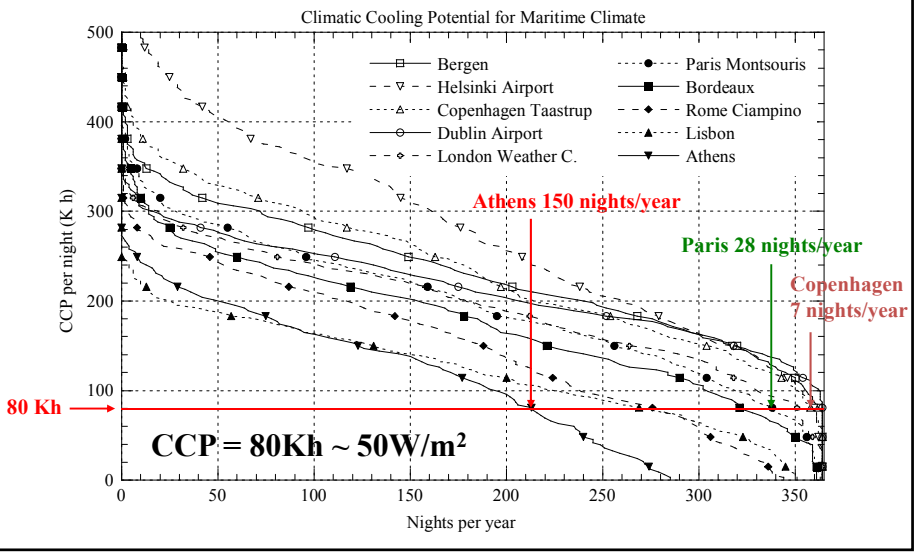
SEMI-SYNTHETIC DATA (METEONORM) FROM 259 LOCATIONS IN EUROPE

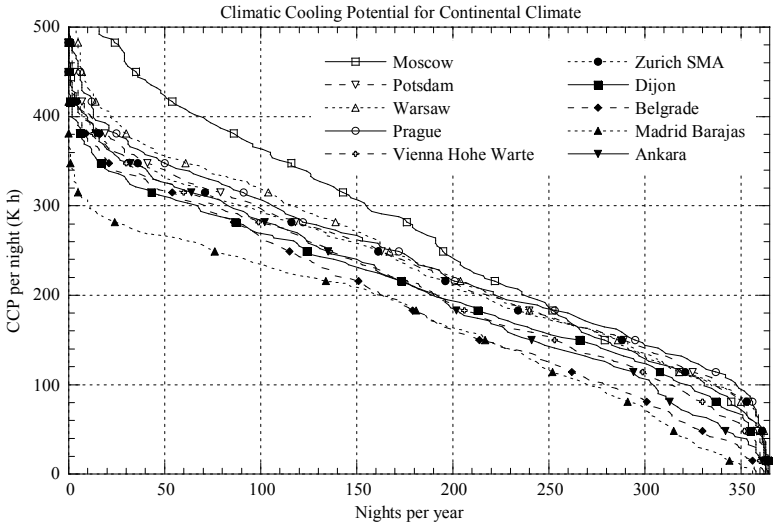
- Very high potential of 120 – 180 Kh in Northern Europe (incl. British Isles)
- High cooling potential 80 – 140 Kh in Central, Eastern and parts of Southern Europe
- Low cooling potential in Southern Europe: 0 – less than 80 Kh



Map of mean climatic cooling potential (K h / night) in July (Meteonorm data)

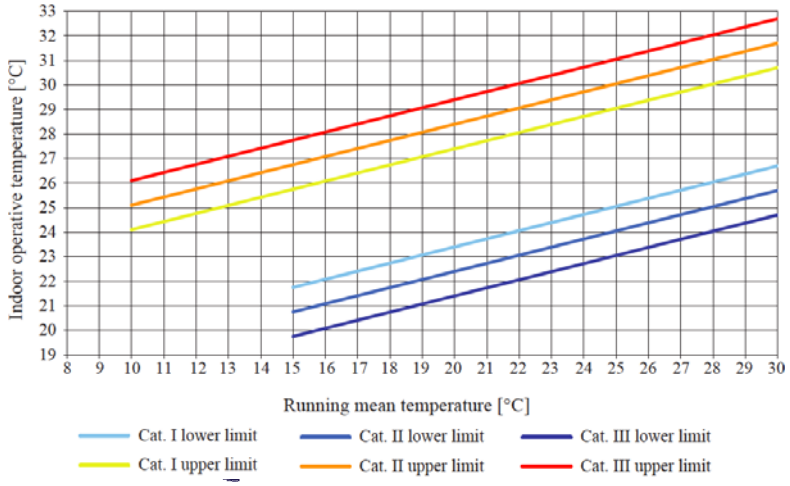
CUMULATIVE FREQUENCY DISTRIBUTION OF CCP



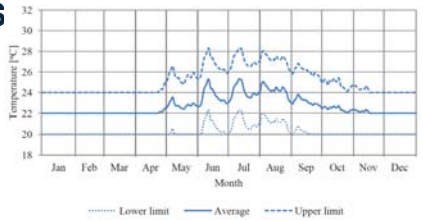


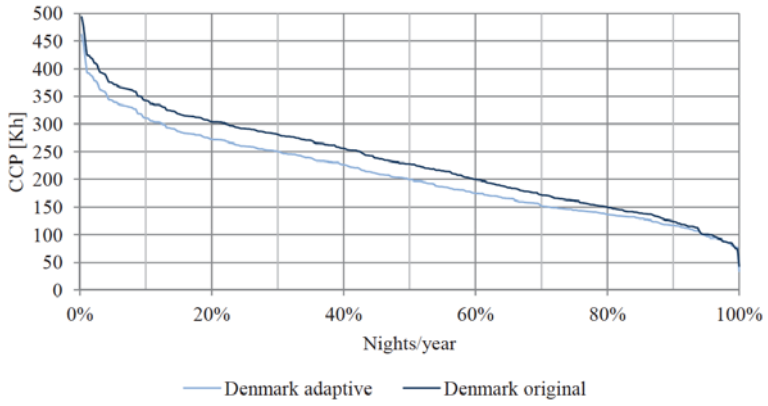
ADAPTIVE COMFORT APPROACH

OPERATIVE TEMPERATURE AS FUNCTION OF EXTERNAL RUNNING MEAN, EN 15251

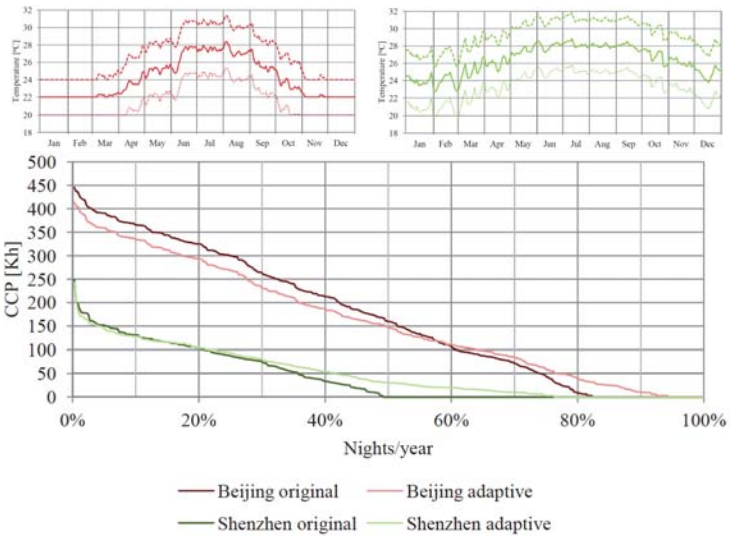


IMPACT IN COOL CLIMATES DENMARK





IMPACT IN WARMER CLIMATE
BEIJING, SHENZHEN



Limitations

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LIMITATIONS

- Temperature increase due to climate change might reduce potential
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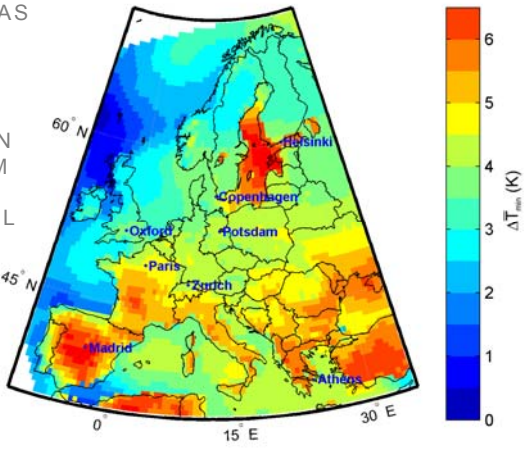
CHANGE IN LONG-TERM MEAN DAILY MINIMUM TEMPERATURE IN SUMMER (JJA)

"A2" EMISSIONS SCENARIO FOR THE YEARS 2071-2100 RELATIVE TO THE BASELINE 1961-1990, AS SIMULATED BY THE DANISH METEOROLOGICAL INSTITUTE

REGIONAL CLIMATE MODEL. SIMULATIONS WERE BASED ON BOUNDARY CONDITIONS FROM THE HADAM3H ATMOSPHERIC GENERAL CIRCULATION MODEL (TABLE A1: SCENARIO NO S1). DATA FROM PRUDENCE (2006)

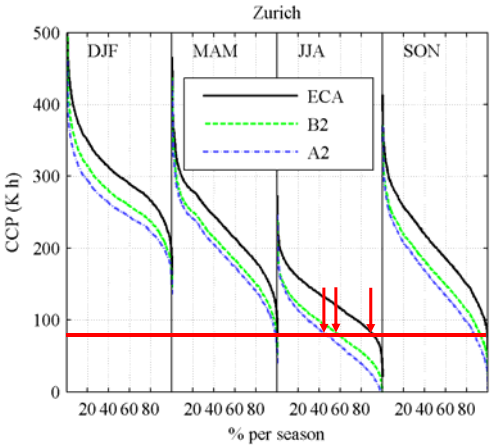


CUMULATIVE DISTRIBUTION

Percentage of summer nights when CCP exceeds e.g. 80 Kh

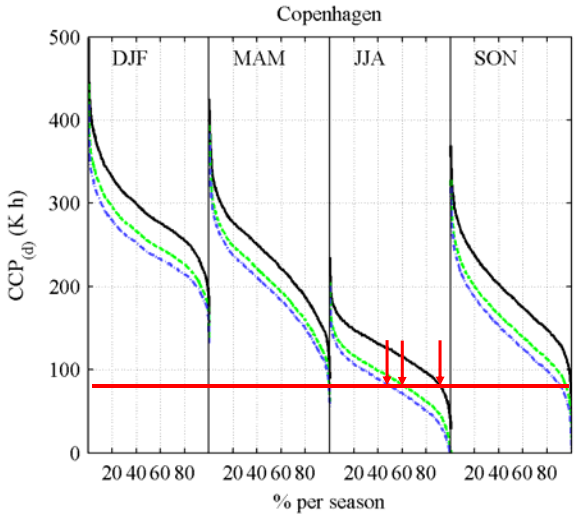
- **Current climate: 90 %**
- **Future climate: 45-55 %**

Significant increase in risk of overheating

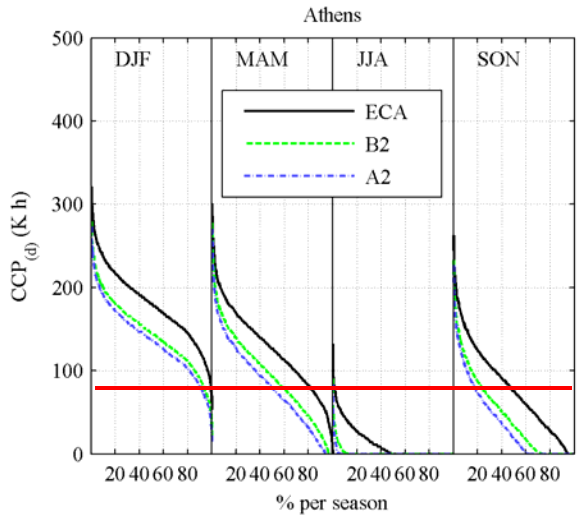


Seasonal cumulative distribution functions of CCP in Madrid for current climate (ECA data) and selected simulation runs with mean values for forcing scenarios A2 and B2

PASSIVE COOLING POTENTIAL



PASSIVE COOLING POTENTIAL



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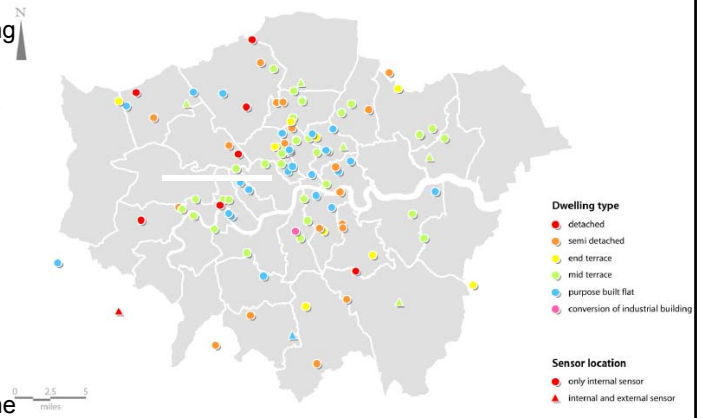
MONITORING SUMMER INDOOR OVERHEATING

- 101 London dwellings of varying morphology
- Convenience sample (UCL staff and students)
- Dry bulb temperature and relative humidity measured during summer 2009 (HOBO U12-012)
- 36 dwellings monitored during hot spell (29th June – 3rd July)



Source: LUCID Project, Anna Mavrogianni, UCL, UK

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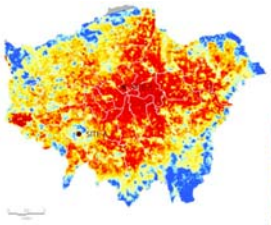
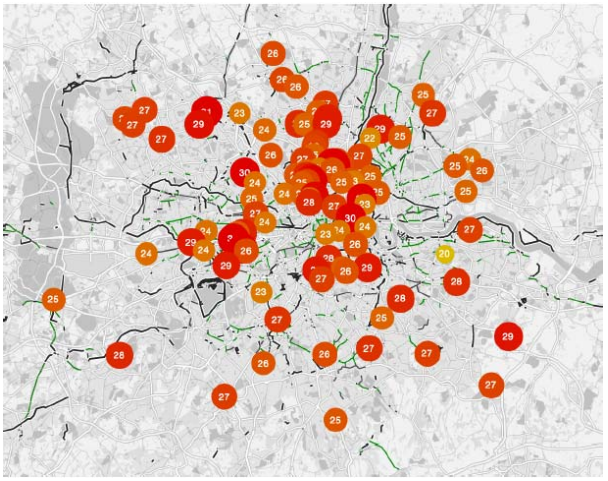
MONITORING SUMMER INDOOR OVERHEATING

NO STRONG CORRELATION BETWEEN INDOOR TEMPERATURE AND DISTANCE FROM THE CITY CENTRE.





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IMPACT OF URBAN ENVIRONMENT
(HEAT ISLAND AND REDUCED NATURAL DRIVING FORCES)

TEMPERATURES AND WIND SPEEDS IN 10 STREET CANYONS IN ATHENS WAS MEASURED AND COMPARED WITH VALUES OUTSIDE

HIGHER TEMPERATURES AND LOWER WIND SPEED WERE FOUND AND THE IMPACT ON AIR FLOW RATE FOR NIGHT COOLING PREDICTED

Urban canyon	Single sided ventilation average difference of ACH	Cross-ventilation average difference of ACH
Ippokratous	0.2	12.6
Solonos	0.4	17.8
Kavalas	3.0	34.6
Papastratos	2.5	4.2
Valaoritou	2.2	34.9
Mavromihali	10.0	60.0
Kodrou	2.9	52.9
Giannitson	1.6	27.4
Omirou	2.6	69.3
Evrota	3.2	53.8

Reference: Geros et al., *Energy and Buildings* 37 (3), pp. 243–257 2005

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VENTILATIVE COOLING OFFICES IN COLD CLIMATE

VENTILATIVE COOLING OFFICES IN COLD CLIMATE

WITH HIGH INSULATION AND AIR TIGHTNESS LEVELS ALWAYS A COOLING NEED DURING OCCUPIED HOURS EVEN IN COLD WINTER

COOLING IS NOT A NEW TECHNOLOGY, BUT THE NEED FOR COOLING IS INCREASING AND MORE EFFICIENT SYSTEMS HAVE TO BE DEVELOPED TO FULFILL FUTURE ENERGY REQUIREMENTS

APPLICATION OF THE FREE COOLING POTENTIAL OF OUTDOOR AIR IS WIDELY USED IN MECHANICAL VENTILATION SYSTEMS, BUT ENERGY USE FOR TRANSPORT OF AIR IS RELATIVELY HIGH

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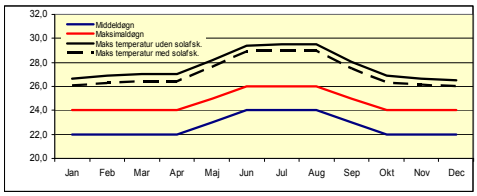
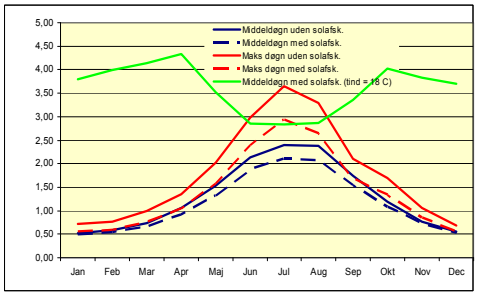
CHALLENGES IN A COLD CLIMATE





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SUMMARY

VENTILATIVE COOLING CAN BE A VERY ENERGY EFFICIENT COOLING SOLUTION FOR BOTH MECHANICAL AND NATURAL SYSTEMS

EVEN IF HIGH SUMMER TEMPERATURES MIGHT DECREASE POTENTIAL IN SUMMER DEVELOPMENT TOWARDS “NEAR” ZERO ENERGY BUILDINGS WITH A COOLING NEED ALL YEAR WILL INCREASE THE POTENTIAL CONSIDERABLY

NEW SOLUTIONS FOR COLD AIR SUPPLY NEEDS TO BE DEVELOPED FOR BOTH MECHANICAL AND NATURAL SYSTEMS

INTEGRATION AND CONTROL OF VENTILATIVE COOLING IN RELATION TO OTHER PASSIVE COOLING MEASURES, MECHANICAL COOLING SOLUTIONS AND USER PRACTICES WILL BE ESSENTIAL FOR OPTIMUM PERFORMANCE BOTH IN RELATION TO ENERGY USE AND THERMAL COMFORT

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Thanks for your attention
More information on IEA EBC Annex 62 on
www.venticool.eu

Tight Vent Europe
BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM

Comparison of building preparation rules for airtightness testing in 11 European countries

35th AIVC Conference

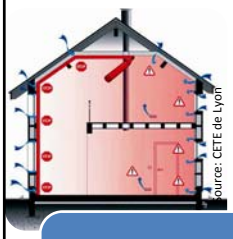
Poznan, Poland

24-25 September, 2014

Analysis of answers of airtightness associations representatives performed by:
Valérie Leprince, Rémi Carrié

Tight Vent Europe

Introduction: The reliability of airtightness tests



Building airtightness is a key issue to reach low energy level

More and more regulations and labels impose airtightness testing

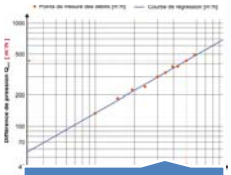
In this context airtightness tests have to be reliable

- Not to discredit the approach
- To avoid competition distortion

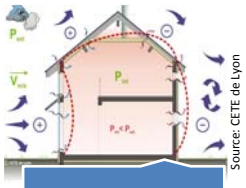
Tight Vent Europe

Uncertainty in airtightness testing

Measurement devices

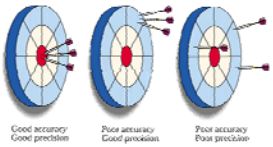


Calculation



Source: CETE de Lyon

External conditions



The tester behaviour

Interpretation and respect of the measurement protocol

Context: building preparation one of the main sources of uncertainty

- (Rolfsmeier, 2010) : 17 testers perform a test on the same building:
  - **Preparation** made by the tester **himself** => difference till **70%** on V_{50}
  - **Homogeneous** preparation rules=>V_{50} within **7%**

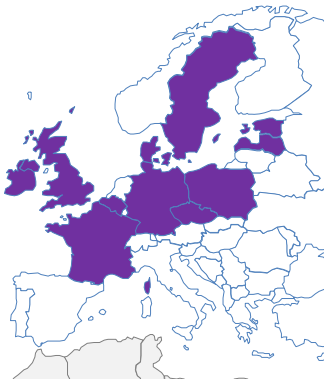
⇒ **Consequences can be crucial for building professionals** or owners

  - Condition for subsidies
  - Cost of the remedial actions

- If result is used in energy performance calculation method:
  - ⇒ The building **preparation has to be consistent with the EP-calculation** method
  - ⇒ May be ambiguous for devices such as unvented combustion appliances.

Objective

- The objective of this study is to compare the preparation of building for airtightness test in the context of EP-regulation or energy saving program in various European countries.



Demarch

- TAAC working group
- Questionnaire on building preparation
- Comparison of the preparation

Answers

- The synthesis of answers from 11 European countries

Country	Specific document	Country	Specific document
Belgium	"Spécifications supplémentaires"	Latvia	No specific document
Czech Republic	Metodický pokyn - Pravidla pro měření průvzdušnosti obálky budovy (Methodical instruction – Rules for mesurement of air permeability of building envelopes, in Czech)	Denmark	"Metoder for certificerede virksomheders trykprøvning efter EN 13829 og gældende bygningsreglement" version 1,
Ireland	ATTMA publication "Measuring air permeability of Building Envelopes" & EN 13829	Germany	EnEG_Staffel11 – Auslegungsfragen zur Energieeinsparverordnung – Teil 11
Estonia	No specific document	Sweden	No specific document
France	GA –P 50-784 (application guide of NF EN 13829)	Poland	No specific document
		UK	ATTMA Technical Standard L1 – Measuring Air Permeability of Building Envelopes (Dwellings)

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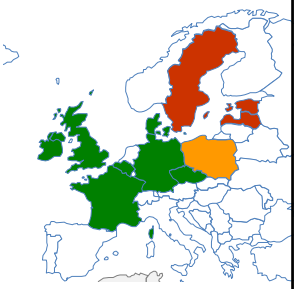
Specific guidelines for the building preparation prior to an airtightness test?



- In the context of EP-Regulation or Energy saving program.

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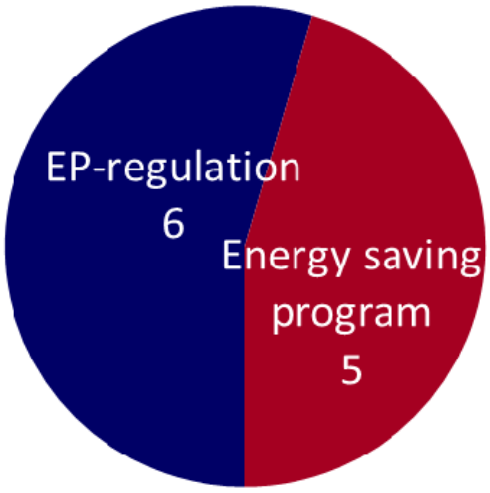
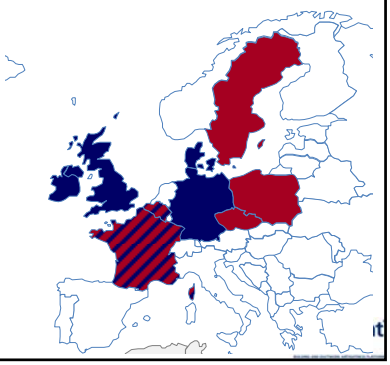
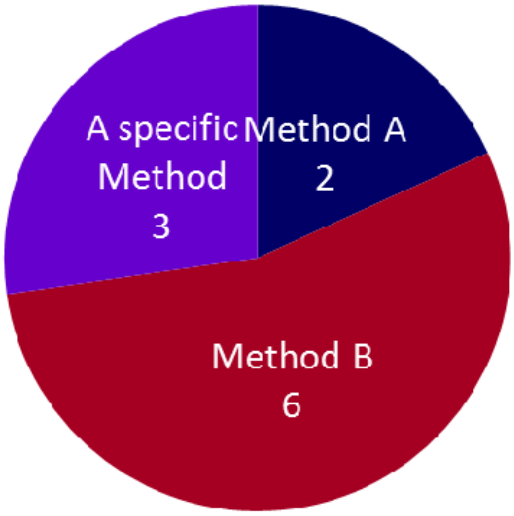
The context of following answers:

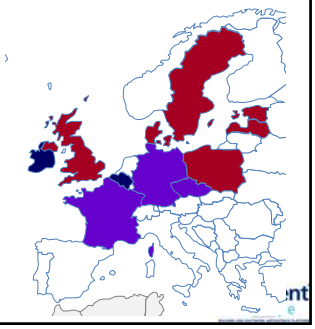




The test has to be done according to…



CZ and DE in method B for measurements in the context of the EP-regulation



Method A or B?

Method A

- Seems more consistent with the energy performance calculation.

Method B

- Appropriate if the purpose is to impose a minimum requirement for the envelope only, excluding all penetrations (due to HVAC equipment's, mailbox, etc.)

=> How useful would be such a requirement?

⇒ **Motivations behind the choice of method B versus method A are rather unclear**

⇒ **Method B seems mostly chosen by default because method A is too restrictive**

Time of measurement

- **SE**: Depends on the client demand, most of the time when the air barrier is still reachable
- **B:** required: envelope completed, recommendation: all work is done
- **DK,UK:** building envelope in its final complete state
- **DE:** Building envelope – all airtightness concerning parts – shall be completed
- **CZ, FR:** After all work that may affect airtightness is completed
- **IE:** On "practical completion" that is to say almost ready for occupation (possibly just needs to have painting done and furniture placed)

Pros and cons test at final stage

Pros

- If the purpose is to estimate the energy losses by leakage

⇒ Test shall be done after all work that may affect airtightness is completed

Cons

- Can lead to organizational problem
- Hard to improve efficiently the airtightness then

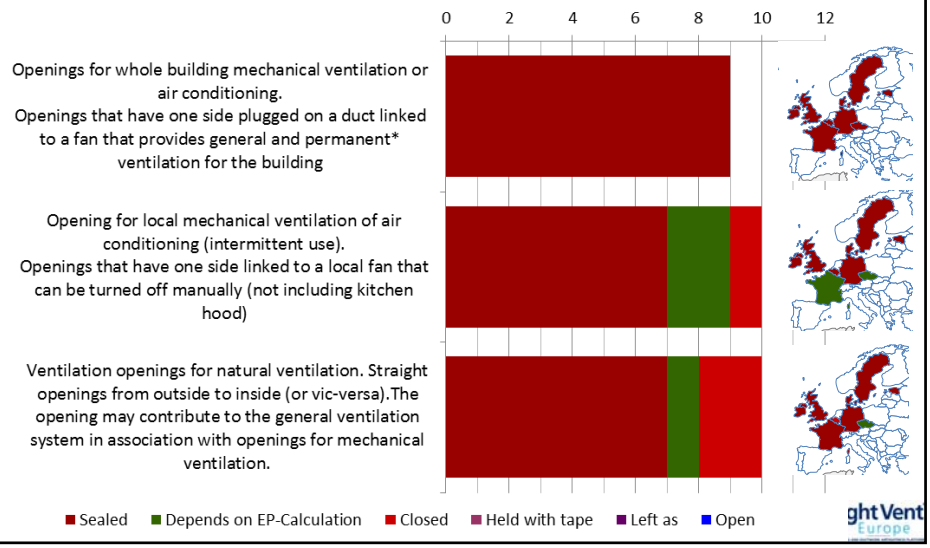
=> Some design allows testing before completion
=> With some other systems airtightness level may be severely affected by work until completion

The building preparation

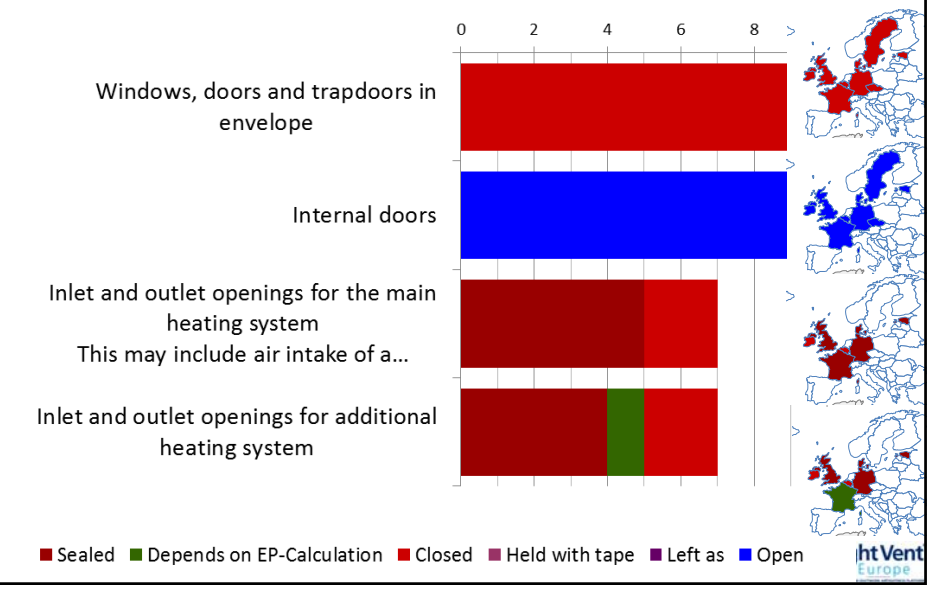
- **Sealed**
- **Depends on EP-Regulation**: sealed if it is taken into account in the EP-calculation, left as if not
- **Closed***: Closed if closing device, left as if not
- **Held with tape**: to prevent moving not to make it airtight
- **Left as:** left in normal position of use (this can be closed if the normal position is closed like some fire-door)
- **Open**

- * In UK the rule can be closed if closing device, sealed if not: in this case both categories are selected (sealed and closed)

Openings for ventilation



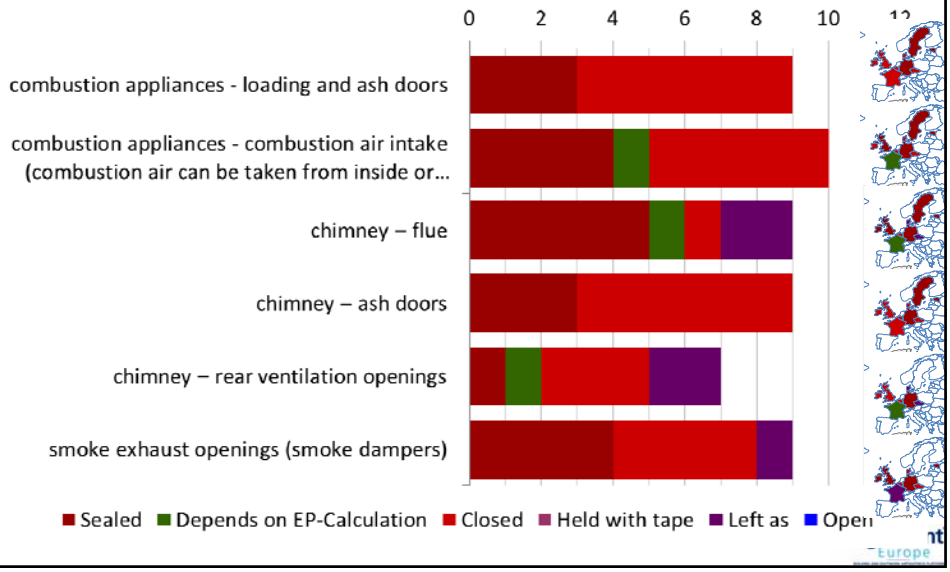
General Openings



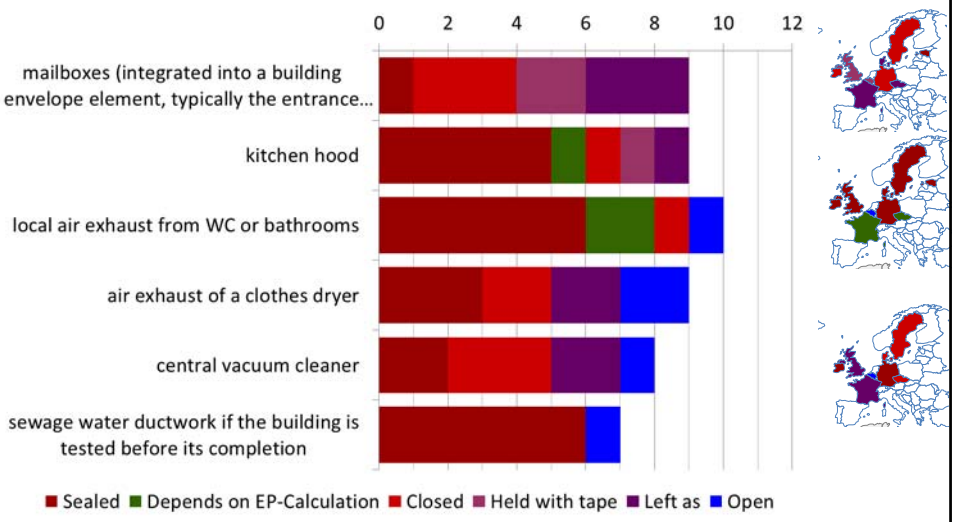
General openings

⇒ Most countries agree on basic principles

Specific openings for heating system and smoke exhaust



Other openings



Other openings

⇒The interpretation of the purpose and details of methods A and B varies significantly

⇒To check the compliance with the energy regulation, the general rule should be :

⇒ Seal or close the openings taken into account

⇒ Leave as what is not.

⇒ Underlying idea is closer to method A but deviate significantly depending on each calculation method.

Conclusion

- Method B is the favorite one
  - Probably because Method A is too restrictive
- Agreement on the general principles for the preparation
- But, a lot of differences on the details of the preparation
  - Kitchen hood, air exhaust of clothes dryer, combustion appliances…

⇒ Motivations behind choices are unclear

⇒Consistency with EP-regulation is unclear

⇒ Difficult to compare measurements

⇒ Difficult to perform test in a foreign country unless acquainted with specificities

Conclusion

- There are two obstacles to harmonize pressurization test methods between countries:
  - In each country the test method shall be consistent with the energy performance calculation method.
    - Significant differences in calculation methods between countries in the way airflow rates are taken into account.
  - There are specific devices and construction traditions in each country that may require tailored rules.

Conclusion

- The revision of the standard shall,
  - in one hand, describes more precisely the basic principles and avoid ambiguities
  - in another hand, allows some flexibility to the countries to specify rules consistent with the energy performance calculation method.
  - At the same time, it should allow the identification of tests performed under comparable conditions to allow meaningful comparative analysis between countries.

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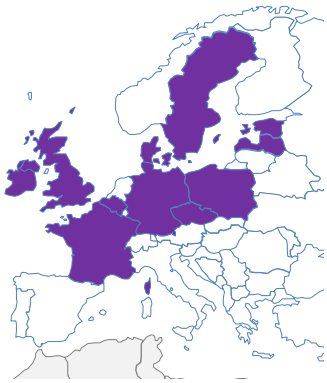
Acknowledgment

- Special thanks to the persons who have kindly answered the questionnaire:
  - Clarisse Mees, Belgium
  - Jiri Novak, Czech Republic
  - Walter Sebastian, Denmark
  - Valerie Leprince, France
  - Oliver Solcher, Germany
  - Paul Carling , United Kingdom
  - Targo Kalamees , Estonia
  - Andrejs Nitijevskis, Latvia
  - Andrzej Gorka, Poland
  - Owe Svensson, Sweden
  - Mark Shirley, Ireland



TightVent Europe

THANK YOU FOR YOUR ATTENTION

Analysis of answers of airtightness associations representatives performed by:
Valérie Leprince, Rémi Carrié

Questions?

Comments?

Interest in joining TAAC?

Belgian framework for reliable fan pressurization tests for buildings

Christophe Delmotte, Ir
BBRI – Belgian Building Research Institute

Fan pressurization tests must be reliable

European directive
on the energy performance of buildings

The 3 regions of Belgium impose
energy requirements for new buildings

- Among others, it takes airtightness of buildings into account based on measurements

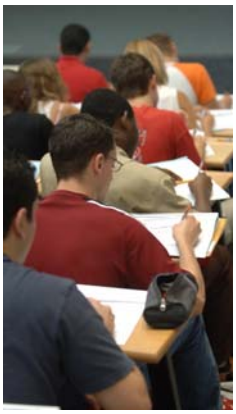
Fan pressurization tests must be reliable

A framework for reliable tests
has been developed in Belgium

Belgian framework for reliable tests

1. Qualification of testers
2. Technical criteria for the measurements
3. Controls

Qualification of testers



Accreditation

- National accreditation body

or Qualification examination

- Theory
  - 50 multiple choice questions
- Practice
  - Test of a dedicated building
  - 5 reports in accordance with the technical criteria

Technical criteria

Mainly based on EN 13829 (ISO 9972)

Preparation of the building

- Method A + further details

Mode of test

- Depressurization & pressurization

Zero-flow pressure difference

The legislator wants to make measurement possible for nearly all buildings

Criteria have been loosened for large buildings

- $\Delta p_0 > 5$ Pa is allowed
- But $\Delta p_{min} \geq 5 \times \Delta p_0$
  - $\Delta p_0 \leq 20\% \Delta p_{min}$
- Δp_{min} is limited to 40 Pa to avoid extrapolation for values at 50 Pa

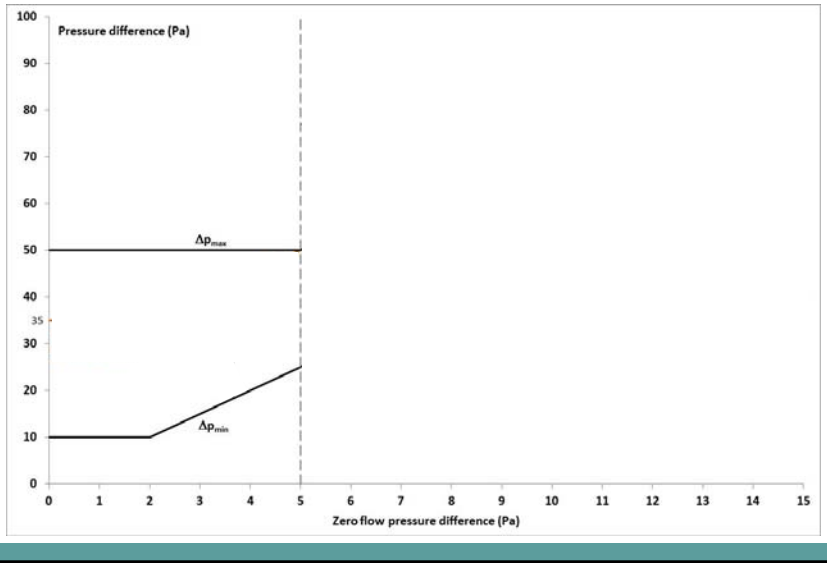
Highest pressure difference

Small buildings

- Highest pressure difference ≥ 50 Pa
- Going to 100 Pa is recommended

Large buildings

- 50 Pa is required
  - but can be limited to Δp corresponding to 85 000 m³/h if $\Delta p_0 \leq 5$ Pa
- In all cases $\Delta p_{max} \geq \Delta p_{min} + 25$ Pa



Measurement system

Periodic calibration is required

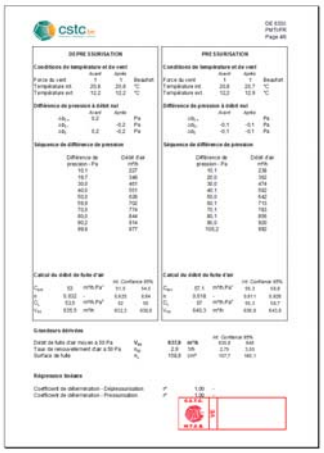
- Manometer 2 years
- Thermometer 2 years
- Blower door Not specified

Software

Any software can be used

- It must have been tested with a specific set of input values
- Statement that it has passed the test

Test report



Any format can be used

- Minimum content is required
  - Building info
  - Pictures
  - Measurement devices
  - Software
  - Measured values…
- Statement that all requirements have been met

Control

On site control

- SMS when starting the test
- SMS at the end of the test + air leakage rate
- Controller can come on site
  - New measurement with tester's system
  - New measurement with own system
  - Check building preparation

Control of the report

Declaration of conformity

Unified technical specification - STS

Documents published by the Federal Public Service Economy

Reference documents

- Rules of good workmanship for the building sector
- Not constraining by themselves
- Can be referred to by regulation or private contracts
  - Mandatory in the Flemish region from January 1st 2015

POZNAN UNIVERSITY OF TECHNOLOGY
Large buildings airtightness measurements using ventilation systems
Michał Szymański
Andrzej Górka
Radosław Górzeński
Institute of Environmental Engineering
Faculty of Civil and Environmental Engineering
Poznan University of Technology, Poznań
TightVent Europe
venticool
35th AIVC Conference, 4th TightVent Conference,
2nd venticool Conference, Poznań, 24-25.09.2014

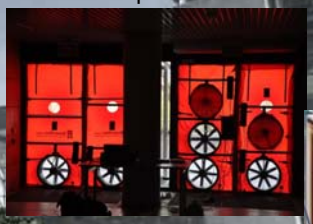
Outline
• Introduction to large building airtightnes testing
• Preparation of the building
• Location of air leakages
• Airtightness measurement using ventilation system
  • AHU airflow measurement
  • VAV-terminals airflow measurement
  • BMS application
• Case studies
  • Termy Maltańskie Aquapark, Poznań
  • Mechatronics, Biomechanics and Nanoengineering Centre, Poznań
• Conclusions
TightVent Europe
venticool
35th AIVC Conference, 4th TightVent Conference,
2nd venticool Conference, Poznań, 24-25.09.2014

Introduction

Airtightness test of large buildings → huge air flows

Three main technical possibilities to pressurize the building

Set of multiple small fans



Large fan

Building ventilation system

Multi-zone test → combination

Building preparation

- **High influence** of building **preparation** on the test **result**
- Some **objections about sealing** of mechanical ventilation systems (diffusers and exhaust terminals sealing is difficult to perform)
- In EN 13829 **method A** (testing of an operated building), most commonly the **installation is cut off by closing the dampers** on the side of the air intake and extract.
- Comprehensive **preparation** of the large building consumes in most cases **much more time than** just **testing and leakage detection**.
- Due to the lack of education in the field of building construction and technical equipment, some testers underestimate the role of this stage
- Effect of this approach is getting results differing from the real airtightness of the object (some examples further)

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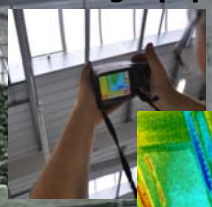
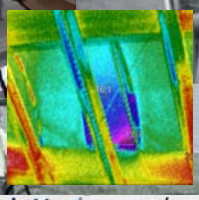
2nd venticool Conference, Poznań, 24-25.09.2014

Location of leakages

Leakage detection techniques

- smoke tubes (pens)
- hot-wire anemometers,
- **infrared cameras**
- **powerful smoke generators**

lifting equipment and permissions

Ventilation system and leakage test

- The most important difference between MV and BD application for airtightness test is the **method of the airflow measurement**.
- Measurement of the differential pressures → in a standard way
- In large or complex, public buildings, the maximum air flow rate of MV is enough for the airtightness test (in our cases $n_{Vent.}$ = 2.1÷2.8 h^{-1} and n_{50} = 0.3÷0.6 h^{-1})
- Precise airflow measurement in the following locations:
  - on the air intake or air outlet
  - on the elements of the air handling unit
  - on the ventilation ducts upstream or downstream of the AHU
  - on the supply or exhaust grilles (terminals of the ventilation system)

Airtightness of ventilation components !

- Few large AHUs – OK, lot of small AHUs – problematic because of time
- Building automation often unable to perform automated measurement

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2nd venticool Conference, Poznań, 24-25.09.2014

Ventilation system

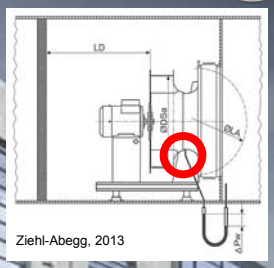
AHU airflow measurement

The airflow rate in AHU can be determined on the basis of:

a. measurement of the **dynamic pressure at the inlet to the fan**,

b. measurement of the **differential static pressure between the front of the inlet ring and the narrowest point of the nozzle** (8% accuracy ☹ conditionally)

c. measurement of the **average dynamic pressure at the place of the air filter** replaced temporarily by measuring element (7% accuracy ☺)



Ventilation system

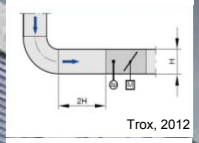
VAV-terminals airflow measurement

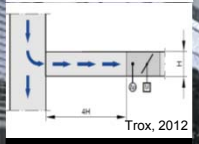
VAV devices are **factory-equipped with a sensing element** that generates an **analog output signal proportional to airflow**.

However, the accuracy is variable and meets the requirements of EN 13829 only when:

- the elements are **correctly mounted**,
- the **flow is higher than 70% of the nominal flow**

The measurement of the air flow using the terminal devices of ventilation system should take into account the possible **leakage of air in the ventilation system**



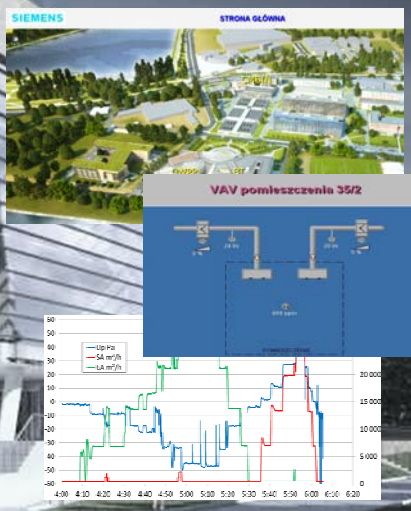


V/Vnom	Accuracy
20%	14%
40%	8%
70%	5%
100%	5%

Ventilation system

BMS application

- It is theoretically possible to perform the airtightness test even remotely.
- The only task to do on site is to close external openings and open inner door.
- With use of BMS, appropriate dampers will be closed and fans will be operated to reach desired pressure in the building.
- The results of the measurement is obtained from BMS as a record of key parameters: air flow rates, differential pressures etc.
- In practice, such a method of measurement encounters serious problems
- **BMS can be an effective tool by carrying out test using AHU fans**



Case study #1

Termy Maltańskie Aquapark

- Second largest water park in Europe
- Public investor - **city of Poznan**
- **PUT** – design & energy advisor
- Floor area A_f ~ **20 000 m²**
- Int. Volume V_i ~ **200 000 m³**
- A/V ratio ~ **0,20 m⁻¹**
- **Winter climate inside/outside**
  ΔT≈48°C (-18/30°C)
  Δx≈15 g/kg (4 x higher than typical)
- Construction:
  - concrete frames + masonry fillings
  - flat roof, steel construction

Case study #1

Termy Maltańskie Aquapark

1st air leakage test - 2012

- Tester utilized the existing mechanical ventilation system
- Declared flow measurement accuracy at AHUs ± 2÷5% (???)
- Testing team – 2 persons
- Mistakest during building preparation and test:
  - 3-zone test with no simultaneous pressurization of adjacent zones,
  - airflow measurement with unknown accuracy and several ventilation systems (not involved in the test) operating,
  - building not prepared properly for the test: conducted with no control on inter-zonal opening positions (doors), some windows were opened, etc.

Results 2012

n_{50} = 1,30 h^{-1}

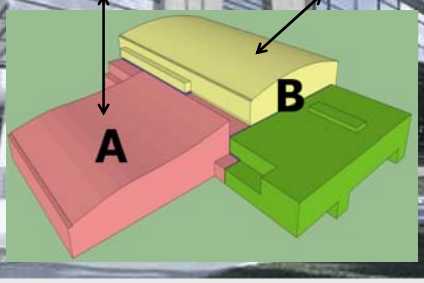
q_{50} = 6,46 $m^3/(h \cdot m^2)$

Case study #1

Termy Maltańskie Aquapark

2nd air leakage test - 2013

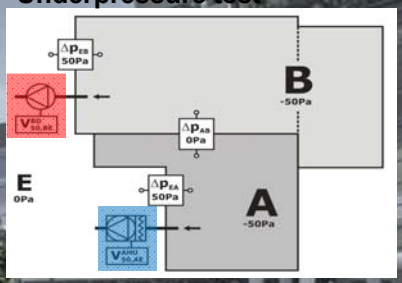
- Minneapolis Blower Door set-up (7 fans)
- Flow measurement accuracy ± 5%
- Testing team – IEE PUT - 10 persons
- 2 zones measurement
  - A – recreation area
  - B – sports pool hall and office area
- Pressurization of adjacent zones (AHUs)
- BMS data aquisition



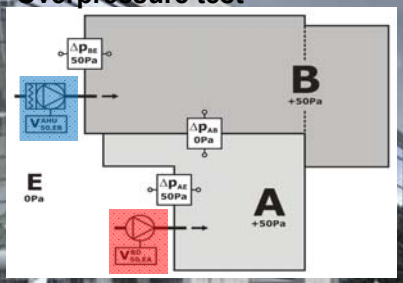
Case study #1

Termy Maltańskie Aquapark
2nd air leakage test - 2013

Underpressure test



Overpressure test



Results 2013	BD	AHU	Δ_{BD-AHU}
n_{50} [h^{-1}]	**0,64**	0,83	**30%**
q_{50} [$m^3/(h \cdot m^2)$]	**3,17**	4,11	

Case study #2

Mechatronics, Biomechanics and Nanoengineering Centre, PUT

- Public Investor - Poznan University of Technology (2011)
- Purpose: laboratories, lecture halls, staff offices
- Floor area A_f ~ **14 000 m²**
- Int. volume V_i ~ **50 000 m³**
- A_e/V_e ratio ~ **0,20 m⁻¹**
- Special airtight concerns during designing and construction
- Contract's n_{50} demand of maximum **1.5 ACH**
- Tested by PUT – 2 times

Case study #2

Mechatronics, Biomechanics and Nanoengineering Centre, PUT

1st air leakage test – 2011

- Minneapolis Blower Door set-up (6 fans)
- 2-3 fans were necessary
- Flow measurement accuracy ± 5%
- Testing team – PUT - 6 persons
- 1 zone measurement

Results

$n_{50} = 0{,}30\ h^{-1}$

$q_{50} = 1{,}18\ m^3/(h \cdot m^2)$

Case study #2

Mechatronics, Biomechanics and Nanoengineering Centre, PUT

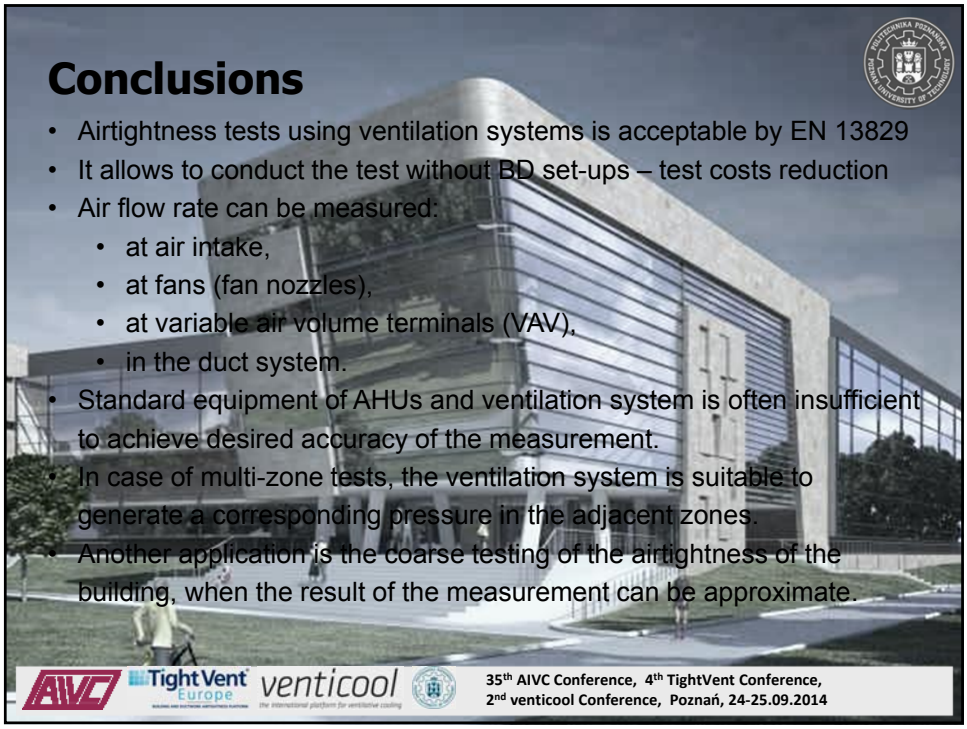
2nd air leakage test - 2014

- Testing team – IEE PUT - 6 persons
- 1 zone measurement
- **Minneapolis Blower Door set-up (3 fans)**
- Flow measurement accuracy ± 5 %
- **VAV-terminals airflow measurement**
- Flow measurement accuracy ± 5-14 %
- BMS data aquisition
- ducts leakages error ± 2 %
- VAVs measurement was more labor-intensive than BD

Results 2014	BD	VAV	Δ_{BD-VAV}
n_{50} [h^{-1}]	**0,44**	0,54	**22 %**
q_{50} [$m^3/(h \cdot m^2)$]	**1,70**	2,07	

- **Durability**: after 3 years of operation **n_{50} + 50%**

35th AIVC Conference, 4th TightVent Conference, 2nd venticool Conference, Poznań, 24-25.09.2014


Conclusions
• Airtightness tests using ventilation systems is acceptable by EN 13829
• It allows to conduct the test without BD set-ups – test costs reduction
• Air flow rate can be measured:
• at air intake,
• at fans (fan nozzles),
• at variable air volume terminals (VAV),
• in the duct system.
• Standard equipment of AHUs and ventilation system is often insufficient to achieve desired accuracy of the measurement.
• In case of multi-zone tests, the ventilation system is suitable to generate a corresponding pressure in the adjacent zones.
• Another application is the coarse testing of the airtightness of the building, when the result of the measurement can be approximate.
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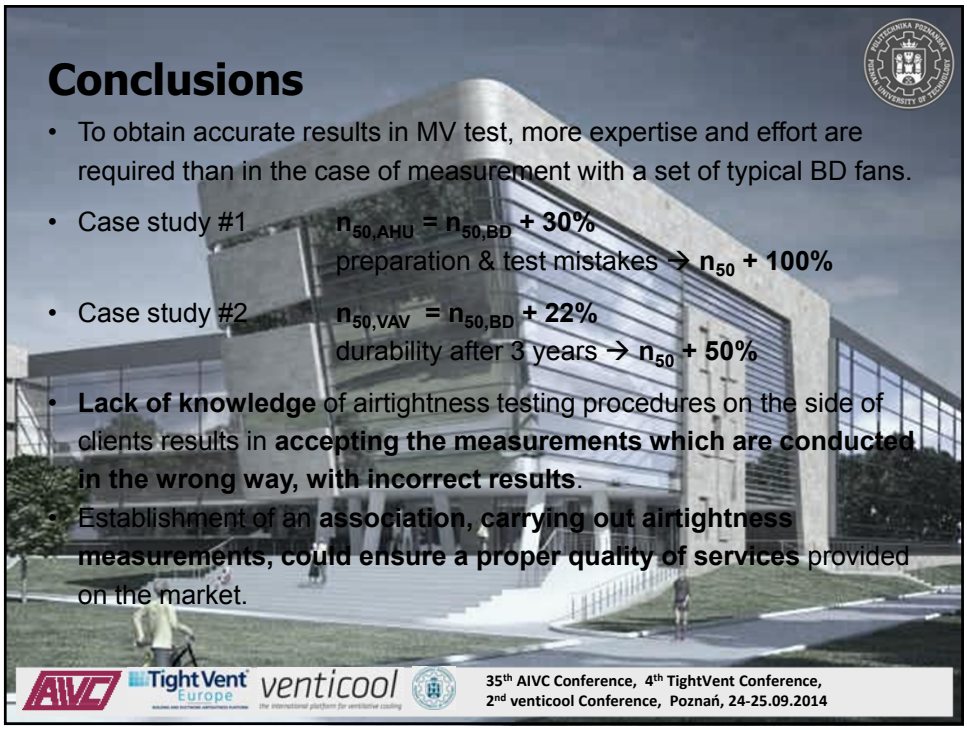
Conclusions
• To obtain accurate results in MV test, more expertise and effort are required than in the case of measurement with a set of typical BD fans.
• Case study #1 $n_{50,AHU} = n_{50,BD}$ + 30%
preparation & test mistakes → n_{50} + 100%
• Case study #2 $n_{50,VAV} = n_{50,BD}$ + 22%
durability after 3 years → n_{50} + 50%
• Lack of knowledge of airtightness testing procedures on the side of clients results in accepting the measurements which are conducted in the wrong way, with incorrect results.
• Establishment of an association, carrying out airtightness measurements, could ensure a proper quality of services provided on the market.
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Thank you for your attention!
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Model error due to steady wind in building pressurization tests

François Rémi Carrié[1] and Valérie Leprince[2]
[1] ICEE
[2] PLEIAQ

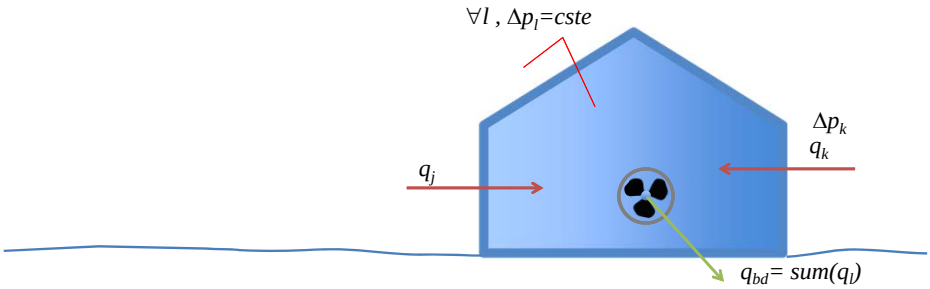
AIVC Conference
Poznan, Poland
24-25 September 2014

Outline

- Problem statement
- Building idealization
- Estimating model errors
- Results
- Summary

Problem statement

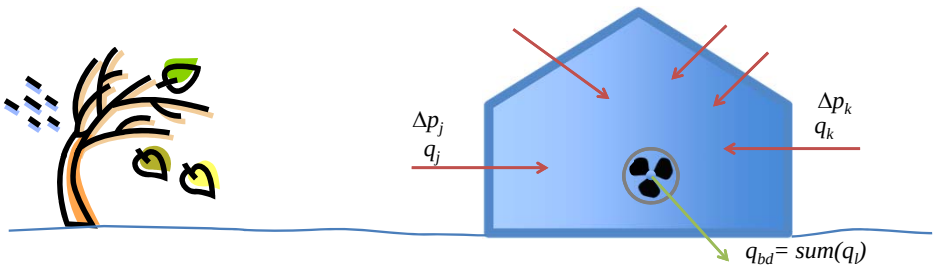
- Standard test method and analysis implicitly assume that all leaks “see” the same pressure difference during the test



Problem statement

- Not true in windy conditions
- How bad is it to fit a power law in that case ?

$$q_{bd} = C\,\Delta p^{n} \quad ?$$



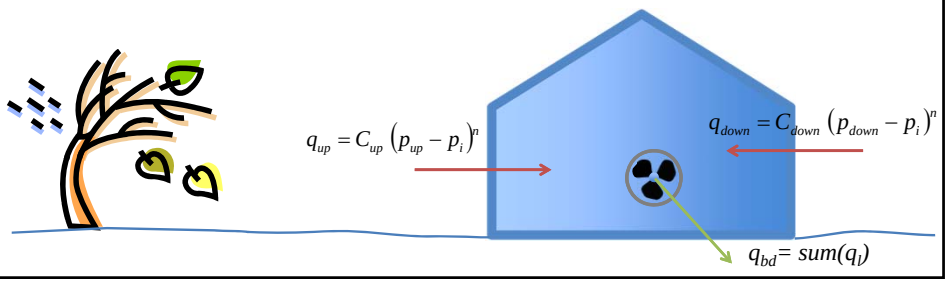
Building idealization

- Let's assume:
  - Isothermal conditions
  - All leaks have the same flow exponent
  - All leaks on the windward side are subjected to the same wind pressure
  - All leaks on the leeward side are subjected to the same wind pressure
- The mathematical problem reduces to a 2-leak problem

Building pressurization

$$q_{bd} = C_{up}\left(p_{up} - p_i\right)^n + C_{down}\left(p_{down} - p_i\right)^n$$

$$p_{up} = C_{p,up}\frac{\rho U^2}{2} \qquad p_{down} = C_{p,down}\frac{\rho U^2}{2}$$



Building pressurization

- Zero-flow pressure

$$C_{up}\left(p_{up}-p_{zp,i}\right)^n+C_{down}\left(p_{down}-p_{zp,i}\right)^n=0$$

$$p_{zp,i}=\frac{1+\left(\frac{C_{down}}{C_{up}}\right)^{1/n}\frac{C_{p,down}}{C_{p,up}}}{1+\left(\frac{C_{down}}{C_{up}}\right)^{1/n}}C_{p,up}\frac{\rho U^2}{2}$$

True versus estimated leakage coefficient

- True leakage coefficient is: $C_{up}+C_{down}$
- Estimated leakage coefficient is:

$$C_{est}=\frac{C_{up}\left(p_{up}-p_s\right)^n+C_{down}\left(p_{down}-p_s\right)^n}{\left(p_{zp,i}-p_s\right)^n}$$

Zero-flow pressure

Test pressure

Estimating the model error

- Using dimensionless quantities, we obtain an analytical expression of the error with only 3 parameters

$$\left(\frac{\delta q}{q}\right)_{model,wind} = \frac{1}{1+z}\,\frac{(1-x_s)^n + z\,(1+y\,x_s)^n}{\left(1-\dfrac{1-y\,z^{1/n}}{1+z^{1/n}}\,x_s\right)^n} - 1$$

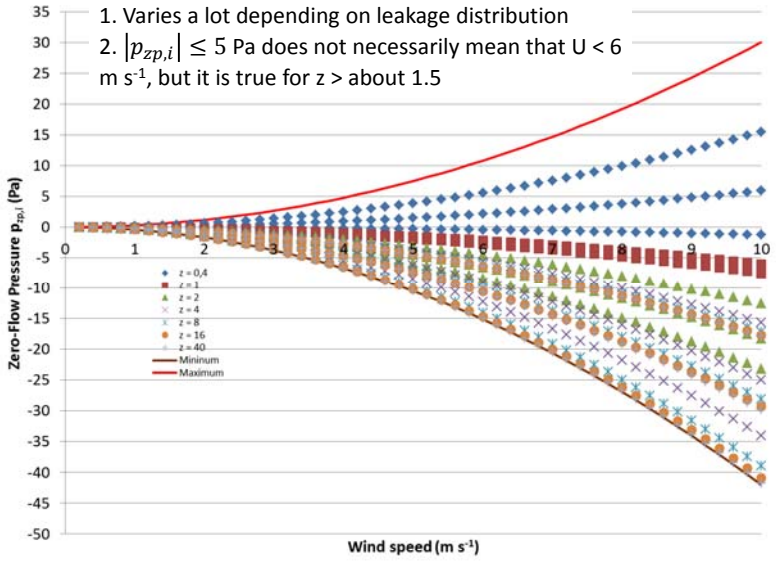
$$x_s = \frac{p_{up}}{p_s} \qquad y = -\frac{C_{p,down}}{C_{p,up}} \qquad z = \frac{C_{down}}{C_{up}}$$

Estimating model errors

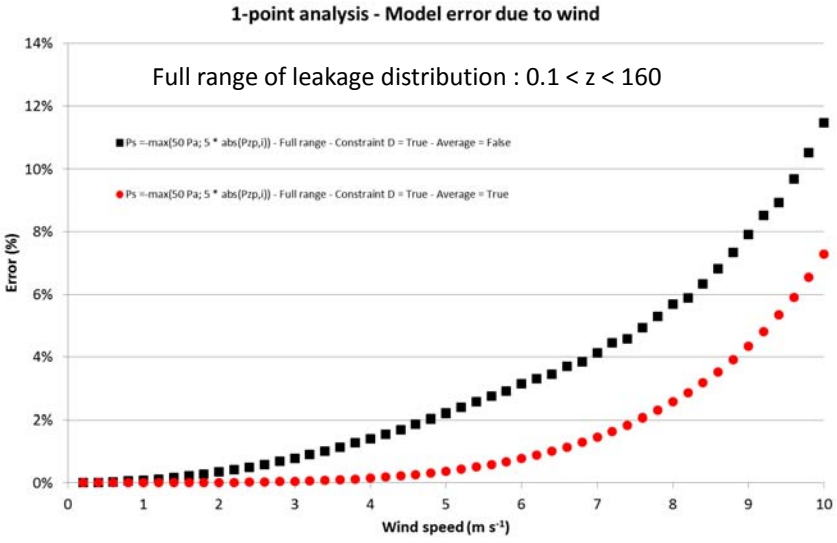
- Error can be developed in Taylor-series
- This shows that to first order, the error is proportional to x_s, i.e. to the zero-flow pressure
- => It makes sense to require that the first measurement point scales with the zero-flow pressure

Results : Zero-flow pressure

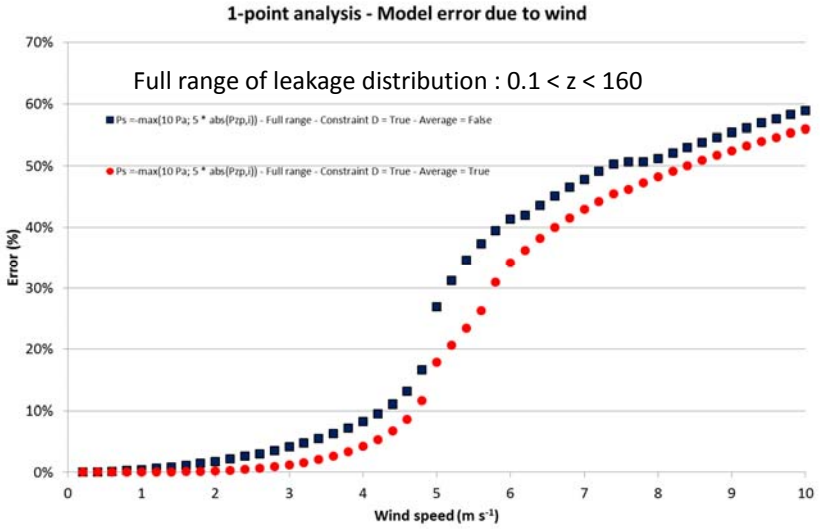
1. Varies a lot depending on leakage distribution
2. $|p_{zp,i}| \leq 5$ Pa does not necessarily mean that U < 6 m s^{-1}, but it is true for z > about 1.5



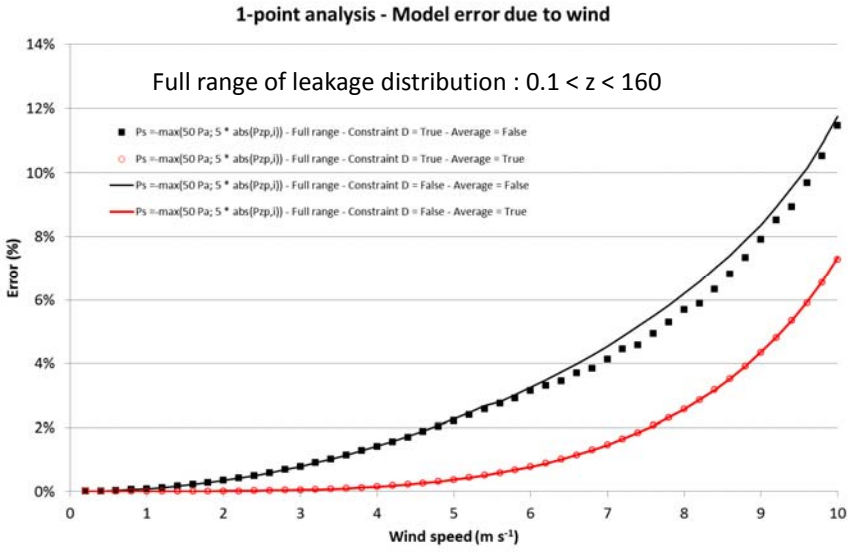
Averaging presurization and depressurization



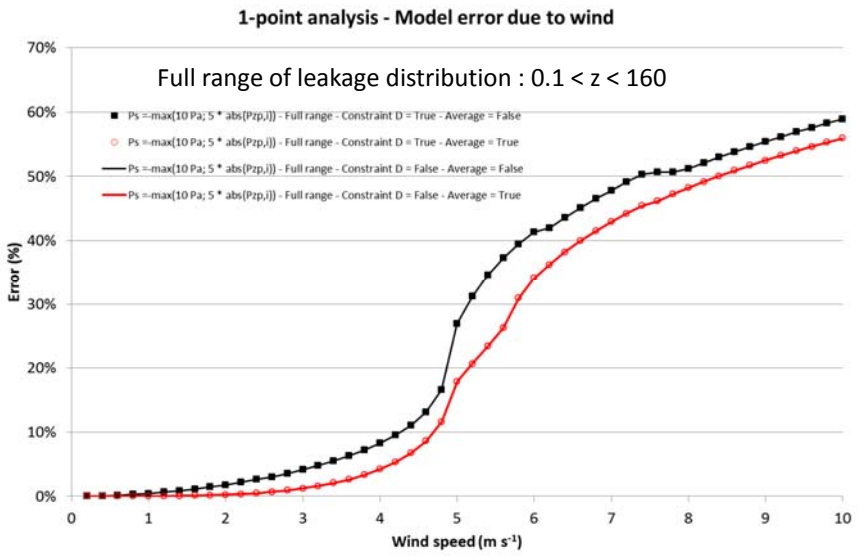
Averaging presurization and depressurization



Relaxing Constraint $\left|p_{zp,i}\right| \leq 5$ Pa



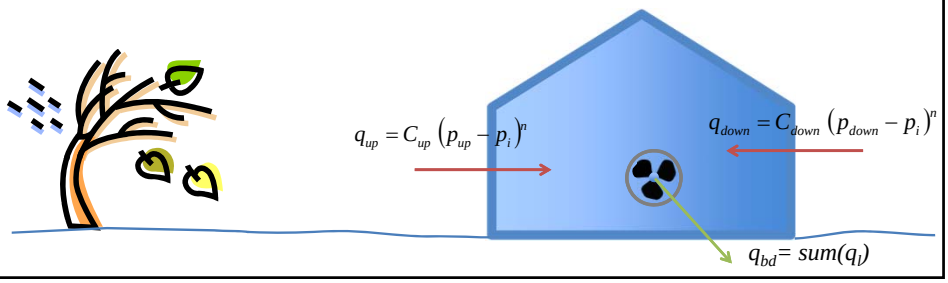
Relaxing Constraint $|p_{zp,i}| \leq 5$ Pa



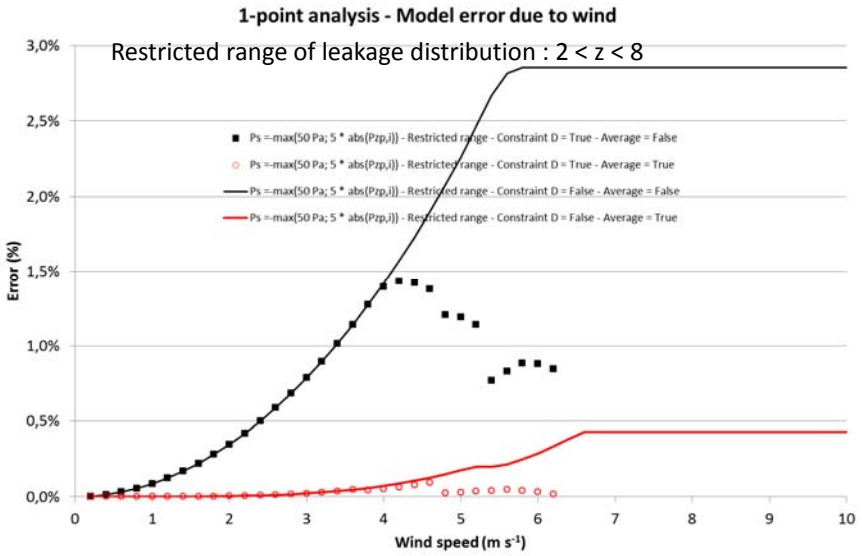
Impact of leakage distribution

$$q_{bd} = C_{up}\left(p_{up} - p_i\right)^n + C_{down}\left(p_{down} - p_i\right)^n$$

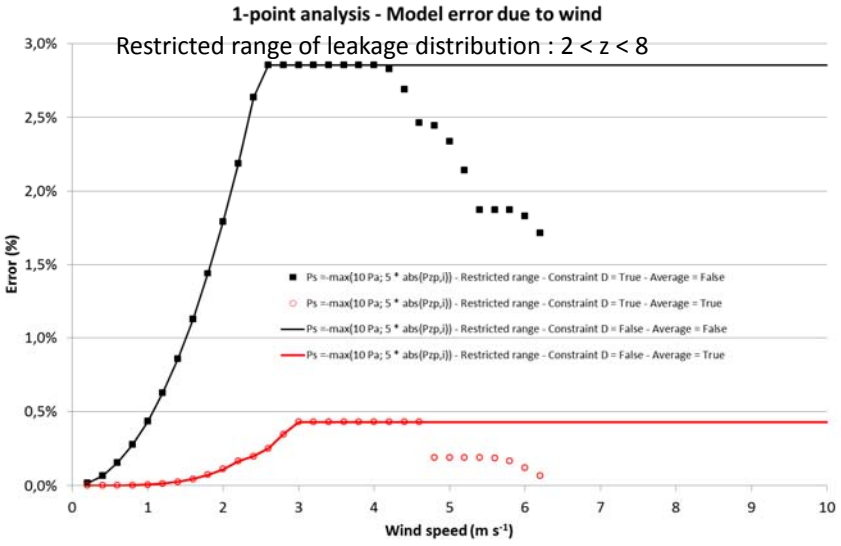
$$z = \frac{C_{down}}{C_{up}}$$ What if 2 < z < 8 ?



Impact of leakage distribution



Impact of leakage distribution



Summary

- We have developed a mathematical model to estimate the error due to steady wind
- The error on estimated leakage airflow rate is relatively small for the high pressure point, but can be very high for the low pressure point
- Benefit of averaging pressurization and depressurization is proven but remains relatively small
- Constraint on zero-flow pressure does not seem efficient
- The error for the low pressure point is very sensitive to the leakage distribution

Perspectives

- This is only one component of the uncertainty
- Other sources include:
  - Precision and bias errors
  - Deviation of the flow exponent
  - Temperature differences

IEA EBC Annex 62
Ventilative Cooling

Per Heiselberg
Aalborg University

EBC
Energy in Buildings and Communities Programme

Background

- The current development towards nearly-zero energy buildings have lead to an increased need for cooling – not only in summer but all year.
- Elevated temperature levels are the most reported problem in post occupancy studies, even in residences in the "heating season"
- There has been a large focus on reducing the heating need in buildings. There is also a need to address the cooling need and to develop more energy-efficient cooling solutions

Why have we experienced an overheating problem?

- Overheating is a ”new and increasing problem” for Low energy buildings (residences)
  - More focus on energy than indoor environment (less requirements for documentation)
  - is underestimated and are not given enough focus in the design process
  - Old rules of thumb still used

Annex 62 Ventilative Cooling

Why have we experienced an overheating problem?

- Too simplified design methods are used
  - Averaging heat loads in time and space
  - Uncertain correlation between cooling need and overheating risk

Annex 62 Ventilative Cooling

Why have we experienced an overheating problem?

- No (very few) standard technical solutions available, especially for dwellings
- No (very limited) user experience on handling of overheating problems - "one-of-a-kind" solutions are often not well-adapted to "practical use"

Annex 62 Ventilative Cooling

Why have we experienced an overheating problem?

- It is not possible to reach goals through more:
  - Envelope insulation, Building airtightness, Ventilation heat recovery,
- Which are robust technologies without user interaction
- New measures needs to be included:
  - Demand controlled ventilation, Shading for solar energy or daylighting control, Lighting control, Window opening
- All technologies:
  - Where performance is very sensitive to **control**
  - Which involve different degree of user interaction
  - Whose function and performance are difficult for users to understand

Annex 62 Ventilative Cooling

Ventilative cooling is a solution

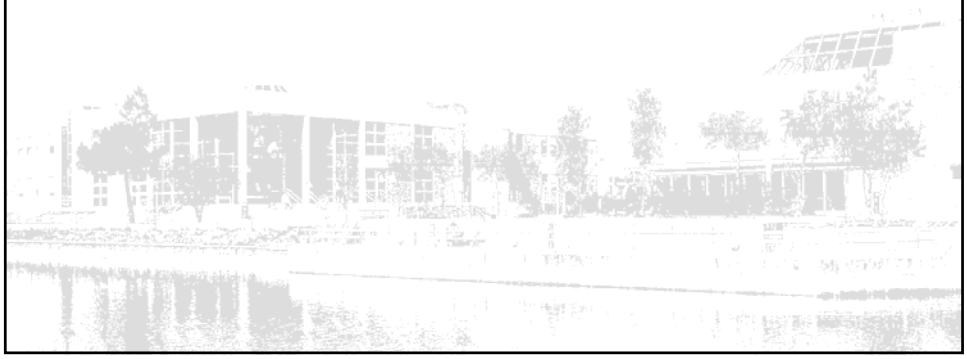
- Ventilative cooling can be an attractive and energy efficient passive solution to avoid overheating.
  - Ventilation is already present in most buildings through mechanical and/or natural systems using opening of windows
  - Ventilative cooling can both remove excess heat gains as well as increase air velocities and thereby widen the thermal comfort range.
  - The possibilities of utilizing the free cooling potential of low temperature outdoor air increases considerably as cooling becomes a need not only in the summer period.

Annex 62 Ventilative Cooling

Status of Application

- Application of Ventilative cooling for residential buildings is at a low level
  - It is considered difficult to evaluate
  - Few technical solutions available – mainly manual window opening only very few automated
- Ventilative cooling is a standard solution in offices with mechanical ventilation
  - Designed for IAQ criteria
  - Limited benefit due to fan energy use
- Ventilative cooling by natural/hybrid ventilation is known
  - But only used in a few cases in offices

IEA EBC Annex 62 Ventilative Cooling



Annex 62 Ventilative Cooling

Definition of Ventilative Cooling

- Ventilative Cooling is application (distribution in time and space) of ventilation air flow to reduce cooling loads in buildings
- Ventilative Cooling utilizes the cooling and thermal perception potential (higher air velocities) of outdoor air
- In Ventilative Cooling the air driving force can be natural, mechanical or a combination

Annex 62 Ventilative Cooling

Annex Objectives

- To analyse, develop and evaluate suitable methods and tools for prediction of cooling need, ventilative cooling performance and risk of overheating in buildings that are suitable for design purposes.
- To give guidelines for integration of ventilative cooling in energy performance calculation methods and regulations including specification and verification of key performance indicators.
- To extend the boundaries of existing ventilation solutions and their control strategies and to develop recommendations for flexible and reliable ventilative cooling solutions that can create comfortable conditions under a wide range of climatic conditions.
- To demonstrate the performance of ventilative cooling solutions through analysis and evaluation of well-documented case studies.

Annex 62 Ventilative Cooling

Annex Outcome

- Guidelines for energy-efficient reduction of the risk of overheating by ventilative cooling
- Guidelines for ventilative cooling design and operation in residential and commercial buildings
- Recommendation for integration of ventilative cooling in legislation, standards, design briefs as well as on energy performance calculation and verification methods
- New ventilative cooling solutions including their control strategies as well as improvement of capacity of existing systems
- Documented performance of ventilative cooling systems in case studies

Annex 62 Ventilative Cooling

Annex Organization

- Subtask A: Methods and Tools
- Subtask B: Solutions
- Subtask C: Case Studies

Annex 62 Ventilative Cooling

Subtask A: Methods and Tools

- Will analyse, develop and evaluate methods and tools for prediction of cooling need, ventilative cooling performance and risk of overheating in buildings that is suitable for design purposes
- Will give guidelines for integration of ventilative cooling in energy performance calculation methods and regulation including specification and verification of key performance indicators

Annex 62 Ventilative Cooling

Subtask B: Solutions

- Will investigate the cooling performance of existing mechanical, natural and hybrid ventilation systems and technologies and typical comfort control solutions as a starting point for extending the boundaries for their use.
- Will develop recommendations for flexible and reliable ventilative cooling solutions that can create comfort under a wide range of climatic conditions.

Annex 62 Ventilative Cooling

Subtask C: Case Studies

- Will demonstrate the performance of ventilative cooling through analysis and evaluation of well-documented case studies.

Annex 62 Ventilative Cooling

Annex Leadership

- Participating countries
  - Austria, Belgium, China, Denmark, Finland, Ireland, Italy, Japan, Netherlands, Norway, Switzerland, UK, USA
- Operating Agent:
  - Denmark, represented by Per Heiselberg, Aalborg University
- Subtask A:
  - Leader: Switzerland, represented by Fourentzos Flourentzou, ESTIA
  - Co-leader: Italy, represented by Annamaria Belleri, EURAC
- Subtask B:
  - Leader: Austria, represented by Peter Holzer, IBRI
  - Co-leader: Denmark, represented by Theofanis Psomas, AAU
- Subtask C:
  - Leader: China, represented by Guoqiang Zhang, Hunan University
  - Co-leader:

Annex 62 Ventilative Cooling

Overview and state-of-the art of Ventilative Cooling

- **Ch1- Introduction**
- **Ch2- Potential and limitations to Ventilative Cooling**
- **Ch3- Ventilative cooling in Building Regulations and Energy Performance Standards**
- **Ch4- Exemplary existing buildings using Ventilative Cooling**
- **Ch5- Existing components and control strategies for ventilative cooling**
- **Ch6- Existing analysis and design methods and tools**

To be published at the Annex 62 website by mid 2015

Thanks for your attention
More information on IEA EBC Annex 62 on
www.venticool.eu

Annex 62
Ventilative Cooling

Design and analysis methods for ventilative cooling

Annamaria Belleri (EURAC)
35th AIVC – 4th TightVent – 2nd Venticool conference
24th September 2014, Poznan

EURAC research

International Energy Agency
Energy Conservation in Buildings and Community Systems Programme

EURAC research

Main objective

- to document existing modelling methods and tools for ventilative cooling performance prediction;
- to assess capabilities, gaps, needs and limitations;
- to investigate their applicability at design stages depending on the required input data detail level and output data accuracy.

Literature review include up to 80 references to journal papers, reports, PhD thesis, conference paper and link to software websites!

International Energy Agency
Energy Conservation in Buildings and Community Systems Programme

Overview

- Empirical models
- EPBD calculation method
- Detailed modelling tools
  - Airflow network models (AFN)
  - Zonal models
  - Computational Fluid Dynamics (CFD)
  - Coupled AFN – BES models
  - Coupled CFD – AFN – BES models
- Early stage modelling tools
  - Monozone models
  - Multizone models
- Validity of methods and tools
- Performance of methods and tools
- Applicability to design stages

Empirical models

correlations derived analytically or experimentally (wind tunnel or full scale measurements, emptying water-filling box model) to predict ventilation airflow rates for simple opening configuration.

Application: components pre-sizing

Limitations: as they refer to a limited number of case studies or to more detailed model simplifications, they are based on specific assumptions.

Empirical models

Steady state or transient state calculations where indoor building temperatures can be assumed:

- as constant and equal to cooling setpoint;
- to oscillate harmonically according to a predefined function to simulate the dynamic effect of heat storage in the structure materials;

$$T_{b,h} = 24.5 + \cos\left(2\pi \frac{(h - h_i)}{24}\right)$$

where

Tb,h = building temperature at a certain hour h [° C]

hi = initial time of night ventilation

- or estimated using the simplified calculation method described in EN13792:2005 or the complex method in EN13791:2005.

Openings nr	Configuration	Equation	Reference
1	W	$Q = \pm c_D A \sqrt{\left\lvert U^2 - \left(\frac{2\gamma P_s}{\rho V}\right)\omega \right\rvert}$ where Q = ventilation flow rate C_D = discharge coefficient γ = polytrophic exponent, 1.4 for adiabatic flows and 1.0 for isothermal flows	pulsation theory derived through wind tunnel testing by Cockroft J.P. and Robertson P. [7]
1	B	$q_B = \frac{1}{3} A C_d \sqrt{\frac{\lvert T_{in} - T_{out} \rvert Hg}{(T_{in} + T_{out})/2}}$	derived analytically by Warren P.R. [8]
1	W	$q_w = 0.025 A v_{w,ref}$	wind tunnel tests and full-scale experiments in 2 real buildings by Warren P.R. [8]
1	W&B	$q_{bw} = \frac{1}{2} A \sqrt{C_1 + (C_2 v_{w,ref}^2) + (C_3 H \lvert T_{in} - T_{out} \rvert)}$	33 measurements on a full-scale building by Phaff H. and De Gids W. [9]
1	W&B	$q_{bw} = A \sqrt{C_1 \lvert C_P \rvert v_{w,ref}^2 + C_2 H \Delta T + C_3 \frac{\Delta C_{P,opening}\, \Delta T}{v_{w,ref}^2}}$ with $\Delta C_{p,opening} = 9.1894 \cdot 10^{-9} \cdot \varphi^3 - 2.626 \cdot 10^{-6} \cdot \varphi^2 - 0.0002354 \cdot \varphi + 0.113$ where C_1, C_2 and C_3 are empirical coefficients	wind tunnel test and 48 full-scale measurements on real buildings by Larsen T.S. [10]
1	W	$Q = CAU$ where	ASHRAE handbook [11] and Yamanaca T. et al.

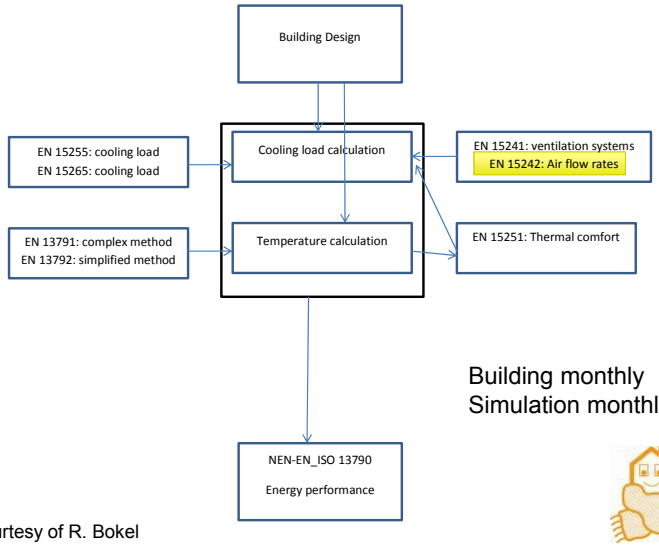
Extract of table collecting empirical models found in literature.

W=wind driven

B= buoyancy driven

W&B = wind and buoyancy driven.

EPBD calculation method



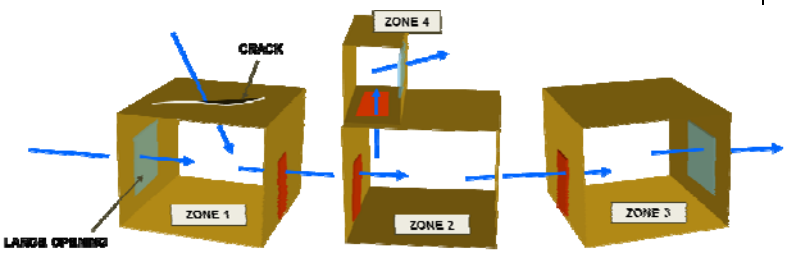
Building monthly
Simulation monthly

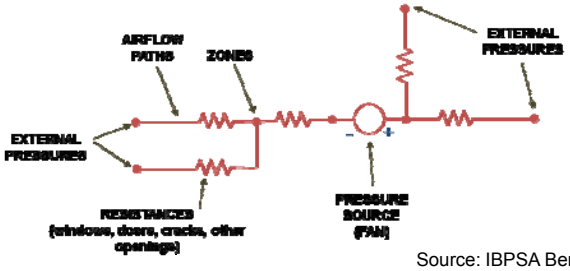
Image courtesy of R. Bokel

Detailed modelling tools

- Airflow network (AFN) models
- Zonal models
- Computational Fluid Dynamics (CFD)
- Coupled BES – AFN models
- Coupled BES – AFN – CFD models

Airflow network models





COMIS and CONTAM are the most widely used airflow network software.

Source: IBPSA BemBook

Airflow network models

Applications:

- airflow in multizone building models
- integration of airflow calculations within whole building energy simulation
- infiltration calculation
- hybrid ventilation systems evaluation

Airflow network models

Limitations:

- heavily dependency on coefficients like wind profile exponent, wind pressure coefficients and discharge coefficients;
- temperature distribution within air volumes (e.g. stratification) cannot be determined;
- local surface convection determination is limited by the insufficient resolution;
- turbulent fluctuations of wind pressures are neglected;
- air momentum effect is neglected;
- air speed in rooms cannot be calculated.

Wang L., Chen Q., "Evaluation of some assumptions used in multizone airflow network models," *Building and Environment,* vol. 43, no. 10, pp. 1671-1677, 2008

Zonal models

bounded space is divided into a number of smaller control volumes to calculate velocity and temperature field within the zone.

Applications:

- to study the interaction between the terminal unit of the mechanical system and the rest of the room;
- to detail indoor environment and to estimate thermal comfort in a fast way;
- to obtain information as temperature stratification, thermal interaction with cold façade, draft and thermal radiation performances.

Limitations:

To date, there is no commercial program based on the zonal modelling approach, limiting the possibility to use this kind of models for design purposes.

CFD models

CFD solves Navier-Stokes equations which are based on conservation of mass, momentum and energy for viscous and incompressible fluid.

Applications:

- to evaluate velocity and temperature fields in rooms and buildings;
- to evaluate envelope flows;
- to assess surface wind pressure distributions;
- whole field calculations within atria;
- to assess flow characteristics of openings.

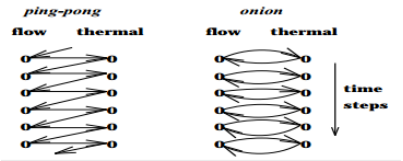
Limitations:

- boundary condition settings
- choice of calculation domain, grid and convergence requirements
- high computational time
- large amount of output data

Coupled BES+AFN

Thermal analysis is coupled with airflow network mode:

Temperature ←-→ airflow



Source: Hensen J., *Modelling coupled heat and airflow*, 16th AIVC Conference, 1995

Applications:

- to predict passive cooling performance, where a higher ventilation rate can avoid overheating and improve thermal comfort.
- mainly over summer period evaluation

Limitations:

- correlations for convection heat transfer coefficient are still too simplified for night cooling predictions
- models for some components (i.e. windcatchers, solar chimneys..) are missing

Coupled BES+AFN+CFD

CFD boundary conditions are defined by a coupled BES+AFN model:

- CFD receives more precise and real-time thermal boundary conditions (i.e. inlet airflows, surface temperatures..) and can predict the dynamic indoor environment conditions that are important for the assessment of indoor air quality and thermal comfort;
- BES obtains more accurate convection heat from enclosures and can provide more accurate estimation of building energy consumption and dynamic thermal behaviours of building envelopes.

Limitations:

- higher computational effort
- only few BES tools have already integrated CFD modules

.

Performance and validity

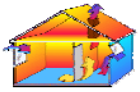
- all airflow network models yield similar airflow predictions, which are within 30% error compared to experiment measures on simple geometry cases.
- few studies are available on comparison between AFN predictions and real building measurements
- AFN predictions are highly sensitive to input parameters like internal gains, occupancy profiles, window opening controls. With sufficient input data, AFN predictions can be informative.

The following possible software enhancements have been identified:

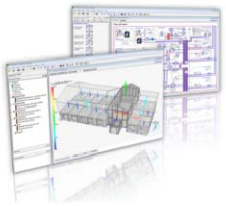
- to add new features/types for new solutions and technologies modelling;
- to include more detailed occupant comfort-based window control algorithm.

Early design stage modelling tools

COMIS



EDSL Tas



IDA-ICE

NatVent

CONTAM

LoopDA
Natural Ventilation Opening Sizing Tool

ESRU

DIAL

CoolVent

Buildings Research
SUNREL®

International Energy Agency
Energy Conservation in Buildings and Community Systems Programme

Early design stage modelling tools

Tool	Type of airflow model	Developer	Coupling with other tools	Coupling approach	Output	Particular features
COMIS	Airflow network	LBNL IEA Annex 23	EnergyPlus Trnsys (Trnflow)	Ping-pong coupling with EnergyPlus Onion coupling with Trnsys	– airflows due to infiltration or natural ventilation; – interactions of the HVAC system, ducts, and exhaust hoods and fans.	Variable air density model allowable. Ability to apply a density gradient on each side of the opening.
CONTAM	Airflow network	NIST	Trnsys	Onion coupling with Trnsys. It could either be integrated in Type 56 or be included in the model as a separate Type.	– airflows due to infiltration or natural ventilation; – interactions of the HVAC system, ducts, and exhaust hoods and fans; – air contaminant concentration; – user exposure.	Graphical interface for data input and result viewer. Fully coupled multizone CFD model CONTAM does not allow the user to modify the wind speed reference height.
mfs	Airflow network	ESRU	ESP-r	Various way of coupling possible	– airflows due to infiltration or natural ventilation; – velocity at connections; – air contaminant concentration;	Poor representation of single-sided ventilation. Bidirectional flow can be approximated with a pair of airflow openings. Different wind profile options available. It has a built-in pressure coefficient database.
LoopDA	Loop equation method	NIST			size ventilation airflow components of natural and hybrid ventilation systems	The equations are re-written to form physical closed loops around which the sum of the pressure

Applicability to design stages

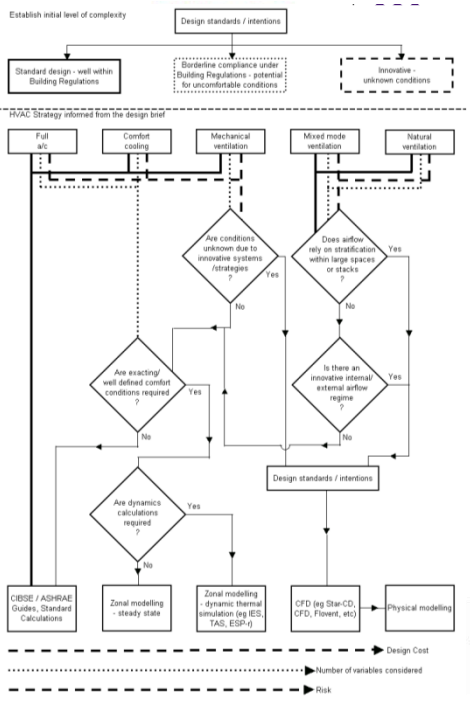
The choice depends on:

- performance indicators required
- resources available (computing capacity, manpower and time)
- ventilative cooling solution to be modelled

Design stage	Schematic design	Design development	Constructive documents
Target	To explore design solutions	To size building components for standard accomplishment	To detail the description of building components
Performance indicators	cooling demand reduction thermal comfort improvement achievable ventilation rates fan electricity primary energy	Min required ACR guaranteed Max number of overheating hours Max heating/cooling power Max/min temperature in the zone PPD, PMV Contaminant distribution	conformity of building components to simulation components local discomfort

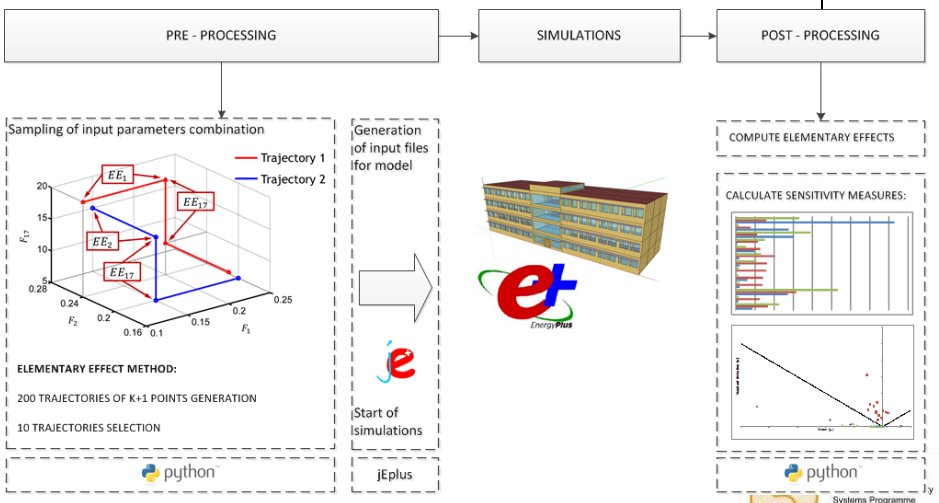
Tool selection

Djunaedy E. in her PhD work proposes a guideline **to select the most appropriate and convenient level of resolution and complexity** for airflow simulations depending on simulation objectives and the ventilative cooling strategy to be modeled.



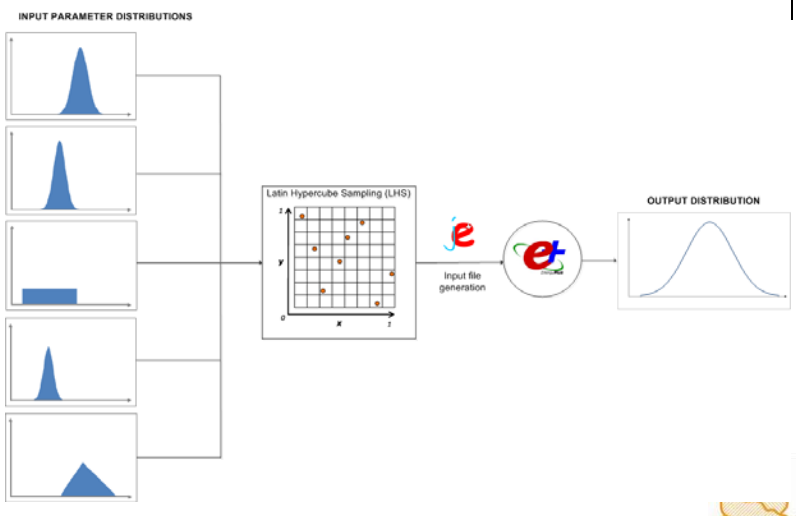
Source: Djunaedy E. , Hensen J., Loomans M., *Selecting an appropriate tool for airflow simulation in buildings*, Building Services Engineering Research and Technology, vol. 25, no. 3, pp. 269-278, 2004

Sensitivity analysis



Source: A. Belleri, *Integrated design methods for natural ventilation*, PhD Thesis, 2014

Uncertainty analysis



Source: A. Belleri, *Integrated design methods for natural ventilation*, PhD Thesis, 2014

Conclusions

Further developments needed:

- guidelines for airflow predictions' reliability and usefulness as well as definition of suitable boundary conditions and prediction assumptions;
- simplified calculation methods for ventilative cooling predictions to be included in national regulation;
- models development for components like wind catchers, solar chimneys,…;
- guidelines for use of tools and methods within the design process.

Thanks for your attention

Annamaria Belleri
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Experiences with ventilative cooling in practical application
Based on experiences with completed Active Houses

Peter Foldbjerg, Kurt Emil Eriksen and Karsten Duer
VELUX A/S, Department of Daylight, Energy and Indoor Climate
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35th AIVC conference
24-25 September 2014, Poznan, Poland

Ventilative cooling as means to prevent overheating

- Several low energy demonstration buildings completed during the last decade have shown problems with overheating, also in Scandinavia
- A UK review finds that refurbished dwellings have an increased risk of overheating
- Intensive ventilation (ventilative cooling) and solar shading can be efficient means of preventing overheating
- This presentation gives examples of practical experiences with ventilative cooling as means to prevent overheating in Active Houses

Active House Specification

- buildings that gives more than they take

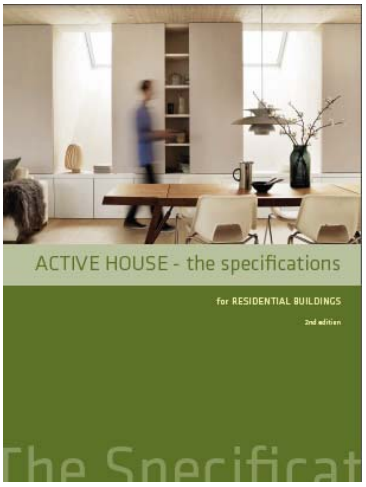
Quantitative Criteria
Ratings: 1 (best) – 4 (acceptable)

Comfort
- Daylight
- Thermal environment
- Indoor air quality

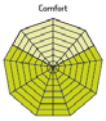
Energy
- Energy demand
- Energy supply
- Energy performance

Environment
- Environmental loads
- Freshwater consumption
- Sustainable construction

Qualitative Criteria; checklist



Indoor Air Quality

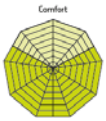


PARAMETER	VALUE	CRITERIA	SCORE
1.3.1 Standard fresh air supply		The fresh air supply shall be established according to the below limit values for indoor CO_2 concentration in living rooms, bedrooms, study rooms and other rooms with people as the dominant source and that are occupied for prolonged periods: 1. 500 ppm above outdoor CO_2 concentration 2. 750 ppm above outdoor CO_2 concentration 3. 1000 ppm above outdoor CO_2 concentration 4. 1200 ppm above outdoor CO_2 concentration	

Methodology
Based on EN 15251

- Air change rate must be individually adjustable in each room
- Any type of ventilation system can be used
- No specific requirements for airtightness, but *energy* requirements must be met (indirect requirement for airtightness)

Thermal Comfort



Thermal Environment

PARAMETER	VALUE	CRITERIA	SCORE
1.2.1 Maximum operative temperature		The maximum indoor temperature limits apply in periods with an outside T_{rm} of 12°C or more. For living rooms, kitchens, study rooms, bedrooms etc. in dwellings without mechanical air conditioning and with adequate opportunities for natural (cross or stack) ventilation, the maximum indoor operative temperatures are: 1. $T_{i,o} < 0.33 \times T_{rm} + 20.8$°C 2. $T_{i,o} < 0.33 \times T_{rm} + 21.8$°C 3. $T_{i,o} < 0.33 \times T_{rm} + 22.8$°C 4. $T_{i,o} < 0.33 \times T_{rm} + 23.8$°C T_{rm} is the Running Mean outdoor temperature as defined in 'chapter 3.11 External temperature, running mean of EN 15251:2007'. For living rooms etc. in residential buildings with air conditioning, the maximum operative temperatures are: 1. $T_{i,o} < 25.5$°C 2. $T_{i,o} < 26$°C 3. $T_{i,o} < 27$°C 4. $T_{i,o} < 28$°C For bedrooms (especially at night time), a 2°C lower value should preferably be used than indicated above as people are more sensitive to high temperatures when sleeping or trying to fall asleep.	

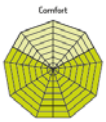
Methodology

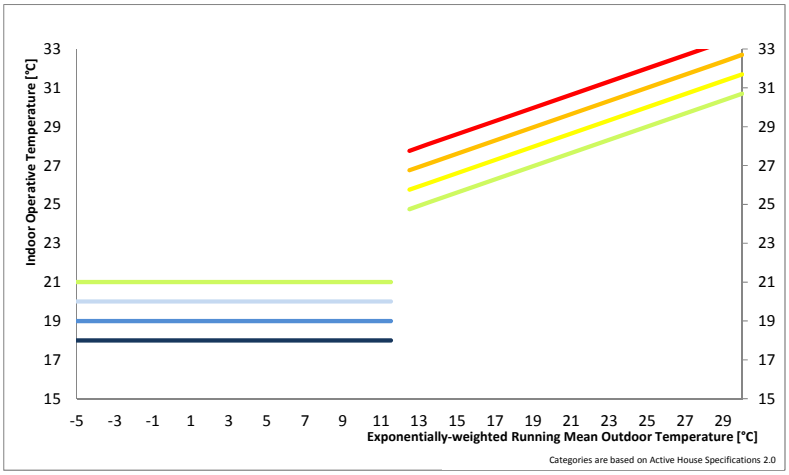
Based on EN 15251

Adaptive comfort for naturally ventilated buildings

- Means to prevent overheating (solar shading, window openings, mechanical cooling) must be individually adjustable in each room
- Means to control heating system must also be adjustable at room level

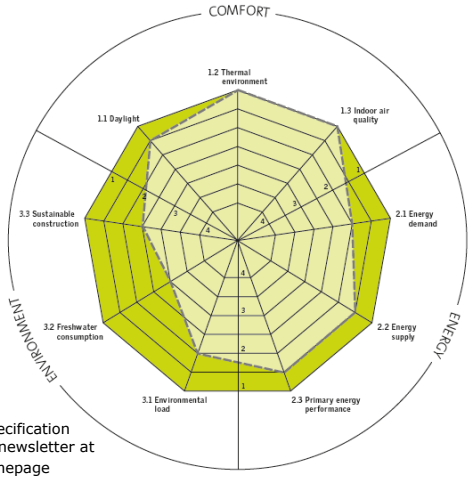
Adaptive Thermal Comfort

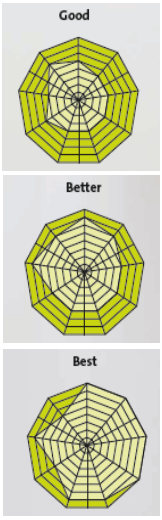




Active House Specification

- performance in the radar diagram





Download the Specification
and subscribe to newsletter at
Active House Homepage
www.activehouse.info

Increase in "Climate Renovation" projects

- De Poorters van Montfoort in Netherlands: Ten row houses in social housing association renovated as Active House within public budget frame
  Hybrid ventilation (NV with MV extract)
- LichtAktiv Haus in Germany:
  Typical 1950's "settler house" renovated to CO2 neutral level
  Natural ventilation all year
- From "energy renovation" to "climate renovation"

Typical ventilation systems

- Hybrid ventilation based on mixed-mode strategy
  - Natural ventilation when outdoor temperature is "high" (e.g. above 12,5°C)
  - Mechanical ventilation with heat recovery when outdoor temperature is "low" (e.g. below 12,5°C)
- Demand-controlled ventilation with CO2-level as indicator (typically ~ 900 ppm set point)
  - Humidity also used as indicator
- Window opening for summer thermal comfort (ventilative cooling)
  - Control based on indoor temperature (e.g. 24°C set point)

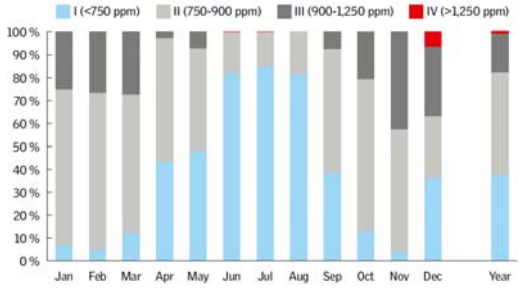
Airtightness

	Home for Life DK, 2009	Sunlighthouse AT, 2010	Maison Air et Lumiére F, 2011	CarbonLight Homes GB, 2011	LichtAktiv Haus D, 2010
n50 (h^{-1})	1,5	0,5	0,6	-	1,1
l/s/m² @ 50 Pa	-	-	-	1,3	-

Experience from completed Active Houses:

- The achieved airtightness is related to the competence level of the craftsmen building the house.
- The competence level has increased in the relatively short period from 2009 to 2011
- ..possibly due to increased awareness of the importance of airtightness for low energy buildings
- Satisfying airtightness can be achieved, and not a big challenge, compared to other challenges

Measured IAQ

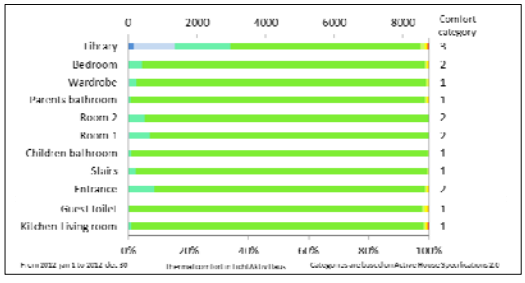


Kitchen-dining room
LichtAktiv Haus in Germany
(naturally ventilated)
Absolute, measured values

Criteria according to EN 15251

- Best IAQ in summer; CO2 levels in category I or II almost all hours (side-effect of ventilative cooling)
- In winter, 20-30% of hours in category III – acceptable annual result
- Is it the right criteria? From EN 15251 "offices" – how to evaluate the IAQ in dwellings, especially bedrooms?
- General experience that both NV and MV delivers acceptable IAQ

Measured thermal comfort



Kitchen-dining room
LichtAktiv Haus in Germany
(naturally ventilated)

Criteria according to Active House Specification
(corresponds to EN 15251)

- The experience is that excellent daylight conditions can go hand-in-hand with good thermal comfort
- Overheating can be prevented with the right measures
- .. dynamic solar shading, overhangs, ventilative cooling

Use of windows for ventilative cooling

Kitchen/dining room
LichtAktiv Haus

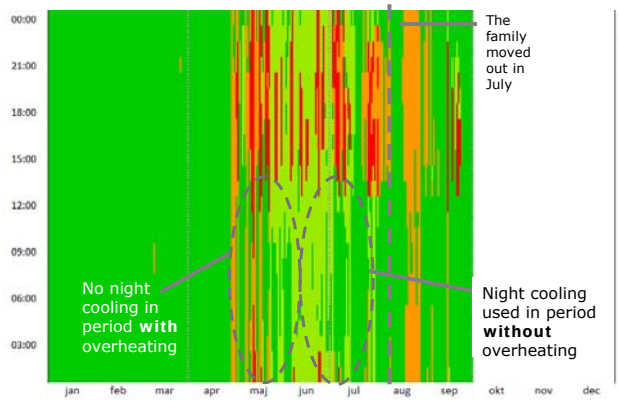
Cat 1 or 2, windows closed
Cat 1 or 2, windows open
Cat 3 or 4, windows closed
Cat 3 or 4, windows open

Category refers to Active House / EN 15251 category

"Open window" if one or more windows are open in the room

- Window openings are used during all hours of the day from May to September (incl. night cooling)
- Airings at 8:00 and 20:00 in transition periods
- Window openings (ventilative cooling) support good thermal comfort

Automated night cooling reduced overheating



Active House, Russia
Bedroom 3

Cat 1 or 2, windows closed
Cat 1 or 2, windows open
Cat 3 or 4, windows closed
Cat 3 or 4, windows open

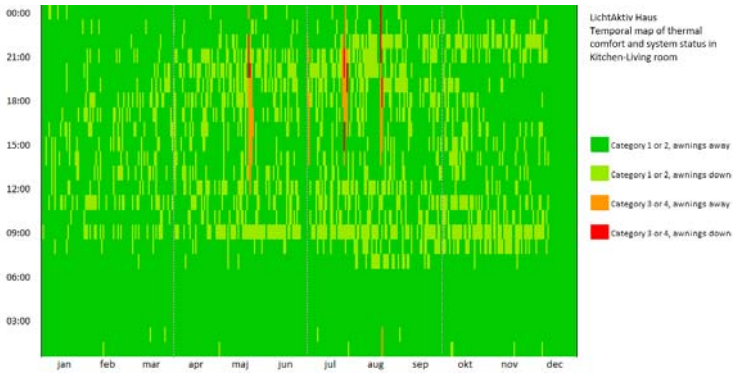
Category refers to Active House / EN 15251 category

"Open window" if one or more windows are open in the room

- Warm, stabile period from April to July
- April and May: no use of night cooling, and nighttime overheating
- June and July: Automated night cooling in use, no nighttime overheating

Shading contribute to good thermal comfort

- External shading (awning blinds) in use during daytime hours in all seasons
- Follows the time for sunrise and sunset
- Not used permanently during the day
- Relation between the use of shading and the occurrence of good thermal comfort



Energy performance

- The four first projects have demonstrated that the energy targets of 2020 can be achieved with the knowledge, technology and building components that were available when the houses were planned in 2008–2010
- In some cases the energy performance has been communicated by the consultants based on national compliance tools – which can be misleading, as compliance tools are not necessarily made to predict the actual energy consumption of the completed buildings
- The actual occupants behavior, control system setup and quality of components and construction had a significant impact on the results
- Based on these experiences, it is evident that it would create more value for a customer if the calculated energy consumption is communicated as a range of values – because the actual performance depends on the actual use of the building

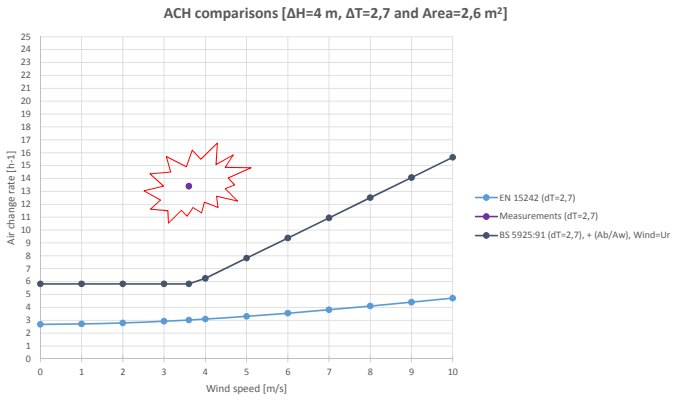
High air flows with ventilative cooling can be measured and calculated

		South bedroom temp	North bedroom temp	Bath room temp	Wind speed m/s	Tracer Gas ACH	Simulated CONTAM ACH
Morning	Closed door	23.7	21.3	22.5	3.6	13.4	13.9*
	Open door	23.7	21.3	22.5	2.8	22.5	20.6
Afternoon	Closed door	27.1	26.5	26.2	2.3	13.2	16.6*
	Open door	27.1	26.5	26.2	2.3	19.8	19.5
Morning	Closed door	24.2	22.5	23.3	3.6	13.4	14
	Open door	24.2	22.5	23.3	3.6	14.6	17.4
Afternoon	Closed door	26.5	25.2	25	2.9	10.6	13.2
	Open door	27	26.1	25.6	2.8	13.1	17

Good correspondence between measured and simulated air change rate – max 30% difference per case, 10% difference in average

Measurements performed in Maison air et Lumiere by Armines in France in cooperation with VELUX

But calculation standards underestimate high air flows



- True and fair calculation methods are important for practical application of ventilative cooling (EN 15242 under revision, new calculation method is being discussed)

Ventilative cooling in legislation

- Some national, mandatory compliance tools for energy also include an estimate of the risk of overheating
  - .. which is important, as no other software evaluation is performed for the typical residential building project
- Important that the compliance tools provide a reasonable correct account of the performance of ventilative cooling

Ventilative cooling, theory and practice

- Ventilative cooling performs well in practice
- Ventilative cooling performs well in theory
- Ventilative cooling is not sufficiently supported by standards
- Ventilative cooling is not sufficiently supported by many compliance tools
- Ventilative cooling is therefore difficult to apply in practice
- Venticool.eu and IEA Annex 62 have been initiated to facilitate the practical application of ventilative cooling

venticool
the international platform for ventilative cooling

IEA EBC
Annex 62
The IEA project
on ventilative cooling
EBC

Control systems are important

- The control of windows, solar shading, mechanical ventilation, etc. must be simple and intuitive
- The automatic control system must be intuitive and transparent for the users (more important than simple)
- Occupants must always be able to override the system and make manual activations
- The switch between mechanical and natural ventilation can be based on exterior temperature
- Lack of simple and affordable control systems for residential buildings currently on the market
- Occupants are interested in the performance of their house

Conclusions

- Good IAQ can be achieved with both mechanical and natural ventilation systems; hybrid ventilation has best energy performance
- Use of ventilative cooling improves summer IAQ as a side-effect of ventilative cooling
- Preventing overheating is a very important issue, and focus on this issue is needed
- Use of dynamic solar shading and natural ventilation (ventilative cooling) is able to eliminate overheating, also in buildings with high daylight levels
- Ventilative cooling needs better support in standards and compliance tools

VELUX

Thanks for listening!

Experiences with ventilative cooling in practical application
Based on experiences with completed Active Houses

Peter Foldbjerg
VELUX A/S

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35th AIVC conference
24-25 September 2014, Poznan, Poland

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Residential ventilative cooling in national energy performance regulations: requirements and sensitivity analysis

Ventilative cooling and Annex 62 - AIVC 2014 - Poznan

Ivan Pollet - Renson Ventilation - Gent University

Content

- EP calculation and ventilative cooling in BE, FR, NL
  - Devices and requirements
  - Sensitivity analysis
- Conclusions

Ventilative cooling means - requirements

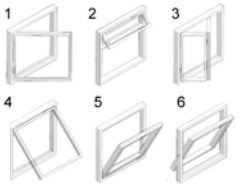
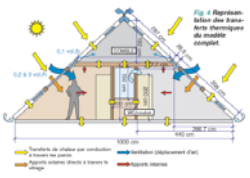


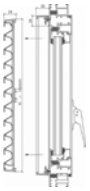
Table 3: Ventilative cooling means for dwellings in Belgian, French and Dutch EPBD regulation

Ventilative cooling means	Belgium	France	The Netherlands
Openable windows			
Turn windows	Net area (m²)	Max. opening ratio (%)	Yes / no
Tilt windows	Net area (m²)	Max. opening ratio (%)	Yes / no
Sliding windows	---	Max. opening ratio (%)	Yes / no
Roof windows	Net area (m²)	Max. opening ratio (%)	Yes / no
Vents integrated in/around windows (~ window grills)	---	---	
Wall louvres	---	---	
Natural extract chimney	---	---	
Mechanical extract and/or supply fans	---		

	Belgium	The Netherlands
Burglary proof		No / Rec
Insect proof		---
Water tightness		No / Rec
Acoustic attenuation		---

No harmonisation
Limited requirements





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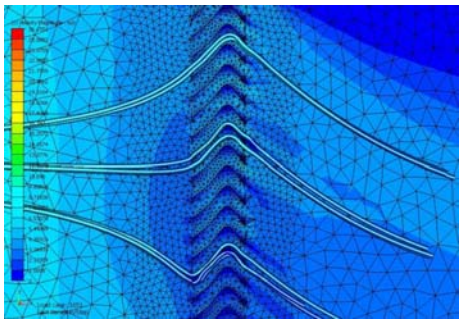
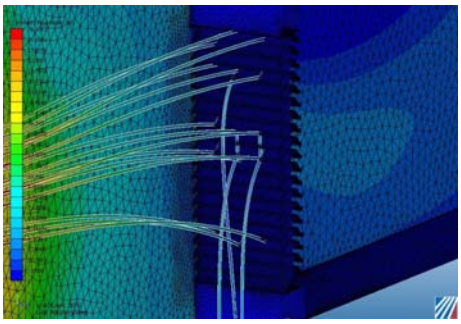
Ventilative cooling means - requirements

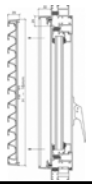
- Water tightness



speed of air 2 m/s, air particles trajectory



speed of air 2 m/s, water particles trajectory



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Ventilative cooling means - requirements

- Water tightness
- Insect proof

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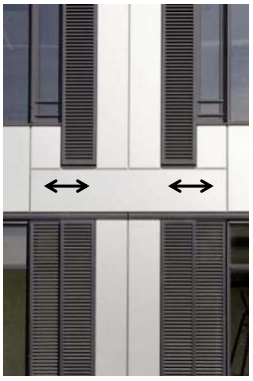
Ventilative cooling means - requirements

- Water tightness
- Insect proof
- Burglary proof RC2 (EN 1627 till 1630)



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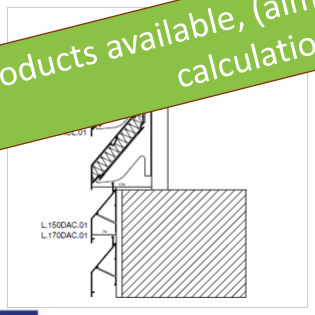
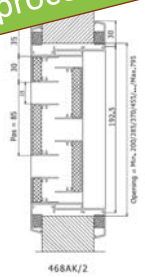
Ventilative cooling means - requirements

- Water tightness
- Insect proof
- Burglary proof (EN 1627 till 1630)
- Acoustic attenuation

Products available, (almost) none integrated in EP calculation procedures





RENSON Creating healthy spaces

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Content

- EP calculation and ventilative cooling in BE, FR, NL
  - Devices and requirements
  - Sensitivity analysis
- Conclusions

Sensitivity analysis: software - output parameters

Table 5: Used EP software

Country	EP software	Version
Belgium	3G-Software	5.0.5
France	Clima-Win	2.0
The Netherlands	Enorm	1.5

Table 1: Output of different national EP calculations

Output	Belgium	France	The Netherlands
Heating demand	Net yearly heating demand [MJ]	Net yearly heating demand [MJ]	Net yearly heating demand [MJ]
Cooling demand	Fictive net yearly cooling demand [MJ]	---	Fictive net yearly cooling demand [MJ]
Summer comfort	Overheating indicator [Kh]	Indoor temperature exceed T_{ic} [K]	---
Primary energy consumption	E-level [-] $PEF_{el} = 2.5$ $PEF_{fuel} = 1.0$	C_{ep} [kWh/m²] $PEF_{el} = 2.58$ $PEF_{fuel} = 1.0$	EPC [-] $PEF_{el} = 2.56$ $PEF_{fuel} = 1.0$

Table 2: National boundary conditions for heating and cooling demand calculations

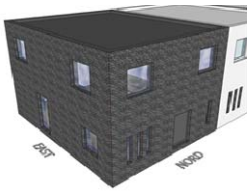
Country	Heating set point	Cooling set point
Belgium	18°C	23°C
France	19°C / 16°C (non occ.)	28°C / 30°C (non occ.)
The Netherlands	20°C	24°C

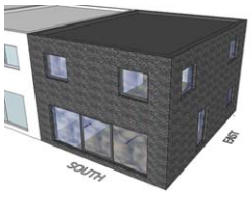
Sensitivity analysis

1 Reference dwelling: 2 levels, 472 m³, 160 m² floor surface

Varying input parameters:

1. Fraction openable windows
   0 / 25 / **50** / 75 / 100%
2. Thermal mass
   moderate heavy / light
3. Solar shading and solar control
   no sun shading / manual operated on South / automatically operated on South and East
4. Window-to-floor area ratio
   15 / **22%**
5. Building air tightness
   2 / 10 m³/(h.m²)
6. Active cooling
   Yes (EER = 2.5) / **no**





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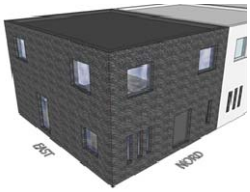
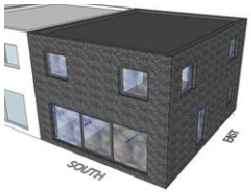
Sensitivity analysis

1 Reference dwelling: 2 levels, 472 m³, 160 m² floor surface

Varying input parameters: Ventilative cooling

1. Fraction openable windows
   0 / 25 / **50** / 75 / 100%
2. Thermal mass
   moderate heavy / light
3. Solar shading and solar control
   no sun shading / manual operated on South / automatically operated on South and East
4. Window-to-floor area ratio
   15 / **22%**
5. Building air tightness
   2 / 10 m³/(h.m²)
6. Active cooling
   Yes (EER = 2.5) / **no**





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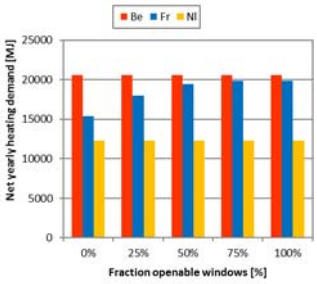
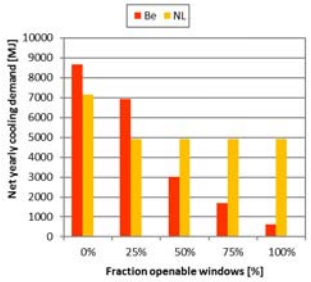
Sensitivity analysis: fraction openable windows (OW)



Heating season:

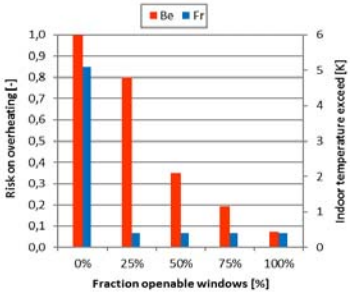
- Be – Nl: windows closed, except in France
- Fr: windows opened, demand ↑ (= potential VC ↓)
- Nl: coldest climate, highest setpoint ↔ lowest demand



Cooling season:

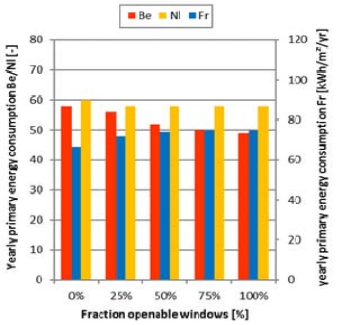
- Be: fraction OW ↑ → Cooling demand ↓ (burglary res)
- Nl: independent of fraction; 1 openable window suffices, but limited potential of VC
- Fr: no output of software

Sensitivity analysis: fraction openable windows (OW)



Risk on overheating/Temperature exceed:

- Be: dependent on fraction of OW
- Nl: not considered
- Fr: independent of fraction OW, high effect



Primary energy consumption:

- Be: significant effect of VC (when burglary resistant, depending on case), dependent on fraction of OW
- Nl: smaller effect of VC compared with Be independent on fraction of OW
- Fr: significant, but negative effect of VC !

Sensitivity analysis

1 Reference dwelling: 2 levels, 472 m³, 160 m² floor surface

Varying input parameters: Ventilative cooling

1. Fraction openable windows
   0 / 25 / **50** / 75 / 100%
2. Thermal mass
   moderate heavy / light
3. Solar shading and solar control
   no sun shading / manual operated on South / automatically operated on South and East
4. Window-to-floor area ratio
   15 / **22%**
5. Building air tightness
   2 / 10 m³/(h.m²)
6. Active cooling
   Yes (EER = 2.5) / **no**

2 references:

REF 1:

$f_{openable\ windows}$ = 0%

No ventilative cooling

REF 2:

$f_{openable\ windows}$ = 50%

Ventilative cooling

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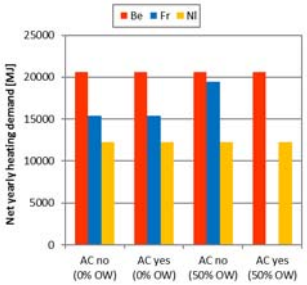
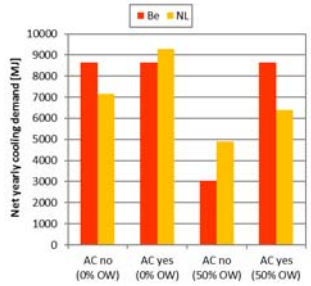
Sensitivity analysis: active cooling (AC)



Heating season:

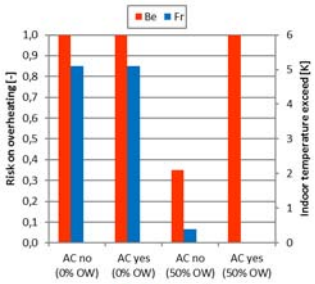
- Be – Nl: no effect of AC (logical)
- Fr: active cooling and openable windows impossible



Cooling season:

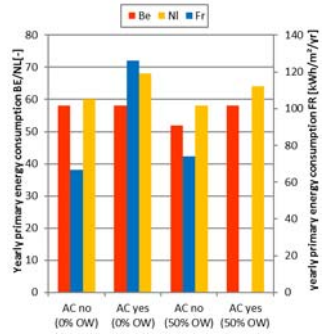
- Be: dependent on risk on overheating, if 100%, no effect
- Nl: always increase of cooling demand when AC
- Fr: no output of software

Sensitivity analysis: active cooling (AC)



Risk on overheating/Temperature exceed:

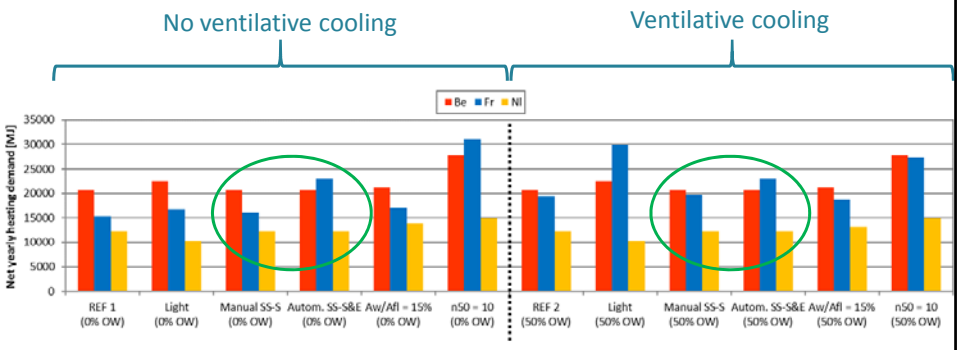
- Be: if AC: risk on overheating = 1
  = chance on placing AC
- Nl: not considered
- Fr: AC no impact on temperature exceed



Primary energy consumption:

- Be: if risk on overheating = 1, no effect of AC
- Nl: when AC, always higher energy consumption
- Fr: significant when no openable windows
  openable windows not possible with AC

Sensitivity analysis: mobile solar shading (SS)



Impact of mobile solar shading (manual or automated) on heating demand:

- Be – Nl: mobile solar shading (manual or automated): no impact on heating demand
- Fr: especially automated solar shading increases significantly heating demand (use of SS in winter)

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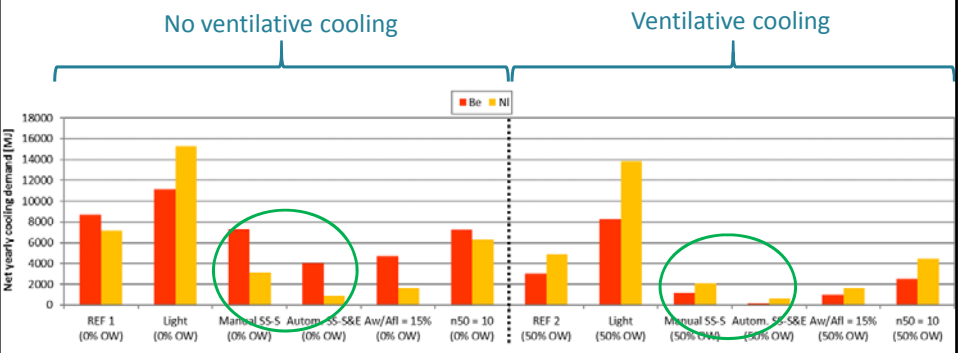
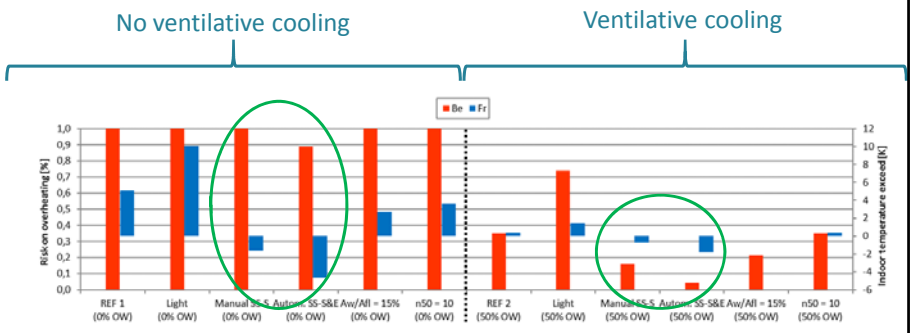
Sensitivity analysis: mobile solar shading (SS)



Impact of mobile solar shading (manual or automated) on cooling demand:

- Be – Nl: clear impact, **if** cooling demand
  lowest cooling demand, when applying VC and SS
- Fr: not an output

Sensitivity analysis: mobile solar shading (SS)



Impact of mobile solar shading (manual or automated) on overheating risk:

- Be: clear impact on overheating risk, when situated between 0 and 1
- Fr: clear impact, negative values

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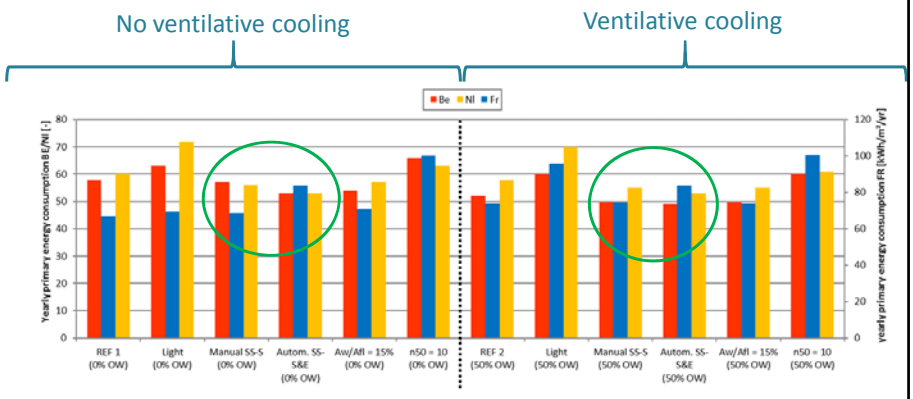
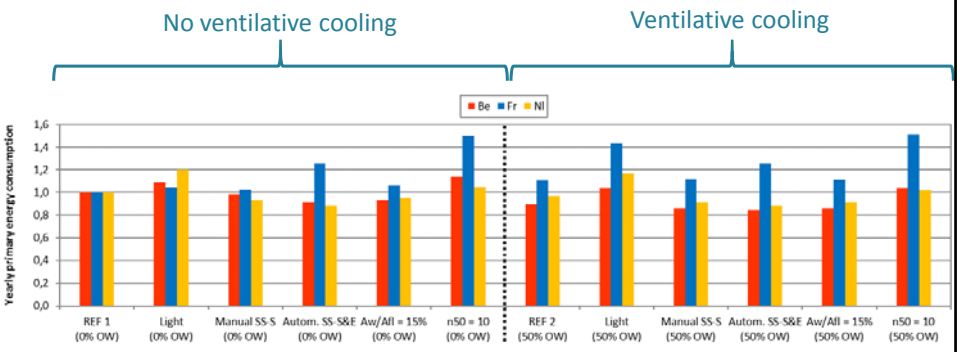
Sensitivity analysis: mobile solar shading (SS)



Impact of mobile solar shading (manual or automated) on primary energy consumption:

- Be - NI: lower primary energy consumption, with more advanced solar shading
- Fr: higher primary energy consumption, with more advanced solar shading ?
  Effect on heating demand greater, than on cooling demand !

Sensitivity analysis: ventilative cooling (VC)



Impact of ventilative cooling on primary energy consumption:

- VC reduces primary energy consumption, especially in Belgium with burglary resistant VC devices,
- except in FR, VC often increases energy consumption (supposed to be opened during heating season ?)

Conclusions

- **National EP approaches** with respect to residential ventilative cooling can differ significantly, when considering: - requirements
  - heating demand
  - cooling demand / overheating risk
  - primary energy consumption

- Especially **openable windows** considered as VC means, not other devices
- **No/few requirements** on VC devices, although impact on the operating time

- **Be**: - when burglary resistant VC devices, significant effect possible
  - impact of risk on burglary via openable windows: yet to define
- **Nl**: - limited impact of VC
  - no overheating risk evaluation
- **Fr**: - VC and advanced SS increase primary energy consumption ?
  - openable windows and active cooling not possible

- Need for a **European Standard** to harmonize

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EXPERIMENTAL CHARACTERISATION OF DOMINANT DRIVING FORCES AND FLUCTUATING VENTILATION RATES FOR A SINGLE SIDED SLOT LOUVER VENTILATION SYSTEM

Paul D O'Sullivan[1,2] , Maria Kolokotroni[2]

35th AIVC Conference, Poznan, Poland, 24th & 25th Sept 2014

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2. *Howell Building, Mechanical Engineering, School of Engineering and Design, Brunel University, Uxbridge UB8 3PH, United Kingdom*

Corresponding author: paul.osullivan@cit.ie

Background & Context

- Increased need for assessment of cooling demand and overheating risk with well insulated airtight buildings
- Ventilative cooling an important strategy for to deal with these situations (particularly in temperate climates)
- Single sided ventilation attractive strategy for external retrofit of existing cellular isolated spaces
- purpose provided Louvre vent components can address barriers to ventilative cooling (noise, rain ingress, security)
- Investigate modified geometry compared to plain openings

Objectives

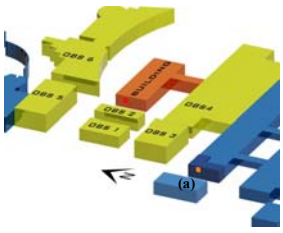
- To Investigate any modification in effect of conditions contributing to ventilation rates for a retrofit louvre system
- consider the combined effect of momentum and buoyancy forces and the character of the ventilation rate using a fluctuation parameter, σ_c

How?

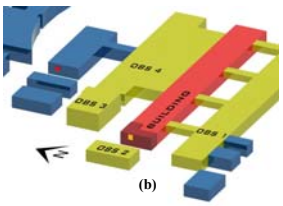
- Use full scale testing – data not exhaustive for architectural louvre components / testbed available
- Compare measurements of a retrofit space with an existing un-refurbished control space

Experimental Setup

Control Space



Retrofit Space



Site Plan

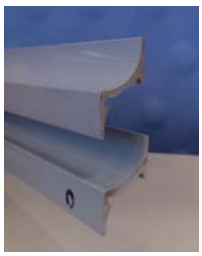
Materials and Methods

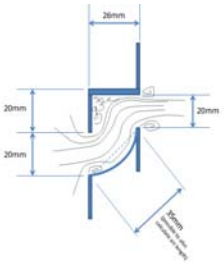
- Concentration Decay Method used with ACH calculated using linear regression technique and C_N
- 25 ACH retrofit space / 13 ACH control space tests completed
- Full scale, normal operation modes for all tests
- Test method, experimental set up and ACH results published in IJV and not discussed further here

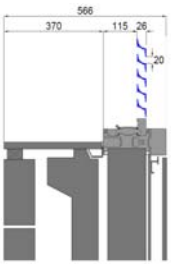
Ventilation rate test results published in IJV:

Paul D O Sullivan and Maria Kolokotroni (2014) Time-averaged single sided ventilation rates and thermal environment in cooling mode for a low energy retrofit envelope system. *International Journal of Ventilation:* September 2014, Vol. 13, No.2, pp. 153-168

Ventilation Component







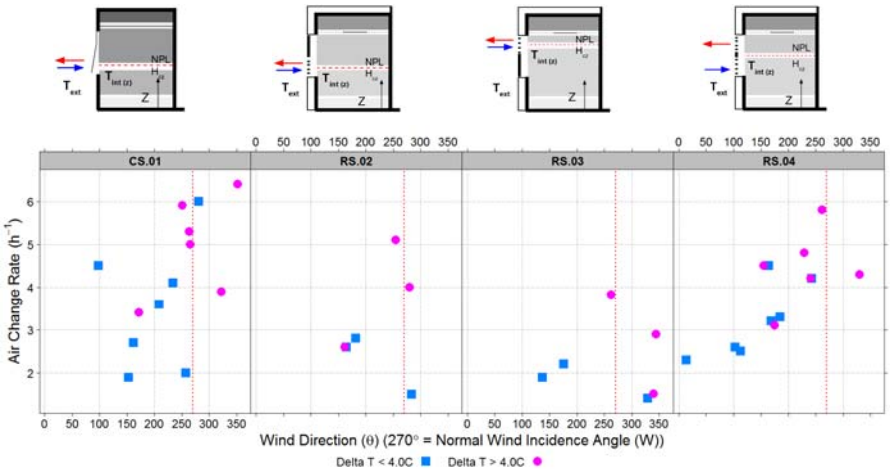
CS.01

RS.02

RS.03

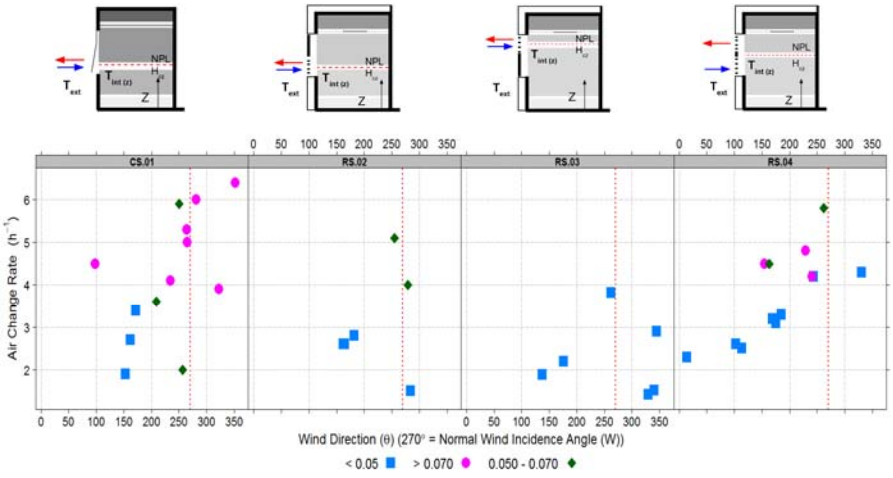
RS.04

Results - ΔT_{ie}



Test Config ventilation rates (h^{-1}) as a function of wind direction grouped according to ΔT_{ie}

Results - σ_c



Test Config ventilation rates (h^{-1}) as a function of wind direction grouped according to σ_c

Summary of Findings

- Largest ACH at $\Delta T_{ie} > 4.0°K$ in retrofit and control spaces
- Wind direction influenced magnitude of ACH for RS config
- Wind direction influence magnitude of σ_c for RS config
- However, consistently higher σ_c values in control space
- ACH a function of ΔT_{ie} & σ_c but also wind direction & opening geometry

Non Dimensional Analysis of Driving Forces

Archimedes number, $Ar = (Gr/Re^2)$ described as:

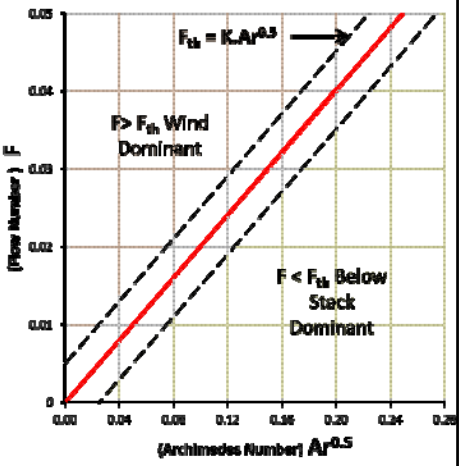
$$Ar^{0.5} = \frac{\Delta T g H}{T v_{wind}^2}$$

Dimensionless Flow number, F, described as:

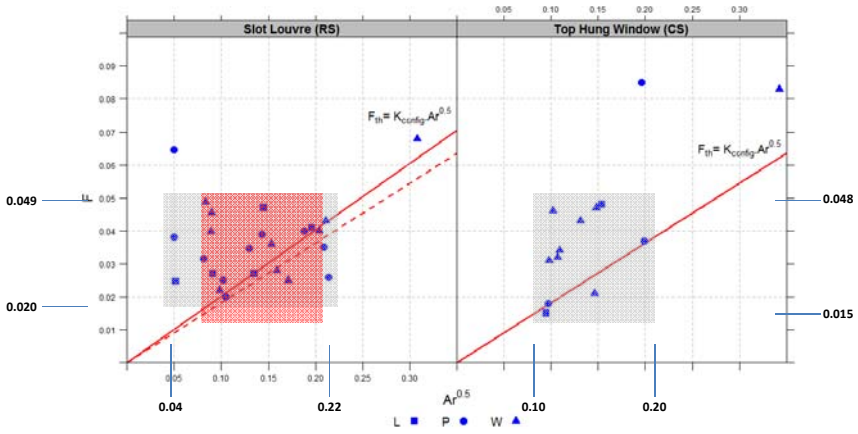
$$F = \frac{q_{ACH}}{A_{eff} v_{wind}}$$

The use of a flow number due to thermal stack effect alone, F_{th}, is introduced to the plot.

$$F_{th} = K.Ar^{0.5} \text{ (Stack Dominant)}$$

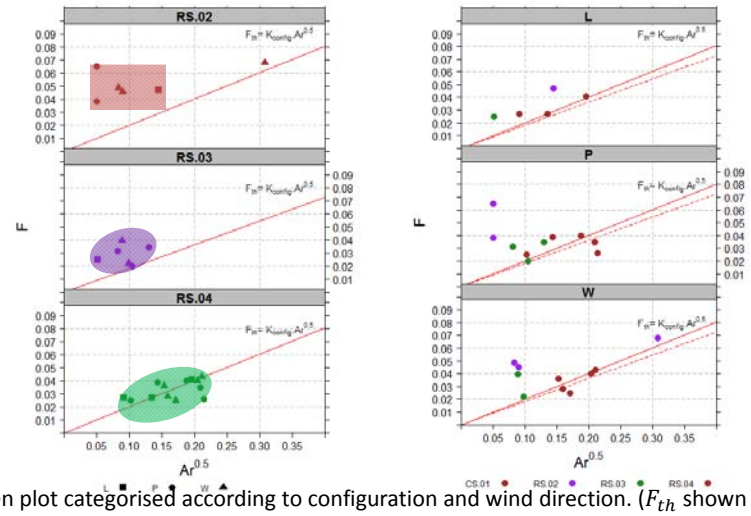


Non Dimensional Analysis of Driving forces



Warren plots for slot louvre system in RS and top hung window in CS. (F_{th} shown in red)

Non Dimensional Analysis of Driving Forces



Warren plot categorised according to configuration and wind direction. (F_{th} shown in red)

Overall Conclusions

- ACH generally increased according to ΔT_{ie} and σ_c for all tested spaces
- Ventilation rate and character shown to be influenced by both wind direction & opening geometry for louver ventilation system
- No substantial difference in driving forces for RS and CS
- Different driving force patterns emerge according to opening height and opening location in RS
- At Low $Ar^{0.5}$ wind incidence angle more important in determining whether wind is dominant

Challenges & Future Work

Challenges

- Boundary conditions needed at opening – local phenomena
- Effects of complex geometry of opening insulated doors -
- Improved understanding of cause and impact of σ_c
- Translation to cooling potential of the system

Current & Future Work

- 44 additional tests completed already in summer 2014
- Boundary conditions measured at the opening
- Inc temp resolution of Velocity & Temp at opening & within space
- Single opening tested with & without louvre, retrofit space only
- CFD model planned to investigate cooling potential of the system

Thank you.

REQUIREMENTS AND HAND-OVER DOCUMENTATION FOR ENERGY-OPTIMAL DEMAND-CONTROLLED VENTILATION

Mads Mysen*, Axel Cablé, Peter G. Schild, and Kari Thunshelle

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NO-0314, Oslo, NORWAY
*Corresponding author: mads.mysen@sintef.no

Why?

- DCV can reduce the energy use of ventilation by more than 50 % compared to CAV
- Real energy-performance is to high and IAQ is poor
- This have many causes, including:
  - inadequate specifications
  - inadequate hand-over documentation
  - balancing report not suitable for DCV

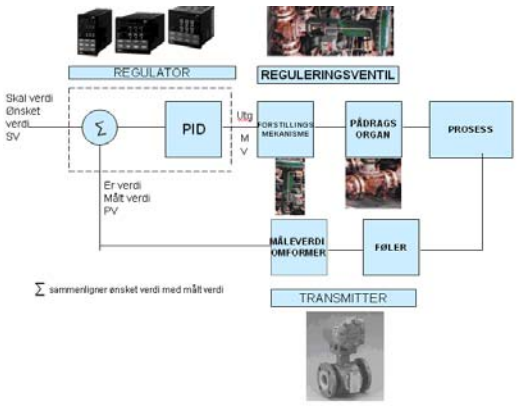
Based on experiences from case-studies, an expert group has developed new requirements and hand-over documentation.

DEFINITION OF VAV & DCV

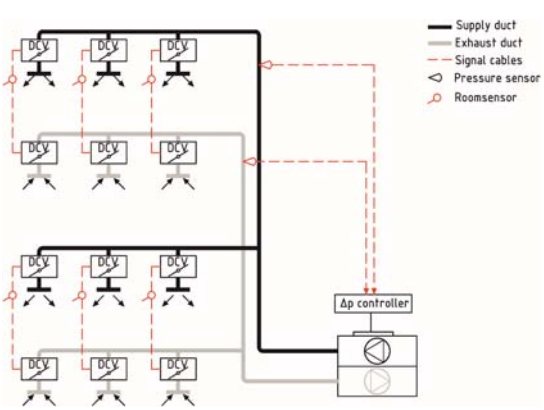
VAV -Variable Air Volume

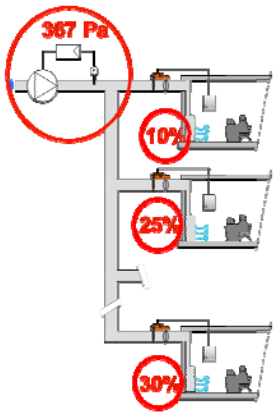
DCV - Demand Controlled Ventilation

DCV systems are ventilation systems where the air flow rate is controlled automatically according to a measured demand at room level.

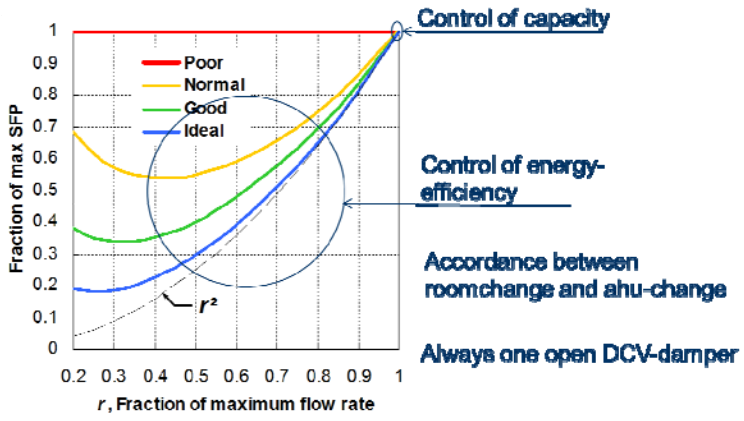


Pressure controlled DCV





Requirements for energy-optimal DCV

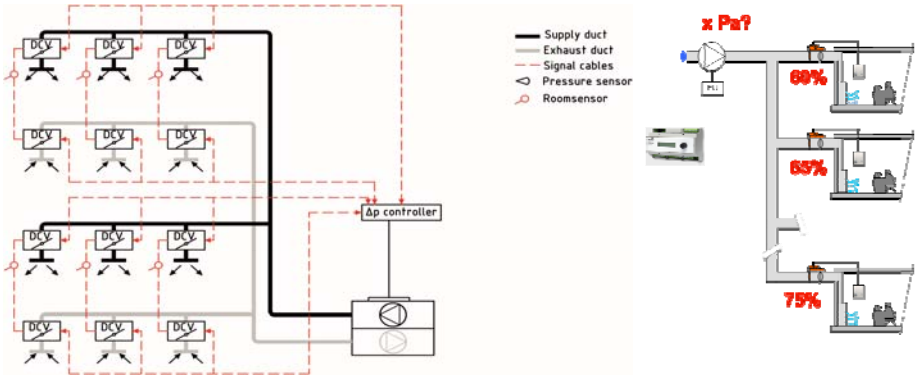


Pressure controlled DCV:

Step 1 balancing - find minimum pressure set point?

- Performed at maximum load
- Control that all the DCV-units, room sensors/ room regulators etc have supply voltage and no polarity error
- Control the pressure sensor position
- Select a pressure set point - higher than necessary
- Program V_{max} and V_{min} on each DCV-damper and set the dampers to automatic mode
- Force each DCV-dampers to V_{max} and read the opening grade.
- Find the index DCV-damper, which is the damper with the highest opening grade.
- Adjust the pressure set point until the index damper has maximum opening grade
- Continue with the load tests

Damper optimized DCV



Damper optimized DCV:

Step 1 balancing – program and control the units

- Control that all the DCV-units, room sensors/ room regulators etc have supply voltage and no polarity error
- Program V_{max} and V_{min} on each DCV-damper and set the dampers to automatic mode
- If the DCV-units do not give the expected response, check the polarity on the supply voltage.
- Continue with the load tests

MAX-MAX-MIN LOAD TEST

The Max-max-min load test is a functional test of the DCV-system at the maximum airflow rate (*ie.* maximum simultaneity) that the AHU is designed for.

Work steps :

- Control each DCV-unit for V_{max} and V_{min}
- Fill in the pink columns in VAV-control form

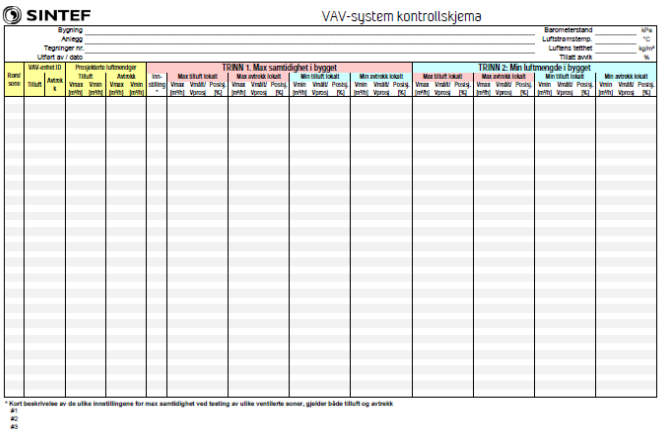
For system designed for a limited maximum simultaneity: Force a share of DCV-units to V_{max}, until the AHU's airflow rate increases to the design value. Control these DCV-units for V_{max} and V_{min}

Continue until all DCV-units are controlled at maximum load

MIN-MAX-MIN LOAD TEST

Work steps :

- Control each DCV-unit for V_{max} and V_{min}
- Fill in the blue columns in VAV-control form


SINTEF VAV-system kontrollskjema

Bygning
Anlegg
Tegninger nr.
Utført av / dato

Barometerstand
Luftstrømstemp.
Luftens tetthet
Tillatt avvik

Rom/ sone	VAV-enhet ID		Prosjekterte luftmengder				TRINN 1: Max samtidighet i bygget										TRINN 2: Min luftmengde i bygget							
	Tilluft	Avtrekk	Tilluft		Avtrekk		Inn-stilling *	Max tilluft lokalt			Max avtrekk lokalt			Min tilluft lokalt			Min avtrekk lokalt			Max tilluft lokalt			Max avtrekk lokalt			Min tilluft lokalt			Min avtrekk lokalt		
			Vmax [m³/h]	Vmin [m³/h]	Vmax [m³/h]	Vmin [m³/h]		Vmax [m³/h]	VmaxU [m³/h]	Pcorrq [%]	Vmax [m³/h]	VmaxU [m³/h]	Pcorrq [%]	Vmin [m³/h]	VminU [m³/h]	Pcorrq [%]	Vmin [m³/h]	VminU [m³/h]	Pcorrq [%]	Vmax [m³/h]	VmaxU [m³/h]	Pcorrq [%]	Vmax [m³/h]	VmaxU [m³/h]	Pcorrq [%]	Vmin [m³/h]	VminU [m³/h]	Pcorrq [%]	Vmin [m³/h]	VminU [m³/h]	Pcorrq [%]

* Kort beskrivelse av de ulike innstillingene for max samtidighet ved testing av ulike ventilerte soner, gjelder både tilluft og avtrekk
#1
#2
#3

http://www.sintef.no/Projectweb/reDuCeVentilation/

Questions?

AERECO

MONITORING OF AN INNOVATIVE ROOM-BY-ROOM DEMAND CONTROLLED HEAT RECOVERY SYSTEM ON FOUR LOCATIONS

COLETTE MADELINE

HRV MONITORING CAMPAIGN

- Monitoring campaign in 4 dwellings:
  - Nuremberg
  - Dortmund
  - Frankfurt
  - Paris
- The aim of the campaign?
  - Check the good working of the HRV
  - Performance of the HRV in terms IAQ, comfort, energy efficiency
  - Future improvement

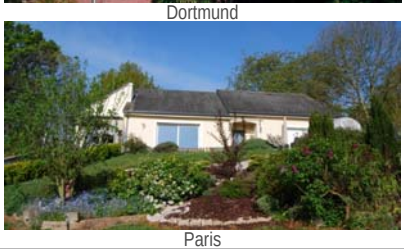
Location of the 4 dwellings

DESCRIPTION OF THE MONITORING INSTALLATIONS

Nuremberg

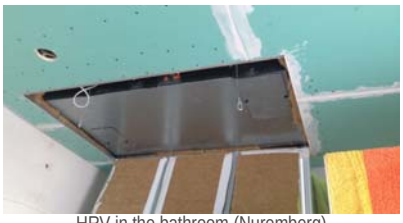
Dortmund

Frankfurt



Paris

DESCRIPTION OF THE MONITORING INSTALLATIONS



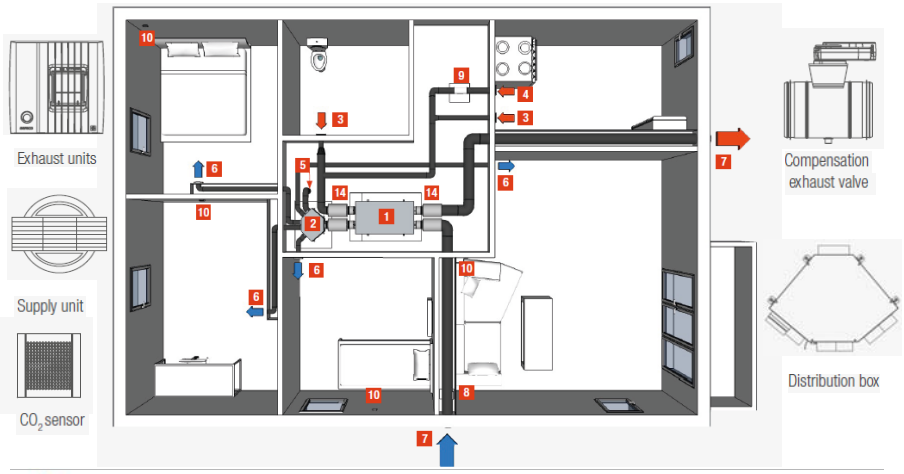
HRV in the bathroom (Nuremberg)

HRV in the stairs (Dortmund)

HRV in the attic (Frankfurt)

HRV in the insulated / non insulated attic (Paris)

DESCRIPTION OF THE HRV INSTALLATION



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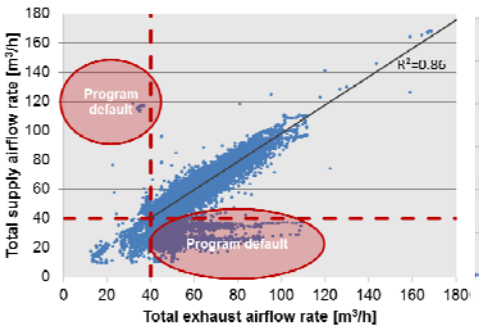
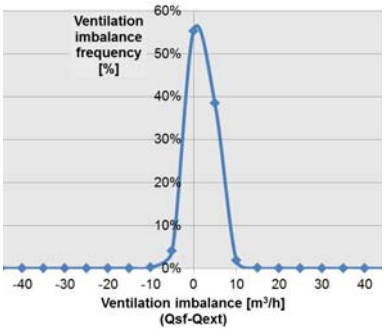
CHECK OF THE WORKING OF THE HRV

Good balancing of the airflow rate: included in the interval [-10; 10[m^3/h



Relationship between total exhaust airflow rate and total supply airflow rate.

(Frankfurt, from 2014/01/03 to 2014/05/31)



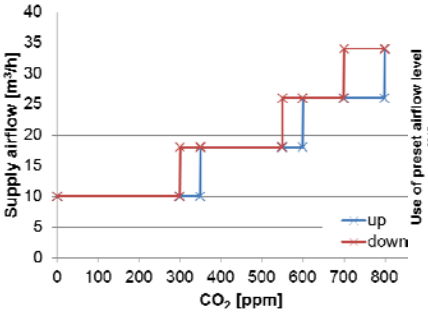
Balance of exhaust and supply airflow rate above 40 m^3/h.

(Frankfurt, from 2014/01/03 to 2014/05/31).

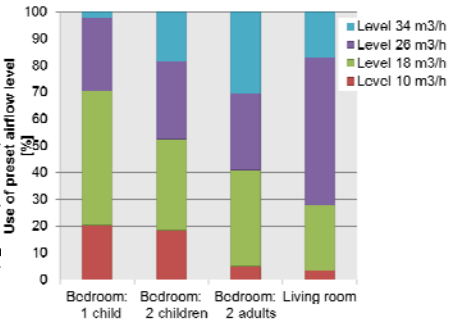
AERECO

CHECK OF THE WORKING OF THE HRV

Good distribution of the supply airflow among the 4 preset rates: 10, 18, 26 and 34 m3/h depending on the occupancy of the room.

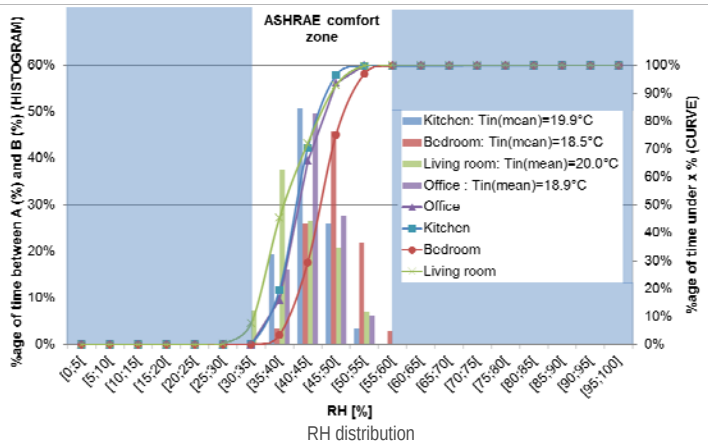


Preset CO_2 level
(Above ambient concentration)



Use of preset supply airflow rate
(Frankfurt, from 2013/11/15 to 2014/05/31)

HUMIDITY IN THE DWELLING



RH distribution
(Frankfurt, from 2014/02/13 to 2014/05/31)

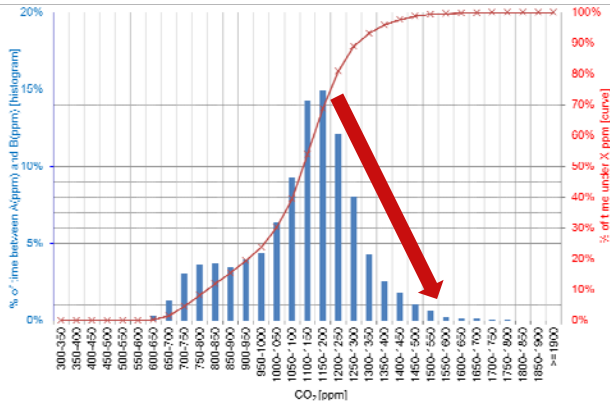
HUMIDITY IN THE DWELLING

Risks of condensation in the dwelling
(Frankfurt, from 2014/02/13 to 2014/05/31)

Room (Mean dew point temperature [°C] in March 2014)	Risk of condensation [number of minutes] (From 2014/02/13 to 2014/05/31)			
	Double glazing U=1.2 W/(m².K)	Double glazing U=2.3 W/(m².K)	Insulated ext. wall U=0.51 W/(m².K)	Non insulated ext. wall U=2.25 W/(m².K)
Kitchen (6.5)	26	116	3	112
Bedroom (6.2)	0	2	0	2
Living room (5.7)	0	0	0	0
Office (5.5)	0	0	0	0

Frankfurt: Nearly 0 risk of condensation.

CO_2 IN THE DWELLING



Good management of the supply airflow in case of high CO_2 concentrations

CO_2 distribution in a bedroom occupied by 2 adults
(Nuremberg, from 2013/11/15 to 2014/05/31)

CO_2 IN THE DWELLING

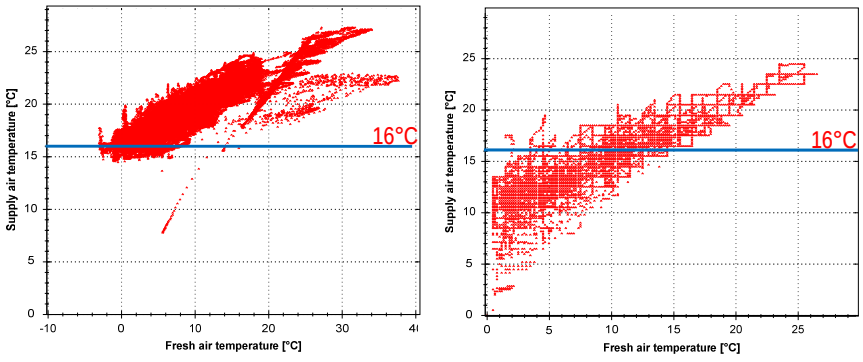
CO_2 distribution: main results in bedrooms (absolute CO_2 values in ppm)

Monitoring ref.	100 % of time under X ppm	80 % of time under X ppm
Nuremberg: 1 child	1 400	1 100
Nuremberg: 2 children	1 600	1 200
Nuremberg: 2 adults	1 650	1 250
Dortmund: 1 adult	1 250	1 100
Dortmund: 1 child	1 550	1 150
Frankfurt: 2 adults	1 600	1 050

- Occupancy of 1 person: less than 1 150 ppm 80 % of the time
- Occupancy of 2 people: less than 1 250 ppm 80 % of the time

THERMAL COMFORT

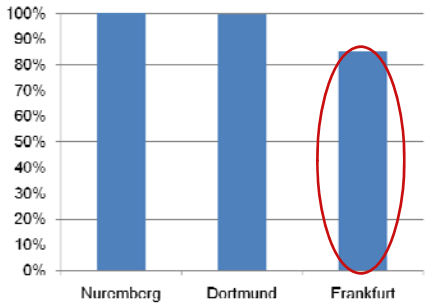
%age of time between 16 and 26°C: Nuremberg 99.3 %, Dortmund 95.6 %, Frankfurt 39.5 %



Supply air temperature as a function of fresh air temperature
(From left to right: Dortmund and Frankfurt)

THERMAL COMFORT

DR: predicted percentage of people dissatisfied due to annoyance by draft



Draught rate < 15 % in parents' bedroom (at 2 meters)

Strongly recommend the installation in the heated space.

ENERGY EFFICIENCY

Monitoring ref. (Surface m²)	Considered period	Mean airflow rate [m³/h]	Heat losses (final energy) [kWh/(m².year)]	Mean fan power (exhaust + supply) [W]
Nuremberg (106 m²)	2013/11/15 to 2014/05/31	101.6	6.5	21.9
Dortmund (111 m²)	2013/11/15 to 2014/05/31	116.9	2.2	30.7

Price per month of the ventilation (Considering a gas appliance for heating):

- Nuremberg: 10.13 €(incl. Taxes)/month
- Dortmund: 6.91 €(incl. Taxes)/month

Gas: 6.89 c€(incl tax)/kWh

Electricity: 29.21 c€(incl tax)/kWh

(Source: Eurostat European comission, 2014).

CONCLUSION AND FURTHER STEPS

- Good working of the HRV
  - Improvement of the management system.
- Good indoor air quality
  - No hours over 1 250 ppmCO_2 in the bedrooms (above ambient concentration)
  - 30 % < RH < 60%
- Good thermal comfort
  - 16°C < T_{supply} < 26°C more than 95 % of the time
- Energy efficiency
  - Nuremberg (mean SFP):
    - $SFP_{exhaust}$=0.13 W/(m^3/h)
    - SFP_{supply}=0.08 W/(m^3/h)
  - Dortmund (mean SFP):
    - $SFP_{exhaust}$=0.17 W/(m^3/h)
    - SFP_{supply}=0.08 W/(m^3/h)
- Until spring 2015
  - Study the summer functioning
  - Generalize the efficiency results

THANK YOU FOR YOUR ATTENTION

AERECO

Evaluation Methodology to Quantify the Energy Potential of DCV Strategies

S. Caillou, N. Heijmans (BBRI, Belgium)
J. Laverge, A. Jansens (Ugent, Belgium)

What is Demand Controlled Ventilation (DCV)?

Aim is to **adapt the flow** rates to the **real needs**

Detection of the needs (sensors)

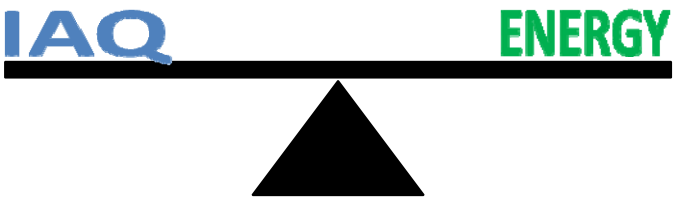
→ Regulation of the flow rates (fans, dampers, …)

➔ Energy savings

But how much are these energy savings?!

DCV is a compromise between IAQ and Energy

…But IAQ is complex!



Random or arbitrary: Flow rate ↘ ➔ Indoor Air Quality ↘

Intelligent DCV : Flow rate ↘ ➔ Indoor Air Quality =

Objective of the study

- Development of an evaluation **methodology** to **quantify the energy savings** for strategies of **DCV** systems in **dwellings**
- In the context of EPC calculation method in Belgium: Determination of **Reduction Factors** ($0 < \mathbf{f_{DCV}} < 1$)

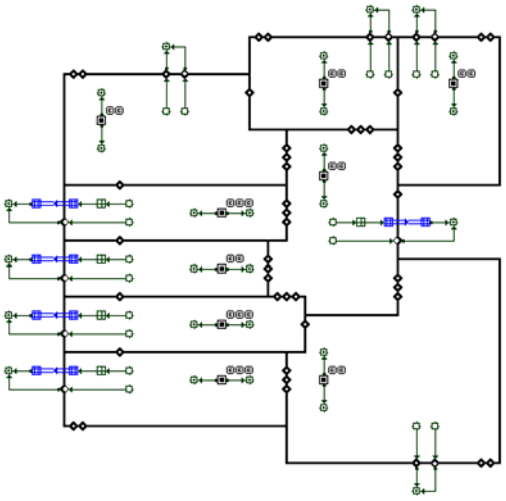
Modelling

Numerical simulations (Contam)

- Model dwelling
  - Flow rates (m³/h):

    Living: 108
    Bedroom 1: 44
    Bedroom 2: 35
    Bedroom 3: 39
    Kitchen: 60
    Service: 60
    Toilet: 30
    Bathroom: 60
    Hall: 16

    Total: 226 m³/h



Modelling

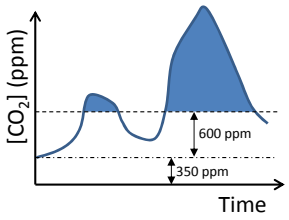
Numerical simulations (Contam)

- Sources (CO_2 and humidity)
- Output: Flow rates, CO_2, exposure, humidity, etc.
- Different occupancy profiles
- Monte Carlo Approach

How to **check** the **IAQ**?

Definition of IAQ criteria for dwellings

- **CO_2**: tracer for human occupation
  - Exposure of the occupants to [CO_2] > 600 ppm (above outdoor)
  - « Relative » criteria (no absolute limit)



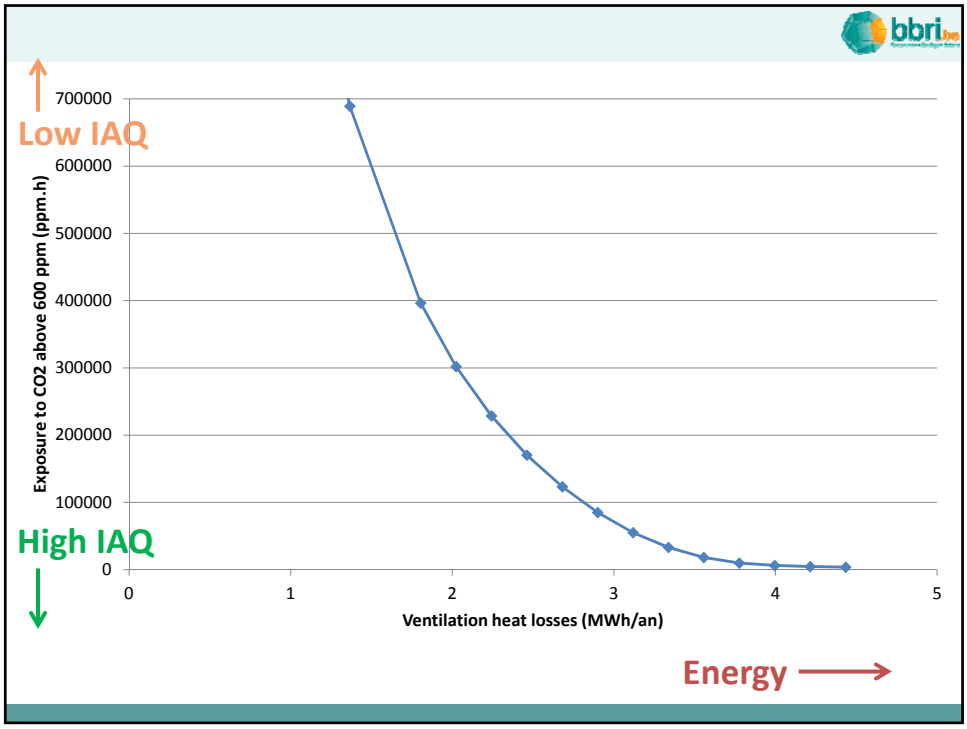
- **Relative Humidity (RH)**: risk of mold growth
  - RH on a thermal bridge (temp. factor: 0.7) must ≤ 80% (monthly average)
  - « Absolute » criteria

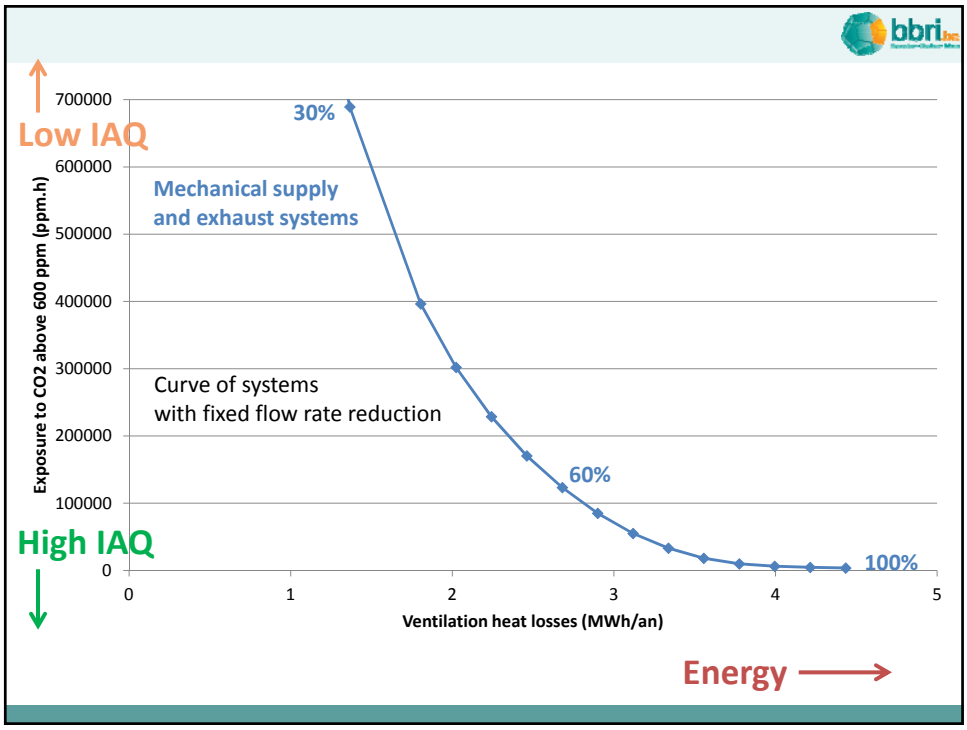
- 2 others criteria:
  - Dispersion of odours from toilets and emission from materials

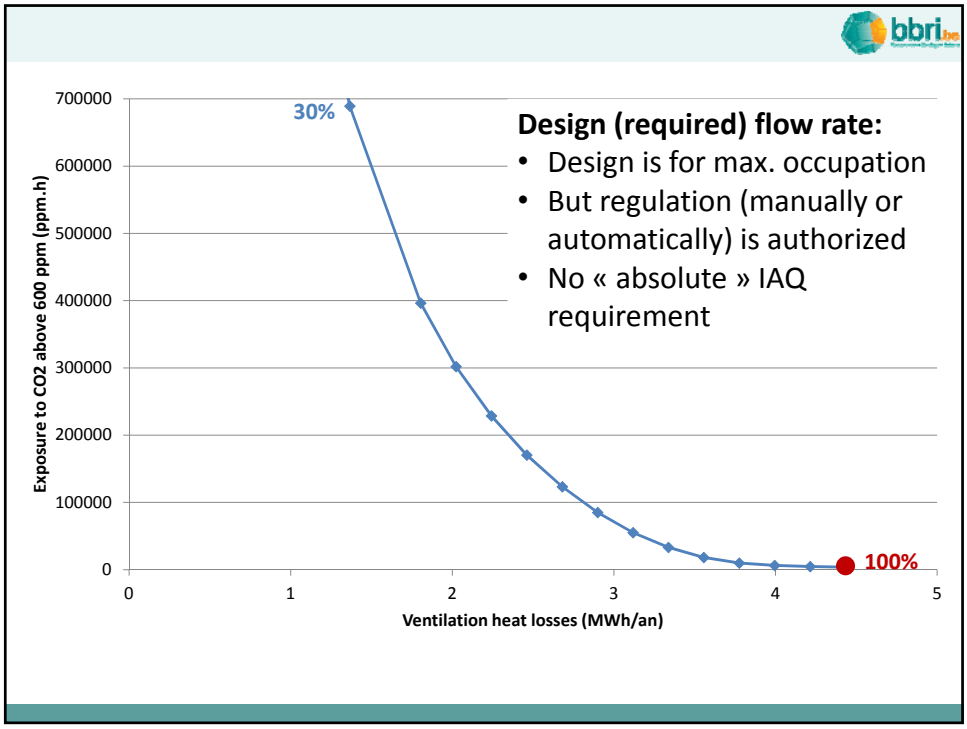
How to **quantify** the **flow rate reduction**?

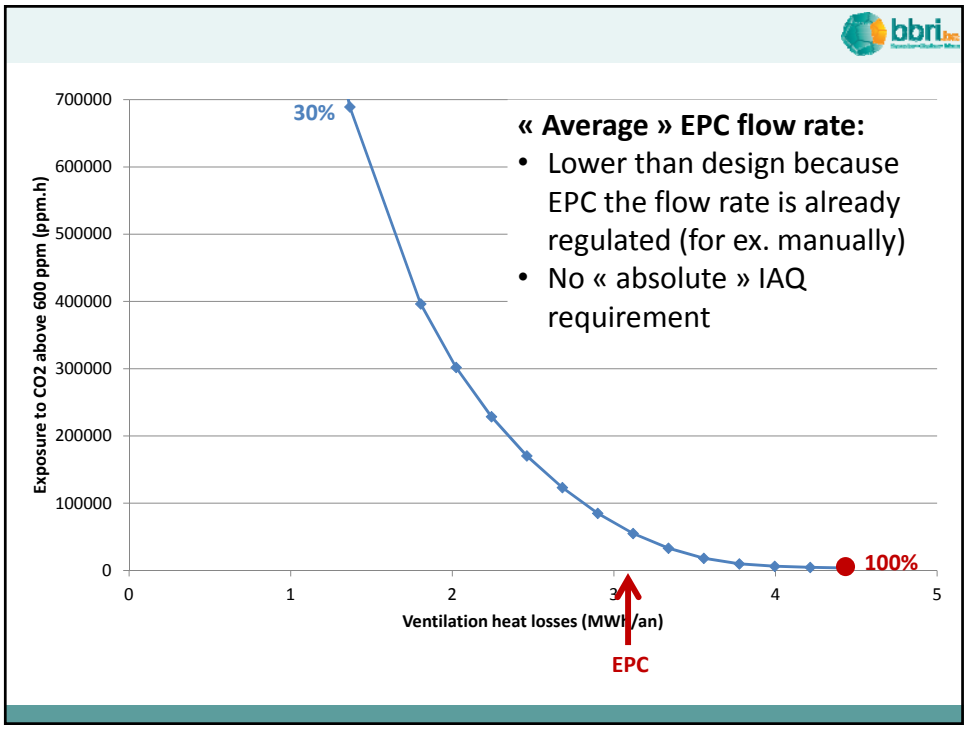
Need **reference flow rate**: which one?

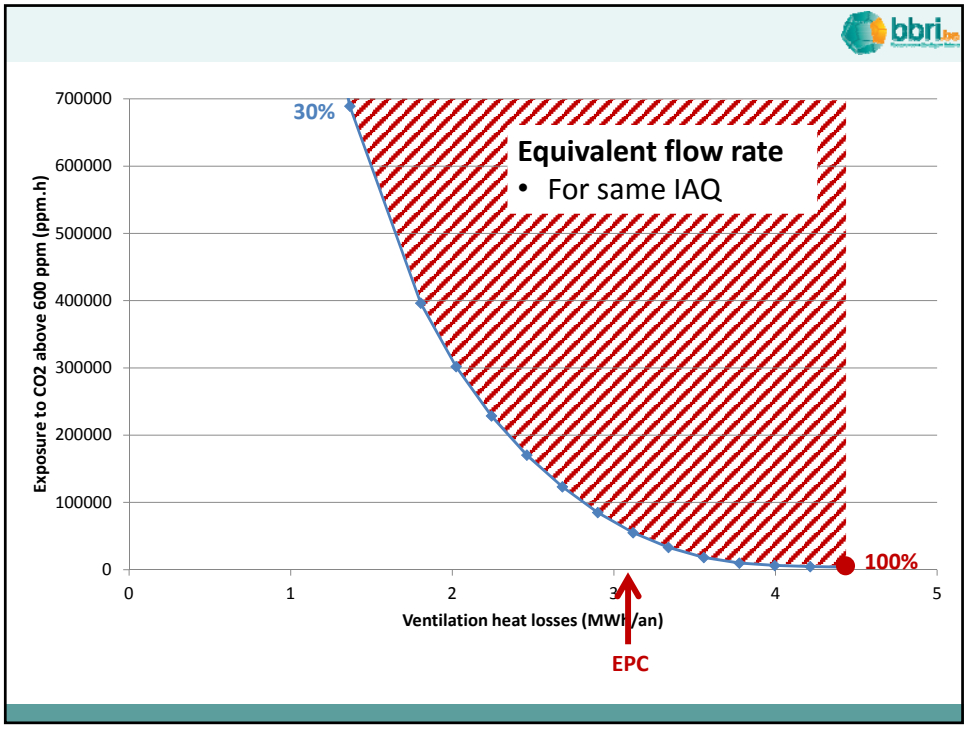
- Design (required) flow rate ?
- « Average » flow rate used in EPC calculation
- Equivalent flow rate (for same IAQ)?

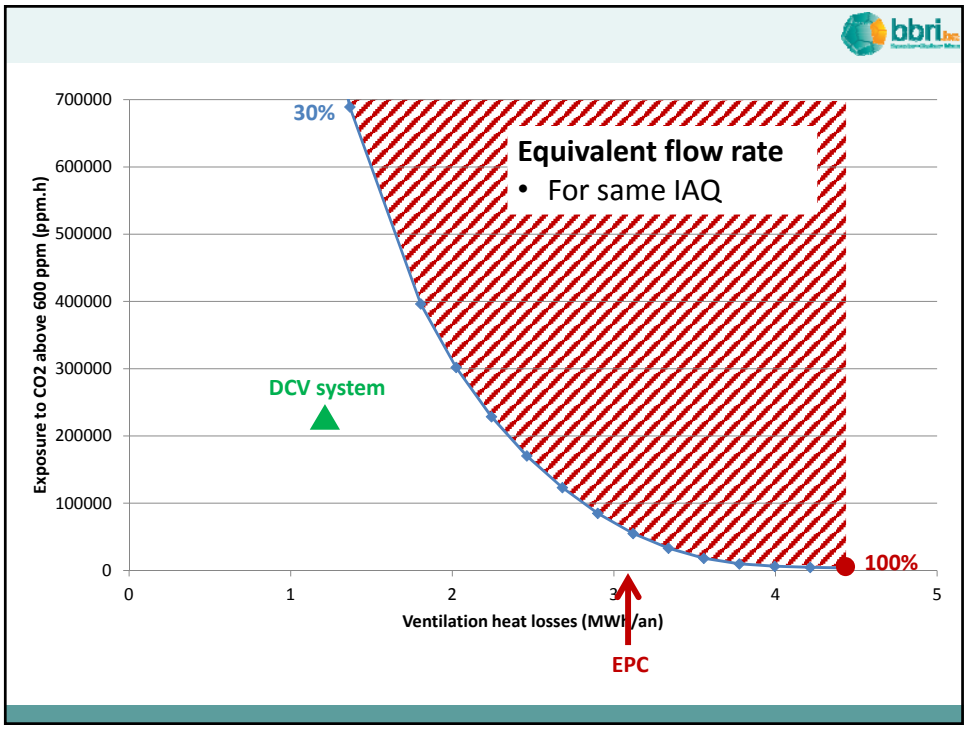

Low IAQ
High IAQ
Exposure to CO2 above 600 ppm (ppm.h)
700000
600000
500000
400000
300000
200000
100000
0
0
1
2
3
4
5
Ventilation heat losses (MWh/an)
Energy

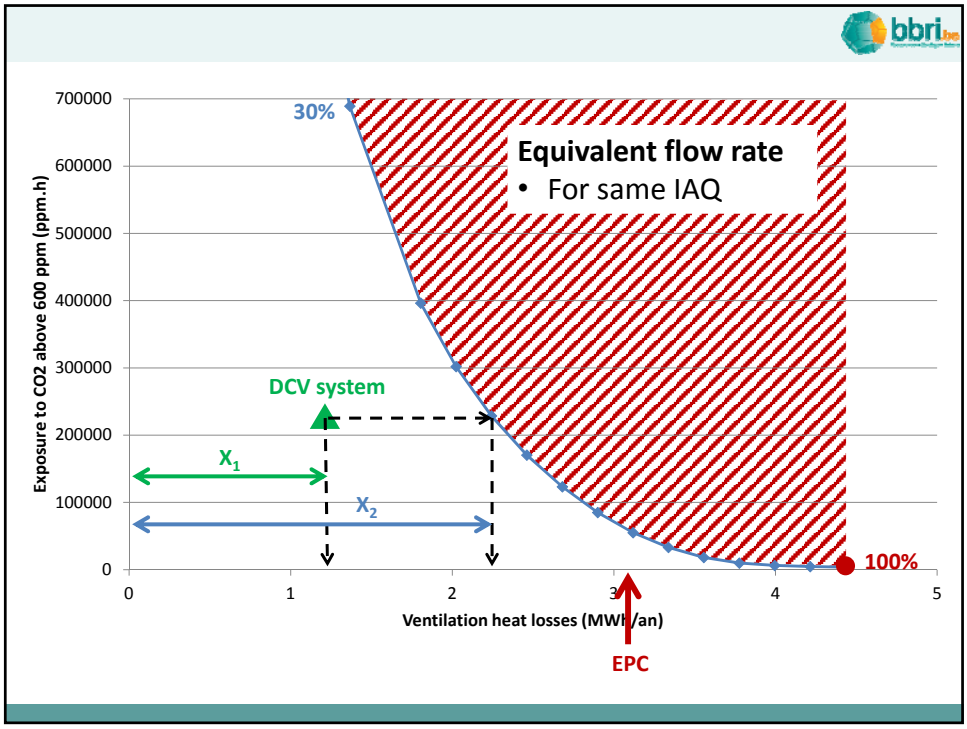

Low IAQ
High IAQ
Exposure to CO2 above 600 ppm (ppm.h)
700000
600000
500000
400000
300000
200000
100000
0
30%
Mechanical supply
and exhaust systems
Curve of systems
with fixed flow rate reduction
60%
100%
0
1
2
3
4
5
Ventilation heat losses (MWh/an)
Energy


700000
600000
500000
400000
300000
200000
100000
0
Exposure to CO2 above 600 ppm (ppm.h)
30%
100%
0
1
2
3
4
5
Ventilation heat losses (MWh/an)
Design (required) flow rate:
• Design is for max. occupation
• But regulation (manually or automatically) is authorized
• No « absolute » IAQ requirement


700000
600000
500000
400000
300000
200000
100000
0
Exposure to CO2 above 600 ppm (ppm.h)
30%
100%
0
1
2
3
4
5
Ventilation heat losses (MWh/an)
EPC
« Average » EPC flow rate:
• Lower than design because EPC the flow rate is already regulated (for ex. manually)
• No « absolute » IAQ requirement


700000
600000
500000
400000
300000
200000
100000
0
Exposure to CO2 above 600 ppm (ppm.h)
30%
Equivalent flow rate
• For same IAQ
100%
0
1
2
3
4
5
Ventilation heat losses (MWh/an)
EPC


700000
600000
500000
400000
300000
200000
100000
0
Exposure to CO2 above 600 ppm (ppm.h)
30%
Equivalent flow rate
• For same IAQ
DCV system
100%
0
1
2
3
4
5
Ventilation heat losses (MWh/an)
EPC



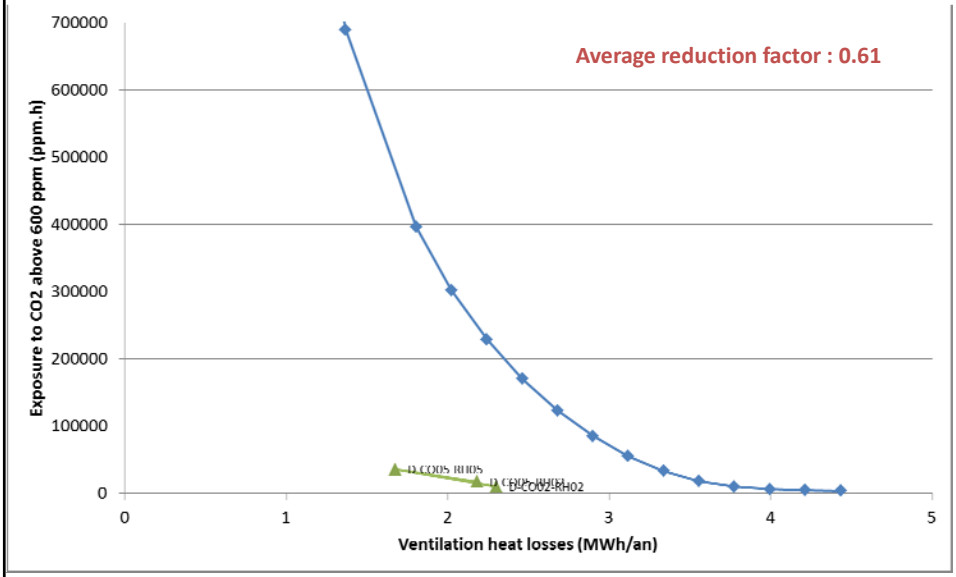
Tested DCV strategies

- Type of **detection**
  - Type of sensors
    - Living spaces: no detection, **CO_2** or **presence detection**
    - Service spaces: no detection or **RH** (kitchen, bathroom, laundry) + **presence detection** in toilets
  - **Local** (sensor in each space), **partially local** or **centralised** (sensor in plenum) detection
- Type of **regulation**
  - **Supply** and/or **exhaust**
  - **Local** (each space separately) or **centralized** (at the fan) regulation

CO_2 + RH: Maximum potential of DCV

- Living spaces
  - CO_2 detection locally in each living space
  - Local regulation of the supply flow rate in each living space
- Service spaces
  - RH detection locally in each service space (presence detection in toilet)
  - Local regulation of the exhaust flow rate in each service space
- Total supply and total exhaust ajusted to highest detection

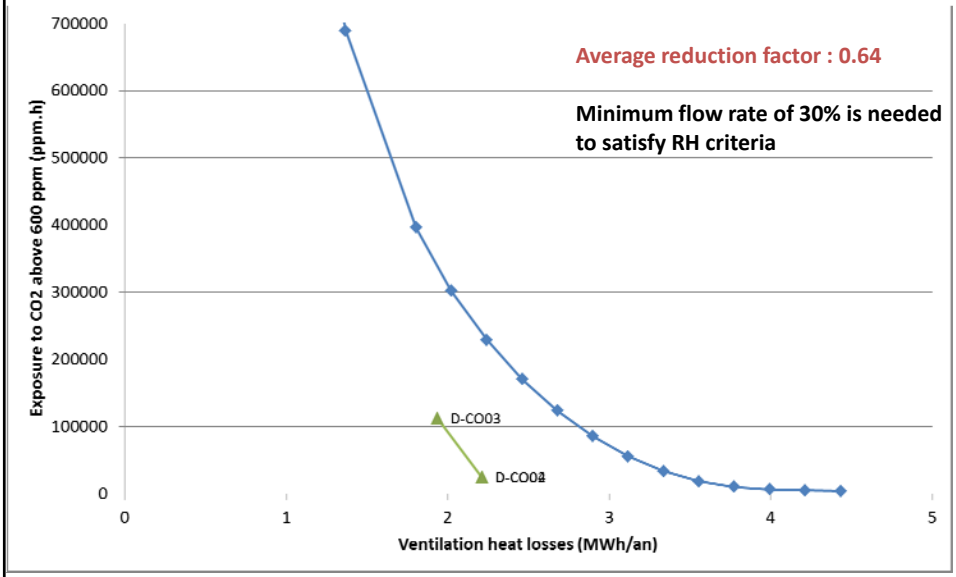
CO_2 + RH: Maximum potential of DCV



DCV with only CO_2 detection in living spaces

- Living spaces
  - CO_2 detection locally in each living space
  - Local regulation of the supply flow rate in each living space
- Service spaces
  - Total exhaust ajusted to total supply flow rate

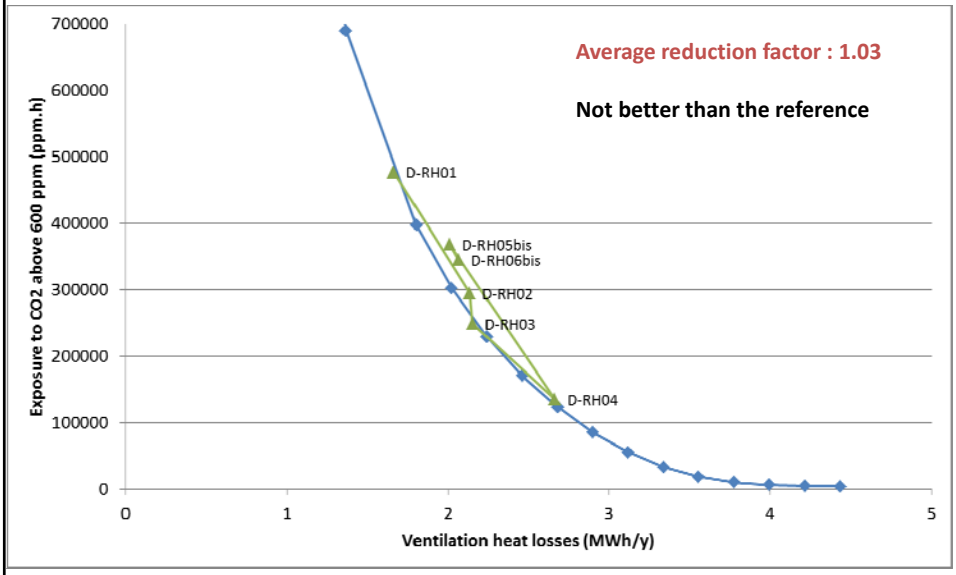
DCV with only CO_2 detection in living spaces



DCV with only RH detection in the service spaces

- Service spaces
  - RH detection locally in each service space (presence detection in toilet)
  - Local regulation of the exhaust flow rate in each service space
- Living spaces
  - Total supply ajusted to total exhaust flow rate

DCV with only RH detection in the service spaces



Conclusions

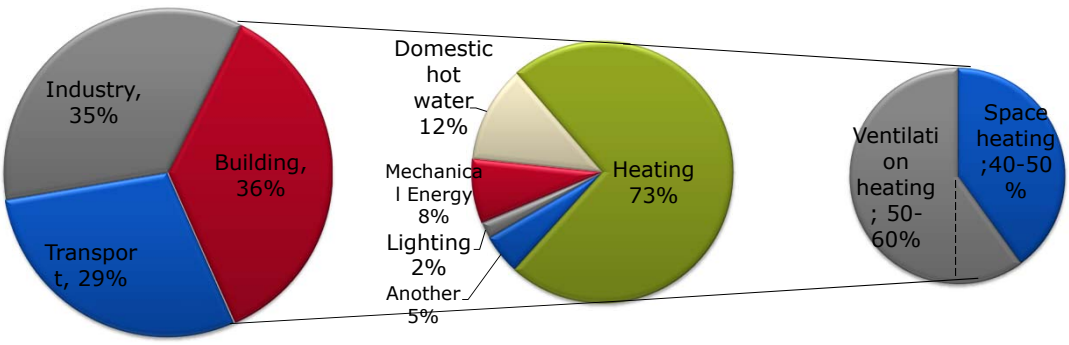
- DCV requires a careful quantification
  - IAQ ⟷ Energy
  - IAQ is complex!
- An equivalent flow rate is proposed as E reference
- Tested DCV strategies
  - CO_2 + RH: max → f_{DCV} = 0.61
  - CO_2 only → f_{DCV} = 0.64
  - RH (service) only → not better than reference

Multi-zone demand-controlled ventilation in residential buildings: An experimental case study

Arefeh Hesaraki

KTH Royal Institute of Technology
Division of Fluid and Climate Technology

Energy consumption in north EU



Background

- 90 % of our time indoor
- 60 % in our residential building
- Indoor contaminant is more dangerous than outdoor pollutant
- Essential to have sufficient ventilation rate and acceptable indoor air quality
- Reducing infiltration and changing windows to retrofit old buildings with natural ventilation causes reduction in air circulation
- Results in poor IAQ
- IAQ should be never sacrificed to save energy
- Efficient mechanical ventilation is needed to have better IAQ, e.g. demand-controlled ventilation, heat recovery system

Demand-controlled ventilation (DCV)

- Why fresh air is needed in vacant room?
- Reduce the primary energy consumption (heat loss and ventilation fan) by adjusting the amount of ventilation air based on the occupants' needs

- Ventilation in occupied building: 0.35 $l \cdot s^{-1} \cdot m^{-2}$
- Ventilation in vacant building: 0.10 $l \cdot s^{-1} \cdot m^{-2}$ to remove pollutants from furniture and building materials

- More common in office buildings due to more unpredictable occupancy levels
- The need to reduce energy demand has led to this system also becoming interesting in residential buildings

Controlled variables

- In residential and office buildings human are the main pollutant source in the room → CO_2 is used as an indicator of indoor air quality
- CO_2 level in habitable spaces: threshold is 1000 ppm as an indicator of acceptable IAQ
- VOC level: 0.1 ppm (problem in new building with high emission rate)

Case study

Location	Borlänge, Sweden
Type	Single family house
Built in	1950s
Area	92 m^2 in 2 stories
Renovation status	• Heat source was changed from furnace to ground source heat pump in 2009 • Renovated with better windows and insulated internally in 2013

Case study

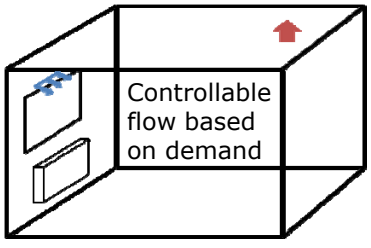
- Problem after retrofitting: natural ventilation significantly decreased due to reducing the pressure difference caused by chimney and infiltration rate caused by leaky envelope
- Consequence: poor IAQ
- Solution: mount controllable mechanical ventilation in order to force enough air based on the demand in each zone, called multi-zone demand-controlled ventilation

Aim

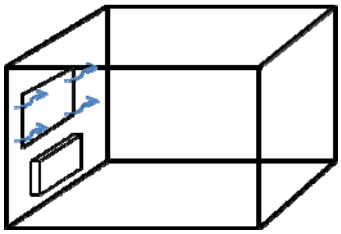
Measure :

- CO_2 level,
- temperature,
- airchange rate, and
- relative humidity before and after retrofitting

- Demand controlled ventilation



- Natural ventilation

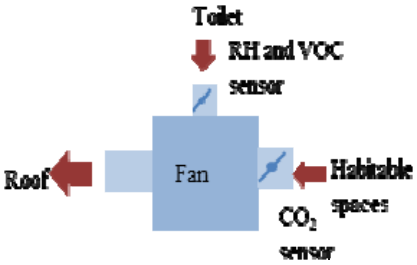


Method

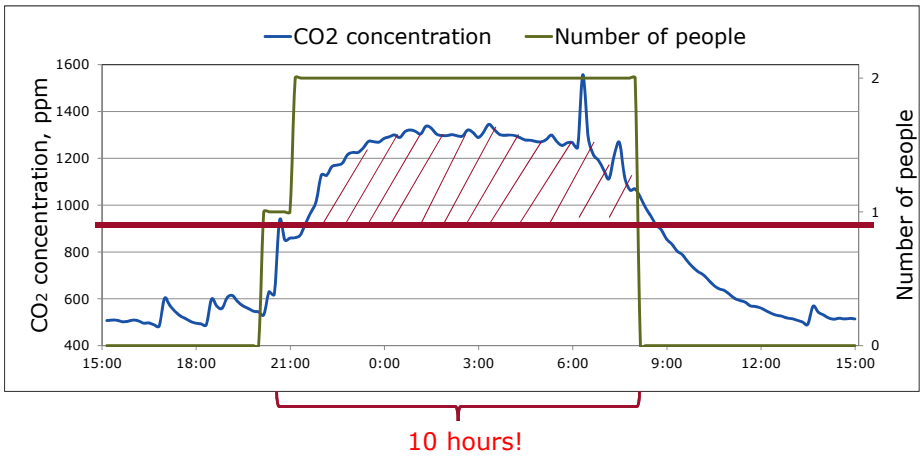
- Experimental investigation of IAQ and energy consumption before and after mounting demand-controlled ventilation

✓IAQ: CO_2 and RH (not uniform in the whole room, so to detect mean value sensors were placed in the exhaust valves)

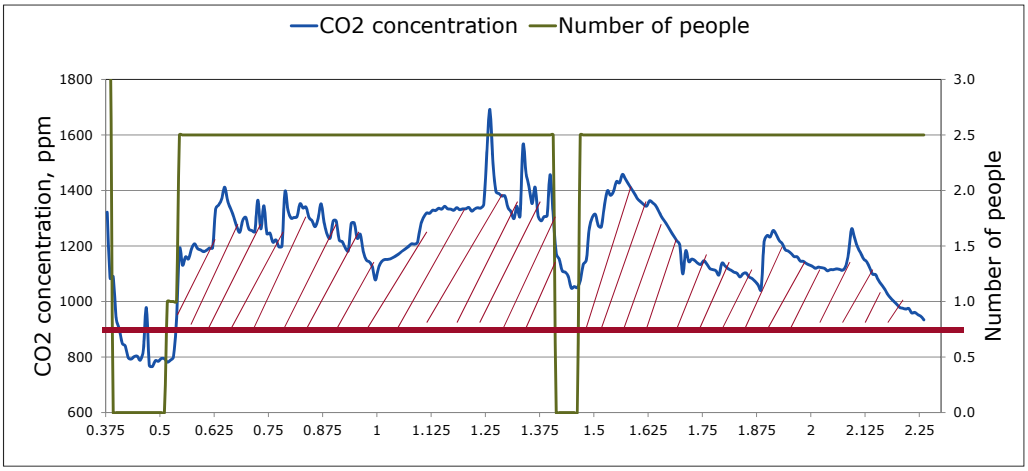
✓Energy saving: ventilation fan energy consumption and ventilation heat loss



Result: IAQ with natural ventilation in working day

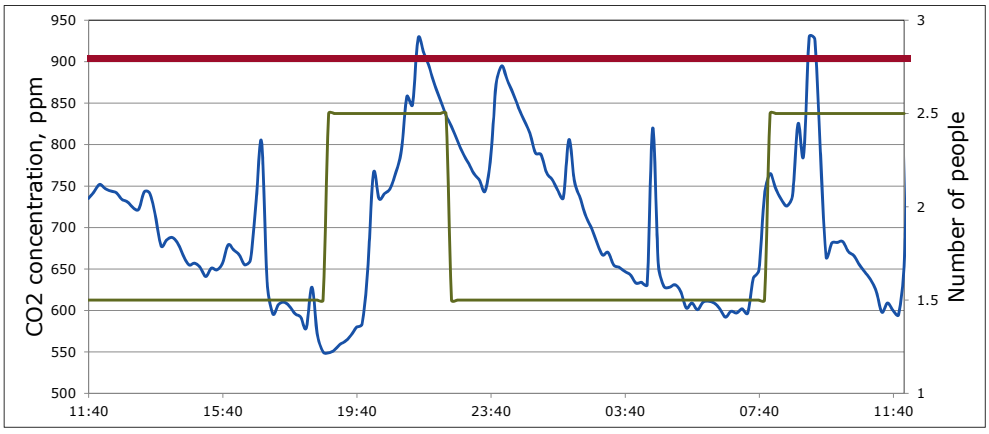


Result: IAQ with natural ventilation during weekend

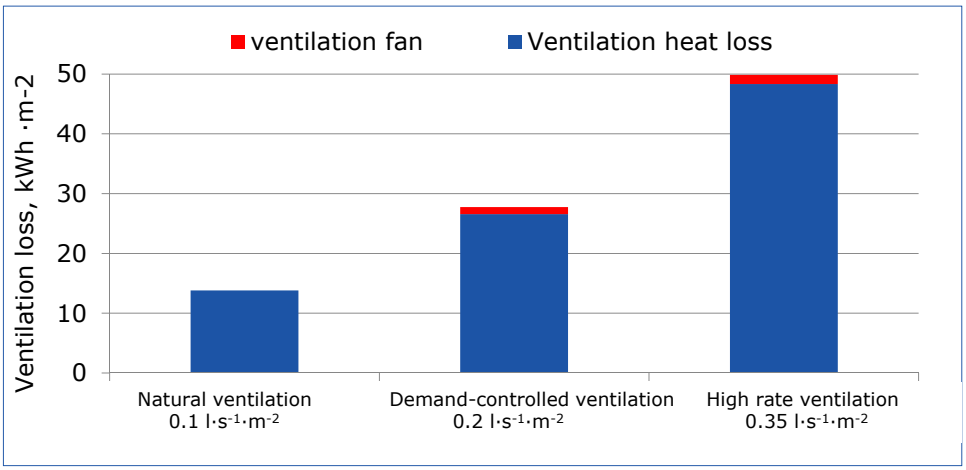


Result: IAQ with demand-controlled ventilation

- Threshold level for CO_2 was set to 900±50 ppm



Result: Energy saving



Conclusion

- Renovating old houses by making them more airtight or changing furnace with other types of heat source causes to lose natural ventilation rate
- Degrade IAQ
- Need to change ventilation system
- Demand controlled-ventilation
- Control set point for ventilation flow rate was based on the CO_2 level in habitable spaces and the relative humidity and VOC for the toilet and bathroom
- DCV provided better IAQ compared to natural ventilation
- 44 % saving in ventilation heating and ventilation fan consumption compared to constant ventilation system

Thanks for your attention!

arefeh@kth.se

DURABLE AIRTIGHTNESS IN SINGLE-FAMILY DWELLINGS

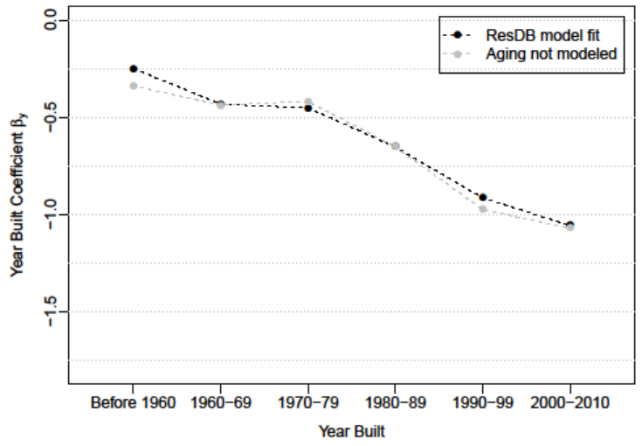
MAX SHERMAN
WANYU (RENGIE) CHAN
LBL

AIVC 2014 Conference

BACKGROUND

- Our analysis from Residential Diagnostic Database (ResDB) suggests that air leakage increases for older homes
  - Were they built leakier: Year of construction effect
  - Did they become leaker: Aging effect
- See http://resdb.lbl.gov for database

Year Built or Aging?



Normalized Leakage is Metric

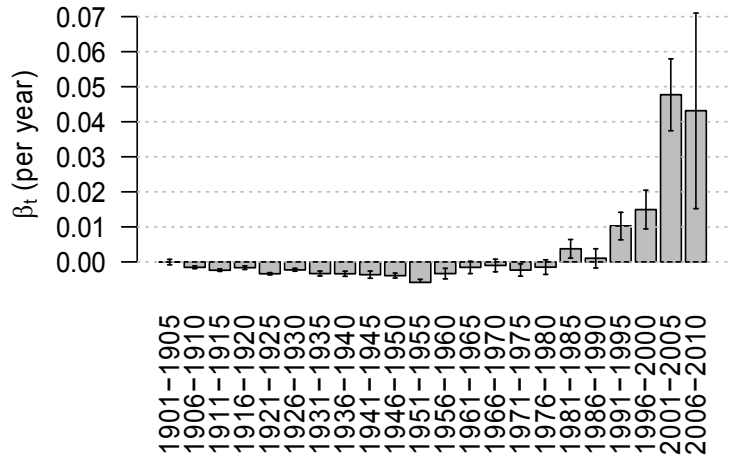
- Scales well
  - Skip definition today $n_{50} = N_{50} \approx 20 \cdot NL$
- Database Regresses NL

$$ln(NL_0) = \boldsymbol{\beta}_z \square \mathbf{CZ} + \boldsymbol{\beta}_y \square \mathbf{YR} + \beta_i LI + \beta_e EN + \beta_a FA + \beta_h H + \beta_f FR + \beta_d DT + \varepsilon$$

- Can we get aging factor?

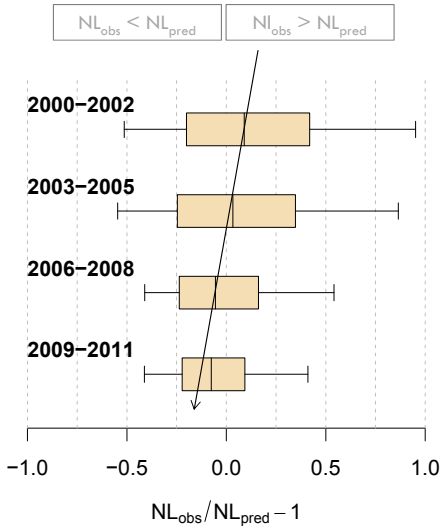
$$ln(NL_t) = ln(NL_0) + \beta_t T$$

Can Estimate Aging From ResDB



What is Recent Trend: No Aging

- We selected homes in ResDB built after year 2000, all tested within one year of year-built
- We then applied the same regression model to account for the dependency of normalized leakage (NL) on other house characteristics, with the exception of year built
- Comparison of the observed (NL_{obs}) and predicted (NL_{pred}) normalized leakage suggests NL is decreasing with year built



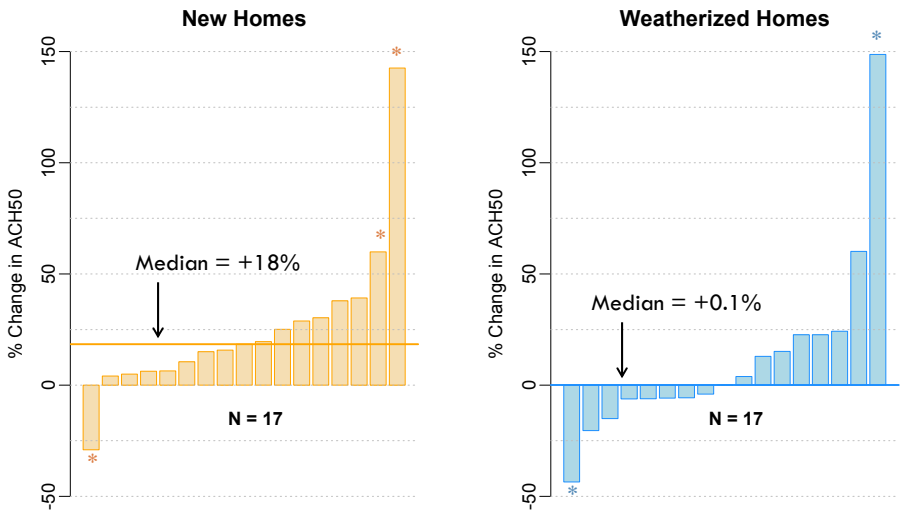
How To Sort Out?

- How much of it is from houses getting leakier with time and how much from improved construction?
- We collected blower door data from single-family homes to evaluate the change in airtightness over time.
- This data makes the case to not only consider the test-when-new blower door results, but also value building systems that are durable.

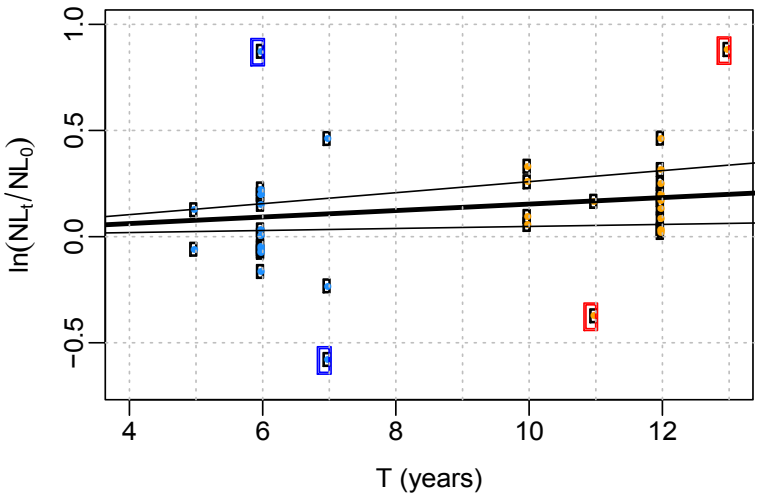
Used 2 Partners to Take New Data

- Field testing done in collaboration with two organizations:
  - Southface Energy Institute (Building America Team: PHI)
  - Community Action Partnership of Idaho (CAPAI)
- Each did 17 houses
  - One set new houses
  - One set "weatherized" older houses

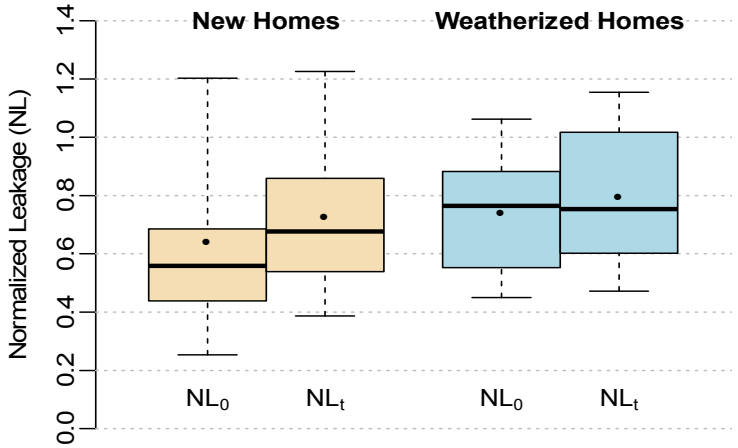
% Change: ⇧ in N_{50} in New Homes



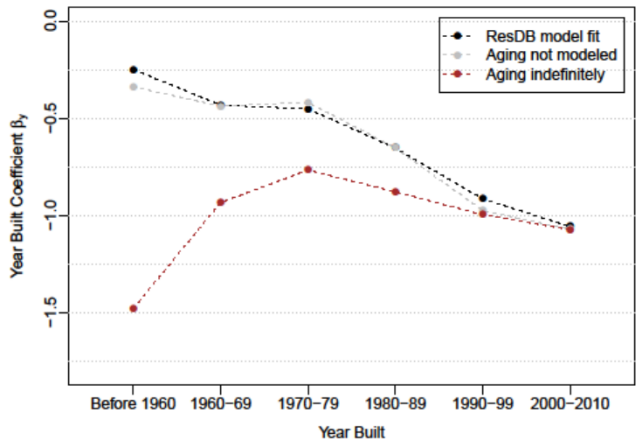
NL Change Over Time



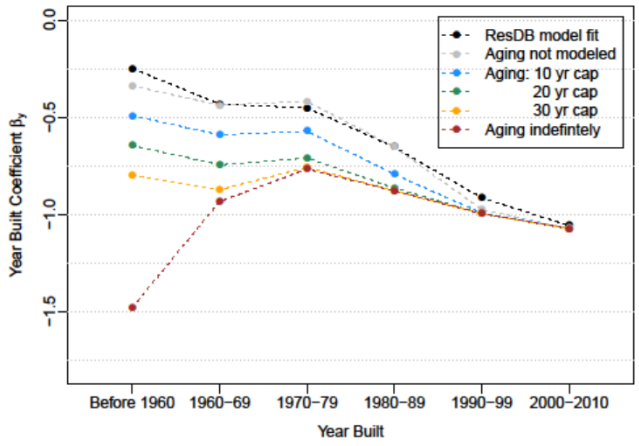
Use DB to Isolate Aging Effect



Use Aging Factor From New Data



Suppose We Cap Aging Time?



TENTATIVE CONCLUSIONS

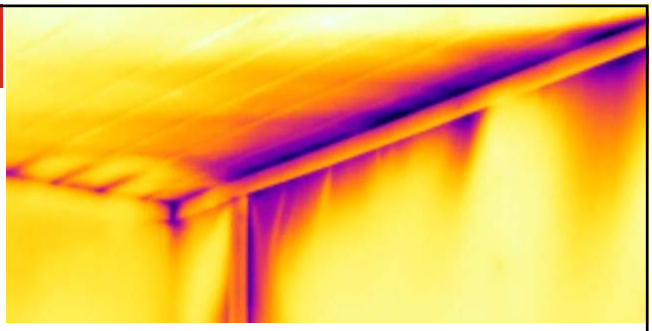
- New Houses Get Leakier As They Age
  - 1% per year seems like a representative value
- Aging Effect Goes Away
  - Maybe after 10-20 years
  - Occupant repairs/improvements balance degradation
- Needs More Data
  - Based on only 2x17 houses…would like big data
  - But effect seems qualitatively correct

QUESTIONS?

Thank you for your attention

What Does That Tell Us?

- Data is the subset of full dataset that has they date the tightness test was made: *Could* be biased.
- Aging factor *could* be variable
  - E.g., houses get leakier for the first 20 years or so and then reach some kind of equilibrium
- Occupants *could* modify air tightness over time
  - Improvements would show as negative values
- Let's consider limited aging factor based on measurements for database.



DURABILITY OF BUILDING AIR TIGHTNESS

POZNAN 24-25 September 2014

Magnus Hansén

SP Sveriges Tekniska Forskningsinstitut

THE PROJECT GROUP

Project leader:	Peter Ylmén
Project coordinator:	Pär Åhman
Project group:	FoU-Väst
	Rolf Jonsson, Wäst-Bygg
	Martin Sandberg, NCC
	Patrik Bengtsson, Skanska
	Magnus Hansén, SP
	Jörgen Romild, SP
	Stefan Almström, SP

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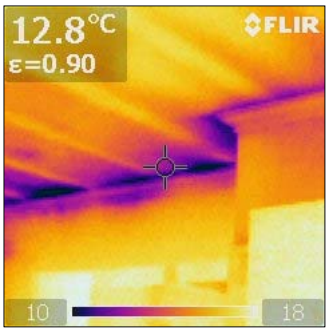
THE PROJECT CONSISTS OF TWO PARTS…

TESTS IN REAL BUILDINGS



LABORATORY TESTS OF PRODUCTS

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TESTING OF BUILDINGS

Six residential houses were tested.

Wooden construction with plastic sheeting.

Five houses built approx. 20 years ago and one 10 years ago.

Difficult to find unchanged houses with enough documentation from previous tests.

Half had original design while the others had made some kind of refurbishment or add-on.

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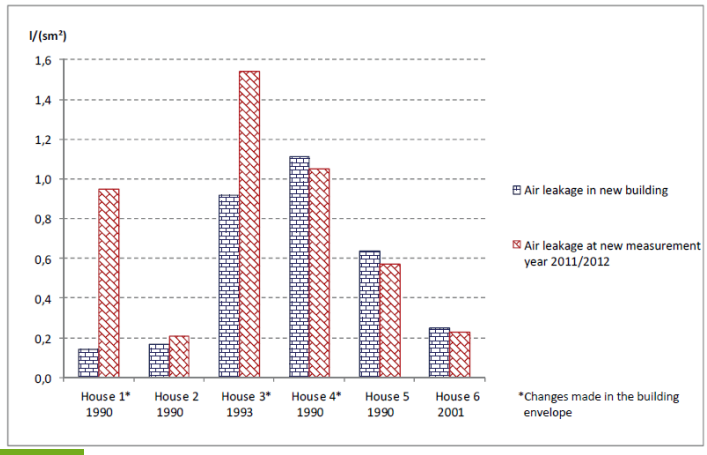
RESULTS FROM REAL BUILDINGS



Two of the houses had a large increase in air leakage while the other had maintained their air tightness.

The increase in air leakage could to a large extent be explained by insufficiently air tight add-ons.

Since the air tight layer is located inside the construction and no damage to the buildings were allowed we don't know exactly the solutions that have been implemented.

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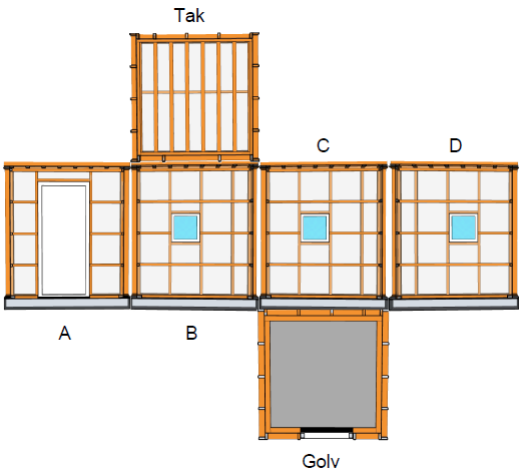
LABORATORY TEST OF PRODUCTS

To test different products in real life scale a 2.2x2.2x2.4 m test rig was built.

Smaller samples was also placed inside the room to perform standardized tests.



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TEST RIG IN REALITY

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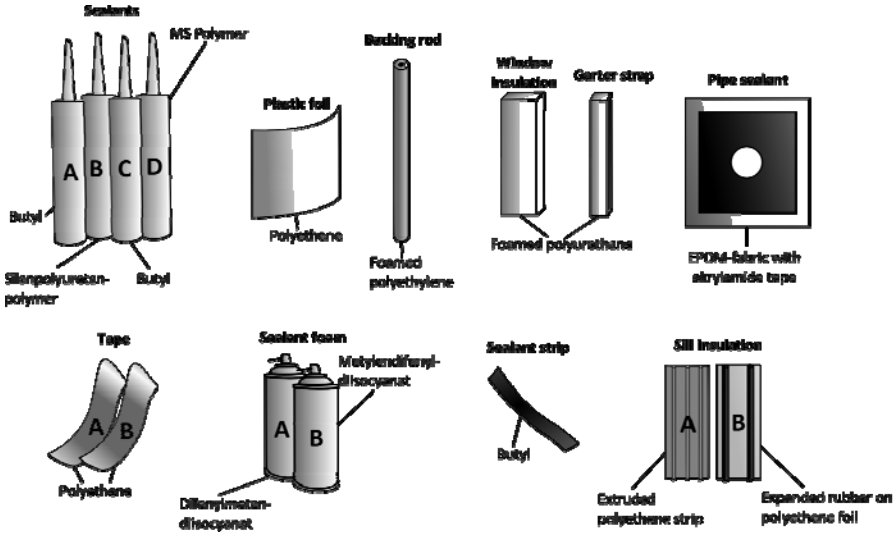
TESTED MATERIALS



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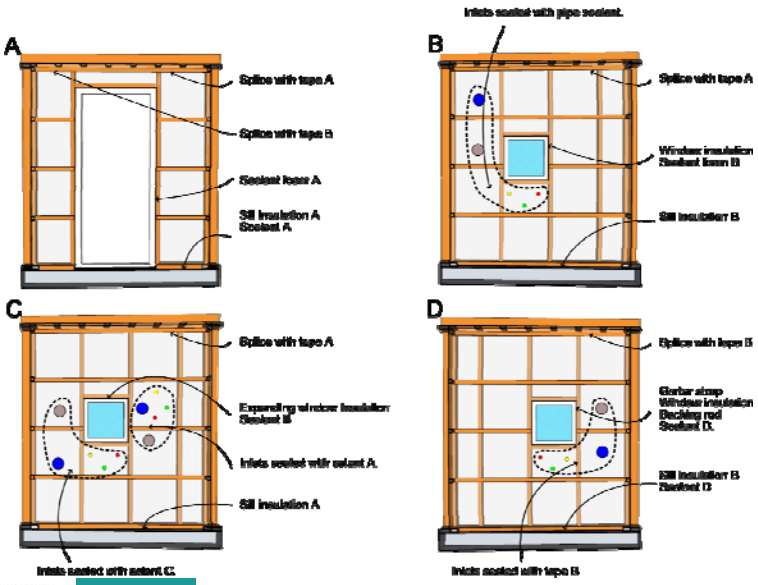
PLACEMENT OF PRODUCTS



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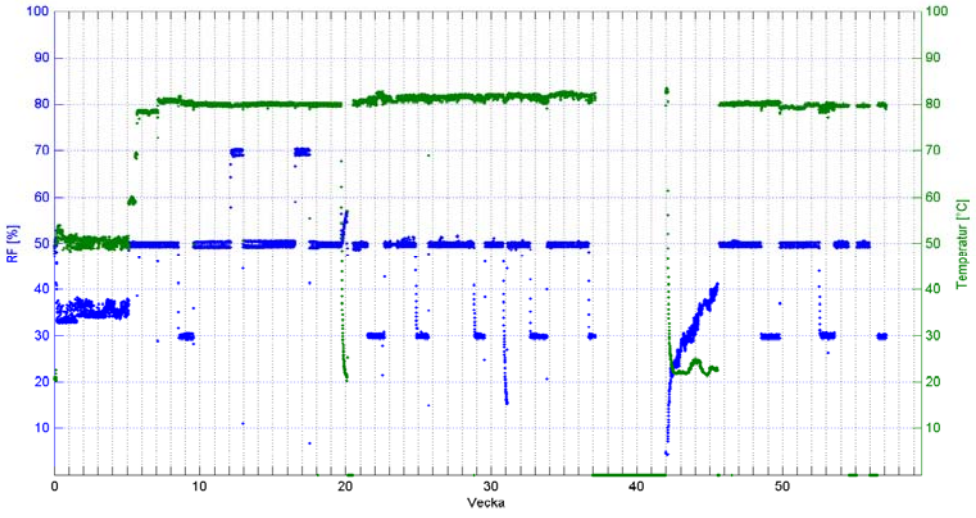
CLIMATE INSIDE THE TEST RIG

80 °C for approx. one year.

Varied 50 % and 30 % relative air moisture.

Corresponds to approx. 50 years.



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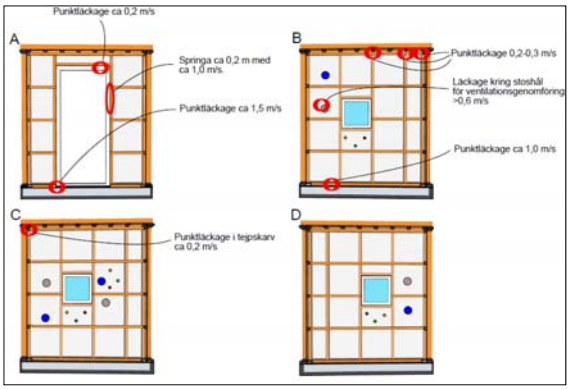
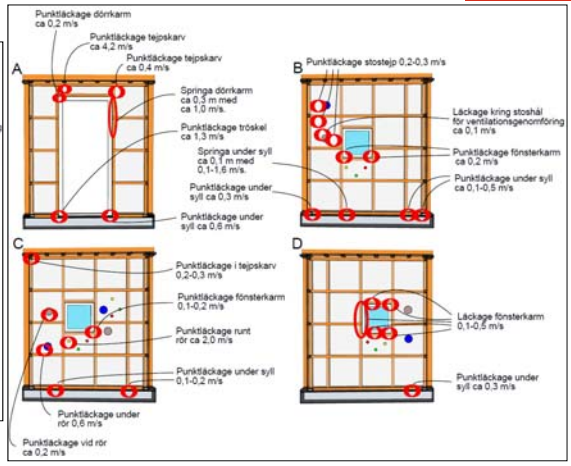
AIR LEAKAGE BEFORE AND AFTER AGEING





BEFORE

AFTER

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RESULTS FROM TEST RIG

Most of the products were air tight after accelerated ageing.

Exceptions were the tapes, one sill insulation and two sealants.

Evaluation was performed by visual inspection.

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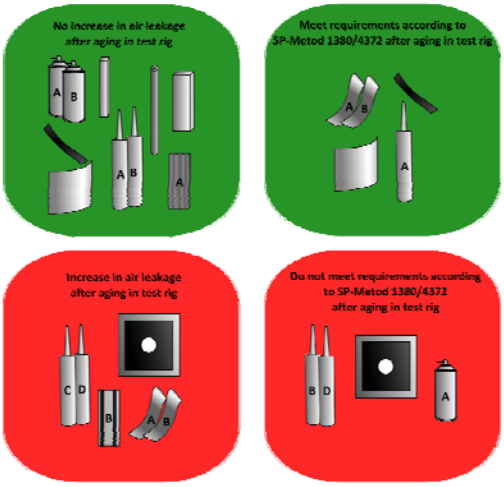

RESULT FROM TEST SAMPLES

Not all products were tested this way.

The result differed for two tapes, one sealant and the sealant foam compared to the test rig.

Sealant foam and sealant can eventually be explained by extra margins in the requirements.

For the tapes it can be dependent on the differences in scale between the tests.

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CONCLUSIONS

From the results that been achieved in this project the following conclusions are made:

- It is possible to build construction with plastic foil as an air tight layer and maintain the air tightness in buildings. Tests from real buildings shows that the method has a durability of at least 20 years and laboratory tests shows that the durability can be as long as 50 years if the right products are used.
- At refurbishments there is a great risk that the air leakage is increased.

In the laboratory test there were small basis for each product type. Thus no general conclusions can be made and the results are only for the tested products. These results shows that:

- The chosen tape products pass the requirements for sample tests but lowered their performance in the real scale test. This might mean that the test methods as well as the splicing methods with tapes needs to be looked into .
- The chosen products for sealant foam failed the standardized tests but passed in the test rig.
- Some of the chosen sealants remained air tight after accelerated aging while other had poor durability. The results differed between standardized tests and the test rig here as well. The differences might be explained that thicker joints have been used in the test rig and that the are some safety margins in the standardized tests.
- One sill insulation had a similar degradation as the tapes – air channels are created because of different dimension stability between the materials in the products.
- There are no signs that the construction material used in the test rig influences the durability of the sealants products at normal conditions for buildings. Although it hasn't been investigated how e.g. dynamic mechanical forces like wind loads or water affects the materials.

SP Sveriges Tekniska Forskningsinstitut

DO YOU WANT TO KNOW MORE…

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Report (Swedish):
www.sbuf.se
www.cerbof.se

SP Sveriges Tekniska Forskningsinstitut

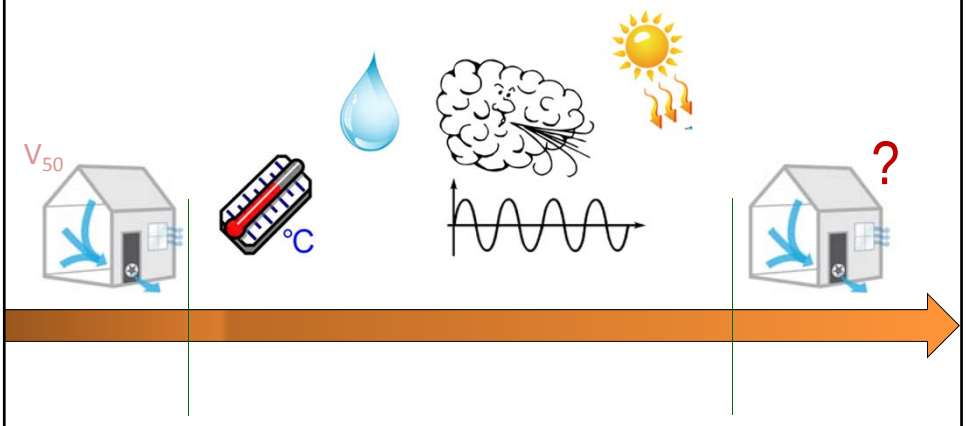
Assessment of the durability of the airtightness of building elements via laboratory tests

Clarisse Mees
Benoît Michaux
Evelyne Nguyen
Xavier Loncour

Conference AIVC 2014 – Poznan

Pressurization test at the end of the construction works

But later… ?



Pressurization test at the end of the construction works

But later… ?

Tests campaign

Which building elements did we test ?

- 48 different walls divided into 4 families:
  - Walls of blocks/bricks whose airtightness is ensured by coatings/plastering
    - Plastering (internal side)
    - Clay-based coating (internal side)
    - External coatings/plastering
  - Walls whose airtightness is ensured by a membrane
  - Walls whose airtightness is ensured by wood panels
  - Walls composed by industrialized systems
    - Sandwich panels
    - Architectural concrete panels

Tests campaign

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    - Sandwich panels
    - Architectural concrete panels

Building elements tested in laboratory

What do we measure ?

- Illustration of the installation:

→Air permeability q_{50} ($m^3/(h.m^2)$)

Tests campaign

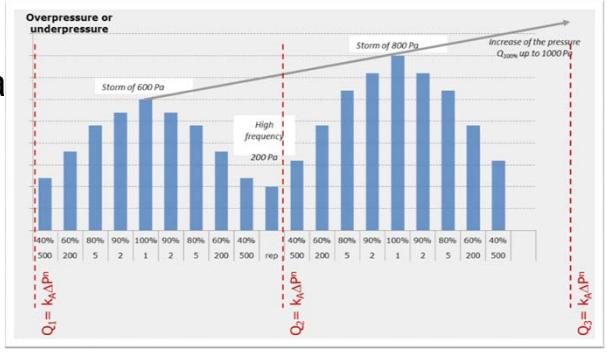
Which ageing methods did we use ?

- Wind cycles - Storm
- Moisture variation
- Temperature variation

Tests campaign

Which ageing methods did we use ?

- Wind cycles – Storm
- Moisture variation
- Temperature varia



Tests campaign

Which ageing methods

- Wind cycles - Storm
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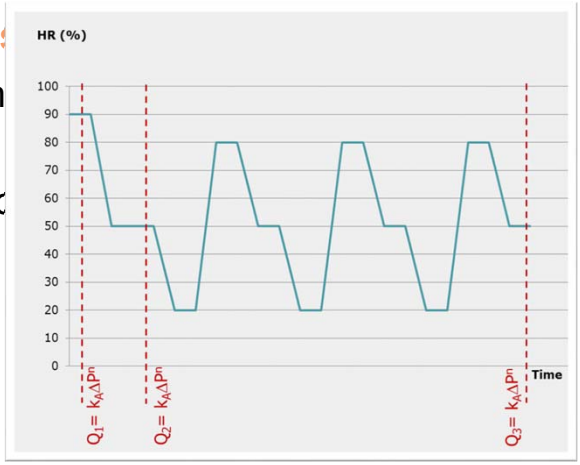

Tests campaign

Which ageing methods did we use ?

- Wind cycles - Storm
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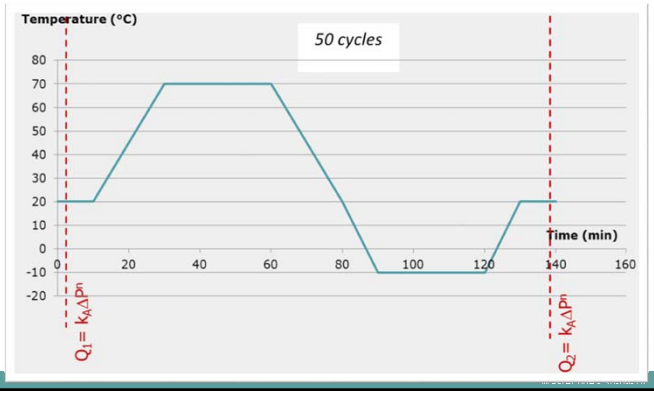
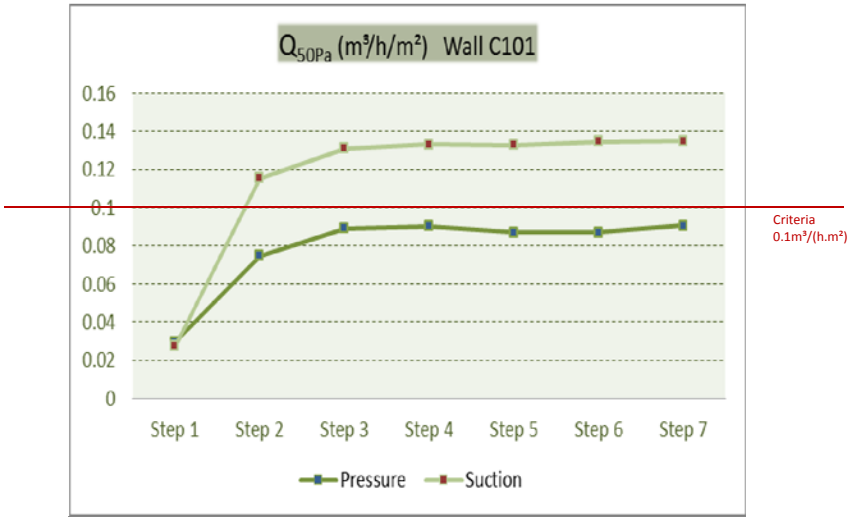
- Temperature variation



Criteria

Example of results



The results

Evolution of the Q50 and impact on the construction details

- Walls of blocks/bricks whose airtightness is ensured by plastering on the internal side
- Walls whose airtightness is ensured by a membrane

The results

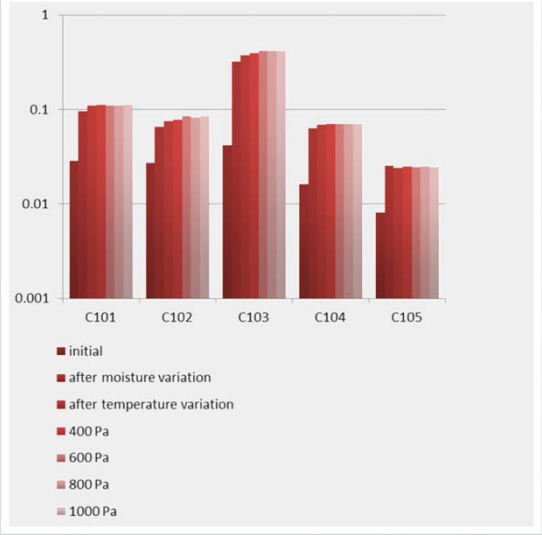
Evolution of the Q50 and impact on the construction details

- **Walls of blocks/bricks whose airtightness is ensured by plastering on the internal side**
- Walls whose airtightness is ensured by a membrane

Airtightness ensured by plastering on the internal side

Airtightness ensured by plastering on the internal side

Evolution of the q_{50} for different types of plastering



Ref	Description
C 101	Wall of blocks + plastering (thickness= **6 mm**)
C 102	Wall of blocks + plastering (thickness= **17 mm**)
C 103	Wall of blocks + plastering (thickness= **3 mm**)
C 104	Wall of blocks + plastering (thickness= **4 mm**)
C 105	Wall of blocks + plastering (thickness= **18 + 2 mm**)

Airtightness ensured by plastering on the internal side

Conclusions

- The thickness but also the quality of the surface (finishing) and the particle size influence the airtightness initial performance
- Only moisture and thermal ageing influence the airtightness
- Significant loss of airtightness after hygrothermal cycles

The results

Evolution of the Q50 and impact on the construction details

- Walls of blocks/bricks whose airtightness is ensured by plastering on the internal side
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The results

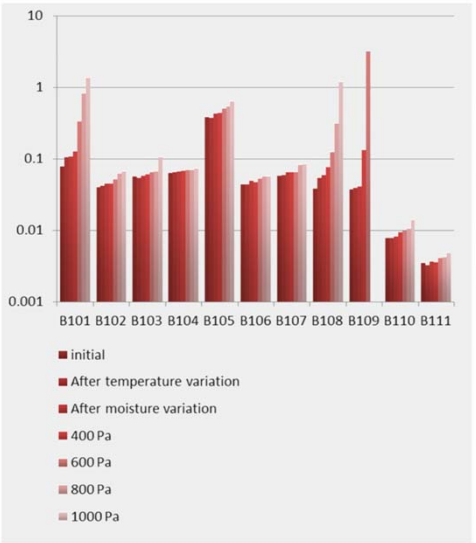
Evolution of the Q50 and impact on the construction details

- Walls of blocks/bricks whose airtightness is ensured by plastering on the internal side
- **Walls whose airtightness is ensured by a membrane**

Walls whose airtightness is ensured by a membrane

Walls whose airtightness is ensured by a membrane

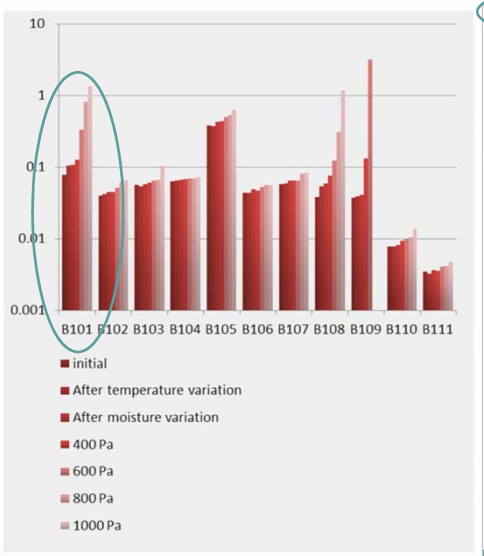
Evolution of the q_{50} for different membranes and/or implementation



Ref	Description
B 101	Membrane type A, in one piece (no joint), **stapled, without tape or lathing**. (Dim.: 1.2x1.2m)
B 102	Membrane type A, in one piece (no joint), **stapled, with vertical lathing**. (Dim.: 1.2x1.2m)
B 103	Membrane type A, stapled, vertical placing, joint made with **double sided tape, staples and vertical lathing**. (Dim.: 1.2x1.2m)
B 104	Membrane type A, stapled, vertical placing, joint made with **single sided tape, staples and vertical lathing**. (Dim.: 1.2x1.2m)
B 105	Membrane type A, stapled, vertical placing, joint made with single sided tape and staples. And **horizontal lathing**. (Dim.: 1.2x1.2m)
B 106	Membrane type A, stapled, vertical placing, joint made with **single sided tape, staples and vertical lathing**. (Dim.:2.4x2.4m)
B 107	**Membrane type B**, stapled, vertical placing, joint made with single sided tape, staples and vertical lathing (Dim.:2.4x2.4m)
B 108	Membrane type A, stapled, **horizontal placing**, joint made with single sided tape, staples and horizontal lathing. (Dim.:2.4x2.4m)
B 109	**Membrane type C**, stapled **+ tape**, vertical placing, joint made with single sided tape, staples and horizontal lathing. (Dim.:2.4x2.4m)
B 110	Membrane type C, stapled, vertical placing, **standing joint made with double sided tape**, staples and vertical lathing. (Dim.:2.4x2.4m)
B 111	Membrane type C, stapled, vertical placing, **standing joint with glue and vertical lathing.** (Dim.: 1.2x1.2m)

Walls whose airtightness is ensured by a membrane

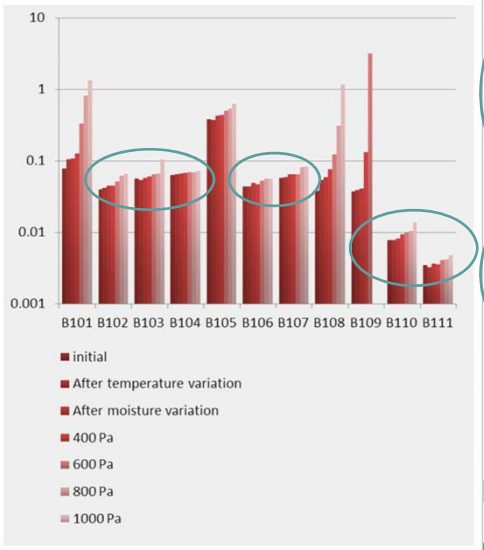
Evolution of the q_{50} for different membranes and/or implementation



Ref	Description
B 101	Membrane type A, in one piece (no joint), **stapled, without tape or lathing**. (Dim.: 1.2x1.2m)
B 102	Membrane type A, in one piece (no joint), **stapled, with vertical lathing**. (Dim.: 1.2x1.2m)
B 103	Membrane type A, stapled, vertical placing, joint made with **double sided tape, staples and vertical lathing**. (Dim.: 1.2x1.2m)
B 104	Membrane type A, stapled, vertical placing, joint made with **single sided tape, staples and vertical lathing**. (Dim.: 1.2x1.2m)
B 105	Membrane type A, stapled, vertical placing, joint made with single sided tape and staples. And **horizontal lathing**. (Dim.: 1.2x1.2m)
B 106	Membrane type A, stapled, vertical placing, joint made with **single sided tape, staples and vertical lathing**. (Dim.:2.4x2.4m)
B 107	**Membrane type B**, stapled, vertical placing, joint made with single sided tape, staples and vertical lathing (Dim.:2.4x2.4m)
B 108	Membrane type A, stapled, **horizontal placing**, joint made with single sided tape, staples and horizontal lathing. (Dim.:2.4x2.4m)
B 109	**Membrane type C**, stapled + **tape**, vertical placing, joint made with single sided tape, staples and horizontal lathing. (Dim.:2.4x2.4m)
B 110	Membrane type C, stapled, vertical placing, **standing joint made with double sided tape**, staples and vertical lathing. (Dim.:2.4x2.4m)
B 111	Membrane type C, stapled, vertical placing, **standing joint with glue and vertical lathing.** (Dim.: 1.2x1.2m)

Walls whose airtightness is ensured by a membrane

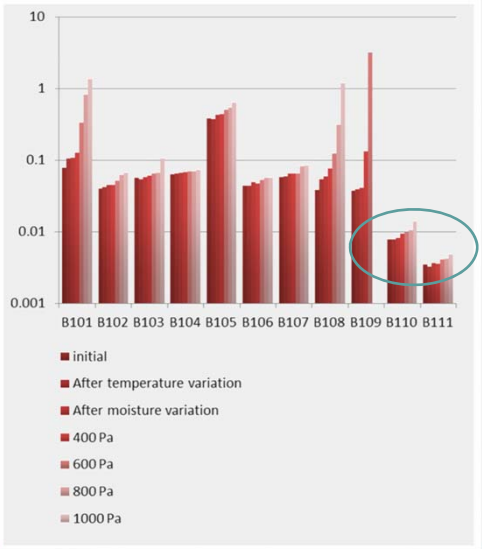
Evolution of the q_{50} for different membranes and/or implementation



Ref	Description
B 101	Membrane type A, in one piece (no joint), **stapled, without tape or lathing**. (Dim.: 1.2x1.2m)
B 102	Membrane type A, in one piece (no joint), **stapled, with vertical lathing**. (Dim.: 1.2x1.2m)
B 103	Membrane type A, stapled, vertical placing, joint made with **double sided tape, staples and vertical lathing**. (Dim.: 1.2x1.2m)
B 104	Membrane type A, stapled, vertical placing, joint made with **single sided tape, staples and vertical lathing**. (Dim.: 1.2x1.2m)
B 105	Membrane type A, stapled, vertical placing, joint made with single sided tape and staples. And **horizontal lathing**. (Dim.: 1.2x1.2m)
B 106	Membrane type A, stapled, vertical placing, joint made with **single sided tape, staples and vertical lathing**. (Dim.:2.4x2.4m)
B 107	**Membrane type B**, stapled, vertical placing, joint made with single sided tape, staples and vertical lathing (Dim.:2.4x2.4m)
B 108	Membrane type A, stapled, **horizontal placing**, joint made with single sided tape, staples and horizontal lathing. (Dim.:2.4x2.4m)
B 109	**Membrane type C**, stapled + **tape**, vertical placing, joint made with single sided tape, staples and horizontal lathing. (Dim.:2.4x2.4m)
B 110	Membrane type C, stapled, vertical placing, **standing joint made with double sided tape**, staples and vertical lathing. (Dim.:2.4x2.4m)
B 111	Membrane type C, stapled, vertical placing, **standing joint with glue and vertical lathing.** (Dim.: 1.2x1.2m)

Walls whose airtightness is ensured by a membrane

Evolution of the q_{50} for different membranes and/or implementation



Ref	Description
B 101	Membrane type A, in one piece (no joint), **stapled, without tape or lathing**. (Dim.: 1.2x1.2m)
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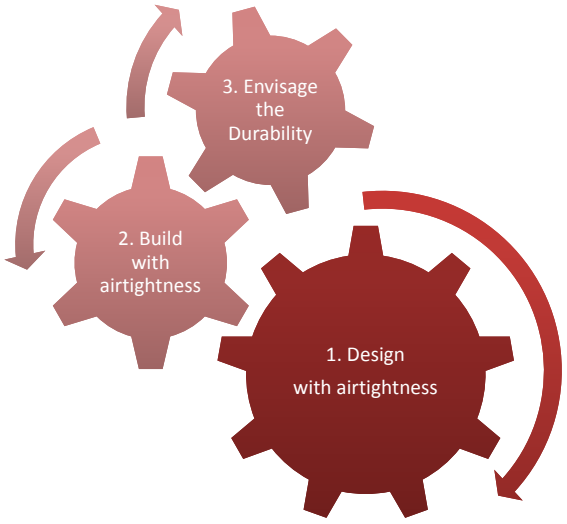
B 106	Membrane type A, stapled, vertical placing, joint made with **single sided tape, staples and vertical lathing**. (Dim.:2.4x2.4m)
B 107	**Membrane type B**, stapled, vertical placing, joint made with single sided tape, staples and vertical lathing (Dim.:2.4x2.4m)
B 108	Membrane type A, stapled, **horizontal placing**, joint made with single sided tape, staples and horizontal lathing. (Dim.:2.4x2.4m)
B 109	**Membrane type C**, stapled + **tape**, vertical placing, joint made with single sided tape, staples and horizontal lathing. (Dim.:2.4x2.4m)
B 110	Membrane type C, stapled, vertical placing, **standing joint made with double sided tape**, staples and vertical lathing. (Dim.:2.4x2.4m)
B 111	Membrane type C, stapled, vertical placing, **standing joint with glue and vertical lathing.** (Dim.: 1.2x1.2m)

Walls whose airtightness is ensured by a membrane

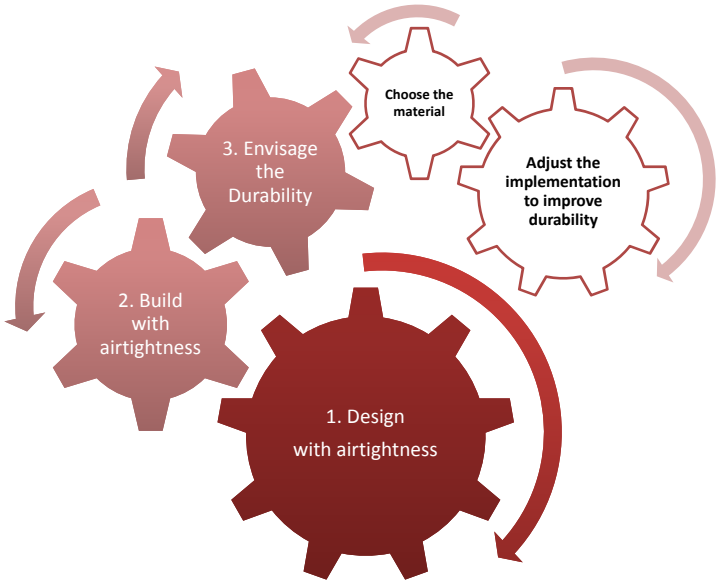
Conclusion

- Stapling the membrane is not a durable implementation
- If construction is exposed to wind, an additional lathing recovery is needed
- The horizontal lathing is not sufficient when the construction is exposed to wind
- The compatibility between membrane and tape requires verification
- When the membranes are glued with a non-rigid stand, folding the two membranes with double-sided tape gives significant performance

General conclusions



General conclusions



Thank you for your attention

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AIRTIGHTNESS OF BUILDING PENETRATIONS

Wolf Bracke
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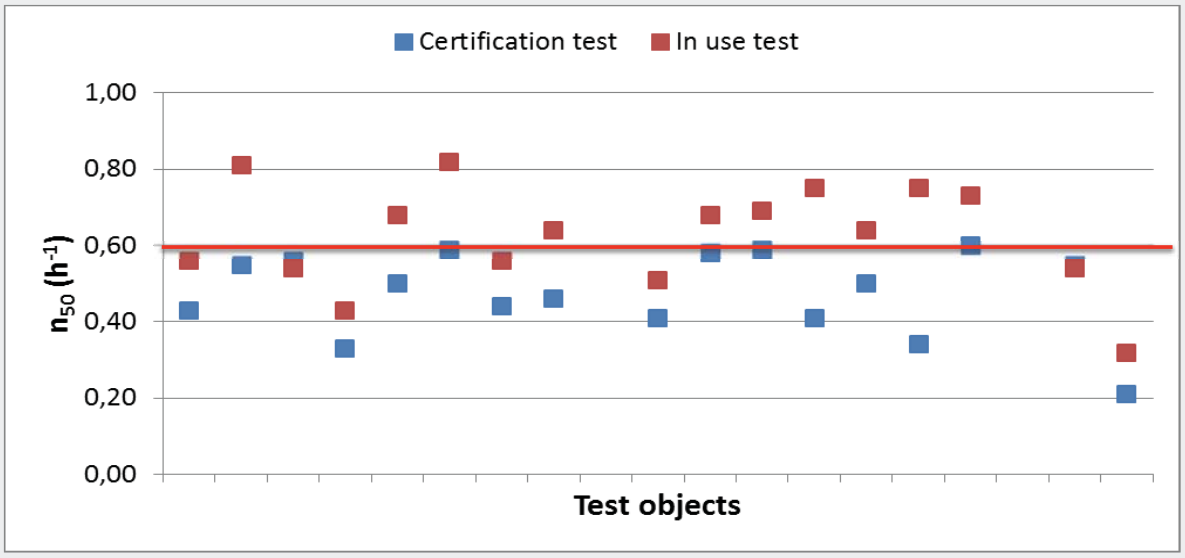
35th AIVC Conference • Poznan, Poland • 24-25 September 2014

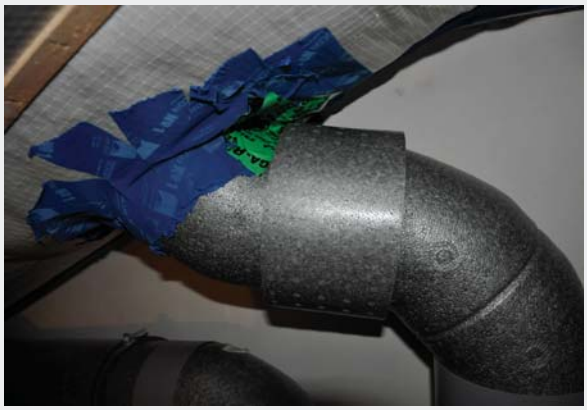
Department of Architecture and Urban Planning – Research Group of Building Physics
Ghent University

- Presentation outline
  - Airtightness problems in practice
  - Test setup and measurement procedure
  - Test results
  - Classification of tested solutions

- Measurement campaign in passive houses: durability of airtightness



Average increase in air leakage: 32%

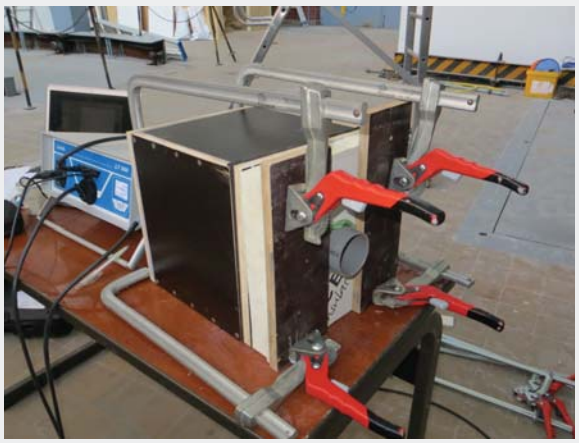


→

V_{50_house} = 254 m^3/h → V_{50_house} = 239 m^3/h

$V_{50_penetration}$ = 15 m^3/h = 6 % V_{50_house}

Large-scale test setup
→ Penetrations installed together in wood-frame wall

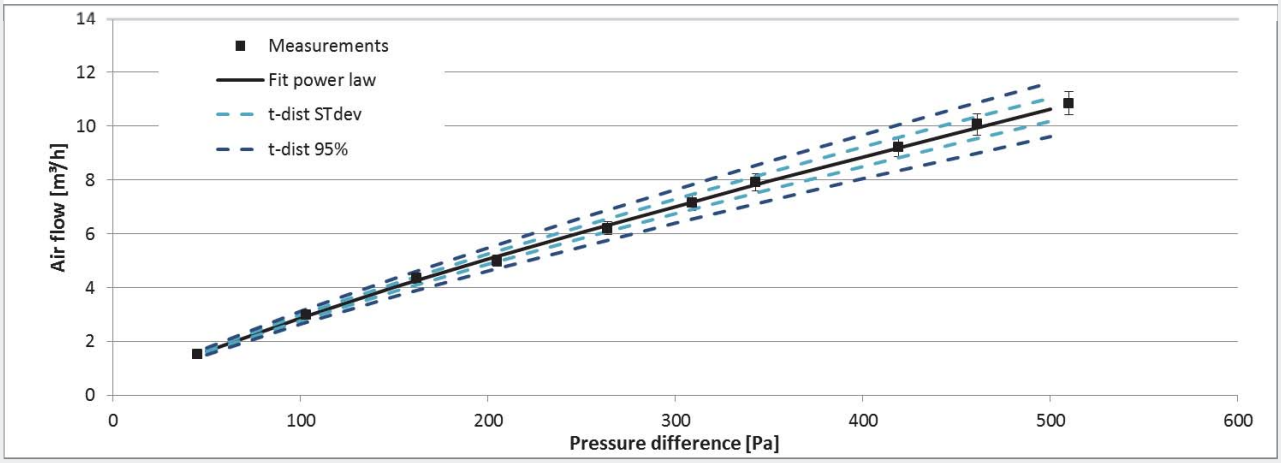


Small-scale test setup
→ Penetrations installed one by one in separate samples

Large-scale test setup:

- Designed to test airtightness of windows
- Air flow measurement: pressure difference over orifice plate

Measurements										
ΔP [Pa]	45	103	162	205	264	309	343	419	461	510
V [m³/h]	1,50	2,94	4,29	4,95	6,14	7,09	7,83	9,13	9,96	10,73



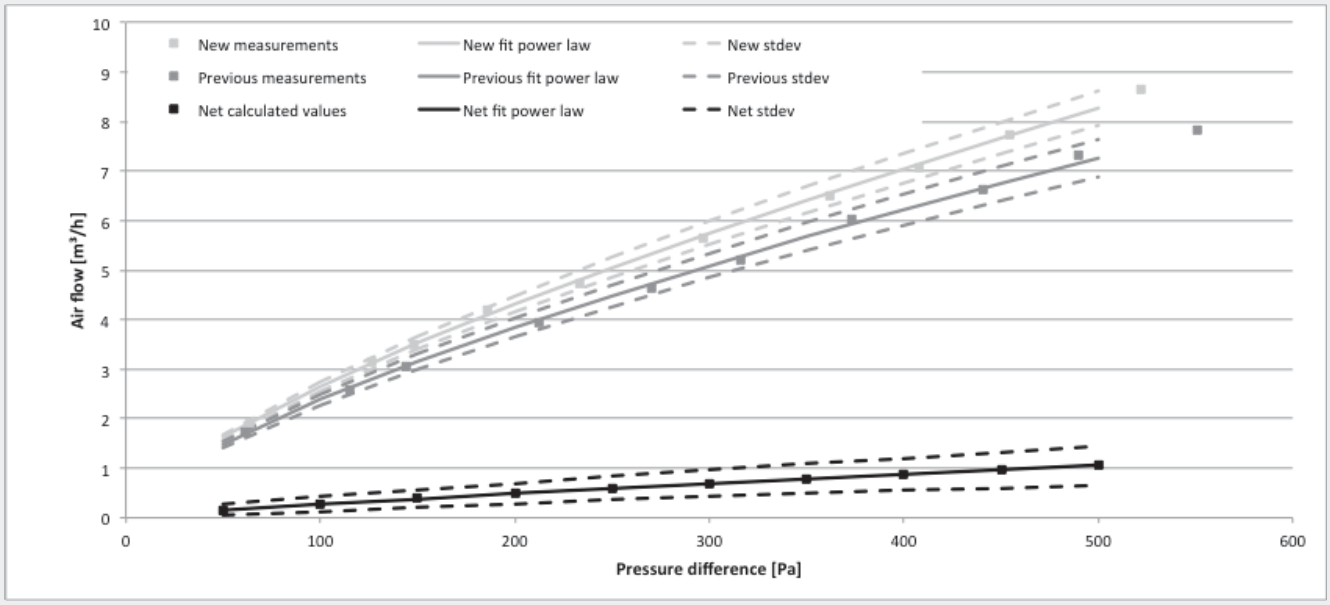
Fit to $V = C \cdot \Delta P^n$										
ΔP [Pa]	50	100	150	200	250	300	350	400	450	500
V [m³/h]	1,65	2,88	4,00	5,05	6,05	7,02	7,95	8,86	9,74	10,61
σ [m³/h	0,06	0,10	0,15	0,19	0,23	0,27	0,32	0,36	0,40	0,44

New penetration installed → new measurement

New: $V_{50_new} \pm \sigma_{50_new}$

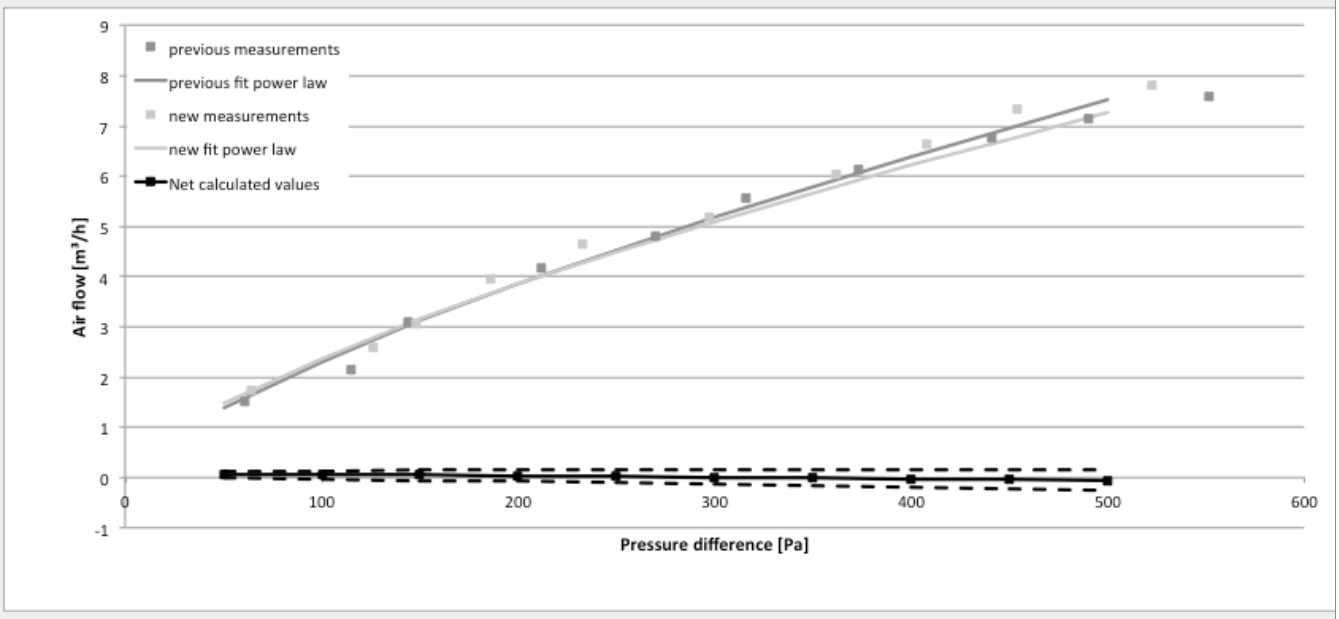
Previous: $V_{50_prev} \pm \sigma_{50_prev}$

Net leakage: $(V_{50_new} - V_{50_prev}) \pm (\sigma_{50_new}^{2} + \sigma_{50_prev}^{2})^{(1/2)}$



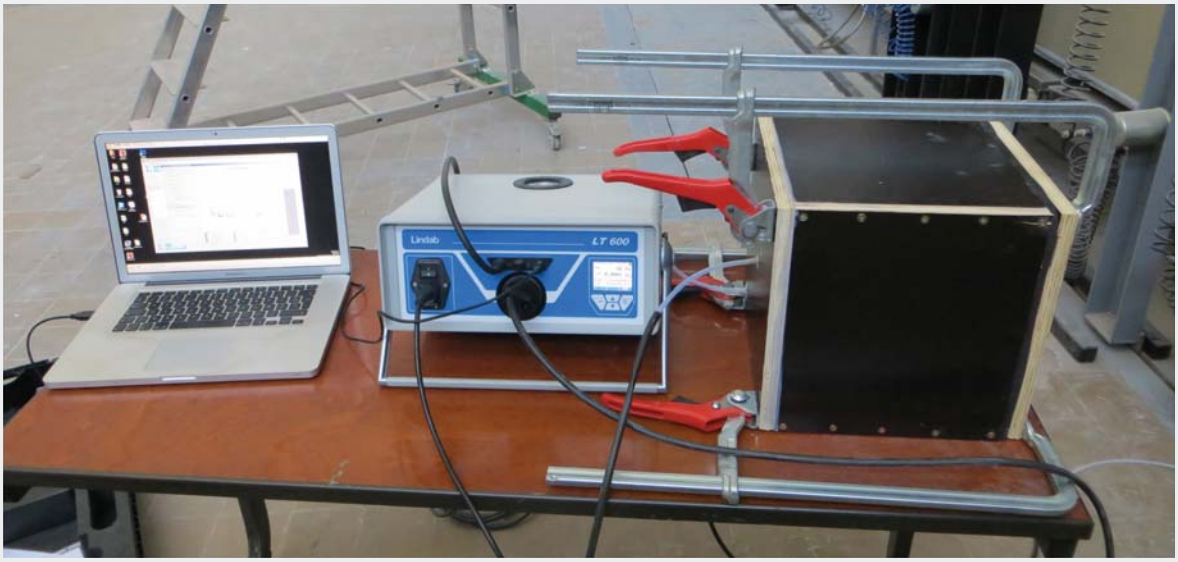
Leaky penetration

- Clear difference between fitted curves
- Net leakage can be calculated
- Relatively high stdev for net calculated values



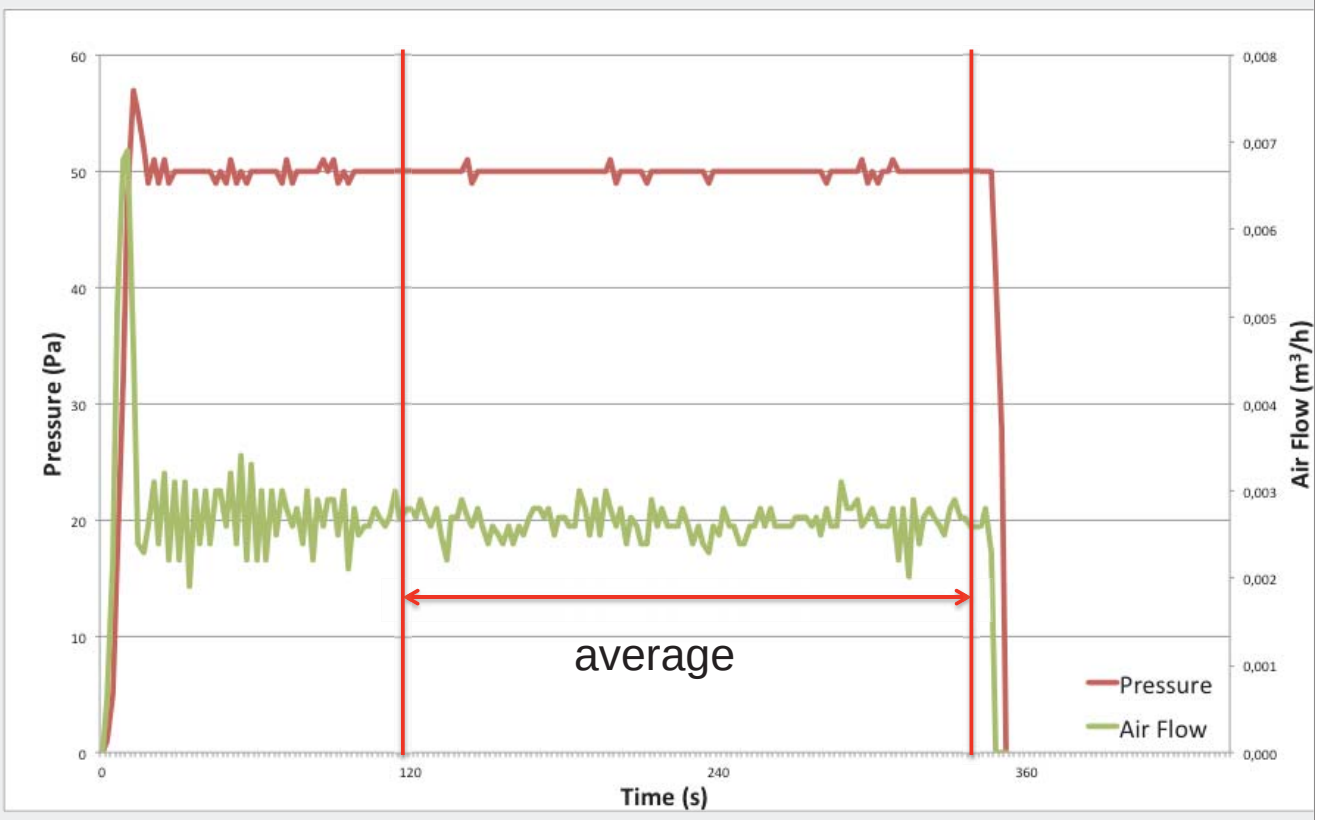
Very airtight penetration

- Fitted curves cross at 250 Pa
- Negative net leakage calculated between 250-500 Pa
- Large part of confidence interval is positive



Small-scale test setup:

- Designed to test airtightness of ductwork and chimneys
- Air flow measurement: temperature difference over hotplate



Measurement #		1	2	3	4	5
Pressure	average	50,05	49,98	49,93	50,03	50,05
	stdev	0,83	0,79	0,36	0,36	0,59
	rel stdev	1,65%	1,57%	0,72%	0,73%	1,18%
	min	49	49	49	49	49
	max	51	51	51	51	51
	spread	2	2	2	2	2
	rel spread	4,00%	4,00%	4,01%	4,00%	4,00%
Air flow	average	0,0025	0,0023	0,0026	0,0025	0,0026
	stdev	0,0005	0,0005	0,0002	0,0002	0,0002
	rel stdev	18,58%	22,00%	6,94%	6,79%	8,67%
	min	0,0018	0,0015	0,0020	0,0022	0,0023
	max	0,0033	0,0032	0,0031	0,0029	0,0033
	spread	0,0015	0,0017	0,0011	0,0007	0,001
	rel spread	60,28%	72,67%	41,94%	27,93%	38,88%

Average leakage: 0,0025 m^3/h
Stdev: 0,0001 m^3/h

5 measurements at 50 Pa, 250 Pa & 500 Pa

Gross: $V_{50_gross} \pm \sigma_{50_gross}$

Tare: $V_{50_tare} \pm \sigma_{50_tare}$

Net: $(V_{50_gross} - V_{50_tare}) \pm (\sigma_{50_gross}^{2} + \sigma_{50_tare}^{2})^{(1/2)}$

Tare leakage of test setup: 0,0006 ± 0,0001 m^3/h @ 50 Pa

→ higher reliability test results

Tests executed on large-scale test setup

	Ø 4 mm	Ø 20 mm	Ø 75 mm	Ø 130 mm
EPDM				
PUR				
tape				

Test results large-scale test setup

	#	50 Pa		250 Pa		500 Pa	
		Air leakage (m^3/h)	σ (m^3/h)	Air leakage (m^3/h)	σ (m^3/h)	Air leakage (m^3/h)	σ (m^3/h)
Ø 4 mm	16	*0.001*	0.004	*0.003*	0.017	*0.005*	0.032
Ø 20 mm	9	*0.005*	0.007	*0.017*	0.029	*0.030*	0.053
Ø 75 mm	2	*0.049*	0.068	*0.022*	0.131	*-0.057*	0.208
Ø 130 mm	2	*0.092*	0.092	*0.113*	0.174	*0.045*	0.286

EPDM gasket:

- Very low air leakage
- High confidence interval compared to net leakage
  → hard to measure exact value
  → unreliable values for Ø 75 mm and Ø 130 mm
- Easy to apply, not prone to errors
- Durable

Test results large-scale test setup

	#	50 Pa Air leakage (m^3/h)	σ (m^3/h)	250 Pa Air leakage (m^3/h)	σ (m^3/h)	500 Pa Air leakage (m^3/h)	σ (m^3/h)
Ø 4 mm	16	*0.026*	0.006	*0.077*	0.022	*0.123*	0.040
Ø 20 mm	16	*0.118*	0.014	*0.327*	0.050	*0.501*	0.088
Ø 75 mm	2	*0.077*	0.056	*0.298*	0.119	*0.526*	0.194
Ø 130 mm	1	*1.475*	0.046	*4.252*	0.109	*6.695*	0.181
Ø 130 mm	1	*0.048*	0.090	*0.302*	0.214	*0.603*	0.360

Sprayed PUR
- high air leakages, but
- 'wall' thickness only 18 mm
  → PUR sprayed on the fibreboard, around penetration
- not a convenient solution for smaller diameters

Test results large-scale test setup

	#	50 Pa Air leakage (m^3/h)	σ (m^3/h)	250 Pa Air leakage (m^3/h)	σ (m^3/h)	500 Pa Air leakage (m^3/h)	σ (m^3/h)
Ø 4 mm	16	*0.001*	0.005	*0.017*	0.018	*0.039*	0.033
Ø 20 mm	16	*0.140*	0.042	*0.343*	0.154	*0.488*	0.275
Ø 75 mm	2	*0.128*	0.043	*0.325*	0.106	*0.477*	0.176
Ø 130 mm	1	*1.847*	0.115	*4.698*	0.333	*6.988*	0.552
Ø 130 mm	1	*0.837*	0.219	*1.581*	0.636	*1.982*	1.026

tape
- high air leakages
- standard airtightness tape (reinforced PE membrane + adhesive)
  → not designed for 3D connections
- very dependent on workmanship quality

Test results large-scale test setup

	#	50 Pa		250 Pa		500 Pa	
		Air leakage (m^3/h)	σ (m^3/h)	Air leakage (m^3/h)	σ (m^3/h)	Air leakage (m^3/h)	σ (m^3/h)
Ø 4 mm	16	*0.030*	0.006	*0.115*	0.026	*0.206*	0.049
Ø 20 mm	9	*0.600*	0.012	*1.788*	0.043	*2.850*	0.076
Ø 75 mm	2	*6.275*	0.186	*16.130*	0.566	*24.148*	0.930

No attention to airtightness
- Worst-case scenario
- Results dependent on diameter of opening
  → Ø 6 mm, Ø 22 mm, 80 mm

Test results small-scale test setup

	# tests	50 Pa		250 Pa		500 Pa	
		Air leakage (m^3/h)	σ (m^3/h)	Air leakage (m^3/h)	σ (m^3/h)	Air leakage (m^3/h)	σ (m^3/h)
PUR	5	*0.0003*	0.0002	*0.0005*	0.0006	*0.0021*	0.0013
gasket	5	*0.0019*	0.0001	*0.0108*	0.0010	*0.0211*	0.0018
tape (1)	1	*0.0211*		*0.0712*		*0.1308*	
tape (2)	5	*0.0016*	0.0002	*0.0042*	0.0005	*0.0057*	0.0011

Ø 75 mm PVC pipe

PUR: higher wall thickness
→ very low air leakage
→ long term performance?
EPDM gasket: relatively higher, but still negligible
tape (1): standard tape: bad solution
tape (2): flexible butyl tape: very good results

How can we evaluate the airtightness of building components?

- no normative documents
- literature: very rare

In the Netherlands: guidelines to achieve three airtightness classes: 1 (basic), 2 (good) & 3 (passive house)

Diameter (mm)	Air leakage @ 50 Pa (m^3/h)		
	Class 1	*Class 2*	*Class 3*
15	9.3	3.4	0.7
25	15.6	5.4	1.1
50	27.8	10.7	2.1
80	91.9	17.1	3.4
100	112.9	21.5	4.3
125	139.7	27.4	5.5
150	167.1	32.2	6.4
200	220.4	43.0	8.6

All tested solutions: class 3

→ No problem?

Example: passive house, volume = 500 m^3

→ max leakage n_{50} = 0,6 h^{-1} → V_{50} = 300 m^3/h

	Ø (mm)	#	max_class3 (m^3/h @ 50 Pa)	max_class3_total (m^3/h @ 50 Pa)
ventilation/chimney	200	3	8,6	25,8
sewer drain	125	2	5,5	10,9
waste-drain-vent	80	1	3,4	3,4
solar boiler + water + gas	50	4	2,1	8,6
electricity	25	10	1,1	10,7
			total	59,5
			Share of accepted air leakage	19,8%

20% of total leakage at 20 local penetrations

→ not very ambitious airtightness level?

→ could easily be improved

Workmanship quality: watertightness tests

- Static pressure: EN 1027
  → 0 – 50 – 100 – 150 – 200 – 250 – 300 – 450 – 600 – 900 Pa
- Pulsating pressure: EN 12865
  → 0 – 150 – 300 – 450 – 600 - 750 Pa

Spray load: 8 l/min

Stetic pressure												
		#	0	50	100	150	200	250	300	450	600	900
EPDM	Ø 4 mm	32	0	0	0	0	0					
	Ø 20 mm	9	1	0	0	0	0					
	Ø 75 mm	4	0	0	2	0	1	0	1	-	-	-
	Ø 130 mm	2	0	0	1	0	0	0	0	0	0	0
PUR	Ø 4 mm	16	0	0	0	0	2					
	Ø 20 mm	16	6	0	0	3	1					
	Ø 75 mm	2	2	-	-	-	-	-	-	-	-	-
	Ø 130 mm	1	1	-	-	-	-	-	-	-	-	-
tape	Ø 4 mm	16	2	0	0	1	1					
	Ø 20 mm	4	2	0	0	0	2	-	-	-	-	-
	Ø 75 mm	2	1	0	0	0	0	0	1	-	-	-
	Ø 130 mm	2	2	-	-	-	-	-	-	-	-	-

Pulsating pressure								
		#	0	150	300	450	600	750
EPDM	Ø 4 mm	32	0	0	2	0	0	0
	Ø 20 mm	9	0	1	8	-	-	-
	Ø 75 mm	2	0	1	3	-	-	-
	Ø 130 mm	2	0	0	1	0	0	1
PUR	Ø 4 mm	16	0	0	7	3	3	0
	Ø 20 mm	16	4	12	-	-	-	-
	Ø 75 mm	2	2	-	-	-	-	-
	Ø 130 mm	1	1	-	-	-	-	-
tape	Ø 4 mm	16	1	0	10	0	1	0
	Ø 20 mm	4	1	2	0			
	Ø 75 mm	2	1	0	1	-	-	-
	Ø 130 mm	2	2	-	-	-	-	-

Conclusions

- In practice: large leakages around building penetrations
  → bad workmanship quality, wrong methods/products

- Appropriate products are available
  → EPDM gaskets, PUR, flexible tape
  → long-term performance?

- EPDM gasket: relatively higher leakage, but less vulnerable for damage after installation

- Need for normative documents or building guidelines for airtightness of building components?

Thank you for your attention! Questions?

CHALMERS

Airtightness variation over the year

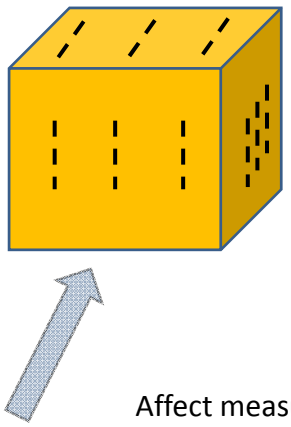
Paula Wahlgren
Chalmers University of Technology

SP Technical Research Institute of Sweden

Aim

- Does the airtightness in buildings vary over the year?
- If so, how does it vary?

Calculated climate dependent airtightness



Varying wind and air leakage distribution:

Affect measured airtightness values for pressurization and for depressurization but not the average value.

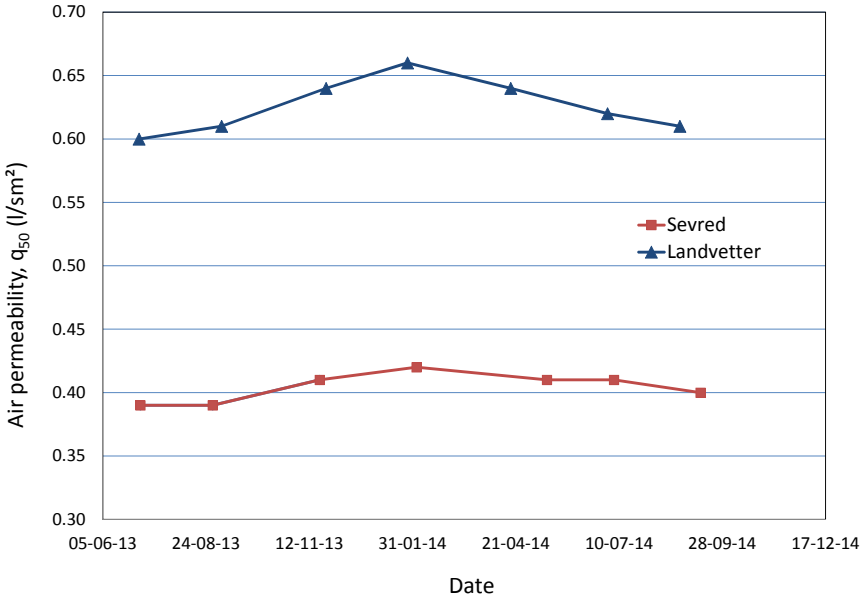
Measured buildings

Sevred: Light weight wooden construction with polyethylene foil, 1993

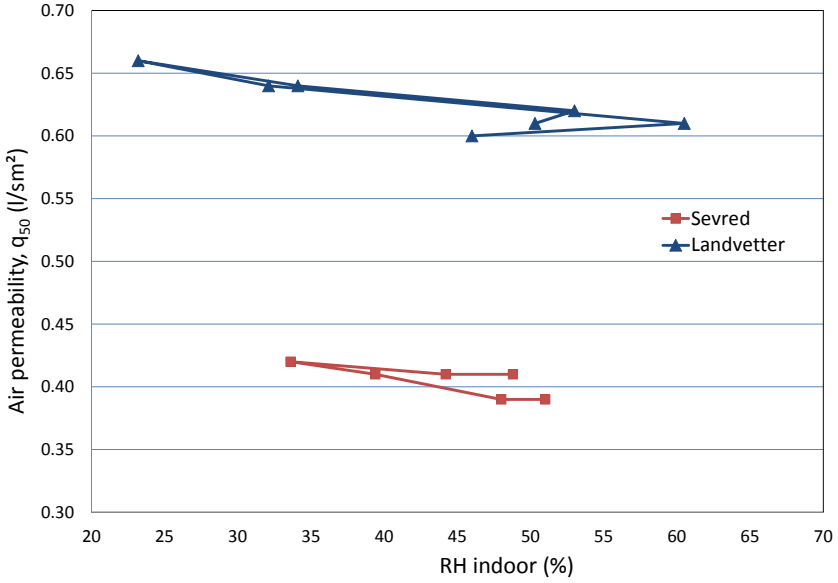
Landvetter: Light weight wooden construction with polyethylene foil, 2004

Ytterby: Concrete, multifamily building, 2013

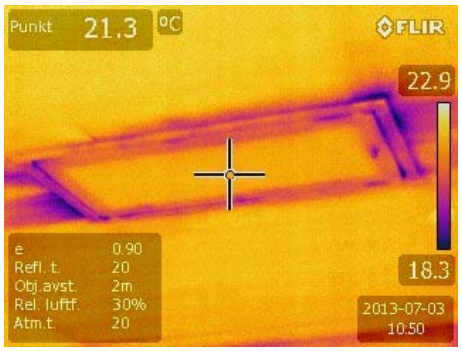
Airtightness over time, summer/winter/summer

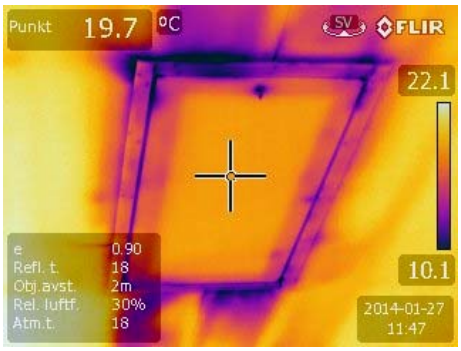


Correlation with indoor relative humidity



Air leakage around attic hatch





CONCLUSION

The airtightness changes over time in the investigated wooden buildings, approximately 10% leakier in wintertime.

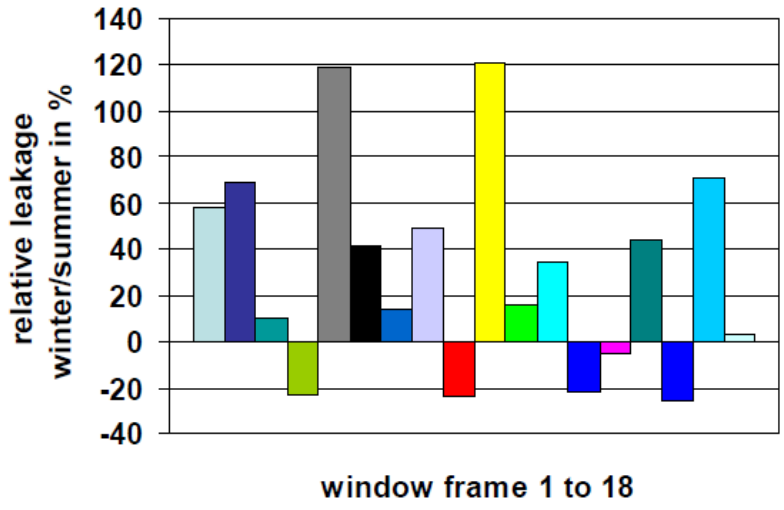
NEXT STEPS

I. Expain why

Investigate air leakages (air velocities) during different seasons

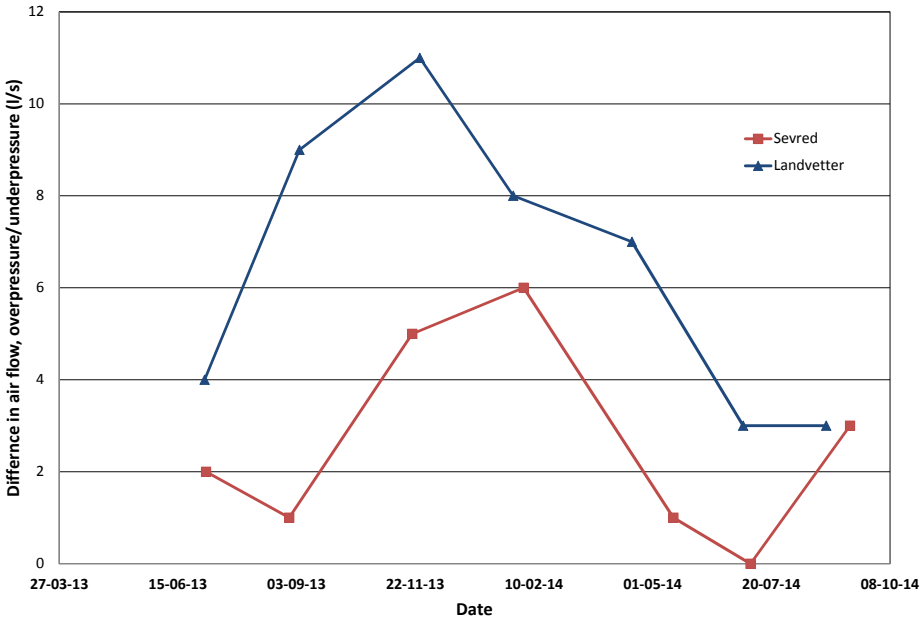
Include different types of buildings

II. How should this be taken into account?



Window constructions (mostly wooden) in brick and concrete buildings from the 80ies (Boorsboom & de Gids, 2012)

Difference overpressure/underpressure



Syftet med projektet är att visa på

- Om den uppmätta lufttätheten varierar över året
- Hur varierar detta i så fall?

Nästa steg (om projektet fortsätter):

- Vilka tänkbara orsaker till variationen finns?
- Hur tar man hänsyn till variationen?

Resultatspridning

NSB 2014, Nordic symposium on Building Physics, Lund, Juni 2014

AIVC, Ventilation and airtightness in transforming the building stock to high persformance, Poznan, Polen, September 2014

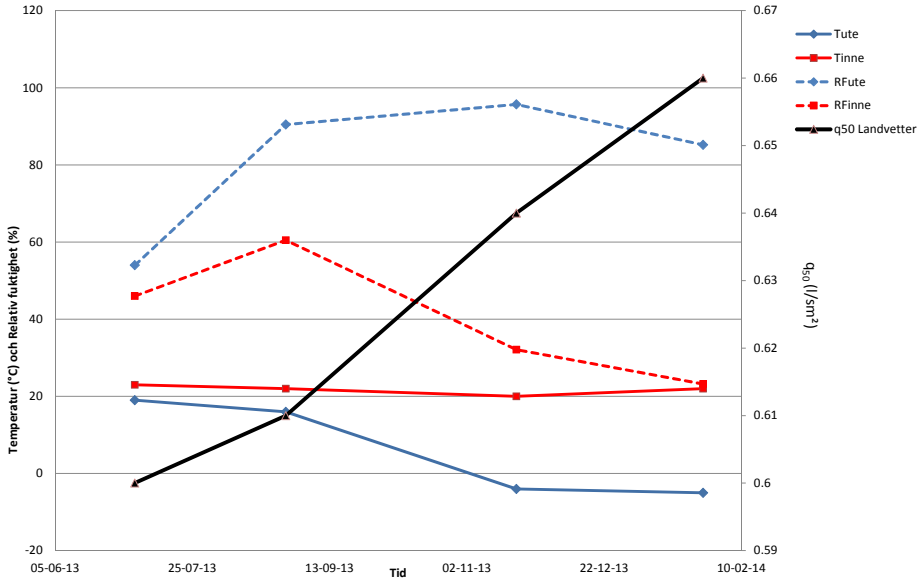
DURABILITY AND MEASUREMENT UNCERTAINTY OF AIRTIGHTNESS IN EXTREMELY AIRTIGHT DWELLINGS

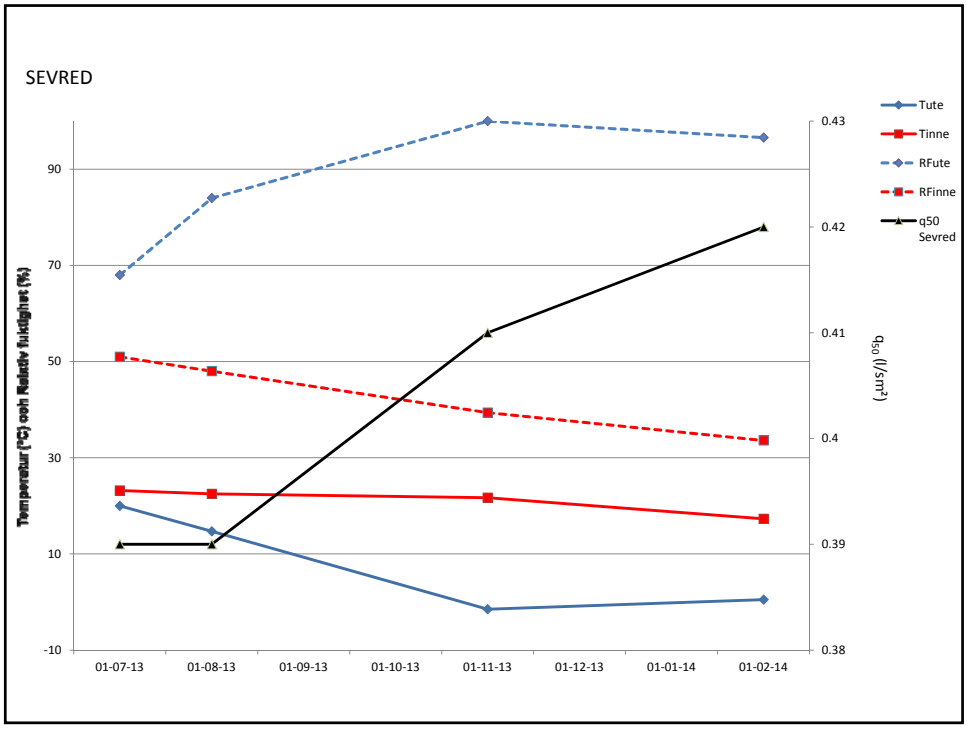
Wolf Bracke, Jelle Laverge*, Nathan Van Den Bossche and Arnold Janssens,
Gent Universitet

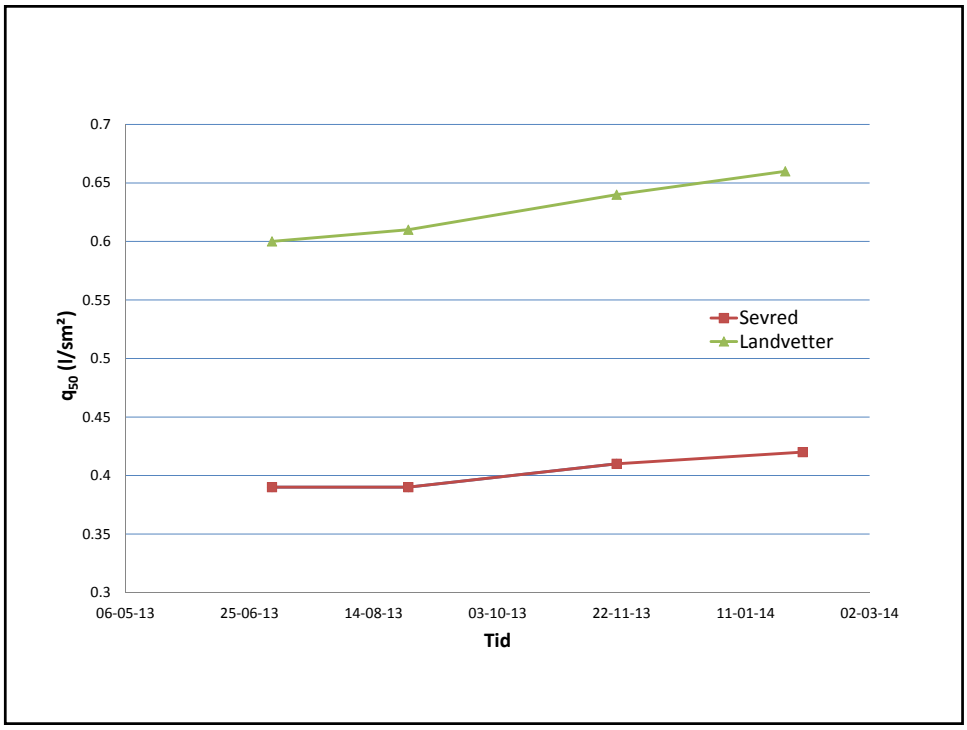
Although house 2 has a wood construction with wooden windows and doors and the Belgian climate creates a similar evolution in moisture content, it does not display the decreasing leakage in summer reported by Persily (Persily, 1982). In contrast to traditional wood frame construction, in passive houses such as this, all joints between wood panels and around envelope details such as windows etc. are sealed with tape. As these joints already are airtight, the swelling of wooden elements can't make them more airtight.

Spekulerar i om minskad lufttäthet kan bero på att tätheten skadas av upprepad provning, främst ventilationskanaler.

LANDVETTER

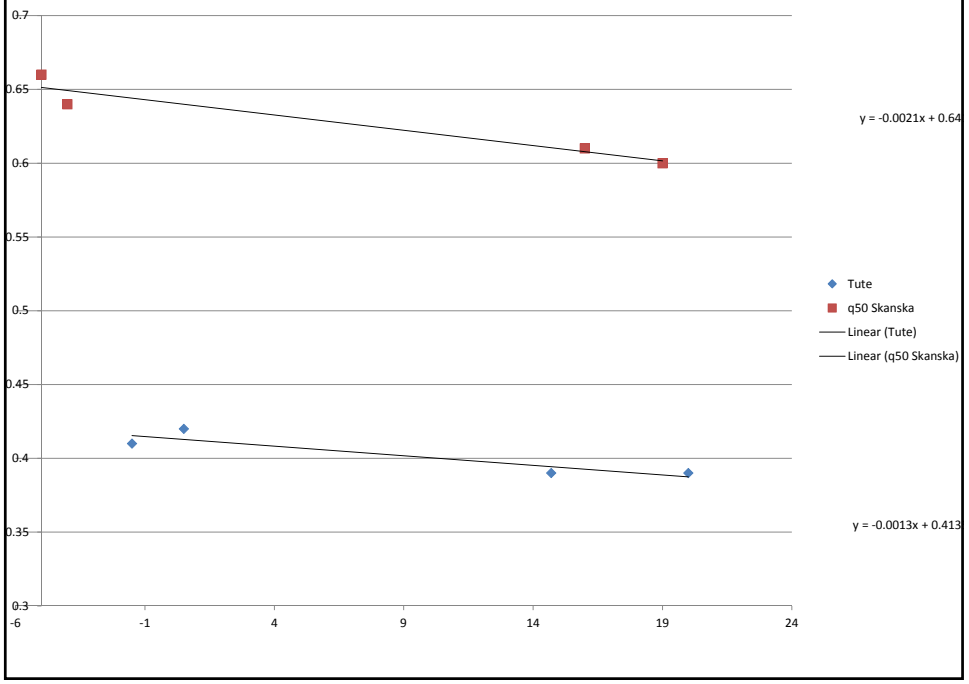



SEVRED
Tute
Tinne
RFute
RFinne
q50 Sevred
90
70
50
30
10
-10
0.43
0.42
0.41
0.4
0.39
0.38
q_{50} (l/sm²)
01-07-13
01-08-13
01-09-13
01-10-13
01-11-13
01-12-13
01-01-14
01-02-14


0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
q_{50} (l/sm²)
Sevred
Landvetter
06-05-13
25-06-13
14-08-13
03-10-13
22-11-13
11-01-14
02-03-14
Tid

Nästa mätning:
Noga läckagesökning
Med och utan tätning av fönster och dörrar (spec. vindslucka)
Analys av uppmätt lufttäthet
Analys av skillnad mellan övertryck och undertryck

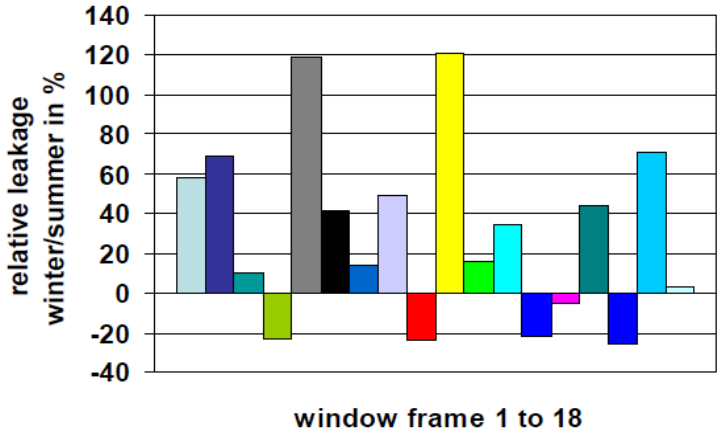
+
tung konstruktion



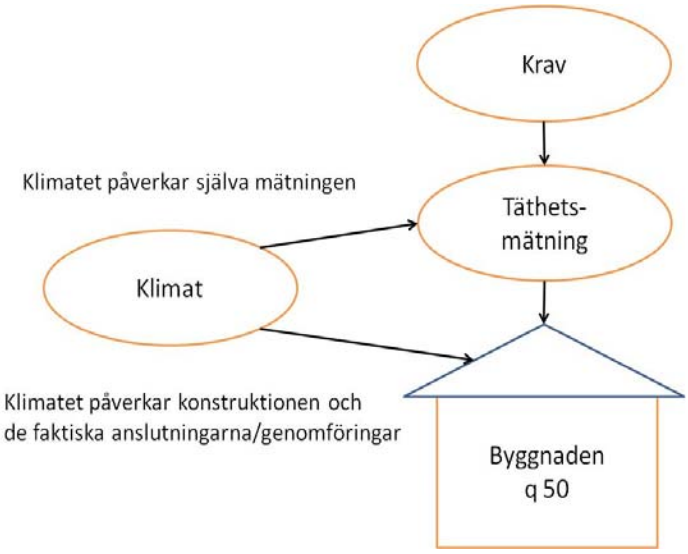
Påverkas mätresultat av klimat/årstid?

Bakgrund

- Undersökningar visar att resultaten från täthetsprovningar varierat med årstid/klimat.



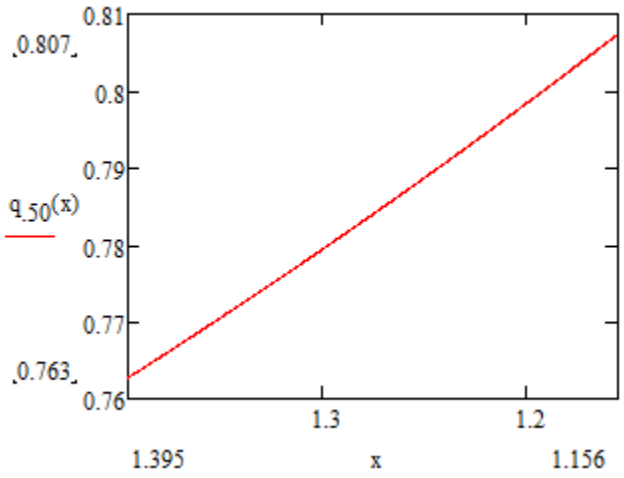
Boorsboom & de Gids, 2012



Börjat med påverkan av vind, därefter skorstenseffekt

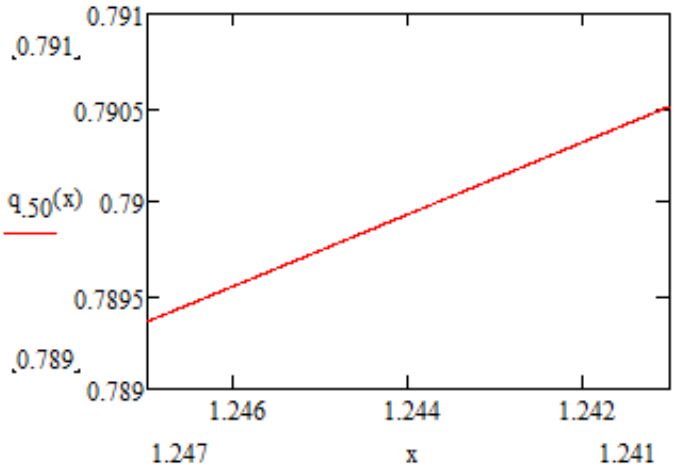
Varierande densitet hos luften- ger varierande motstånd i otätheter

Temperatur mellan -20°C och 30°C (RF 40%)
5.7% skillnad i q_{50} (0.1% per grad)



Varierande densitet hos luften- ger varierande motstånd i otätheter

Relativ fuktighet mellan 0 och 100% (Temperatur 10°C)
0.14% skillnad i q_{50}



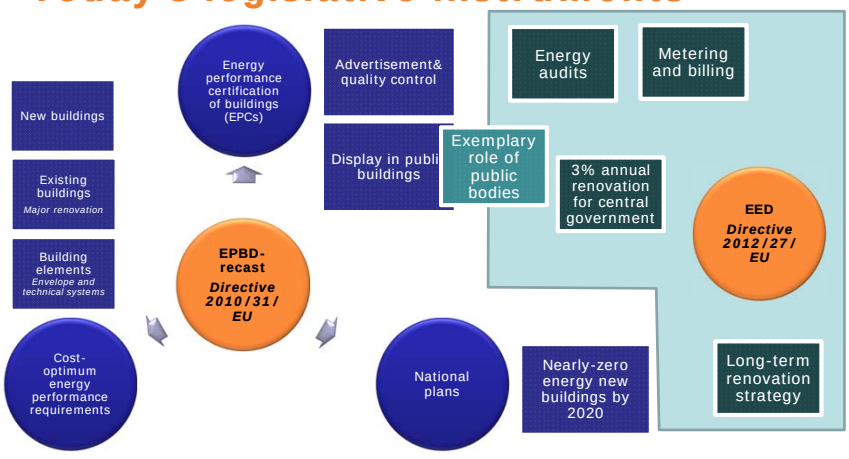
European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

EU Mandate (M480) for CEN to develop the second generation CEN-EPB standards supporting the implementation of the EPBD Recast in EU.
- Results Phase 1 & 2
- Cooperation with ISO

Jaap Hogeling
Chair CEN TC 371 Program Committee on EPBD
j.hogeling@isso.nl
Fellow of ASHRAE
Fellow of REHVA

BUILDING SERVICES RESEARCH INSTITUTE THE NETHERLANDS

Energy efficiency in buildings
Today's legislative instruments



1. Are we on track for 2020?
2. If not, what should we do about it?
3. What is the optimal level of ambition for energy efficiency in 2030?
4. What should be the approach to achieve it?

2020: outlook and lessons learned

Energy efficiency of the EU economy is steadily increasing; and economic growth is being decoupled from energy consumption

Based on an analysis of Member State actions and additional forecasts, the Commission now estimates that the EU will achieve energy savings of around 18-19% in 2020.

In order to bridge the gap to the target, efforts should be concentrated on the following elements:

1. **Strengthening local and regional verification of national building codes and accurately informing consumers of the energy performance of buildings for sale or rent;**
2. **Fully implicating utilities in working with their customers to obtain energy savings;**
3. **Strengthening market surveillance of the energy efficiency of products.**

Make full use of available financing, in particular ESIF

2030: the proposed policy ambition and direction

Just two quotes:

"*No changes in policy mix; just intensity*"

"*Finding the right balance between costs and benefits*"

The ambition of the target

- **30% savings by 2030 vs 2007 Reference ensures broadly that the current level of energy efficiency policy ambition is continued.**
  - **2020 target requires us to cut consumption by 15% between 2010 and 2020**
  - **2030 target requires us to cut consumption by 12% between 2020 and 2030**
- **While leading to marginally higher energy system costs than savings below that level it results in significant benefits in terms of:**
  - ✓ **security of supply of energy;**
  - ✓ **the economy;**
  - ✓ **health and environment.**

One last quote from the Commission's energy efficiency communication:

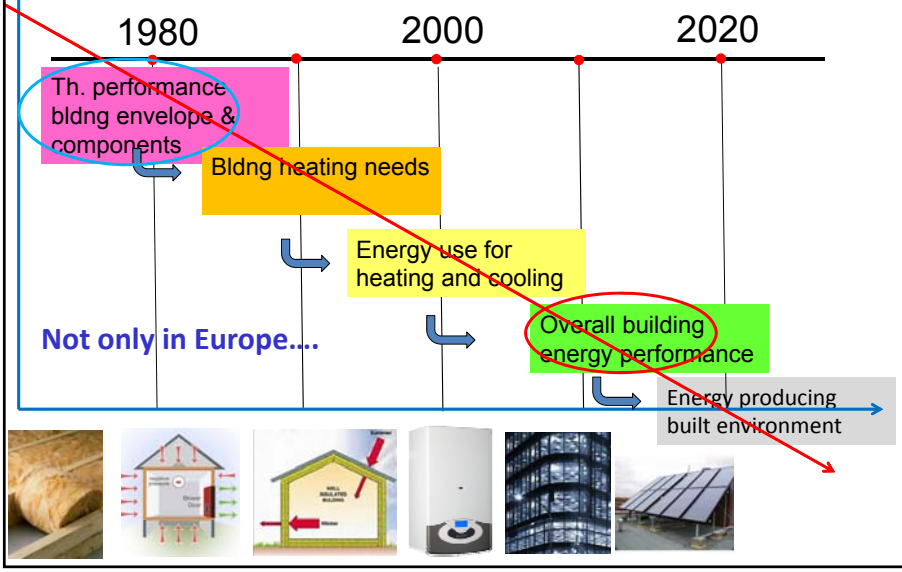
"**The Energy Performance of Buildings Directive (2010 EPBD-recast)**
and the Energy Efficiency Directive of 2012 (EED)
have the potential to further drive energy efficiency in the EU
provided they are properly implemented by Member States."

Conclusion

- **One of the important instruments to support the proper implementation of the EPBD**
  is a modularly structured, transparent, unambiguous, but flexible* set of CEN EPB standards

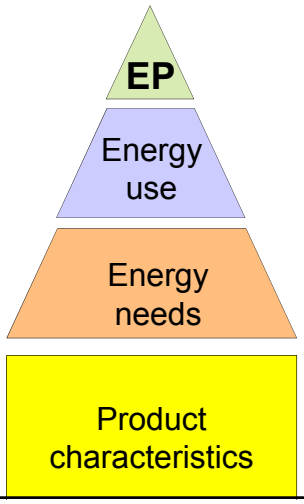
*: for local climate, national legal framework, building tradition, building use

CEN standards related to energy performance of buildings (EPB): TIME LINE



Principle

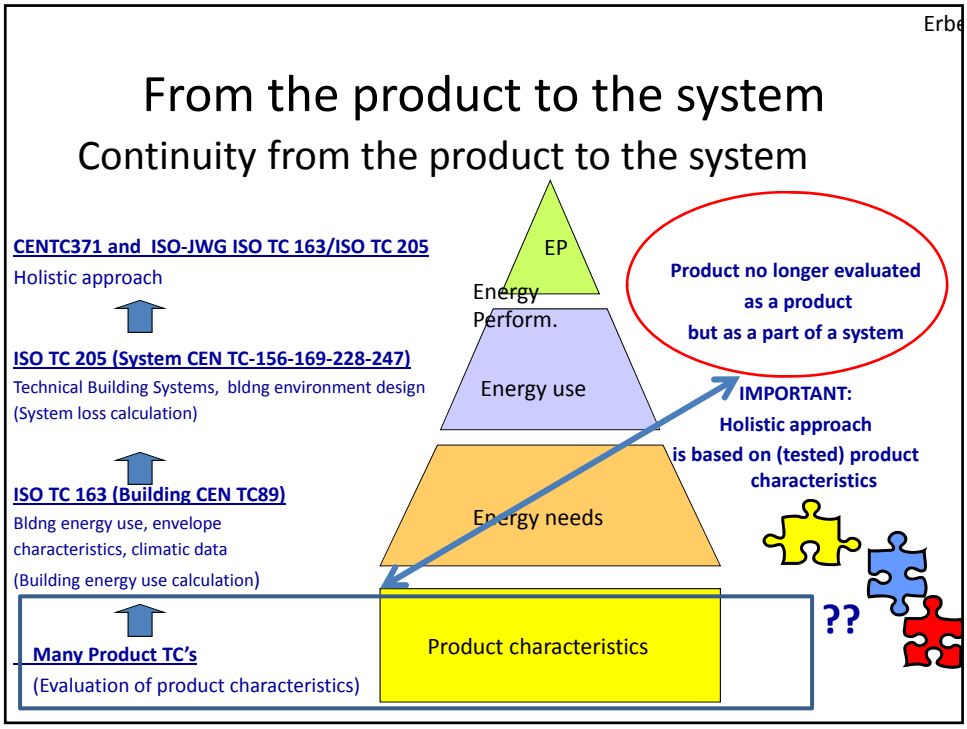
EP: Overall Building Energy Performance

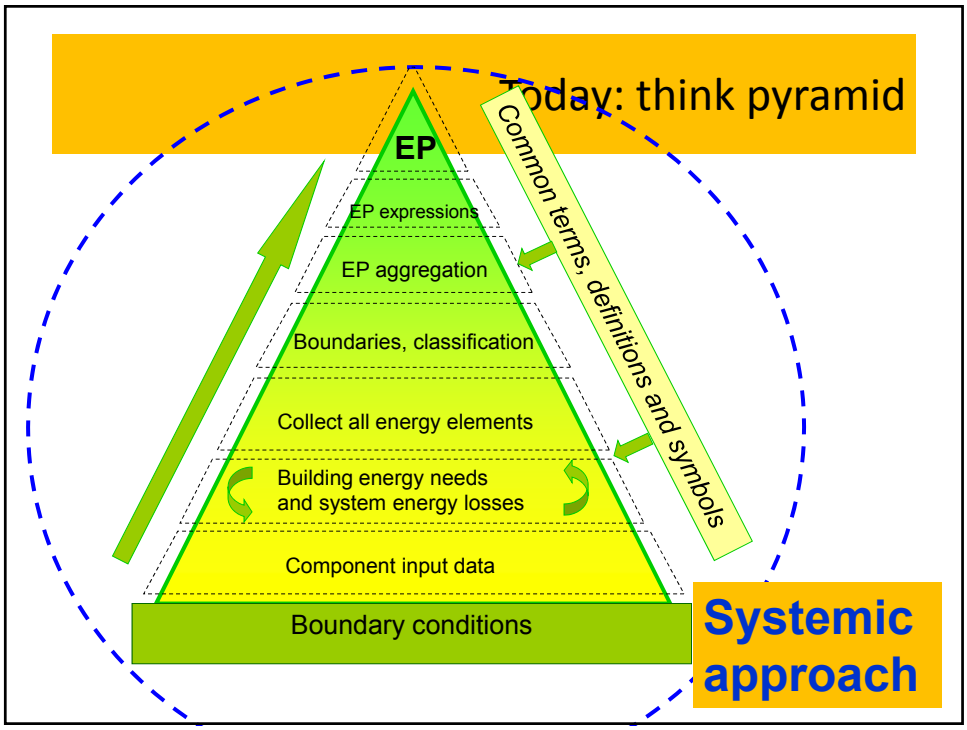


From product standards to overall energy use
incl. technical building systems

Product is not longer evaluated as a product but as part of a system

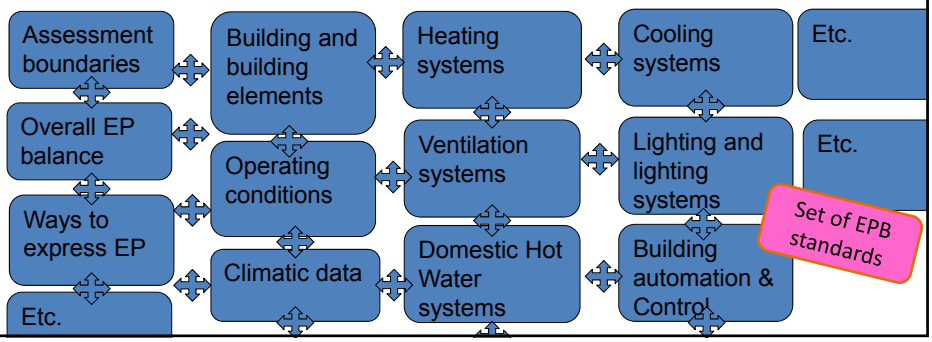
Maintain the links between product testing and system evaluation


Erbe
From the product to the system
Continuity from the product to the system
CENTC371 and ISO-JWG ISO TC 163/ISO TC 205
Holistic approach
ISO TC 205 (System CEN TC-156-169-228-247)
Technical Building Systems, bldng environment design
(System loss calculation)
ISO TC 163 (Building CEN TC89)
Bldng energy use, envelope
characteristics, climatic data
(Building energy use calculation)
Many Product TC's
(Evaluation of product characteristics)
EP
Energy Perform.
Energy use
Energy needs
Product characteristics
Product no longer evaluated
as a product
but as a part of a system
IMPORTANT:
Holistic approach
is based on (tested) product
characteristics
??

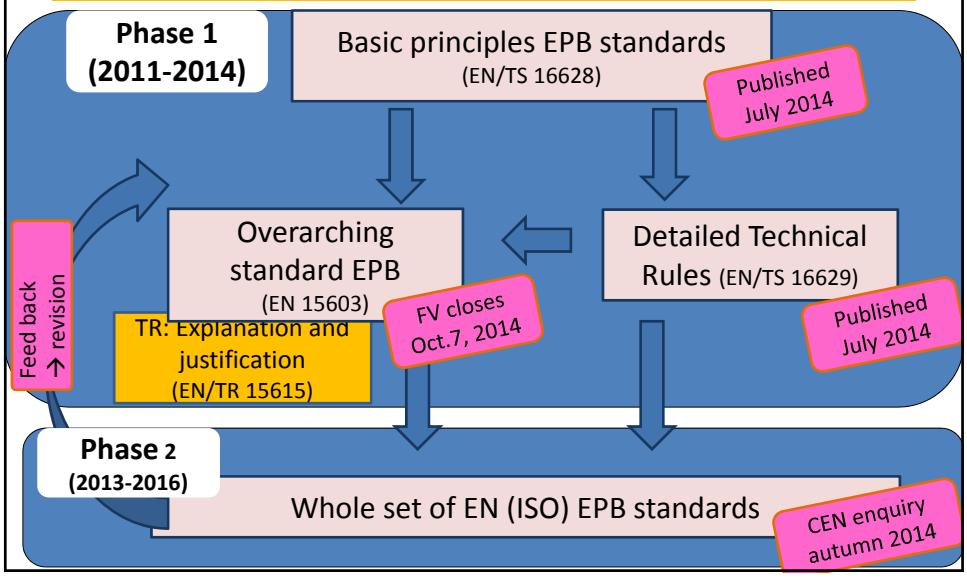

Today: think pyramid
EP
EP expressions
EP aggregation
Boundaries, classification
Collect all energy elements
Building energy needs
and system energy losses
Component input data
Boundary conditions
Common terms, definitions and symbols
Systemic approach

Overarching modular structure

- **Matrix of modules and submodules**
- **Common terms, definitions and interactions between the modules**
- **Overall energy performance**



CEN work plan EPB standards



phase 1 results

- **FprEN 15603:2014 Over-Arching Standard out for FV (closes Oct 8)**
- **FprTR (Technical Report) 15615:2014 on the prEN 15603 (expected 2015)**

Supporting documents for the EPB standard developers

- CEN TS (Technical specification) 16628:2014 on Basic Principles is published
- CEN TS 16629:2014 on Detailed Technical Rules is published
- Software tool to support the checking of the calculation procedures given in the various standards and their interconnection

Current status of the FprEN15603 and connected TR

- The OAS is currently out for FV (closure 8th Oct. 2014)
- **As soon EN15603 is published CENTC371 will request registering new WI to update the OAS.**
- final draft TR 15615:2014 ready by end of September ; includes
- Publication EN15603 expected: December/January
- Draft TR out for 2nd TCA summer 2015: 2 months Enquiry
- next: processing and amend proposals for TC decision to publish the TR– this will be done parallel to the update of OAS (2nd-version) by the end of 2015

Phase 2 of the CEN EPB project

- the improvement and expansion of the current set of CEN-EPB standards on the basis of :
  - communication with stakeholders such as the regulators of the EU- member states
  - Resulting in 40-50 standards and TR's or parts thereof
    - Standards are expected just to include normative text
    - TR's providing backgrond info, justification of assumptions and example cases
  - For all standards an excel file will be produced to report the input and output data and to verify the described calculation procedure and correct interconnection with referred standards

ventilation related standards

(CEN TC 156: Ventilation for buildings: new EN16798 series)

- **EN 15251 Indoor environmental input parameters for the design and assessment of energy performance of buildings (Bjarne Olesen)**
- Rev. 13779 Ventilation for non-residential buildings — Performance requirements for ventilation, air conditioning and room conditioning systems
- **Rev. 15241: Calculation methods for energy requirements of ventilation and air conditioning systems — Part 5-1 & 5-2: Distribution and generation (Gerhard Zweifel)**
- **Rev. 15242: Calculation methods for energy requirements of ventilation and air conditioning systems — Part 7: Emission (determination of air flow rates) (Gerhard Zweifel)**
- Methods for the calculation of the energy performance of cooling systems — Part 13: Generation
- Calculation of cooling systems — Part 15: Storage
- **Part 17: Guidelines for inspection of ventilation and air conditioning systems; (revision of EN 15239 and EN 15240) (Rémie Carrié)**
- **Rev. 15243: Calculation methods for energy requirements of cooling systems — Part 9: General (Gerhard Zweifel)**

Instruments to facilitate the flexibility in the EN/ISO standards- Annex A/B approach

- Most EPB standards will have an informative Annex B where we report all default input values and choices
- In addition to that they will have a similar Annex A where we left out all values and choices; this annex A should be used to declare the particular (national) input values and choices; this to report the use of the EPB standards in a transparent way.

Example EN15242: B.1.2 Product technical data B.1.2.1 Discharge coefficient for vents, air terminal devices, windows

- **Annex B defaults:**
- default values for the discharge coefficients :
  - *C*D;vent = 0,6
  - *C*D;ATD = 0,6
  - *C*D;w = 0,67
- default values for the air flow exponents are:
  - *n*vent = 0,5
  - *n*ATD = 0,5
  - *n*w = 0,5

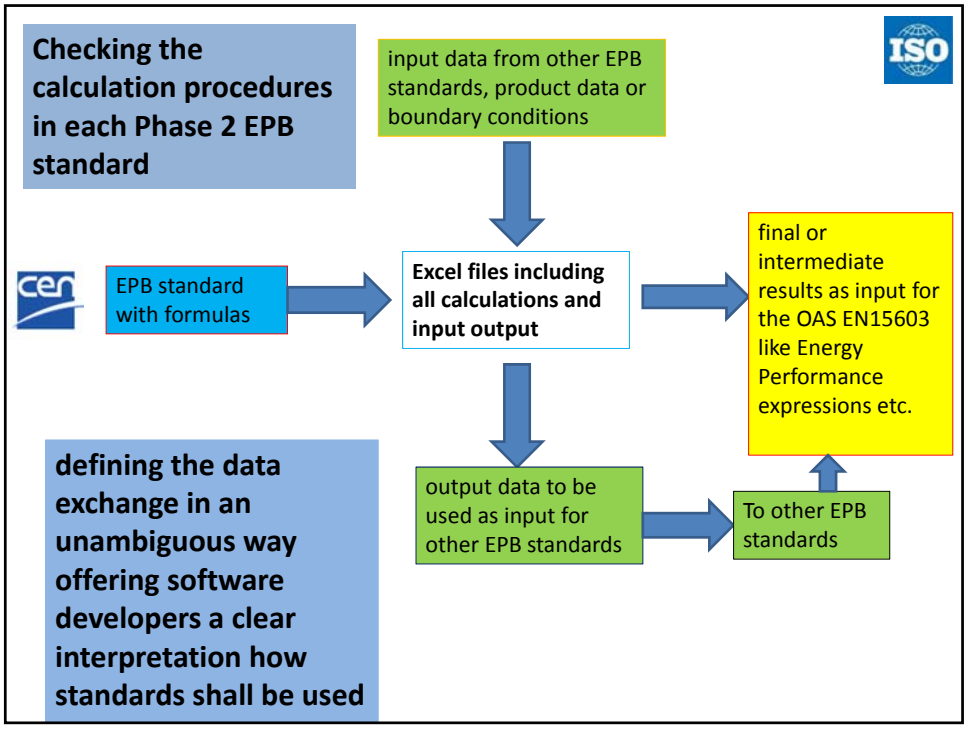
- **Annex A reporting format :**
- Chosen values for the discharge coefficients :
  - CD;vent =
  - CD;ATD =
  - CD;w=
- Chosen values for the air flow exponents are:
  - nvent =
  - nATD =
  - nw =

Status/Planning M480-Phase 2

- **September-December 2014** publication of the prEN's for enquiry
- It is expected to reach and possibly finish the enquiry stage of all EPB-standards around **April-May 2015**
- **Before the end of 2015** we expect all Enquiry comments to be resolved and Formal Vote versions ready at TC level.
- After publishing and voting we expect that **during 2016 all EPB-standards will ready and available as EN** (or EN-ISO) standards
- **By 2016 stable versions of these EPB standards will become available; to serve for a long period of time;**
- **But upgraded versions are expected to support neutralising the energy use in the build environment during the coming decades!**

Software tool to support the development and future use of the EPB-standards by software developers

- **Phase 2:internal tool to support, to demonstrate and validate**
  - the consistency and unambiguity of equations in the set of EPB-standards and
  - their interconnecting procedures: all in- and outputs of the EPB standards will clearly be defined

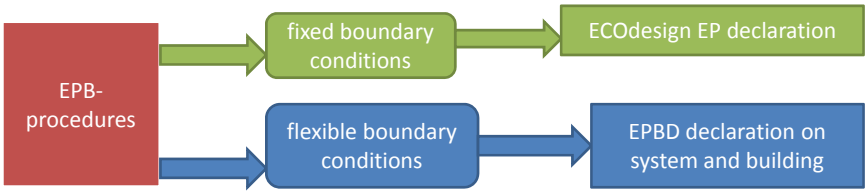


Building and system EP: also depending on product EP: relation to the ECO-DESIGN Directive and connected M495

- By developing system standards we have to consider, where possible, the relevant product standards on:
  - product performance data needed for our EPB building/system descriptions
  - the EPB system standards should be considered as basis for the product EP evaluation when declaring product-EP 's at the product labels
  - be aware that many "products" can be considered as sub-systems as they are including control-devices, electronics, storage element, other auxiliary functions, etc.

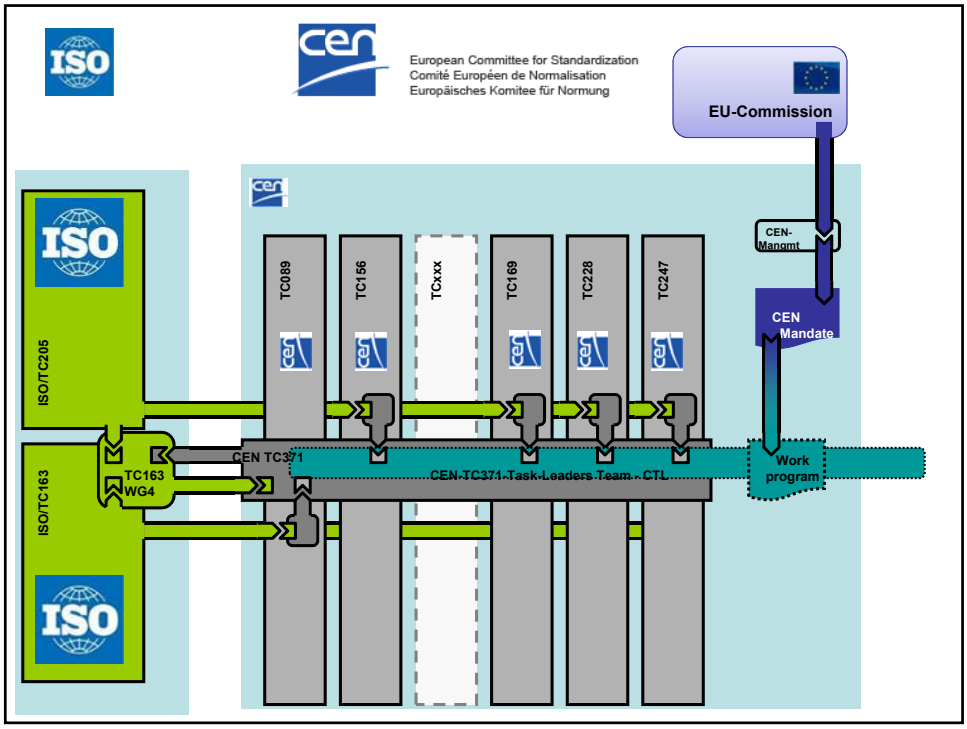
Building and system EP: also depending on product EP: relation to the ECO-DESIGN Directive and connected M495

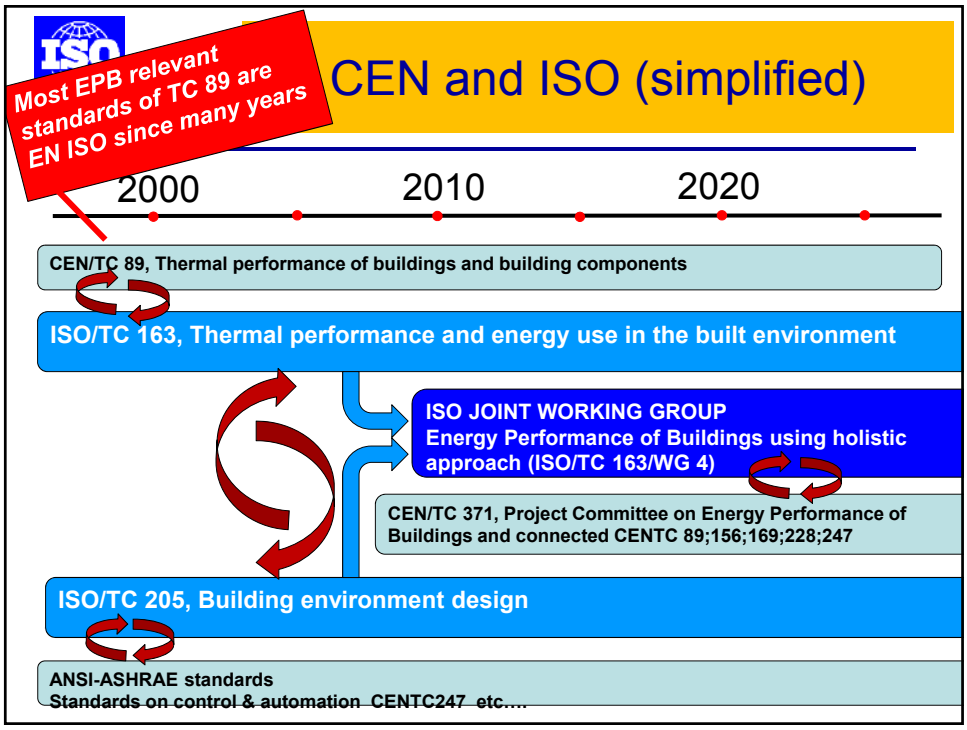
- The current status is that, given the independent process developing the ECOdesign EP assessment procedures (some of them are already in place), the **result of not using the EPB** procedures for the Ecodesign EP assessment is not predictable. Using these Ecodesign-EP declared values as input for EPB system assessment procedures may lead to misleading EPBD declarations.
- **Ideal situation: USE EPB Procedures:**

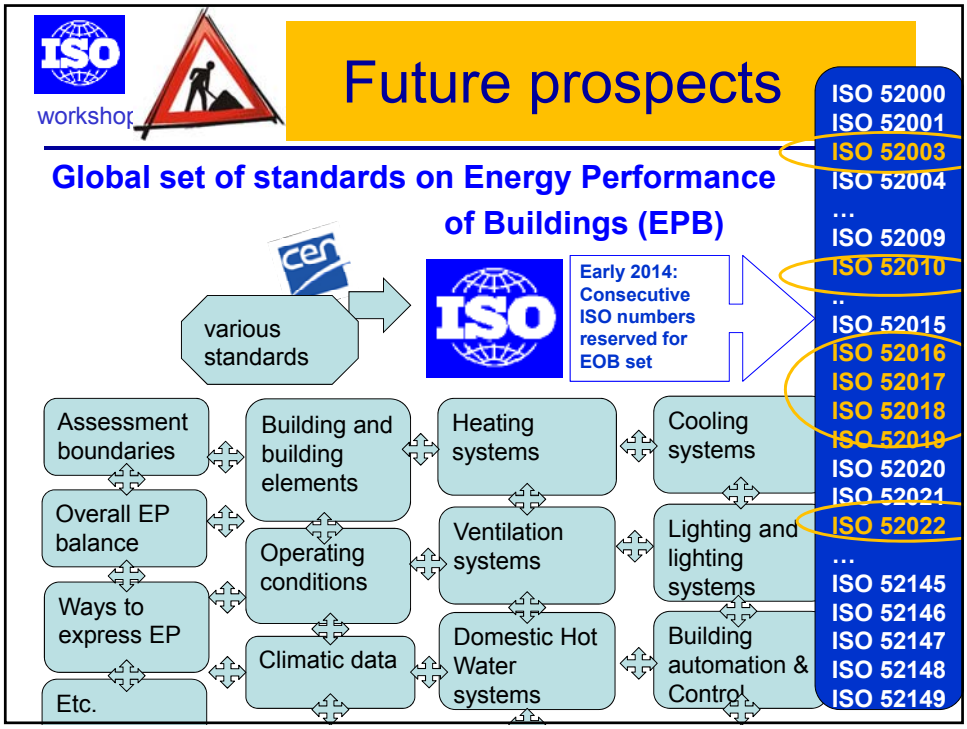


The CEN ISO interaction

- An active process of interaction for the **Overarching Type of standards** through the **JWG of ISO TC 163 & 205**
- for the other standards via the different WG's of ISO TC 163 and 205, Sharing early prelim draft texts
- Sharing experts in the ISO and CEN teams working on these standards, with the ultimate goal to agree on ISO standards
- A challenge given the geographic and other differences in the building sector, given the very tight time scale at CEN level, for EPB standards under some of the CEN TC's the cooperation with ISO is for the time being informal, no parallel voting yet but hoped for in the near futur.
- In ISO a series of numbers has been reserved for all EPB standards (52000----52150); it is expected that most Building Physics related standards (CENTC89) will be published as EN-ISO standards in this series.

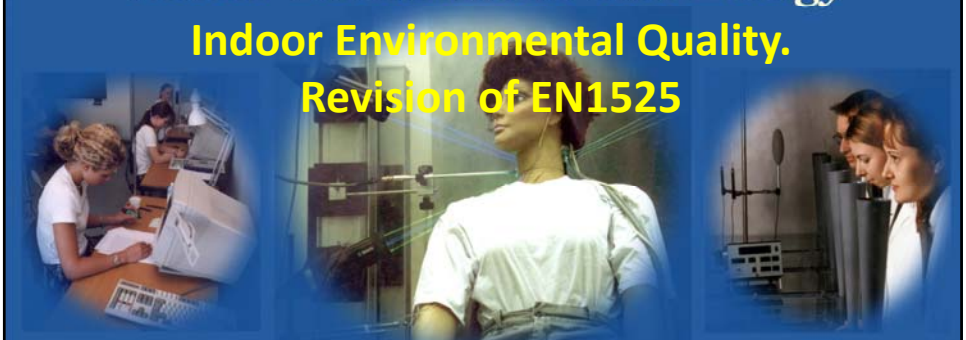

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung
EU-Commission
CEN-Mangmt
CEN Mandate
Work program
ISO/TC205
ISO/TC163
TC163 WG4
CEN TC371
CEN-TC371-Task-Leaders-Team - CTL
TC089
TC156
TCxxx
TC169
TC228
TC247


Most EPB relevant standards of TC 89 are EN ISO since many years
CEN and ISO (simplified)
2000
2010
2020
CEN/TC 89, Thermal performance of buildings and building components
ISO/TC 163, Thermal performance and energy use in the built environment
ISO JOINT WORKING GROUP
Energy Performance of Buildings using holistic approach (ISO/TC 163/WG 4)
CEN/TC 371, Project Committee on Energy Performance of Buildings and connected CENTC 89;156;169;228;247
ISO/TC 205, Building environment design
ANSI-ASHRAE standards
Standards on control & automation CENTC247 etc….


workshop
Future prospects
Global set of standards on Energy Performance of Buildings (EPB)
various standards
Early 2014: Consecutive ISO numbers reserved for EOB set
Assessment boundaries
Overall EP balance
Ways to express EP
Etc.
Building and building elements
Operating conditions
Climatic data
Heating systems
Ventilation systems
Domestic Hot Water systems
Cooling systems
Lighting and lighting systems
Building automation & Control
ISO 52000
ISO 52001
ISO 52003
ISO 52004
…
ISO 52009
ISO 52010
..
ISO 52015
ISO 52016
ISO 52017
ISO 52018
ISO 52019
ISO 52020
ISO 52021
ISO 52022
…
ISO 52145
ISO 52146
ISO 52147
ISO 52148
ISO 52149

International Centre for Indoor Environment and Energy

Indoor Environmental Quality. Revision of EN1525



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STANDARDS

- ISO EN 7730-2005
  - Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort effects.
- ASHRAE 55-2013
  - Thermal environment conditions for human occupancy
- ASHRAE 62.1 and 62.2 -2013
  - Ventilation and indoor air quality
- EN15251
  - Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustic
- EN 13779
  - Ventilation for non-residential buildings - performance requirements for ventilation and room-conditioning systems

International Standards
Indoor Environmental Quality

- prEN15251-1 and ISO CD 17772:
  - Indoor environmental input parameters for the design and assessment of energy performance of buildings.
- TR15251-2 and ISO NWI TR 17772:
  - Guideline for using indoor environmental input parameters for the design and assessment of energy performance of buildings.

Indoor environmental input parameters for the design and assessment of energy performance of buildings

- This International Standard deals with the indoor environmental parameters for thermal environment, indoor air quality, lighting and acoustic.
- This standard specifies how to establish indoor environmental input parameters for building system design and energy performance calculations.
- This standard includes design criteria for the local thermal discomfort factors. draught, radiant temperature asymmetry, vertical air temperature differences, floor surface temperature.
- This standard specifies occupancy schedules to be used in standard energy calculations.

Categories

Cate-gory	Explanation
I	High level of expectation and also recommended for spaces occupied by very sensitive and fragile persons with special requirements like some disabilities, sick, very young children and elderly persons, to increase accessibility.
II	Normal level of expectation
III	An acceptable, moderate level of expectation
IV	Low level of expectation. This category should only be accepted for a limited part of the year

MODERATE THERMAL ENVIRONMENTS

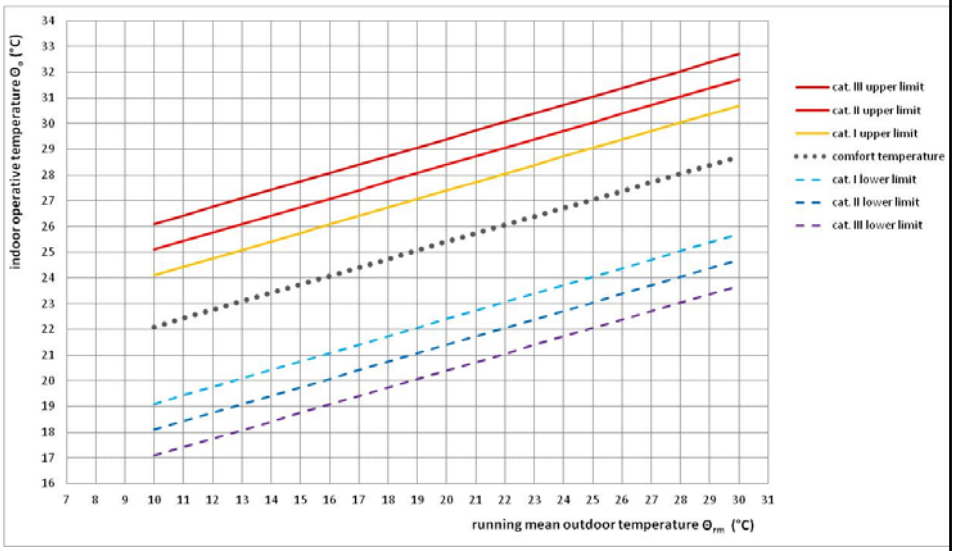
- GENERAL THERMAL COMFORT
  - PMV / PPD, OPERATIVE TEMPERATURE
- LOCAL THERMAL DISCOMFORT
  - Radiant temperature asymmetry
  - Draught
  - Vertical air temperature difference
  - Floor surface temperature

Temperature ranges for hourly calculation of cooling and heating energy in three categories of indoor environment

Type of building/ space	Category	Operative Temperature for Energy Calculations °C	
Offices and spaces with similar activity (single offices, open plan offices, conference rooms, auditorium, cafeteria, restaurants, class rooms, Sedentary activity ~1,2 met		Heating (winter season), ~ 1,0 clo	Cooling (summer season), ~ 0,5 clo
	I	21,0 – 23,0	23,5 - 25,5
	II	20,0 – 24,0	23,0 - 26,0
	III	19,0 – 25,0	22,0 - 27,0
	IV	17,0 – 26,0	21,0 - 28,0

ADAPTATION IN NATURAL VENTILATED BUILDINGS ?

- Behavioural
  - Clothing, activity, posture
- Psychological
  - Expectations



$$\Theta_{rm} = (\Theta_{ed\ -1} + 0{,}8\ \Theta_{ed\ -2} + 0{,}6\ \Theta_{ed\ -3} + 0{,}5\ \Theta_{ed\ -4} + 0{,}4\ \Theta_{ed\ -5} + 0{,}3\ \Theta_{ed\ -6} + 0{,}2\ \Theta_{ed\ -7})/3{,}8$$

CRITERIA FOR INDOOR AIR QUALITY ~VENTILATION RATES

- COMFORT (Perceived Air Quality)
- HEALTH
- PRODUCTIVITY
- ENERGY

HEALTH CRITERIA FOR VENTILATION

Minimum 4 l/s/person

Concept for calculation of design ventilation rate

People Component Building Component

Breathing Zone Outdoor Airflow V_{bz} = R_pP_z + R_sS_d + R_aA_z

- R_pP_z: Minimum l/s/Person; Number of People
- R_sS_d: Ventilation per Smoker; Number of Smokers
- R_aA_z: Building Area; Minimum l/s/m²

Total ventilation rate

$$q_{tot} = n \cdot q_p + A_R \cdot q_B$$

$q_{supply} = q_{tot} / \varepsilon_v$

- Where
- ε_v = the ventilation effectiveness (EN13779)
- q_{supply} = ventilation rate supplied by the ventilation system
- q_{tot}= total ventilation rate for the breathing zone, l/s
- n = design value for the number of the persons in the room,
- q_p = ventilation rate for occupancy per person, l/s, pers
- A_R= room floor area, m^2
- q_B = ventilation rate for emissions from building, l/s,m^2

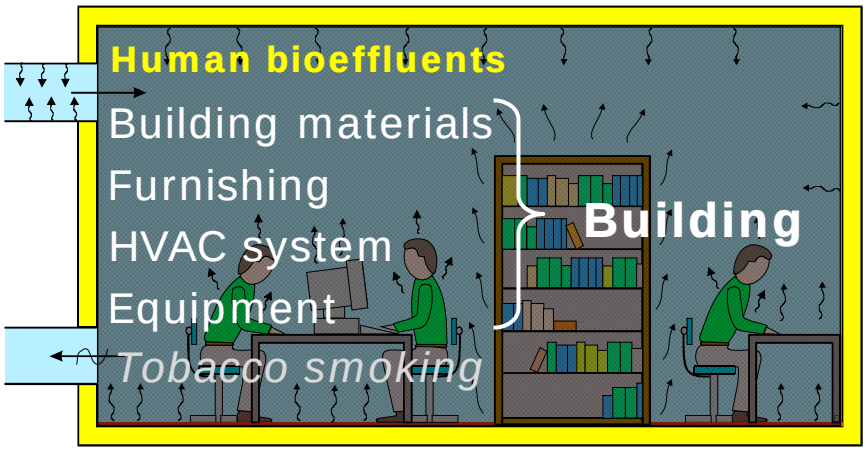
Basic required ventilation rates for diluting emissions (bio effluents) from people for different categories

Category	Expected Percentage Dissatisfied	Airflow per non-adapted person l/(s.pers)
I	15	10
II	20	7
III	30	4
IV	40	2,5*

*The total ventilation rate must never be lower than 4 l/s per person

ASHRAE Standard 62.1 : Adapted persons 2,5 l/s person (Cat. II)

Indoor pollution sources



Design ventilation rates for diluting emissions from buildings

Category	Very low polluting building l/(s m^2)	Low polluting building l/(s m^2)	Non low-polluting building l/(s m^2)
I	0,5	1,0	2,0
II	0,35	0,7	1,4
III	0,2	0,4	0,8
IV	0,15	0,3	0,6
Minimum total ventilation rate for health	4 l/s person	4 l/s person	4 l/s person

Example on how to define low and very low polluting buildings

SOURCE	Low emitting products for low polluted buildings	Very low emitting products for very low polluted buildings
Total VOCs TVOC (as in CEN/TS 16516)	< 1.000 µg/m³	< 300 µg/m³
Formaldehyde	< 100 µg/m³	< 30 µg/m³
Any C1A or C1B classified carcinogenic VOC	< 5 µg/m³	< 5 µg/m³
R value (as in CEN/TS16516)	< 1.0	< 1.0

Example of design ventilation air flow rates for a single-person office of 10 m^2 in a low polluting building (un-adapted person)

Cate-gory	Low-polluting building l/(s*m^2)	Airflow per non-adapted person l/(s*person)	Total design ventilation air flow rate for the room l/s	l/(s*person)	l/(s* m^2)
I	1,0	10	20	20	2
II	0,7	7	14	14	1,4
III	0,4	4	8	8	0,8
IV	0,3	2,5	5,5	5,5	0,55

Default design CO2 concentrations above outdoor concentration assuming a standard CO2 emission of 20 L/(h/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)

Specific Pollutans

The ventilation rate required to dilute a pollutant shall be calculated by this equation:

$$Q_h = \frac{G_h}{C_{h,i} - C_{h,o}} \cdot \frac{1}{\varepsilon_v} \qquad \text{Eq (2)}$$

where:

- Q_h is the ventilation rate required for dilution, in litre per second;
- G_h is the pollution load of a pollutant, in micrograms per second;
- $C_{h,i}$ is the guideline value of a pollutant, see Annex B6 , in micrograms per m^3;
- $C_{h,o}$ is the supply concentration of pollutants at the air intake, in micrograms per m^3;
- ε_v is the ventilation effectiveness

NOTE. $C_{h,i}$ and $C_{h,o}$ may also be expressed as ppm (vol/vol). In this case the pollution load G_h has to be expressed as l/s.

Pollutant	WHO Indoor Air Quality guidelines 2010	WHO Air Quality guidelines 2005
Benzene	No safe level can be determined	-
Carbon monoxide	15 min. mean: 100 mg/m^3 1h mean: 35 mg/m^3 8h mean: 10 mg/m^3 24h mean: 7 mg/m^3	-
Formaldehyde	30 min. mean: 100 µg/m^3	-
Naphthalene	Annual mean: 10 µg/m^3	-
Nitrogen dioxide	1h mean: 200 µg/m^3 Annual mean: 40 mg/m^3	-
Polyaromatic Hydrocarbons (e.g. Benzo Pyrene A B[a]P)	No safe level can be determined	-
Radon	100 Bq/m^3 (sometimes 300 mg/m^3, country-specific)	-
Trichlorethylene	No safe level can be determined	-
Tetrachloroethylene	Annual mean: 250 µg/m^3	
Sulfure dioxide	-	10 min. mean: 500 µg/m^3 24h mean: 20 mg/m^3
Ozone	-	8h mean:100 µg/m^3
Particulate Matter PM 2,5	-	24h mean: 25 µg/m^3 Annual mean: 10 µg/m^3
Particulate Matter PM 10	-	24h mean: 50 µg/m^3 Annual mean: 20 µg/m^3

WHO guidelines values for indoor and outdoor air pollutants

Filtration and air cleaning

- The influence of position of outdoor air intakes, filtration and air cleaning shall be considered. (EN13779, TR15251)
- If filtration and air cleaning is used the following points shall be considered:
  - Reducing the amount of airborne pollutants (pollens, molds, spores, particles, dust) from the outdoor air intake by circulating the air through a filter.
  - Circulating secondary air through a filter or other air cleaning technology to reduce the amount of pollutants in the air
  - Reduce the concentration of odors and gaseous contaminants by circulating the secondary air or recirculating the return air (gas phase air cleaning)

    - Note: Design guidelines on air cleaning and filtration are given in EN13779 and ISO DIS 16814. How to partially substitute outside air by air cleaning is described in TR15251

Example of recommended design criteria for the humidity in occupied spaces if humidification or dehumidification systems are installed

Type of building/space	Category	Design relative humidity for dehumidification, %	Design relative humidity for humidification, %
Spaces where humidity criteria are set by human occupancy. Special spaces (museums, churches etc) may require other limits	I	50	30
	II	60	25
	III	70	20
	IV	> 70	< 20

Examples of lighting criteria for some buildings and spaces

Ref. no. acc. to EN 12464-1	**Type of area, task or activity**	$\bar{E}_m$ lx	$\frac{UG}{R_L}$ –	U_o –	R_a –	**Specific requirements**
5.26.2 5.26.5	Offices - Writing, typing, reading, data processing. Conference and meeting rooms	500	19	0,60	80	DSE-work, see 4.9 Lighting should be controllable.
5.36.1-5.36.3	Educational buildings - Classrooms, tutorial rooms, Classroom for evening classes and adults education, Auditorium, lecture halls	500	19	0,60	80	Lighting should be controllable.
5.36.24	Educational premises – Educational buildings - Sports halls, gymnasiums, swimming pools	300	22	0,60	80	See EN 12193 for training conditions.

Daylight availability classification as a function of the daylight factor $D_{Ca,j}$ of the raw building carcass opening and D_{SNA} 15193

Vertical Facades **Daylight factor $D_{Ca,j}$**	**Roof lights** **Daylight factor D_{SNA}**	**Classification of daylight availability**
$D_{Ca,j} \geq 6$ %	7 % < D_{SNA}[a]	Strong
6 % > $D_{Ca,j} \geq 4$ %	7 % > $D_{SNA} \geq 4$ %	Medium
4 % > $D_{Ca,j} \geq 2$ %	4 % > $D_{SNA} \geq 2$ %	Low
$D_{Ca,j} < 2$ %	2 % > $D_{SNA} \geq 0$ %	None
[a] Values of $D_{SNA} > 10$ % should be avoided due to danger of overheating		

NOISE

Building	**Type of space**	**Equivalent Continuous Sound Level, Leq, nT,A [dB(A)]**		
		I	II	III
Residential	Living room	≤30	≤34	≤38
	Bed room	≤26	≤30	≤34
Places of assembly	Auditoriums	≤20	≤24	≤28
	Libraries	≤24	≤28	≤32
	Cinemas	≤20	≤24	≤28
Hospitals	Bedrooms night-time	≤22	≤26	≤30
	Bedrooms daytime	≤24	≤28	≤32
Hotels	Hotel rooms (during night-time)	≤24	≤28	≤32
	Hotel rooms (during daytime)	≤26	≤30	≤34
Offices	Small offices	≤24	≤28	≤32
	Landscaped offices	≤26	≤30	≤34
Restaurants	Restaurants	≤28	≤32	≤36
Schools	Classrooms	≤24	≤28	≤32
	Teacher rooms	≤28	≤32	≤36

Occupant Schedules

Office, main

Parameters and setpoints

	Parameter	Value	Unit
Operation time	Hour at day, START	7	hour
	Hour at day, END	18	hour
	Breaks, inside range	0	hours
	days/week	5	days
	hours/day	11	hours
	hours/year	2868	hours
Internal gains	Occupants	17	m2/pers
	Occupants (Total)	8.3	W/m^2
	Occupants (Dry)	5	W/m^2
	Appliances	12	W/m^2
	Lighting		
	Moisture production	3.53	g/(m2, h)
	CO_2 production	1.10	l/(m2, h)
Setpoints	Min T,op in unoccupied hours	16	°C
	Max T,op in unoccupied hours	32	°C
	Min T,op	20	°C
	Max T,op	26	°C
	Ventilation rate (min.)	0.8	l/(s m^2)
	Ventilation rate for CO2 emission	0.53	l/(s m^2)
	Max CO_2 concentration (above outdoor)	500	ppm
	Min. relative humidity	25	%
	Max. relative humidity	60	%
	Lighting, illuminance in working areas	500	lux
Other	Domestic hot water use	100	l/(m2 year)

* u.r. : Usage rate, summed load factors/usage time

Usage schedule

	Energy calculation					
	Weekdays			Weekends		
h	Occupants	Appliances	Lighting	Occupants	Appliances	Lighting
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0.2	0.2	0.2	0	0	0
9	0.6	0.6	0.6	0	0	0
10	0.6	0.6	0.6	0	0	0
11	0.7	0.7	0.7	0	0	0
12	0.7	0.7	0.7	0	0	0
13	0.4	0.4	0.4	0	0	0
14	0.6	0.6	0.6	0	0	0
15	0.7	0.7	0.7	0	0	0
16	0.7	0.7	0.7	0	0	0
17	0.6	0.6	0.6	0	0	0
18	0.2	0.2	0.2	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
*u.r.	0.55	0.55	0.55	0.00	0.00	0.00

International Standards
Indoor Environmental Quality

- prEN15251-1 and ISO CD 17772:
  - Indoor environmental input parameters for the design and assessment of energy performance of buildings.
- TR15251-2 and ISO NWI TR 17772:
  - Guideline for using indoor environmental input parameters for the design and assessment of energy performance of buildings.

Example of equivalent increase in CO_2 levels indoor for the total ventilation rates specified

Type of building or space	Category	occupancy	ΔCO_2 [ppm]		
		person/m²	Very low-polluting	low-polluting	Not low-polluting
Single office	I	0,1	370	278	185
	II	0,1	529	397	265
	III	0,1	926	694	463
	IV	0,1	1389	1010	654
Land-scaped office	I	0,07	317	222	139
	II	0,07	454	317	198
	III	0,07	741	556	347
	IV	0,07	1235	794	483
Conference room	I	0,5	505	463	397
	II	0,5	722	661	567
	III	0,5	1263	1157	992
	IV	0,5	1462	1389	1502
Auditorium	I	1,33	535	517	483
	II	1,33	765	738	690
	III	1,33	1347	1300	1208
	IV	1,33	1576	1398	1576

Adapted persons. Examples of recommended ventilation rates for non-residential buildings with default occupant density for three categories of pollution from building itself

Type of building or space	Cate-gory	Floor area m²/per-son	q_p		q_B	q_{tot}		q_B	q_{tot}	
			Adapted q_p according to table B1							
			l/s, m²	l/s,person	l/s,m²	l/s,m²	l/s,person	l/s,m²	l/s,m²	l/s,person
			for occupancy		for very low-polluted building			for low-polluted building		
Conference Class room	I	2	1,75	3,5	0,5	**2,25**	**4,5**	1	**2,75**	**5,5**
	II	2	1,25	2,5	0,35	1,60	(3,2)4	0,7	1,95	(3,9)4
	III	2	0,75	1,5	0,3	1,05	(2,1)4	0,4	1,15	(2,3)4
	IV	2	0,50	1	0,25	0,75	(1,5)4	0,3	0,80	(1,6)4
Auditorium	I	0,75	4,67	3,5	0,5	5,17	(3,9)4	1	**5,67**	**4,3**
	II	0,75	3,33	2,5	0,35	3,68	(2,8)4	0,7	4,03	(3,0)4
	III	0,75	2,00	1,5	0,3	2,30	(1,7)4	0,4	2,40	(1,8)4
	IV	0,75	1,33	1	0,25	1,58	(1,2)4	0,3	1,63	(1,2)4

Adapted or Un-adapted ?

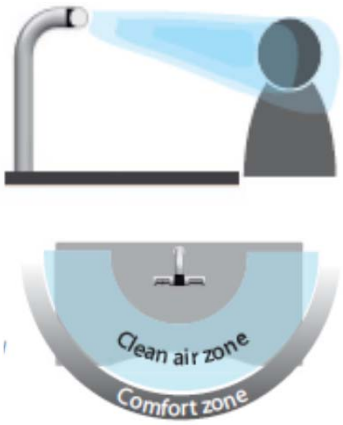
- Conference rooms. Adapted?
- Classrooms. Adapted?
- Restaurants. Un-adapted?
- Department stores. Un-adapted

Basic required ventilation rates for diluting emissions (bio effluents) from people for different categories

Category	Expected Percentage Dissatisfied	Airflow per non-adapted person l/s*pers	Airflow per adapted person l/s*pers
I	**15**	**10**	**3,5**
II	**20**	**7**	**2.5**
III	**30**	**4**	**1.5**
IV	**40**	**2,5**	**1.0**

ASHRAE Standard 62.1 : Adapted persons 2,5 l/s person (Cat. II)

Personalized systems



- Can “standard” criteria be directly applied also to a personal system, where the occupants try to meet their own preferences?
- If the occupants have a personalized system is it then possible to relax on the requirements to the general environment?
- Increased satisfaction

Trends Regarding Emissions from Materials

- Several national methods for material declarations and certification
- Work on establishing common EU concepts
- Will give incentives to manufacturer of building materials and furnishing

Trends regarding ventilation

- Increasing use of air cleaning
  - Filtration
  - Gas phase air cleaning
- Personalized systems for better comfort and energy savings
- Demand control ventilation
  - Occupant precense
  - CO_2 sensors
  - Artificial nose

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Calculations methods: Revision of EN 15241-15242-15243 - the prEN 16798 Falimy

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Existing ventilation and cooling related standards

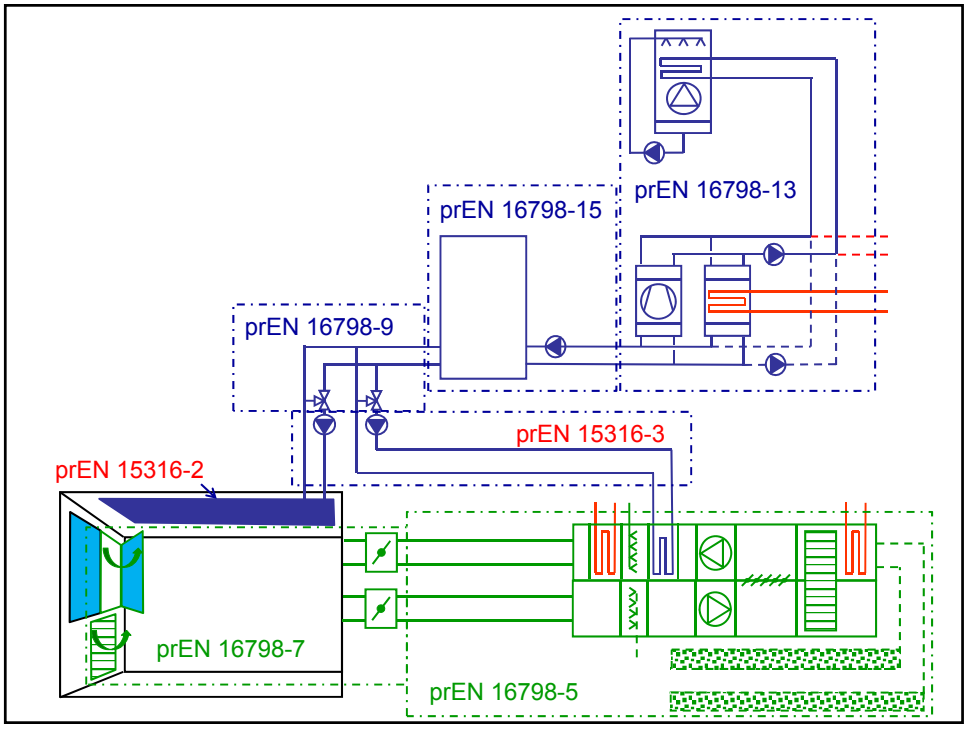
	Technical Building Systems								
	Heating	Cooling	Ventilation [1]	Humidification	Dehumidification	Domestic Hot water	Lighting	Building automation & control	PV, wind, ..
sub1	M3	M4	M5	M6	M7	M8	M9	M10	M11
1	General	General	General	General	General	General	General	General	General
2	Needs	Needs	Needs	Needs	Needs	Needs	Needs		---
3	Maximum Load and Power	Maximum Load and Power	Maximum Load and Power	Maximum Load and Power	Maximum Load and Power	Maximum Load and Power	Maximum Load and Power	---	---
4	Ways to Express Energy	Ways to Express Energy	Ways to Express Energy	Ways to Express Energy	Ways to Express Energy	Ways to Express Energy	Ways to Express Energy	Ways to Express Energy	Ways to Express Energy
5	Emission & control	Emission & control	Emission & control	Emission & control	Emission & control	Emission & control	Emission & control	Emission & control	---
6	Distribution & control	Distribution & control	Distribution & control	Distribution & control	Distribution & control	Distribution & control	Distribution & control	Distribution & control	Distribution & control
7	Storage & control	Storage & control	Storage & control	0	0	Storage & control	--	Storage & control	Storage & control
8	Generation & control	Generation & control	Generation & control	Generation & control	Generation & control	Generation & control	Generation & control	Generation & control	Generation & control
9	Load dispatching and operating conditions	Load dispatching and operating conditions	Load dispatching and operating conditions	--	--	Load dispatching and operating conditions	--	Load dispatching and operating conditions	--
10	Measured Energy Performance	Measured Energy Performance	Measured Energy Performance	Measured Energy Performance	Measured Energy Performance	Measured Energy Performance	Measured Energy Performance	Measured Energy Performance	Measured Energy Performance
11	Inspection	Inspection	Inspection	Inspection	Inspection	Inspection	Inspection	Inspection	Inspection
12	---	---	---	---	---	---	---	BMS	---

EN 13779
EN 15251
EN 15243
EN 15242
EN 15241
EN 15239/40

prEN 16798-Family

Overarching		Technical Building Systems					
	Descriptions		Descriptions	Cooling	Ventilation	Humidifi-cation	Dehumi-dification
sub1	M1	sub1		M4	M5	M6	M7
1	General	1	General	prEN 16798-9	prEN 16798-3		
2	Common terms and definitions; symbols, units and subscripts	2	Needs				
3	Applications	3	Maximum Load and Power	prEN 16798-11			
4	Ways to Express Energy Performance	4	Ways to Express Energy Performance	prEN 16798-9	prEN 16798-3		
5	Building Functions and Building Boundaries	5	Emission & control		prEN 16798-7	prEN 16798-5	prEN 16798-5
6	Building Occupancy and Operating Conditions prEN 16798-1	6	Distribution & control		prEN 16798-5		
7	Aggregation of Energy Services and Energy Carriers	7	Storage & control	prEN 16798-15			
8	Building Partitioning	8	Generation & control	prEN 16798-13	prEN 16798-5	prEN 16798-5	prEN 16798-5
9	Calculated Energy Performance	9	Load dispatching and operating conditions				
10	Measured Energy Performance	10	Measured Energy Performance				
11	Inspection	11	Inspection	prEN 16798-17	prEN 16798-17	prEN 16798-17	prEN 16798-17

PE launch: Dec. 11, 2014



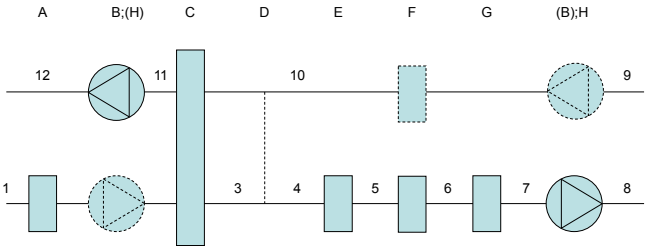
prEN 16798-7 Calculation methods for the determination of air flow rates (revision of EN 15242)

- Full coverage of module M5-5 “emission”
- Extension towards:
  - Air flow rates also for mechanical ventilation system, including VAV systems
  - For required air flow rates:
    link to prEN 16798-1 (EN 15251 rev.) / prEN 16798-3 (EN 13779 rev.)
  - Distribution leakage -> prEN 16798-5
  - Required conditions of supply air (depending on system type and control)

prEN 16798-5 Calculation methods for energy requirements of ventilation and air conditioning systems (revision of EN 15241)

- Modules M5-6, M5-8, M6-5, M6-8, M7-5, M7-8
- Redistribution of content between this module and prEN 16798-7 (revision of EN 15242) – modular structure
- Split in 2 documents:
  1. Detailed method for ventilation and air conditioning systems
     - Hourly calculation step
     - Comprehensive calculation of all aspects of AC systems
     - “generation” (=AHU) and distribution
  2. Simplified method for compact residential systems
     - Based on proposal from TC 156 WG 2
     - Monthly calculation step
     - including heat generation (a/a HP) and domestic hot water heating

prEN 16798-5-1 Calculation methods for energy requirements of ventilation and air conditioning systems (revision of EN 15241) – method 1



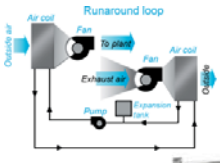
General	A	B	C	D	E	F	G	H
Volume flow rates Detailed	Frost protection / ground preheating/-cooling	Exhaust air fan	Heat recovery	Recirculation	Cooling / dehumidification	Humidification	Heating	Supply fan
Air handling unit localisation	Ground air preheating and -cooling	localisation	Heat recovery type			Humidifier type		Fan motor localisation
NC	else	DOWN_HR	ROT_SORBT	yes		CONTACT		OUTS_AIR
Supply air temperature control	Frost protection type		only for FLAT_PLATE and ROT_HYG	Recirculation control		humidifier control		System type for variable air volume flow rate fan energy calculation
ODA_COMP	PREH		-	VARIABLE		SPEED		SINGLE_ZONE
Control of the volume flow rate	Control of the frost protection		Control of the heat recovery device			Adiabatic cooling		Control of the fan
VARIABLE	INDIRECT		SPEED					DIRECT
								localisation
								DOWN_HR

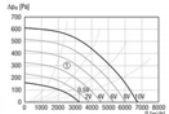
11 Extract air after heat recovery
12 Exhaust air

prEN 16798-5-1 Calculation methods for energy requirements of ventilation and air conditioning systems (revision of EN 15241) – method 1

- Air flow control types (-> TC 247, EN 15232 rev.)
- Supply air control types (-> TC 247, EN 15232 rev.)
- Heat recovery:
  - Types:
    - flat plate
    - Rotary
    - Pumped circuit

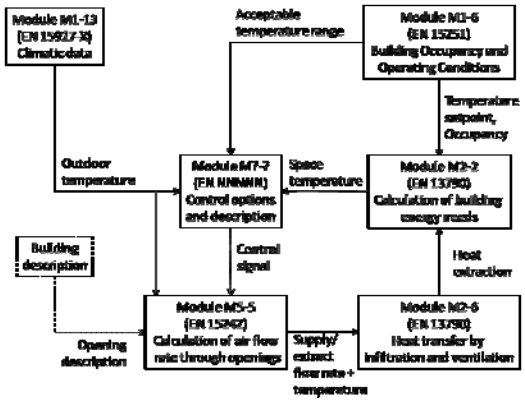
    Connection to product standards (EN 308, 13053)
  - Control
  - Frost protection
  - Auxiliary energy
- Recirculation control
- Fan control
  - Input from TC 247 – single zone / multi zone systems
  - Big impact on fan energy
  - Link to product standards (fans, new WG 17 in TC 156)
- Ground preheating / -cooling
- Adiabatic cooling





prEN 16798-9 Calculation of cooling systems – general (rest of EN 15243)

- Informative annexes (many!) will be transferred to TR
- Dito for Design process related issues from normative text
- + energy performance expression
- ./. Cooling generation
- ./. Cooling load calc.
- New: consolidation of the calculation pieces
- Load dispatching
- TR also:
  method for treatment of ventilative cooling

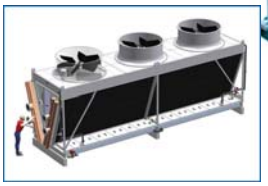


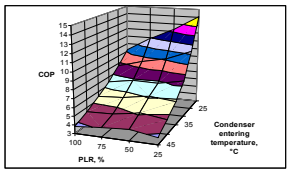
prEN 16798-11 Calculation of the design cooling load

- Collaboration project with TC 89 / ISO TC 163
- Intention: use same unified model as for energy needs calculation
- Different boundary / operational conditions
  - Design period climate
  - Use patterns with less simultaneity factors
- Simplified method: offers from countries received
- Project not time critical, because no direct link to energy calculation
  - Equipment dimensioning = engineering task, not subject to standardisation

prEN 16798-13 Calculation of cooling systems – generation

- New WI, until now covered only informative in an annex of EN 15243
- 2 Methods
  - Method A: hourly calculation step
  - Method B: monthly calculation step
- Compression and absorption chillers
- Multiple generators handling
- “Free cooling” control option
  - Direct cooling via heat rejection device
- Heat rejection types
  - Air cooled condenser
  - Dry, wet and hybrid heat recovery devices
  - Control
- Connection to product standards:
  - Data for performance map: EN 14825, based on EN 14511 tests
  - 4 measurement points not sufficient
  - Manufacturers: more data shall be made available





prEN 16798-15 Calculation of cooling systems - storage

- New WI
- Method applicable to any calculation time step
- Covers different storage types:
  - Water tanks
  - Ice storage
  - PCM
- Storage charging circuit included

Thank you

Inspection of ventilation systems and air conditioning systems

François Rémi Carrié, ICEE
Anne-Marie Bernard, ALLIE'AIR

AIVC Conference
Poznan, Poland
24-25 September 2014

Outline

- Context
- Major changes
- New scope and structure
- Phases of the inspection
- Specific issues
  - Inspection levels
  - Pre-inspection
  - On-site inspection
  - Report
  - Additional information
- Summary

Context

- 1st EPBD required inspection of air conditioning systems
- 2 standards supported these requirements
  - EN 15239 – Ventilation systems
  - EN 15240 – Air conditioning systems
- In practice, many problems have been reported to implement inspection schemes, namely through the Concerted Action

Overview of EPBD requirements relevant to inspection

Article	Essential characteristics in relation to inspection	Notes
4	Requirements shall take account of general indoor climate conditions, in order **to avoid negative effects** such as **inadequate ventilation**.	The methodology includes identification of non-energy related problems
15	Introduction of **measures** to establish a **regular inspection** of the **accessible parts** of air conditioning systems of an effective rated output of **more than 12 kW**.	The standard is also applicable to fixed system of smaller output <12 kW
	The inspection shall include an **assessment of the air-conditioning efficiency and the sizing** compared to the cooling requirements of the building.	Assessment can be based on analysis of the cooling load vs. cooling capacity
	Advice to be provided to the users **on the possible improvement or replacement** of air-conditioning systems or on other modifications to the air-conditioning system.	Recommendations in accompanying TR
16	An **inspection report** shall be issued and handed to the owner or tenant of the building **after each inspection** of a heating or air-conditioning system.	Contents of inspection report in EN standard
	The **inspection report** shall contain the **result of the inspection** performed and **include recommendations** for the cost-effective **improvement of the energy performance** of the inspected system.	Recommendations in accompanying TR

Major changes

- Substantial changes in structure, form, content
- Merger into one single standard. Content is restricted to normative text, informative content has been pushed in the Technical Report
- Clarification of the outputs of each inspection step
- Introduction of 3 levels of inspections
- Clarification on the inspection of air filters
- Emphasis on advice for improvements

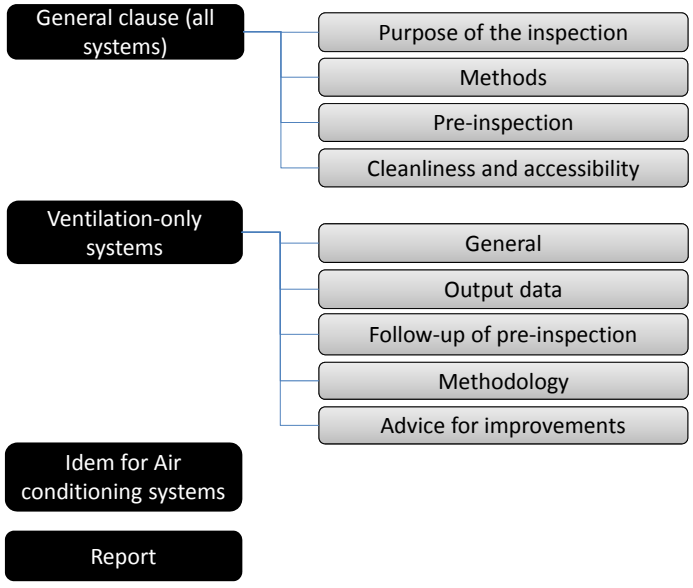
Scope of the inspection

- Standard is applicable to residential and non-residential buildings, equipped with:
  - air conditioning system without mechanical ventilation; or
  - air conditioning system(s) with mechanical ventilation; or
  - natural and mechanical ventilation system(s)
- …is applicable to the accessible parts that contribute to the cooling and mechanical ventilation services (fixed systems)

Purpose of the inspection

- The principal purpose of the inspection is to *provide advice* to building operators and owners on ways of reducing their energy consumption while maintaining acceptable indoor environmental conditions
- => *inspection report* easy to understand

General structure of the standard



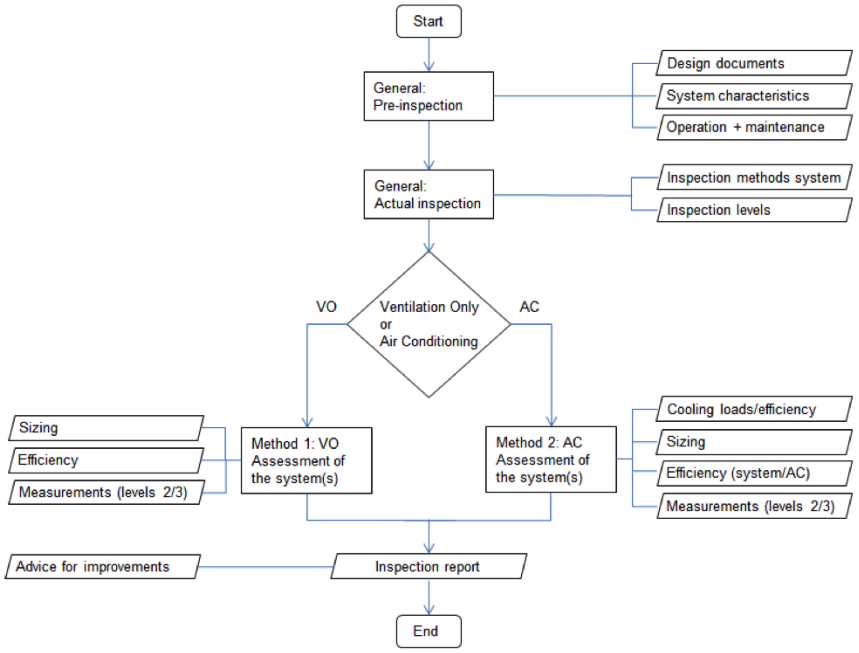


Figure 1 — Flow chart representing steps involved in inspection

Inspection levels

Inspection level	Type of inspection	Description
1	**Pre-inspection and functional checks**	Basic level to: • gather all documentation and identify priority inspection areas in relation to designs, installation and operation • identify on site features of system operation wasting energy
2	**Functional measurements**	Level requires measurements to: • check if system is operating as is intended • identify sources of energy wastage
3	**Special measurements**	Level requires additional measurements to: • provide more detailed assessments of system performance (e.g. extended measurement periods in time or in-situ components performance)

Note: The minimum level (level 1) does not require measurements and is sufficient to comply with the requirements of the EPBD recast

Pre-inspection - Output

- Output *shall* include:
  - Identification of lacking/outdated information
    - (checklist available in standard)
  - Advice to building manager on completing missing issues
  - Priority areas for the actual inspection:
    - Collecting missing information during inspection on site
    - Where the design installation is important for system functioning in a way likely to affect its performance

On-site inspection - Output

- For methods 1 & 2, output *shall* include:
  - Checking correspondence between:
  - Design documentation and actual installed components
  - As-installed drawings and actual system
- Method 1: Output *shall* include:
  - Air flow rates (inventory)
  - Specific fan power (inventory)
  - Assessment of sizing compared to ventilation requirements
- Method 2: Output *shall* include:
  - Specific cooling load (based on activity/design)
  - Specific cooling capacity (inventory)
  - Assessment of AC-efficiency
  - Assessment of sizing compared to cooling requirements

Inspection report

Table 3 — Information to be given in the inspection report depending on the method (1 of 2)

Information	Method		Part
	1	2	
General			
Name, address and status of the person and organization in charge of the inspection	X	X	—
Official designation and address of the property	X	X	—
Name and address of the building owner	X	X	—
Date of the inspection	X	X	—
Pre-inspection / Compliance with design documentation			
Status of the documentation or information, see Table 4, including identification of lacking and outdated documentation	X	X	5.3.6
Priority areas for the collection of missing information during the inspection on site	X	X	5.3.6
Priority areas for the inspection where the design installation appear to depart from good practice in a manner likely to affect its performance	X	X	5.3.6
Any difference between documentation and actual installed components	X	X	6.3, 7.3
Any difference between working or as-installed drawings and the actual system	X	X	6.3, 7.3
Aspects of the inspections simplified or reduced because of clear evidence that a good practice program of maintenance is being carried out	X	X	6.4.1.1, 7.4.2
Check of the system			
Number of measurements and building parts inspected	X	NA	6.4.1.2
In case of presence of specific ventilation systems for the reduction in the concentration of specific gas (e.g. radon), the operation or not of these specific	X	NA	6.4.1.5

Additional information in technical report

- Includes a number of checklists
- Information to estimate the cooling loads and cooling capacity

Table 28 — Checklist for refrigeration equipment (including water-loop heat pumps)

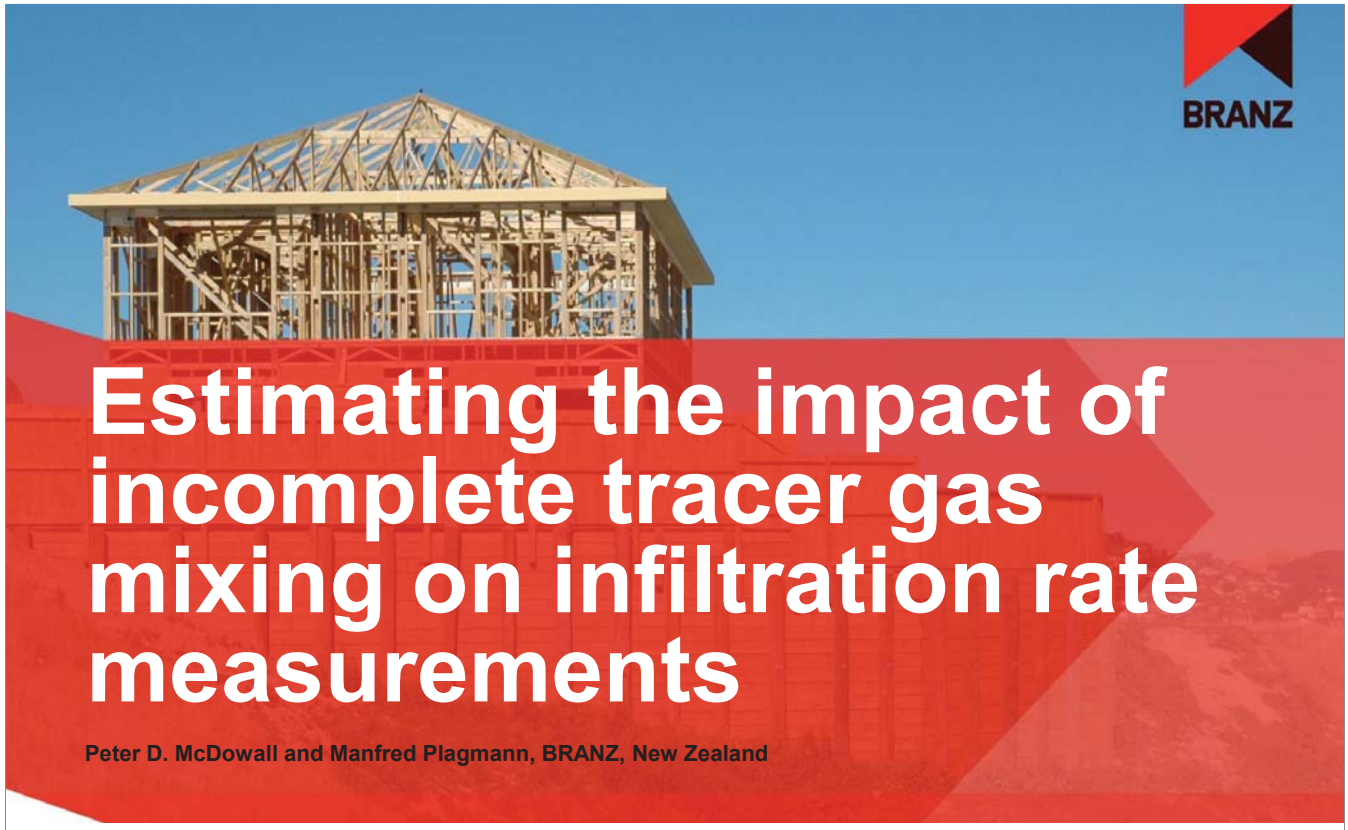
No.	Assessment topic	Notes and advice
28.1	Visual appearance of refrigeration plant and immediate surrounding area	Note whether the plant appears clean and unobstructed. If dirty and cluttered, then regular inspection and maintenance is unlikely and this should be noted. Visual signs of refrigerant leakage should be noted and, if present, evidence of attention to any leakage sought. If this has not been attended to, then recommend prompt skilled maintenance.
28.2	Locate refrigeration plant and check operation	Note whether there are any discrepancies between actual and documented plant. Note whether plant is operational.
28.3	Availability of measurement records	If available, use the records for checking of the functioning of the equipment.

Table 6 — Items for supply duct systems

No.	Inspection item	Details			Level		
					1	2	3
6.1	Documentation	No □	Incomplete □	Complete □	X	X	X
6.2	List missing documentation				—	X	X
6.3	Type	Circular □	Rectangular □		X	X	X
6.4	Nominal length estimated	m			X	—	—
6.5	Nominal length designed	m			—	X	X
6.6	Nominal supply air flow	m^3/h or m^3/s			—	X	X
6.7	Material of the duct system				X	X	X
6.8	Tightness, visual	Satisfactory □	Not satisfactory □		X	X	X
6.9	Tightness measured	Pa			—	—	X
6.10	Insulation, visual	Satisfactory □	Not satisfactory □		X	X	X
6.11	Surface temperature, measured	°C			—	X	X
6.12	Temperature drop in/out, measured	°C			—	—	X
6.13	Maintenance frequency	Regular □	On demand □	No □	X	X	X
6.14	State of maintenance	Satisfactory □	Not satisfactory □		X	X	X
6.15	Any other information				—	—	—

Summary

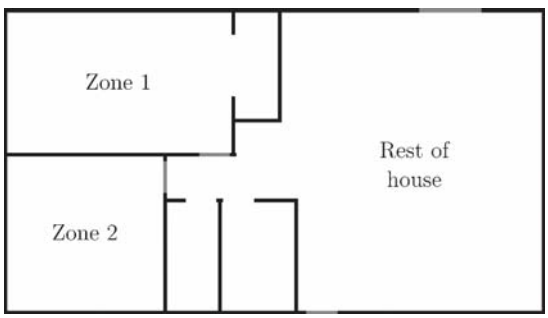
- Inspection of ventilation systems and air-conditioning systems is dealt with in a single standard
- It defines 3 inspection levels, inc. one basic level with no measurements sufficient to comply with the EPBD
- The new standard gives the essential steps for the inspection
- It clarifies the outputs of each step
- It gives a number of checklists which should help for its implementation and use

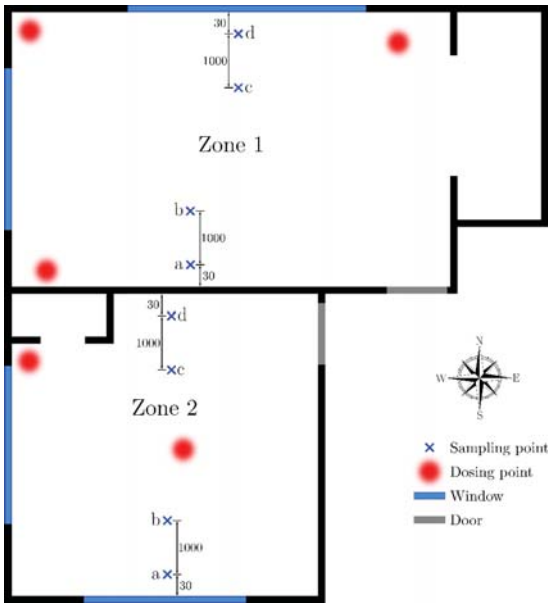


Estimating the impact of incomplete tracer gas mixing on infiltration rate measurements

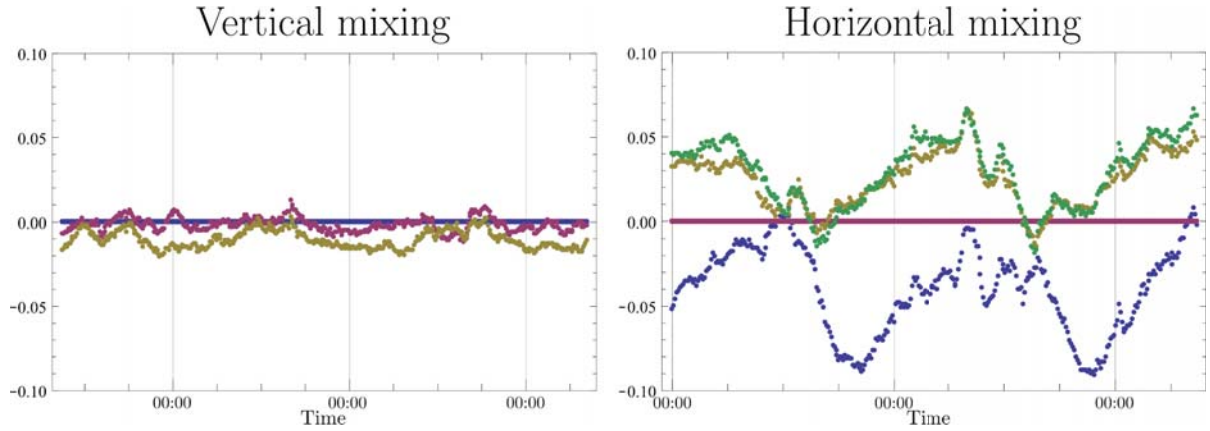
Peter D. McDowall and Manfred Plagmann, BRANZ, New Zealand

Experimental test house





Difference in SF_6 concentration



The 10 steps to conceive and build airtight buildings

Clarisse Mees
Yves Martin
Xavier Loncour
Christophe Delmotte

Conference AIVC 2014 – Poznan

Step 3: Choose equipment types and their position regarding the airtight zone

- Conciliate fire safety, ventilation requirements and airtightness by choosing appropriate equipment.

Equipment / rooms	Recommended position
Garages	Foresee specific ventilation system or place them outside the protected volume
Technical shafts	Depending on the fire regulations. If not applied in the considered building: inside the protected volume If applied in the considered building: outside the protected volume or provide a partitioning of the shafts
Elevator shafts	Inside the protected volume and provide a ventilation system with motorized valves Or Outisde the protected volume

Etanch'air project

- Estimation of local air leakages

→ Which constructive node has to be treated in priority ?

Step 7: Prioritize the constructive nodes

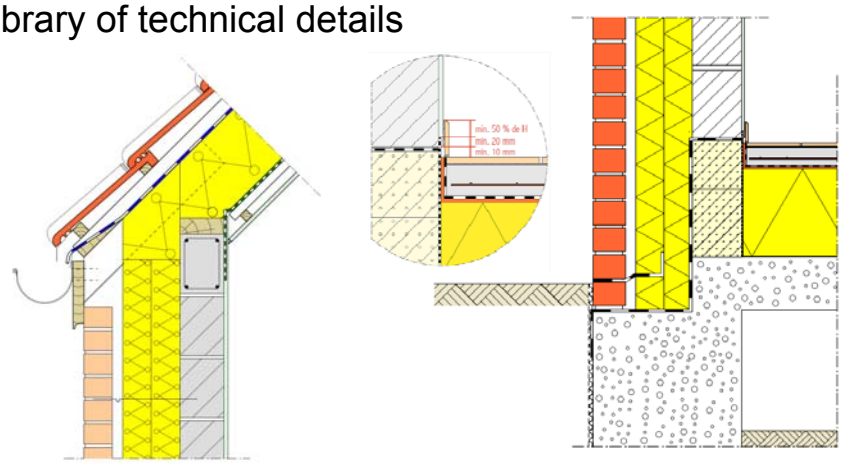
Prioritization order	
****	Priority 1
***	Priority 2
**	Priority 3
*	Priority 4

- For cavity walls

Constructive nodes	Priority
Ground bearing floor	* → **
Junction between separating wall and façade	*
Junction between intermediate floor and façade	**
Pitched roof: Purlins	*** → ****
Pitched roof : Gable	****
Pitched roof : Eaves	*** → ****
Service penetration through roof	***
Junction between window and façade	** → ***

Step 8: Choose technical solutions for each constructive nodes… and implement it !

- Library of technical details



Thank you for your attention

The research project ETANCH'AIR funded by the Walloon Region
and the project LUCHTDICHT BOUWEN VAN A TOT Z funded by the Flemish Region.

Wallonie

luchtdichtbouwen.

ACH and Air Tightness Test Results in the Croatian and Hungarian Border Region

Dr. László Fülöp, György Polics
Faculty of Engineering and Information Technology,
University of Pécs, Hungary

The project is co-financed by the European Union through the Hungary-Croatia IPA Cross-border Co-operation Programme

Air tightness and natural air change rate field test project

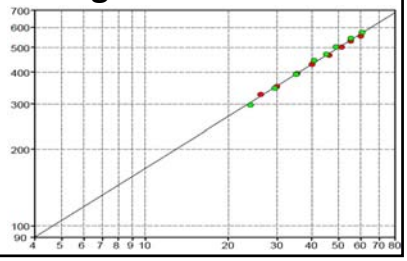
- **A joint project of University of Pécs, Hungary and University of Osijek, Croatia is aimed to gather information on the air tightness and air change rate of dwellings in the border region of Hungary and Croatia**
- **The project was supported by the EU Hungary-Croatia IPA** (Instrument for Pre-Accession Assistance) **Cross-border Co-operation Programme**

The project is co-financed by the European Union through the Hungary-Croatia IPA Cross-border Co-operation Programme

PÉCSI TUDOMÁNYEGYETEM
Pollack Mihály Műszaki Kar

The types of tests performed

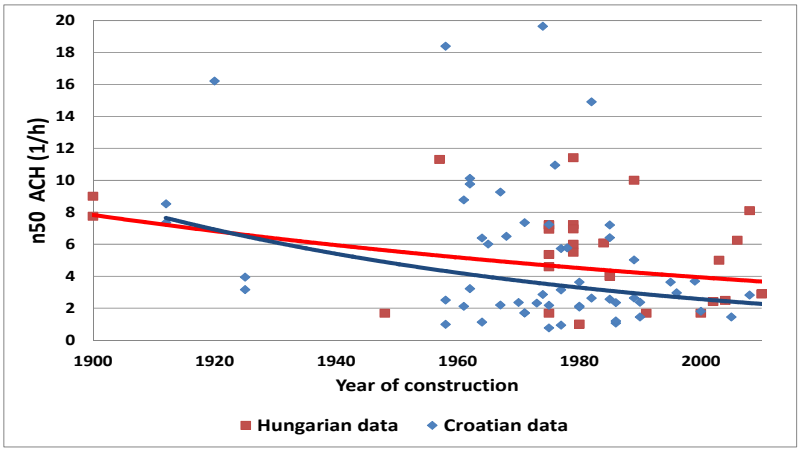
- Blower Door Type A (ACH) and Type B (air tightness) pressurization and depressurization tests at 50 Pa pressure difference
- In case of ACH a series of tests at various pressure differences and projection the trend line to 4 Pa pressure difference that is an average for the heating period
- Natural air change rate by SF_6 tracer gas tests



The project is co-financed by the European Union through the Hungary-Croatia IPA Cross-border Co-operation Programme

PÉCSI TUDOMÁNYEGYETEM
Pollack Mihály Műszaki Kar

Summary of Type A n_{50} ACH test results



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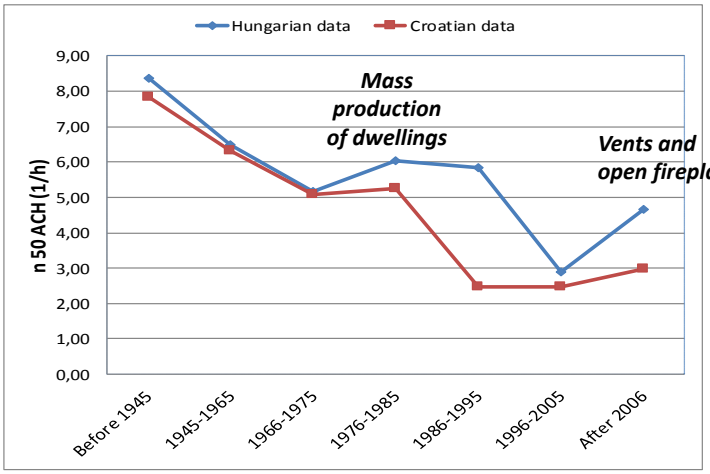
Average n_{50} ACH values for typical periods



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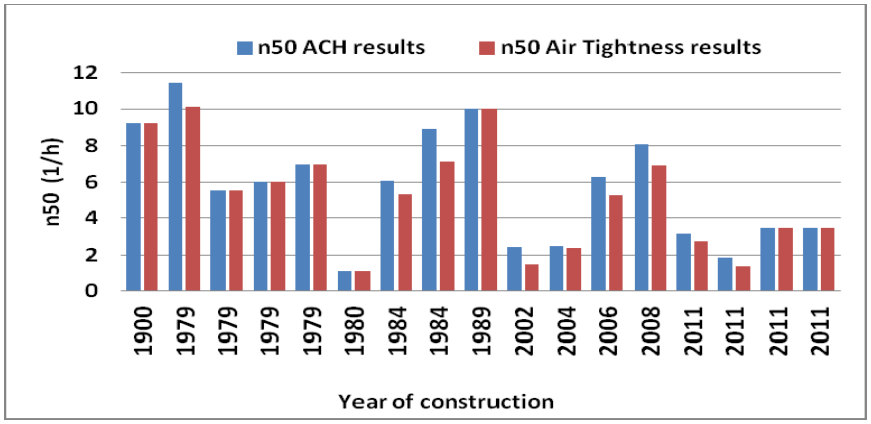
Comparison of Type A (ACH) and Type B (air tightness) test results



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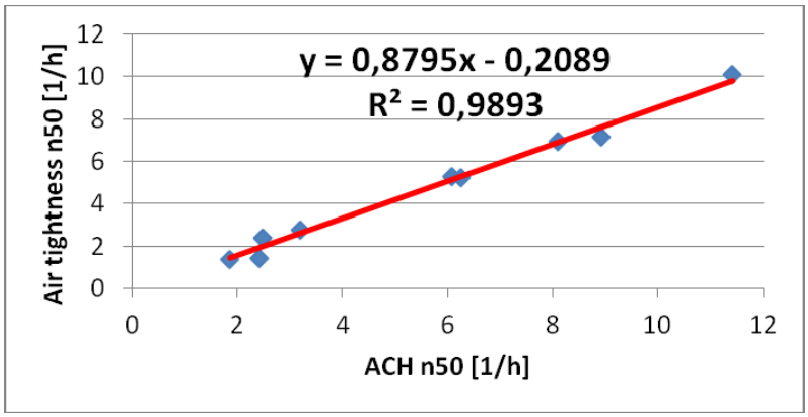
Pollack Mihály Műszaki Kar

Correlation of Type A (ACH) and Type B (air tightness) test results



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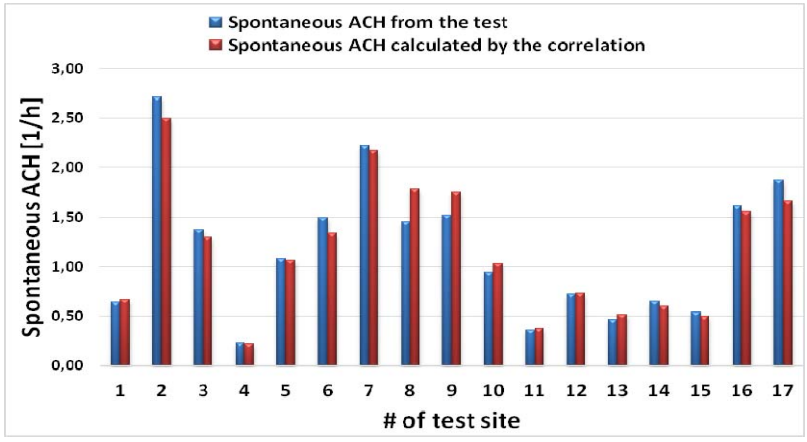
PÉCSI TUDOMÁNYEGYETEM
Pollack Mihály Műszaki Kar

Comparison of projected and measured ACH at 4 Pa pressure difference



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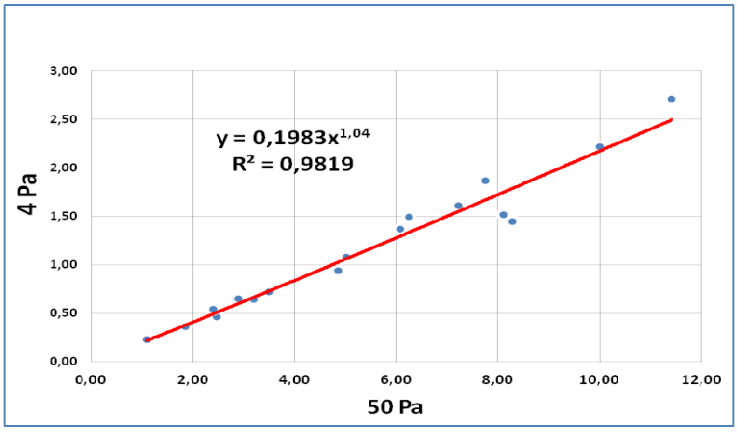
ACH at 4 Pa pressure difference as a function of 50 Pa test results



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Pollack Mihály Műszaki Kar

Conclusion

- **Although the difference between type A and B BlowerDoor test result is depends on the actual type and size of the vents very much, good correlation found between the two test results**
- **However, legally Type B air tightness test cannot be replaced by Type A test for qualification purposes**
- **Also, quite good correlation found between n_{50} and n_4 ACH test result but does not agree with the standard 20 factor. Tests to be continued…**

The project is co-financed by the European Union through the Hungary-Croatia IPA Cross-border Co-operation Programme

ACH and Air Tightness Test Results in the Croatian and Hungarian Border Region

Thank you for your kind attention,

For more details please consult our paper and visit our poster

Dr. László Fülöp
Department of HVAC
Faculty of Engineering and Information Technology
University of Pécs, Hungary

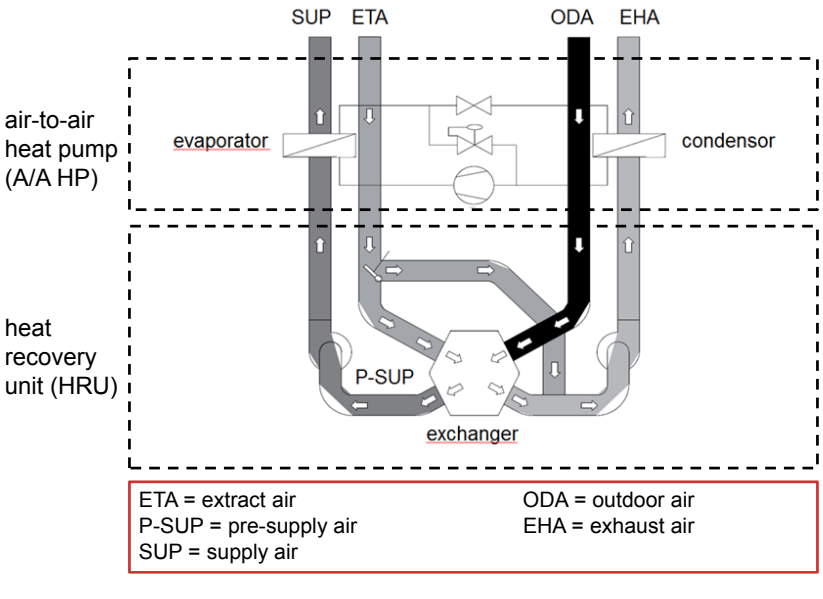
The project is co-financed by the European Union through the Hungary-Croatia IPA Cross-border Co-operation Programme

Summer performance of residential heat recovery ventilation with an air-to-air heat pump cooling system

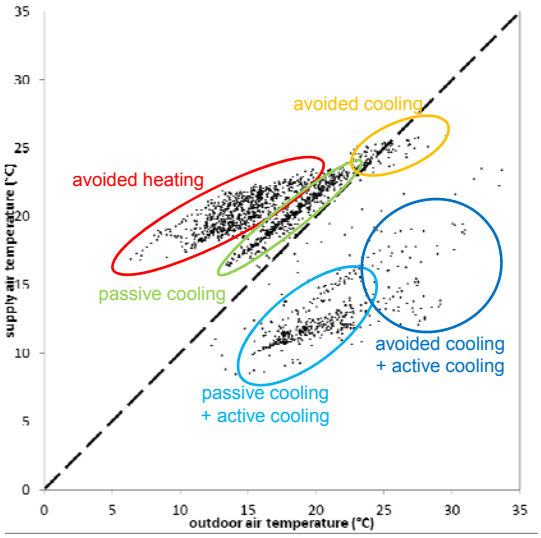
Monitoring during summer (July - October 2012)

Bart Cremers, Knowledge Centre, Zehnder Group Netherlands

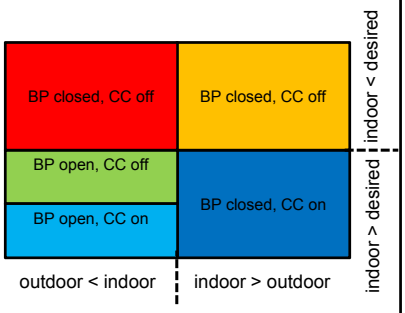
Working principle



Supply air temperature vs. outdoor air temperature

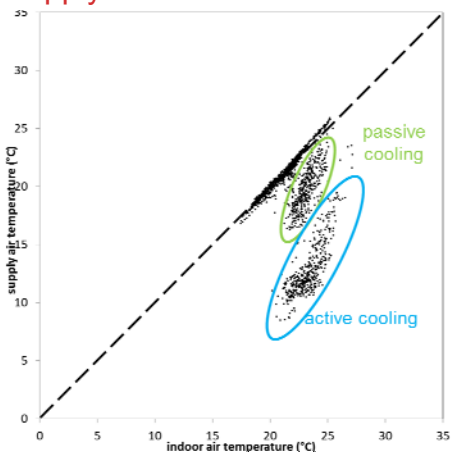


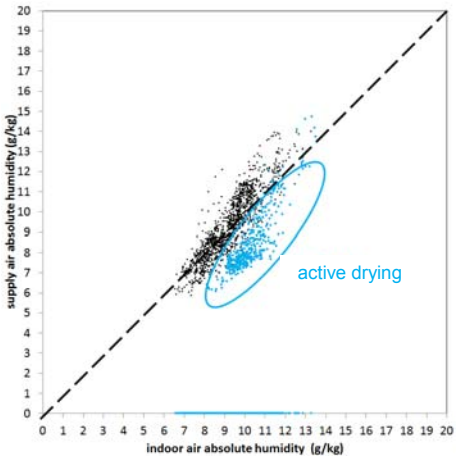
BP: bypass (no recovery)
CC: air-to-air heat pump cooling



Five states can be observed in the supply air temperature chart

Supply conditions vs. indoor conditions





Passive cooling
For flow rate 150 m³/h → 500 W
Active cooling
For flow rate 150 m³/h → 1000 W
For flow rate 270 m³/h → 1600 W
Compressor consumption 800 W

Active drying
Approximately 2 g/kg

Comfortable solutions for fresh air in every room of the house

Winter:
Insulation & Airtightness

Summer: shading & passive cooling

OR

Summer: shading & passive cooling
& active cooling

zehnder group

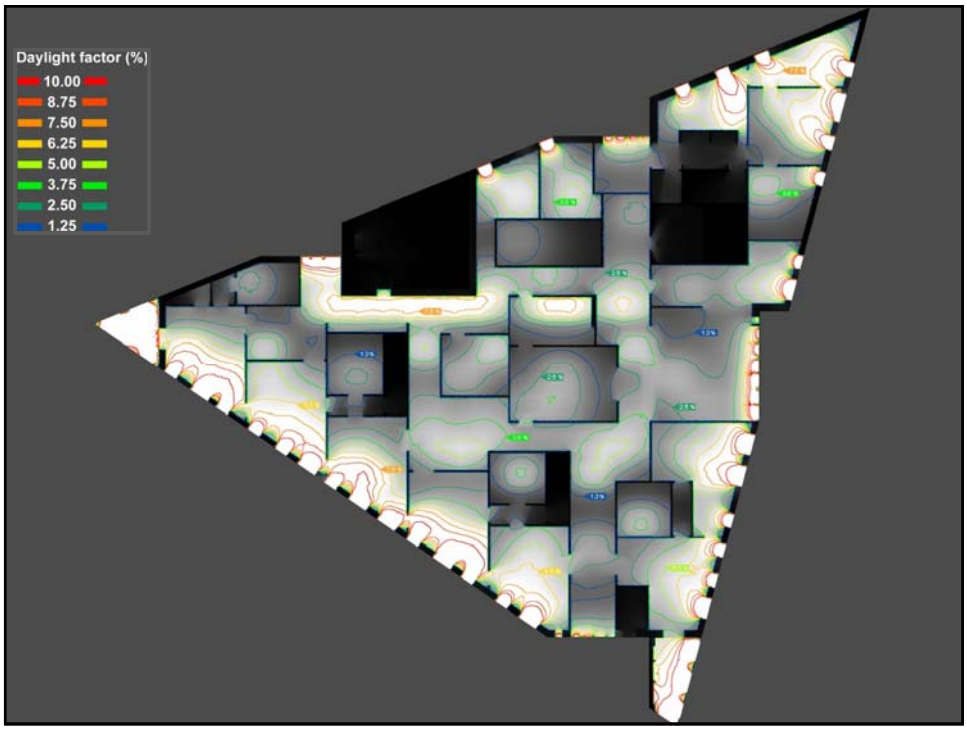
Indoor Climate in a Danish Kindergarten built according to Active House Principles
Measured thermal comfort and use of electrical light

Peter Foldbjerg, Thorbjørn Færing Asmussen, Karsten Duer
VELUX A/S, Department of Daylight, Energy and Indoor Climate

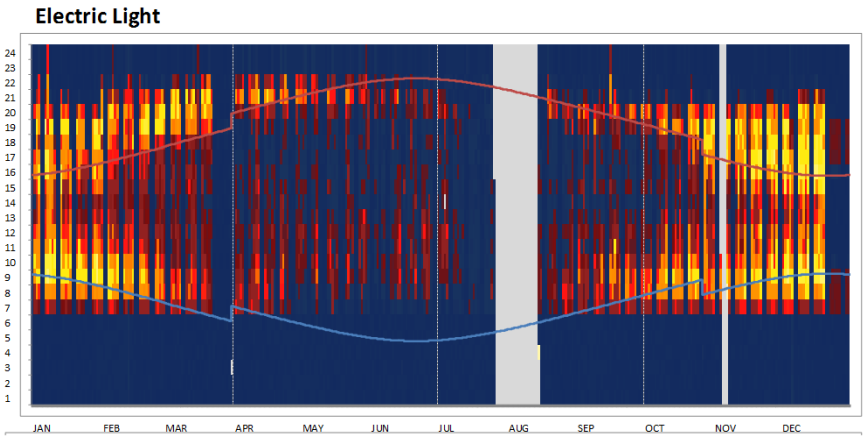
Peter.foldbjerg@velux.com

35th AIVC conference
24-25 September 2014, Poznan, Poland

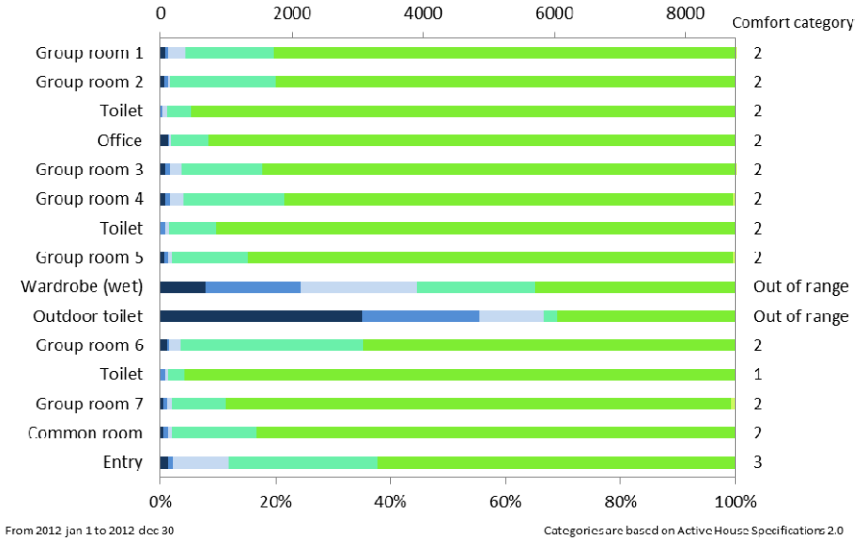
VELUX®



Use of electric light



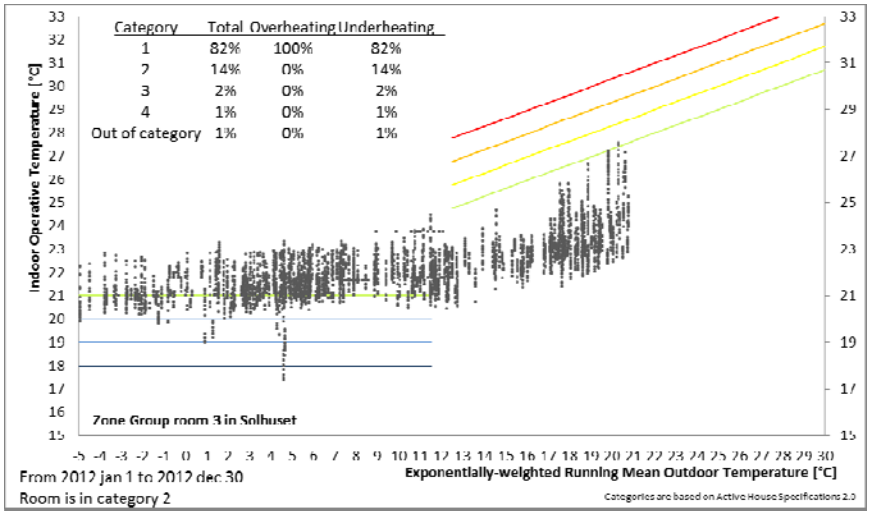
Thermal comfort



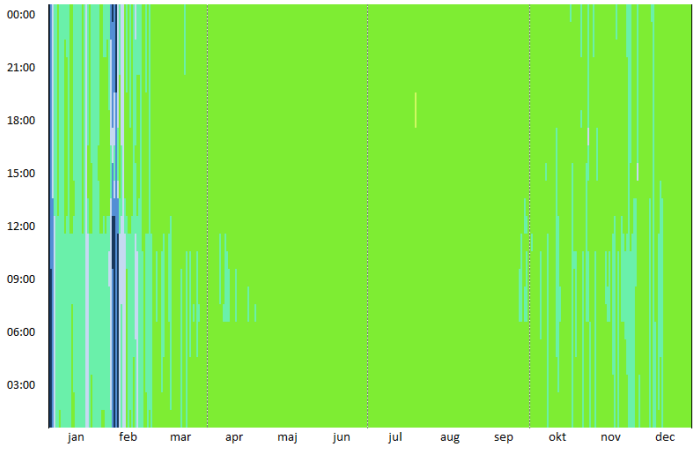
From 2012 jan 1 to 2012 dec 30

Categories are based on Active House Specifications 2.0

Adaptive comfort



Temporal distribution



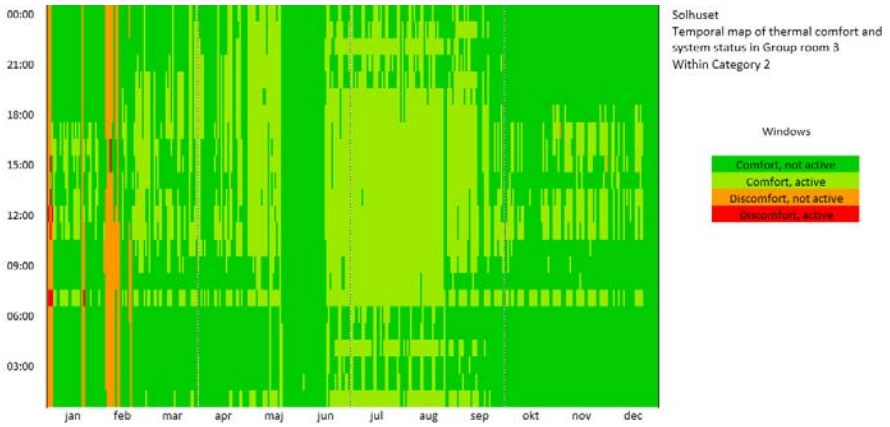
Solhuset
Temporal map of thermal comfort in Group room 3

Too High	0%
4 high	0%
3 high	0%
2 high	0,%
1	82%
2 low	14%
3 low	2%
4 low	0,9%
Too low	0,7%

From 2012 jan 1 to 2012 dec 30

Room is in category 2
Accumulated part in:
Category 1: 82%
Category 2: 14%

Use of windows



Thanks for listening!

Indoor Climate in a Danish Kindergarten built according to Active House Principles
Measured thermal comfort and use of electrical light

Peter Foldbjerg
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CommONEnergy

Strategies for exploiting climate potential through ventilative cooling in a renovated historic market

Annamaria Belleri, Federico Noris, Roberto Lollini
EURAC

35th AIVC – 4th TightVent – 2nd Venticool conference
24th – 25th September 2014, Poznan

EURAC research

CommONEnergy

EURAC research

Objective

development of ventilative cooling strategies for the retrofit of existing shopping malls to exploit the architectural and climate drivers potential

Case study: Mercado del Val, Valladolid

CommONEnergy partners and the local design team defined a modular glazed façade that aims at integrating thermal, daylighting and ventilation functions, being responsive when internal and external loads change.

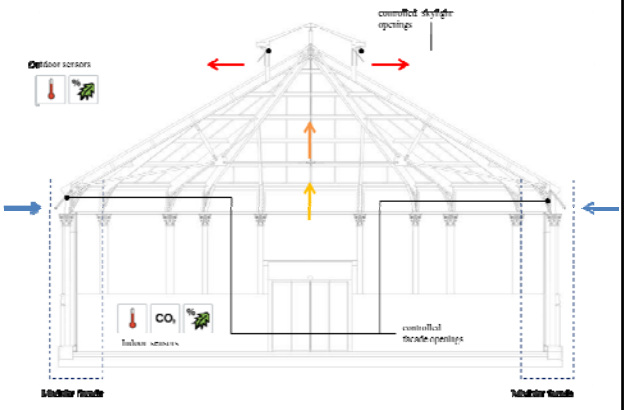
Figure 1 - 2: Interior and exterior building view of Mercado Del Val before the retrofit intervention.

EURAC/Annamaria Belleri

Ventilative cooling strategy

Methods:

1) Climate suitability and design constraints analysis
2) Basic design of ventilation strategy and controls
3) Energy savings assessment by coupled thermal and airflow simulations
4) Support design decisions providing quantitative building performance evaluations



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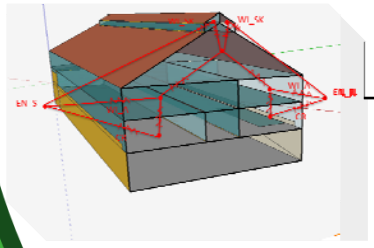
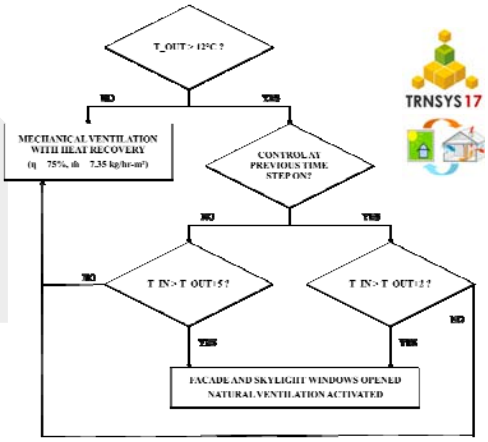
Control strategy

Trnflow airflow network
integrated in the Trnsys model





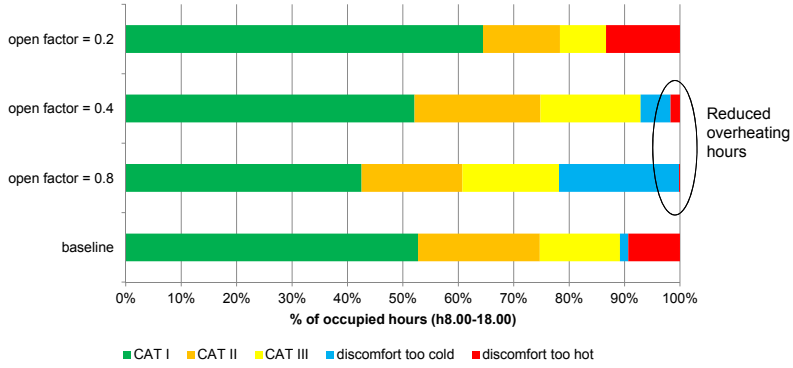
TRNSYS 17

EURAC/Annamaria Belleri

CommONEnergy

EURAC research

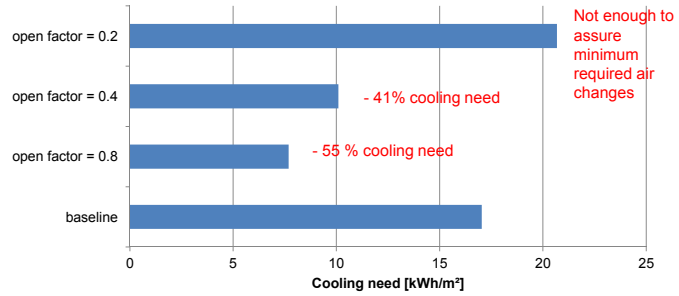
EN 15251 adaptive comfort results



The definition of a more detailed control strategy and the introduction of opening modulation would allow us to reduce also too cold hours number.

EURAC/Annamaria Belleri

Simulations results: cooling need



	Cooling need [kWh/m²]	Number of operation hours of the mechanical ventilation system
open factor = 0.2	20.68	1897
open factor = 0.4	10.10	2858
open factor = 0.8	7.69	3617
baseline	17.04	5136

EURAC/Annamaria Belleri

Thanks for your attention

Annamaria Belleri
annamaria.belleri@eurac.edu

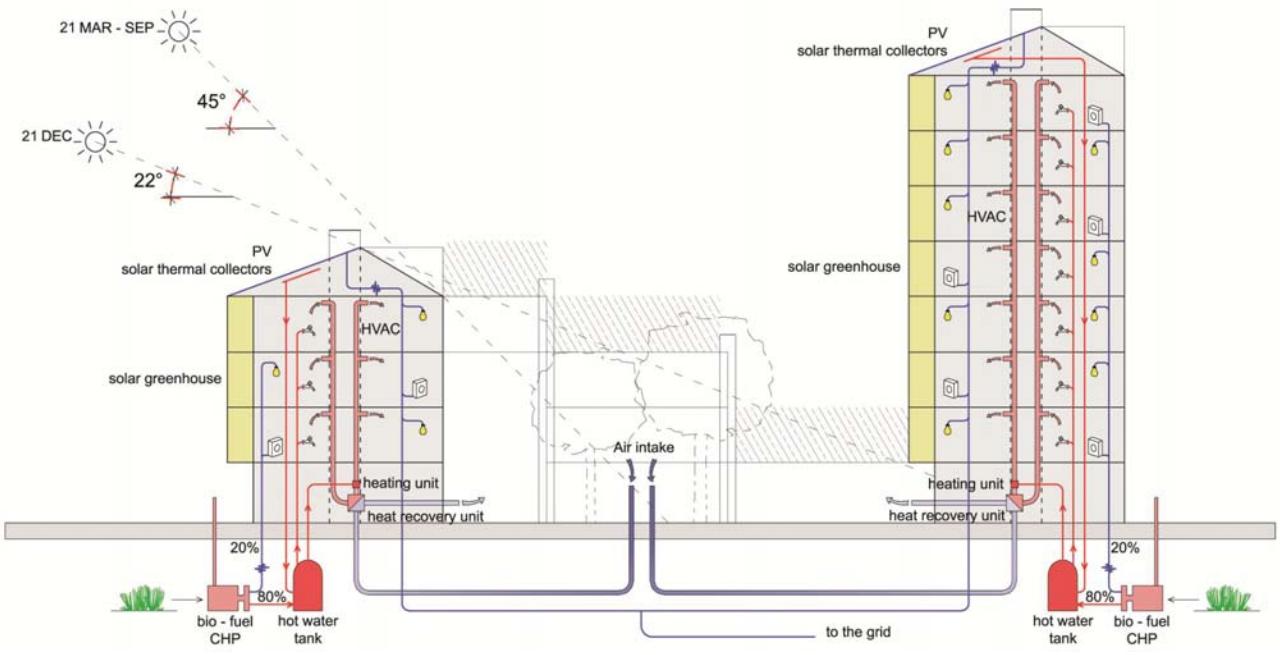
EURAC/Annamaria Belleri

Luca Guardigli, Paolo Cappellacci, Fausto Barbolini

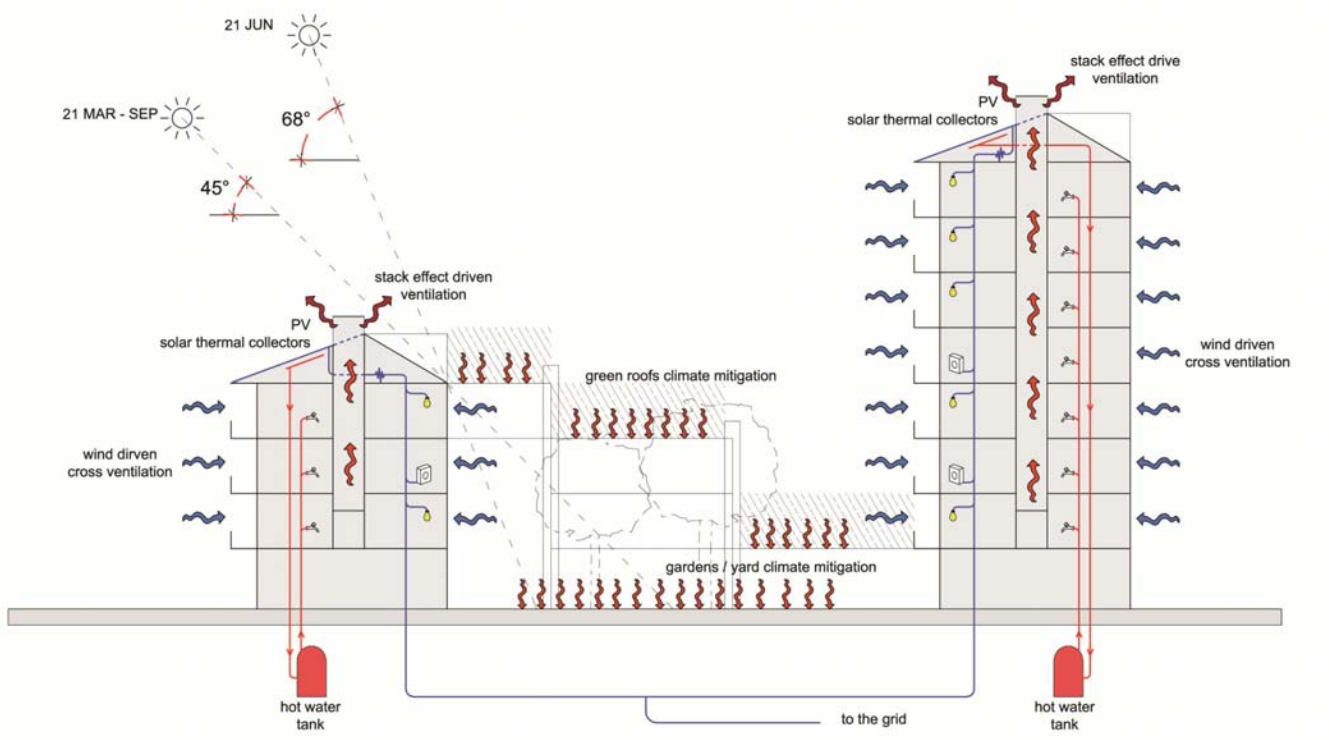
School of Engineering and Architecture, University of Bologna, Italy

Passive Cooling Through Ventilation Shafts in High-Density Zero Energy Buildings: A Design Strategy to Integrate Natural and Mechanical Ventilation in Temperate Climates

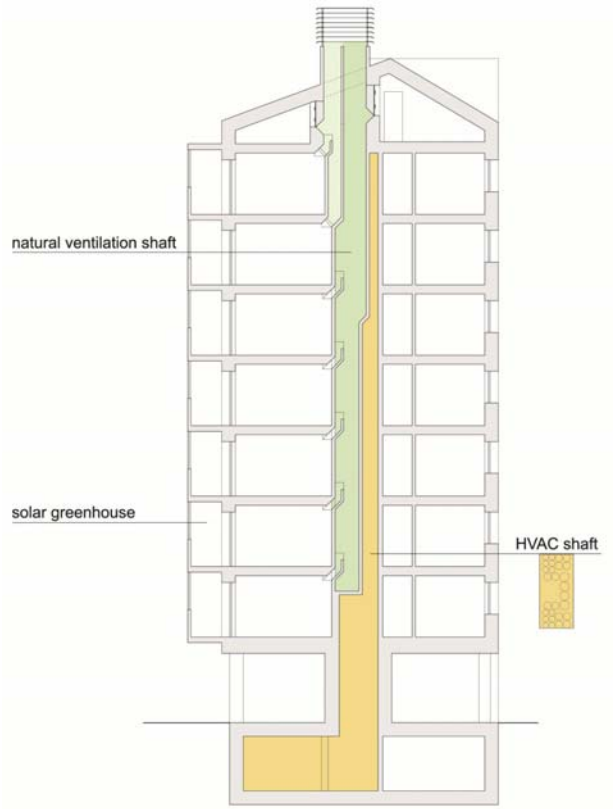
Operational Scheme in the cold Season – New Building Section

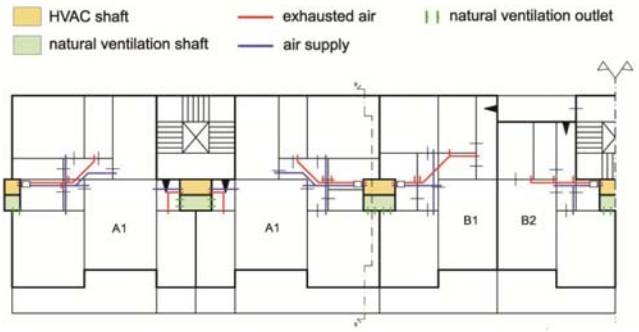


Operational Scheme in the warm Season – New Building Section



Ventilation Shaft Design





main data:

Annual Energy Consumption= 7,7 kWh/m^{2}a

Estimated Electric Needs = 171000 kWh

Energy Production by PV = 155100 kWh

Electric Energy by CHP = 86400 kWh/a

(surplus of **70500** kWh/a)

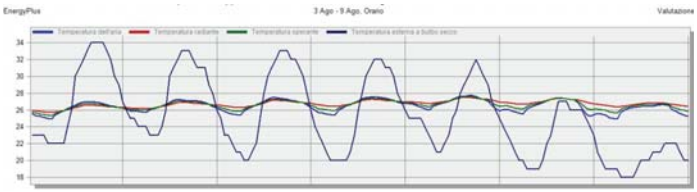
Thermal Energy by CHP = 150000 kWh/a

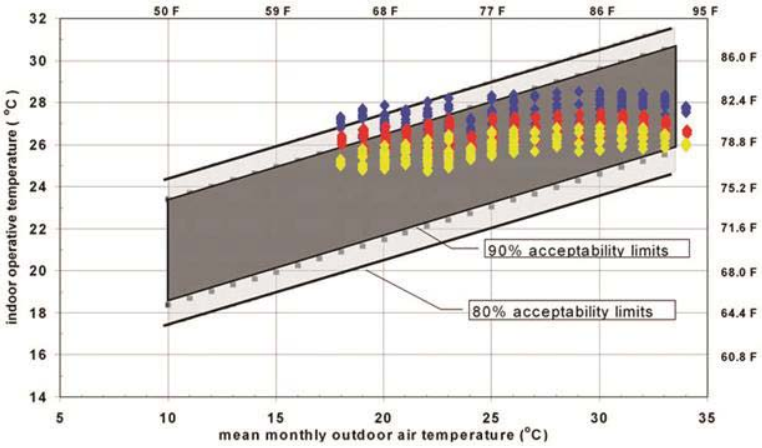
Multizone Thermodynamic (Energy+) and CFD Analysis Results

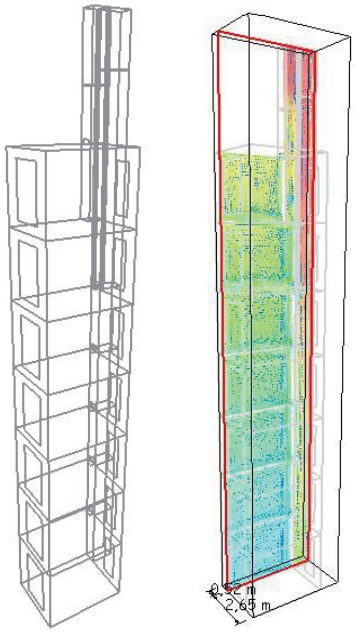
Summer Design Week: 3 - 9 August

Infiltration rate: 0,5 vol/h

Night Cooling Program: 5% windows opening from 8pm to 7am







Typical Night Cooling: 7 August, 4am

Outdoor temp: 20°C – Indoor av. temp: 26,5 °C

Airspeed never exceeds 0,25 m/s

POLITECHNIKA POZNAŃSKA

OPTIMIZATION OF DATA CENTER CHILLED WATER COOLING SYSTEM ACCORDING TO ANNUAL POWER CONSUMPTION CRITERION

Piotr KOWALSKI MSc. Eng
Mieczysław POROWSKI Ph. D., Dr. Sc.
Poznan University of Technology
Faculty of Engineering and Environmental Engineering

Problem formulation

- System model
  - CRAH,
  - chiller,
  - frecooling coil,
  - pump,
  - hydraulic system
- Constant parameters
- Decision variables
- Limiting conditions
- Optimization criterion: minimum annual power consumption

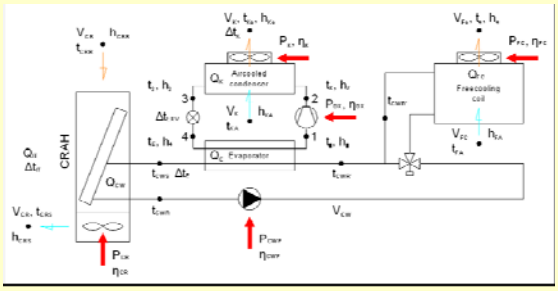


Fig. 1 Technological scheme of the chilled water based data center cooling system

$$E_{TOT} = \min(E_{TOT1}, \ldots E_{TOTj}, \ldots E_{TOTj\,max})$$

Optimization procedure

- Complete review optimization procedure
- Set of permissible variants after applying limiting conditions
- Test reference year annual consumption calculation (8760h):

$$E_{TOT}(t_A) = E_{CR}(t_A) + E_{FC}(t_A) + E_{DX}(t_A) + E_E(t_A) + E_{CWP}(t_A)$$

$$E_{TOT} = \sum_{t_{A\,min}}^{t_{A\,max}} E_{TOT}(t_A), \rightarrow TRY = 8760h/year$$

- Mechanical Power Usage Effectiveness ratio calculated:

$$PUE(\pi) = \frac{E_{TOT} + E_{IL}}{E_{IT}} \rightarrow E_{IT} = 8760P_{IT}$$

Fig. 2 General algorithm of the optimization procedure

Case study calculations

- 200kW IT power/cooling capacity
- Open and closed aisle architecture considered
- 24 permissible variants calculated
- CW temperature range from 5/13°C to 20/26°C
- ASHRAE 2011 A1 Data Center class recommended temperature and humidity range

Table 1. Case study selected input data

Variant No.	Architecture	Q_{IT} [kW]	t_{CWS} [°C]	t_{CWR} [°C]	Δt_{DX} [°C]	Δt_{CWmin} [°C]	Δt_{CWmax} [°C]
[-]	[-]	[kW]	[°C]	[°C]	[°C]	[°C]	[°C]
1	open	200	5	15	11,5	1	12
2	open	200	5	15	11,5	1	12
3	closed	200	15	22	15	1	12
4	closed	200	16	24	15	1	12
5	closed	200	18	26	15	1	12

Table 2. Case study selected results

t_{CWS}/t_{CWR}	E_{DX}	E_E	E_{FC}	E_{CWP}	E_{CR}	E_{TOT}	PUE(π)
[°C]	[kWh/year]	[kWh/year]	[kWh/year]	[kWh/year]	[kWh/year]	[kWh/year]	[-]
5/13	176820	26791	43232	59489	83154	379215	1,22
5/15	165987	25416	47376	22547	83867	345208	1,20
15/22	77413	10382	46798	22547	40514	197649	1,11
16/24	69851	7687	44699	16887	41108	173452	1,10
18/26	46337	5265	40973	16887	41258	151420	1,09

Conclusions

- Total power consumption difference of 60% between maximum and optimum variant
- Chiller (DX+K) power consumption reduced by 75%
- Aisle separation reduces CRAH power consumption by 50%
- Increasing share of CWP power consumption for high cooling water temperatures – optimization of the mass flow recommended

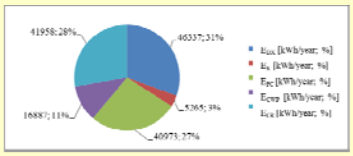


Fig. 3 Cooling system energy consumption split (optimum variant)

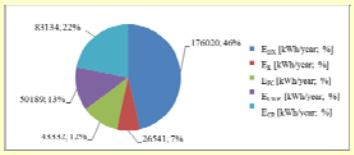


Fig. 4 Cooling system energy consumption split (maximum variant)

Thank you for your attention

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Mieczysław Porowski, mieczyslaw.porowski@put.poznan.pl

P. Kowalski
M. Porowski
35th AIVC Conference, Poznań, Poland
24-25 September 2014

AIVC2014
September 24-25, 2014, Poznań, Poland

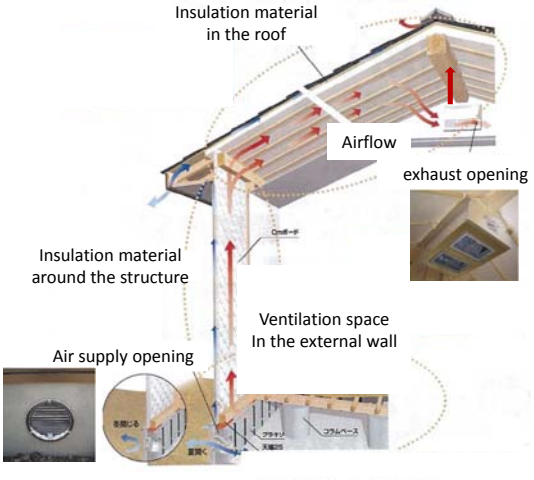
Simulation analysis for indoor temperature increase and reduction of heating load in the detached house with buoyancy ventilated wall in winter

○ Kan LIN(林 侃)　　PhD Candidate, the University of Tokyo, Japan
Shinsuke KATO(加藤 信介)　Professor, IIS, the University of Tokyo, Japan

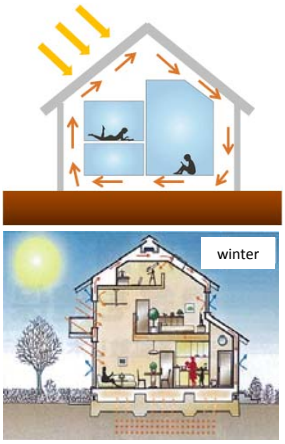
東京大学
THE UNIVERSITY OF TOKYO

1. Backgrounds and Objectives of the Study
   1.1 Overview of Buoyancy Ventilated Wall House

Insulation material with gap



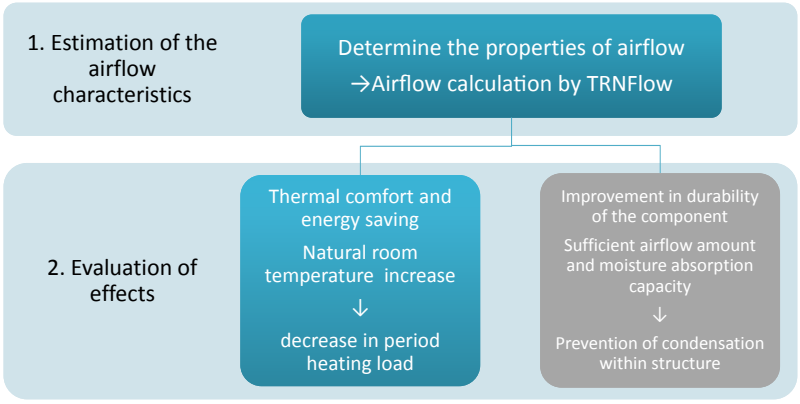
Overview of the ventilation system



operation in winter

1. Backgrounds and Objectives of the Study
1.2 Objectives and flow of the research

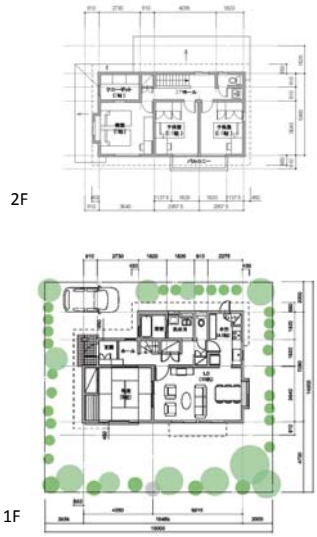
- Objectives : to understand the basic properties of the system, to evaluate the effects during the winter period by performing a ventilation network simulation.
- Flow of the research :



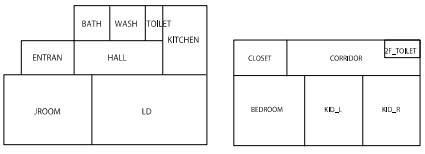
In this paper, we evaluated the airflow rate, temperature increase and reduction in heating load during the winter period.

Kan Lin and Shinsuke Kato, AIVC2014

2. Overview of the calculation
2.1 Modeling of analysis object



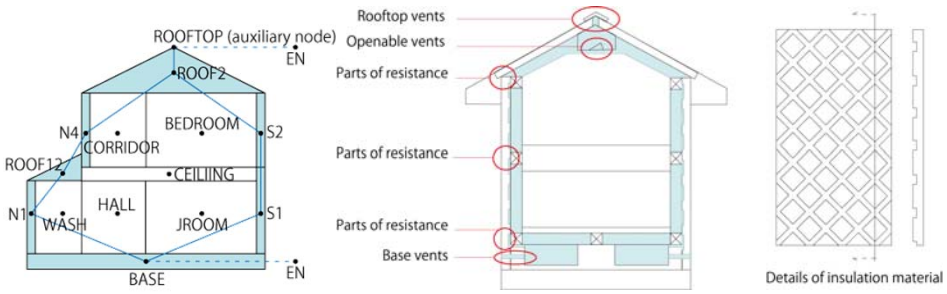
- Standard residential house model proposed by IBEC
- Each schedule (occupants, heating and cooling, interior heat gain, ventilation, lighting, hot water supply) is determined on the basis of experimental data.



total floor area	120.07m^2
floor height	2.825m
opening ratio	21.00%
opening area	25.22m^2
family make-up	4 person (a couple and 2 children)

Kan Lin and Shinsuke Kato, AIVC2014

2. Overview of the calculation
2.2 Modeling of analysis object



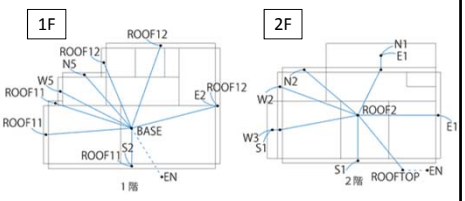
Air Links

In TRANFlow, airflow is calculated on the basis of the following equation.

$$\dot{m} = \alpha A \sqrt{\Delta p \cdot 2\rho} \left[\mathrm{kg/s}\right]$$

$\dot{m}$: massflow[kg/s] α : coefficient of discharge[-] A : area of the opening $\left[\mathrm{m}^2\right]$

Δp : pressure difference[Pa] ρ : air density $\left[\mathrm{kg/m}^3\right]$



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3. Result

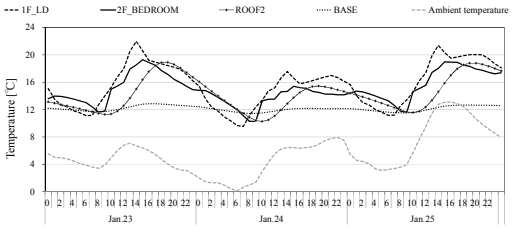


Figure 1: Temperature during representative days

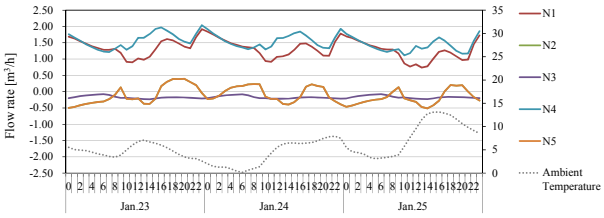
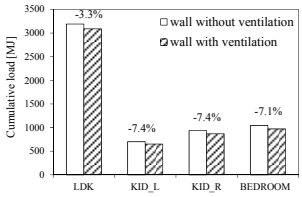


Figure 2: Flow rate for north walls during representative days



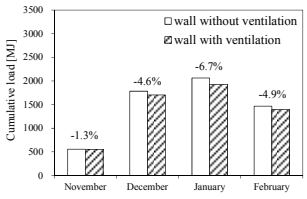


Figure 3: Total heating load in each room/month

Kan Lin and Shinsuke Kato, AIVC2014

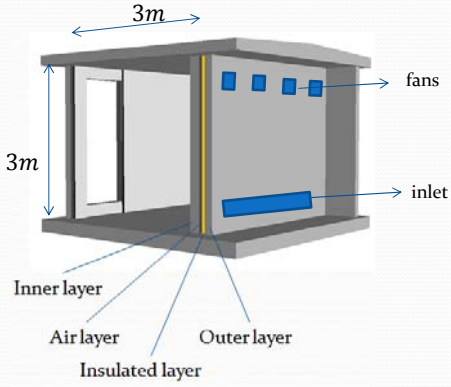
Reducing cooling energy needs through an innovative daily storage based facade

Department of Energy Engineering

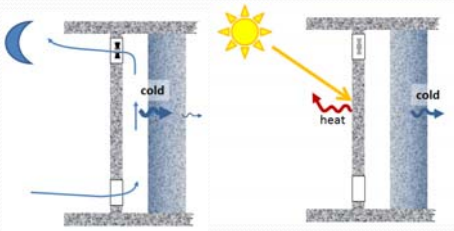
University of Seville

Javier García Ramos

Experimental cell



Summer



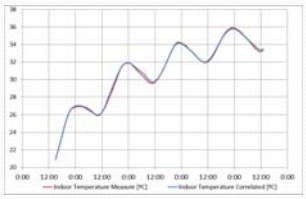
Inner layer: Concrete with high thermal inertia

Outer +insulating layer: low thermal transmittance

Methods:

1) Reference cell characterization (without active façade)

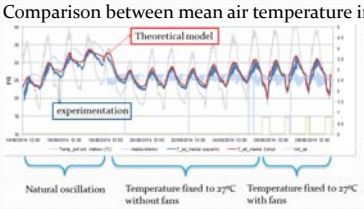
Comparison between indoor temperature measured and indoor temperature correlated



This will allow us to obtain the equivalent temperature inside the cell when the active façade is installed

2) Active façade characterization

Comparison between mean air temperature in the air layer using the theoretical model and experimentation

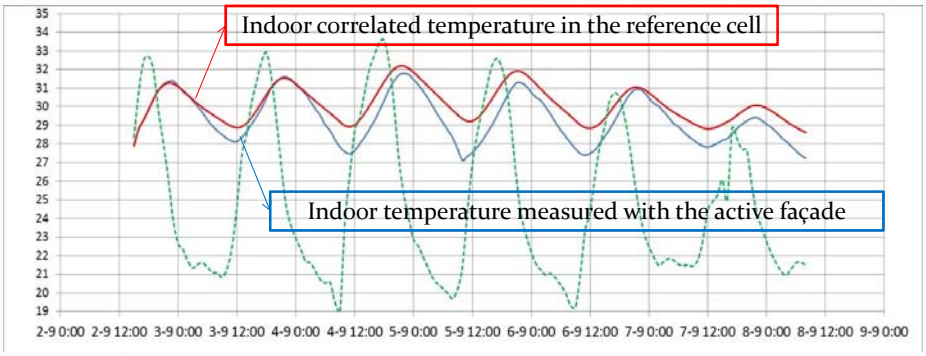


This allows us to apply the model to a dwelling, thus we can calculate the saved energy in a real scenary

Results

- Decrease in temperature using the façade in natural oscillation

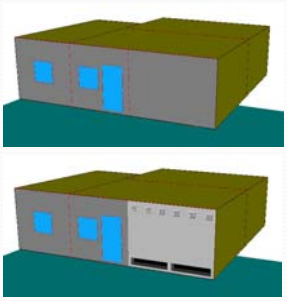
From 2/09/2014 to 8/09/2014

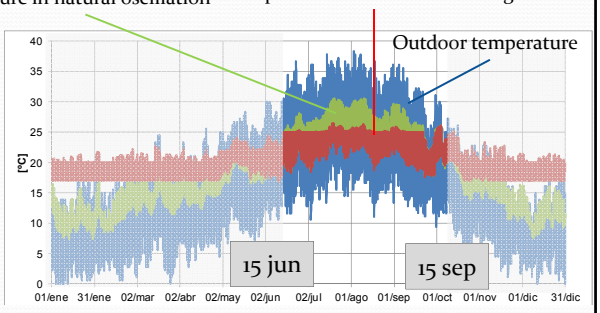


This graph shows that the temperature is reduced when fans are working.

Results

- Application to a dwelling





Using the active façade characterization, the delivered energy through the active façade can be compared with the gained energy through a conventional wall:

Q[with active façade] = -11.4 kWh/m²
Q[wall] = 0.1 kWh/m²

Thanks for your attention

See you at the poster

Department of Energy Engineering
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FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE

Monitoring Results and Optimization

of a Façade Integrated Ventilation Concept for Building Retrofit

Fabien Coydon

Fraunhofer Institute for Solar Energy Systems ISE

www.ise.fraunhofer.de

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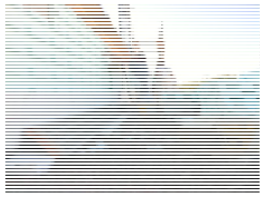
Façade Integrated Ventilation Concept for Building Retrofit

- Use of two main components
  - Preformed insulation boards for an easy mounting of ventilation ducts
  - Prefabricated window modules including air inlets and outlets



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Heat recovery efficiency – 3 definitions

◆ : Efficiency of the device:

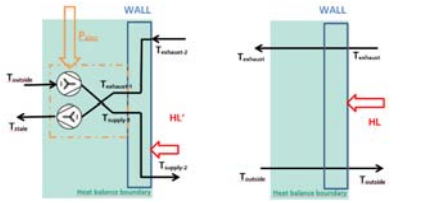
$$\eta_{device} = \frac{\dot{m}.Cp.\ (T_{supply-1} - T_{outside}) - P_{elec}}{\dot{m}.Cp.\ (T_{exhaust-1} - T_{outside})}$$

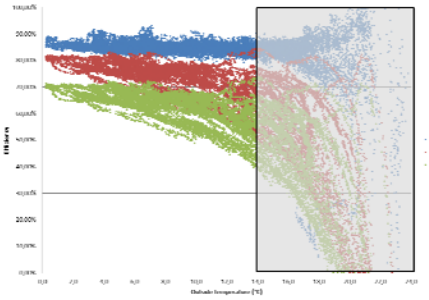
◆ : Heat losses in air ducts:

$$\eta_{with\ ducts} = \frac{\dot{m}.Cp.\ (T_{supply-2} - T_{outside}) - P_{elec}}{\dot{m}.Cp.\ (T_{exhaust-2} - T_{outside})}$$

◆ : Influence on heat losses through the façade:

$$\eta_{with\ wall} = \frac{\dot{m}.Cp.\ (T_{supply-2} - T_{outside}) - P_{elec} + HL - HL'}{\dot{m}.Cp.\ (T_{exhaust-2} - T_{outside})}$$





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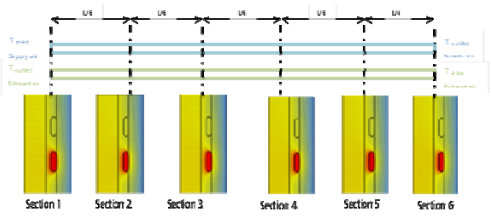
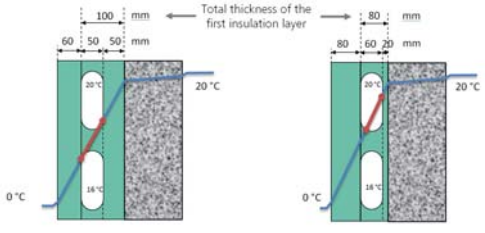
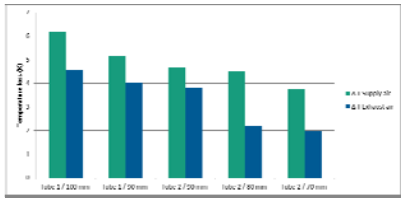
Numerical model and optimization







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Conclusion and Outlook

- It is possible to integrate air ducts in the external insulation layer of a façade without reducing the energy performance of the ventilation system.
- Next steps:
  - Implementation on a demonstrator: multifamily home in Frankfurt
  - Main challenge: fire protection

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Improvement of protocols measurements used to characterize ventilation systems performance

Adeline Bailly - Cerema, France

Cerema

Center for studies and expertise on Risks, Environment, Mobility, and Urban and Country Planning

CONTEXT

- Evolution of French regulation and labels towards Energy-efficient buildings
  - More airtight
  - With technically advanced mechanical ventilation systems

    BUT Many dysfunctions are observed
- In order to limit impact on indoor air quality and energy consumption, they are needs for:
  - Improvement of ventilation systems quality: information & training
  - Controls

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CONTEXT

- Controls in France: 3 major cases
  - Regulatory compulsory control
  - Buildings applying for new Effinergie label (Effinergie +)
  - IAQ issues
- Control protocols used :

  Regulatory control, Effinergie, HQE and OQAI protocols, DIAGVENT method, EN 12599, PrEN16211 …
- **Issue : Are all of those protocols reliable enough ?**

OBJECTIVES

- To improve the quality of ventilation system controls
  - To ensure the reliability of ventilation measurement protocols concerning pressure and airflow differences at airvents, and ductwork airleakage
  - To test repeatability, reproductibility and feasibility of existing protocols in order to define a more reliable protocol for ventilation system controls.
- Scope : residential buildings
  - Single-family dwellings with balanced ventilation
  - Multi-family dwellings with single humidity demand-controlled ventilation.
- **Final production:**
  - **Unique protocol that will be drawn up as a proposed draft standard**
  - **Guide intended to ventilation operators**

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ORGANISATION

- 8 partners

- 2 financial supports
  - ADEME (French Agency for the Environment and Energy Management)
  - French Ministry for Ecology, Sustainable Development and Energy

- 30 months dividing in different tasks which include:
  - Various laboratory and in-situ campaigns
  - Meetings with professionals of ventilation sector
  - End of the project: December 2016

Thank you for your attention

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Impact of a poor quality of ventilation systems on energy efficiency for energy efficient houses

Adeline Bailly - Cerema, France

Cerema — Center for studies and expertise on Risks, Environment, Mobility, and Urban and Country Planning

VIA-Qualité Project

- Objective: to develop quality management approaches in order to increase both on-site ventilation and indoor air quality in energy-efficient houses
  - design, implementation, maintenance… of ventilation systems
  - Control of pollutants (construction products, sources due to occupying the dwelling)
- Schemes developed from review and in-situ campaign
  - Tested with 8 different houses
  - Effectiveness: to assess through ventilation and IAQ measurements
  - Feasibility:
    - Builders experiences
    - Energetic and economic studies

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Indicator for energy impatc

- RT2012 calculations
- Scenarios: based on the list of dysfunctions

1) Lack of humidity-control	2) Excessive number of air inlets	3) Low battery in toilets air outlets	4) Duct leakage	5) Over ventilation	6) Fan performance

- Impact on:
  - Energy Consumption for heating
  - Energy consumption total

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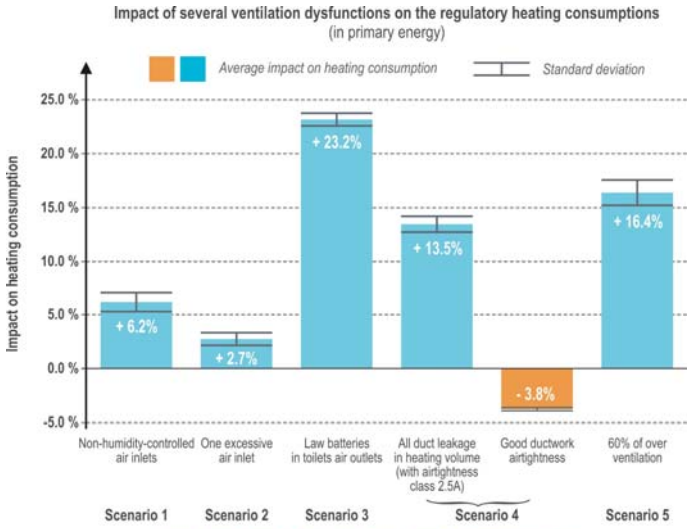
First Results



* Cpe is calculated with a 2.58 - Coefficient for electrical source

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Thank you for your attention

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Center for studies and expertise on Risks, Environment, Mobility, and Urban and Country Planning

Anna DUTKA
Tomasz M. MRÓZ
Faculty of Civil and Environmental Engineering
Poznan University of Technology

EXERGY EVALUATION OF MECHANICAL VENTILATION SYSTEMS

Poznań, September 24th, 2014

PLAN OF PRESENTATION

- The concept of exergy analysis
- Case study analysis
- Calculation results

THE CONCEPT OF EXERGY ANALYSIS

Thermodynamically open system:

Mathematical form

$$\dot{B}_{in} = \delta\dot{B} + \dot{B}^{use}_{out} + \delta\dot{B}_{ext} \pm \Delta\dot{B}_{HS}$$

$\dot{B}_{in}$ - flux of exergy entering the control volume of a thermodynamically open system, W,

$\dot{B}^{use}_{out}$ - flux of useable exergy leaving the control volume of a thermodynamically open system, W

$\delta\dot{B}$ - flux of the internal exergy losses of a thermodynamically open system, W

$\delta\dot{B}_{ext}$ - flux of external exergy losses of a thermodynamically open system, W

$\Delta\dot{B}_{HS}$ - flux of change of exergy of an external heat source being in contact with a thermodynamically open system, W

Graphical form

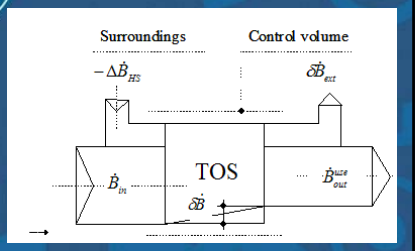

Figure 1. Grassmann-Szargut graph of exergy balance of a thermodynamicallyopen system (TOS)

CASE STUDY ANALYSIS

Description of building:

- Office building
- Located in Poznań
- Three stoires, each of it is divided into six separate different zones

The main part of air handling unit:

- rotating heat / mass regenerator
- air heater
- air cooler
- steam humidifier
- fans
- air filters
- air dampers

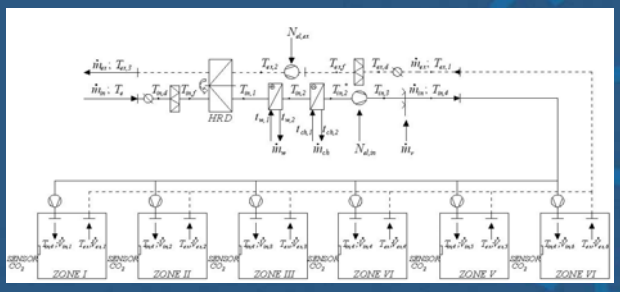

Figure 2: The schematic of mechanical ventilation system.

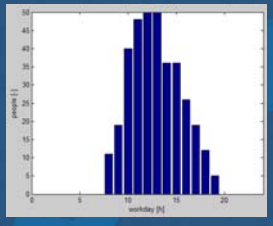

Figure 3: The daily occupancy profile of all six zones

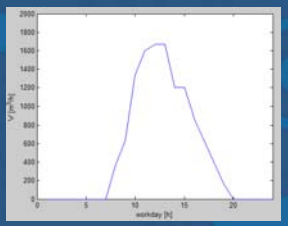

Figure 4: Modelled hourly air flow for all zones during work day

CALCULATION RESULTS

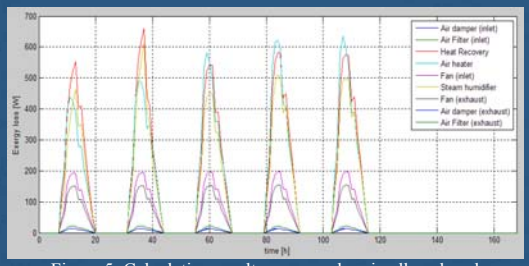

Figure 5: Calculation results – exergy loss in all analysed energy items during reference winter week.

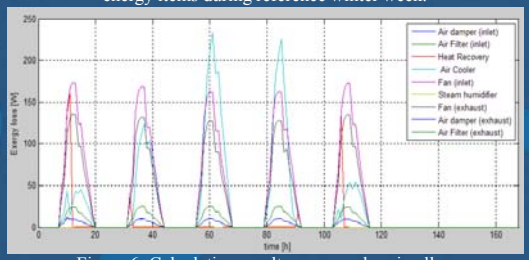

Figure 6: Calculation results – exergy loss in all analysed energy items in reference summer week.

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POLITECHNIKA POZNAŃSKA

MULTI-PIPE EARTH-TO-AIR HEAT EXCHANGER (EAHE) GEOMETRY INFLUENCE ON THE SPECIFIC FAN POWER (SFP) AND FAN ENERGY DEMAND IN MECHANICAL VENTILATION SYSTEMS

Łukasz AMANOWICZ, Janusz WOJTKOWIAK

Poznan University of Technology

35th AIVC Conference

Introduction

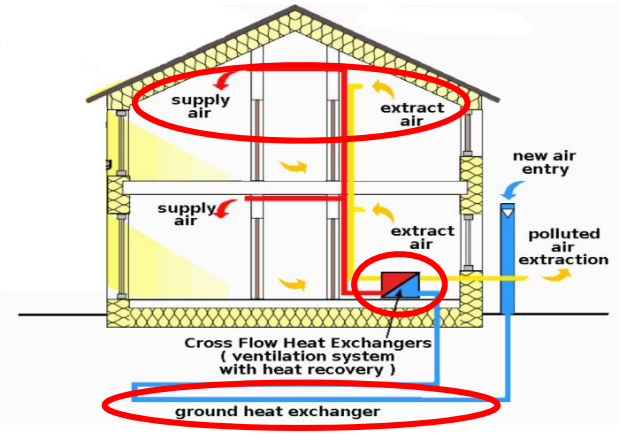


Fig. 1. Considered system

Image source: http://mocoblog.com/heat-recovery-ventilator-for-room-comfort.html/drain-water-heat-recovery-system

EAHEs (earth-to-air heat exchangers)

Additional pressure losses (operational cost)

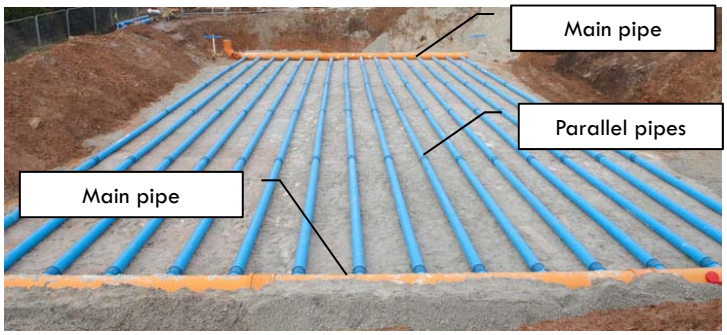


Fig. 2. Multi-pipe earth-to-air heat exchanger

EAHEs (earth-to-air heat exchangers)

/ 9

Geometrical EAHE parameters affecting pressure losses:

- parallel pipes length
- parallel pipes diameter
- main pipes diameter
- angle of connection main and parallel pipes
- …

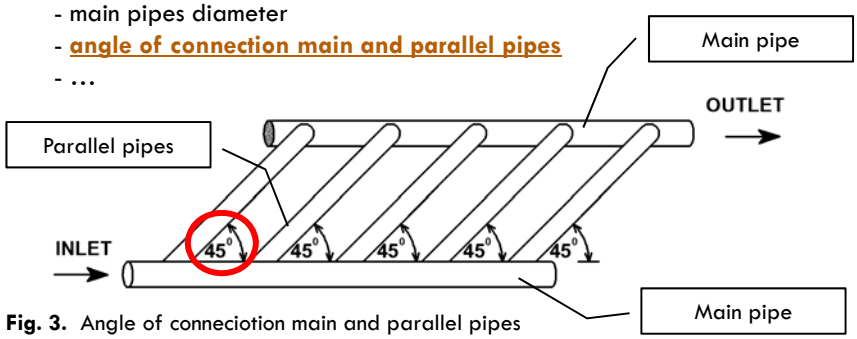


Fig. 3. Angle of conneciotion main and parallel pipes

SFP (specific fan power)

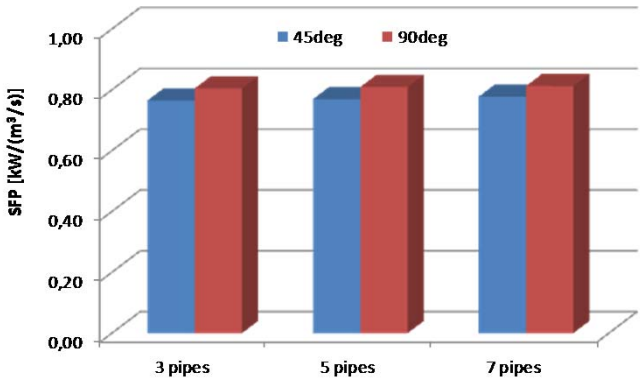


Fig. 5. SFP for ventilation system with 45 and 90 degrees multi-pipe EAHE

Whole year energy demand

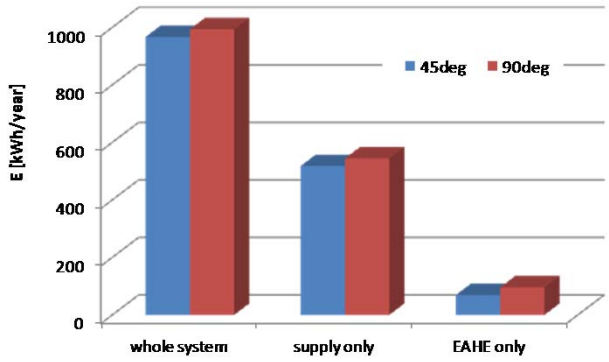


Fig. 6. Whole year energy demand for ventilation system with 45 and 90 degrees multi-pipe EAHE

Supply fan power

/ 9

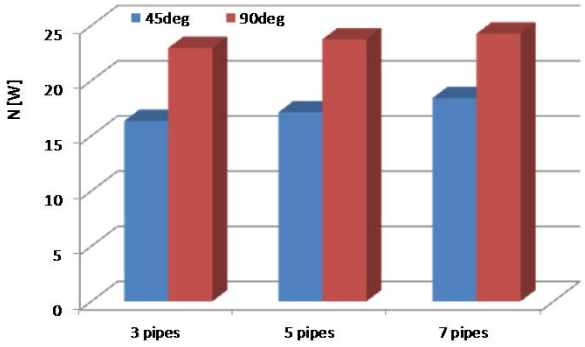


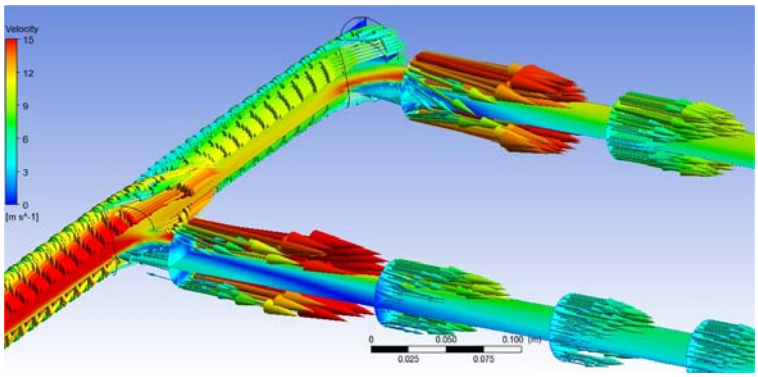
Fig. 7. Supply fan power for ventilation system with 45 and 90 degrees multi-pipe EAHE

Conslusions

/ 9

- **EAHEs with angle of connection 45 degrees results in lower SFP and lower energy demand**
- 4-5% for SFP
- **3%** less energy for total system
- 28% less energy for fan units
- **25%-30% smaller supply fan** can be used for 45 degrees EAHEs structures

Thank You for the attention!



Ł. Amanowicz
J. Wojtkowiak

Implementation and performance of ventilation systems : first review of voluntary certification controls in France

Sarah Juricic - Cerema, France

Cerema
Center for studies and expertise on Risks, Environment, Mobility, and Urban and Country Planning

Regulatory frame and voluntary certification

- Recent compulsory envelope airtightness test in dwellings
  → Urgent need to master air renewal quality
- Voluntary scheme for very-low energy building certification
  - Implies for the first time compulsory ventilation visual controls and ductwork airtightness tests
  - Tests at commissioning require a qualified technician
  - First buildings are being commissioned since last summer
  - Technicians aspiring to the required qualification fulfill a full training program including many measurements on their own

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A picture of today's ventilation in low-energy buildings in France

- Distribution of ventilation systems somewhat unusual
  - More balanced ventilation esp. in detached housing
  - More galvanized steel ducts esp. in detached housing
- A small database but some promising trends
  - Galvanized steel ducts performed the better in overal
  - Flexible ducts performed the worse in overal
  - Particularly poor performance in detached housing in comparison to the rest of the database : lack of qualified craftmanship on this market
- Performance reached not much better than… 15 years ago !
  - ½ perform worse than default value in EP calculation
  - Only 1/3 perform at class A or better

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Thank you for your attention

Contact

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Center for studies and expertise on Risks, Environment, Mobility, and Urban and Country Planning

ENERGY SAVING AND THERMAL COMFORT IN RESIDENTIAL BUILDINGS WITH DYNAMIC INSULATION WINDOWS

○ PhD, The University of Tokyo, Daisuke KAWAHARA
Professor, The University of Tokyo, Shinsuke KATO

Motivation

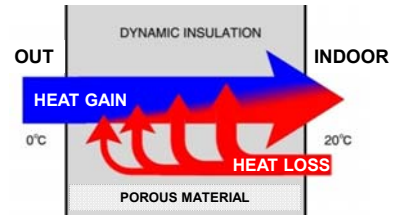
Window has ....

- a poor insulation performance
- a low comfortability because of a draught

We focus on a **dynamic insulation system**.

- preheat outer air
- reduce heat loss from window

Principle of the Dynamic Insulation system

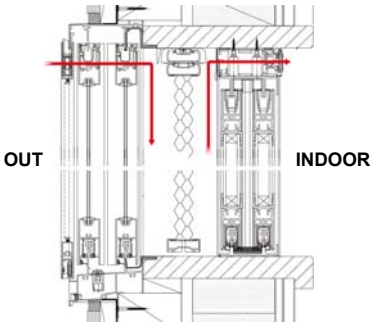


$$k\frac{d^2T(x)}{dx^2} - u\rho_a C_p \frac{dT(x)}{dx} = 0 \Rightarrow U_{dyn} = \frac{u\rho_a C_p}{\exp(u\rho_a C_p L/k) - 1}$$

HEAT LOSS [Conduction] | HEAT GAIN [Airflow] | *Depends on the air velocity!!*

T = Temperature [K], C_p = Heat capacity [J/kg・K], ρ_a = Density [kg/m³]

u = Velocity [m/s], L = Thickness of wall [m], k = Thermal conductivity [W/m・K]



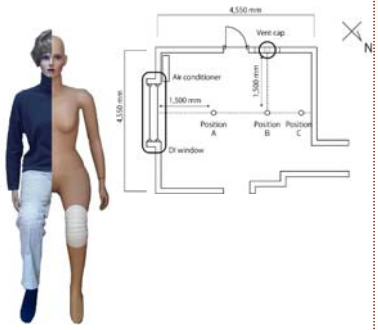
Cross section of the DI Window

・The air flow which is opposite direction against heat loss recovers a part of heat loss.
・Heat loss is nearly zero because outer surface temperature gradient is nearly zero.
・In this study, we applied this system to windows.

The University of Tokyo, Kato lab.

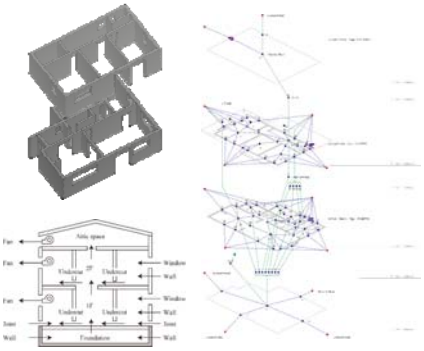
Measurements and computational analysis

▼ Thermal comfort



・A field test in the cold area in Japan
・Use a thermal manikin
・Different position
・General ventilation cap

▼ Energy simulation



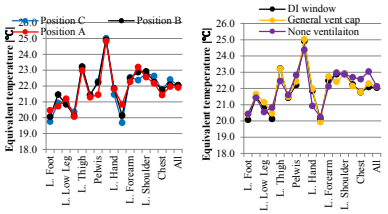
・We verified 40% increase of thermal insulation performance by a hot box method.
・TRNFlow
・Detail air node model

The University of Tokyo, Kato lab.

The University of Tokyo, Kato lab.

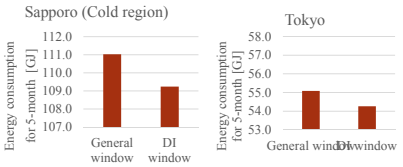
Results

▼ Thermal comfort



If the manikin has clothes, there are few draught risks.

▼ Energy simulation



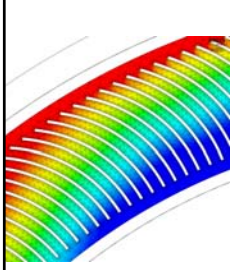
・Realize low energy consumption especially in the cold region.

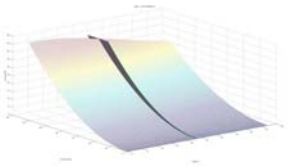
Conclusion

・DI windows can realize low energy buildings.
・In the day time, there is low effect on thermal comfort around windows.

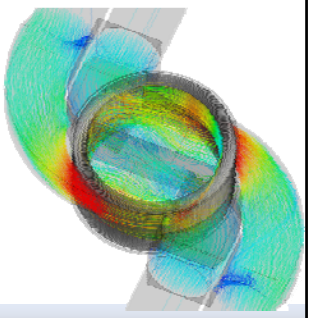
Development of a Decentralized and Compact Comfort Ventilation System with Highly Efficient Heat Recovery for Minimal Invasive Refurbishment of Buildings

Janez Zgaga, David Lanthaler, Christoph Speer and Rainer Pfluger





vent4Reno



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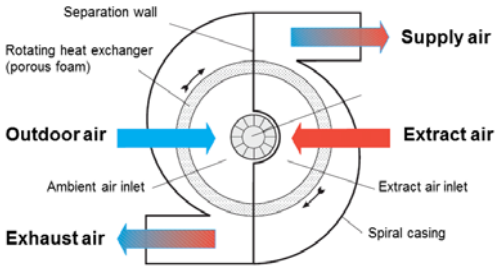
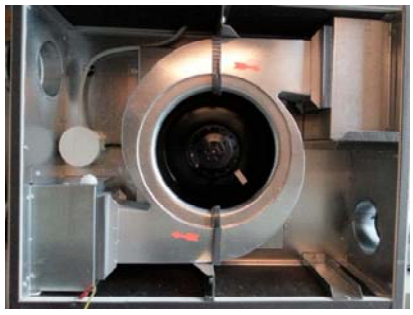
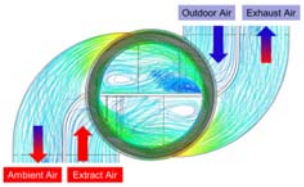
Existing heat recovery centrifugal fan



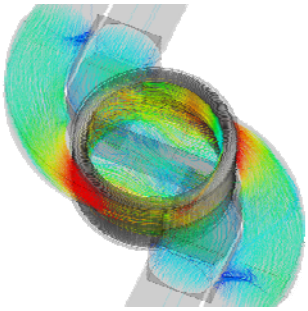


Modified counterflow heat recovery fan

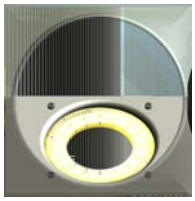
2D Flow



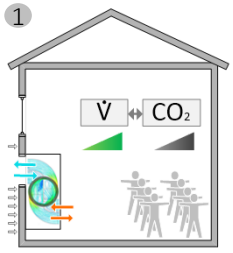
3D Flow

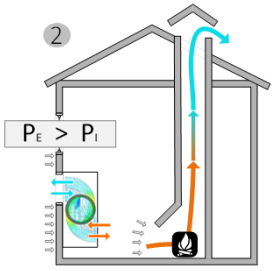


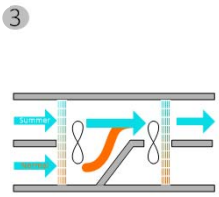
Airflow Balancing



Advanced functions



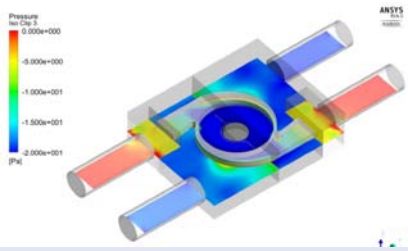


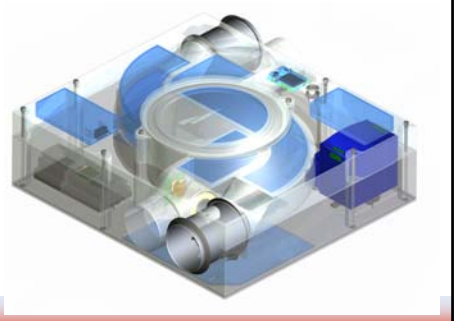


SITUATION	RESULT
1 Indoor air quality control strategy	Guarantees good air quality
2 Ventilation in combination with a fireplace	System shutdown
3 Summer bypass	No heat exchange

Preliminary Results

FEATURE	EXISTING SYSTEM	MODIFIED DESIGN CONCEPT
Dimensions	570 x 460 x 170 mm	560 x 420 x 160 mm
Fan outer diameter	Ø 250 mm	Ø 260 mm
Fan width	60 mm	120 mm
Air flow	100 m³ per hour	120 m³ per hour
Rotational speed	15,2 rotations per second	20 rotations per second
Heat recover efficiency up to	48%	80%
Summer bypass	No	Integrated





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Thank You For Your Attention!

Any Questions?

www.vent4reno.eu

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This work was carried out as part of the research project VENT4RENO within the framework of the funding program "Interreg IV" of the European Regional Development Fund.

Equation for CO_2 Production Rate Included in Exhaled Breath

was developed
See p427-

DERIVATION OF EQUATION [illegible]ERSONAL CARBON DIOXIDE IN EXHALED BREATH INTENDED TO ESTIMATION OF BUILDING VENTILATION

KOCHI UNIVERSITY OF TECHNOLOGY

School of Systems Engineering

Masaki TAJIMA*, Takayuki INOUE and Yuji OHNISHI

tajima.masaki@kochi-tech.ac.jp

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.
- In Japan, occupants' CO_2 production rate written in JIS A 1406[1974] has been used in Japan, for measurement or been cited by some other standard.
- Also, other method, e.g. ASTM D6245, shows CO_2 production rate based on Westerner adult subjects.

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)

The purpose and the procedure of this work

Purpose:

Developing a new equation for personal CO_2 production rate, using variables as Met, personal attribute(body height, body weight and gender difference) with Japanese subjects (approximately total 70)

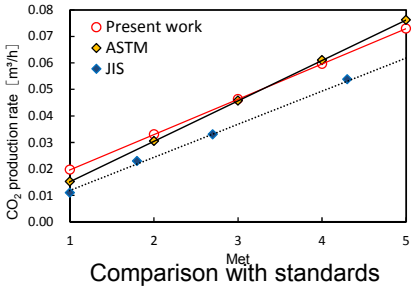
Procedure:

(1)Measurement of personal CO_2 production rate with Douglas bag metho

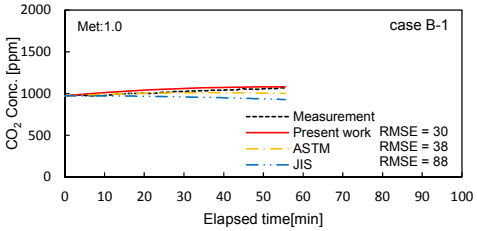
(2)Developing an equation with using regression analysis

(3)Accuracy testing in single zones

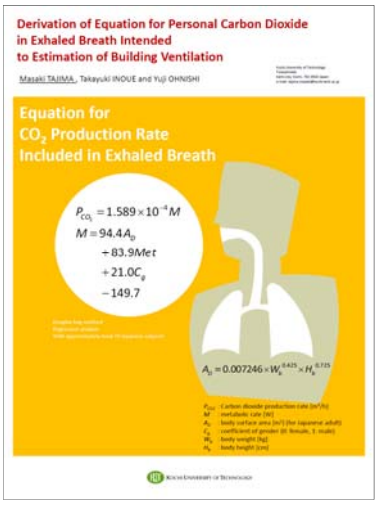
Results and the Poster



Comparison with standards



Measurement result in single zone



Thank you for bearing so long presentation

IMPACT OF A PHOTOCATALYTIC OXIDATION LAYER COVERING THE INTERIOR SURFACES OF A REAL TEST ROOM:

VOLATILE ORGANIC COMPOUND MINERALISATION, RISK ASSESSMENT OF BY-PRODUCT AND NANOPARTICLE EMISSIONS

Franck ALESSI || CEA, INES || 35th AIVC Conference
24-25 September 2014, Poznan (Poland)

CONTEXT AND GOAL

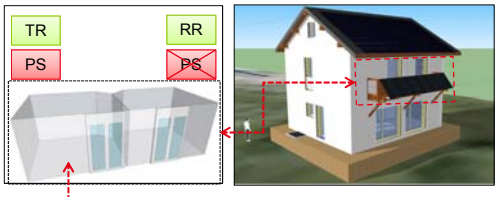
- **Task of the CETIEB project**
  - European Commission
    - 7th Framework Programme
    - Grant Agreement No. 285623

- **Development and assessment of a Passive Systems (PS) to improve IEQ & energy efficiency :**
  - PS: 4 different layers
  - **Focus on 1 layer : photocatalyst**
    - Nanoparticles of TiO_2 doped

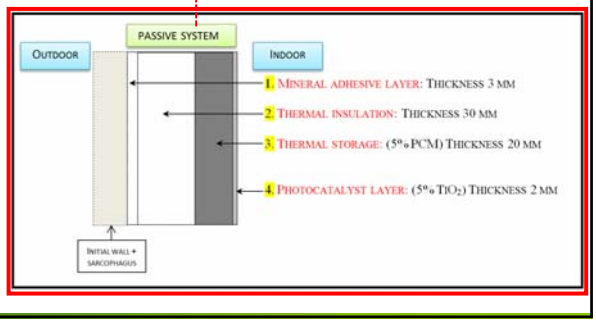
PASSIVE SYSTEM IMPLEMENTATION

- **2 Real test rooms:**
  - First floor
  - South-facing
  - Similar: Surface ≈ 10m², Volume, Materials…

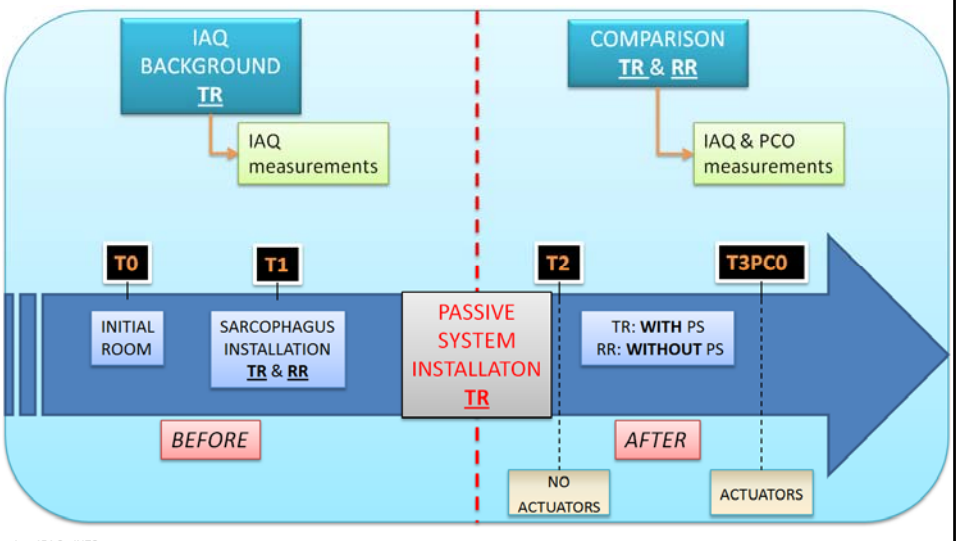
TR & RR



- **Passive system** PS **:**
  - Made with 4 layers
  - Applied on
    - Walls + Ceiling TR
  - Photocatalyst:
    - TiO_2 doped



EXPERIMENTAL PROTOCOL



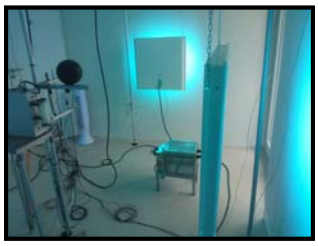
RESULTS WITH THE PS

NO ACTUATORS

- **T2:**
  - [TVOC] ↗↗
    - PS → Natural emissions
    - $RH_{TR} \approx 90\%$ → Competitive adsorption
  - [HCHO] ↘
    - $RH_{TR} \approx 90\%$ → Dissolution

WITH ACTUATORS

- **T3PCO:**
  - Ramp of Ta(°C) → [TVOC] & [HCHO] ↗
  - UVA → [TVOC] & [HCHO] ↗↗
    - HCHO : **by-product**
    - NP **x19.5** compared to T2 ↗↗



CONCLUSION

- **PS integration in real test room (*SCALE 1*):**
  - Real air mixture
  - Real room: low natural UV
  - Natural variations: Ta & RH…
  - PS→ Natural pollutant emissions

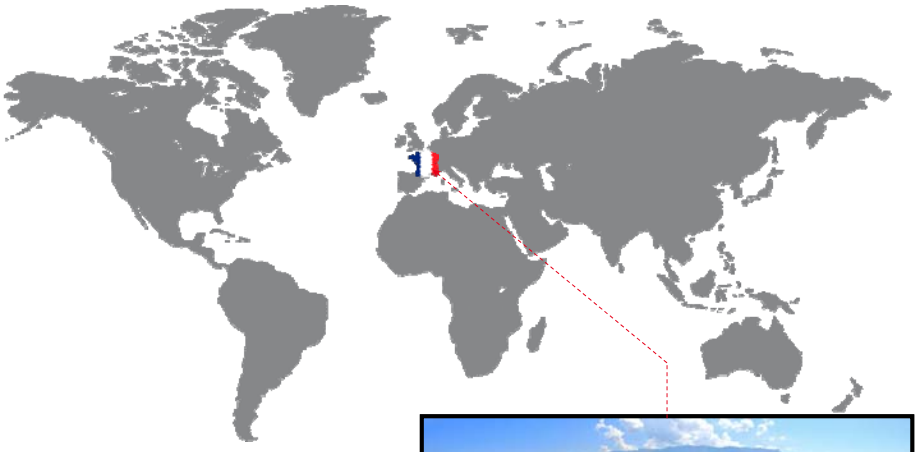
  → RIGOROUS TEST CONDITIONS

- **PS alone (T2) & PS + Actuators (T3PCO):**
  - No PCO effect highlighted (EVEN WITH UVA)
  - Increase - [TVOC]
    - [HCHO]
    - NP

  → ESPECIALLY WITH UVA!

PERSPECTIVES

- **Perspectives:**
  - Improvement of intrinsic photocatalyst properties
  - TiO_2: Better implementation (layer & room / quantity / quality…)
    → better activation
  - Safety tests…



Thank you for your attention!

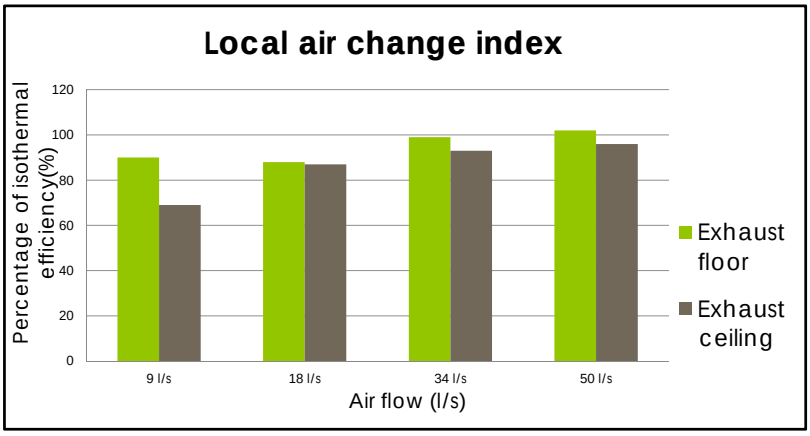
DCV FOR HEATING AND THE INFLUENCE ON IAQ

Vegard Aslaksen

Objectives

- At what temperature difference does indoor air quality problems start to occur?
- How does the use of DCV affect the IAQ?
- And how does the exhaust placement affect IAQ?

Result



Conclusions

- High local air change index
- Good IAQ

A STUDY OF CARBON DIOXIDE CONCENTRATIONS IN ELEMENTARY SCHOOLS

John Sifnaios*, Paraskevi Vivian Dorizas, Margarita-Niki Assimakopoulos

Faculty of Physics,
Department of Environmental Physics & Meteorology,
University of Athens,
Greece
* john_sif@hotmail.com

Joint Conference
35th AIVC - 4th TightVent – 2nd Venticool
24-25 September 2014, Poznan, Poland

Presentation contents

- Objectives
- Methodology
- Results & Discussion
- Conclusions

Objectives

1) Effect of CO_2 to students' productivity
2) Effect of occupancy density, window opening and ventilation rate to the CO_2 concentration
3) Evaluation of the schools' ventilation rate.

Methodology

Sample: 9 schools

Measurement period:
April & May 2013

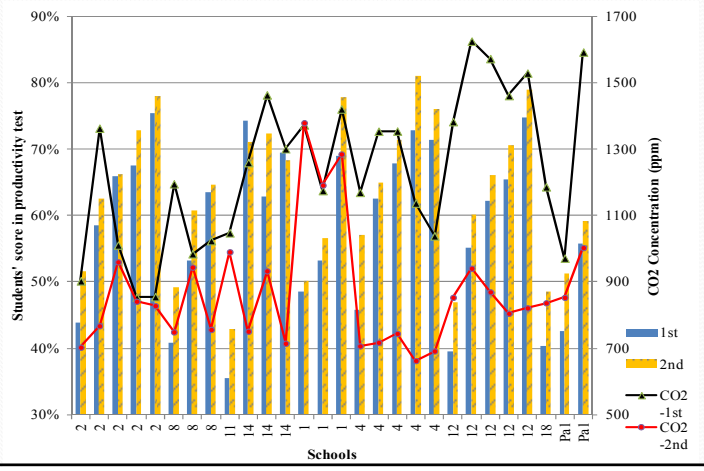
Measurements from 1 to 5 days per school

Measurement of the indoor CO2 concentrations

Measurement of the outdoor CO2 concentrations

Results & Discussion

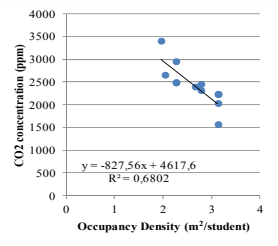
Trend of test scores per school per day and corresponding CO_2 concentrations



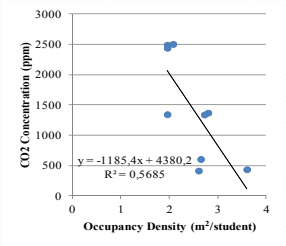
Results & Discussion

Occupancy density correlated to CO_2 concentration for different window positions

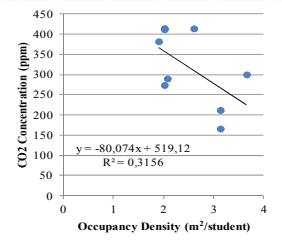
All windows closed



One window open (1,56 m² surface)



Two windows open (3,28 m² surface)

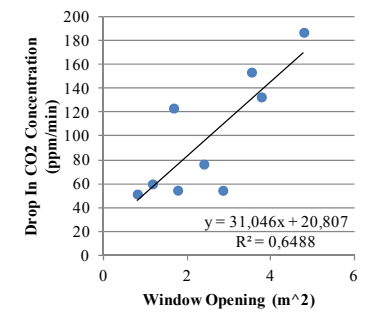


The average student contribution to the CO2 concentration for a period of one hour

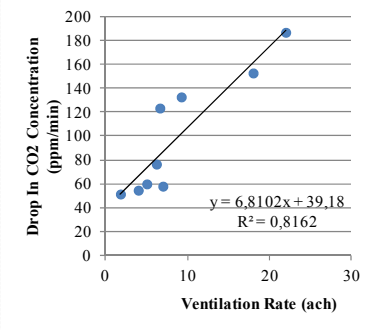
Window Opening	Average Student Contribution to CO_2 concentration (ppm)
All windows closed	116,8
One window opens halfway the lesson hour (open window surface = 1,56 m²)	77,5
Windows open the whole lesson (open window surface = 3,28 m²)	13,8

Results & Discussion

Concentration of CO_2 vs window opening



Concentration of CO_2 vs ventilation rate



Results & Discussion

Ventilation rates (l/p/s) for different window opening for each school

Window Opening	School	Ventilation Rate (l/p/s)
Closed windows the whole lesson time	14	1,43
	1	0,99
	4	0,57
	12	1,18
One window opens halfway the lesson hour (open window surface = 1,56 m^2)	8	11,72
	14	12,98
	4	11,09
	12	3,19
	18	16,55
Two windows open the whole lesson (open window surface = 3,28 m^2)	2	15,85
	4	39,31
	Pal	14,52
	11	9,39

Conclusions

- Negative correlation between the students' scores in tests and CO_2.
- Occupancy density affects CO_2 if outdoor air is not entering the classrooms.
- When open window area gets bigger, student contribution to CO_2 drops.
- Ventilation rate has a greater impact on the decrease of CO_2 concentration than the window open surface.
- All cases with closed widows during the lesson time had inadequate ventilation rate (below 8 l/p/s), while sufficient ventilation rates were observed with open windows.

Thank you for your attention!

John Sifnaios*
Paraskevi Vivian Dorizas
Margarita-Niki Assimakopoulos

Faculty of Physics, Department of Environmental Physics & Meteorology, University of Athens, Greece
* john_sif@hotmail.com

The effect of enthalpy recovery ventilation on the residential indoor climate

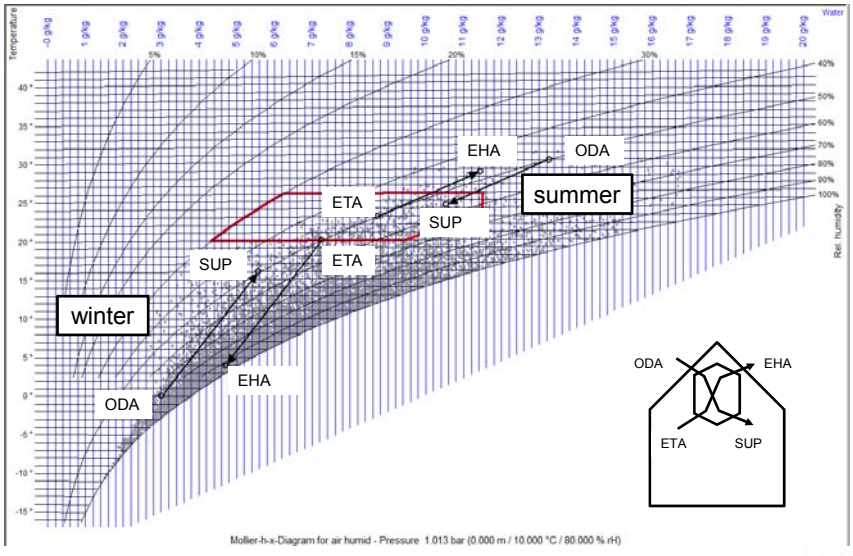
Enthalpy recovery (ERV) = heat recovery (HRV) + moisture recovery

Enthalpy recovery prevents too dry indoor air in winter

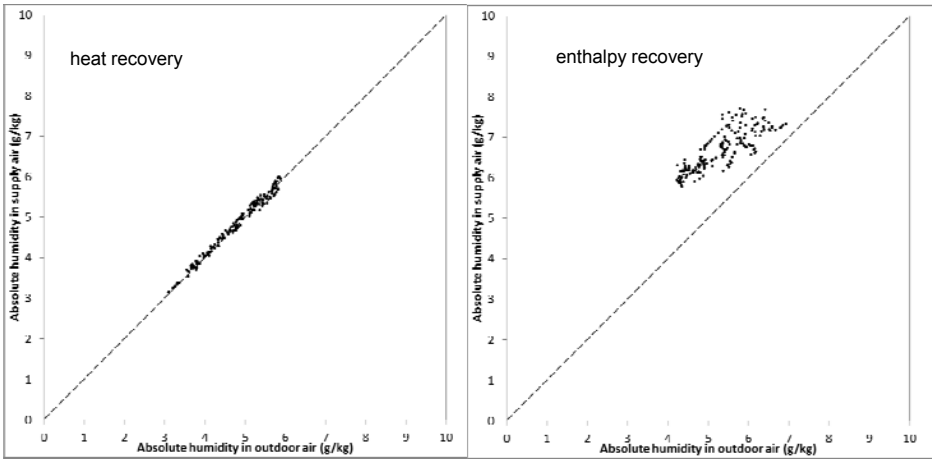
Enthalpy recovery ≠ Humidifier

Bart Cremers, Knowledge Centre, Zehnder Group Netherlands

Enthalpy recovery: theory in Mollier diagram



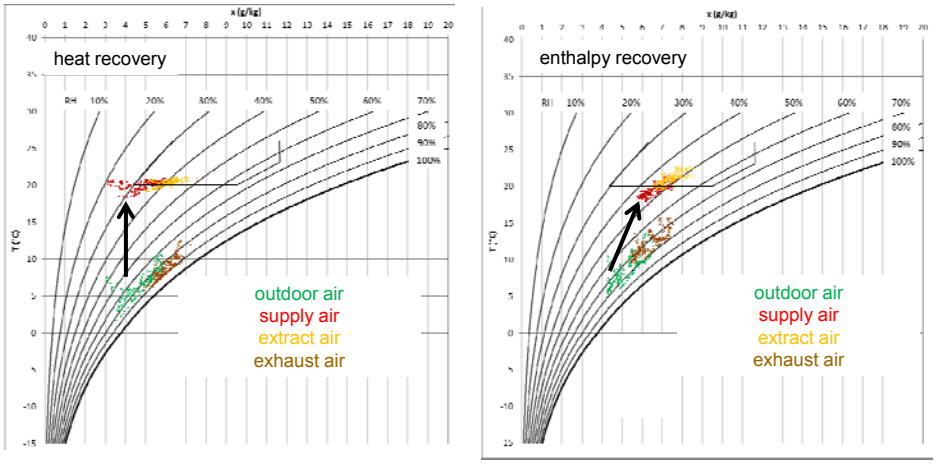
Comparison for 8-day period (T_{ODA}= 5-10 °C, x_{ODA}= 4-6 g/kg)



- Heat recovery: no increase in supply absolute humidity
- Enthalpy recovery: increase in supply absolute humidity of 1 – 2 g/kg

  (@150 m³/h this means humidity recovery of 4 – 8 liter/day)

Comparison for 8-day period (T_{ODA}= 5-10 °C, x_{ODA}= 4-6 g/kg)



- Heat recovery: inside relative humidity 35% - 45%
- Enthalpy recovery: inside relative humidity 45% - 50%

Conclusion: Enthalpy recovery increases winter inside RH with 10%point

Conclusions

During cold and dry winter conditions

- ERV recovers the humidity from the extract air (supply air rises 1-2 g/kg)
- ERV reduces risk of dry indoor air in winter (RH rise up to 10%point)
- Enthalpy recovery prevents formation of condensation in the exchanger

During hot and humid summer conditions

- ERV helps to keep the humidity outdoors
  - comfortable
  - energy efficient in combination with cooling

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Air renewal effectiveness

of decentralized ventilation devices with heat recovery

Fabien Coydon

Fraunhofer Institute for Solar Energy Systems ISE

www.ise.fraunhofer.de

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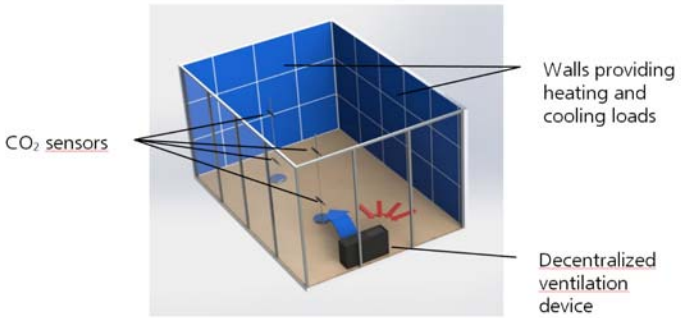
Evaluation of ventilation effectiveness of decentralized ventilation systems

- Comparison of 2 different methods
  - Smoke visualization
  - CO_2 measurements
- 3 modes: isothermal, heating and cooling
- Test room



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Smoke visualization

- Isothermal mode
- Heating mode
- Cooling mode

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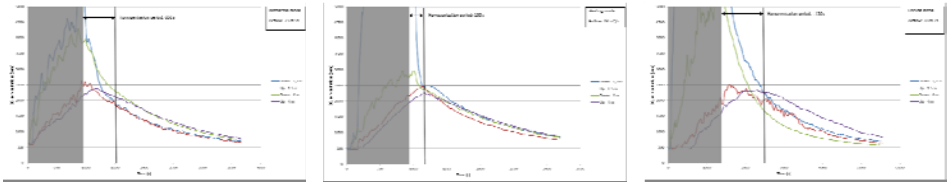
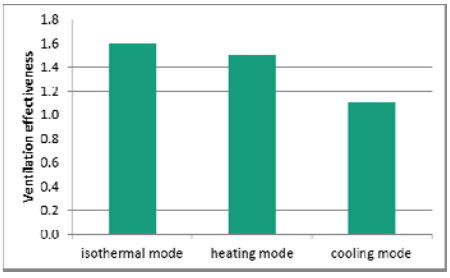
CO_2 measurements

- Isothermal mode
- Heating mode
- Cooling mode



- Ventilation effectiveness



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Conclusion and Outlook

- Isothermal and heating modes are providing a better ventilation effectiveness as cooling mode.
- Next step:
  - Development of an evaluation method of decentralized ventilation systems including energy performance and ventilation effectiveness in one single parameter.

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Thank you for your attention!

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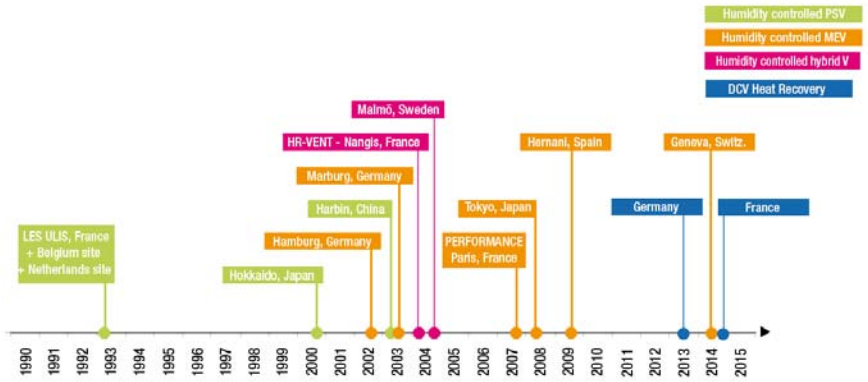
AERECO

DEMAND-CONTROLLED VENTILATION
20 YEARS OF IN-SITU MONITORING IN THE RESIDENTIAL FIELD

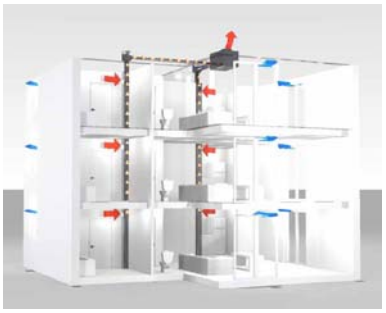
Jean-Luc Savin, Stéphane Berthin and Marc Jardinier
Aereco France

20 YEARS OF MONITORING IN DEMAND CONTROLLED VENTILATION



AERECO

THE MONITORED VENTILATION SYSTEMS



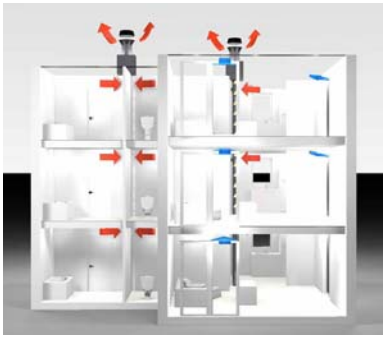
Mechanical exhaust ventilation

Humidity controlled air inlet (bedroom and living room)

Demand controlled exhaust unit (bathroom, kitchen and toilets)

AERECO

THE MONITORED VENTILATION SYSTEMS



Hybrid ventilation

Humidity controlled air inlet (bedroom and living room)

Demand controlled exhaust unit (bathroom, kitchen and toilets)

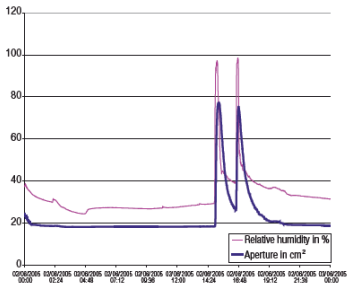
AERECO

DCV: HIGH PUNCTUAL AIRFLOW, LOW AVERAGE AIRFLOWS

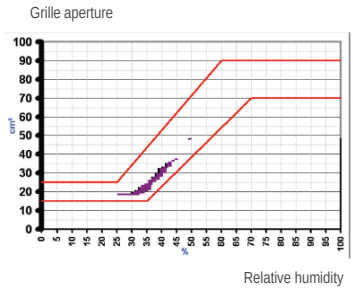
Measurements on a humidity controlled exhaust grille, in the bathroom

Winter

Instantaneous / punctual behavior (on day)



Statistical behavior (two months)



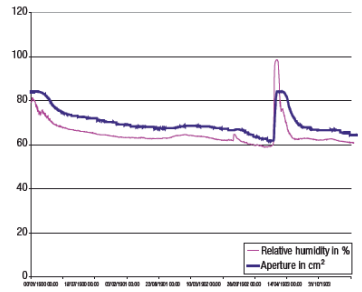
AERECO

DCV: HIGH PUNCTUAL AIRFLOW, LOW AVERAGE AIRFLOWS

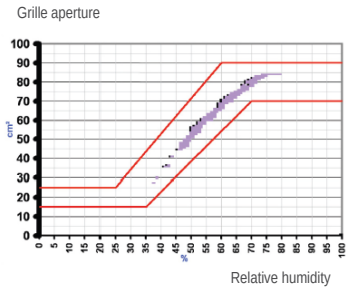
Measurements on a humidity controlled exhaust grille, in the bathroom

Summer

Instantaneous / punctual behavior (on day)



Statistical behavior (two months)



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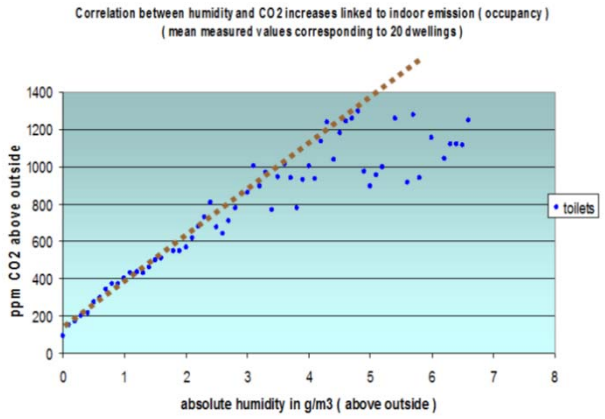
HUMIDITY DETECTION IS ADEQUATE TO EXHAUST CO_2 INDOOR EMISSIONS TOO



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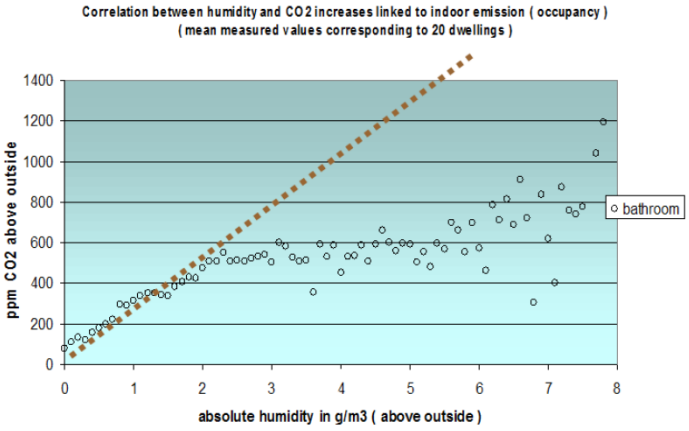

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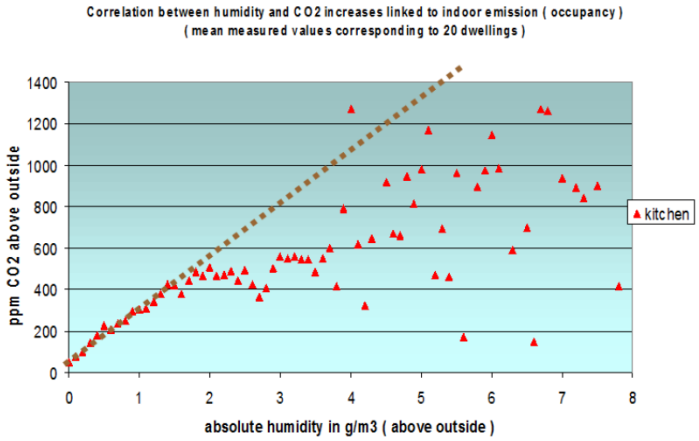

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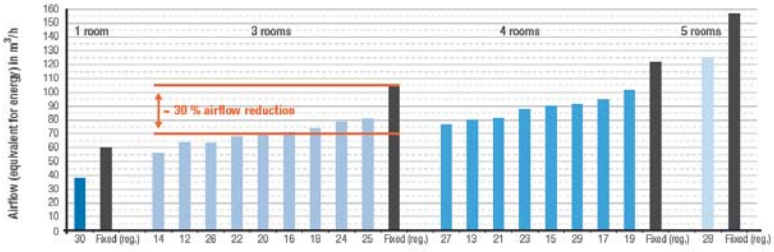
HEAT ENERGY LOSSES CAN BE LARGELY REDUCED BY THE VENTILATION ADAPTED TO THE DEMAND



Statistical equivalent airflows for energy per dwelling on Paris site. Rated by dwelling types.
Comparison with French regulatory constant airflow (grey bars). 2007-2008 heating period.

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CONCLUSION

- In real occupancy conditions, the measured demand controlled ventilation **work in conformity with the characteristics measured in laboratory**
- The humidity controlled ventilation has a **statistical seasonal behavior**. Giving naturally an average airflow lower in winter than in summer, **the humidity controlled ventilation saves significantly energy on heat losses** (30% and more).
- The demand-controlled ventilation gives the opportunity to automatically **get the indoor air quality optimized at every moment.**
- **The average fan power consumption is also reduced**, as a consequence of the low statistical airflow induced by the system.
- The demand-controlled ventilation can be considered as a **relevant alternative to the heat recovery ventilation systems in the residential field**.

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THANK YOU FOR YOUR ATTENTION

And see you on the poster

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AIR HEATING OF PASSIVE HOUSE OFFICE BUILDINGS IN COLD CLIMATES – HOW HIGH SUPPLY TEMPERATURE IS ACCEPTABLE?

Axel Cablé[1], Mads Mysen[1], Hugo Lewi Hammer[2], Kari Thunshelle[1]
1 SINTEF, Norway
2 Oslo and Akershus University College, Norway

HEATING PASSIVE HOUSE OFFICES IN COLD CLIMATE USING ONLY THE VENTILATION SYSTEM – COMPARISON OF TWO VENTILATION STRATEGIES

Hugo Lewi Hammer[2] , Mads Mysen[1], Axel Cablé[1], Kari Thunshelle[1]
1 SINTEF, Norway
2 Oslo and Akershus University College, Norway

CONTEXT

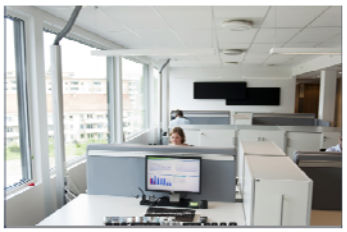
- 1st passive house office building in Norway
- Reduced heating demand
- Air heating

Objective

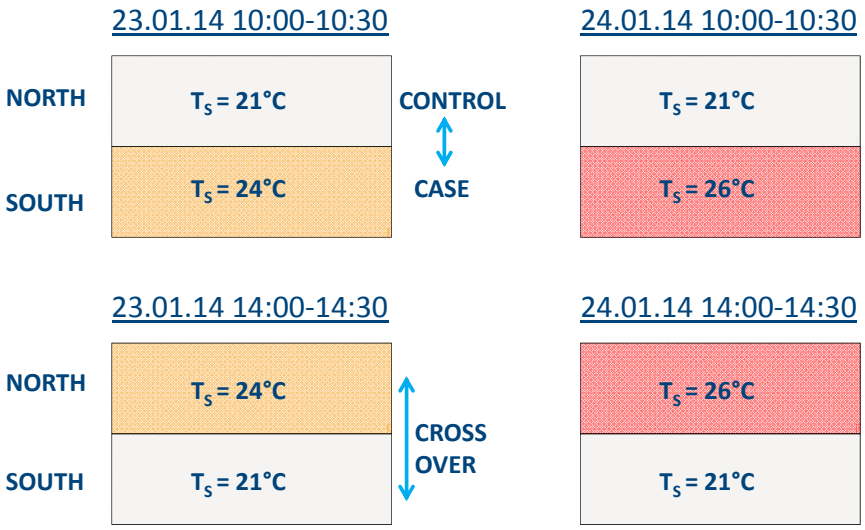
- Does air heating provide a comfortable perceived indoor climate?

➢ Questionnaires in real conditions

(open plan offices) during the coldest days of winter 2013/2014 (-10°C to -5°C)



INTERVENTIONS: Supply of warm air during 30 minutes



QUESTIONNAIRES

19 questions:

- Perceived thermal comfort
- Sick Building Syndrome-symptoms (SBS)
- Scale of 1 (unsatisfied) to 10 (satisfied)

Sum of all scores for a participant: **S (-/190)**

= indicator of the well-being

Examples:
Do you have a headache ?
Is there bothersome warmth because of sunshine?
Do you feel bothersome draught around your feet or your neck?
Is there is a unpleasant smell? …

RESULTS

- Number of answers on questionnaire:

January 23: 65 **; January 24**: 49 **; November 19**: 46

- Average score on all health and well-being questions :

(1: very uncomfortable, 10: very comfortable)

Ts=21°C: 8.65

Ts=24°C: 8.40

Ts=26°C: 8.90

November 19: 8.28

- The users are generally highly comfortable for all air supply temperatures

RESULTS

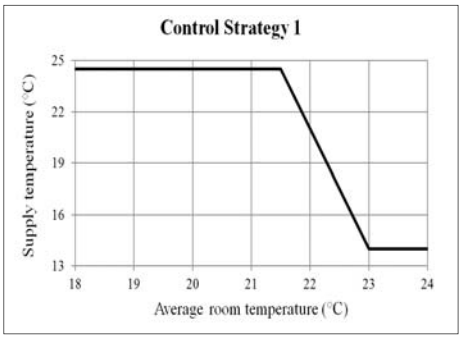
Regression analysis with **S** as the dependent variable

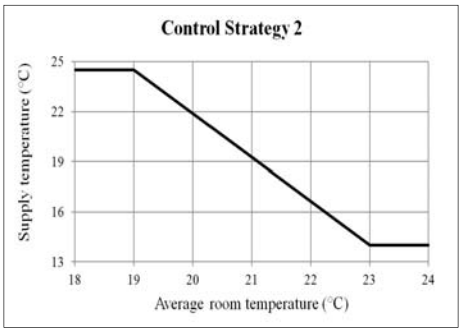
Parameter	Estimate	St. err.	df	t value	p value
Supply temperature	-0.16	0.52	59.55	-0.31	0.755
Gender male (reference: female)	19.42	7.82	51.01	2.48	0.016 *
Asthma (reference: No asthma)	17.29	16.83	50.42	1.03	0.309
Has a cold (reference: No cold)	4.98	5.37	72.07	0.93	0.357

Signif. codes: p-value < 0.01:**, p-value < 0.05:*

- No significant relationship between the supply temperature and **S**
- With 95% certainty, increasing the supply air temperature by 1°C will cause a maximum reduction of the SBS score (**S**) of 1.02 point (out of 190).

VENTILATION CONTROL STRATEGIES





- Control towards 21.8°C indoor temperature
- Strategy 1: "faster" control
- Strategy 2: "slower" control

➢ Perceived indoor climate for both strategies

INTERVENTIONS

13.01.14 06:00-14:30

NORTH — Vent. strat. 2

SOUTH — Vent. strat. 1

CONTROL CASE

14.01.14 06:00-14:30

NORTH — Vent. strat. 1

SOUTH — Vent. strat. 2

CROSS OVER

CONTROL AUTUMN

19.11.13 06:00-14:30

Normal operation (= Demand control)
Normal operation (= Demand control)

RESULTS

- Number of answers on questionnaire:

November 19: 46

January 13: 35

January 14: 36

- Average score on all health and well-being questions :

  (1: very uncomfortable, 10: very comfortable)

November 19: 8.28

Vent.strat.1 (fast): 8.76

Vent.strat.2(slow): 8.35

- The users are generally highly comfortable under both control strategies

RESULTS

Regression analysis with **S** as the dependent variable

Parameter	Estimate	St. err.	df	t value	p value
Vent. strat. 1 (reference: vent. strat. 2)	6.6	2.9	42.5	2.26	0.029 *
19th November (reference: vent. strat. 2)	2.8	2.9	44.9	0.98	0.332
Office temperature	5.1	6.0	46.4	0.84	0.405
Gender male (reference: female)	20.8	6.9	67.9	3.01	0.004 **
Asthma (reference: No asthma)	– 31.1	10.9	69.6	2.83	0.006 **
Cold (reference: No cold)	– 5.3	4.1	49.4	1.28	0.205

Signif. codes: p-value < 0.01:**, p-value < 0.05:*

- Perceived indoor climate better under strategy 1 (fast) compared to strategy 2 (slow). Strategy 2 not significantly poorer than the control autumn (19th November).
- Perceived indoor climate better for male users.

CONCLUSIONS

- Good perceived indoor climate was reported when using air heating to cover the heating demand
- Winter 2013/2014 was mild: study repeated in Winter 2014/2015 to evaluate results for colder outside conditions, over longer periods and with a larger population
- Perceived indoor climate significantly better for male users:
  - ➢ Individual control of the supply temperature?

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CLEANLINESS OF AIR FILTERS IN THE EXPERIMENTAL PASSIVE HOUSE

Michał Michałkiewicz
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Institute of Environmental Engineering
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The aim of the study was to determine the contamination of different air filters after several months of their continuous work

The analysis was carried out on the basis of tests conducted in the experimental building, prior modernized to a passive house condition

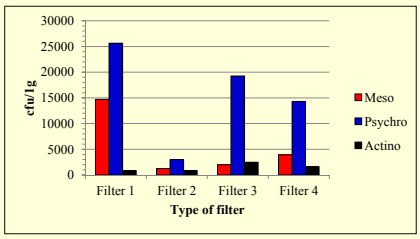
Three different types of wooden frame wall barriers, showing different thermal insulation properties, have been applied in the building

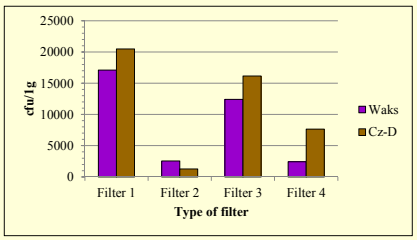
One of these wall barriers has been built into a modern vacuum insulation system

Characteristics of examined filters

Filter	Filter pack weight [g]	Filter type	Filter parameters
Filter 1	230,0	EU5	Ventilation unit, intake line,
Filter 2	1100,0	EU5	Ventilation unit, exhaust line,
Filter 3	320,0	EU5	Bag from ventilator of level I cleaning machine (acc. to PN-EN 779)
Filter 4	190,0	EU5	Bag from ventilator of level II cleaning machine

During microbiological examination of filters, the following microorganisms were determined:
• the general count of mesophilic bacteria and psychrophilic bacteria,
• the count of *Staphylococcus* (*Staphylococcus*) mannitol positive (type α) and mannitol negative (type β),
• the count of *Pseudomonas fluorescens* bacteria, actinomycetes (*Actinobacteria*) as well as the general count of microscopic fungi





CLEANLINESS OF AIR FILTERS IN THE EXPERIMENTAL PASSIVE HOUSE

Michał Michałkiewicz *michal.michalkiewicz@put.poznan.pl*

Małgorzata Basińska *malgorzata.basinska@put.poznan.pl*

Poznan University of Technology
Institute of Environmental Engineering
Division of Heating, Air Conditioning and Air Protection

ENERGY-OPTIMAL VENTILATION STRATEGY OUTSIDE OF THE OPERATING TIME FOR PASSIVE HOUSE OFFICE BUILDINGS IN COLD CLIMATES

Per Magnus Holth[1], Mads Mysen [2], Axel Cablé [2], Kari Thunshelle [2]

[1]Oslo and Akershus University College, Norway

[2]SINTEF, Norway

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Methodes

- The paper looks at 3 different air volumes that have organized after the amount of air in each flow, V'min, V'HygMin and V'Max. V'min has an airflow of 2,5 m^3/hm^2, representing the minimum airflow by NS 15251 without presence. V'HygMin are with presence, with an airflow of 4,2 m^3/hm^2. V'Max are the maximum airflow for the AHU's, with an total airflow of 10,8 m^3/hm^2. This corresponds to an airflow at 40.000 m^3/h.
- Experiments are conducted on nights when the outdoor temperature has dropped well below 0.
- Tests at Environmental house GK is then used as the basis for verifying calculations. Basic equations for heat loss is calculated by NS 3031(Calculation of energy performance of buildings – Method and data).

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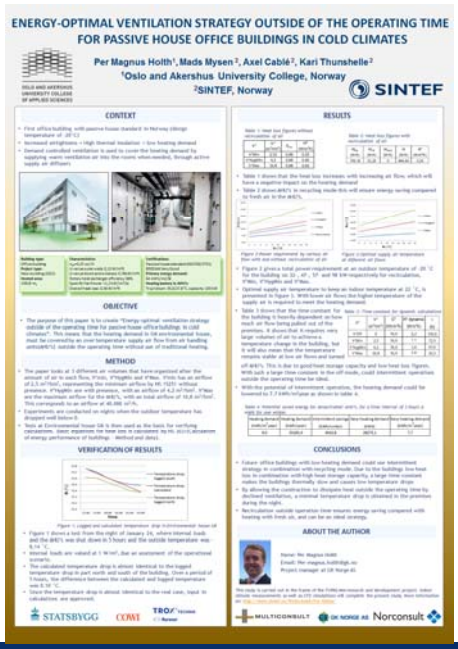
Conclusions

- Future office buildings with low heating demand could use intermittent strategy in combination with recycling mode. Due to the buildings low heat loss in combination with high heat storage capacity, a large time constant makes the buildings thermally slow and causes low temperature drops
- By allowing the construction to dissipate heat outside the operating time by declined ventilation, a minimal temperature drop is obtained in the premises during the night.
- Recirculation outside operation time ensures energy saving compared with heating with fresh air, and can be an ideal strategy.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[1]Oslo and Akershus University College, Norway
[2]SINTEF, Norway

CONTEXT

OBJECTIVE

METHOD

VERIFICATION OF RESULTS

RESULTS

CONCLUSIONS

ABOUT THE AUTHOR

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CAN AIR HEATING ALONE BE USED IN PASSIVE HOUSE OFFICE BUILDING IN COLD CLIMATES? REVIEW OF THE OBTAINED RESULTS

Kari Thunshelle[1] Axel Cablé[1], Mads Mysen[1], Hugo Lewi Hammer[2]

[1] SINTEF, Norway

[2] Oslo and Akershus University College, Norway

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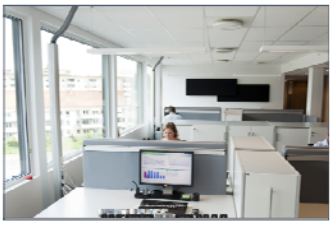
Context

- The research project "Simplified demand controlled air conditioning in office buildings with very low heating demand" (ForKlima) aims to develop strategies for ventilation based space heating and document function and conditions that must be fulfilled



Objectives

- Is it possible to cover the heating demand with warm ventilation air exclusively in cold climates and totally eliminate backup systems?
- Does air heating provide a comfortable perceived indoor climate?
- Review of the results after the first of two winter test periods

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Ventilation strategies

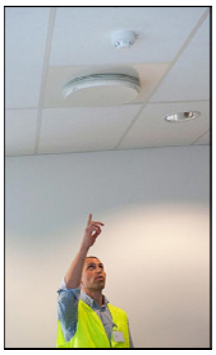
- Demand controlled ventilation is used to cover the heating demand by supplying warm ventilation air into the rooms when needed
- Active air supply diffusors that can regulate supply area to keep stable supply air velocity are used
- The heating demand is entirely covered with air heating – but with backup electrical heating
- Recirculation is possible during night time

Studies within the project

- Indoor climate measurements in a cubic office at GK environmental house
- User survey with cross over design on perceived indoor climate for different ventilation strategies
- Tracer gas measurements in laboratory for different strategies of air heating, air change rates and placing of exhaust valves
- CFD simulations are also done within this project but not reviewed in this paper

Summary

- The studies done so far seems to indicate that demand controlled ventilation alone can cover the heat demand, while providing a good thermal comfort.
- Both field- and laboratory measurements show good ventilation efficiency for a broad range of supply temperature and ventilation rate.
- Given the efficient insulation of the building, it is necessary to supply air only 2-4ºC above room temperature on the coldest days, and even less most of the year.
- These are preliminary results that have to be confirmed by further studies next winter.



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SINTEF

CONTEXT

OBJECTIVES

VENTILATION STRATEGIES

PROJECT STUDIES REVIEWED

SUMMARY

ABOUT THE AUTHOR

AFFILIATIONS

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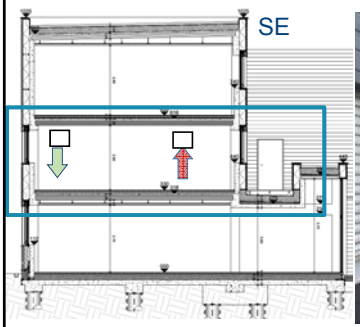
TECHNOLOGIECAMPUS GENT

Impact of the use of a front door on thermal comfort in a classroom in a passive school

Hilde Breesch, Barbara Wauman, Alexis Versele

Passive School Building



- New building block with 3 floors in Belgium
- Urban regulations -> open corridor on 1st floor -> classrooms with front door
- Contradictory to basic idea passive school

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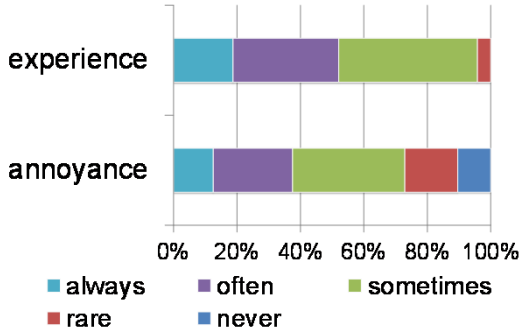
Evaluation impact on thermal comfort

- Survey



48 respondents
Jan 6-10, 2014
T_{mean} = 9°C
Wind direction: S
v_{mean} = 16 km/h

  - No clear link to position in classroom
  - Strong link to door use & wind and T_e

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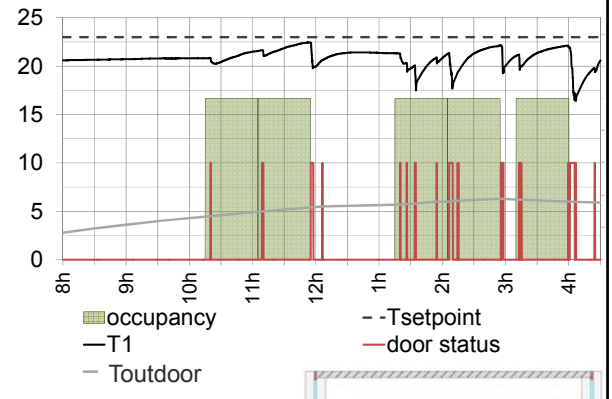
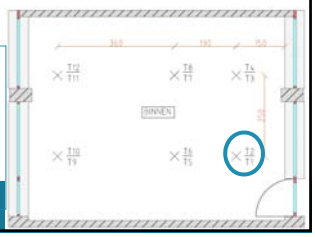
Evaluation impact on thermal comfort

- Measurements
  - Front door use
    - Frequency
    - Duration
  - Air flow rate
  - Effect on T_i
    - Local effect
    - Influencing zone



T_{op}, H = 0.1 m
Feb 24-28, 2014
$\Delta T_{i-e,mean}$ = 16° C
wind: SE, v_{mean} = 10.4 km/h



Conclusions

- Front door use affects thermal comfort & increases infiltration losses in this classroom
- Consider effect of front door in rooms in
  - Heating system design
  - Energy performance assessment future passive house projects

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Development of a Unique Thermal and Indoor Air Quality Probabilistic Modelling Tool for Assessing the Impact of Lowering Building Ventilation Rates

James A. McGrath and Miriam A. Byrne

School of Physics and Centre for Climate & Air pollution Studies (C-CAPS),
National University of Ireland Galway, Galway, Ireland.

seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND

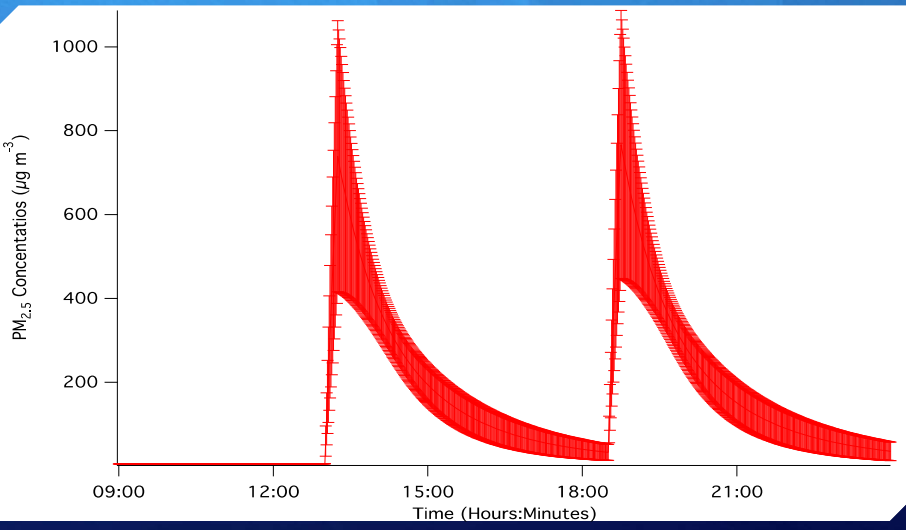
C-CAPS Ionad Aeráide agus Truaillíú Aeir Centre for Climate & Air Pollution Studies

NUI Galway OÉ Gaillimh

Aim

- To incorporate a temperature parameter into an existing probabilistic air pollutant exposure model, IAPPEM
- Predict time-varying indoor temperature concentrations in a multi-zone approach based on
  - Outdoor temperature
  - Solar gain
  - Heat transfer based on airflow and building structure
  - Heat gains through internal heating sources

Frying Scenario



Various AERs

Emission Scenario	24 Hour Mean $PM_{2.5}$ (µg/m³)	
	Kitchen	Living Room
World Health Guidelines	25	25
Air Exchange Rate of 1.0 ACH^{-1}	55 ± 4	57 ± 3
Air Exchange Rate of 0.7 ACH^{-1}	70 ± 6	74 ± 4
Air Exchange Rate of 0.5 ACH^{-1}	91 ± 9	97 ± 7 m
Air Exchange Rate of 0.3 ACH^{-1}	112 ± 12	122 ± 10

Conclusions

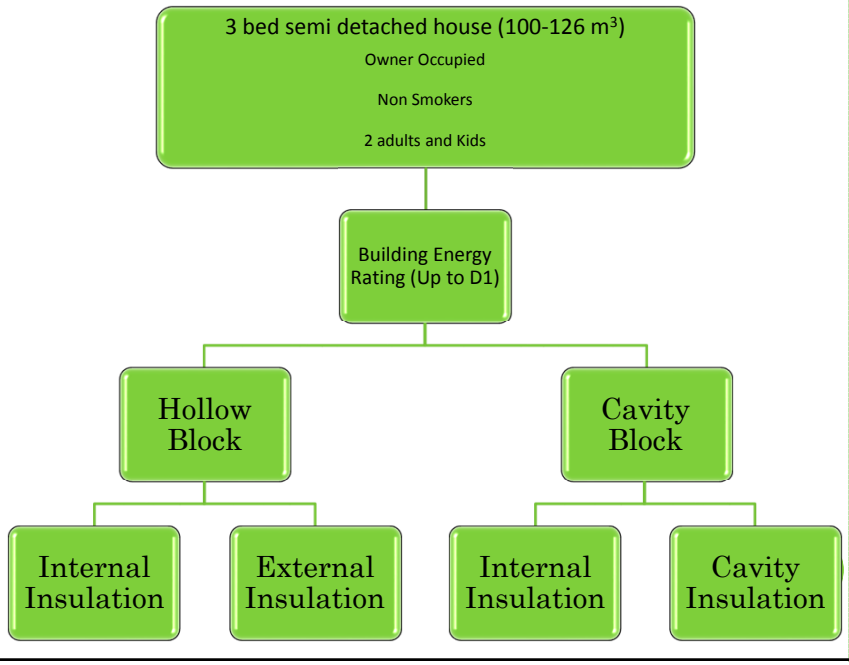
- Assess both internal temperature and indoor air pollutants, resulting in a time-series analysis of both parameters.
- Simulate variations in household characteristics, occupants behavioural patterns, mechanical and natural ventilation.
- Provide a computational tool with relevance in epidemiology studies, building design, ventilation studies, traffic management studies, and many other fields.

A protocol for assessing indoor air quality in retrofitted energy efficient homes in Ireland

Áine Broderick

Supervisors

Dr. Marie Coggins,
Dr. Miriam Byrne.



Location of equipment

Equipment	Pollutants monitored
TSI SidePak AM510 Personal Aerosol Monitor	PM 2.5
Gradko Passive Diffusion Tubes	NO_2
GrayWolf IQ-610	CO_2 , VOCs, CO, %RH, Temperature
GrayWolf FM-801	Formaldehyde
Telaire 7001	CO_2, Temperature
Passive detectors	Radon

CFD SIMULATION OF AN OFFICE HEATED BY A CEILING MOUNTED DIFFUSER

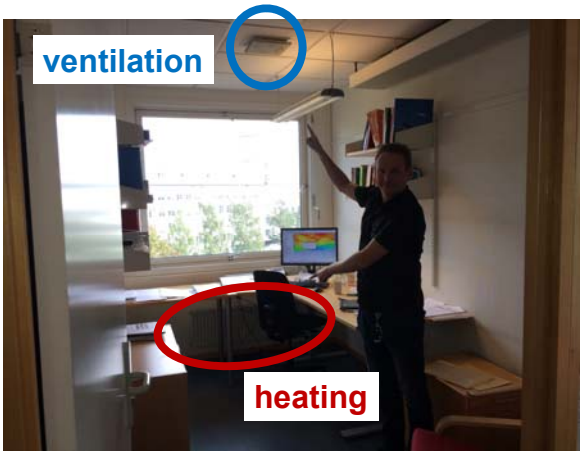
Bård Venås, Trond Thorgeir Harsem, and Bent A. Børresen

Norconsult

Welcome to my office in Norway!

Norconsult

It has both ventilation and heating



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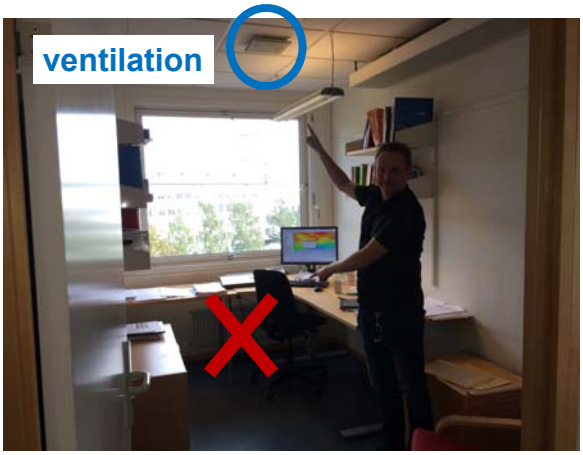
What if we removed the radiator …



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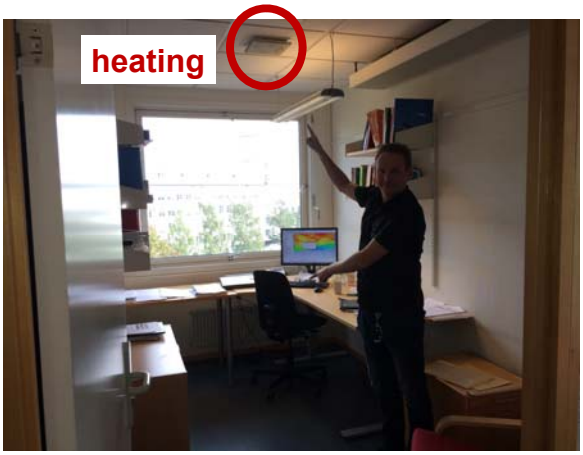
and used ventilation for heating as well?

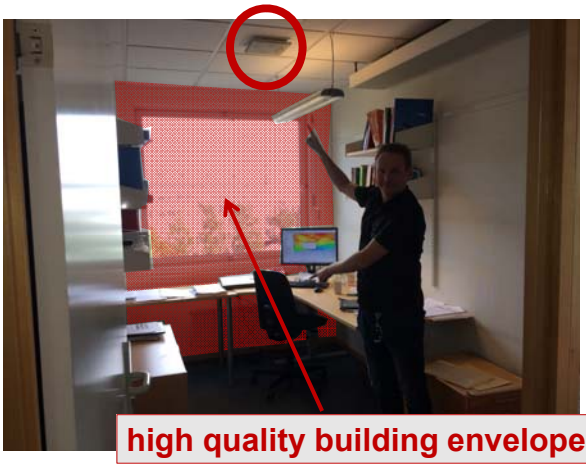


Norconsult

But … will the buoyant hot air mix?

Norconsult

Well maybe if it was a *passive house*?



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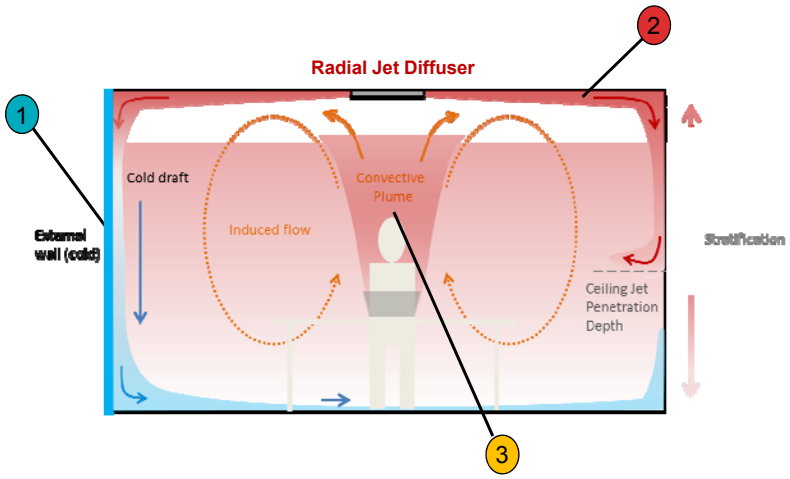
3 mechanisms promote mixing



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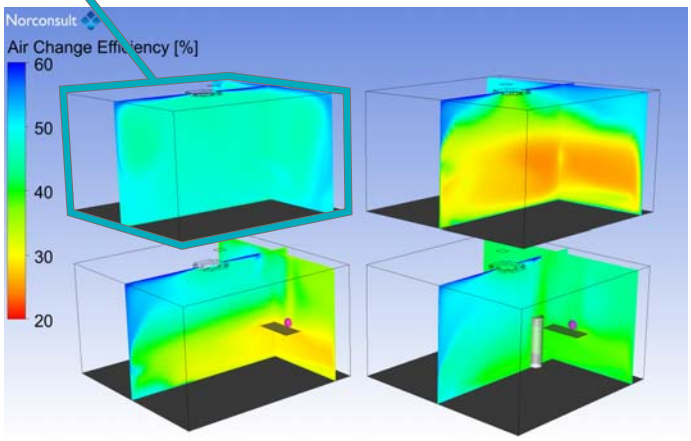
Air Change Efficiency (in 10 seconds)

Norconsult

No heating



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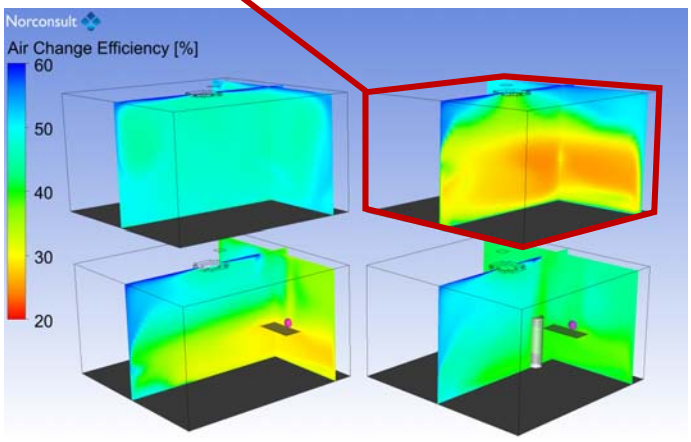
Heating (but no internal heat loads)



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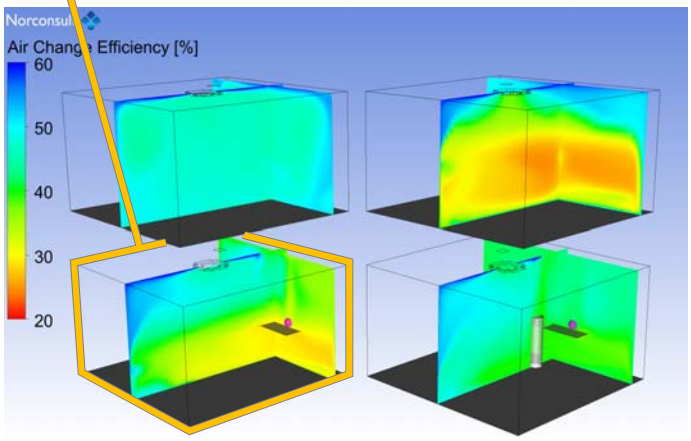
A laptop turned on



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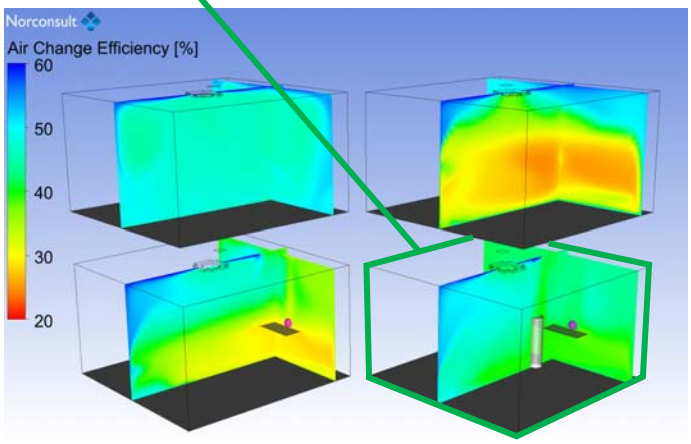
A laptop and a person

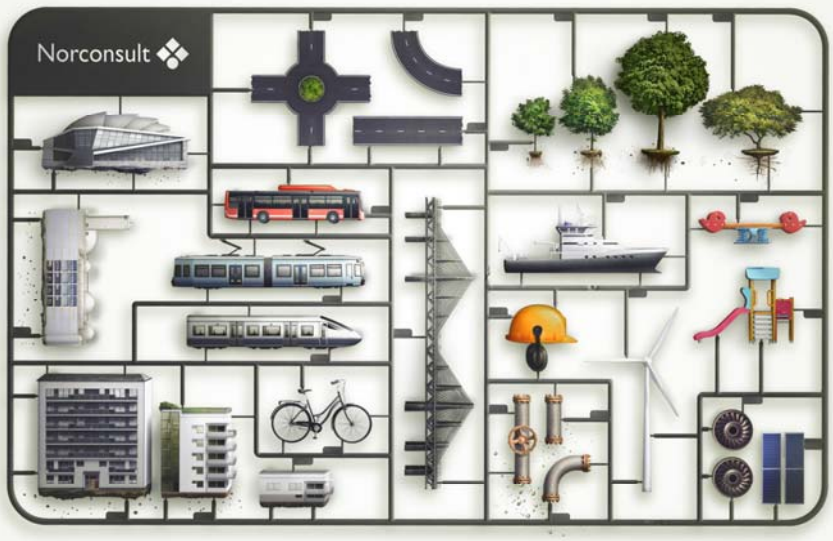


Norconsult

Conclusion

- the principle seems to work fairly well when the building is occupied
- the system is likely to be able to deliver **peak load heating** for **passive houses** in cold climates

Norconsult



Thank you

KTH Architectural Engineering

Optimal positioning of exhaust grills in an operating room based on recovery test: a numerical study

Sasan Sadrizadeh*, Sture K M Holmberg

Department of Civil and Architectural Engineering, Divisions of Fluid and Climate Technology, KTH Royal Institute of Technology, Stockholm, Sweden

Email: sasan.sadrizadeh@byv.kth.se

KTH Architectural Engineering

Agenda

- Introduction and Background
- Method
- Results and discussion
- Conclusions
- Reference

KTH Architectural Engineering

Background

- The ventilation system of a hospital operating room is to provide a comfortable and healthy environment for the patient and the surgical team.
- Operating room ventilation is the primary objective for:
  - Remove anesthetic gases and odors released during an operation
  - Reduce bacteria, viruses and dust concentration to acceptable levels
  - Provide optimum and comfortable working conditions for the occupants
- The greatest amount of bacteria (90 %) in an operating room comes from the staff, and is often a result of their surgical activities.

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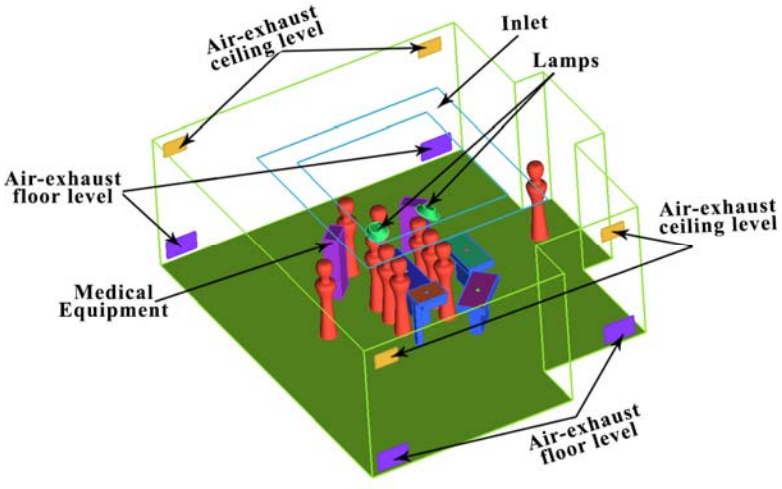
Method



A single-zone standard OR, 8.5m L × 7.7m W × 3.2m H

KTH Architectural Engineering

Method

Recovery test and particle simulation:

- Three common anaesthetic gases:
  - » Halothane (C2HBrClF3) Density 6,48 kg/m^3
  - » Desflurane (C3H2F6O) Density 5,44 kg/m^3
  - » Nitrogen (N_2) Density 1,02 kg/m^3
- Bacteria-carrying particles with aerodynamic size of 12 μm

KTH Architectural Engineering

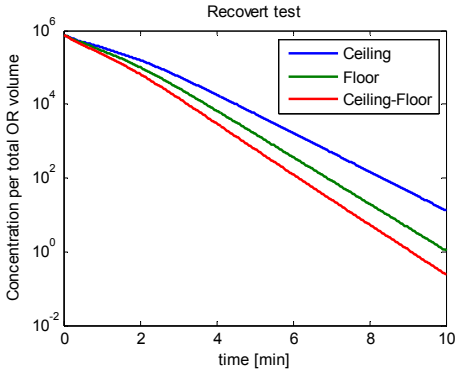
Method

Mathematical model:

- RNG k–ε turbulence model to solve the flow field.
- Lagrangian discrete random walk approach to simulate particle dispersion
- Model validation was performed through result comparisons with published measurement data from literature.
- ICEM CFD for mesh generation and double precision solver of ANSYS Fluent 14.5 for solve the equations.

KTH Architectural Engineering

Results and discussion



Recovery test results for three different air-exhaust outlet configurations

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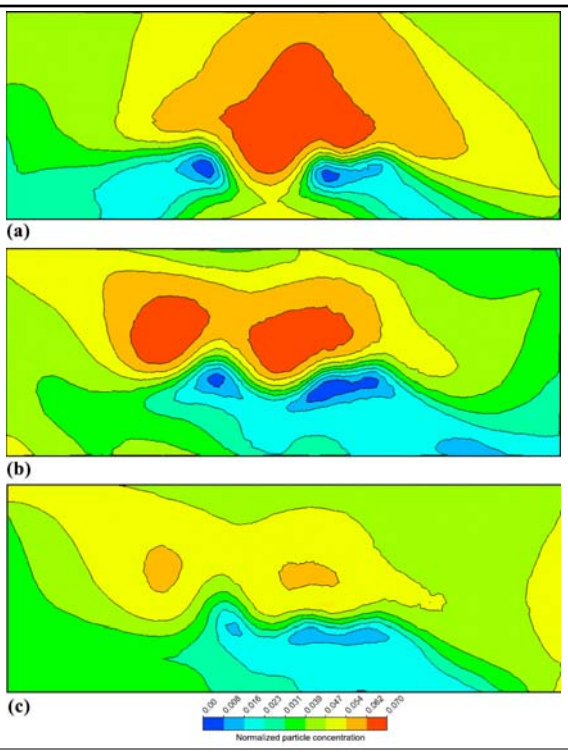
a) ceiling level

b) floor level

c) ceiling-floor level



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Conclusions

- Ceiling exhaust openings:
  - ❖ Effective at removing any bacteria or other pathogen-containing particles and chemical substances that may become airborne during a surgical procedure.
- Floor-level outlets:
  - ❖ Efficient at removing various anesthetic gases and infectious particles that may be heavier than the air.
- Optimum layout:
  - ❖ Both ceiling- and floor exhausts at every corner of the OR.
  - ❖ Totally four floor and four ceiling-mounted exhausts.
  - ❖ This arrangement contributes to a more uniform airflow pattern within the OR.

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Reference

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Noble WC, Lidwell OM, Kingston D (1963). The size distribution of airborne particles carrying micro-organisms. J Hyg (Lond) 385–391.

THE INFLUENCE OF TRAFFIC EMISSION ON INDOR AIR QUALITY - ESPECIALLY IN STREET CANYONS

Zbigniew Bagieński
Institute of Environmental Engineering

One of the most important factors determining the quality of the air is its chemical composition.

In typical ventilation systems of residential, office or commercial buildings, external air pollution is introduced without any adjustment to the rooms.

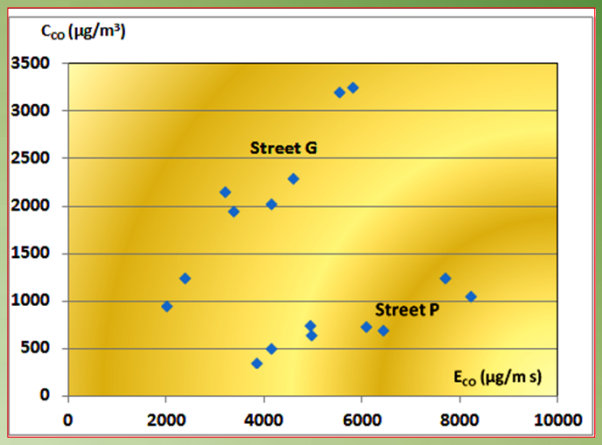
This includes (for example) pollutants from traffic emission, especially in the areas of compact settlement and intensive vehicle traffic in street canyons.

I compared the conditions and effects of the vehicle emissions in two urban traffic routes

Street G – one-way traffic (two-line), factor: $H_{Bav}/W > 0.8$ – street canyon
Average height of building to width of the street

Street P – four-line street, factor: $H_{Bav}/W < 0.2$

Street canyon structure limits pollutant dispersion.
In the case of the canyon - street G, emission causes several times higher pollutant concentrations by the road, than in the case of the open street - street P



Measured CO concentration C_{CO} referred to CO emissions E_{CO} for G and P streets

Buildings are responsible for wind flow disturbances and generating the cavity recirculation region and the wake region. The vortices move traffic pollutions causing high local concentration, especially on the leeward side of the canyon.

Line source of emission in the street canyon - when $H_{Bav}/W=1.0$,

Line source of emission in the street - when $H_{Bav}/W=0.3$

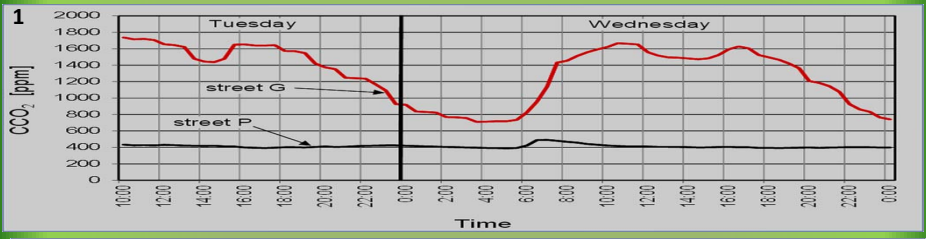
wind speeds u=2m/s, perpendicular to the street

This phenomenon is confirmed by measurements of CO_2 concentrations in air intakes to the buildings ventilation system for the streets G and P :

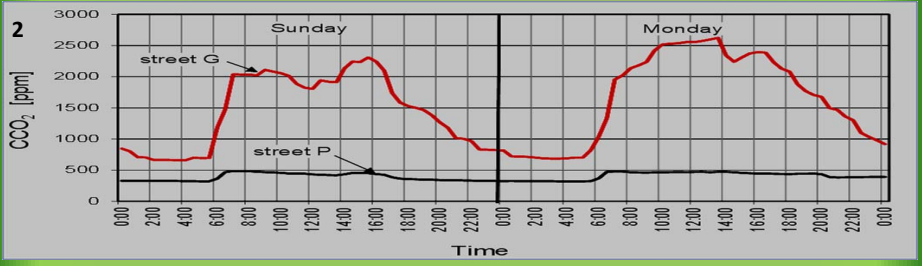
- in the case of small wind speeds u<1.2 m/s (1)

- and at higher wind speeds u=2-3.5 m/s, perpendicular to the streets (2)

1



2



Concentrations for street G were 3-5 times higher (up to 2600 ppm), especially on days with increased wind velocity. With the wind perpendicular to the street, the whole canyon was in the cavity recirculation region

Temperature and pressure corrections for power-law coefficients of airflow through ventilation system components and leaks

François Rémi Carrié
ICEE

AIVC Conference
Poznan, Poland
24-25 September 2014

Outline

- Pressure-flow relationship
- Pressure and temperature conditions seen by the leaks
- Flow coefficient correction
- Application to pressurization tests
- Summary

Pressure-flow relationship

- Ventilation system components and leaks in ductwork systems or buildings are commonly characterized by a flow-pressure relationship
- In laboratory or in the field, we create a series of pressure differences across the components or leaks

Pressure flow relationship

- Power-law

$$q_{v;object;test} = C_{object;test} \cdot \Delta p^{n}$$

- Common approximation is to assume

$$C_{object;test} = Cste$$

- but in fact:

$$C \propto \mu^{1-2n}\, \rho^{n-1}\, L^{2n+1}$$

Pressure-flow relationship

- C depends on the only physical characteristics of the system:
  - μ (kg m^{-1} s^{-1})
  - ρ (kg m^{-3})
  - L (m) (characteristic length)
- $\Rightarrow \qquad C \propto \mu^{\alpha} \cdot \rho^{\beta} \cdot L^{\gamma}$

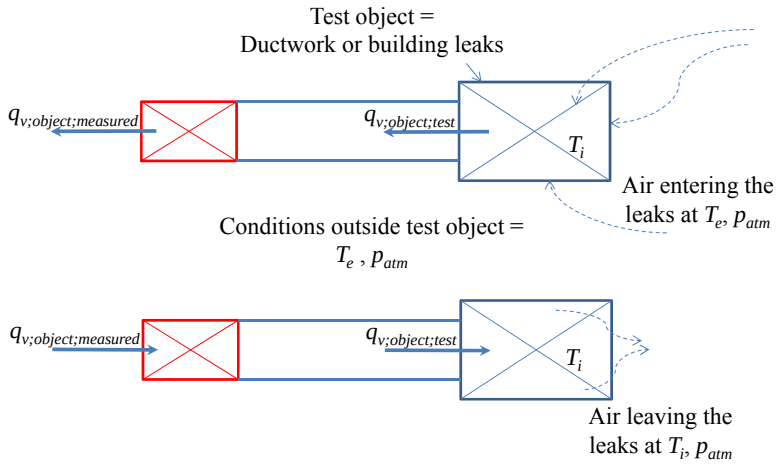
- Dimensional homgeneity gives α, β, γ

Problem statement

- Since C varies with temperature and pressure, how can we deduct C_0 at normal T, P from a measurement ?
- Is it worth it ?

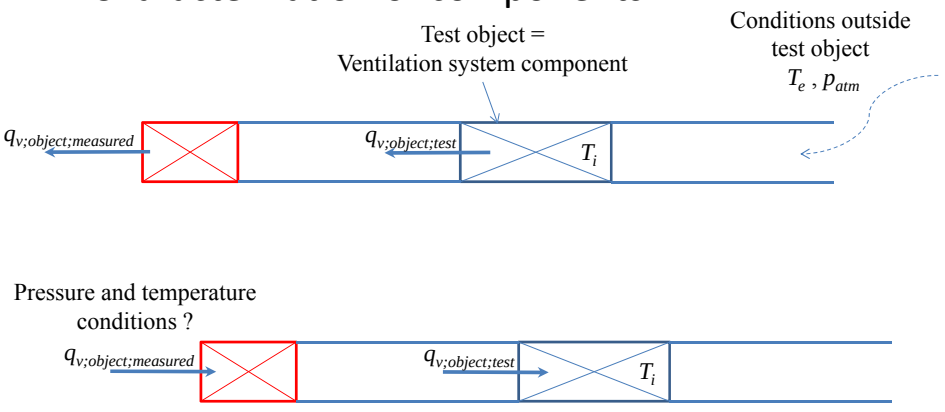
Pressure and temperature conditions seen by the test object

- (De)Pressurization tests



Pressure and temperature conditions seen by the test object

- Characterization of components



Flow coefficient correction

- From dimensional analysis, we obtain:

$$C_{object;0} = \left(\frac{\mu_{test}}{\mu_0}\right)^{2n-1} \left(\frac{\rho_{test}}{\rho_0}\right)^{1-n} C_{object;test}$$

- This correction does not include the correction for the measurement device (i.e. if you measure a volumetric airflow rate, temperature corrections apply)

Application to pressurization tests with unknown flow exponent

- Depressurization

1. Mass flow correction through measurement device $q_{v;object;test} = \frac{\rho_i}{\rho_e} q_{v;meas}$

2. Obtain $C_{object;test}$ and n with mutliple points

3. Flow coefficient correction $C_{object;0} = \left(\frac{\mu_e}{\mu_0}\right)^{2n-1} \left(\frac{\rho_e}{\rho_0}\right)^{1-n} C_{object;test}$

Identical to correction required in ASTM E 779-2010

In pressurization $q_{v;object;test} = \frac{\rho_e}{\rho_i} q_{v;meas}$

$$C_{object;0} = \left(\frac{\mu_i}{\mu_0}\right)^{2n-1} \left(\frac{\rho_i}{\rho_0}\right)^{1-n} C_{object;test}$$

Application to pressurization tests with a default flow exponent

- In this case, we are usually interested in the airflow rate at normal T, P
- Depressurization:

$$q_{v;object;0} = \left(\frac{\mu_e}{\mu_0}\right)^{2n-1} \left(\frac{\rho_e}{\rho_0}\right)^{1-n} \frac{\rho_i}{\rho_e} q_{v;object;meas}$$

- Pressurization

$$q_{v;object;0} = \left(\frac{\mu_i}{\mu_0}\right)^{2n-1} \left(\frac{\rho_i}{\rho_0}\right)^{1-n} \frac{\rho_e}{\rho_i} q_{v;object;meas}$$

Is it worth it ?

		Airflow correction assuming ϑ_e = 10 °C			
p_{atm} (Pa)	ϑ_i (°C)	Eq. (20), n = 0,5	Eq. (20), n = 0,65	Eq. (21), n = 0,5	Eq. (21), n = 0,65
101325	0	0,1%	2,8%	-5,2%	-3,9%
101325	5	-0,8%	1,2%	-3,5%	-2,2%
101325	10	-1,7%	-0,4%	-1,7%	-0,4%
101325	15	-2,6%	-1,9%	0,0%	1,4%
101325	20	-3,4%	-3,4%	1,8%	3,1%
101325	25	-4,2%	-4,8%	3,5%	4,9%
101325	30	-5,0%	-6,2%	5,2%	6,6%
90000	0	6,2%	7,2%	0,6%	0,1%
90000	5	5,2%	5,5%	2,4%	2,0%
90000	10	4,3%	3,8%	4,3%	3,8%
90000	15	3,4%	2,2%	6,1%	5,6%
90000	20	2,5%	0,7%	8,0%	7,5%
90000	25	1,6%	-0,8%	9,8%	9,3%
90000	30	0,8%	-2,3%	11,6%	11,1%

Table 2: Airflow correction derived from equations (20) and (21).

Summary

- The airflow rate coefficient depends on air viscosity, air density and flow exponent.
  - Viscosity depends on temperature
  - Air density depends on temperature and pressure
- Applying corrections to take this into account shows that the deviation in the results is on the order of 1-10% in our test cases
- Not a huge effect, but isn't it easy enough to account for systematically ?

Testing for Building Components Contribution to Airtightness Assessment

Pedro F. Pereira, Ricardo M. S. F. Almeida,
Nuno M. M. Ramos and Rui Sousa

(Presented by **Pedro F. Pereira**)

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TABLE OF CONTENTS

1 – Scope

2 – In Situ Tests

3 – Laboratory Tests

4 - Conclusions

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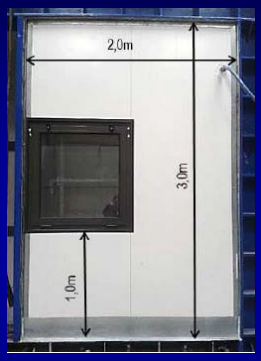
SCOPE



This work presents a case study where in-situ blower door measurements were used to define the contribution of different building components to the airtightness.

There were also laboratory tests where an enclosure sample was built and air permeability tests were performed.

The information from both in-situ and laboratory tests was combined in a methodology for airtightness prevision of a small building.

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IN SITU TESTS
Case Study

The structural scheme of the building corresponds to a steel structure composed of tubular elements.

Floor area [m^2]	48
Volume [m^3]	150
Envelope area [m^2]	178

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IN SITU TESTS
Case Study

Both the façade and the roof are clad with sandwich panels with 4 cm insulation in the interior mechanically fixed to the steel structure.

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IN SITU TESTS
Case Study

The building includes a door and 4 aluminum frame windows, double glazed, distributed in pairs in two opposite façades. The building depends on natural ventilation and therefore a ventilation ridge was included in the roof.

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IN SITU TESTS
Testing devices

Infrared Camara NEC Thermo Tracer TH9100

Anemometer Airflow TA-5

Onset HOBO U12

Blower door Retrotec 1000

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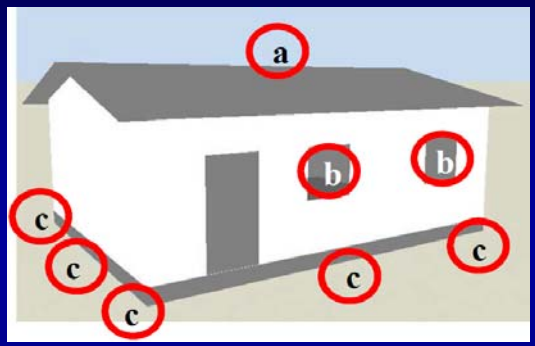
IN SITU TESTS
Methodology



Scenario	(a)	(b)	(c)
1	NS	NS	NS
2	S	NS	NS
3	S	S	NS
4	S	S	S

NS: not sealed
S: sealed

The methodology was based on the successive sealing of the following three building components: (a) ventilation ridge; (b) window frame; (c) connection of the steel columns with the floor.

Consecutive differences between test scenarios allowed evaluation of the individual building components contribution for the building airtightness

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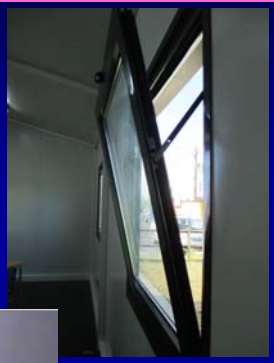
IN SITU TESTS
Building Components

A - ventilation ridge



B - window frame

C - connection of the steel columns with the floor

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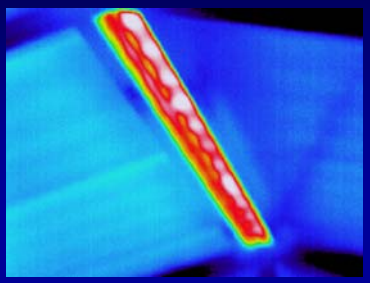
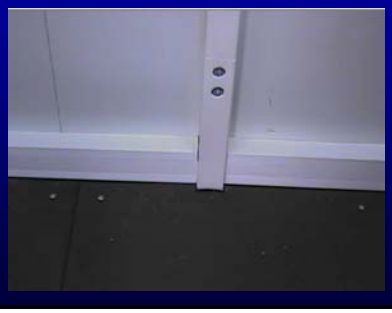
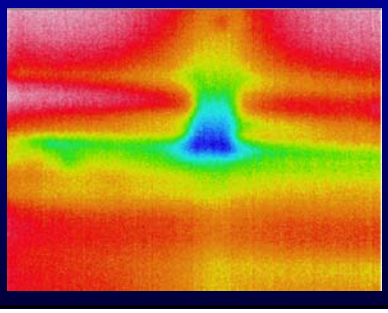
IN SITU TESTS
Thermography







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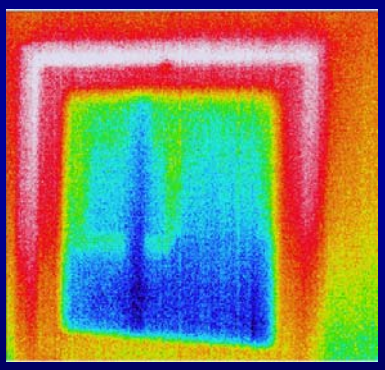
IN SITU TESTS
Thermography



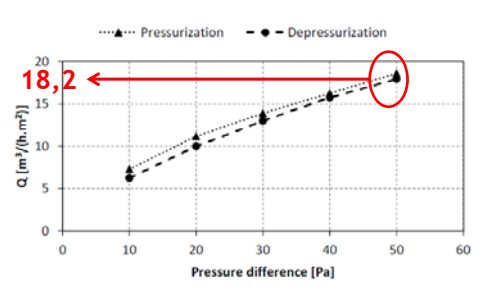
IN SITU TESTS
Building Components Sealed

A - ventilation ridge

B - window frame

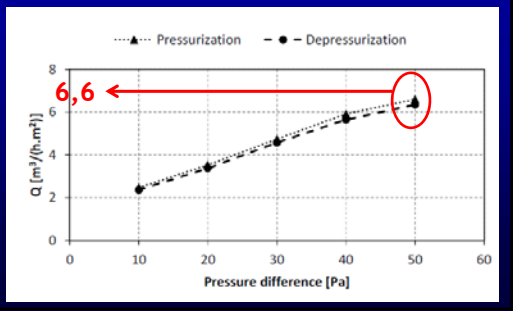
C - connection of the steel columns with the floor

IN SITU TESTS
Results - Air Flow Rate



Pressurization and depressurization test for scenario 1 (the three building components not sealed)

Pressurization and depressurization test for scenario 4 (the three building components sealed)



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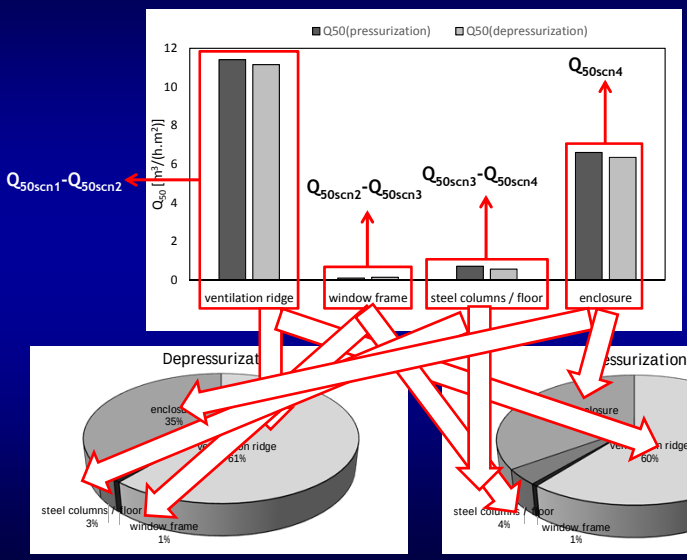
INSITU TESTS
Results - Building components contribution to air flow rate



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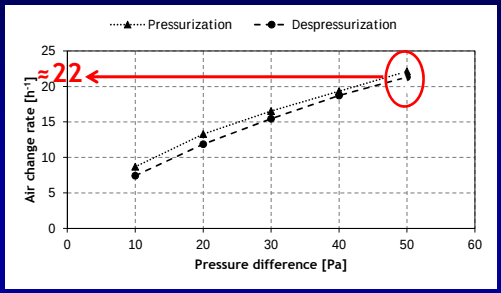
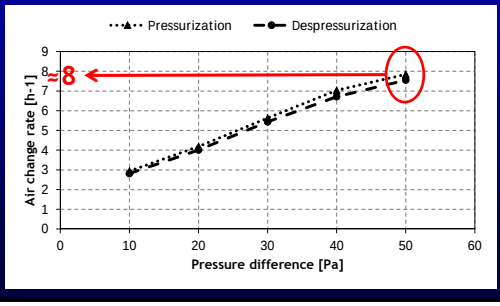
IN SITU TESTS
Results - Air change per hour



N_{50} - scenario 1 (the three building components not sealed)

N_{50} - scenario 4 (the three building components sealed)



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LABORATORY TESTS
Testing Facilities

The enclosure samples were also tested in laboratory.

Tests were carried both for positive and negative pressure differences, applying successive pressure levels starting at ±50 Pa and reaching a maximum level of ±500 Pa.

Wall Panel and Window

Wall Panel

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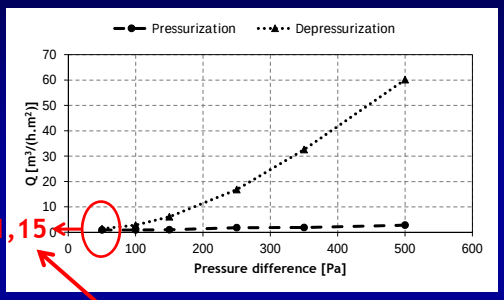
LABORATORY TESTS
Results - Laboratory air permeability

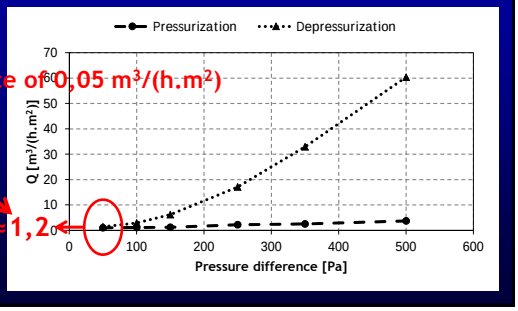


≈ 1,15

Wall panel air permeability tests - panel without window

Diference of 0,05 m³/(h.m²)

Wall panel air permeability tests - panel with window



≈ 1,2

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DISCUSSION

In this study we tried to measure the contribution of some building components to the airtightness to compile some data that could be used in the formula below in similar buildings but with different configurations.

$$n_{50} = \frac{(Ql_{50,wnd}.L_{wnd} + Ql_{50,ridge}.L_{ridge} + Q_{50,enc}.A_{enc} + \dot{V}_{50,fl_con})}{V}$$

Where:

n_{50} – air change rate at 50 Pa [h^{-1}]

$Ql_{50,wnd}$ – air permeability of the windows [$m^3.h^{-1}.m^{-1}$]

L_{wnd} – windows frame length [m]

$Ql_{50,ridge}$ – air permeability of the ventilation ridge [$m^3.h^{-1}.m^{-1}$]

L_{ridge} – Ventilation ridge length [m]

$Q_{50,enc}$ – air permeability of the enclosure, which includes construction joints such as metal panels joints, wall to ceiling/floor and wall to wall ioints [$m^3.h^{-1}.m^{-2}$]

A_{enc} – envelope area [m^2]

$\dot{V}_{50,fl_con}$ – Air flow rate thought connections between columns and the floor [m^3/h]

V – Volume [m^3]

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DISCUSSION

Some comparisons with the values found in the literature were also made.

Although, the air permeability of the ventilation ridge, the wall to wall corner joints and the columns connection with the floor could not be found in the literature. Thus, only a rough approximation of the n_{50} can be established for this particular case.

	In situ	Laboratory + literature
n_{50} [h^{-1}]	7.87	2.2

n_{50} values according to the two methodologies

Scenario 4

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CONCLUSIONS

The airtightness of a building can be tested using a blower door although an estimation procedure applicable in design phase could be very useful.

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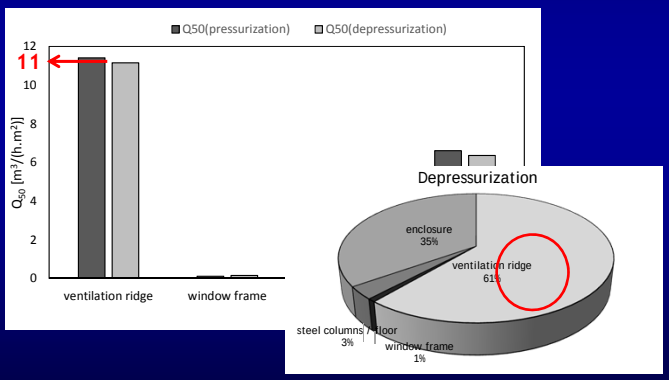
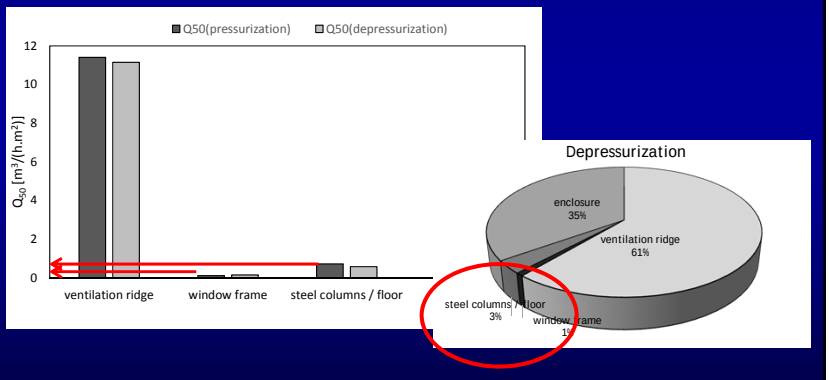
CONCLUSIONS

The ventilation ridge was responsable for the highest percentage of air flow rate with a contribution of 61 %.



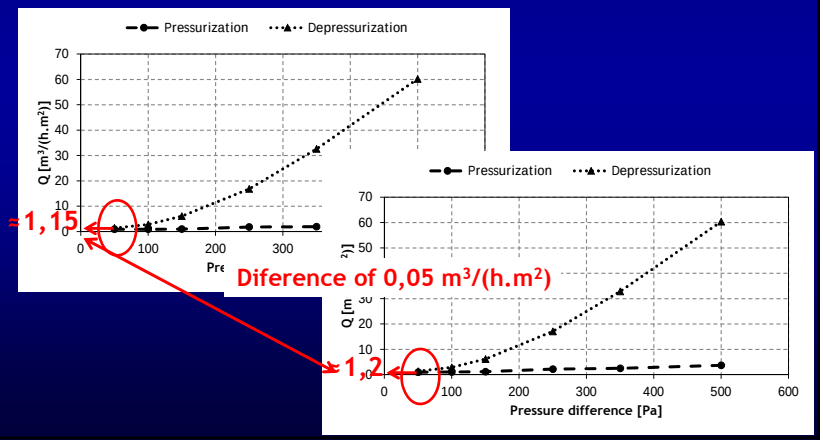
CONCLUSIONS

The window frame and the connection of the steel columns with the floor have no significant impact on the airtightness with a contribution of 4 %.



CONCLUSIONS

The laboratory tests proved that the window frame hasn't got a significant influence as the result of the test sample with or without a windows lead to the same value. The laboratory tests showed that the panel joints permeability was 1,15 $m^3/(h.m^2)$.



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CONCLUSIONS

A very different construction reality from the one in the countries that contribute for the literature database was found and the applicability of it in this methodology can be questioned.

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CONCLUSIONS

The importance of a large number of studies in the Mediterranean countries, where constructions are less airtight, arises and should be the added to the database.

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Thank you!

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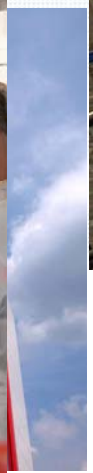
BUILDING AIRTIGHTNESS SOLUTIONS: SEALANTS AND PU-FOAMS

Filip Van Mieghem – Senior Product Manager

BUILD THE FUTURE

SOUDAL

Soudal



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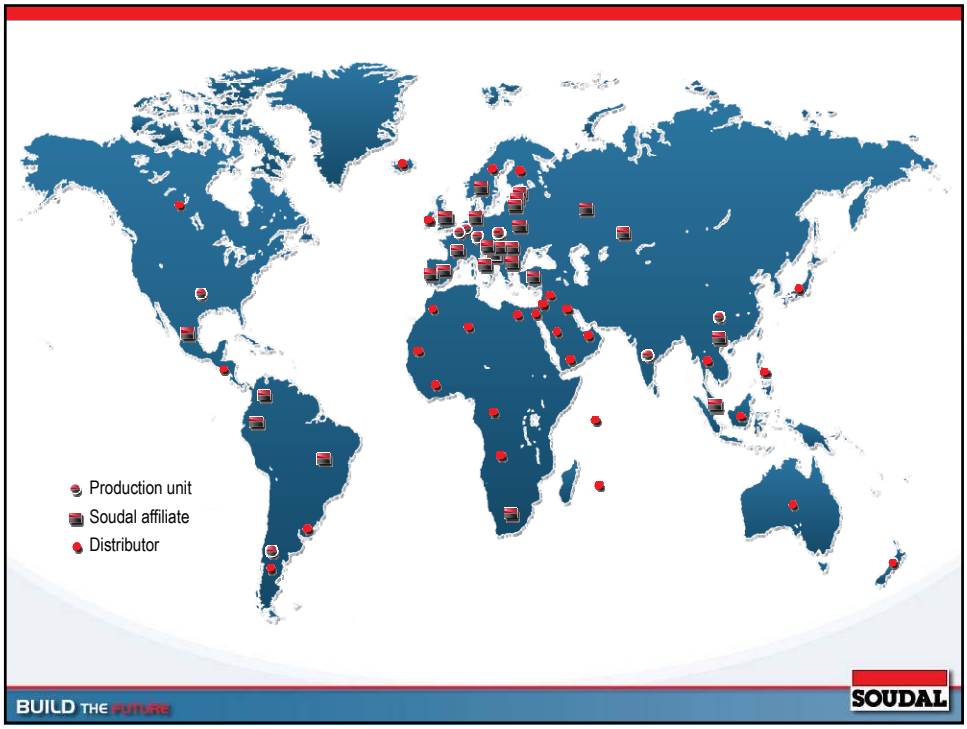

Content

1. Introduction
2. Sealants
3. PU-Foams
4. Soudal Window System
5. Self-adhesive tapes

BUILD THE FUTURE

SOUDAL

Sealants

- Silicone (AC / Alcoxy / Oxime)
- Acrylics
- Hybrid polymers
- Polyurethane
- Polyisobutylene
- Bitumen
- Fire rated sealants
- Fast curing
- Primers & tools

BUILD THE FUTURE

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PU Foams

- Handheld / gun / click & fix
- Construction foam
- Insulation foam
- Sound proofing foam
- All weather foam
- 2K-foam
- Isocyanate free foam
- PU mining foam
- Multi position foam
- Fire rated foam

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Adhesives

- Contact neoprene & SBR
- 1K & 2K PU
- PVA wood
- Construction
- Floor / tile / glass fibre
- PVC
- Cyano
- Epoxy
- Chemical anchors

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Hybrid polymers

- Industrial adhesives
- Parquet applications
- Sealing & bonding
- 2K
- High tack
- Crystal clear
- Ultra

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Legal framework

- National and international standards, requirements, prescriptions, certification, etc
- Legislation on (level of) raw materials / chemicals: Reach, Biocides,…
  - May also influence final product (Soudal = compounder)
  - REACH: SVHC are NOT used in Soudal products
- Danger labelling: from DPD to CLP
- Construction Products Directive :
  - CPD became CPR as of 1/7/2013 !!!!!
  - Energy Perfomance of Buildings (EPB); Sustainability
  - Harmonised norms (CE marking)
    - Sealants: EN15651-1 to -5 (glazing, interior/exterior fassade, sanitary, pedestrian walkways)

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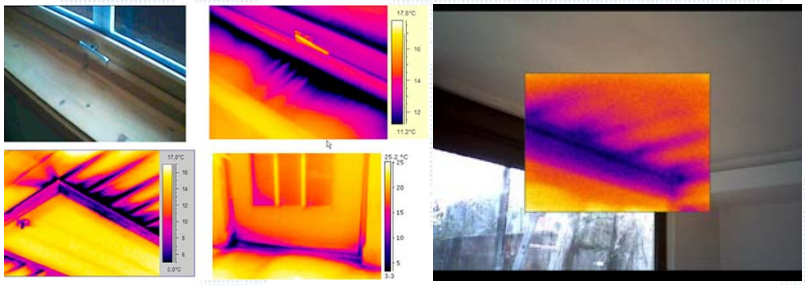
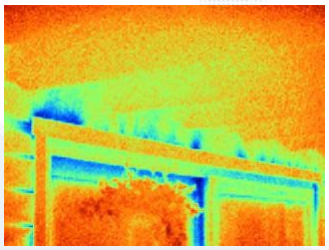
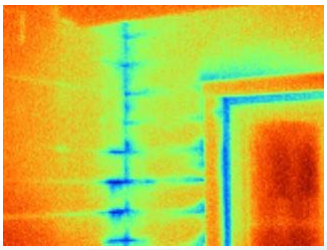
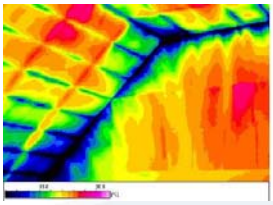
Airtightness: intersection between elements









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Airtightness

- Poorly designed or executed building knots:
  - Airleaks
  - Thermal bridges
  - Or a combination of both
- + invisible effect:
  - Loss of heat
  - Loss of acoustic performance
- + visible effect
  - Mould !

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Construction joints

SWS

- Function/issues:
  - Weather sealing / water tightness
  - Cosmetical
  - Thermal insulation (thermal bridges)
  - Fire proofing
  - Acoustics
  - Burglar resistance
  - Airtightness
  - Vapourtightness
- And mostly a combination thereof…
- Important unimportance !

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Solutions are available!

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Airtightness of 'our' construction materials: standards?

- (Inter)national product standards or airtightness requirements?
  - Mostly nonexistent for foams, sealants, adhesives, tapes, membranes…
    - pre-compressed tapes DIN18542: windtight (BG1) or airtight (BG-R)
- Test methods (reports):
  - EN 1206: Windows and doors - Air permeability – Test method
    - In combination with EN 12207: classification (4 classes)
  - EN 12114: Air permeability of building components and building elements: laboratory test method
    - MO-01: ift: test on construction element: window-wall including airtightness and watertightness – before and after ageing
  - A-value: m^3/h per running meter of joint at 10 Pa

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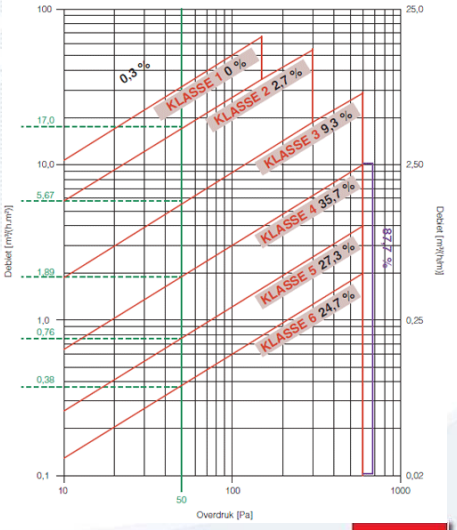
EN 1026

- Test method for air permeability of windows and doors
  - Sometimes referred to for sealing products (eg precompressed tapes)
- Classification (EN12207)
  - Class 4: 0,6 m³/hm² at 10 Pa
    = 1,89 m³/hm² at 50 Pa
  - *Class 5: 0,18 m³/hm² at 10 Pa*
    = 0,76 m³/hm² at 50 Pa
  - *Class 6: 0,05 m³/hm² at 10 Pa*
    = ± 0,38 m³/hm² at 50 Pa

➔from m² to m: divided by 4



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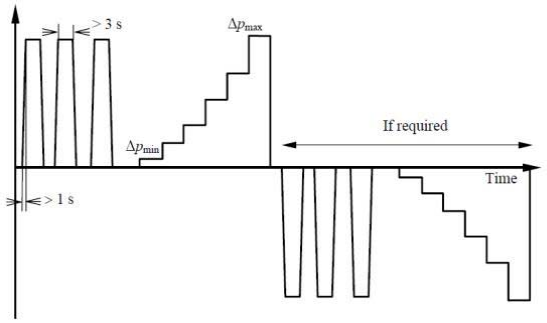
EN 12114

- EN 12114: Air permeability of building components/elements
  - General test method
  - Only for laboratory testing (as opposed to 'in situ' testing)
  - Max. pressures can be chosen: 50, 100, 200, 500, 1.000Pa
  - 3 pulsations and then gradual steps; both positive and negative pressure



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IFT : directive MO/01-1

- Institut für Fenstertechnik (Rosenheim)
- Construction element – test wall
- Window to wall connections
- Watertightness and airtightness combined
- Ageing and repitition of first test series
- Mostly on a combination of products

Bauteilprüfung
Prüfung von Fugeneigenschaften eines Abdichtungssystems zwischen Fenster und Baukörper im Neuzustand sowie nach simulierten Kurzzeitbelastungen
Prüfbericht 10-001746-PR01 (PB-E03-0203-de-01)
ift ROSENHEIM
Soudal N.V.
Ergebnisse *)
*) Einzelergebnisse siehe Prüfbericht Abschnitt 3

Emission: VOC

- Indoor air quality is getting more of a concern with growing airtightness levels
- Sustainability: Leed, Breeam, …(VOC content)
- France: mandatory emissions class labelling
  - All construction products used indoors
  - Highest class is A+
  - Measured after 28 days
- Germany: Emicode - voluntary
  - GEV: start: adhesives for floor coverings
  - EC1(R), EC1 Plus are the highest classes
    - Measured after 10 or 3 /28 days
  - Harder to achieve

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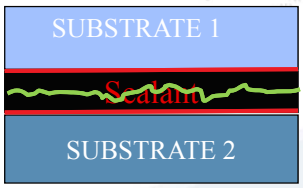
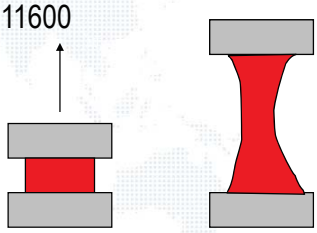
Sealants and airtightness: cohesion/adhesion

- Sealants can easily take the form of all kinds of shapes when applied in a joint (or as adhesives if used in a thin layer)
  - can generally contribute a lot to airtightness
- What is needed:
  - Cohesion: sealants are airtight from their nature
  - Adhesion: you also need a bond to the substrate(s)/supports
- CE marking (transition period: 1/7/2013 – 1/7/2014)
  - EN15651-1: fassade interior and exterior
  - EN15651-2: glazing
- Quality labels



Sealants and airtightness: movement capacity

EN15651: max % of total joint width a sealant can permanently take without shearing (stretched); see also ISO EN 11600

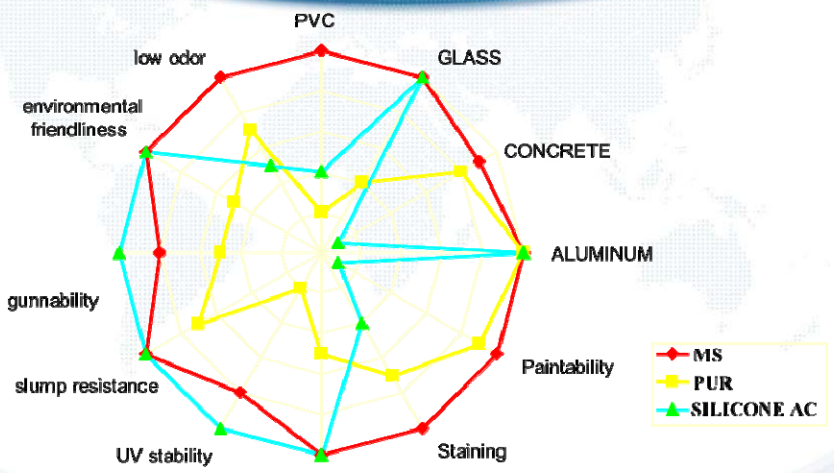


- Min. requirements (no class)
- Lowest class: acrylics/silicones
  - 7,5% and 12,5%
  - Plastic or elastic (P or E)
  - Example: F- EXT/INT-12,5E (Façade)
- Highest class: silicones, PU's, hybrids
  - 20% or 25%
  - All elastic (E)
  - Softer sealants, or harder sealants (LM or HM)
  - Example: F- EXT/INT – 25LM (Façade)

Sealants and airtightness: adhesion

- Make sure supports are clean, dry, free of dust and grease
- Check substrates:
  - Most sealants work better on specific substrates
  - There are also sealants that work on almost all substrates: hybrid sealants for example, even on wet surfaces
  - Always excluded: PE, PP, PTFE
- Watch application temperature (acrylics can even freeze during storage)
- Check curing time of product (physical drying – chemical curing)
  - RH can also have major impact on curing (time)
- Use the right product for the job and apply it the right way

Sealant profiles



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Sealants & Adhesives

- Hybrid sealants: permanently elastic
  - Excellent adhesion on almost any substrate
  - Diverse, low modulus and high modulus
  - High movement capacity (20-25LM or HM)
  - No cracks under UV-radiation
  - Paintable
  - Adhesion on damp surfaces
- Silicone sealants: permanently elastic
  - Excellent adhesion on glass, metals.
  - Ideal for airtight glass sealing
  - High movement capacity (20LM – 25LM)
  - Very resistant to UV

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Silicone and hybrid sealants

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Sealants & Adhesives

- PU
  - Excellent adhesion on mineral substrates (stone, cement)
  - High movement capacity (20-25%)
  - Mostly LM (sealant)
  - Cracks under UV
- Acrylics
  - Mainly interior use/finishing – 7,5P or 12,5P
  - Paintable, “elastic and airtight extension of plaster”
  - Prevents cracks between window frame and plaster
  - New development: meets with ISO 11600 12,5E
  - Physical drying: shrinkage
- Specialties
  - Self adhesive acrylic to glue vapourbarriers

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Inside application

- Airtightness in the proper sense
- Acrylic sealants
  - Mostly used for interior façade sealing
  - Paintable
  - Limited movement capacity (mostly plastic, max 12,5%)
- Hybrid sealants
  - Large movement capacity
  - Paintable (waterbased paints)
- Remark: paint is not flexible!!!

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Acryrub SWS

- New premium acrylic sealant
  - Silanized acrylic
- Part of the SWS (Soudal Window System)
- Airtight and vapourtight (high µ-value)
- Elastic:
  - CE: meets class 12,5E Façade EXT/INT
- Improved adhesion on PVC
- Low Emission: EC1+
- Paintable
- Cartridge and foil bags

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Insulation and airtightness combined ?

Window connection joints

Inside

Outside

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Flexifoam : airtight

- **Air penetration**: ift Rosenheim DIN 18542, Part 7.2
  - *A < 0,1 m³ / (h.m (daPa)$^{2/3}$)*

Prüfung nach DIN EN 12114

	Breite	x	Höhe	
Probekörpermaße	1000	x	1000	in mm
	Anzahl		Länge	
Fugen längs	6	x	990	in mm
Fugenlänge	5,94	m		

DRUCK

Volumenstrom 1	Nullmessung (Fugen abgeklebt)								
Pa	50	73	106	154	224	325	473	688	1000
l/h	13,24	18,53	27,46	38,14	53,72	80,90	110,90	155,60	209,00
V in m³/h	0,0132	0,0185	0,0275	0,0381	0,0537	0,0809	0,1109	0,1556	0,2090

Volumenstrom 2	Fugen nicht abgeklebt								
Pa	50	73	106	154	224	325	473	688	1000
l/h	14,76	20,32	29,88	41,49	57,67	87,90	120,50	166,00	225,70
V in m³/h	0,0148	0,0203	0,0299	0,0415	0,0577	0,0879	0,1205	0,1660	0,2257

Volumenstrom 2 - 1	Luftdurchlässigkeit Fuge								
Pa	50	73	106	154	224	325	473	688	1000
V in m³/h	0,0015	0,0018	0,0024	0,0034	0,0040	0,0070	0,0096	0,0104	0,0167
V_0 in m³/h	0,0015	0,0017	0,0023	0,0032	0,0038	0,0068	0,0093	0,0101	0,0162
längenbezogen in m³/hm	0,0002	0,0003	0,0004	0,0005	0,0006	0,0011	0,0016	0,0017	0,0027

V_0: korrigierter Luftvolumenstrom unter Referenzbedingungen (20 °C / 50 % rel. LF / 101325 Pa Luftdruck)

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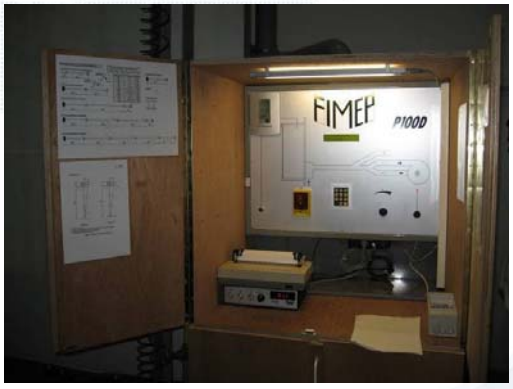
Research at University of Ghent

- Testing according to EN12114



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Airtightness

Standard cavity wall construction

Passive cavity wall construction

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Airtightness Results

Façade element	Description	Flow at 50 Pa [m³/h/m]						
		underpressure	abs. dev.	overpressure	abs. dev.	average	Class	abs. dev
Standard	casing, empty	**30,90**	0,97	**35,23**	1,11	**33,07**	**C**	1,04
	casing, mineral whool	**2,61**	0,13	**3,31**	0,15	**2,96**	**C**	0,14
	casing, Flexifoam	**0,95**	0,09	**1,59**	0,12	**1,27**	**B**	0,10
	casing, Flexifoam, Acryrub	**0,01**	0,06	**0,00**	0,08	**0,00**	**A**	0,07
	plaster, profile, Acryrub	**0,08**	0,03	**0,06**	0,03	**0,07**	**A**	0,03
	Plaster, SWS-foil, inside	**0,08**	0,03	**0,27**	0,03	**0,18**	**A**	0,03
	Plaster, SWS-foil, side	**0,08**	0,03	**0,24**	0,03	**0,16**	**A**	0,03
Passive	plaster, Flexifoam, dry	**0,03**	0,03	**0,00**	0,04	**0,02**	**A**	0,04

<0,4 m³/hm (A) 0,4-2.5 m³/hm (B) >2,5 m³/hm (C)

BUILD THE FUTURE

PU-foams: airtight?

PU-foam can be airtight !

- If used in the correct joint dimensions
- If used between 2 airtight building elements
- If self-expanding
- If flexible

... Thus combining insulation and airtightness

➔ Flexifoam®

➔ **Elasticity: 9000 cycles at 12,5% movement** *(ift report 105 35276)*

➔ **Airtight: A < 0,1 m^3/[h.m $(daPa)^{2/3}$]** *(ift report 105 33428 – EN12114)*

➔ **Thermal insulation: λ = 0,0345 W/m.K** *(MPA report 070598.1)*

BUILD THE FUTURE

SOUDAL

To moisten or not to moisten

Without With

BUILD THE FUTURE

SOUDAL

Content

1. Introduction
2. Sealants
3. PU-Foams
4. Soudal Window System
5. Self-adhesive tapes

BUILD THE FUTURE

SWS Products

Outside

Middle

Inside

BUILD THE FUTURE

Airtightness Results

Façade element	Description	Flow at 50 Pa [m³/h/m]						
		underpressure	abs. dev.	overpressure	abs. dev.	average	Class	abs. dev
Standard	casing, empty	**30,90**	0,97	**35,23**	1,11	**33,07**	**C**	1,04
	casing, mineral whool	**2,61**	0,13	**3,31**	0,15	**2,96**	**C**	0,14
	casing, Flexifoam	**0,95**	0,09	**1,59**	0,12	**1,27**	**B**	0,10
	casing, Flexifoam, Acryrub	**0,01**	0,06	**0,00**	0,08	**0,00**	**A**	0,07
	plaster, profile, Acryrub	**0,08**	0,03	**0,06**	0,03	**0,07**	**A**	0,03
	Plaster, SWS-foil, inside	**0,08**	0,03	**0,27**	0,03	**0,18**	**A**	0,03
	Plaster, SWS-foil, side	**0,08**	0,03	**0,24**	0,03	**0,16**	**A**	0,03
Passive	plaster, Flexifoam, dry	**0,03**	0,03	**0,00**	0,04	**0,02**	**A**	0,04

<0,4 m³/hm (A) 0,4-2.5 m³/hm (B) >2,5 m³/hm (C)

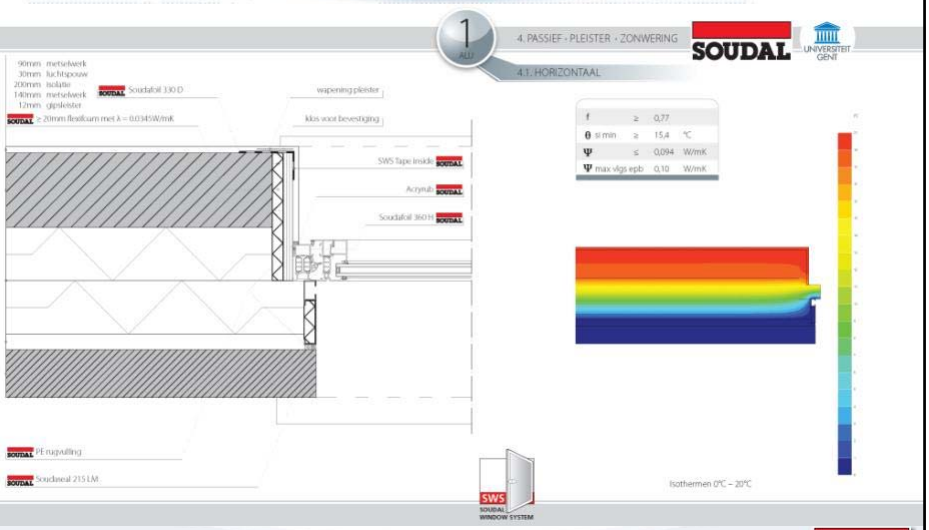
BUILD THE FUTURE

Airtightness

Timber frame

BUILD THE FUTURE

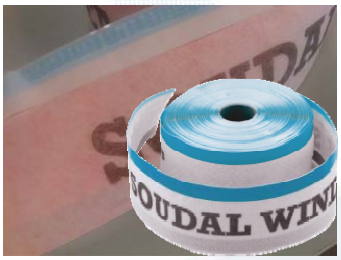
Flexifoam



SWS Inside tape

Airtight membrane for window installation

- PE, polyesther fleece, all laminated
- Vapour tight (Sd ≥ 50m)
- Self-adhesive butylic strip as installation aid
- Self-adhesive, reinforced strip for adhesion to window frame
- Can easily be plastered
- Sizes:
  - 70, 100, 150 and 200mm (25m)
  - 400mm (20m)



SWS tape installation

BUILD THE FUTURE

SOUDAL

Hybrid adhesive

- Soudafoil 360H

BUILD THE FUTURE

SOUDAL

Soudaband Aktiv PLUS

- Multi function:
  - BG1 + BG_R + insulation (Λ : 0,048 W/mK)
- Tested according to ift MO-01
- Wide tapes (width of frame -6mm)
- Red on the inside
- Min and max joint dimension
- Application:
  - Window installation
  - Prefabricated concrete construction
  - Timber frame construction

BUILD THE FUTURE

SOUDAL

Content

1. Introduction
2. Sealants
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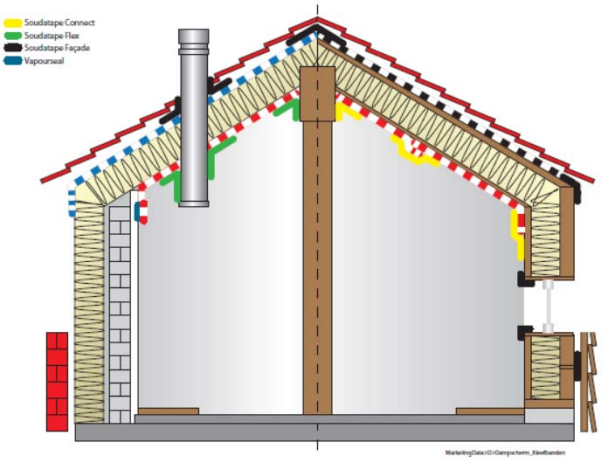
BUILD THE FUTURE

SOUDAL

Self-adhesive tapes

Solid construction | Timber frame



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SOUDAL

International Centre for Indoor Environment and Energy

Do existing international standards support ventilative cooling?

Professor Bjarne W. Olesen, Ph.D.

www.ie.dtu.dk

Technical University of Denmark

Ventilative Cooling

- Indoor Environmental Quality
  - Requirements
  - Predictions
- Calculation of air velocities
- Calculation of Ventilation rates
- Calculation of energy performance

Achieving Excellence in Indoor Environmental Quality

- Physical factors
  - Thermal Comfort
  - Air quality (ventilation)
  - Noise-Acoustic
  - Illumination
  - Exposure time
- Personal factors
  - Activity
  - Clothing
  - Adaptation
  - Expectation

STANDARDS

- ISO EN 7730-2005
  - Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort effects.
- ASHRAE 55-2013
  - Thermal environment conditions for human occupancy
- ASHRAE 62.1 and 62.2 -2013
  - Ventilation and indoor air quality
- EN15251
  - Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustic
- EN 13779
  - Ventilation for non-residential buildings - performance requirements for ventilation and room-conditioning systems

Categories

Cate-gory	Explanation
I	High level of expectation and also recommended for spaces occupied by very sensitive and fragile persons with special requirements like some disabilities, sick, very young children and elderly persons, to increase accessibility.
II	Normal level of expectation
III	An acceptable, moderate level of expectation
IV	Low level of expectation. This category should only be accepted for a limited part of the year

MODERATE THERMAL ENVIRONMENTS

- GENERAL THERMAL COMFORT
  - PMV / PPD, OPERATIVE TEMPERATURE
- LOCAL THERMAL DISCOMFORT
  - Radiant temperature asymmetry
  - Draught
  - Vertical air temperature difference
  - Floor surface temperature

Recommended categories for design of mechanical heated and cooled buildings

Category	Thermal state of the body as a whole	
	PPD %	Predicted Mean Vote
I	< 6	-0.2 < PMV < + 0.2
II	< 10	-0.5 < PMV < + 0.5
III	< 15	-0.7 < PMV < + 0.7
III	< 25	-1.0 < PMV < + 1.0

Temperature ranges for hourly calculation of cooling and heating energy in three categories of indoor environment

Type of building/ space	Category	Operative Temperature for Energy Calculations °C	
Offices and spaces with similar activity (single offices, open plan offices, conference rooms, auditorium, cafeteria, restaurants, class rooms, Sedentary activity ~1,2 met		Heating (winter season), ~ 1,0 clo	Cooling (summer season), ~ 0,5 clo
	I	21,0 – 23,0	23,5 - 25,5
	II	20,0 – 24,0	23,0 - 26,0
	III	19,0 – 25,0	22,0 - 27,0
	IV	17,0 – 26,0	21,0 - 28,0

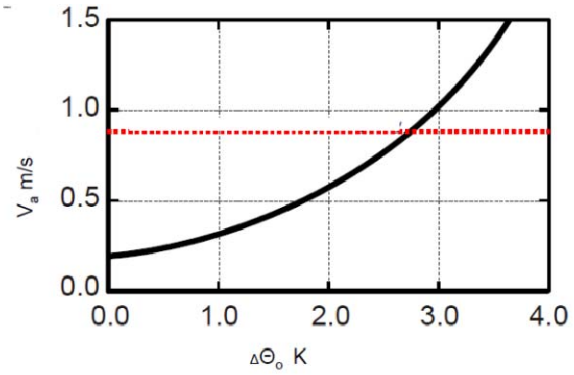
Use PMV criteria at increased air velocity

Indoor operative temperature correction ($\Delta\Theta_o$) that can be applied when buildings are equipped with fans, personal ventilation systems etc that provide building occupants with precise, stepless control over air speed at workstation level.

–

Average Air Speed (V_a) 0.6 m/s	Average Air Speed (V_a) 0.9 m/s	Average Air Speed (V_a) 1.2 m/s
1.2° C	1.8° C	2.2° C

Air speed required to offset increased temperature (EN ISO 7730). The air speed increases by the amount necessary to maintain the same total heat transfer from the skin. Acceptance of the increased air speed will require occupant control of device creating the local air speed.



ASHRAE 55-2013

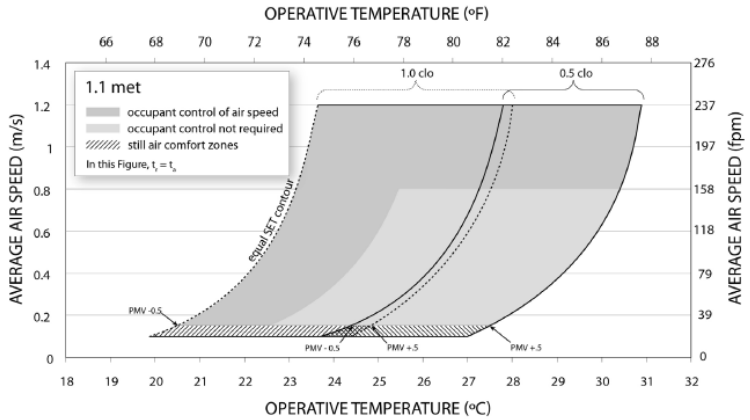


FIGURE 5.3.3A Acceptable ranges of operative temperature (t_o) and average air speed (V_a) for the 1.0 and 0.5 clo comfort zone presented in Figure 5.3.1.1, at humidity ratio 0.010.

DRAUGHT ASHRAE55 EN-ISO-7730

$$DR = (34 - t_{a,l})(\bar{v}_{a,l} - 0{,}05)^{0{,}62}(0{,}37 \cdot \bar{v}_{a,l} \cdot Tu + 3{,}14)$$

For $\bar{v}_{a,l} < 0{,}05$ m/s: use $\bar{v}_{a,l} = 0{,}05$ m/s

For $DR > 100$ %: use $DR = 100$ %

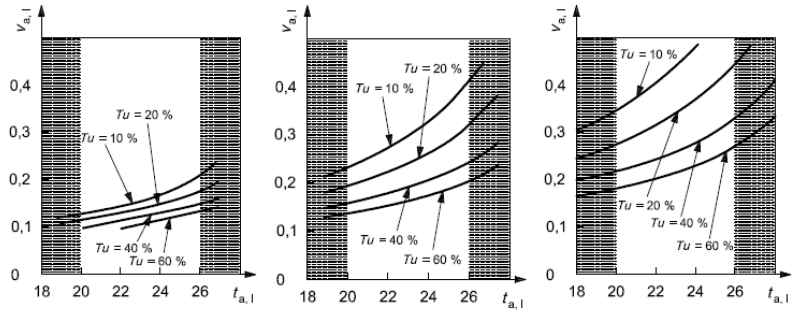
where

$t_{a,l}$ is the local air temperature, in degrees Celsius, 20 °C to 26 °C;

$\bar{v}_{a,l}$ is the local mean air velocity, in metres per second, < 0,5 m/s;

Tu is the local turbulence intensity, in percent, 10 % to 60 % (if unknown, 40 % may be used).

DRAUGHT EN-ISO-7730



Category A: DR = 10 % **Category B: DR = 20 %** **Category C: DR = 30 %**

Key

$t_{a,l}$ local air temperature, °C

$\bar{v}_{a,l}$ local mean air velocity, m/s

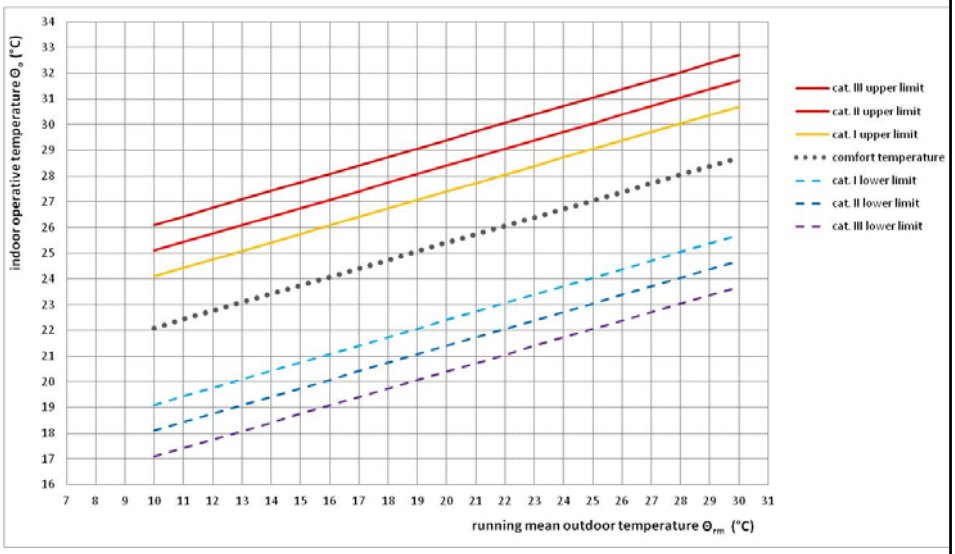
Tu turbulence intensity, %

Temperature Drifts and Ramps

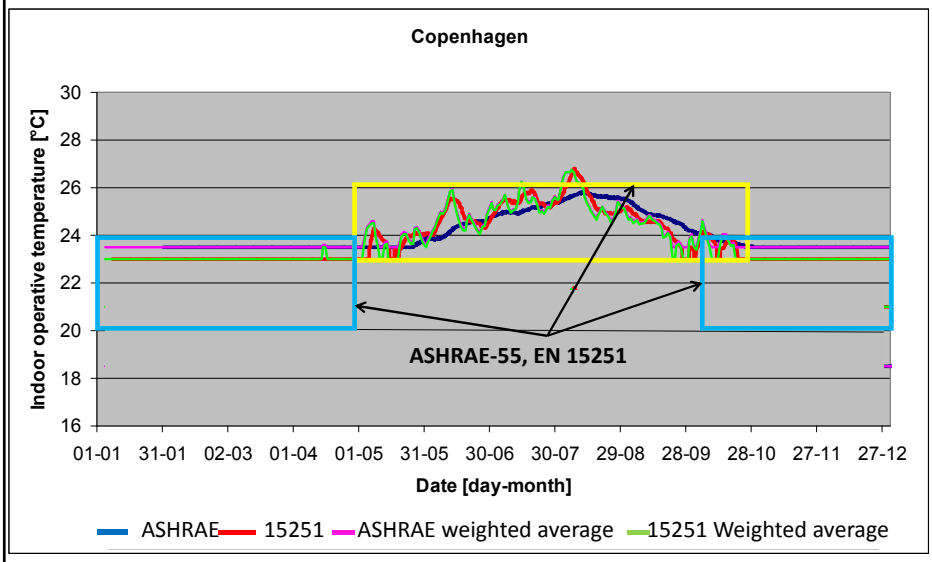
- EN ISO 7730
- If the rate of temperature change for drifts or ramps is lower than 2,0 K/h, the methods for steady-state variation apply.
- ASHRAE 55-2013

Limits on Temperature Drifts and Ramps

Time Period, h	0.25	0.5	1	2	4
Maximum Operative Temperature (t_o) Change Allowed, °C (°F)	1.1 (2.0)	1.7 (3.0)	2.2 (4.0)	2.8 (5.0)	3.3 (6.0)



$$\Theta_{rm} = (\Theta_{ed\,-1} + 0{,}8\,\Theta_{ed\,-2} + 0{,}6\,\Theta_{ed\,-3} + 0{,}5\,\Theta_{ed\,-4} + 0{,}4\,\Theta_{ed\,-5} + 0{,}3\,\Theta_{ed\,-6} + 0{,}2\,\Theta_{ed\,-7})/3{,}8$$



Prediction of Indoor Environmental Quality

- Dynamic calculation of indoor temperatures
- Calculation of Air Velocity in Ventilated Space
  - CFD
  - Others ????
- Calculation of ventilation rates (IAQ, CO_2)

Window Opening

- Increased Ventilation
  - Outside Air Quality
  - Outside Noise
- Safety
- Operation
  - Manual opening in the evening- risk of under cooling.
  - Automatic control according to indoor temperature

NOISE

Building	Type of space	Equivalent Continuous Sound Level, Leq, nT,A [dB(A)]		
		I	II	III
Residential	Living room	≤30	≤34	≤38
	Bed room	≤26	≤30	≤34
Places of assembly	Auditoriums	≤20	≤24	≤28
	Libraries	≤24	≤28	≤32
	Cinemas	≤20	≤24	≤28
Hospitals	Bedrooms night-time	≤22	≤26	≤30
	Bedrooms daytime	≤24	≤28	≤32
Hotels	Hotel rooms (during night-time)	≤24	≤28	≤32
	Hotel rooms (during daytime)	≤26	≤30	≤34
Offices	Small offices	≤24	≤28	≤32
	Landscaped offices	≤26	≤30	≤34
Restaurants	Restaurants	≤28	≤32	≤36
Schools	Classrooms	≤24	≤28	≤32
	Teacher rooms	≤28	≤32	≤36

EN 15242 Calculation methods for the determination of air flow rates in buildings including infiltration

- Mechanical air flow calculation
- Passive and hybrid duct ventilation
- Combustion air flows
- Air flow due to windows opening
- Exfiltration and infiltration using iterative method
- Exflitration and infiltration calculation using direct method

Energy Performance Calculations

- **Revision EN 13790:** *Thermal performance of buildings - Calculation of energy use for space heating and cooling*
- **Revision EN 15241 :** Calculation methods for energy requirements of ventilation and air conditioning systems

Conclusion

- Need for seperate standard for ventilative cooling: NO-MAYBEE
- Need for technical guideline for ventilative cooling: YES

Finnish Institute of Occupational Health

PERCEPTION OF A COOLING JET FROM CEILING - A LABORATORY STUDY

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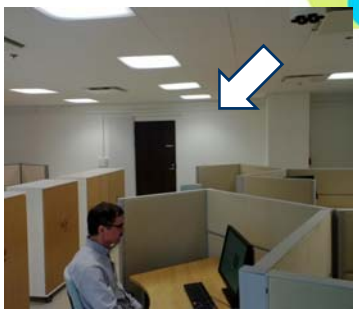
IEA Annex 62
Ventilative cooling

Introduction

- Too warm room air affects negatively on thermal comfort and performance
- Local cooling can be produced by increasing air movement
- Standards (ASHRAE 55, ISO 7730, EN 15251) allow to use increased air speed to compensate for elevated room temperature



- Table fans produce heat and increase the need of cooling
- Supplying an air jet from the ceiling can be integrated to the air conditioning system thus removing the need for a local fan
- The aim of this study was to investigate how the cooling jet is perceived and how it affects the thermal comfort and subjective work performance

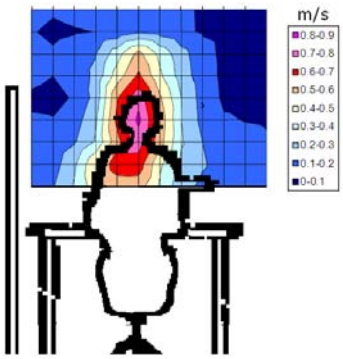
Thermal conditions

- Room air temperature 29.5 °C
- Relative humidity 20 %

- **Thermal condition 1**
  - No cooling jet

- **Thermal condition 2**
  - Cooling jet, angle 45°
  - $\Delta T_{supply\text{-}room}$ -3.5 °C
  - Target velocity 0.8 m/s (the upper limit to air speed without personal control for temperatures above 25.5 °C, ASHRAE 55)

Measured distribution of air speed

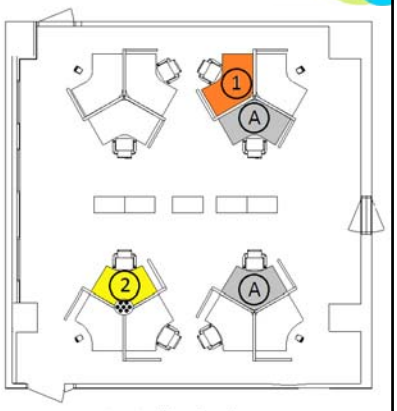


Participants

- 29 participants; 16 female and 13 male
  - University students
  - Aged between 20 and 33 years (average = 24 years)
- The participants were advised to wear trousers, t-shirt, socks and ankle-length shoes (0.71 clo)
- Main task is typing (1.1 met)
- The study had a repeated measures design, i.e. all participants were tested in both thermal conditions and served as their own control
- The order of thermal conditions was counterbalanced between participants

Schedule

0 min.	
Acclimatization	Questionnaire 1 Questionnaire (thermal comfort) Filler task (practice) N-back task (practice) Questionnaire (thermal comfort)
30 min.	
First thermal condition	Questionnaire 2 Questionnaire (thermal comfort) Filler task (7 min.) N-back task (20 min.) Questionnaire 3 Questionnaire (thermal comfort)
70 min.	
Second thermal condition	Questionnaire 2 Questionnaire (thermal comfort) Filler task (7 min.) N-back task (20 min.) Questionnaire 3 Questionnaire (thermal comfort)
110 min.	



A = Acclimatization

1 = Thermal condition 1; no cooling jet

2 = Thermal condition 2; cooling jet

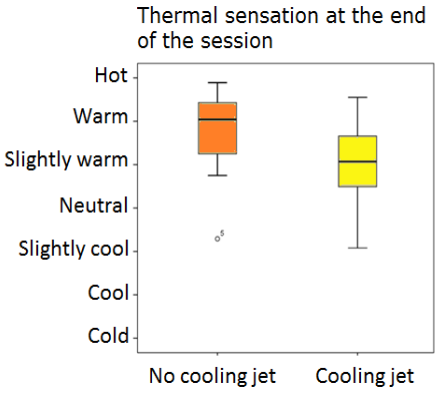
Questionnaires

- Questionnaires were used to assess
  - Local and overall thermal comfort
  - Symptoms
  - Fatigue
    - Lack of motivation
    - Lack of energy
    - Tiredness
  - Subjective performance effects
  - Overall experience of the environment

- Statistical analyses were conducted with SPSS Statistics 20 with a confidence interval of 95 %.
  - The normality of the data was tested with Shapiro-Wilk
  - A repeated measures ANOVA
    - Benjamini-Hochberg procedure was used in paired comparisons.
  - Wilcoxon test

Results: Thermal comfort

- The differences in thermal comfort were statistically significant ($p<.01$)
- Acceptability of thermal conditions
  - 67 % with the cooling jet
  - 28 % without the cooling jet
- The improvement of thermal comfort in all body parts ($p<.05$) except the thighs having similar trend ($p=.068$).
- No gender differences were found.



Results: Perception of cooling jet

Pleasant

- The perception of the cooling jet was contradictory
  - Pleasantness of the jet in certain body parts distributed the opinions
  - Some of the participants would have preferred more air flow and some less

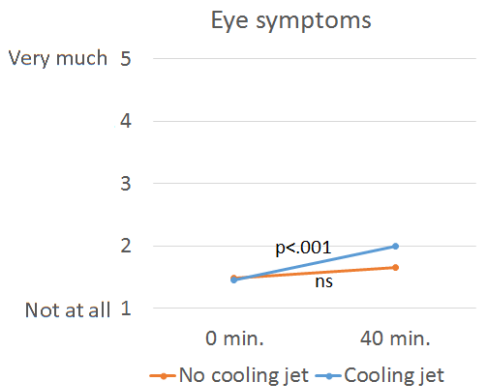
Unpleasant

The percentage of participants reporting airflow pleasant or unpleasant in certain body parts.

%	Top of the head	Face	Neck	Front neck	Torso	Arms	Hands
Pleasant	52	66	7	38	45	72	31
Unpleasant	21	41	10	10	0	10	0

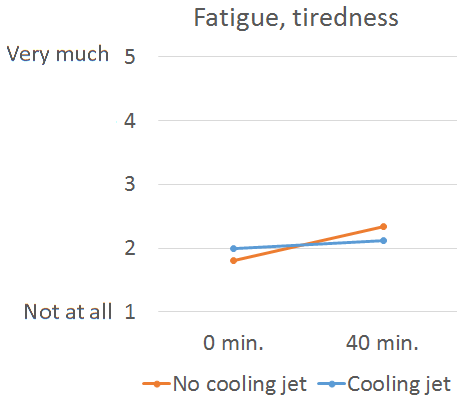
Results: Symptoms

- Eye symptoms increased in time only in the condition with the cooling jet ($p < .001$)
  - The intensity of eye symptoms was minor even at the end of the session
- No effect in any other symptoms



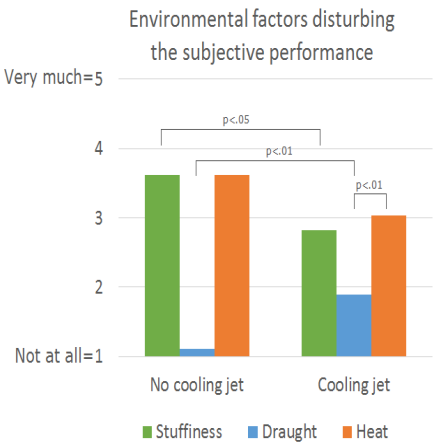
Results: Fatigue

- The occurrence of fatigue was minor
- Tiredness (one factor of fatigue) increased toward the end without the cooling jet ($p < .01$).



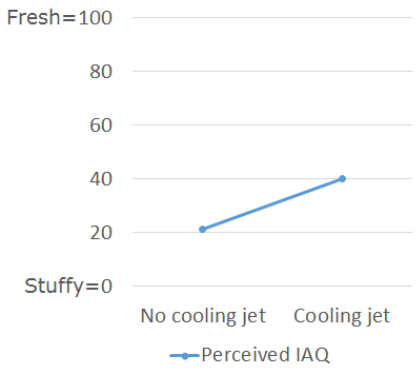
Results: Subjective performance effects

- There was a trend that the subjective performance was better in the condition with the cooling jet (not statistically significant, p=.064)
- Participants were less frustrated with the cooling jet during the most difficult task (p<.05)
- Perceived disturbance to performance:
  - Stuffiness caused less disturbance with the jet (p<.05).
  - High temperature caused less disturbance with the jet (p<.01)
  - Draught caused more disturbance with the jet (p<.01), but lower level



Results: Perceived indoor environment

- The indoor air was perceived more fresh with the cooling jet (p<.01)
- The room air temperature with the cooling jet was perceived to be better for working effectively for a long period of time (p<.05)
- The whole working environment was perceived better with the cooling jet (p<.05)



Conclusions

- Providing local cooling with a supply air jet improves the thermal comfort, subjective performance effects and the perception of the working environment in a warm office.
- The perception of the cooling jet was contradictory
  - Results showed the need for individual control over the airflow already at the air velocity of 0.8 m/s.
- In the future, the effect of individual adjustment on the thermal comfort, perception and subjective performance should be studied.

THANK YOU FOR YOUR ATTENTION!

Coupling hygrothermal whole building simulation and air-flow modelling to determine strategies for optimized natural ventilation

35th AIVC Conference, 24-25 September 2014, Poznań

Matthias Pazold, Florian Antretter, Marcus Hermes

Auf Wissen bauen

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Agenda

- Hygrothermal building simulation
- Air flow model
- EFH application example
  - Input
  - Output
- Summary

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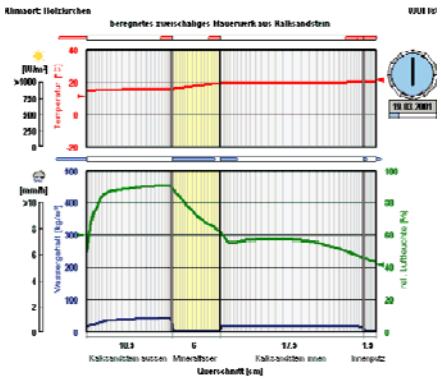
Hygrothermal Component Simulation

- Coupled heat- and moisture transport across building components



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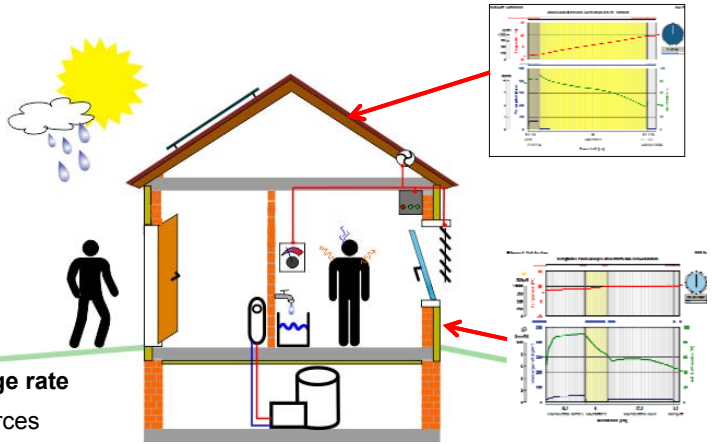
Hygrothermal Building Simulation



- Climate
- **Air change rate**
- Inner sources
- Design conditions
- Ideal HVAC Systems

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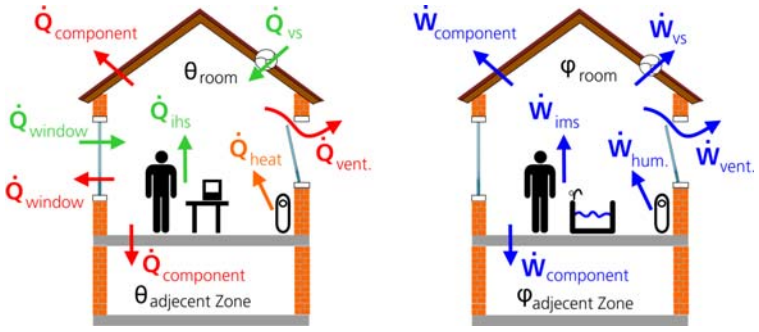
Hygrothermal Building Simulation

- Indoor climate simulation depending on heat- and moisture balance



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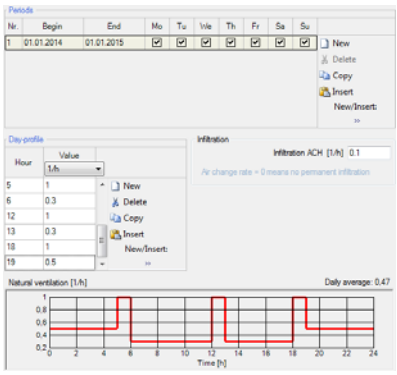
Hygrothermal Building Simulation

- Before: with **pre-defined air change**
  - No wind effects
  - No interaction between air-flow and indoor climate
  - Difficult to define complex air-flow between zones (rooms)

➢ Let's couple a air-flow model



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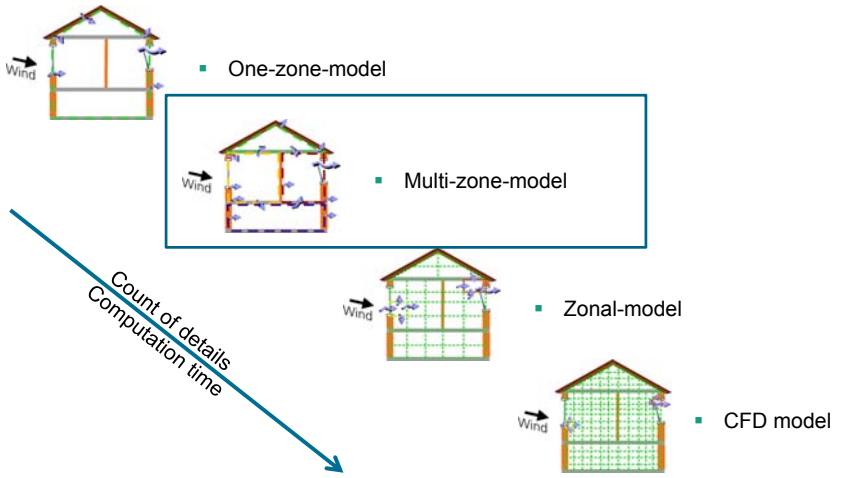
Simulation of the air flow



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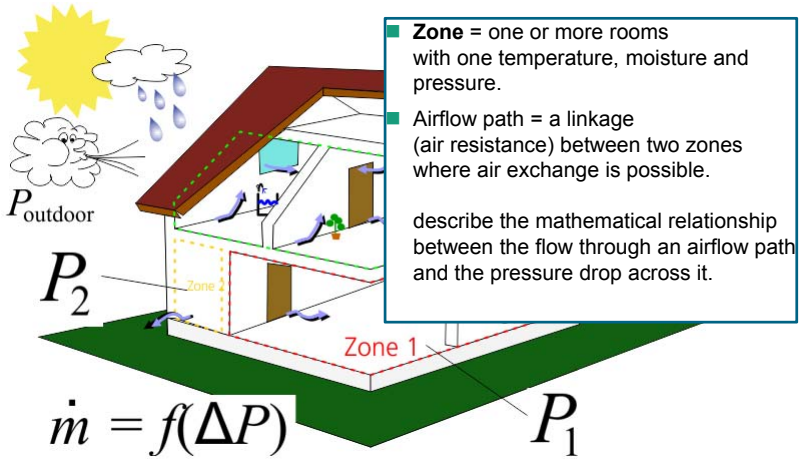
Pressure driven multi zone air flow model



- **Zone** = one or more rooms with one temperature, moisture and pressure.
- Airflow path = a linkage (air resistance) between two zones where air exchange is possible.

describe the mathematical relationship between the flow through an airflow path and the pressure drop across it.

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Multi zone air flow model – mass flow rate

- Sub-models calculate steady mass flow rates depending on pressure difference
- for each simulated time step

$$\dot{m} = f(\Delta P)$$

- Sub models for
  - all building components (walls, roof, closed windows and doors)
  - small openings, cracks
  - large openings / doors, windows (two way flow)
  - fans (constant mass flow rate, volume flow rate, fan-graphs)

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Hygrothermal Building Simulation + air flow model

- Benefits with coupled multi zone air flow model
  - Regarding wind effects
  - Interaction between air-flow and indoor climate
  - Calculating the airflow between the zones (rooms)

➢ Investigate strategies for optimized natural ventilation

  ➢ Input is the user behavior instead of air change

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Optimize natural ventilation
Application Example – Residential Building

- 2-story residential building - 10 heated/simulated zones (different rooms)
  - TFA 150 m²; Net volume 350 m³

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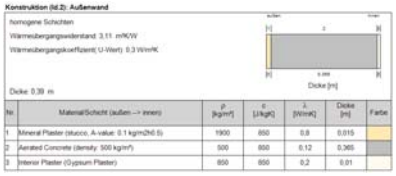
Optimize natural ventilation
Application Example – Residential Building

- Simulation period 1. January - 31. December
- 2 month pre-calculation (dry-out period)
- Time step: one hour



- Thermal resistance
  - Exterior walls (Aerated concrete) R= 3.6 m²K/W
  - Basement slab R= 2.85 m²K/W
  - Roofing R= 5.0 m²K/W
  - Windows (open/closed) U_w = 1.3 W/(m²K); g= 0.6

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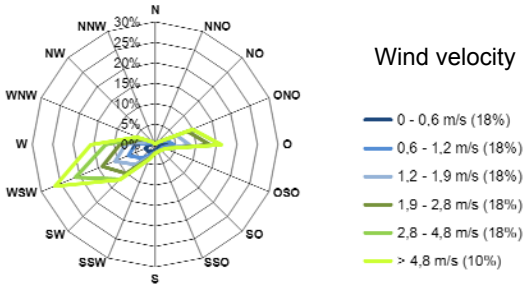
Optimize natural ventilation
Application Example – Residential Building

- Outdoor climate: Holzkirchen, Germany
  - Average Temperature 6.6°C; Relative humidity 81%
  - Average wind velocity 2.2 m/s (mostly west-wind)



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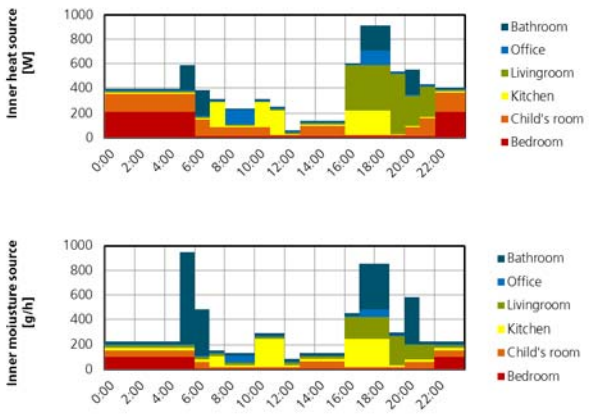
Optimize natural ventilation
Application Example – Residential Building

- Inner loads



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Optimize natural ventilation
Application Example – Residential Building

- **Case study:**
  - Closed Envelope (Infiltration)
  - Normal window turn-opening
  - Frequent window turn-opening
  - Automatic window parallel-opening

- Defined **Air flow paths** (adjusted for 1.5 ACH50):
  - Exterior and inner walls
  - Roof
  - Doors (open/closed)
  - Windows (open/closed/parallel offset)

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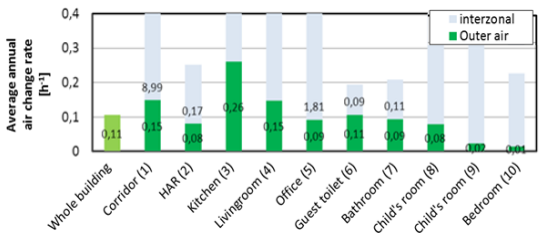
Check plausibility: Closed Envelope (Infiltration)

- All windows are closed
- Inner doors open



- Average air change rate (whole building) 0.11 h^{-1}
  - 25% of the year below 0.04 h^{-1}
- Heating demand (only infiltration) 51 kWh/(m² year)

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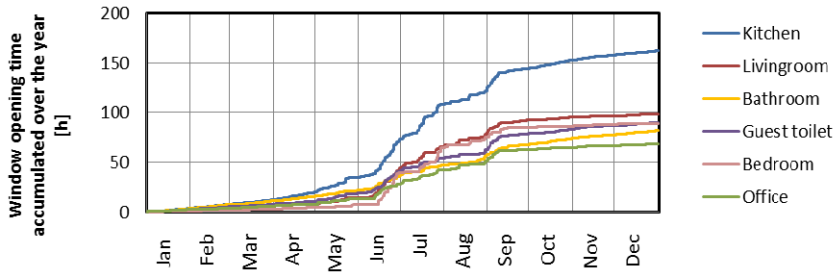
Case: user-driven “normal” window turn-opening

- Depending on outdoor temperature, rain, user presence, random
  - 5 – 10 minutes per day; summer night-ventilation
  - 60 – 160 hours per year



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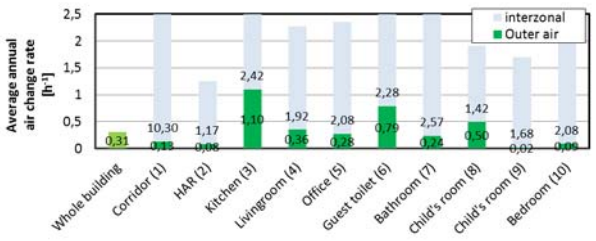
Case: user-driven “normal” window turn-opening

- Results
- Avg. 0.31 h^{-1}



- Heating demand 59 kWh/(m² year)

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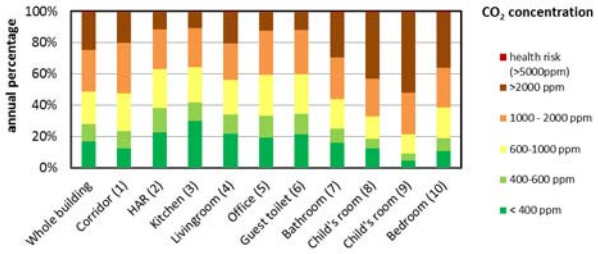
Case: user-driven “normal” window turn-opening

- Results
- Avg. 0.31 h^{-1}



- Heating demand 59 kWh/(m² year)
- Air quality 44% of the year above 1500 ppm CO_2

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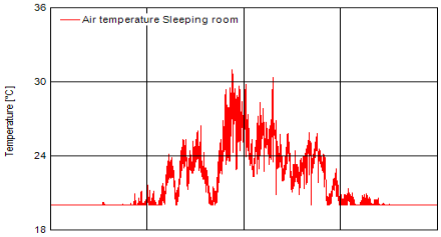
Case: user-driven “normal” window turn-opening

- Results
- Avg. 0.31 h^{-1}



- Heating demand 59 kWh/(m² year)
- Air quality 44% of the year above 1500 ppm CO_2
- Air temperature 4.3% of the year above 26°C

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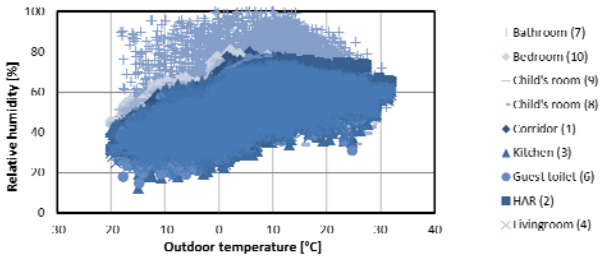
Case: user-driven “normal” window turn-opening

- Results
- Avg. 0.31 h^{-1}



- Heating demand — 59 kWh/(m² year)
- Air quality — 44% of the year above 1500 ppm CO_2
- Air temperature — 4.3% of the year above 26°C
- Moisture risk — mould growth index 0.008 on inner surfaces
  mould might grow in wall corners

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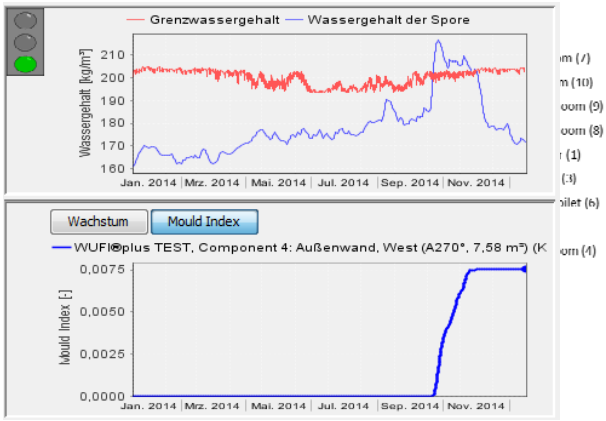
Case: user-driven “normal” window turn-opening

- Results
- Avg. 0.31 h^{-1}



- Heating demand
- Air quality
- Air temperature
- Moisture risk — mould growth index 0.008 on inner surfaces
  mould might grow in wall corners

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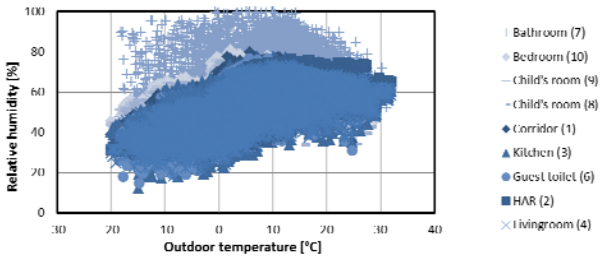
Case: user-driven “normal” window turn-opening

- Results
- Avg. 0.31 h^{-1}



- Heating demand — 59 kWh/(m² year)
- Air quality — 44% of the year above 1500 ppm CO_2
- Air temperature — 4.3% of the year above 26°C
- Moisture risk — mould growth index 0.008 on inner surfaces
  mould might grow in wall corners

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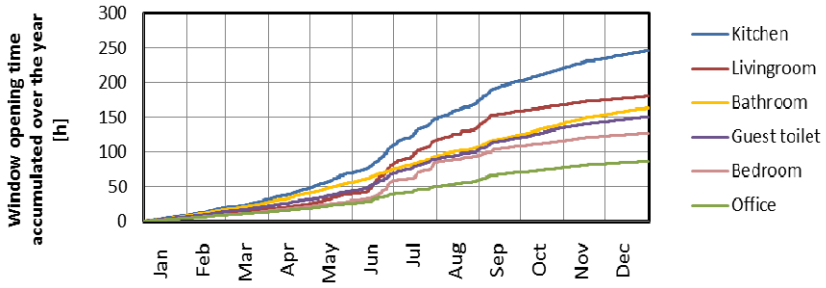
Case: user-driven “frequent” window turn-opening

- Depending on outdoor temperature, rain, user presence, random
  - 5 – 30 minutes per day; summer night-ventilation;
  - 90 – 250 hours per year



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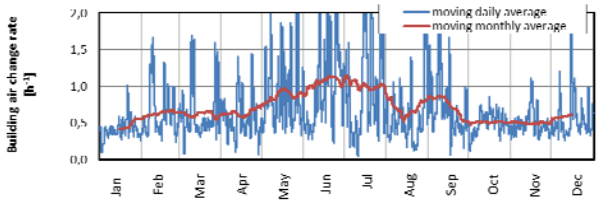
Case: user-driven “frequent” window turn-opening

- Results
- Avg. 0.69 h^{-1}



- Heating demand 84 kWh/(m² year) (59)

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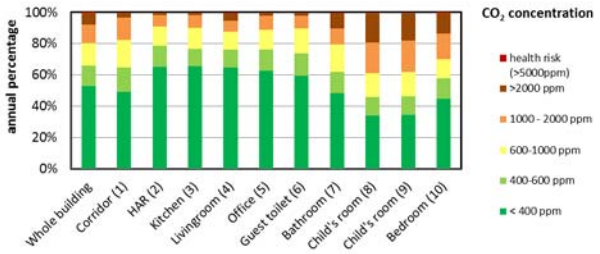
Case: user-driven “frequent” window turn-opening

- Results
- Avg. 0.69 h^{-1}



- Heating demand 84 kWh/(m² year)
- Air quality 12% of the year above 1500 ppm CO_2 (44%)

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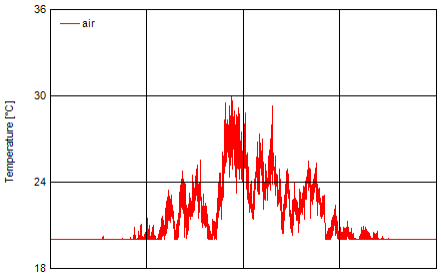
Case: user-driven “frequent” window turn-opening

- Results
- Avg. 0.69 h^{-1}



- Heating demand — 84 kWh/(m² year)
- Air quality — 12% of the year above 1500 ppm CO_2
- Air temperature — 2.4% of the year above 26°C (4.3%)

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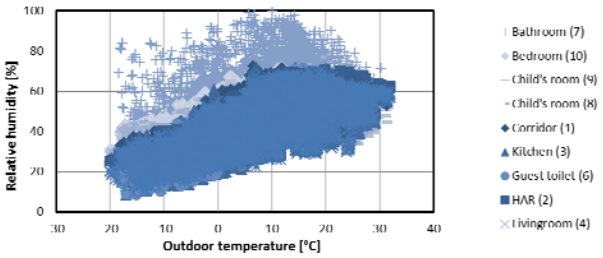
Case: user-driven “frequent” window turn-opening

- Results
- Avg. 0.69 h^{-1}



- Heating demand — 84 kWh/(m² year)
- Air quality — 12% of the year above 1500 ppm CO_2
- Air temperature — 2.4% of the year above 26°C
- Moisture risk — mould growth index 0 on critical surfaces
  significant below critical water content for spore germination

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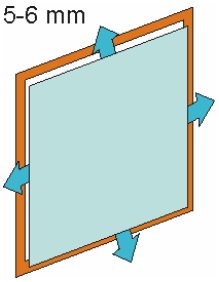
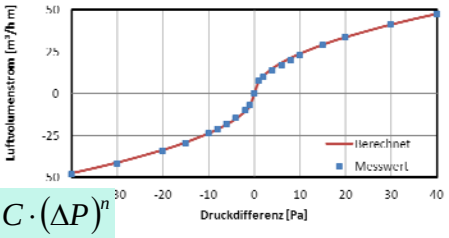
Case: Automatic window parallel-offset-opening

Measured date for flow path input



- measured air flow parameters
- Parallel offsetting (without user interaction)
  2 hours in the morning; half an hour at noon;
  1.5 hours in the evening
- + Night-ventilation

Druck	Luftvolumenstrom in Parallelabstell
[Pa]	[m³/(h•m)]
1	7,181
2	9,620
4	13,685
6	16,721
8	19,574
10	22,550
15	28,777
20	33,633
30	41,268
40	47,520
50	53,297
60	58,408
Sog (Druckstufenangabe mit negativem Vorzeichen)	
-1	7
-2	10
-4	14



$$\dot{m} = L \cdot C \cdot (\Delta P)^n$$

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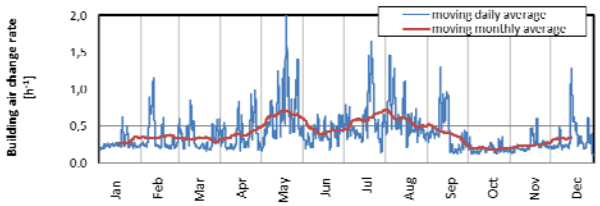
Case: Automatic window parallel-offset-opening

- Results
- Avg. 0.4 h^{-1}



- Heating demand 67.5 kWh/(m² year) (84)

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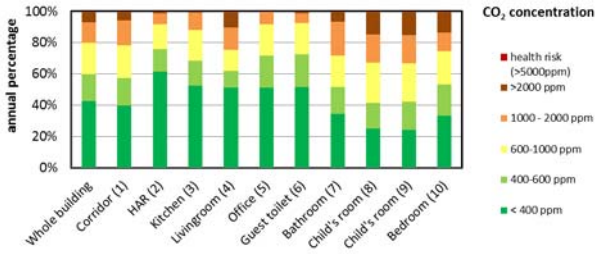
Case: Automatic window parallel-offset-opening

- Results
- Avg. 0.4 h^{-1}



- Heating demand — 67.5 kWh/(m² year)
- Air quality — 7% of the year above 1500 ppm CO_2 (12%)

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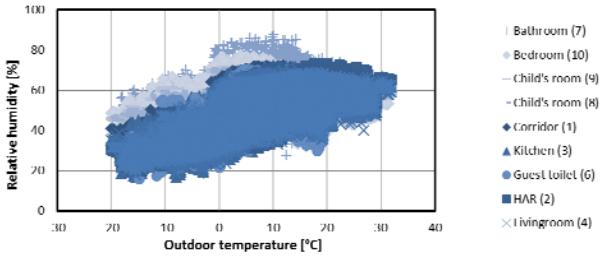
Case: Automatic window parallel-offset-opening

- Results
- Avg. 0.4 h^{-1}



- Heating demand — 67.5 kWh/(m² year)
- Air quality — 7% of the year above 1500 ppm CO_2
- Air temperature — 3.8 % of the year above 26°C
- Moisture risk — mould growth index 0 on critical surfaces
  significant below critical water content for spore germination

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Conclusion

- Coupled hygrothermal whole building simulation with air-flow modelling can be used to determine strategies for optimized natural ventilation, considering:
  - Energy demand
  - User comfort
  - Hygric issues / moisture risks

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Coupling hygrothermal whole building simulation and air-flow modelling to determine strategies for optimized natural ventilation

35th AIVC Conference, 24-25 September 2014, Poznań

Matthias Pazold, Florian Antretter, Marcus Hermes

www.wufi.com

matthias.pazold@ibp.fraunhofer.de

Auf Wissen bauen

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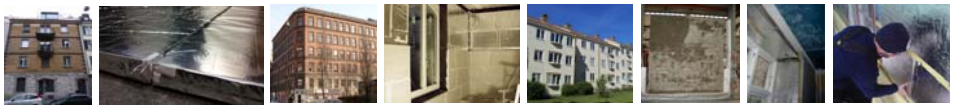


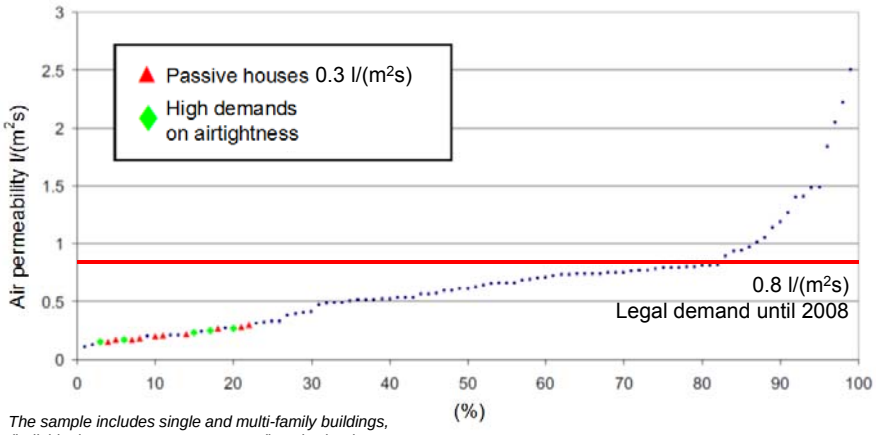
Air leakages in a retrofitted building from 1930

Measurements and numerical simulations

Pär Johansson, Angela Sasic Kalagasidis
Department of Civil and Environmental Engineering
Chalmers University of Technology
Sweden

25 September 2014

Airtightness in 100 newly constructed Swedish buildings

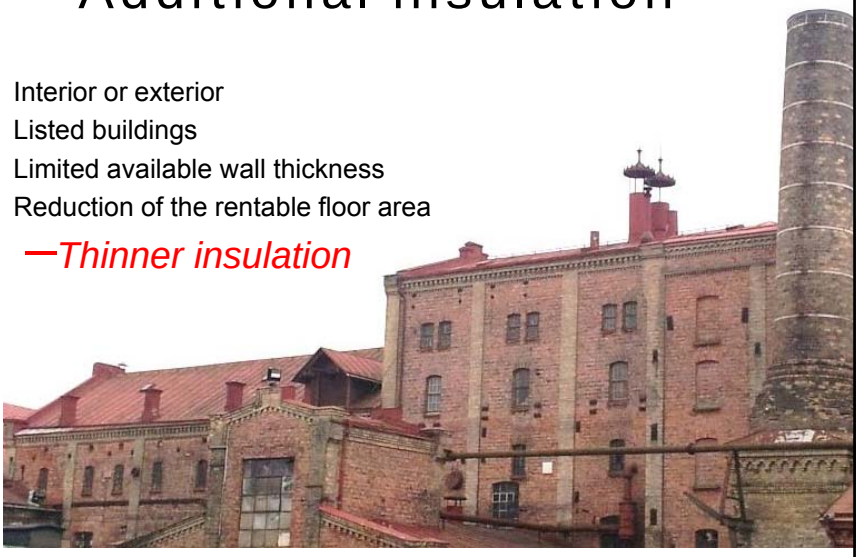


The sample includes single and multi-family buildings, (individual apartments are measured) and schools; both wooden and concrete structures (Wahlgren, 2010)

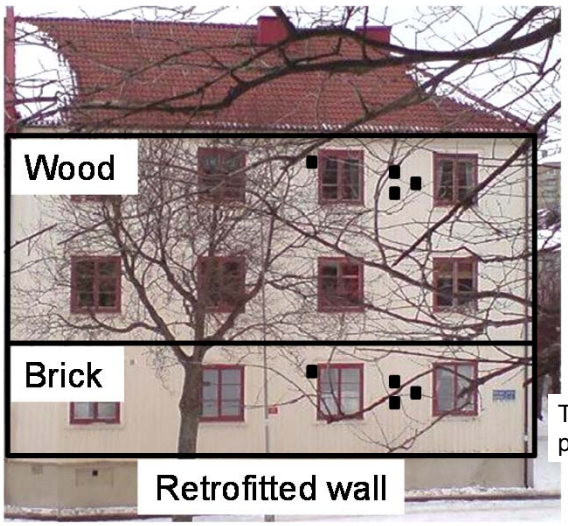
Additional insulation

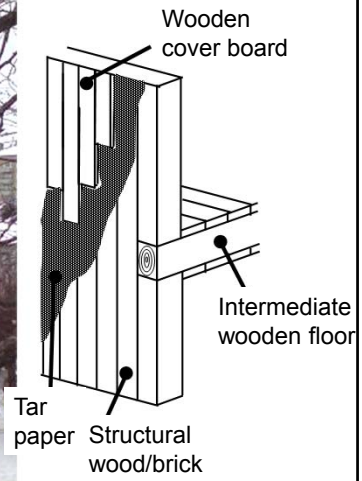
- Interior or exterior
- Listed buildings
- Limited available wall thickness
- Reduction of the rentable floor area

—*Thinner insulation*

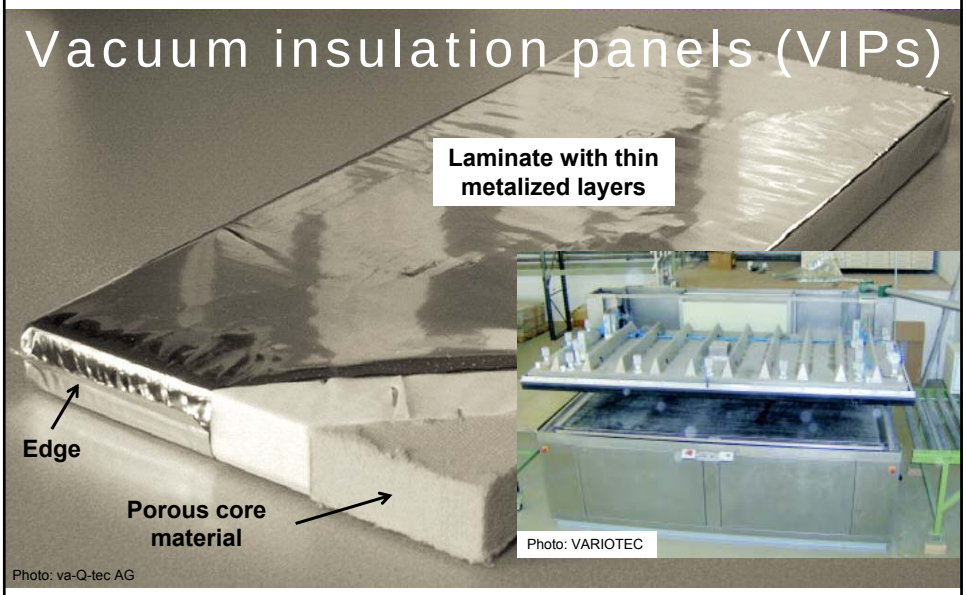


Case study building

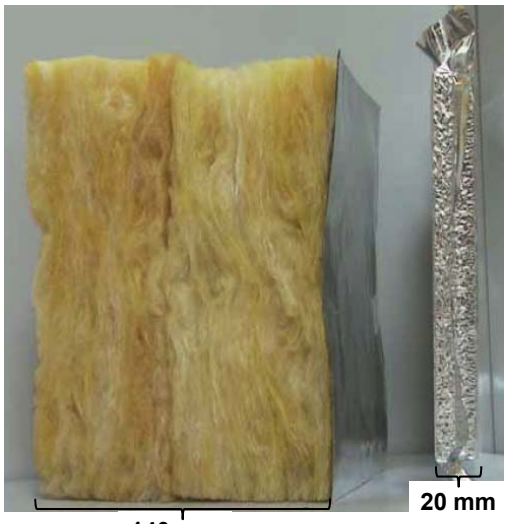




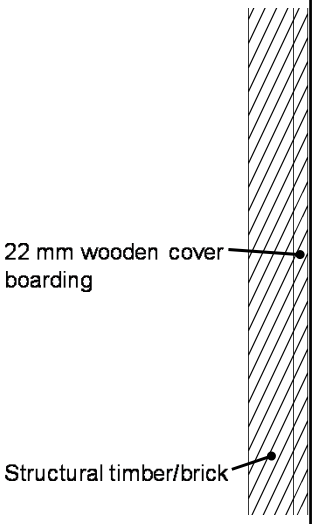
Vacuum insulation panels (VIPs)



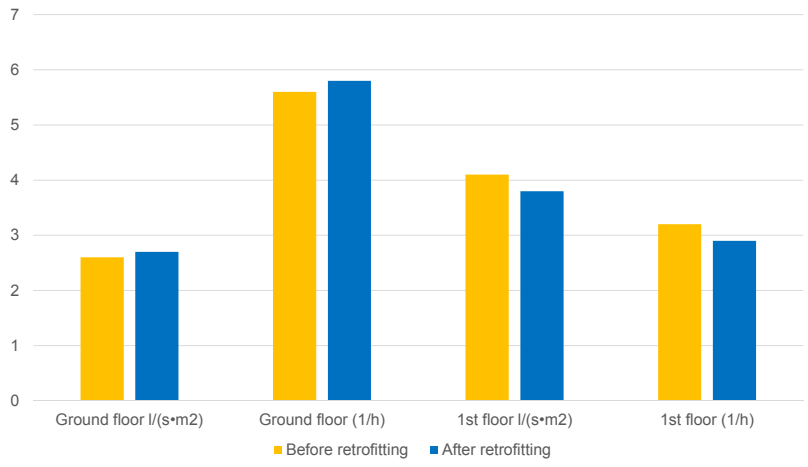
Required thickness is reduced



Wall insulated on the exterior

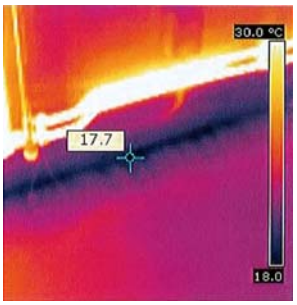


Results from blower door measurements

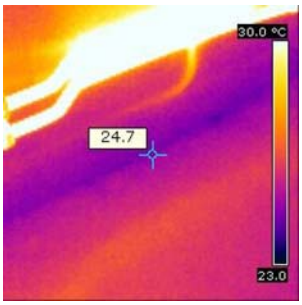


Where does the air come from?

- Indoor environment
- Outdoor environment



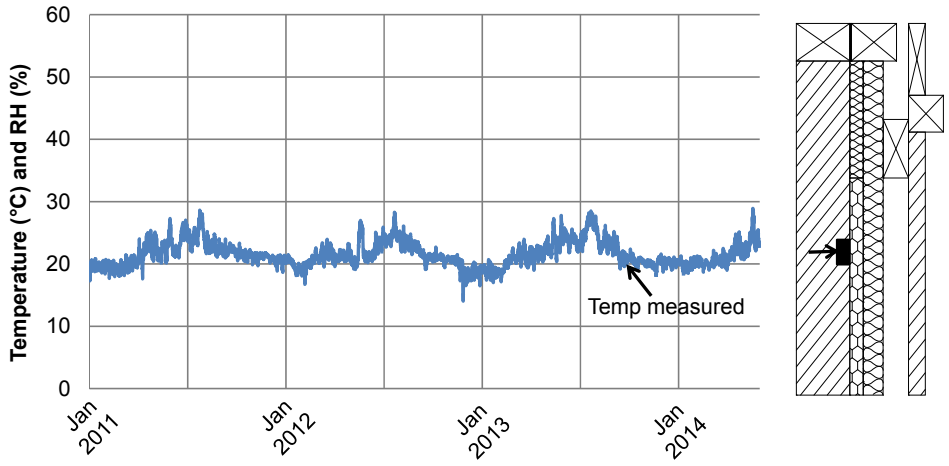
Before retrofitting



After retrofitting

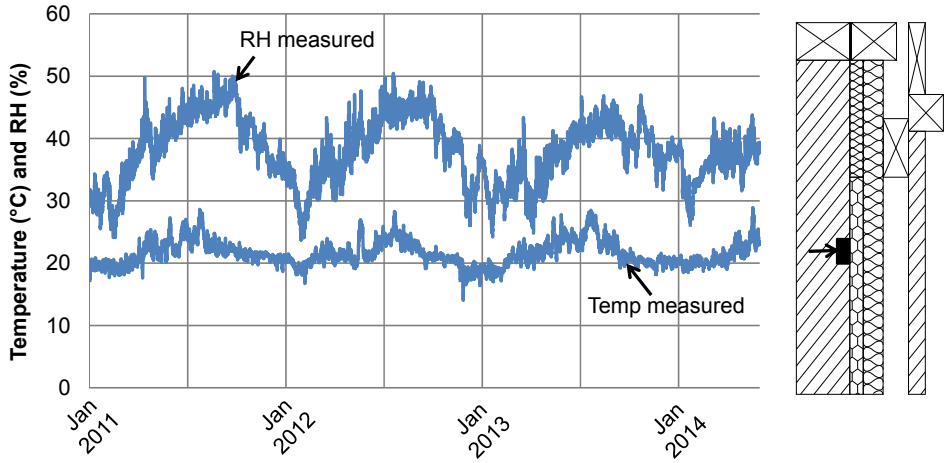
CHALMERS UNIVERSITY OF TECHNOLOGY
35th AIVC- 4th TightVent- 2nd venticool

Measured temperature

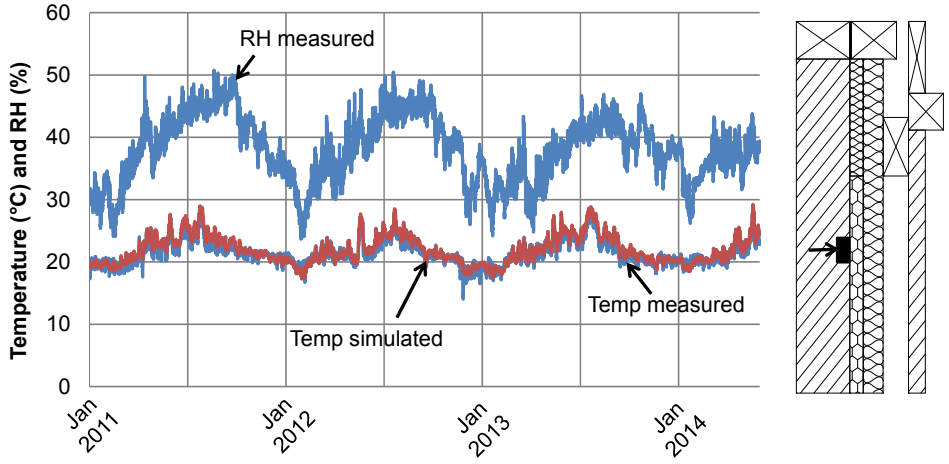


2014-09-25 Pär Johansson

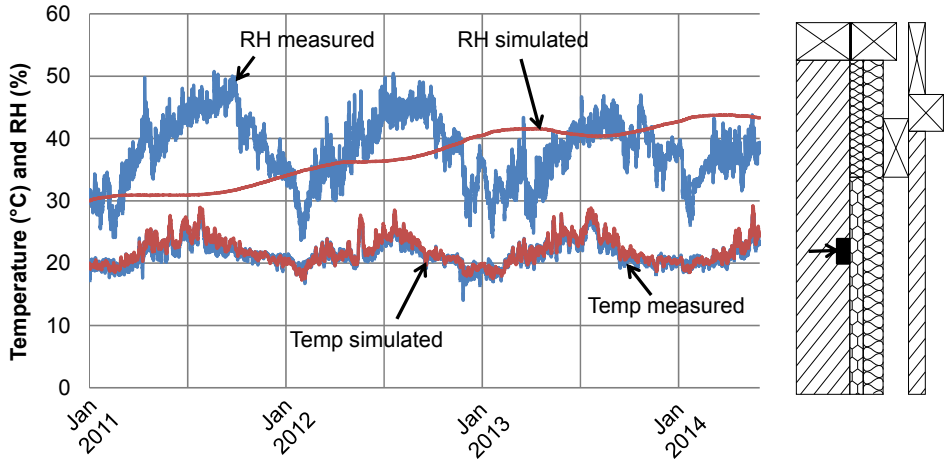
Measured T and RH



Simulated T and RH

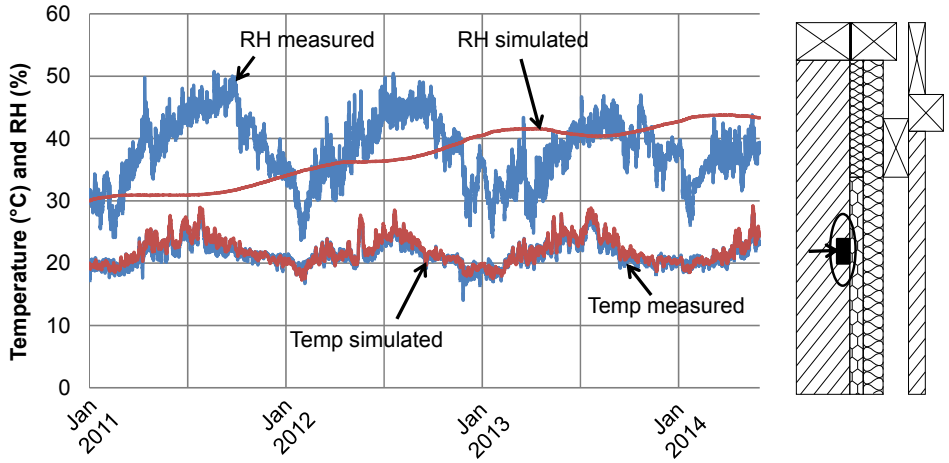


Simulated T and RH



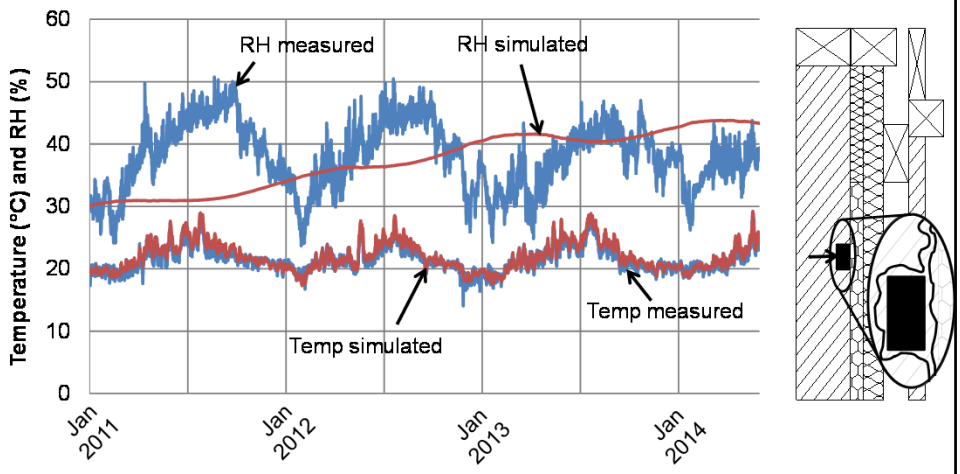
Why this difference?

Simulated T and RH

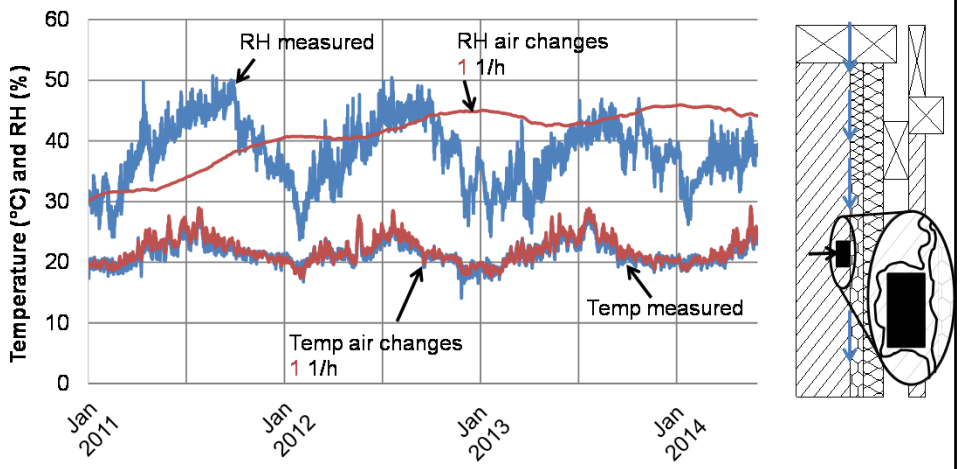


CHALMERS UNIVERSITY OF TECHNOLOGY
35th AIVC- 4th TightVent- 2nd venticool

Simulated T and RH



Air exchange indoor air



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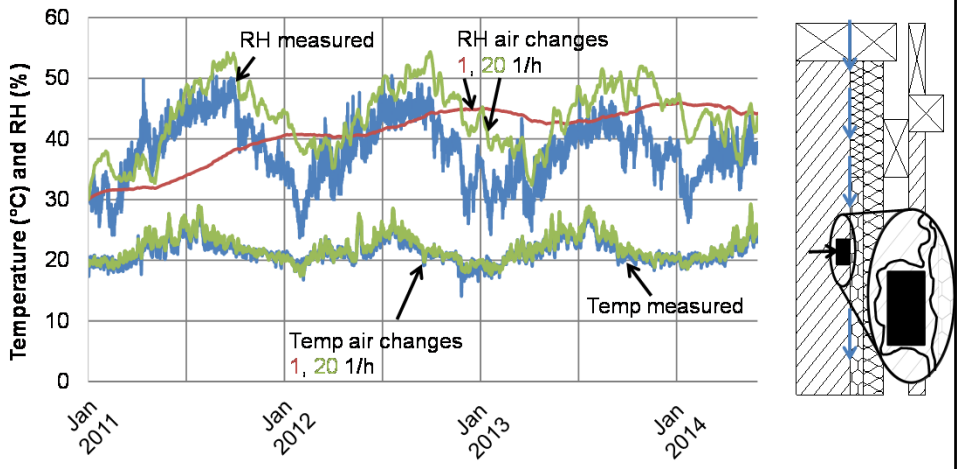
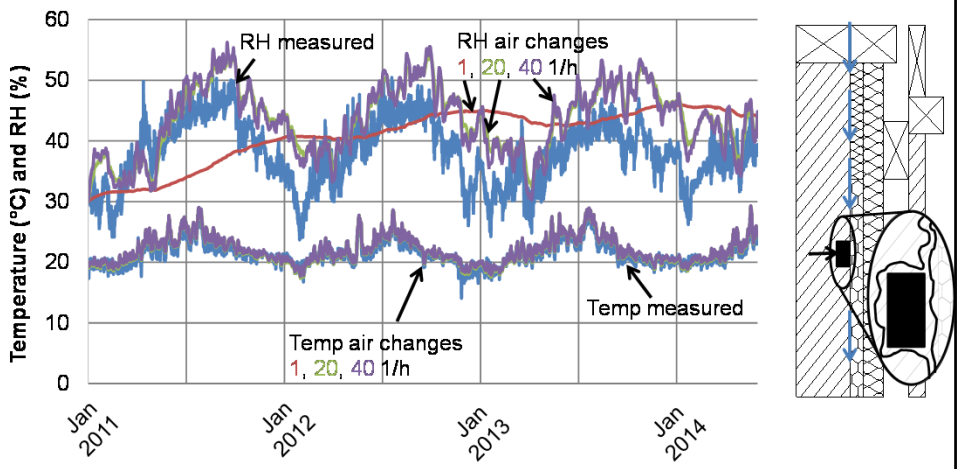
UNIVERSITY OF TECHNOLOGY
35th AIVC- 4th TightVent- 2nd venticool

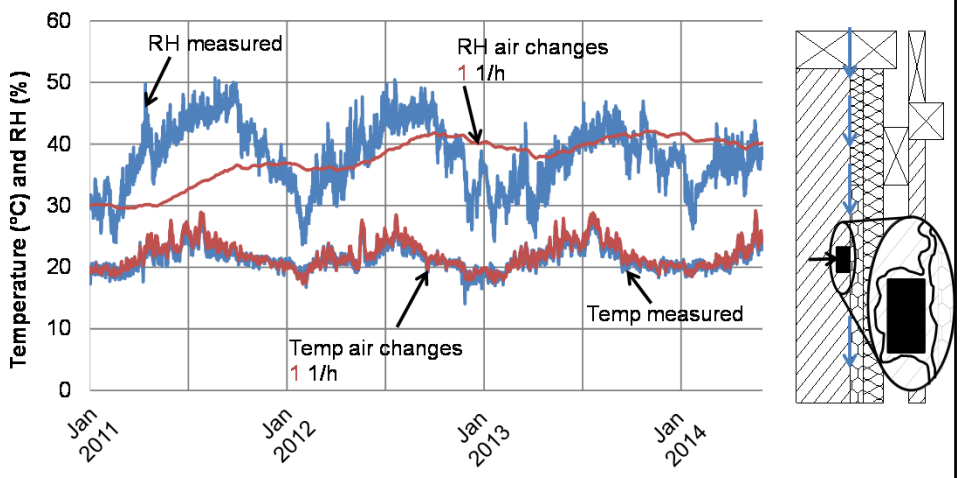
Air exchange indoor air



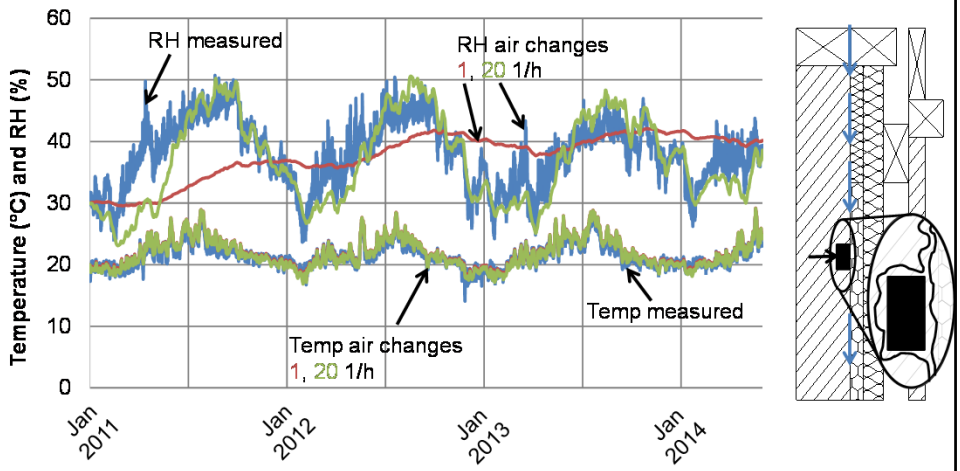
Air exchange indoor air



Air exchange outdoor environment

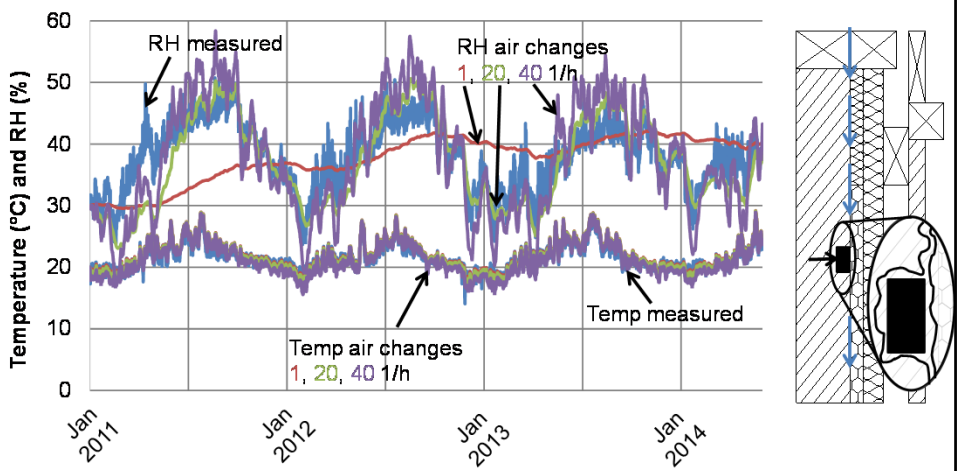


Air exchange outdoor environment



CHALMERS UNIVERSITY OF TECHNOLOGY
35th AIVC- 4th TightVent- 2nd venticool

Air exchange outdoor environment



Conclusions

- Blower door measurements showed the same air leakage before and after the retrofitting
- Most of the air flow between the apartments
  - Spreading of odor, particles and radon
  - Acoustic insulation
- Measurements indicated air leakage between the wall and the additional insulation
  - From the outdoor
  - Low risk for moisture damages

Välten 1930

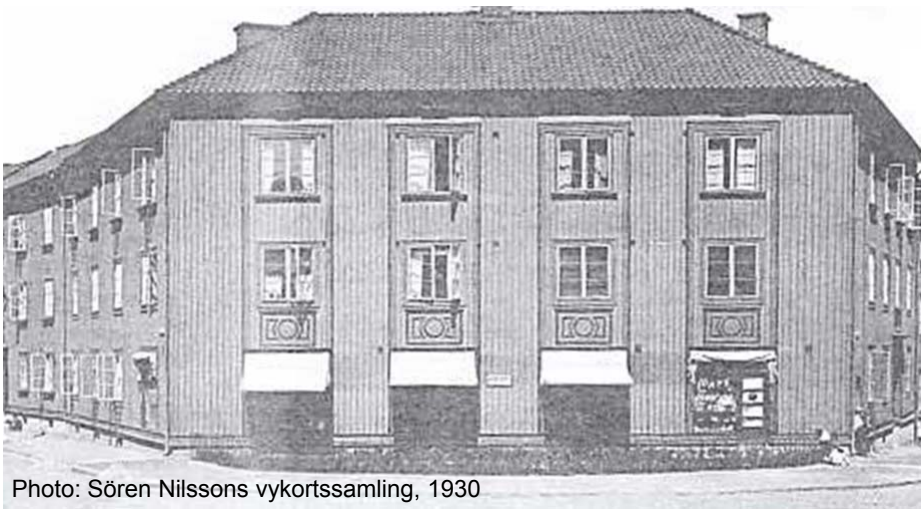
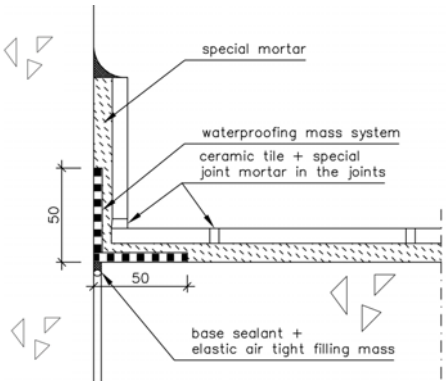


Photo: Sören Nilssons vykortssamling, 1930

Välten 2006

Photo: Melica, 2006

VAHANEN

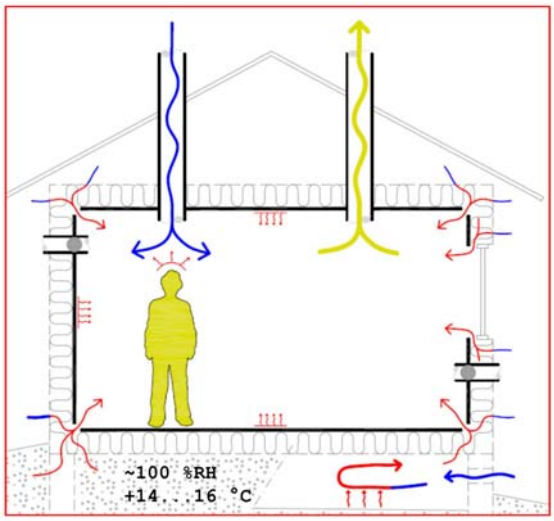


Air tightness of structures to improve indoor air quality

Katariina Laine, M.Sc (Tech.) Vahanen Oy, Finland

Why the inner surface of building must be air tight?

VAHANEN



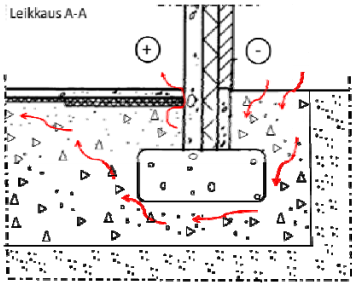
In the indoor air quality problem buildings, the aim of improving air tightness of sturctures is to prevent the uncontrolled air leakages through structures.

Why to improve air tightness of structures?

VAHANEN

Improving air tightness of structures has a positive effect on the following factors:

- Reduction of energy consumption
- Prevention of moisture convection
- Prevention of impurities entering through air leakages
- Living comfort.



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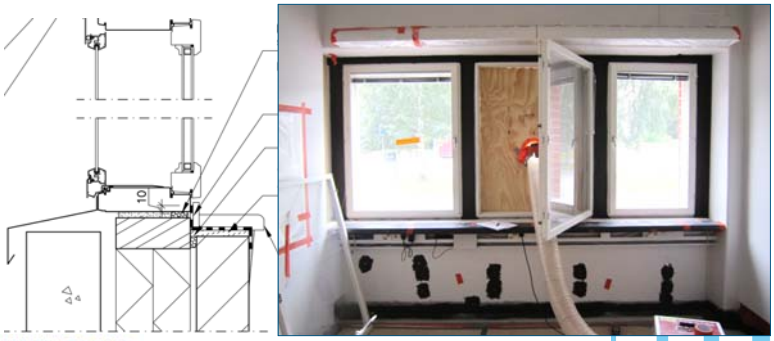
Principles in planning an air tightness renovation

VAHANEN

- Air tightness renovations are not suitable for all structures
- Air tightness renovations needs structural engineering designing; determination of materials and methods.
- It is never the only renovation action but always a part of a larger entity. At least the ventilation system is inspected and adjusted, if neccessary.



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Implementation on the construction site

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- Model works are important for the success of the implementation
- Assesment of the technical implementation
- Quality control with tracer-gas leak testing method

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Summary

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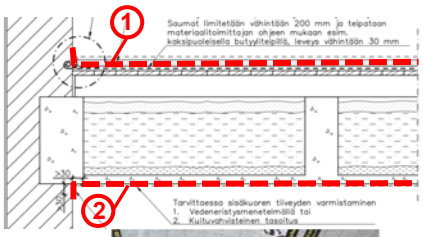

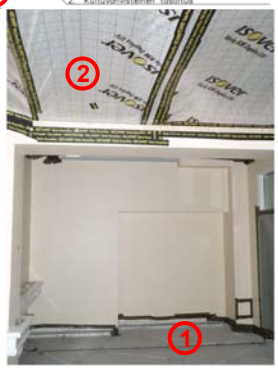

- Structures should never be tightened without inspection, planning and supervision.
- Structures with microbial or moisture damage should not be tightened- the problem needs to be fixed first.
- Air tightening renovation should never be the only renovation action but always a part of a lager entity.
- Careful implementation of the work is detrimental to the success of renovation.
- Remember quality control!

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Thank you for your attention!

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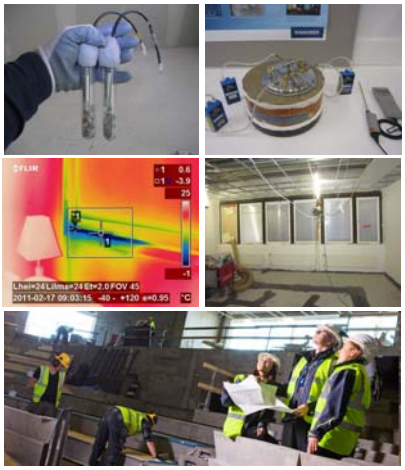
Visit our websites:
www.vahanen.com



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EXPERIENCES IN THE AIRTIGHTNESS OF RENOVATED TERTIARY EXEMPLARY BUILDINGS IN THE BRUSSELS CAPITAL REGION

AIVC 2014 conference
September 25th, 2013

Bram De Meester, Thibaut Hermans and Hendrik-Jan Steeman
ARCADIS Belgium, Green Buildings team, pp
Dpmt. BATIMENTS EXEMPLAIRES – Dir. ENERGIE

BRUXELLES ENVIRONNEMENT
IBGE - INSTITUT BRUXELLOIS POUR LA GESTION DE L'ENVIRONNEMENT

Content

*Introduction – Exemplary buildings
Situation of the Brussels Region
Strategy
Exemplary buildings (BatEx)

*Case studies
European Foundation House
Police office Tritomas

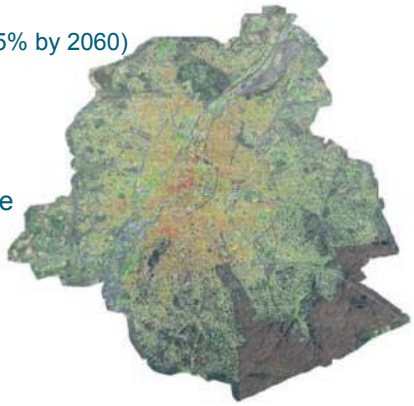
*General trends

*Conclusions

Situation of Brussels Region

Challenges

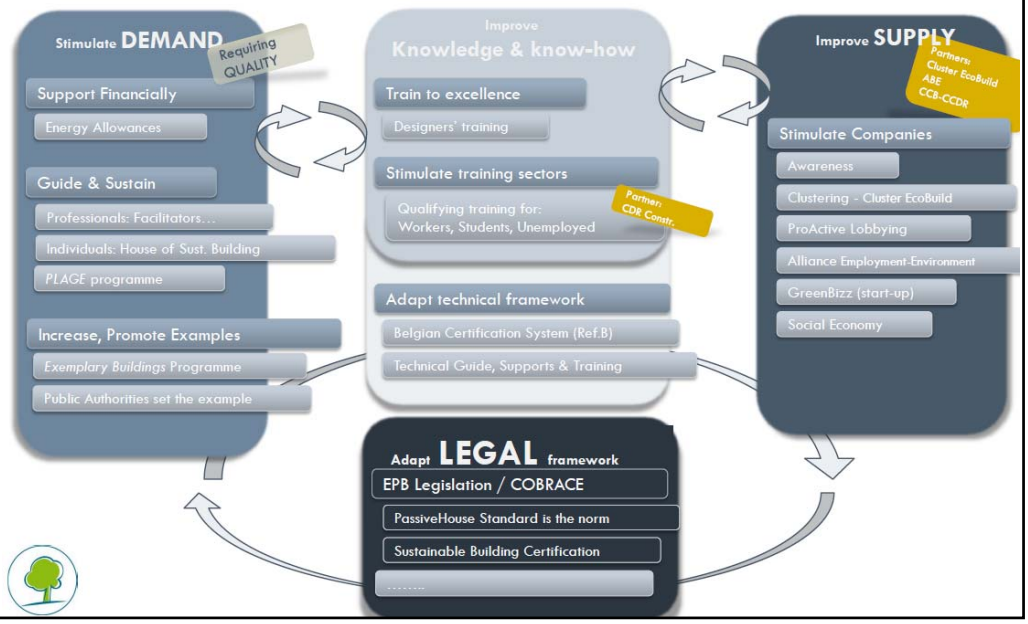
- 162 km², 1,1 million inhabitants (expected + 25% by 2060)
  currently about 7000 inhab./km²
- 630.000 workers (+8% 2001-2010)
- Old building stock
- Lot of tenants and co-ownerships
- Average incomes lower than national average
- 75% of energy consumption by buildings
- Very low renewable energy potential (3%)



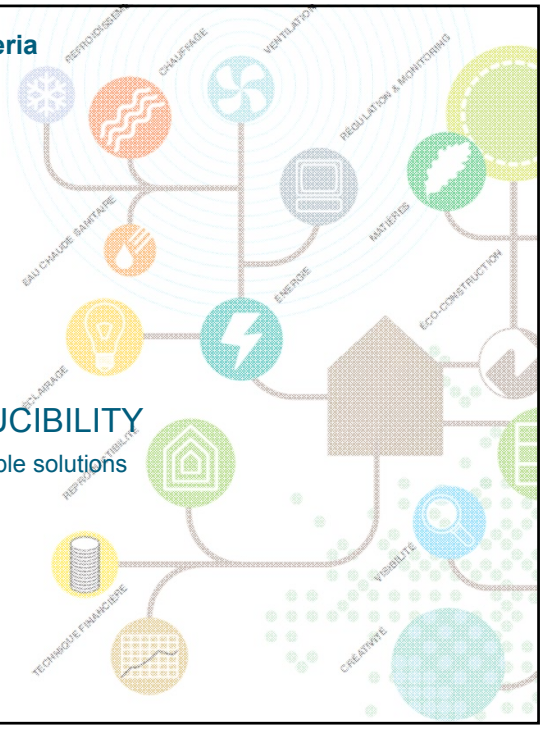
Drivers

- Large regional competences:
  environment, energy, mobility, urbanism, housing, …
- Ambitious policy: Reduce 30% of Greenhouse gas emissions by 2025

Strategy



Exemplary buildings **– Evaluation criteria**



*ENERGY

High performances
= minimum energy demand
Nearly Zero Energy Buildings

*ECO CONSTRUCTION

Minimum environmental impact

*PROFITABILITY & REPRODUCIBILITY

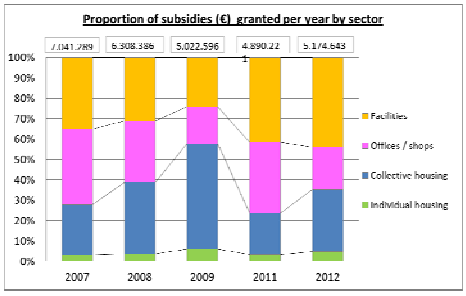
Economically and technically feasible solutions

*ARCHITECTURAL QUALITY

Patrimonial respect
Visibility

Exemplary buildings**-** Regional Grants and support

Call for projects launched in 2007, 2008, 2009, 2011, 2012, 2013



*FINANCIAL SUPPORT

100€/m²
→ 33 Mio € over 6 years

*TECHNICAL SUPPORT

expert guidance, quality control

*PROMOTIONAL

publications, website, …

Exemplary buildings

- total built surface of over 621.000 m²
- 28% refurbishment
- 56% passivehouse
- Finished: 92 projects
- under construction: 42
- in design process: 91
- Cancelled: 18

Exemplary buildings – Criteria

BIJLAGE 1 A – OBJECTIEVEN IVM DE ENERGIEPRESTATIE VOOR EEN RENOVATIE

Tabel 2 – RÉNOVATIE	ééngezins-woning	meergezins-woning > 2 eenheden	School kinder-kribbe	kantoor	Zorgsector, rusthuis	horeca	Commerciële sector/ handel	Culturele sector/ semenarie	sportcentrum	Overdekt zwembad	industrie geconditio-neerde werkplaats
Verwarmingsbehoefte											
maximale netto verwarmingsbehoefte berekend dmv PHPP en/of dynamische simulatie (kWh/m² jaar)	30	30	30	30	45	60	60	60	60	60	60
Ventilatie en Luchtdichtheid											
systeem D, rendement warmtewisselaar >85% (volgens norm NBN EN 308) en/of systeem C	X	X	X	X	X	X	X	X	X	X	X
Luchtdichtheid (n50/u)	1,5	1,5	1,5	1,5	1,5	3	3	3	3	3	3
Koelbehoefte											
Zomercomfort passief te voldoen via gebouwontwerp	X	X	X						X	X	
Zomercomfort passief te voldoen via installatieontwerp.				X	X	X	X	X			X
Verlichting											
maximaal geïnstalleerd gemiddeld vermogen (W/m². 100 lux)			2	2	2,5			3	2,5	2,5	2,5
Sanitair warm water											
minimum aandeel primaire energieverbruik van sanitair warm water uit hernieuwbare energie (%)	50	50	20		30	20			30	30	
Beheer van gebouw											
Regelsysteem (verwarming, ventilatie, klimaat, verlichting)	X	X	X	X	X	X	X	X	X	X	X
Monitoringssysteem: mogelijkheid voor automatische of manuele opvolging van water- en energieverbruiken (koud/warm).	X	X	X	X	X	X	X	X	X	X	X

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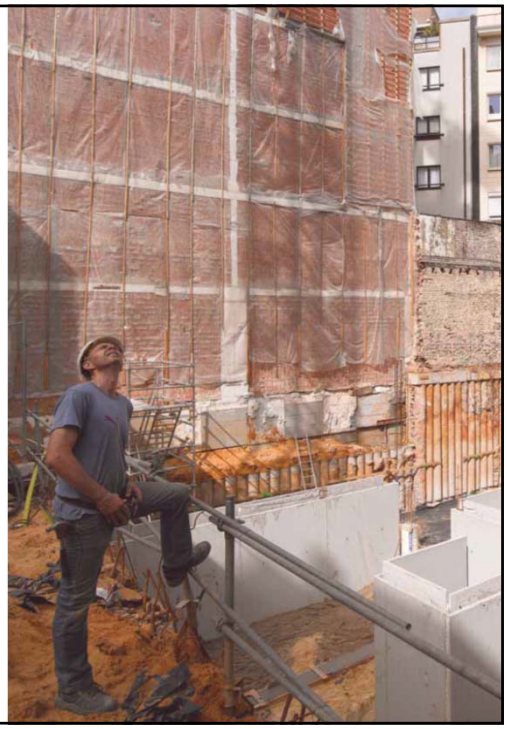


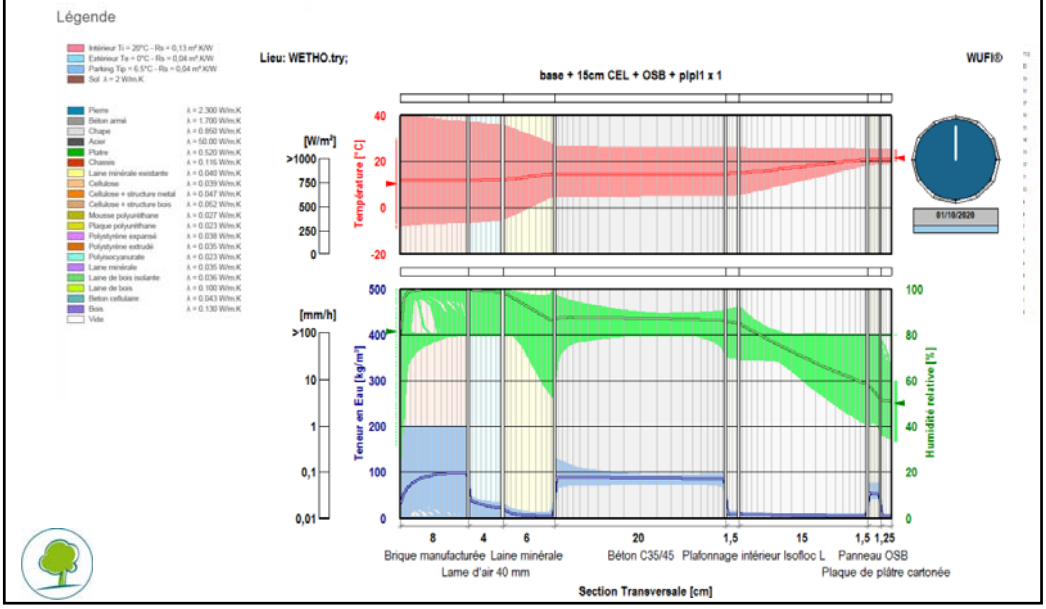
Cases studies - EFH

	European Foundation House (EFH)
Building owners	European Foundation House
Architects	GREENARCH architecture + environment sprl
Engineers	MATRIciel, Delvaux
Contractors	Valens-Eiffage
Location	Brussels
Gross building area	2.229 m²
Start of works	1/12/2012
Completion of works	9/10/2013
Energy demand for heating	15 kWh/m²/yr
Energy saving strategy	Interior insulation, window replacement, mechanical ventilation with heat recovery, air-water heat pump, use of radiant ceilings and thermal inertia of the structure

Cases studies - EFH

Cases studies - EFH

Cases studies - EFH



Cases studies - EFH

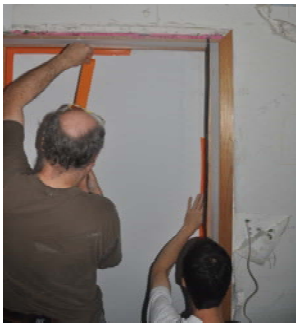
Cases studies - EFH

Cases studies - EFH

Results and lessons learned

- Final result n_{50} = 0,91 h^{-1}

- 3 intermediate airtightness tests
- Allowed for some 'sensitivity analysis':
  - Motorized grills in elevator shaft: 1800 m³/h @ 50Pa
  - Heat pump: 550 m³/h
  - Doors: 700 m³/h



Cases studies - Tritomas

	Police office Tritomas
Building owners	Zone de police 5342 : Uccle, Watermael-Boitsfort et Auderghem
Architects	bg&k associati
Engineers	Crea-tec sprl
Contractors	CFE
Location	Watermael-Boitsfort
Gross building area	2.327 m²
Start of works	1/1/2013
Completion of works	1/1/2014
Energy demand for heating	24 kWh/m²/yr
Energy saving strategy	Interior insulation, window replacement, mechanical ventilation with heat recovery, PV panels, geothermal heating and cooling, chilled beams

Cases studies - Tritomas

Cases studies - Tritomas

Cases studies - Tritomas

Results and lessons learned

- Intermediate n_{50}= 0,73 h^{-1}
- Final result n_{50} = 1,08 h^{-1}

One of the factors will certainly have been the doors between tested volume and the rest of the building

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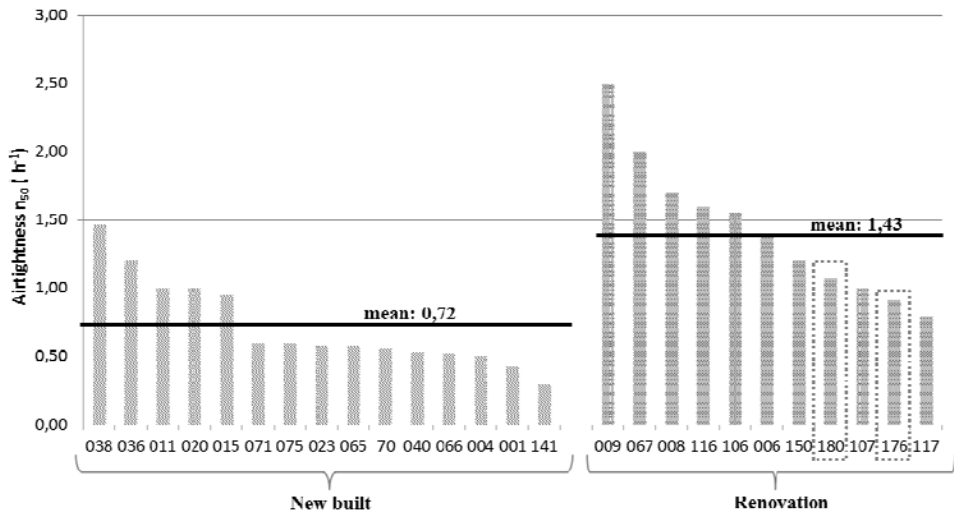
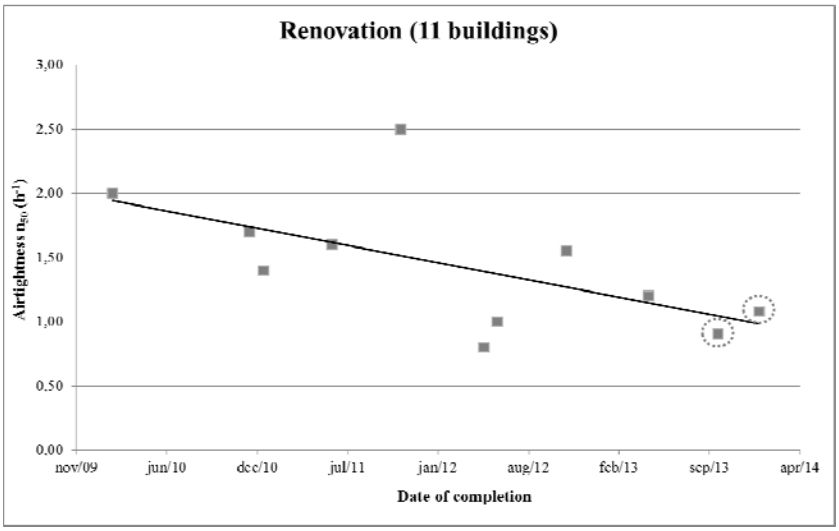
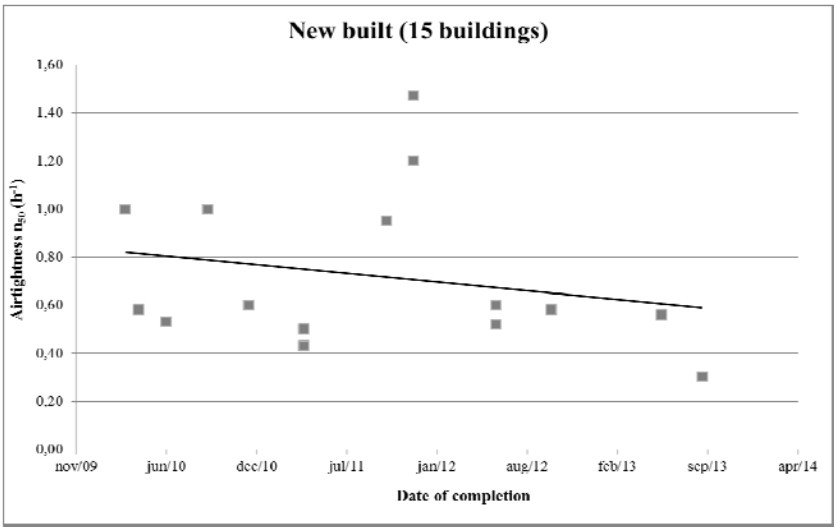
General trends



General trends



General trends



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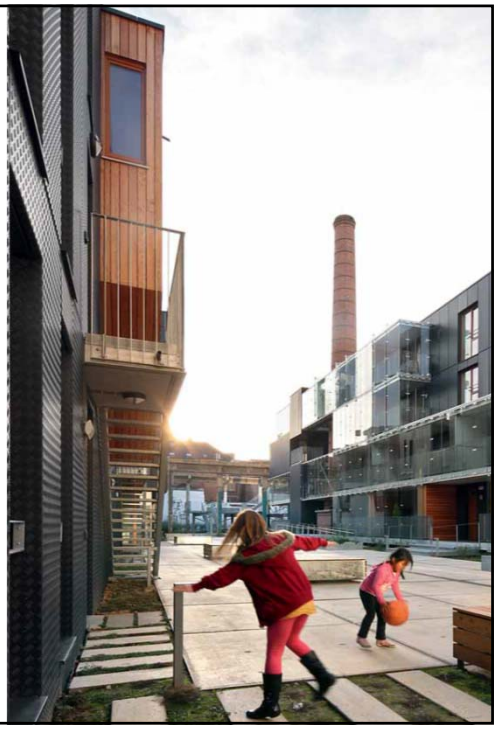


Conclusions

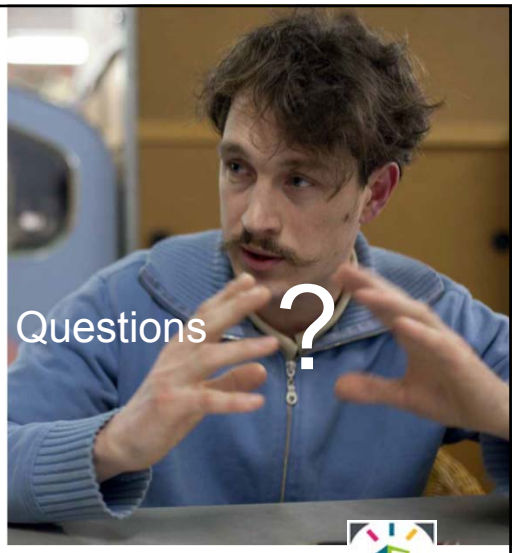
The exemplary building program played a positive role in raising awareness and creating a market for sustainable buildings in the Brussels Capital Region

In renovations of tertiairy buildings high performance airtightness can be achieved

General trends suggest a learning effect in the market

Dziękuję !

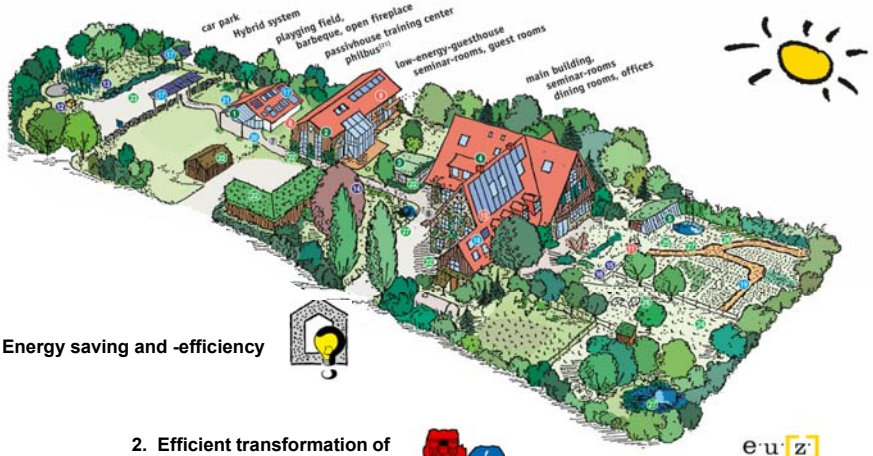
Thank you !



More information: www.bruxellesenvironnement.be/bâtimentsexemplaires

Strategies for the planning and implementation of airtightness on existing sloped roofs

Wilfried Walther, Sachverständiger für Bauphysik,
D-31832 Springe
Walther@e-u-z.de



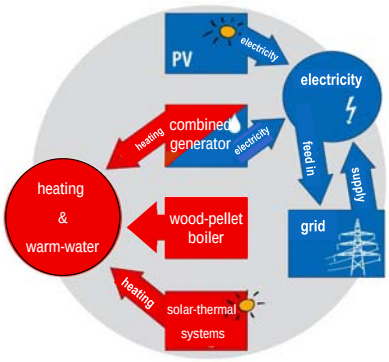
1. Energy saving and -efficiency

2. Efficient transformation of energy-ressources

3. Use of renewable energy

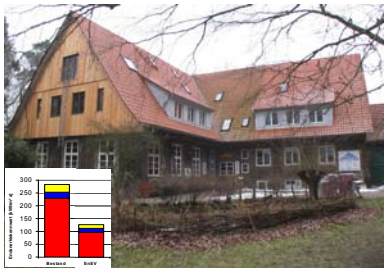
e·u·z energie + umwelt zentrum
Energie- und Umweltzentrum am Deister e.V.
Energie- und Umweltzentrum 1
31832 Springe-Eldagsen
Phone (05044) 975-0
Fax (05044) 975-66
E-Mail: bildung@e-u-z.de
Internet: www.e-u-z.de

Airtightness of sloped roofs



Wilfried Walther, Germany, D-31832 Springe, Walther@e-u-z.de
e·u·z energie + umwelt zentrum

Airtightness of sloped roofs



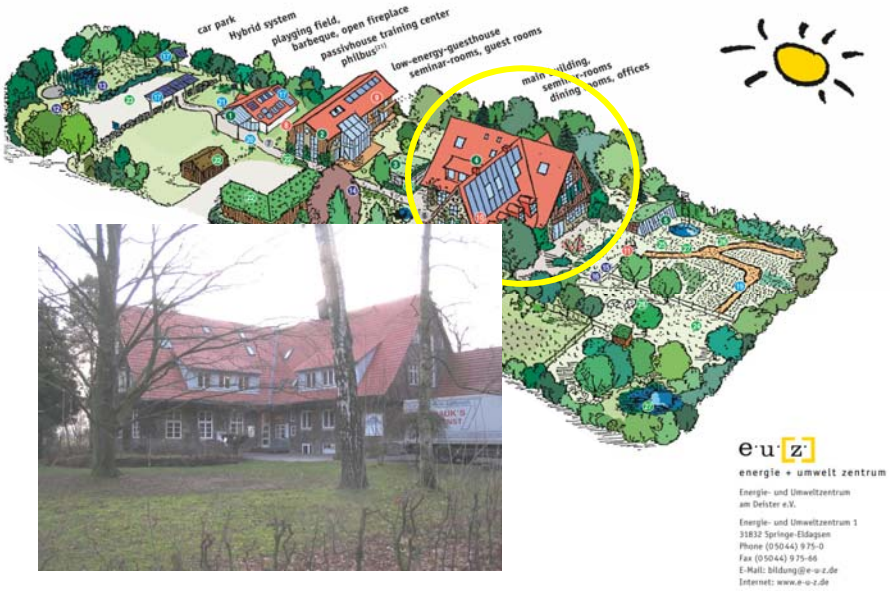
Wilfried Walther, Germany, D-31832 Springe, Walther@e-u-z.de
e·u·z energie + umwelt zentrum

Airtightness of sloped roofs

Wilfried Walther, Germany, D-31832 Springe, Walther@e-u-z.de

Airtightness of sloped roofs

Wilfried Walther, Germany, D-31832 Springe, Walther@e-u-z.de

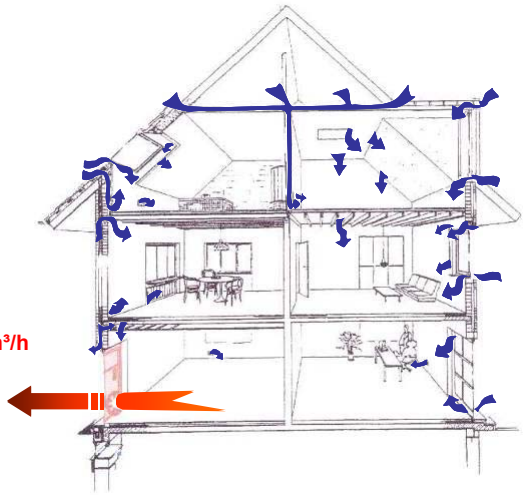


There‘s a problem…

Airtightness of sloped roofs

Insulation? Yes
Airtightness? No

Airtightness measurement



Leckages

Flow measure 8000 m³/h

at 30 Pascal

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Leakage control

Bildquelle: Arbeitskreis Qualifizierung im e.u.[z.]

Are there problems?

YES

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Leakage control

Bildquelle: A^plus-Qualifizierung im e.u.[z.]

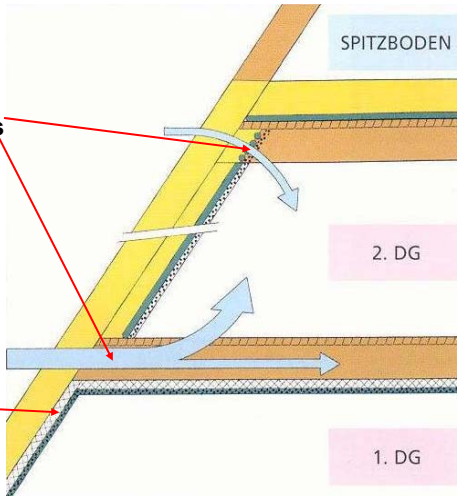
Are there problems?

YES

Reasons

Airflow from the outside into the construction because of gaps

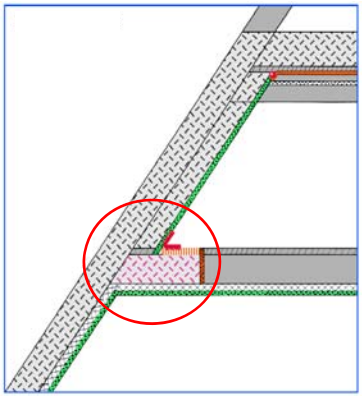
Woodwoll with plaster is airtight



Sealing collar beams

Airtightness of sloped roofs

Bildquelle: A^plus-Qualifizierung im e.u.[z.]



- Opening the tong-nut plates to seal between the collar beams

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Sealing collar beams

Airtightness of sloped roofs

Bildquelle: A^plus-Qualifizierung im e.u.[z.]

- Sealing with gypsonboard, plaster and adhesive
- Quality control with depressure and airflow measurements

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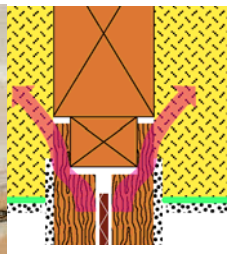
Sealing the indoor walls

Bildquelle: A[plus]-Qualifizierung im e.u.[z.]



- Indoor walls are penetrations

- Sealing with airless- spray method

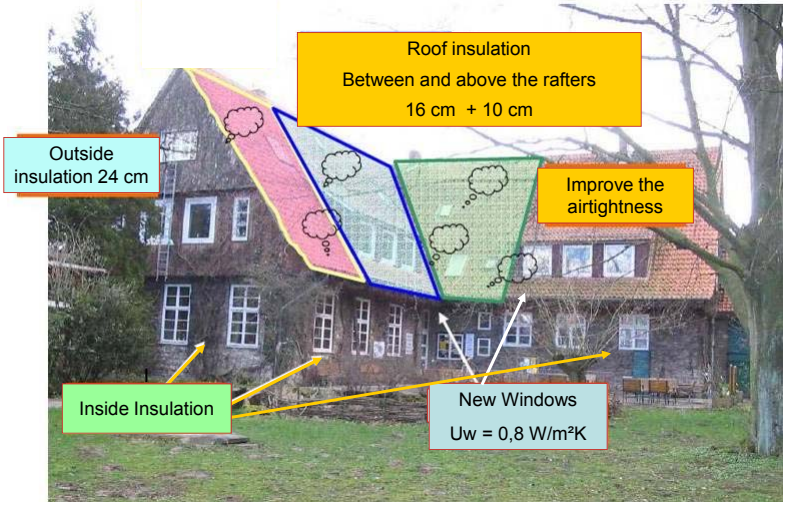
First results

Airtightness

Originally: n_{50} = 12 1/h

1996 - After improvement from inside : n_{50} = 3,5 1/h

Project in 2006 - 2011



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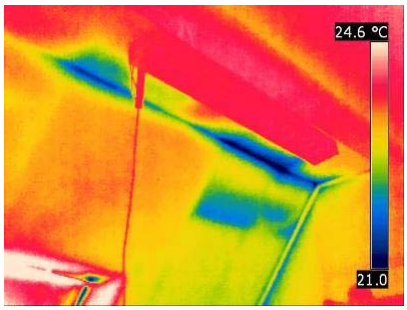
Leakage control

Bildquelle: AUS-Qualifizierung im e.u.[z.]



Problems with airtightness?

No

But there are problems if the wind blows through the construction

YES

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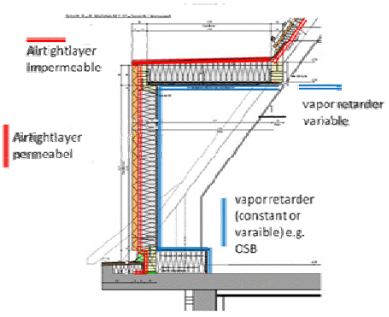
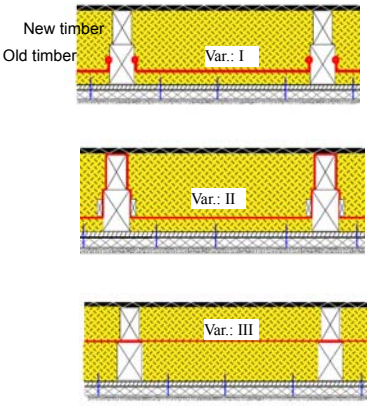
Airtightness		Airtightness after renovation?
original	n_{50} = 12 1/h	n_{50} = 2 - 1,5 - 0,6 1/h ?
After improvement from inside 1996	n_{50} = 3,5 1/h	

Planning



Bildquelle: IGBEU im e.u.[z.] Springe

Which option is the best?

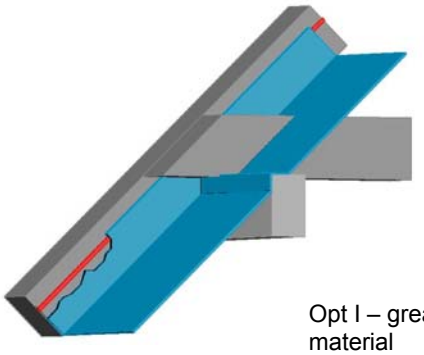


Opt I – airtight and vapor barrier (red) fixed with adhesive bonding compound from rafter to rafter

Opt. II

Opt. III

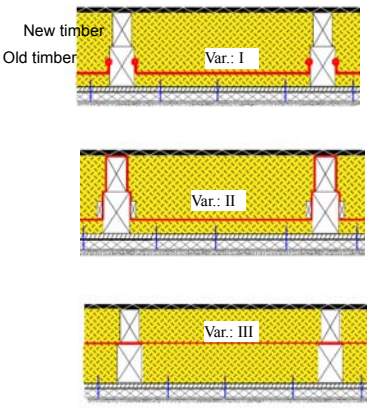
Detail rafter and dormer beams



Opt I – great deal of bonding (adhesive) material

Quelle: WTA-Merkblatt „Luftdichtheit im Bestand"

Which option is sucessful?



Opt I – airtight and vapor barrier (red) fixed with adhesive bonding compound from rafter to rafter

Too expensive

Opt. II - airtight and variable vapor retarder (red) “sub and top” system. (The layer can alternatively be situated between the old and the new timber.)

Opt. III - airtight layer and water vapor permeable layer on the old timber, covered with insulation.

Two option – pro and cons

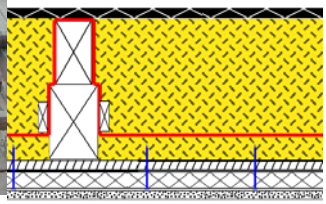
Bildquelle: Aptis-Qualifizierung im e.u.[z.]

Opt. III

Option II

Cons

- Nails can destroy the air tight layer
- Nails must be covered with a thin insulation material



Bildquelle: A^plus-Qualifizierung im e.u.[z.]

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Avoiding folds– big sheeting produced on site

- Folded to an packet and roll out

- Adhesives connects small sheeting to an big sheeting without folds

Bildquelle: A^plus-Qualifizierung im e.u.[z.]

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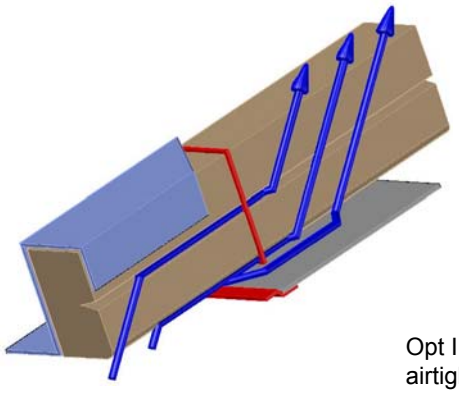
Details

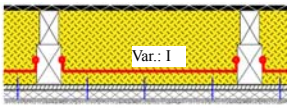
Bildquelle: AIVIE-Qualifizierung im e.u.[z.]

Difficulties when changing the airtight method



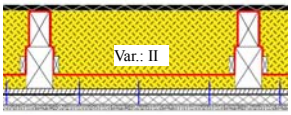
Opt II – Difficulties when changing the airtight layer method to an „inside method“

Quelle: WTA-Merkblatt „Luftdichtheit im Bestand“



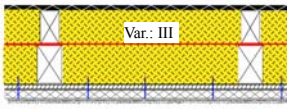
Opt I – airtight and vapor retarder (red) fixed [illegible] bonding compound from rafter to rafter

Too expensive



Opt. II - airtight and variable [illegible] retarder (red) [illegible] can [illegible] old [illegible] timber.)

In some cases usefull



Opt. III - airtight layer and water vapor permeable layer on the old timber, covered with insulation.

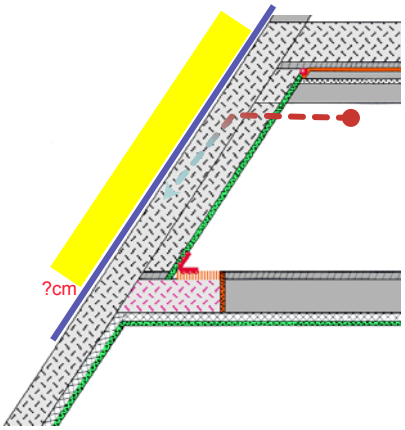
Opt. III

Bildquelle: Aptis-Qualifizierung im e.u.[z.]

A large sheeting produced on site.
Adesive tape without folds and leaks.

Option III

- **Thickness of the insulation must be more than 1/3 of the whole thickness of insulation**



Bildquelle: holzbau – die neue quadriga

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Opt. III

Bildquelle: A[aus]-Qualifizierung im e.u.[z.]

Air tight layer permeability

sd < 0,1 m

Cover the air tight layer with wooden fibre boards

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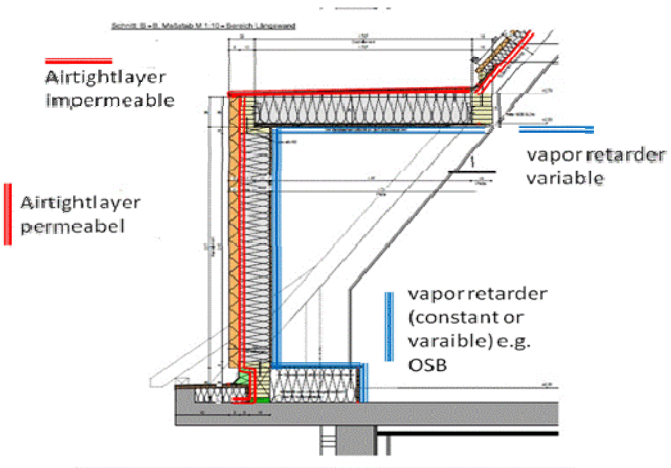
Opt. III

Cover the air tight layer with cellulose fibre and thin wooden fibre boards

Bildquelle: AIVHK-Qualifizierung im e.u.[z.]

Details dormer



Bildquelle: AIVHK-Qualifizierung im e.u.[z.]

Bildquelle: Ausb-Qualifizierung im e.u.[z.]

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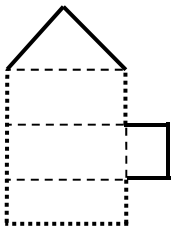
Quality control

Target:
The renovation must be minimum better than the old building



$$q50\ (requir.) = \frac{\text{q50 (prev.)} \times \text{Area(prev.)} + \text{q50 (new)} * \text{Area (new)}}{\text{Area (prev.)} + \text{Area (new)}}$$

Quelle: WTA-Merkblatt „Luftdichtheit im Bestand"

Wilfried Walther, Germany, D-31832 Springe, Walther@e-u-z.de

The results

Target
Heat Transmission:
„Passiv House“
fulfiled!

The results

Target
Infiltration: ?

But airtightnes „only“
n_{50} = 1,4 1/h

Thank you for listening

Wilfried Walther, Germany, D-31832 Springe, Walther@e-u-z.de

e·u·z·
energie + umwelt zentrum

Self-evaluated Thermal Comfort compared to Measured Temperatures during Summer

In three Active Houses where Ventilative Cooling is Applied

Peter Foldbjerg[1], Thorbjørn Færing Asmussen[1], Moritz Fedkenheuer[2] and Peter Holzer[3]
[1] VELUX A/S, Department of Daylight, Energy and Indoor Climate
[2] Humboldt-Universität zu Berlin
[3] Institute for Building research & Innovation

Peter.foldbjerg@velux.com

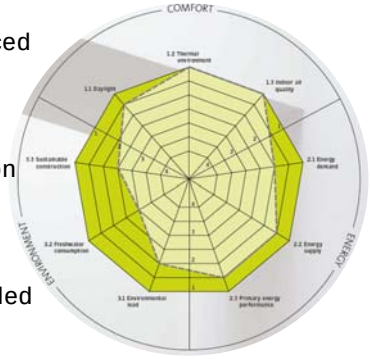
35th AIVC conference
24-25 September 2014, Poznan, Poland

ModelHome 2020
Six experiments
Five countries

- *Completed in 2011:*
  LichtAktiv Haus (LAH) in DE
  Sunlighthouse (SLH) in AT
- Measurements of IEQ and energy for one year
- SLH has been occupied by a family for one year, LAH for two years

Design targets

- Based on Active House principles: balanced focus on IEQ, energy performance and environmental impact
- Generous daylight conditions; windows on all facades and daylight from several directions in each room
- Ventilative cooling, automatically controlled natural ventilation and solar shading



Active House categories for thermal comfort

- Using method from EN 15251, adaptive approach (for naturally ventilated buildings) based on running mean temperature
- Scale: 1 to 4 (four levels, vs. three levels in EN 15251)

The maximum indoor operative temperatures are:
1. $T_{i,o} < 0.33 \times T_{rm} + 20.8°C$, for T_{rm} of 12°C or more
2. $T_{i,o} < 0.33 \times T_{rm} + 21.8°C$, for T_{rm} of 12°C or more
3. $T_{i,o} < 0.33 \times T_{rm} + 22.8°C$, for T_{rm} of 12°C or more
4. $T_{i,o} < 0.33 \times T_{rm} + 23.8°C$, for T_{rm} of 12°C or more (not in EN 15251)

"Too high" used in here applies to $T_{i,o} > 0.33 \times T_{rm} + 23.8°C$, for T_{rm} of 12°C or more

The minimum indoor operative temperatures are:
1. $T_{i,o} > 21°C$, for T_{rm} of 12°C or less
2. $T_{i,o} > 20°C$, for T_{rm} of 12°C or less
3. $T_{i,o} > 19°C$, for T_{rm} of 12°C or less
4. $T_{i,o} > 18°C$, for T_{rm} of 12°C or less (not in EN 15251)

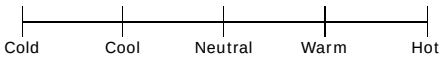
"Too low" used here applies to $T_{i,o} < 18°C$, for T_{rm} of 12°C or less

Measurements

- Continuous hourly measurements in each room:
  - Temperatures, lux, humidity, CO_2-level
  - Energy production and consumption
  - Position of windows and solar shading, manual override of auto control

Dorfstetter family in Sunlighthouse

- Daily response on 5-point thermal sensation scale (response to represent entire day)

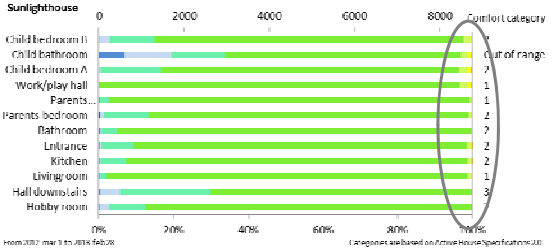


Oldendorf family in LichtAktiv Haus

- The families' experienced were collected by anthropologists through visits and interviews with family members (not presented today)

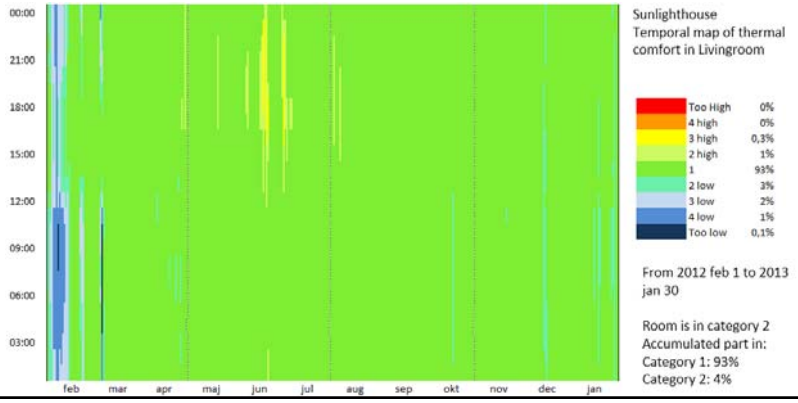
Thermal comfort; overview

- Overheating is prevented in both houses
- All main rooms achieve Active House level 1 regarding overheating (corresponds to EN 15251 category I)
- Focus on combined kitchen/dining: most challenging room due to large glazed area



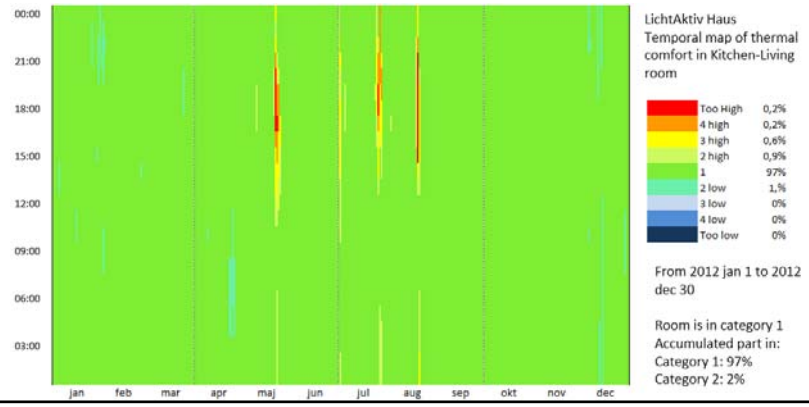
Temporal map, SLH Austria

- Very little overheating
- The few hours with temperatures above category 1 are during summer and during the time interval from 12:00 to 21:00 (caused by solar gains)
- Temperatures in category 3 and below are seen in one specific week before family moved in; heat pump not ready yet



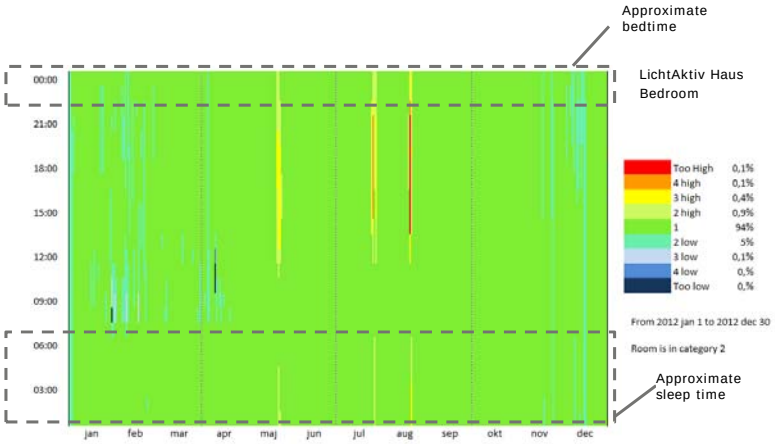
Temporal map, LAH, Germany

- Same summer tendencies as SLH; very little overheating, 3 to 4 episodes, in the afternoon 12:00 to 21:00
- No wintertime undercooling is seen



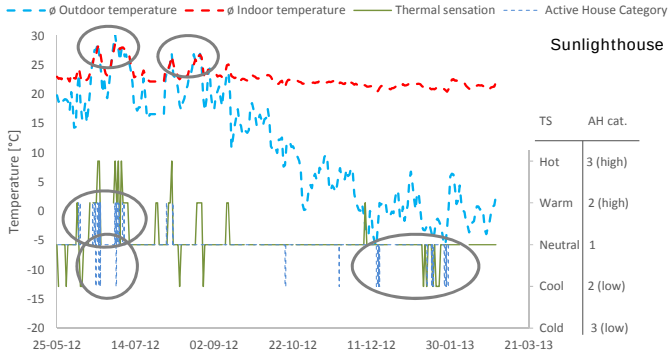
No overheating during night

- Bedrooms show same tendency as other rooms; increased afternoon temperature drops before bedtime
- And practically no hours with temperatures above category 1 at the time of-falling-to-sleep



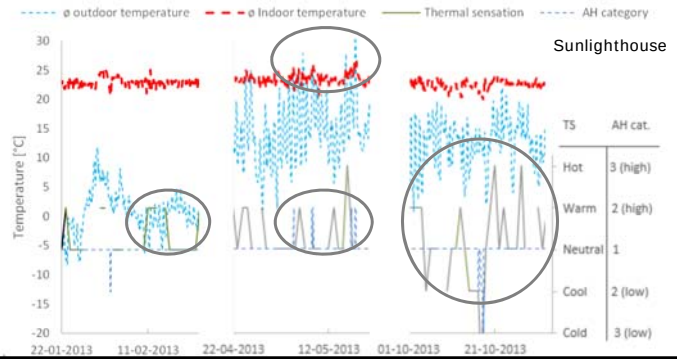
Self-evaluated thermal sensation, SLH

- Indoor temperatures maintained 1°C to 2°C below outdoor temperature (ventilative cooling potential is used)
- During summer: Thermal sensation *generally* follows AH category
  - On days when *indoor temp drops but remains within category*, thermal sensation is rated is cool
- During winter: Thermal sensation *generally* follows AH category



Self-evaluated thermal sensation, LAH

- Indoor temperatures maintained 3°C to 5°C below outdoor temperature (ventilative cooling potential is used)
- Jan. and Feb.: AH category is stabile 1, TS “neutral” or “warm”
- April and May: warm outside, TS often “warm”, AH category generally 1 with some days at 2
  - TS increase is “delayed” a few days compared to AH cat. Increase
- October: Large variation in TS, AH category almost stabile at 1



Conclusions

- The combined kitchen/dining room is the most challenging regarding overheating but achieves category 1: overheating is prevented
- The use of window openings in the summer time generally occurred at the same time as category 1 thermal comfort, indicating that ventilative cooling contributed to good thermal comfort
- Indoor temperatures in summer were maintained below outdoor temperature; potential of ventilative cooling was used
- Self-reported thermal sensation and thermal comfort category follows similar trends
  - Thermal sensation score sometimes changed when temperature increased/decreased slightly without changing category
  - Change in TS vote delayed some days from change in thermal comfort category

Thanks for listening!

Self-evaluated Thermal Comfort compared to Measured Temperatures during Summer
In three Active Houses where Ventilative Cooling is Applied

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35th AIVC conference
24-25 September 2014, Poznan, Poland

CONTROL OF INDOOR CLIMATE SYSTEMS IN ACTIVE HOUSES

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Institute of Building Research & Innovation

VELUX A/S

What is it about ?

CONTROL OF INDOOR CLIMATE SYSTEMS IN ACTIVE HOUSES

What is an Active House?

Buildings
that give more
than they take.

What is an Active House?

- **Comfort**
  - An AH creates healthier and more comfortable life.
  - An AH ensures a generous supply of daylight and fresh air.
- **Energy**
  - An AH is energy efficient.
  - All AH's energy needed is supplied by renewable sources.
- **Environment**
  - An AH interacts positively with the environment through an optimized relationship with the local context

Examples of Active Houses
VELUX model homes 2020

LichtAktiv Haus, Germany

Carbon Light Homes, Great Britain

Maison Air et Lumière, France

Examples of Active Houses
VELUX model homes 2020

Home for Life, Denmark

Green Lighthouse, Denmark

Sunlighthouse, Austria

What is it about ?

CONTROL OF
INDOOR CLIMATE SYSTEMS
IN ACTIVE HOUSES

What are the Aims of Indoor Comfort being adressed in Active Houses?

- Thermal Comfort
- Daylight
- Air Quality

Comfort
+ Health

Indoor Environmental Quality

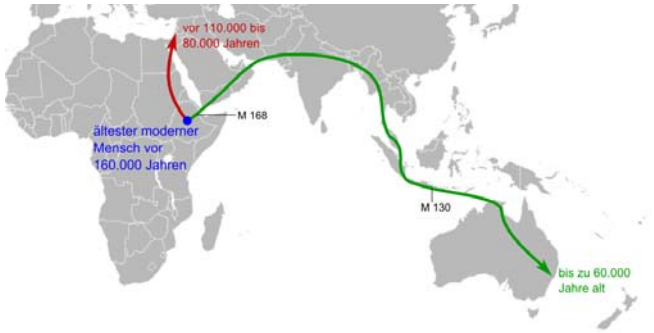
What are the Aims of ~~Indoor Comfort~~ IEQ being adressed in Active Houses?

- Thermal ~~Comfort~~ **IEQ**
- Daylight
- Air Quality

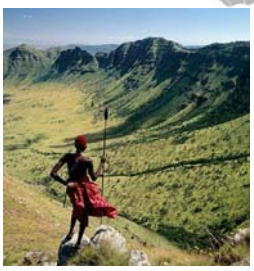
What are the Aims of ~~Indoor Comfort~~ IEQ being adressed in Active Houses?

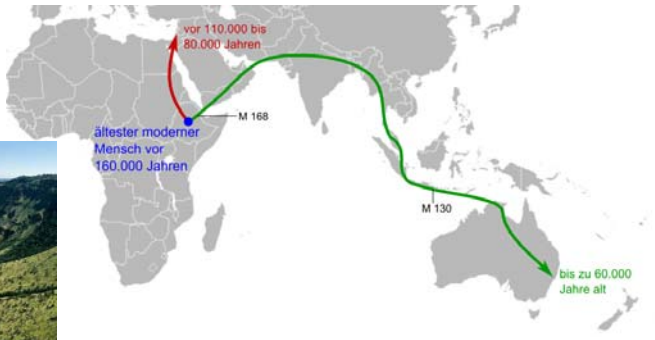
- Thermal IEQ — acc. EN 15251, even extended
- Daylight — DF > up to 5%
- Air Quality — Δ CO2 < down to +500ppm

Why?

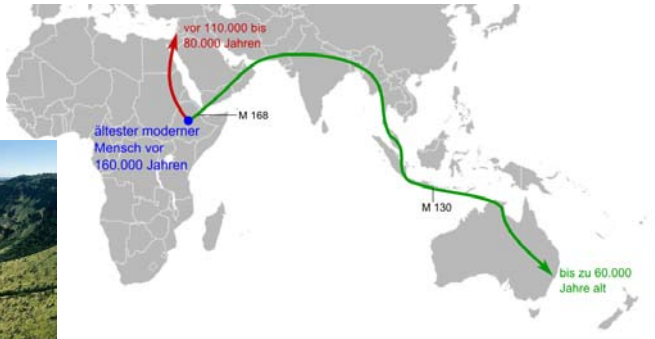


Why?

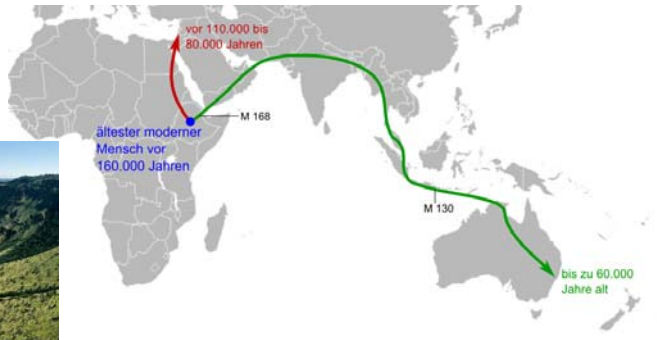



vor 110.000 bis
80.000 Jahren
M 168
ältester moderner
Mensch vor
160.000 Jahren
M 130
bis zu 60.000
Jahre alt

Why?


vor 110.000 bis
80.000 Jahren
M 168
ältester moderner
Mensch vor
160.000 Jahren
M 130
bis zu 60.000
Jahre alt

Get out of comfort zone sometimes !



Hypothesis on Comfort in an Active House

- An AH is and should be intensively connected to the outside climate
- Comfort sensation in an AH is and should be closer to free running mode than to AC-mode
- An AH does and should offer generous individual adaptive options rather than (additional to) automated technical control

What is it about ?

CONTROL OF INDOOR CLIMATE SYSTEMS IN ACTIVE HOUSES

Challenges to Comfort Control in an Active House

- An AH is fast and strong reactive to weather conditions. That calls for technical control.

- An AH targets a maximum of physical and emotional connection to the out-of-doors. That calls for individual, intuitive and adaptive behavior.

Challenges to Comfort Control in an Active House

- Only with technical control,
  physical comfort criteria can be guaranteed.

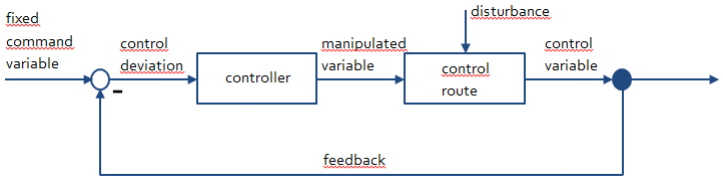
- Only with individual adaptive options
  the delight and the forgiveness factor
  of free running mode buildings can be created.

Challenges to Comfort Control in an Active House

- Automated technical controls are best accepted
  if they work silently, invisible and unnoticed.

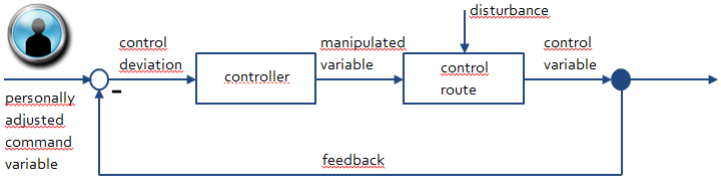
- By no chance you can alter the connection to
  the outside invisibly and unnoticed,
  e.g. operating windows and sunblinds.

Options of user intervention to comfort control



1. **fully automated without users' intervention**
2. automated with users' intervention on command variable
3. users' manual operation
4. user's manual operation, guided by feedback from the automated control system

Options of user intervention to comfort control



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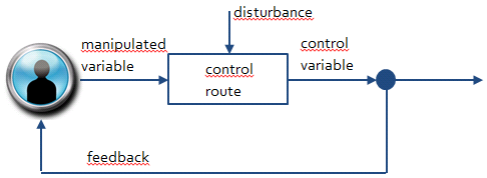

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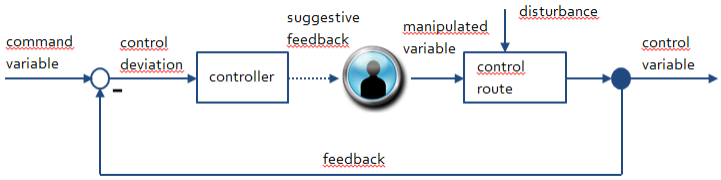
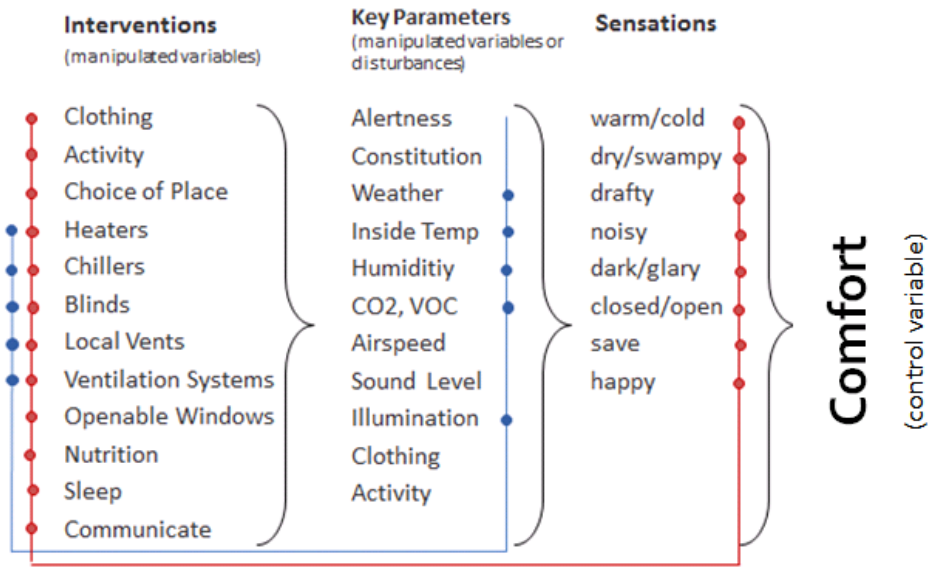
Options of user intervention to comfort control



1. fully automated without users' intervention
2. automated with users' intervention on command variable
3. users' manual operation
4. **user's manual operation, guided by feedback from the automated control system**

You never can control comfort!



Learnings and Recommendations

on the CONTROL OF INDOOR CLIMATE SYSTEMS IN ACTIVE HOUSES

Recommendation 1
Single Room Control Heating Systems

- *Install single room controllers,*
  - *reactive to passive solar gains*
  - *allowing different setpoint temperatures for specific rooms*
- *Do not link the flow temperature to the outside temperature any more*

Recommendation 2
Automated Sunblind Control

- *Automated sunblind control*
  - *is a must-have during summer*
  - *should be turned off in spring, autumn and winter*
- *Close the sunblinds*
  - *at 150 to 200 W/m², equaling 17·000 to 23·000 lux·*
- *Avoid short time intervals of operation·*
  - *Introduce a hysteresis of at least 30 W/m² and a time-lag of at least 15 minutes before reopening the sunblinds*

Recommendation 3
Automated windows for comfort ventilation

- For hygienic ventilation
  - automated windows at a level of 2m and higher, low but wide, top hung or pivot hung
- Don't panic with actuators' noise
- Avoid short time intervals of operation·
  - Introduce a hysteresis of minimum 200 ppm CO2 and a time-lag of at least 60 minutes before reopening the ventilation windows

Recommendation 4
Automated Night Ventilation

- Night ventilation together with sunblind control has definitely to be automated
- In many climates, even simple time-dependent control will do the job
- Central and North European people do not seem to be trained to intuitively use Ventilative cooling

Recommendation 5
regarding Hybrid Ventilation Systems

- Strictly define a switchpoint between periods of natural window ventilation and mechanical ventilation with heat recovery.
- A value of (one-hour-mean) between 10°C and 14°C outside temperature proved to be a good choice

Recommendation 6
User Information

- In case of automated windows and sunblinds user-information seems to be beneficial

Conclusion

It's about people!

AVC

Conclusion

It's about people!

AVC

Conclusion

It's about people!

.

AVC

Thank you !

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Institute of Building Research & Innovation

VELUX® VELUX A/S

Comfort in naturally ventilated offices

Comfort in sustainable buildings - AIVC 2014 - Poznan

Ivan Pollet - Renson Ventilation - Gent University

Content

1. Introduction
2. Cases
3. Conclusions

Global comfort in naturally ventilated buildings

Hygienic ventilation: low(er) air flow rates: IAQ

- Natural supply by means of window ventilators

And/Or

Ventilative cooling: high air exchange rate

- By means of openable windows or great ventilators

Both can be supported mechanically

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RENSON® Creating healthy spaces

First goal: optimal indoor climate - comfort

Thermal comfort

- T, RH, v, DR
- Season: heating – cooling

Indoor air quality (IAQ)

- Physical elements
- Chemical elements
- (Micro)biological elements

Visual comfort

- Daylight factor
- Glare
- Outside view

Acoustic comfort

- Noise level
- Acoustic absorption

"We don't build to consume less energy"

Sustainability assessment methods (Breeam, Leed, Active house, …)

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Global comfort in naturally ventilated buildings

Specific benefits

- Interaction with outdoors (air, temp, daylight, …)
- Natural environment - less system 'pollution'
- Less space loss for technics
- Simple to understand

Specific attentions

- Prevention of - draught in winter
  - overheating
  - outdoor noise
  - rain entrance
- Easy manual operation / optimised automation

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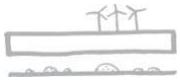

Content

1. Introduction
2. Cases:
   - Renson offices (Belgium)
   - Adeo offices (France)
   - Profound office renovation (Belgium)
   - Nijeboer-Hage offices (The Netherlands)
3. Conclusions

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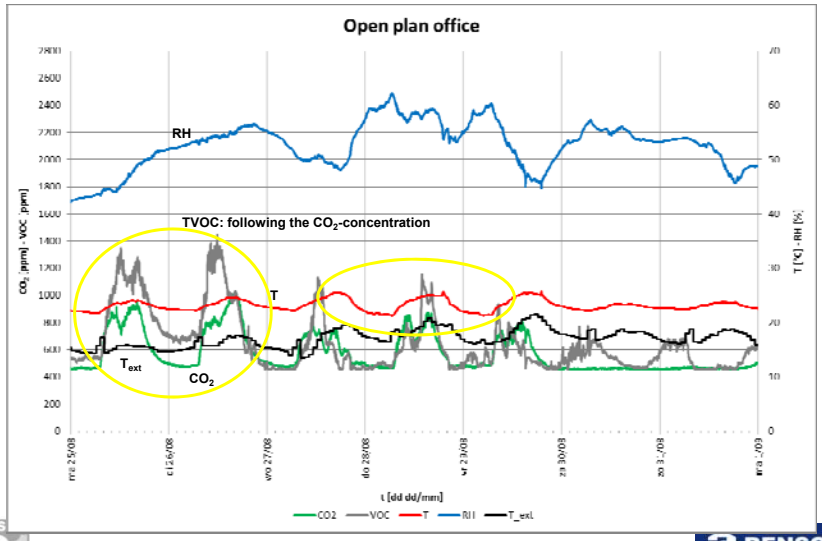
Renson offices (Waregem – Belgium, 2002)

- Hygienic passive stack ventilation (fan assisted)
- Passive stack nightcooling: air exchange rate: 6 h^{-1}
  - Summer of 2006: 76 nights in operation (20 %)
- Combined with external adjustable solar shading and exposed ceiling as thermal mass

Indoor climate: T, RH, CO_2 and TVOC



RENS 10

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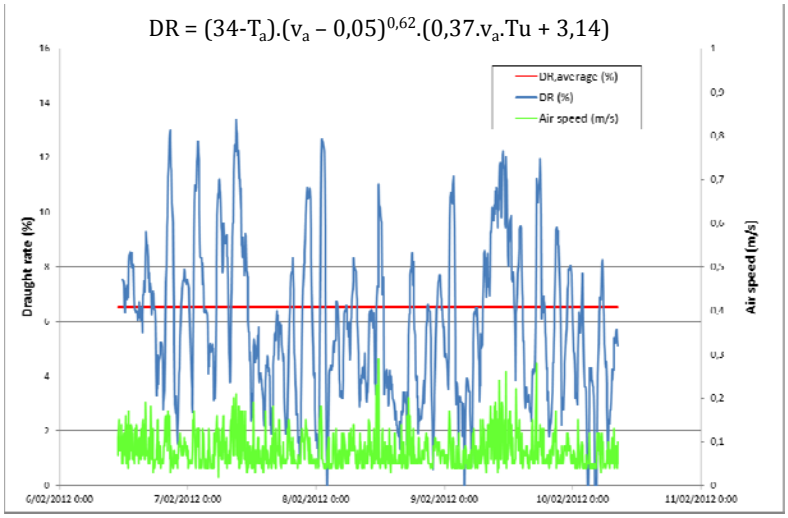
Creating healthy spaces

Indoor climate: draught rate – air speed (h = 1,1 m)

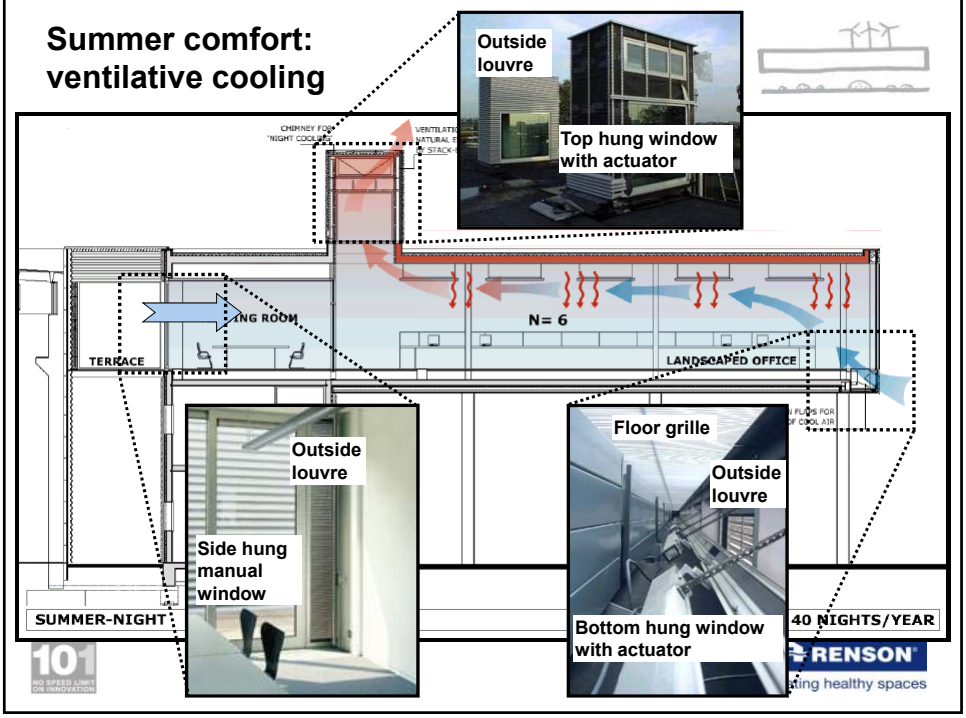
$$DR = (34\text{-}T_a).(v_a - 0{,}05)^{0{,}62}.(0{,}37.v_a.Tu + 3{,}14)$$



RENSON 10 NO SPEED LIMIT ON INNOVATION

RENSON® Creating healthy spaces

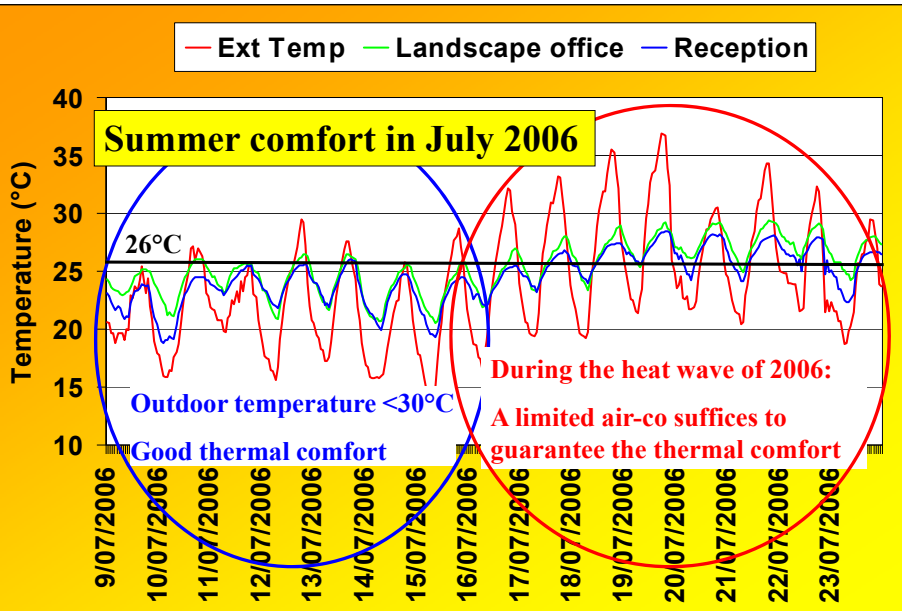
Summer comfort: ventilative cooling



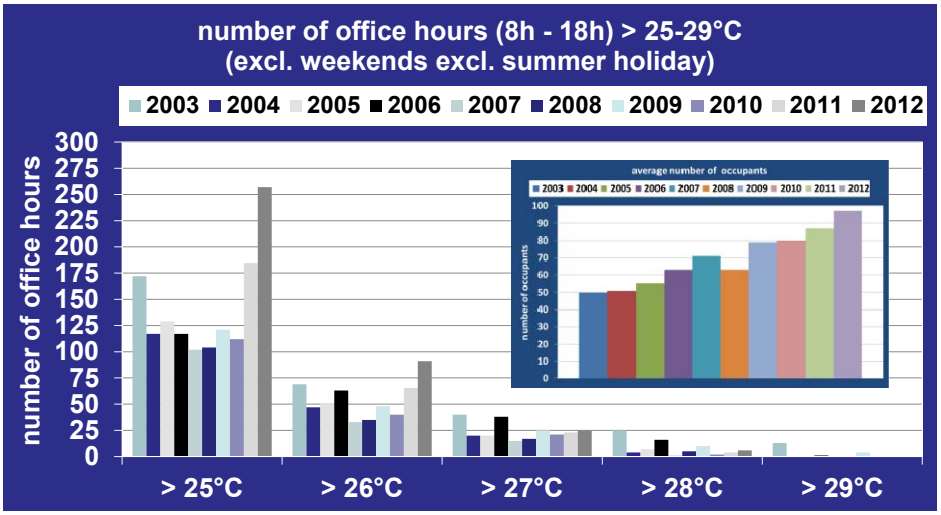
RENSON 10 NO SPEED LIMIT ON INNOVATION

RENSON® ing healthy spaces

Summer comfort



Summer comfort



- Number of occupants more than doubled
- Number / power of computer(screens) strongly increased

Acoustical comfort: insulation and absorption

- **Acoustic air supply**

Sound pressure level (SPL) in the offices: 45 to 50 dB(A)

RENSON 10 NO SPEED LIMIT ON INNOVATION

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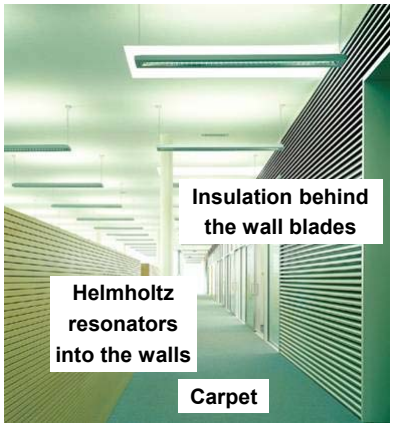
Acoustical comfort: insulation and absorption

Concrete ceiling

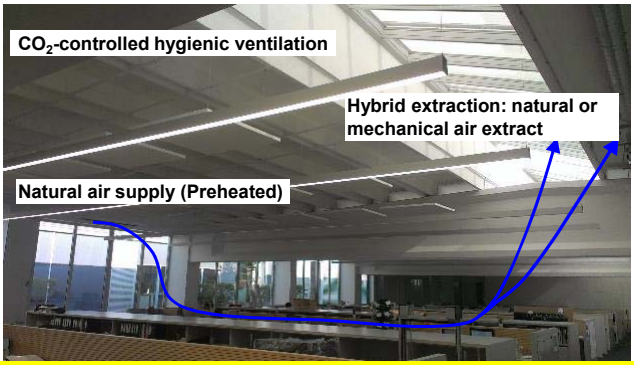


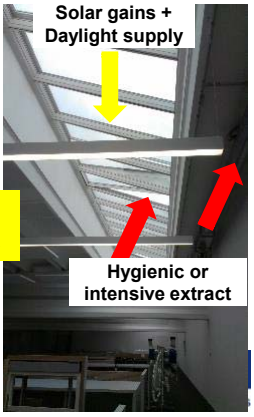
Half open ceiling covered by acoustic absorption profiles or panels

- o thermal mass available
- o acoustic absorption
- o integration of lightings, loudspeakers, ...

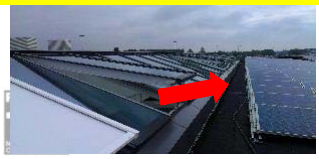
RENSON 10 NO SPEED LIMIT ON INNOVATION

Renson real life laboratory (Waregem – Belgium, 2014)

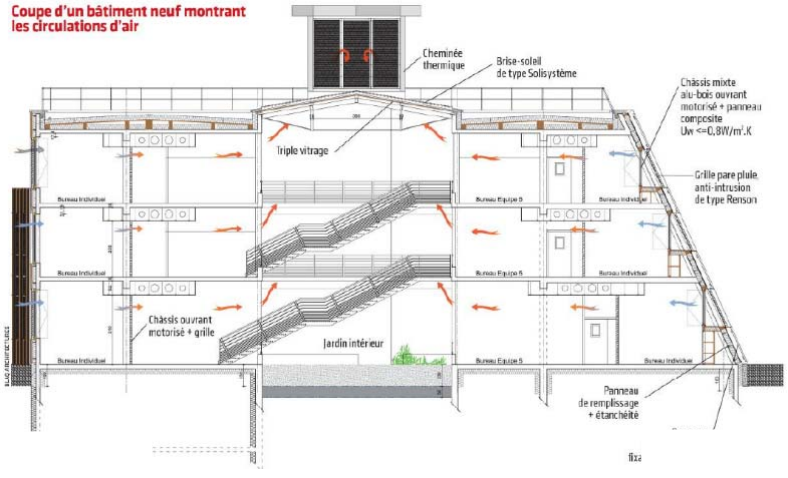




Further research: - Optimisation of BMS and Indoor climate monitoring
- Evaluation according to Active House specifications

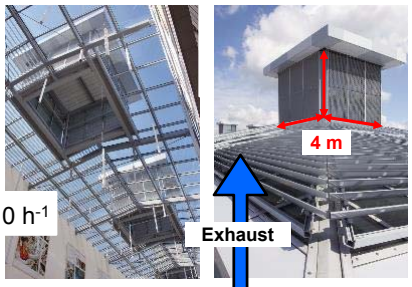


Adeo new offices (Lille – France, 2012)



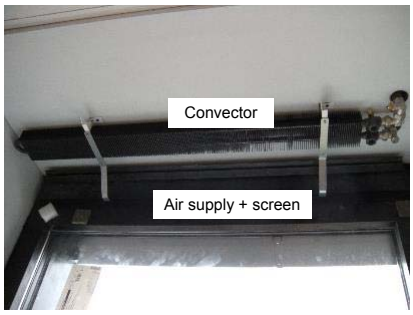
Adeo new offices (France, 2012)

- Insulation: 23 cm MW in walls, 40 cm EPS in roof, triple glazing
- Retractable solar blades
- Passive stack ventilative cooling: 4 – 8°C ↓ / 10 h^{-1}
- Thermal mass: concrete
- Daylight control
- Renewable energy: photovoltaics and solar collector



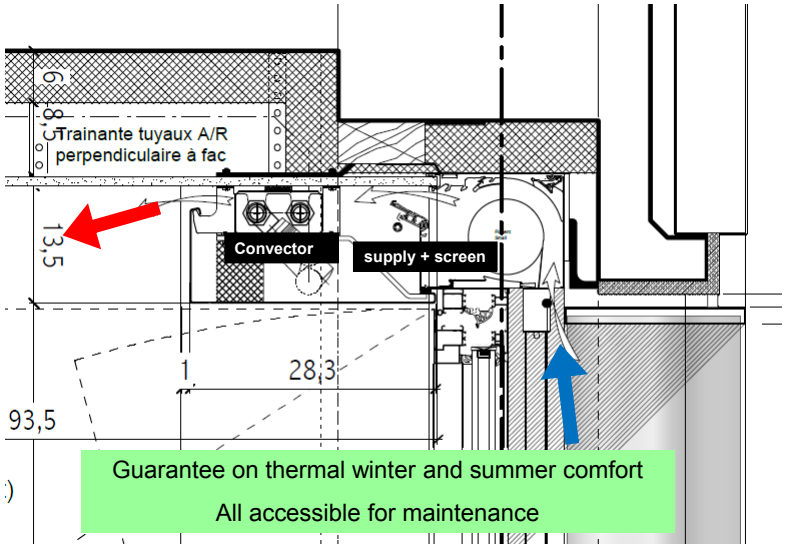
Profound office renovation (2014, Brussel)

- **Hygienic ventilation**: natural air supply with preheating
  → hot water convector 5 x 10 cm - 40/35°C
  demand controlled mechanical extract
- **External solar screens**



Source: JCX- CIT Blaton - Architectes associés - Cenergie

Natural air supply – preheating / solar screen



Source: JCX- CIT Blaton - Architectes associés - Cenergie

Natural air supply – preheating / solar screen

Source: JCX- CIT Blaton - Architectes associés - Cenergie

Offices Nijeboer-Hage (Assen – NL)

First field measurements – lessons

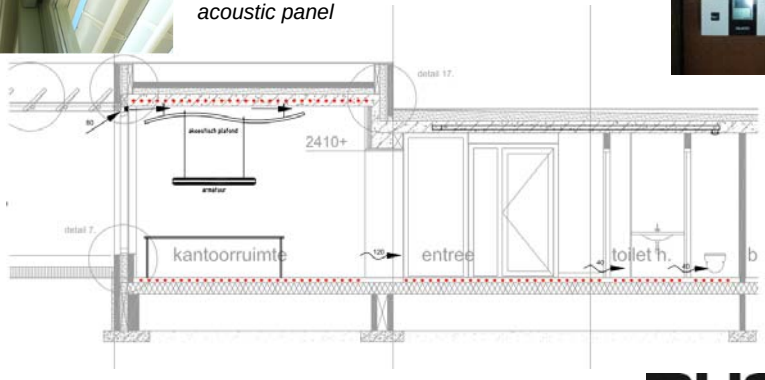
ir. Atze Boerstra, BBA Binnenmilieu
ir. Arjen Raue, BBA Binnenmilieu en Universiteit Utrecht

Foto's: Nijeboer-Hage

DUCO Ventilation & Sun Control

Hygienic ventilation: natural supply - mechanical extract

CO_2 controlled air supply above acoustic panel



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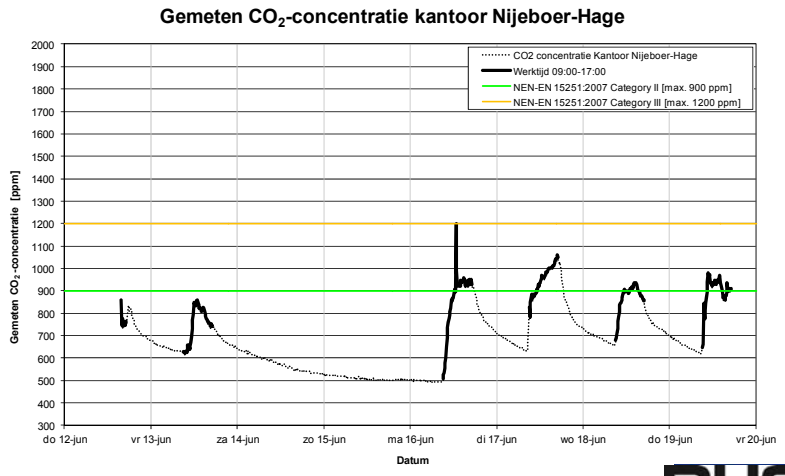
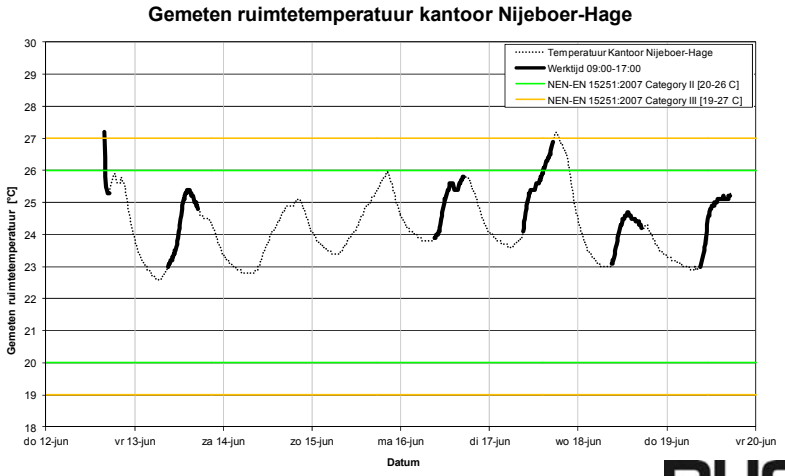
Measured CO_2-concentration in office



DUCO Ventilation & Sun Control

Measured air temperature in office



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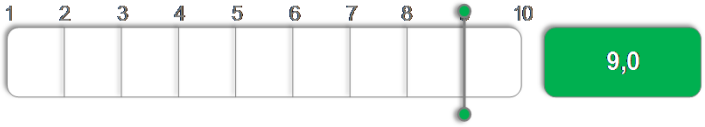
Questionnaire

Indoor climate level



Building Symptom Index (5)

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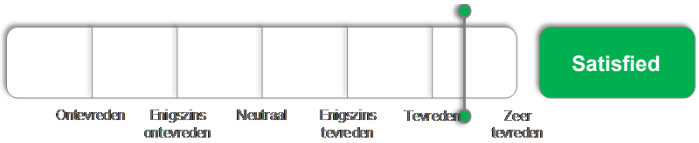
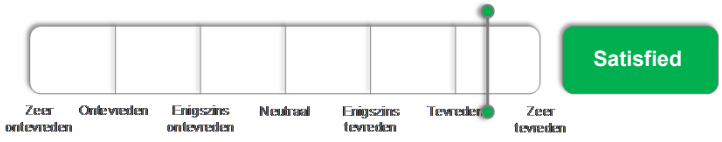
Questionnaire

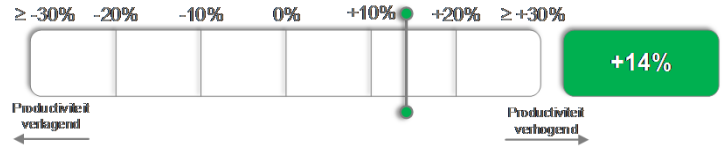
Satisfaction IAQ



Satisfaction Temperature



Self estimated productivity gain due to indoor climate



Lessons learned from users

Positive elements:

- *Fresh outdoor air without system contamination*
- *IAQ equal to outdoors*
- *No draught complaints*
- *No acoustic constraints*
- *System quite simple to understand and control*

Possible improvements:

- *Control of the air supply on wind pressure and CO_2*
- *More information on control panel*
- *More possibilities for summer nightcooling with outdoor air*

DUCO Ventilation & Sun Control

Recent scientific literature: natural ventilation…

Calibrated CFD simulation to evaluate thermal comfort in a highly-glazed naturally ventilated room

Magdalena Hajdukiewicz [a,b,c,*], Marco Geron [a,b,c], Marcus M. Keane [a,b,c]

[a] Informatics Research Unit for Sustainable Engineering (IRUSE), Galway, Ireland
[b] Department of Civil Engineering, National University of Ireland Galway, Galway, Ireland
[c] Ryan Institute, National University of Ireland Galway, Galway, Ireland

Natural ventilation design: An analysis of predicted and measured performance

Annamaria Belleri [a, b, *], Roberto Lollini [a], Spencer M. Dutton [c]

[a] EURAC Research, Institute for Renewable Energy, Bolzano, Italy
[b] Università degli Studi di Bergamo, Italy
[c] Lawrence Berkeley National Laboratory, Berkeley, CA, USA

Sensitivity of night cooling performance to room/system design: Surrogate models based on CFD

Kim Goethals [a,*], Ivo Couckuyt [b], Tom Dhaene [b], Arnold Janssens [a]

[a] Research Group of Building Physics, Construction and Services, Department of Architecture and Urban Planning, Faculty of Engineering and Architecture, Ghent University, J. Plateaustraat 22, B-9000 Ghent, Belgium
[b] Internet Based Communication Networks and Services Research Group, INTEC, IBBT-Ghent University, Gaston Crommenlaan 8 Box 201, B-9050 Ghent, Belgium

A simplified mathematical approach for modelling stack ventilation in multi-compartment buildings

Andrew Acred [a], Gary R. Hunt [b,*]

[a] Department of Civil and Environmental Engineering, Imperial College, London SW7 2AZ, UK
[b] Department of Engineering, University of Cambridge, Cambridge CB2 1PZ, UK

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Conclusions

- **Natural ventilation = indoor climate follows more outdoors**
  = accepted by the occupants, if possibilities to prevent discomfort:
  - prevention of draught
  - acoustic air supply if needed
  - limitation on overheating / daylight control
- **Manual control** suffices, if devices easy accessible/understood by user
- **If automated**: adjustment and follow up of control system is crucial
- Need on **practical design rules**

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Thanks for your attention

Human comfort in Active Houses, learning's from ModelHome2020

Moritz L. Fedkenheuer (Humboldt-Universität zu Berlin)
moritz.fedkenheuer@sowi.hu-berlin.de
35th AIVC conference

VELUX ModelHome 2020

6 houses
5 countries

6 families
5 monitoring teams
3 years

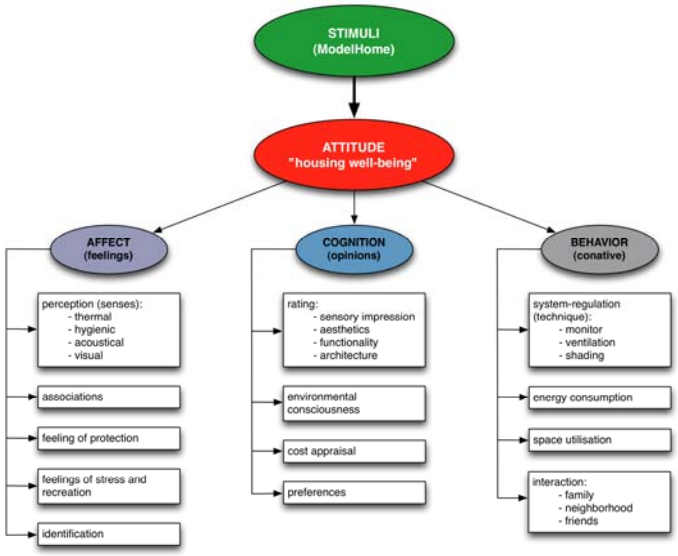
Is it possible to build sustainable houses, that fulfill the growing demand on energy-saving technology and also create an increase on the living comfort?

Monitoring by engineers

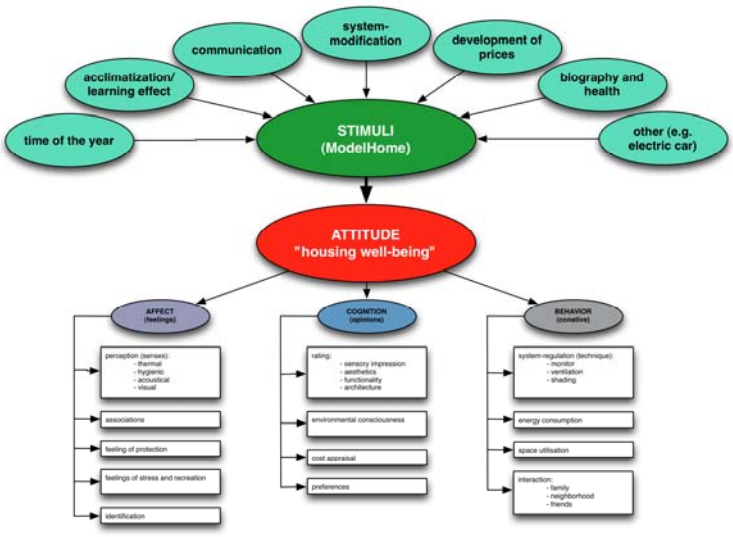
Monitoring by social scientists

„LichtAktiv Haus“ in Hamburg, Germany

research interest: housing well-being (a multi-dimensional construct)



Dynamic model of housing well-being



General findings

- Very positive effect on mood, health and productivity
- Satisfaction was mainly contributed by daylight, fresh air and space
- Overall comfort and indoor climate were mostly rated very good
- But: abrupt changes in temperature may course problems
- Sometimes manual interventions were needed
- Habituation effect: integrated the technique into daily routine
- Positive impact on environmental consciousness and energy saving behaviour (no rebound effect)
- Living preferences changed (daylight and sustainability became important)

Learnings

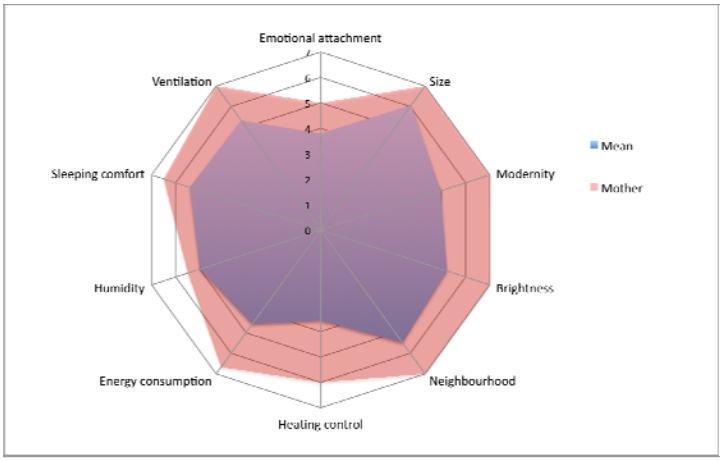
- Sustainability and livability (can) go great together
- Daylight & fresh air have an essential effect on mood and health
- People are not always aware of their needs (preferences change)
- Technique can encourage environmentally friendly behaviour
- Automation can save labour and increase the comfort
- But: no technical sensors can “feel” the residents needs
- Technique is adoptable
- “Less is more” in regards to the technique (acceptance!)
- People should retain control (overriding, turn off)
- Support, support, support

What’s next?

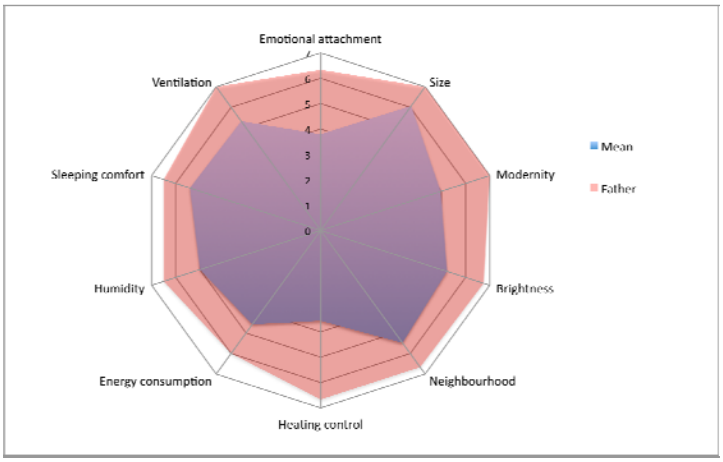
10 main dimensions of housing well-being (first draft)

- Factor 1: Emotional attachment
- Factor 2: Size
- Factor 3: Modernity
- Factor 4: Brightness
- Factor 5: Neighbourhood
- Factor 6: Heating control
- Factor 7: Energy consumption
- Factor 8: Humidity
- Factor 9: Sleeping comfort
- Factor 10: Ventilation

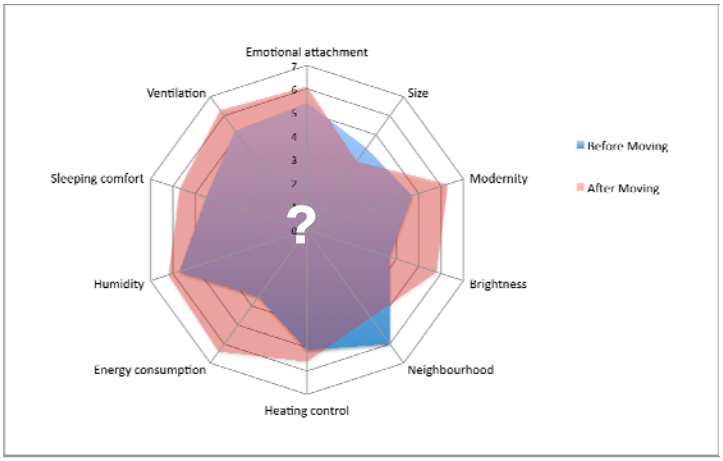
Implementation of the housing well-being scale (example 1)

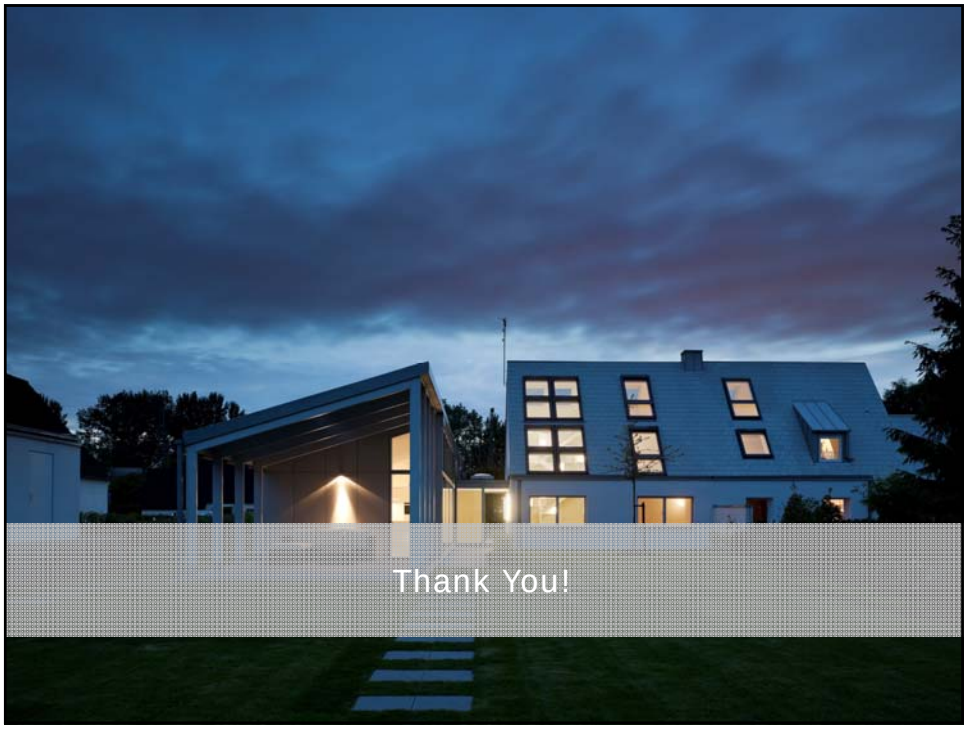


Implementation of the housing well-being scale (example 2)

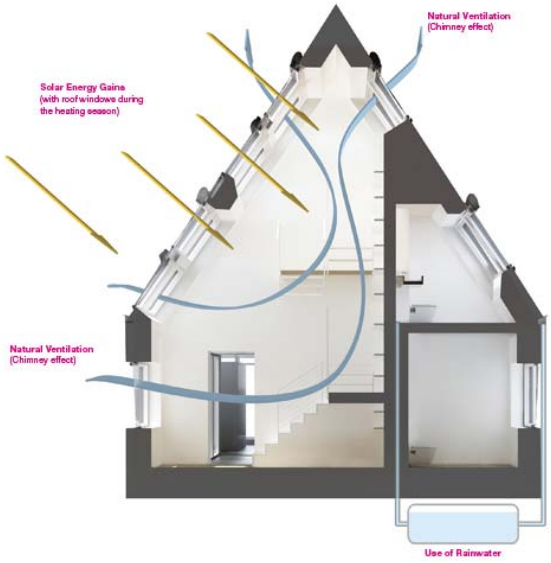


Implementation of the housing well-being scale (tbc)

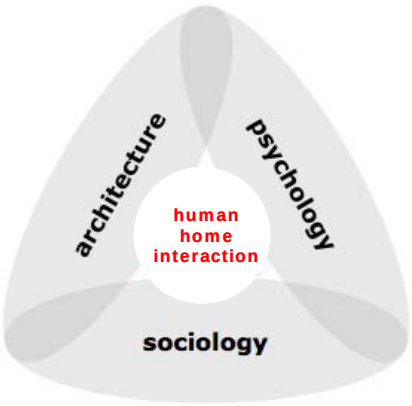




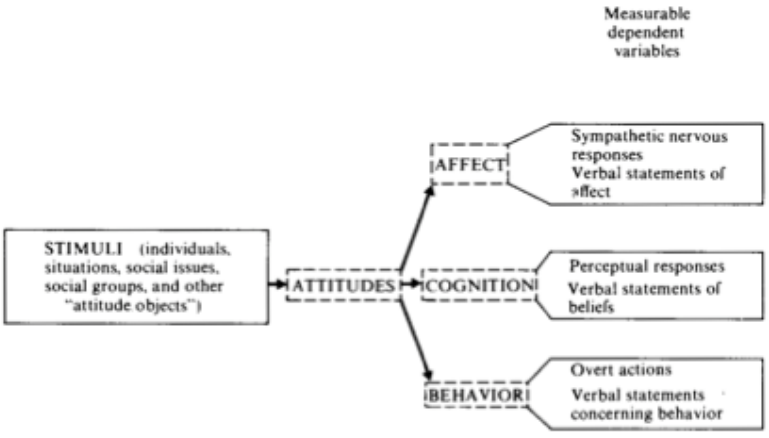
Natural ventilation



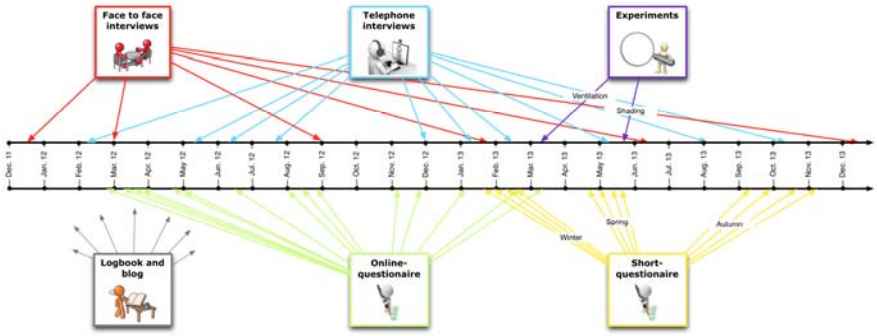
research interest?
human home interaction & housing well-being



The conceptualization of housing well-being as a multi-dimensional construct



The research methods we used (one example – “LichtAktiv Haus”)



Fresh air as a source of energy

- „I think the space and light and natural air is the biggest thing and has the biggest impact on us.“ (father, 3-bed-UK)
- „For me it’s the fresh air that is so important. It keeps me awake, it keeps me alert, it makes me feel more energised.“ (mother, 4-bed-UK)
- „The feeling of fresh air kicks in“ (mother, D)

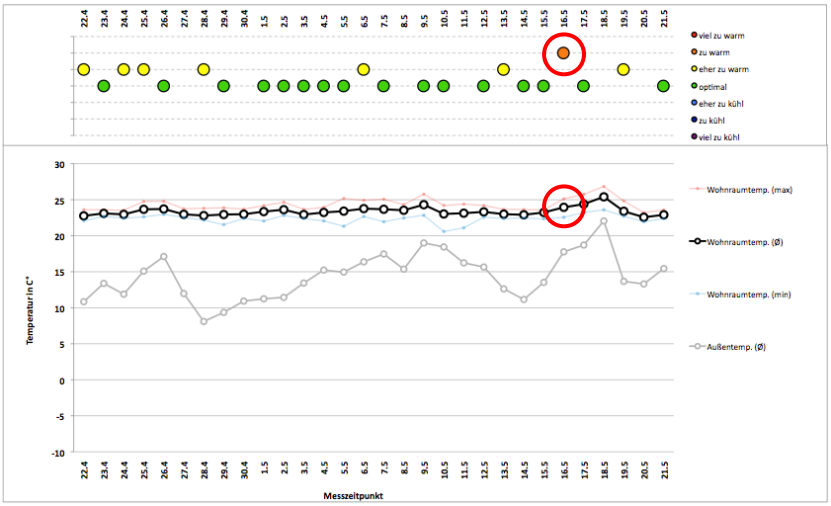
Daylight as a new favourite

- „It is definitely something I would look for before moving to a new house.“ (mother, 4-bed-UK)
- „What we are enjoying the most is the intensity of daylight and the fresh air.“ (father, D)
- „When I go back into the office, I suffer from the neon lights. I am so used to natural light that just two hours under artificial lighting stresses me out.“ (mother, F)

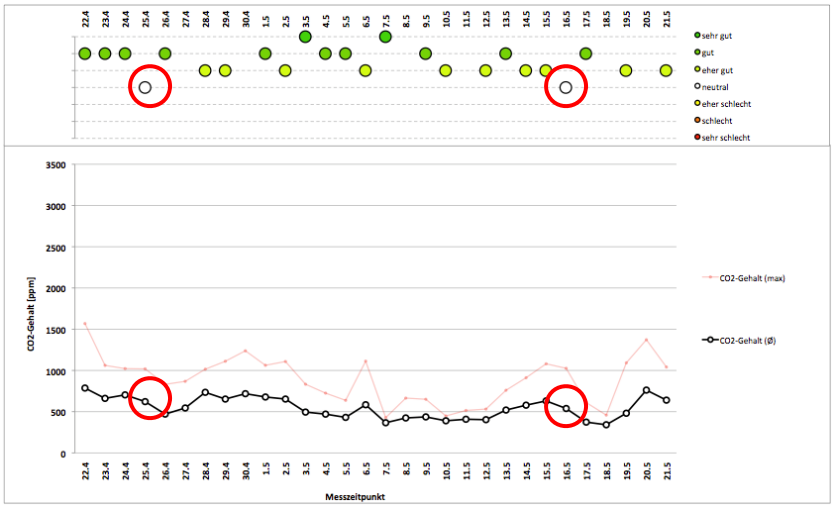
Good for health and recreation

- „Our son, since he was 1, suffered from ear infections. He hasn’t had one since we’ve been here.“ (mother, 3-bed-UK)
- „Healthwise while we’ve been here we haven’t had the colds and the coughs we’d usually have before. I think it has to do with the air quality and the daylight.“ (mother, 4-bed-UK)
- „The improvement in his health is a lasting one… No attacks, no Ventolin.“ (mother, F)
- „Within the last two years no one of us was ever really sick. Before everyone was at least once in a year is seriously ill.“ (mother, D)

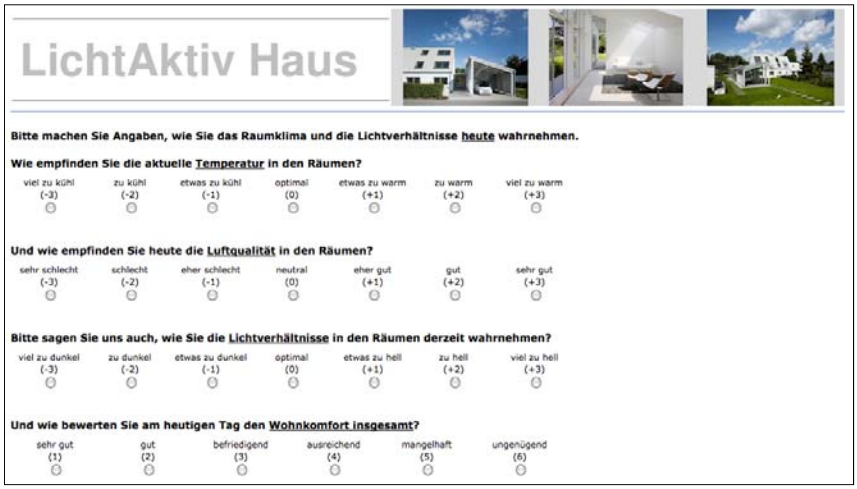
Temperature in spring (father)



Air-quality in spring (father)



The short version of the online-questionnaire for the LAH



LichtAktiv Haus

Bitte machen Sie Angaben, wie Sie das Raumklima und die Lichtverhältnisse heute wahrnehmen.

Wie empfinden Sie die aktuelle Temperatur in den Räumen?

viel zu kühl (-3)	zu kühl (-2)	etwas zu kühl (-1)	optimal (0)	etwas zu warm (+1)	zu warm (+2)	viel zu warm (+3)
○	○	○	○	○	○	○

Und wie empfinden Sie heute die Luftqualität in den Räumen?

sehr schlecht (-3)	schlecht (-2)	eher schlecht (-1)	neutral (0)	eher gut (+1)	gut (+2)	sehr gut (+3)
○	○	○	○	○	○	○

Bitte sagen Sie uns auch, wie Sie die Lichtverhältnisse in den Räumen derzeit wahrnehmen?

viel zu dunkel (-3)	zu dunkel (-2)	etwas zu dunkel (-1)	optimal (0)	etwas zu hell (+1)	zu hell (+2)	viel zu hell (+3)
○	○	○	○	○	○	○

Und wie bewerten Sie am heutigen Tag den Wohnkomfort insgesamt?

sehr gut (1)	gut (2)	befriedigend (3)	ausreichend (4)	mangelhaft (5)	ungenügend (6)
○	○	○	○	○	○

Factor analysis

		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
1.	I have a positive attitude toward my apartment*	.84									
2.	I feel at home in my apartment	-.94									
3.	I don't really like to be in my apartment	-.84									
4.	I have difficulties calling my apartment my home	-.96									
5.	My apartment is too small		-.90								
6.	My apartment meets my need for ample spacing		.90								
7.	I wish I had more room because every-thing is happening at one and the same spot		-.90								
8.	The technical equipment in my apartment satisfies my need for modernity			.80							
9.	My apartment is in need of renovation			-.66							
10.	The technical equipment in my apartment is up to date			.91							

Factor analysis

11.	In my apartment I can make full use of the natural light	.88			
12.	In my apartment I am too much dependent on artificial light	-.90			
13.	My apartment has too many dark rooms	-.78			
14.	On sunny days I can enjoy the light in my apartment to the full	.78			
15.	I have nice neighbours		.83		
16.	I feel accepted by my neighbours		.97		
17.	My neighbours discriminate against me		-.63		
18.	The temperature in my apartment can easily be adjusted according to my needs			.73	
19.	The control of temperature levels in my apartment is satisfactory			.91	
20.	During the winter months I have to adjust the temperature in my apartment quite often			-.52	

Factor analysis

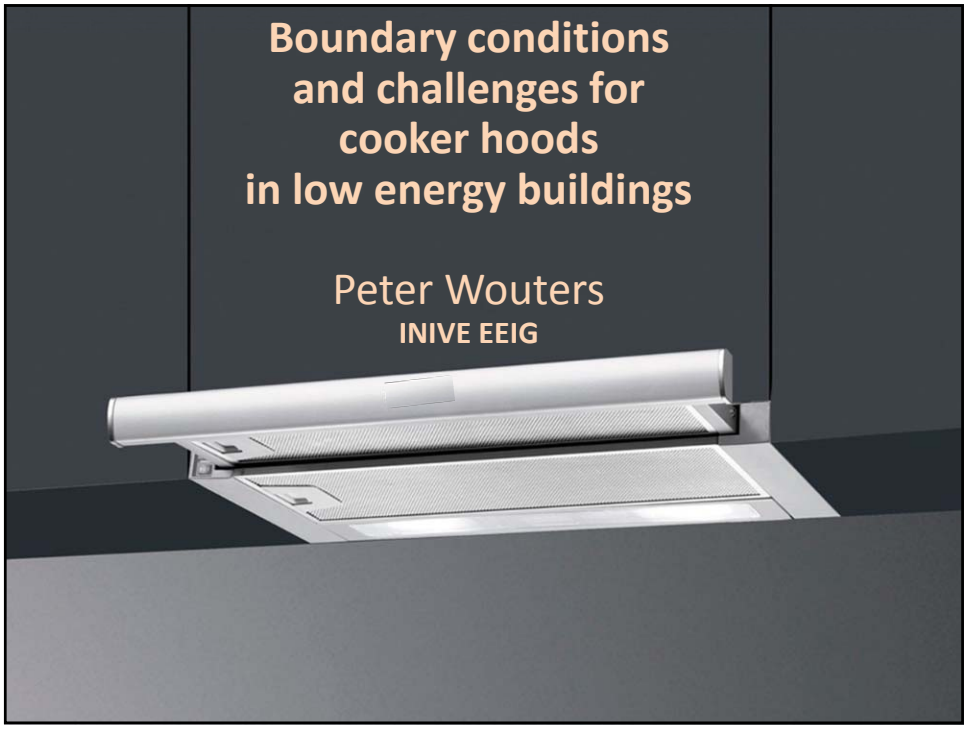
21.	I sometimes wonder if my apartment uses up too much energy	-.77				
22.	Cost for energy in my apartment is too high	-.78				
23.	Compared to other apartments, the cost for energy in my apartment is low	.84				
24.	My window pains often grow damp		.83			
25.	I have a problem with mould-infested rooms in my apartment		.76			
26.	Where I sleep there is too much light			-1.07		
27.	The sleeping environment in my apartment gives me a restful sleep			.52		
28.	My apartment can easily be ventilated				.96	
29.	I wish the temperature in my apartment could be controlled more automatically				-.65	

*The reference "apartment" is replaced for "house" in appropriate applications.

Table 1: HBWI factor and factor loadings (factor loadings < .50 not shown)

Agenda

- **Boundary conditions and challenges for cooker hoods in low energy buildings** by Peter Wouters, Belgium
- **Cooker hoods in the American context-Standardized method for Capture Efficiency** By Max Sherman, USA
- **Cooker hoods in the European standardization and legislative context** By Willem de Gids, The Netherlands
- **Design strategies for efficient cooking hoods** By Wouter Borsboom, The Netherlands



We want to know your opinion during this session…

Voting is open

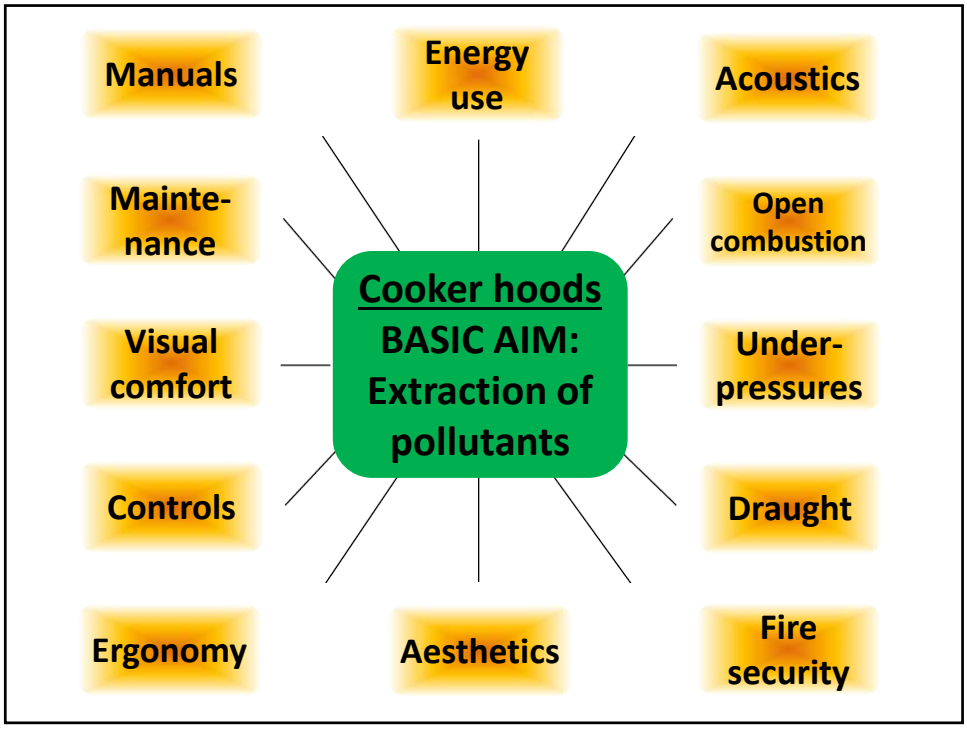
How many persons live in Poznan?

1. 100.000 persons
2. 250.000 persons
3. 500.000 persons
4. 1.000.000 persons

Voting is open

Are in your country cooker hoods common in new residential buildings?

1. Not at all
2. Seldom
3. Frequently
4. always



Voting is open

What is underpressure in an old apartment (200 m^3) if extraction cooker hood has air flow rate of 300 m^3/h and the apartment has an n_{50}-value of 6 h^{-1} (exponent 0.66 – internal doors open)?

1. 0.61 Pa
2. 2 Pa
3. 6.1 Pa
4. 20 Pa
5. 61 Pa
6. 200 Pa

The result…

- **n_{50} = 6 h^{-1}** in apartment of 200 m^3:
  →1200 m^3/h at 50 Pa
- Which pressure difference ΔP needed if extraction flow rate is 300 m^3/h?
- $(\Delta P/50)^{0.66}$ = 300/1200 = 0.25
  →DP = 6.1 Pa

What is specific for low energy buildings?

- Increased building airtightness
- Sometimes limited heating power (e.g. passive houses)
- Handling of cooker hoods in energy performance legislations? Heat recovery? …
- Recirculation cooker hoods within context of growing concerns about IAQ

Voting is open

What is the underpressure in an NZEB apartment (200 m^3) if extraction cooker hood has air flow rate of 300 m^3/h and the apartment has an n_{50}-value of 0.6 h^{-1} (exponent 0.66)?

1. 2 Pa

16% (4)
2. 20 Pa

20% (5)
3. 66 Pa

32% (8)
4. 132 Pa

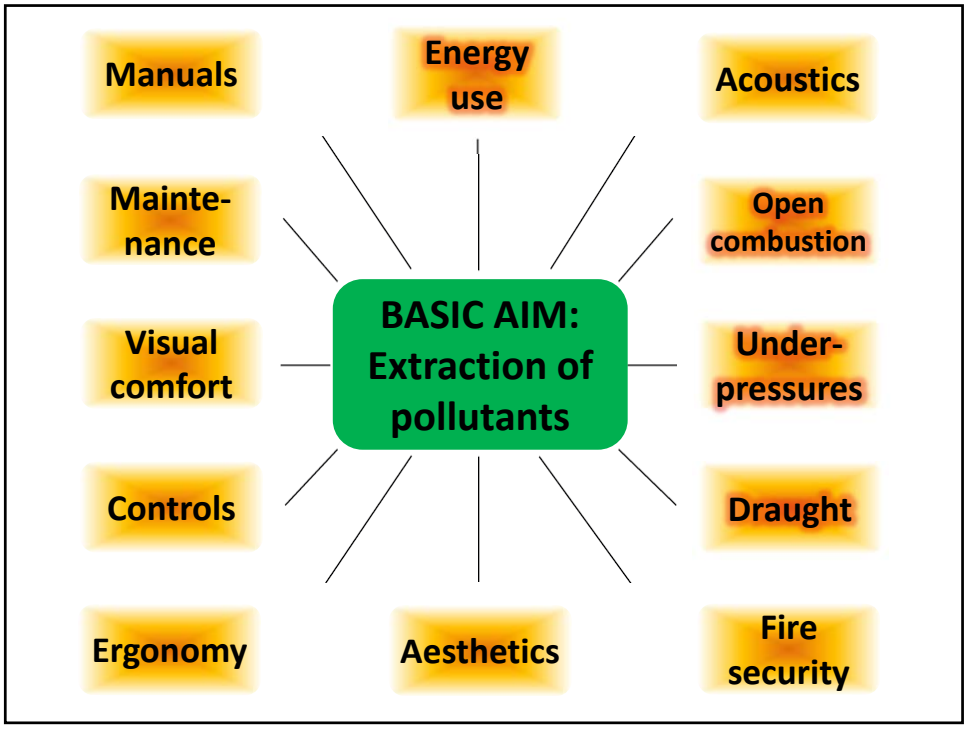
8% (2)
5. 200 Pa

24% (6)

Proefantwoorden

The result…

- n_{50} = 0.6 h^{-1} in apartment of 200 m^3:
  → 120 m^3/h at 50 Pa
- Which pressure difference ΔP needed if extraction flow rate is 300 m^3/h?
- $(\Delta P/50)^{0.66} = 300/120 = 2.5$
- **DP = 200.4 Pa**



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Cooker Hoods in American Context: *Recently LBL Efforts*

Max Sherman
Lawrence Berkeley National Laboratory

What do we want from our range hoods?

Voting is open

1. Remove visible smoke
2. Enhance kitchen aesthetics
3. Control odors & moisture
4. Low price
5. Remove pollutants from burners
6. Low noise
7. Low-power operation
8. Automatic operation

New Focus on Kitchens & Cooking

- Particles most important indoor source
- Kitchens are biggest source of pollutants in house
  - Cooking is only unvented combustion source we can't control
  - Every home has a kitchen
- Even electric cooking produces contaminants
  - Unless all you do is heat water with an induction cooktop
- Technologies exist that can make a difference

Kitchen Ventilation Simplified

PROBLEM:

- Cooking burners & cooking produce odors, moisture and pollutants

OPTIMAL SOLUTION:

- Effective, low-energy and quiet range (cooker) hoods that operate automatically as needed

What do we NOT want?

Voting is open

1. Fire
2. Draught
3. High Maintenance
4. Bad aesthetics
5. Depressurization/backdrafting
6. Higher energy bills

Range hoods can help!

Under cabinet

Microwave

Chimney

Downdraft*

What's missing? CE

- CAPTURE EFFICIENCY
  - Fraction of emitted pollutants removed by hood
  - Need simple definition
    - Complicated situation

LBL Research Activities

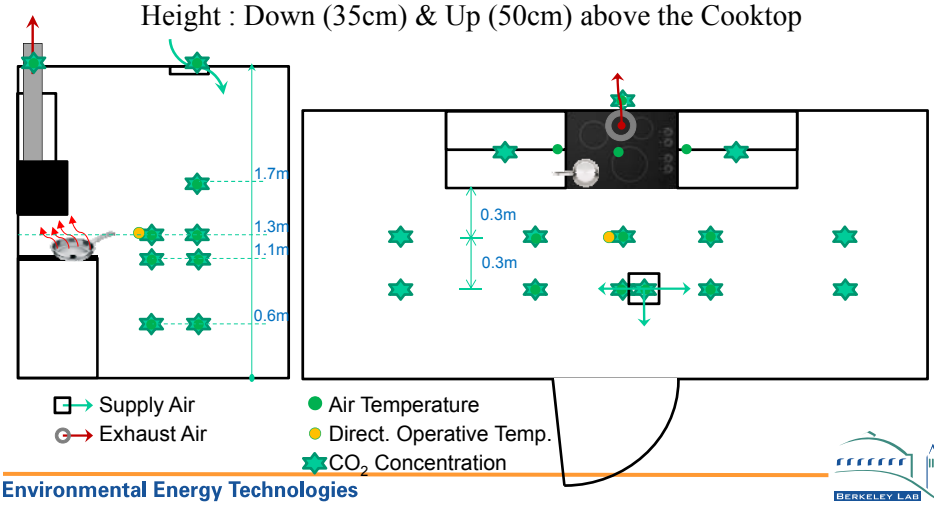
- Develop Method Laboratory Testing for Appliance CE
  - For use in ASHRAE 62.2
  - But an ASTM Standard which can be independently done
- Make Laboratory Measurements
  - To corroborate standard
  - To see range of performance

Test Method Development

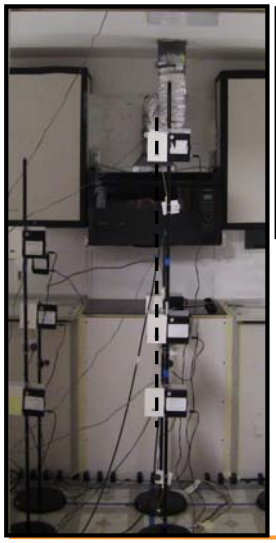
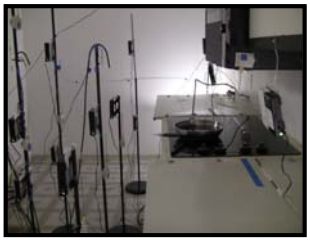
- Based on European Work
  - Uses “small” room with no extra ventilation
  - Uses tracer (nominally CO_2)
- No induced air movement
- First version will be wall-mounted only
- First committee draft waiting on LBL data

Room Setup and Measuring Points

Method (2.5m x 5m):
Range-Hood: Microwave
Exhaust Airflow: Low (200 m^3/h) & High (500 m^3/h)
Height : Down (35cm) & Up (50cm) above the Cooktop



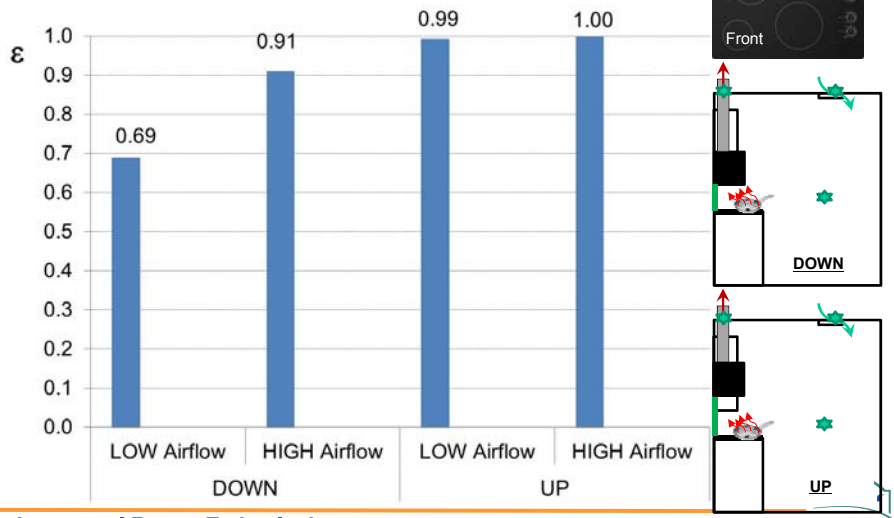
View of Room Setup and Measuring Devices

Environmental Energy Technologies

BERKELEY LAB

Capture Efficiency: Position and Airflow



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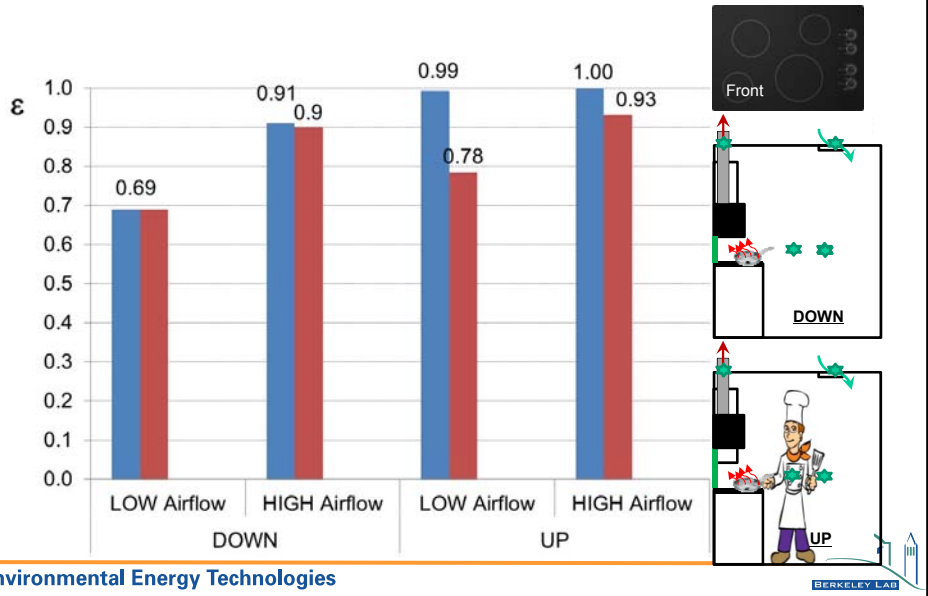

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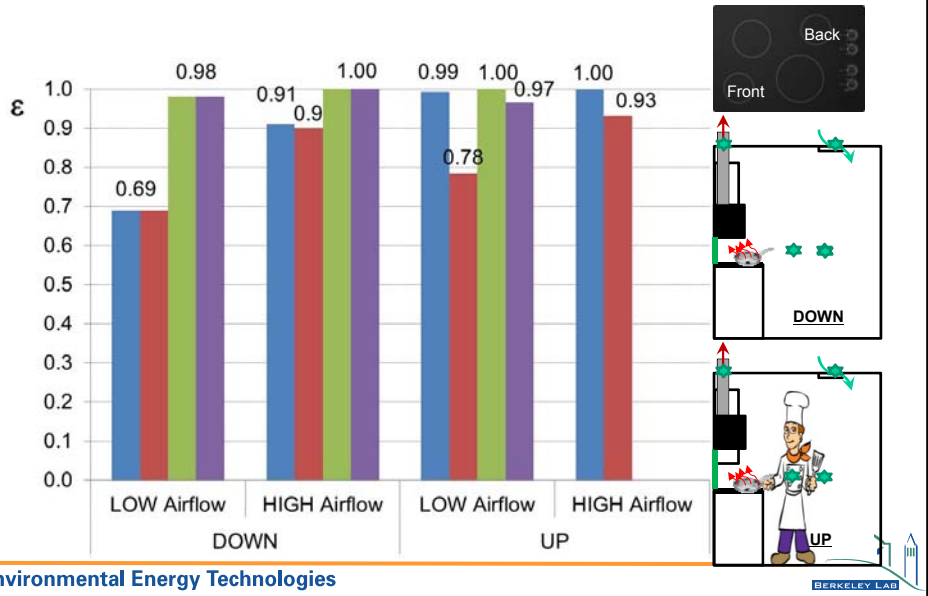


Environmental Energy Technologies

BERKELEY LAB

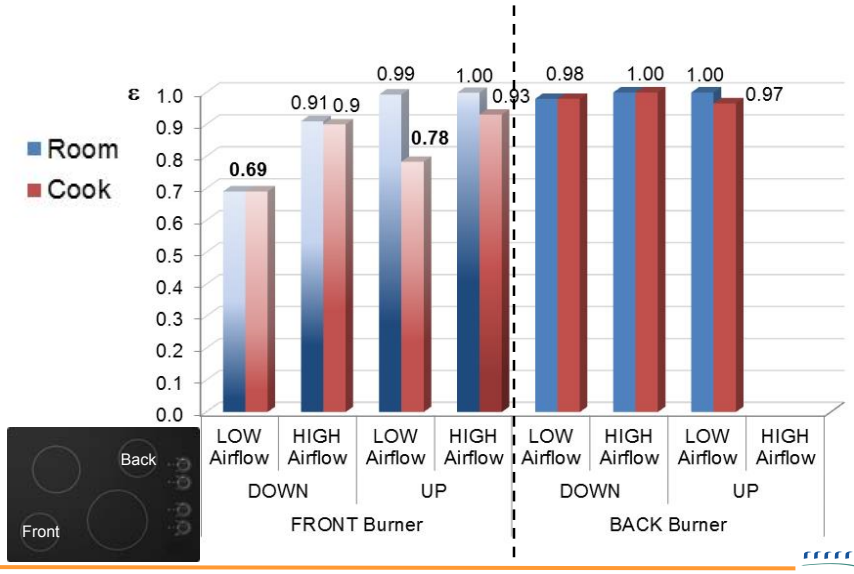
Preliminary Conclusions from Data

- Some things as expected
  - High flow better than low flow
  - Back burner better than front burner
- Interesting results when comparing DOWN vs. UP
  - UP mounting is better for *room*
  - UP mounting is worse for *cook* (especially from FRONT)
- Issues still be looked at
  - Temperature/size of source; combinations of locations
  - Other hood types

QUESTIONS?

Thank you

Capture Efficiency: Position and Airflow



Pollutants from burners and cooking

- Gas burners
  - Moisture & CO_2
  - NO_2 and formaldehyde
  - Ultrafine particles & CO
- Electric elements
  - Ultrafine particles
- Cooking
  - Ultrafine and fine particles
  - VOCs including acrolein
  - Moisture and odors

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

Experimental Evaluation of Pollutant Emissions From Residential Appliances Singer et al., LBNL-2897E

Dennekamp, Occup Environ Med 2001; 58:511–516

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

Compilation of PM2.5 Emission Rates for Cooking and Candles… Hu et al., LBNL-5890E

Measure CE for Hood

- Inject tracer at cooktop
- Measure concentration in inlet, hood exhaust and room
- Don't actually need flow rate or emission rate

$$CE = \frac{C_{exhaust} - C_{room}}{C_{exhaust} - C_{inlet}}$$

Testing Domestic Cooker hoods
Standards and European regulations

Willem de Gids
VentGuide NL

35st AIVC Conference
September 24/25 2014
Poznan
Poland

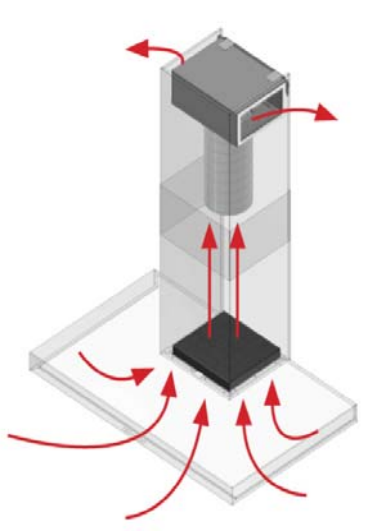
Cooker hoods

Cooker hoods = range hoods

- Kitchen hoods
- Dampfkappe
- Hottes de cuisine
- Afzuigkappen
- Dampkappen
- Wasemkappen
- Köksfläktar

Cooker hoods

Recirculation hoods



Definition according EU Eco design directive

'range hood' means an appliance, operated by a motor which it controls, intended to collect contaminated air from above a hob, or which includes a downdraft system intended for installation adjacent to cooking ranges, hobs and similar cooking products, that draws vapour down into an internal exhaust duct;

Important Properties

- Capture efficiency of:
  - Odours
  - Damp : water vapour
  - Fine particles: grease
- Noise level
- Energy use
- Safety aspects

Influencing factors on the hood efficiency…

- Hooddesign
- Flowrate
- Height above hob
- Adjacent cupboards
- Source strength
- Position of source
- Type of the souce
- Gas or keramic

ASTM F1704 commercial hoods

Schlieren technique for flow visualisation

New work item in CEN TC 156

Since April this year a new work item is approved in CEN TC 156 on commercial cooker hoods

Normally a working group started to make a proposal

French Standard NF E 51-704

Composants de ventilation mécanique contrôlée (VMC)

NF E 51-704

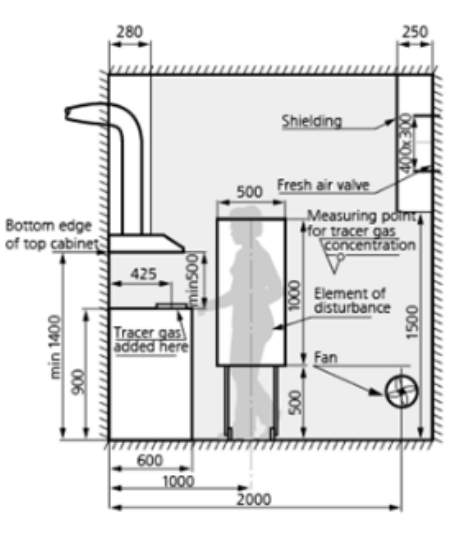
Novembre 1986

Code d'essais aérauliques et acoustiques des hottes de cuisine raccordées à un circuit VMC

		Page
1	OBJET ET DOMAINE D'APPLICATION	2
2	RÉFÉRENCES	3
3	CARACTÉRISTIQUES DES HOTTES DE CUISINE VMC	3
4	MÉTHODES D'ESSAIS DES CARACTÉRISTIQUES AÉRAULIQUES	3
4.1	Perte d'énergie mécanique	3
4.2	Détermination de l'efficacité de captation de la hotte	7
4.3	Procès-verbal d'essais — Présentation des résultats	8
5	CARACTÉRISTIQUES ACOUSTIQUES D'UNE HOTTE DE CUISINE	12
5.1	Bruit propre	13
5.2	Isolement acoustique normalisé D_{n10}	17

Swedish standard SS-EN 61591 A 11

Household range hoods and other cooking fume extractors - Methods for measuring performance



Comparison between the standards

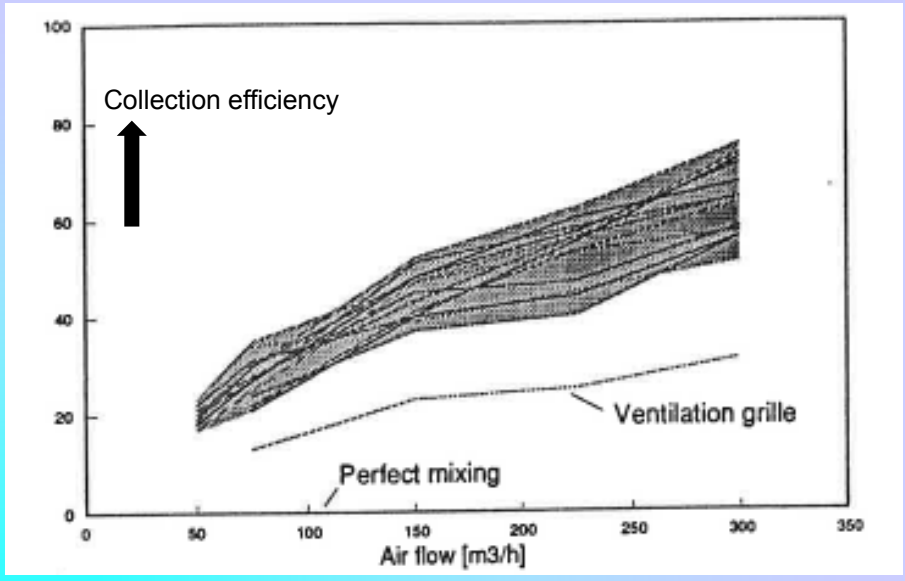
Item	NF E 51-704	SS 433-05-01
Interference device	not required	required
dimensions		width: 500 mm height: 1000 mm
position		500 mm above floor 750 mm from front wall
speed		0,5 m/s
frequency		0,125 Hz
Volume	25 m^3	23±1 m^3
Floor surface	almost rectangular	square
Dimensions cooker		
height	850 mm	900 mm
width	width of test object	600 mm
depth	600 mm	600 mm
Testing object	other description	at least 500 mm above cooker

Wouters BBRI 1991

Comparison between the standards

Cupboards		
lower cupboards	beside cooker	beside cooker
height	900 mm	same dimensions as cooker
width	600 mm	
depth	600 mm	
upper cupboards	beside hood	beside hood
height	700 mm	at least 850 mm
width	600 mm	600 mm
depth	300 mm	280 mm
Hot plate		
diameter	180 mm	220 mm
position	in function of test object	in function of test object
temperature	110±5°C	200±5°C
Air supply		
dimensions	350 x 350 mm	300 x 400 mm
position	middle of wall	2m above floor
screen	diameter 600 mm	width 800 mm
temperature supply air	18-25 °C with stability of 0,5°C	23±1°C
Mixing Fan		
dimensions	no specification	at least 200 mm
flow rate	500 l/s	at least 100 l/s
Tracer injection rate	3 m^3/h	0,85 l/s (≈ 3 m^3/h)
Injection time	10 min	at least 10 min

Wouters BBRI 1991



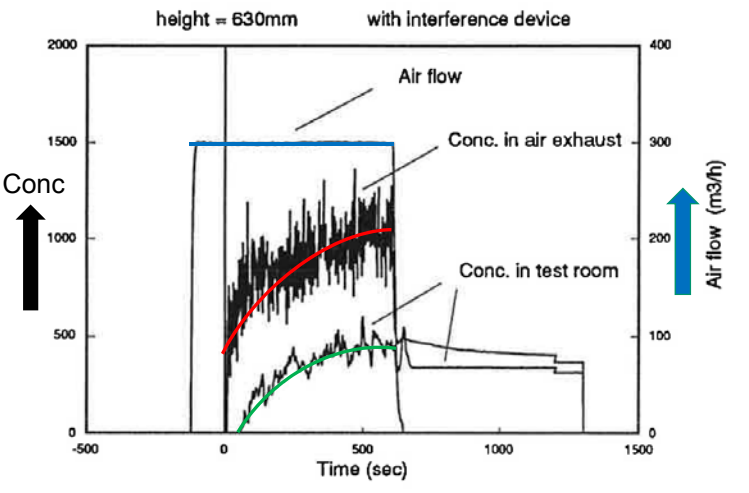
Wouters BBRI 1991

People moving in front of the hood have a negative effect on the efficiency
How big is this influence ?

Voting is open

1. Negative effect is 5% on the efficiency
2. Negative effect is 25% on the efficiency
3. Negative effect is 50% on the efficiency
4. Negative effect is 75% on the efficiency
5. Negative effect is 90% on the efficiency

Efficiency with interference



CETIAT J. Simon 1984

Efficiency including interference

Air flow [m³/h]	With interference device	Without interference device
450	0.74	0.97
300	0.66, 0.67	0.89, 0.90
200	0.46, 0.49	0.95, 0.96
100	0.38, 0.39	0.67, 0.71
'optimal' 300	0.94	-

Ratio interference/without ≈ 0.75
about 25 % reduction

CETIAT J. Simon 1984

Human nose

Logarithmic function

Concentration factor 10 lower equals to a factor of about two perception of the the odour

Eco-design directive

COMMISSION REGULATION (EU) No 66/2014

of 14 January 2014

implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for domestic ovens, hobs and range hoods

(Text with EEA relevance)

Information on the hood Eco design directive

Information for domestic range hoods

	Symbol	Value	Unit
Model identification			
Annual Energy Consumption	AEC_{hood}	X,X	kWh/a
Time increase factor	f	X,X	
Fluid Dynamic Efficiency	FDE_{hood}	X,X	
Energy Efficiency Index	EEI_{hood}	X,X	
Measured air flow rate at best efficiency point	Q_{BEP}	X,X	m^3/h
Measured air pressure at best efficiency point	P_{BEP}	X	Pa
Maximum air flow	Q_{max}	X,X	m^3/h
Measured electric power input at best efficiency point	W_{BEP}	X,X	W

Requirements from Eco design directive

Energy Efficiency Index (EEI_{hood}) and Fluid Dynamic Efficiency (FDE_{hood}) for domestic range hoods

	EEI_{hood}	FDE_{hood}
From 1 year after the entry into force	$EEI_{hood} < 120$	$FDE_{hood} > 3$
From 3 years after the entry into force	$EEI_{hood} < 110$	$FDE_{hood} > 5$
From 5 years after the entry into force	$EEI_{hood} < 100$	$FDE_{hood} > 8$

Requirements from Eco design directive

Calculation of the Energy Efficiency Index (EEI_{hood})

The Energy Efficiency Index (EEI_{hood}) is calculated as:

$$EEI_{hood} = \frac{AEC_{hood}}{SAEC_{hood}} \times 100$$

and is rounded to the first decimal place.

Where:

— $SAEC_{hood}$ = Standard Annual Energy consumption of the domestic range hood in kWh/a, rounded to the first decimal place,

— AEC_{hood} = Annual Energy Consumption of the domestic range hood in kWh/a, rounded to the first decimal place.

The Standard Annual Energy Consumption ($SAEC_{hood}$) of a domestic range hood shall be calculated as:

$$SAEC_{hood} = 0{,}55 \times (W_{BEP} + W_1) + 15{,}3$$

Eco-design directive on cooker hoods

Calculation of the Fluid Dynamic Efficiency (FDE_{hood})

The FDE_{hood} at the best efficiency point is calculated by the following formula, and is rounded to the first decimal place:

$$FDE_{hood} = \frac{Q_{BEP} \times P_{BEP}}{3\,600 \times W_{BEP}} \times 100$$

Where:

— Q_{BEP} is the flow rate of the domestic range hood at best efficiency point, expressed in m^3/h and rounded to the first decimal place,

— P_{BEP} is the static pressure difference of the domestic range hood at best efficiency point, expressed in Pa and rounded to the nearest integer,

— W_{BEP} is the electric power input of the domestic range hood at the best efficiency point, expressed in Watt and rounded to the first decimal place.

Annual energy for ovens, hobs and range hoods

- EU 2010 for Europe
  - 755 PJ primairy energy for ovens,hobs and range hoods
- Even when we assume only 5 % of that consumption is for range hoods: still ≈ 38 PJ
  - Energy consumption for a dwelling in NL
    - 2010 aprox 38 GJ
    - $38.10^{15}/38.10^{9} \approx 1.\ 10^{6}$ dwellings energy consumption
    - Using them correctly is still a necessity

Energy for cookerhoods per year

- **Time used** 1 hour a day
- **Flowrate** 100 dm^3/s or 360 m^3/h
- **Power** 200 W

- **Energy per year?**
  - Fan consumtion

    $E_{fan\ el}$ = Q * T= 200 W * 365 hour = **73 kWh**
  - Heating energy with Δt= 10K

    E_{air} = Q * T= m * c *Δt * 365 hour

    = 0,12 *1* 10 * 365 = **438 kWh**

Some examples ECO design

EEI_{hood}= (AEC/SAEC)*100

- AEC = energy use per year
  - For a hood with 360 m^3/h and 200 W one hour a day
    - =73 kWh/a
- SAEC = standard energy use per year
  - Defined as:

    0,55 ($W_{hood\ el}$+ W_{light}) +15.3

    = 0,55 (200 + 20) +15.3

    = 136.3 kWh/a

    EEI_{hood}= (AEC/SAEC)*100 = (73/136.3)* 100 = 53.6

Best available on the market EEI_{hood} = 22

Requirement five years after directive into use EEI_{hood} < 100

Some examples ECO design

- FDE_{hood}=100 (Q * P) / (3600*W)
- For a hood with 360 m^3/h and 200 W one hour a day
  - 73 kWh/a
  - Δp= 500 Pa

Best available on the market FDE_{hood} = ?

Requirement five years after directive into use

FDE_{hood} > 8

FDE_{hood}= 100 (Q * P) / (3600*W)

= 100 (360 * 500) / (3600*200) = 25

Some examples ECO design

Limitation of time above a flowrate of 650 m^3/h

$t_{limit} = 6000\ m^3/Q_{max}$ (in minutes)

t_{limit} is the time in minutes that the flow should be reduced to 650 m^3/h or lower

Example: Assume Q_{max} is 1000 m^3/h

→ $t_{limit} = 6000\ m^3/Q_{max}$

$= 6000/1000 = 6$ minutes

What is your opinion about the level of requirements for hoods in the ECO design directive?

Voting is open

1. Is it very high demanding requirements
2. Is it just normal level of requirements
3. Is the level of requirements conservative

Conclusions

- Efficiencies of range hoods are far from 100%
- Efficiencies of range hoods in practice are between 50 to 75%
- Standards for testing are at national level
  - These standards are quite different
- Important seems to be the interference
- There is a new work item in CEN TC156 for cooker hoods related to energy use
- The EU ECO design directive gives requirements
  - But it seems there are rather conservative

Thank you for your attention

Design strategies of efficient cooking hoods

Bas Knoll, Wouter Borsboom

Voting is open

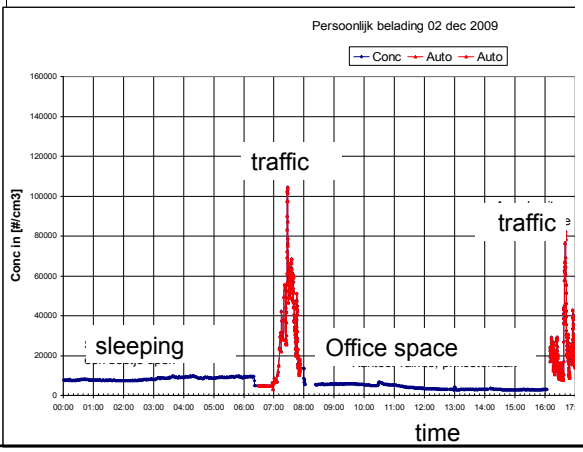
Do you think that there are several types of cooker hoods on the market which balance supply and exhaust?

1. **A lot of solutions**
2. **Several**
3. **A few**
4. **None**

TNO innovation for life

Why do we need a cooker hood?

› **Particle matters: Example a day of TNO-er**



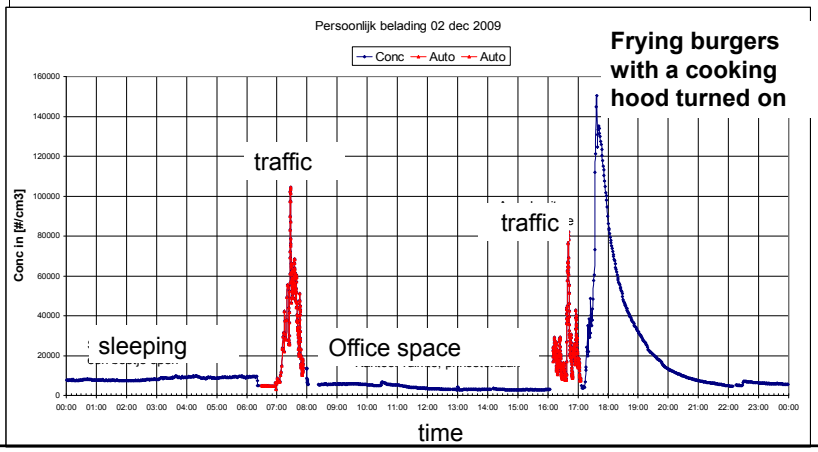
Voting is open

What do you think is the effect of cooker hood efficiency on indoor air quality

1. **There is not a very significant effect**
2. **There is some effect but other sources which are more dominant**
3. **It has about the same impact as other sources**
4. **It has a mayor effect on the indoor air quality**

Why do we need a cooker hood?

- **Particle matters: Example a day of TNO-er**



Other reasons to ventilate

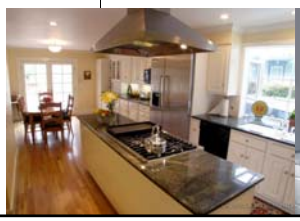
- NO_x, CO, CO_2, VOC like acrolein
- Odour
- Heat
- Moisture (micro-biological contaminants)

TNO innovation for life

Minimize dispersion flow and characterize it

This depends on:

- Type of heat source, e.g. gas burning,;
- Pan type (saucepan, frying pan, pressure cooker),
- Status of the cooking or frying process and typical temperature
- Free flow space (height to cooker hood, closed back), flow conduction and local flow disturbance (nearby windows, doors and pathways);
- Cook behaviour (stirring, temperature control, lid use, moving along).



TNO innovation for life

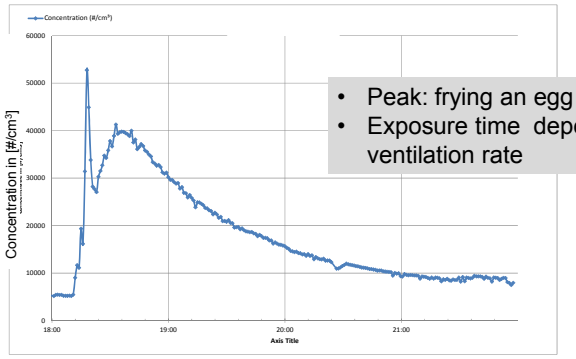
Minimize dispersion flow and characterize it

- The first step to control contamination: minimize the production rate and dispersion forces by altering processes and geometry .

Closed versus open

- For the design of an effective cooker hood, the flow characteristics needs to be measured in critical situations.

Local capture is preferred over dilution



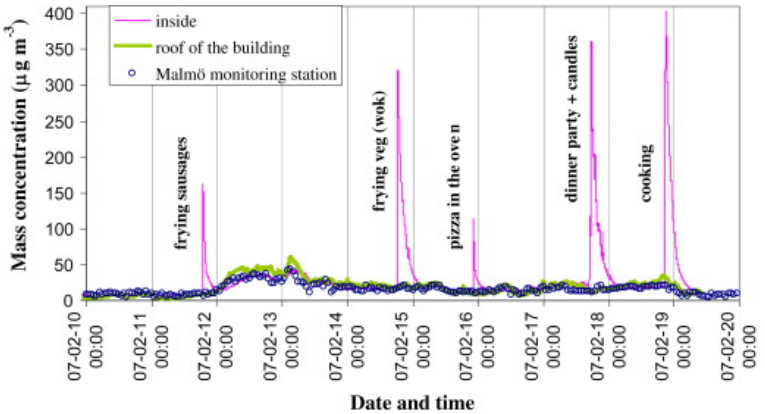
- Peak: frying an egg
- Exposure time depends on ventilation rate

Source: TNO, At home in the town of Ede, NL 1 November 2012

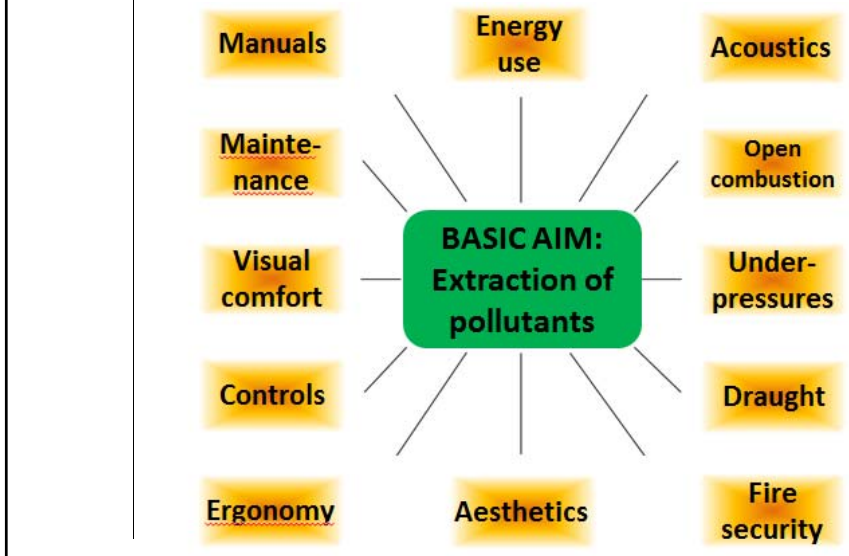
5.000-50.000 #/cm^3

In very airtight dwellings what happens in this situation with CO_2 demand control?

Apartments with 0,3 h^{-1} ventilation, 12h higher exposure to PM 2,5



Source: DustTrak readings indoors in the apartment and on the roof of the building together with PM 2.5 mass concentration measured by TEOM at the monitoring point at the roof level in Malmö city centre.
A. Wierzbicka et.all



Proposal of specifications for user-friendly cooker hoods (comfort)

Aim for 100% reduction

90% reduction of odour concentration reduce odour complaints by maximal half.

A threshold value of 40 dB of Noise is proposed.

TNO innovation for life

Improve local capture efficiency: Redesign the cooker hood

- minimize the capture distance (hood height),
- maximize the overhang,
- move the suction slots to the critical contaminant escape spots at the perimeter,
- avoid large internal pressure drops

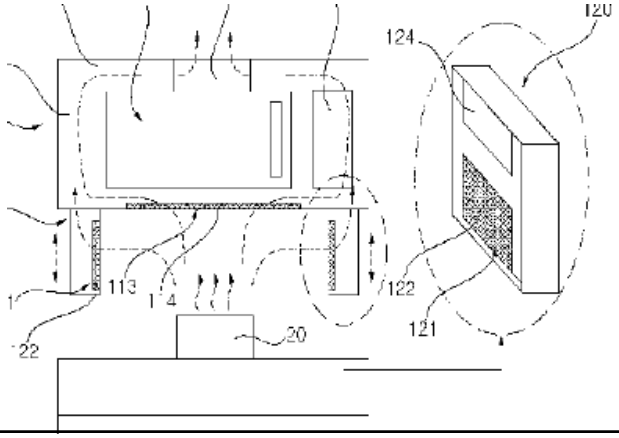
Covered by Ecodesign

100 % capture efficiency and 30% less flow due to optimisation **Vianen**

TNO innovation for life

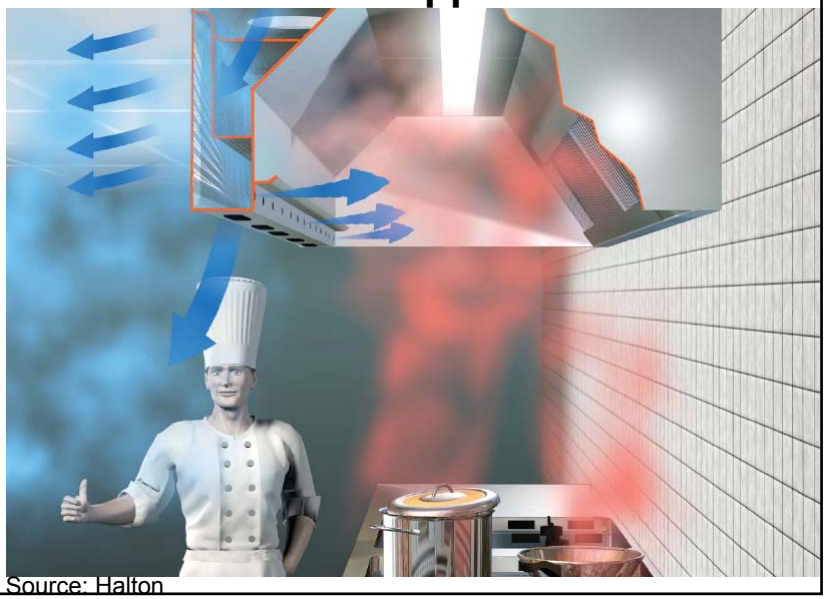
Improve local capture efficiency: enclosure

- Enclose the contaminant flow by conducting plates
- Direct it to the hood by support flows.
- Automatically close down openings when no activities (like stirring) are ongoing;



TNO innovation for life

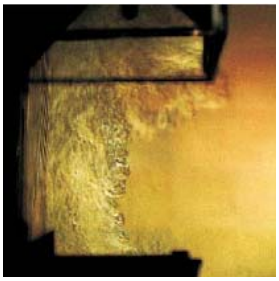
Cooker hood with support beams



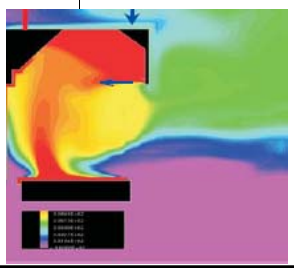
Source: Halton

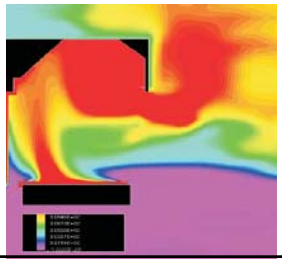
TNO innovation for life

Cooker hood with support beams (Slieger/CFD)



With / without support beams



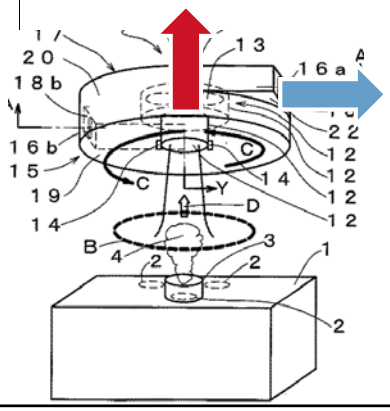


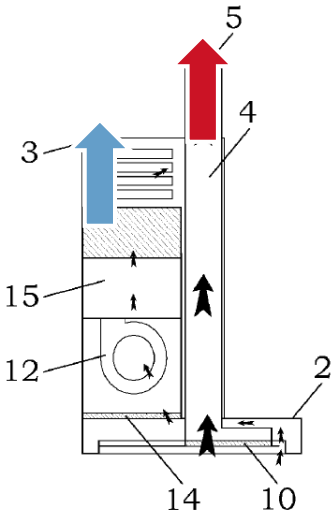
Source: Halton

TNO innovation for life

Improve local capture efficiency: support beams

- Patent examples of combination of exhaust ventilation and recirculation support beams

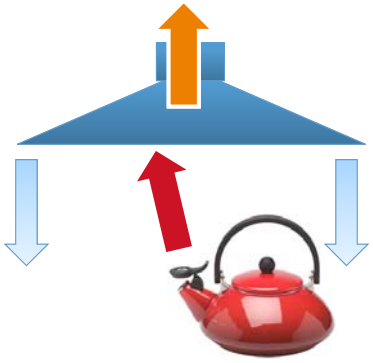




TNO innovation for life

Improve local capture efficiency: correct flow rates

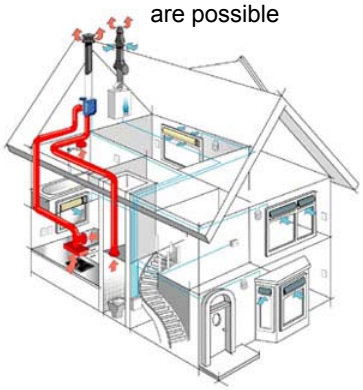
- Derive the correct capture (and support) flow rates from the flow characteristics and the new hood geometry, using known design rules.
- Evaluate and tune this with tests;



Improve local capture efficiency: control

- Optimising energy use and pollution control by smart sensors
- Control the flows and the distribution over the hood depends on production spots and intensity, favourably automated control using sensors.

Duco: Different sensors are possible



Britannia: Automatically detects steams, vapors and smoke

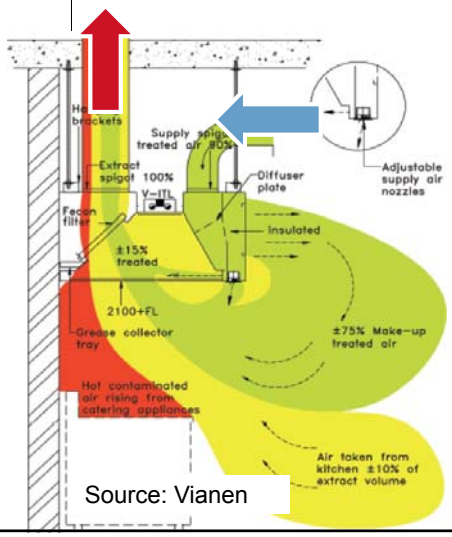
Recirculation or exhaust?

Exhaust:

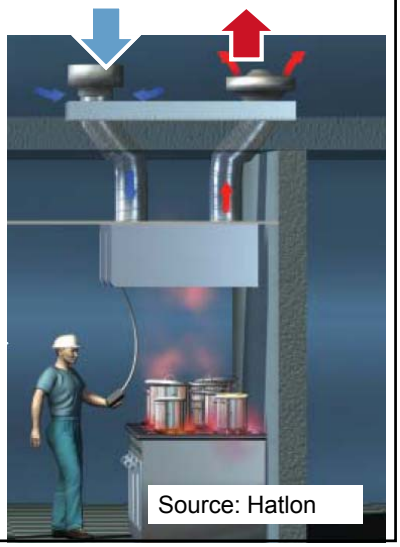
- Provisions for comparable supply flows are necessary, especially in airtight dwellings
- Large flows needed: special kitchen supply provision
- Overflow from surrounding rooms to prevent spread of odour
- Draft, energy loss: heat recovery

TNO innovation for life

Examples of balanced systems



Source: Vianen



Source: Hatlon

TNO innovation for life

Recirculation or exhaust

Recirculation:
High demands of filter, need for filter replacement
Reduction of moisture: Heat pump
Due to filter efficiency extra background filtering is needed.

TNO innovation for life

Background ventilation

- Rest contamination is unavoidable (during or after cooking)
- Therefore a need for prolongation of extra background ventilation

TNO innovation for life

Conclusions

Improve local capture efficiency:

- Redesign the cooker hood,
- Enclose the contaminant flow
- Derive the correct capture (and support) flow rates
- Control the flows and the distribution

Exhaust: Supply provision, draft, heat loss (recovery)
Recirculation: High demands on contaminant reduction

Background ventilation: Rest contamination will occur, elongation of higher flow rates.

Voting is open

Do you think that there are several cooker hoods on the market which balance supply and exhaust?

1. A lot of solutions
2. Several
3. A few
4. None

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1ste Stem(men) 2de Stem(men)

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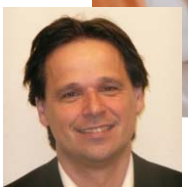
TNO innovation for life

Thanks for your attention



Wouter Borsboom

DEMAND CONTROLLED VENTILATION IN RENOVATED BUILDINGS WITH REUSE OF EXISTING DUCTWORK

Mads Mysen & Kari Sørnes
SINTEF Building and Infrastructure
Forskningsveien 3B
NO-0314, Oslo, NORWAY
**Corresponding author: mads.mysen@sintef.no*

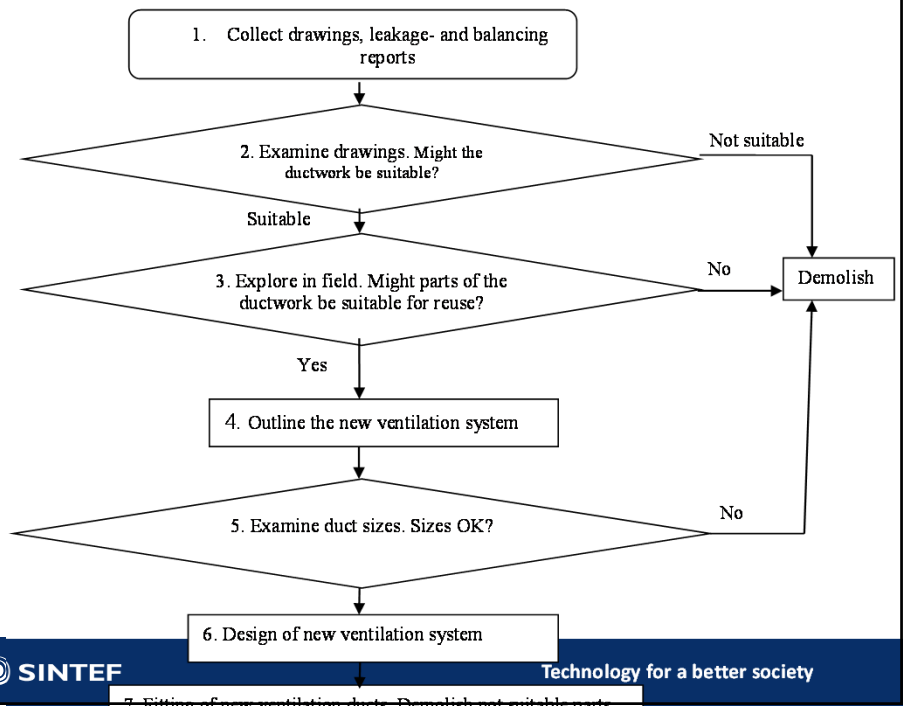
Case – Solbraaveien 23

SINTEF Technology for a better society

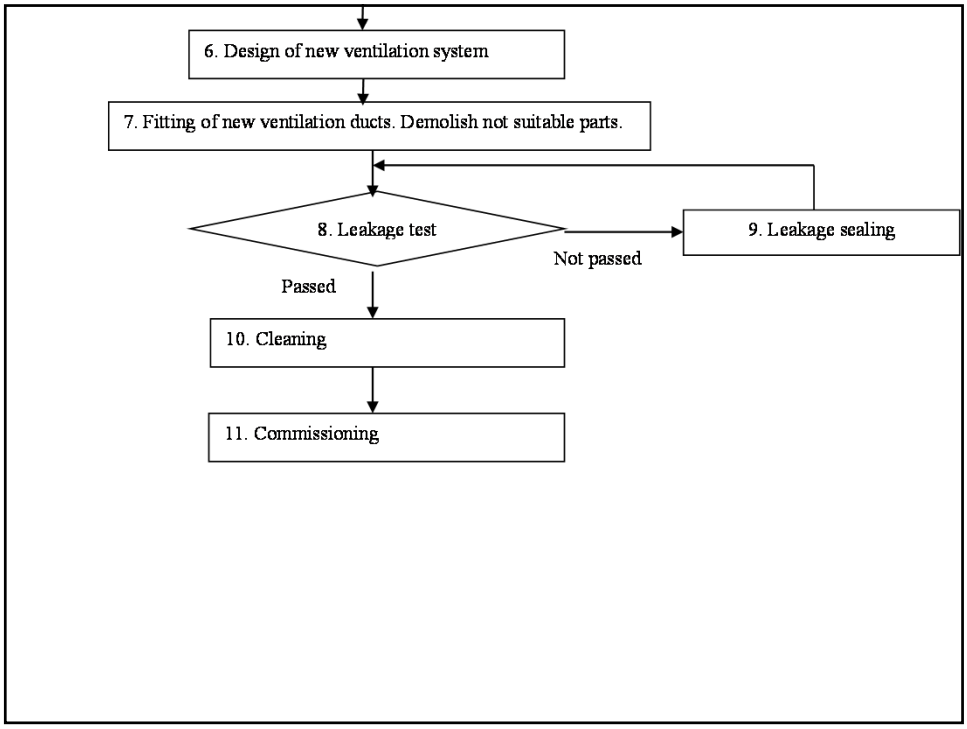
Retrofit measures

- New air-handling-units
- Conversion from CAV to DCV
- The windows were changed, new U-value of 0,8 W/m^{2}K
- Additional insulation on walls and roof
- Improved airtightness
- Air-water heat pump

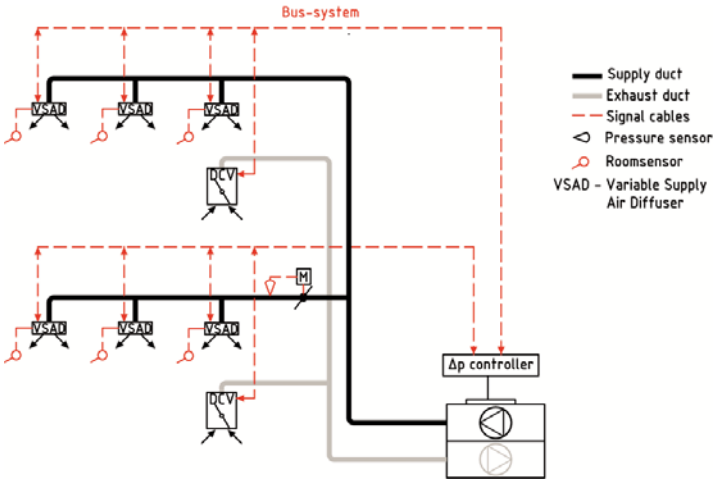
Total delivered energy use was reduced from 250 kWh/m^2 before retrofitting to 80 kWh/m^2 after retrofitting and the indoor environment was improved



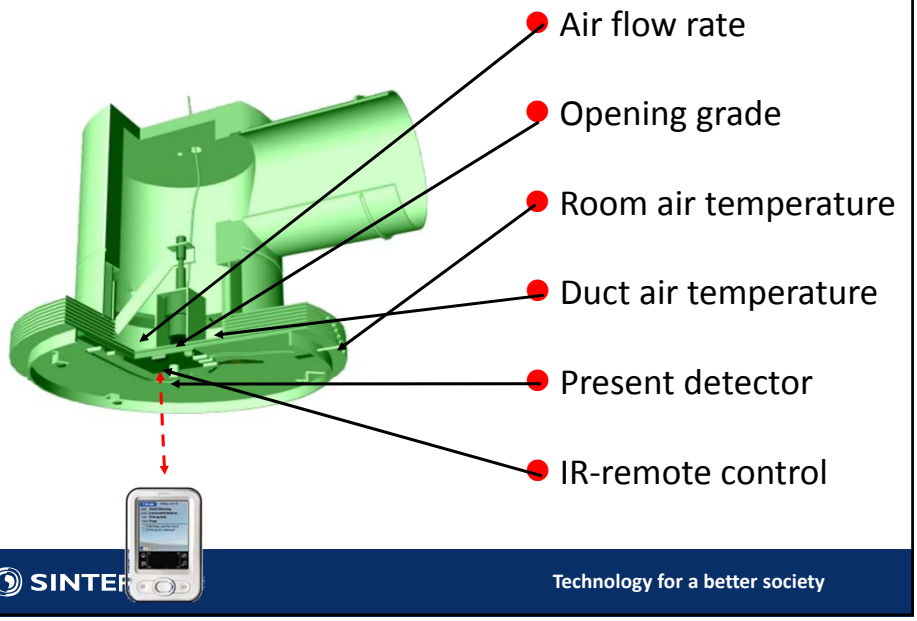
SINTEF Technology for a better society



Variable Supply Air Diffusers



Variable Supply Air diffusers



Reuse and new

Ductwork	**90-95% is re-used**
Air supply terminals	New VSAD
Exhaust terminals	New, controlled by new VAV-dampers
Air-handling-units (AHU)	New
All ventilation parts between outside air and AHU (main building air-intake and air exhaust)	New

Costs	*Total cost in Solbraaveien (with reuse) [Euro/10.000 m²]*	*Total costs with new ducts (traditional solution) [Euro/10.000 m²]*
1.Collect drawings, leakage- and balancing reports	1 250,-	
2. Examine drawing. Might the ductwork be suitable?	1 250,-	
3. Explore in field. Might parts of the ductwork be suitable for reuse?	1 250-13 000,-	
4. Outline the new ventilation system	No difference	
5. Examine duct sizes. Are the existing sizes OK?	2.500 – 6.000	
6. Design of new ventilation system	0	
7a. Demolish not suitable parts.	19 000,-	150 000 – 200 000,-
7b. Fitting of new ventilation ducts	50.000-62.500,-	400 000 - 500 000,-
8. Leakage test	No difference	
9. Leakage sealing	6.250	
10. Cleaning	112.500 -225.000	
11. Commissioning	0	
12. Unforeseen costs		
SUM	194 000 – 328 000	550 000 – 700 000

Remarks

- Reuse of existing ductworks was very profitable in Solbraaveien 23. The ductwork cost was roughly cut in half
- Reuse of the existing ductwork can potentially reduce the refurbishment period and therefore reduce loss of rental income. This is not included in the economical consideration.
- Reuse of ductwork might require some deviations from normal requirements
- One must clarify if the ductwork is suitable for reuse as early as possible in the process
- Evironmentally friendly solution

Success criterias for re-use

- Are the drawings up to date?
- Can the original system partition be reused?
- Do shafts have sufficient capacity and availability?
- Does the ductwork have sufficient access and quality?
- Are there no visible corrosion?
- Are there no risk for any duct parts with asbestos?
- Is the ductwork sufficiently airtight?

http://upgradebuildings.no/

UPGRADE

SINTEF Technology for a better society

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Technology for a better society

Cerema

Direction territoriale Centre-Est

DUCTWORK AIRTIGHTNESS: RELIABILITY OF MEASUREMENTS AND IMPACT ON VENTILATION FLOWRATE AND FAN ENERGY CONSUMPTION

Study from Sylvain BERTHAULT CEREMA

Florent BOITHIAS CEREMA

Valérie LEPRINCE PLEIAQ

Cerema

Objectives in the study

- **Part. 1: Impact of airtightness**

  1.1 Impact of each element of the ductwork on airtightness (branch connections, curve, etc…)

  1.2 Impact of the airtightness level on ventilation flowrates and fan energy consumption

- **Part. 2: Reliability of ductwork airtightness test**

  2.1 Impact of pressure drop in the ductwork on the test result

  2.2 Impact of leakage distribution

Cerema

Protocol

Cerema

Part. 1: Impact of airtightness

1.1 Impact of each element of the ductwork on airtightness (branch connections, curve, etc…)

- Protocol
- Results

1.2 Impact of the airtightness level on ventilation flowrates and fan energy consumption

- Protocol
- Results

Cerema

1.1 Impact of each element of the ductwork on airtightness (branch connections, curve, etc…)

- The airtightness is tested after each specific element is connected (joint and screwed)

1.1 Impact of each element of the ductwork on airtightness (branch connections, curve, etc…)

- Airtightness of each element
- Main problem with

- Need to be sealed to reach class C

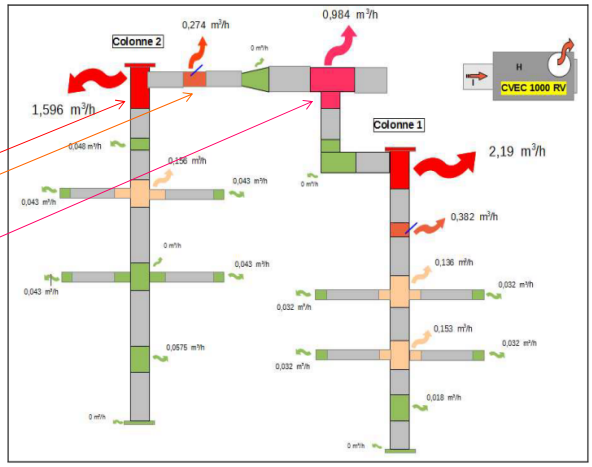


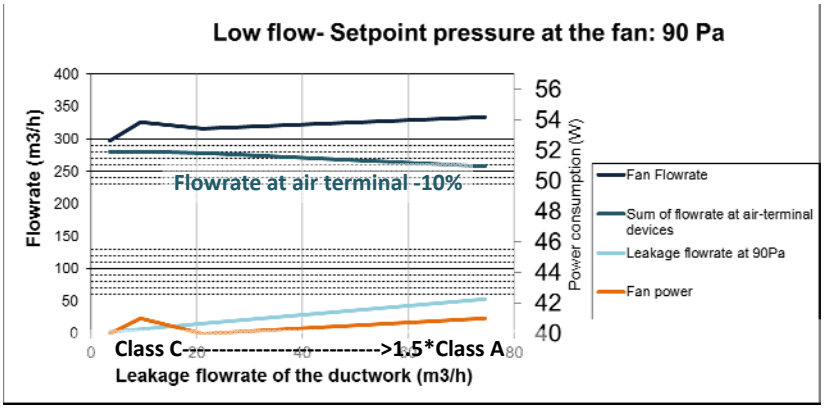
Figure 5-3 : Intensité des fuites mesurées au niveau des différents composants du réseau de ventilation (visés)

1.2 Impact of the airtightness level on ventilation flowrates and fan energy consumption

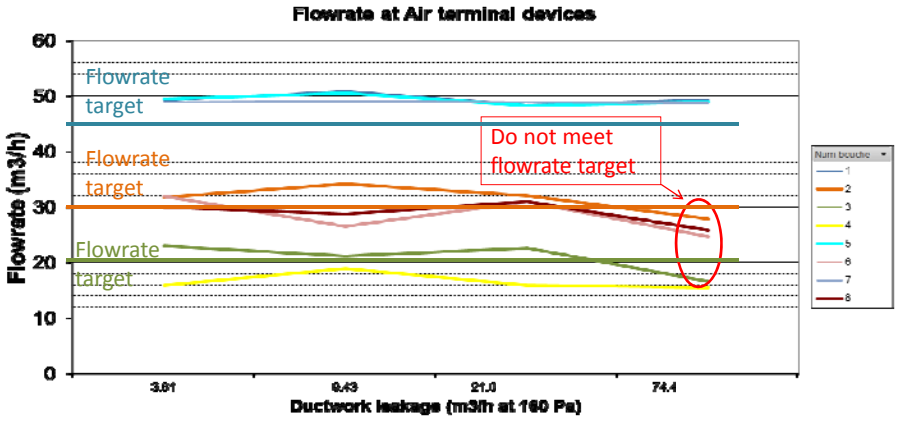
- From class C, the ductwork was drilled to reach class B, A and 1,5*A

- Flowrates and power consumption were controlled

1.2 Impact of the airtightness on ventilation flowrates and fan energy consumption

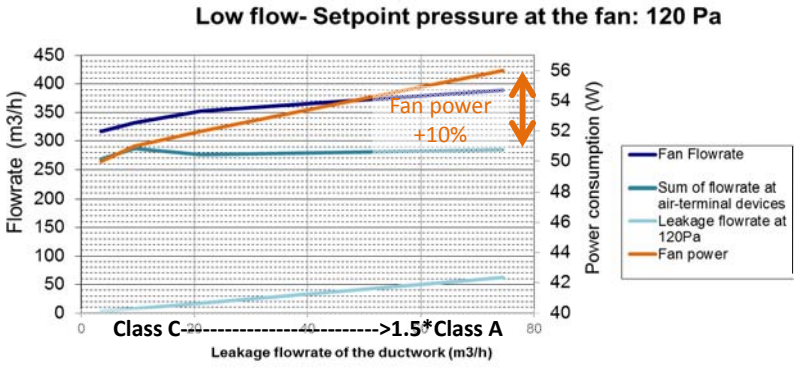


1.2 Impact of the airtightness on ventilation flowrates and fan energy consumption



- Flowrate targets are no longer met for 4 terminal devices
- => The fan setpoint pressure needs to be changed

1.2 Impact of the airtightness on ventilation flowrates and fan energy consumption



- The fan power increases from 40W to 50W when the set point pressure is set at 120 Pa instead of 90 Pa
- Increase to 56W when the ductwork is 1.5 class A
- => **Overconsumption of 40% due to leakage**

Part. 2: Reliability of ductwork airtightness test

2.1 Impact of pressure drop in the ductwork on the test result

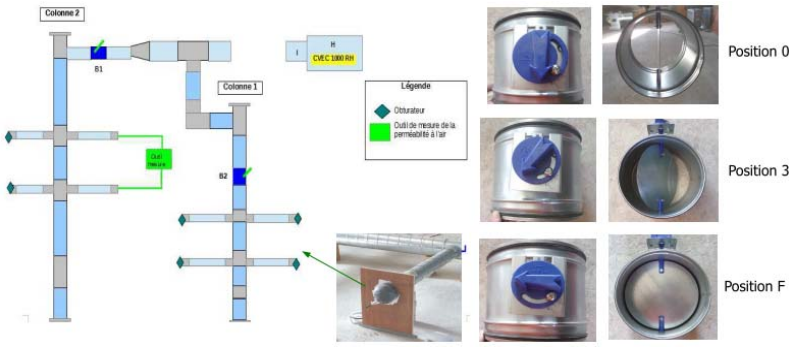
- Protocol
- Results

2.2 Impact of leakage distribution

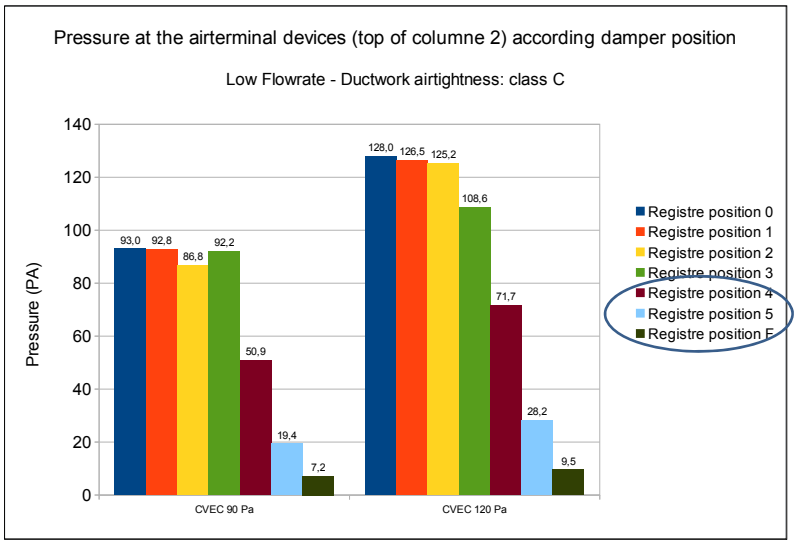
- Protocol
- Results

2.1 Impact of pressure drop in the ductwork on the test result

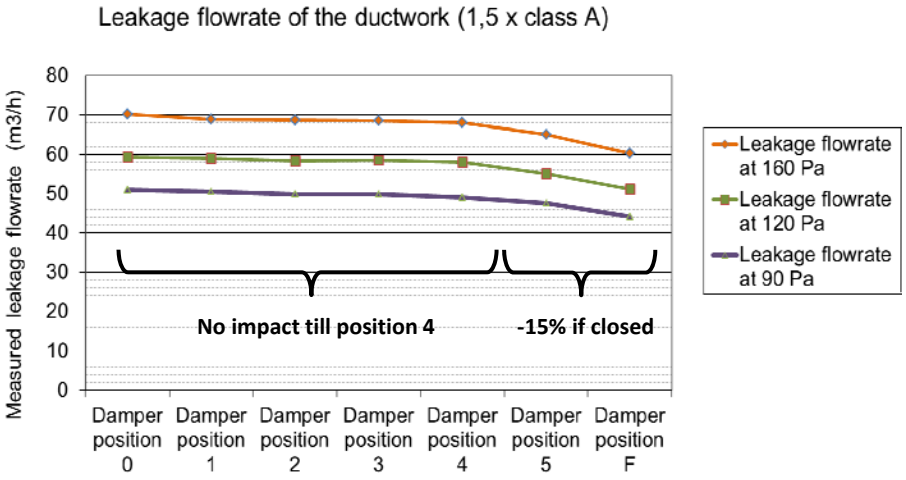
- Change of the dampers position to create pressure drop on the ductwork
- Leakages are equally distributed



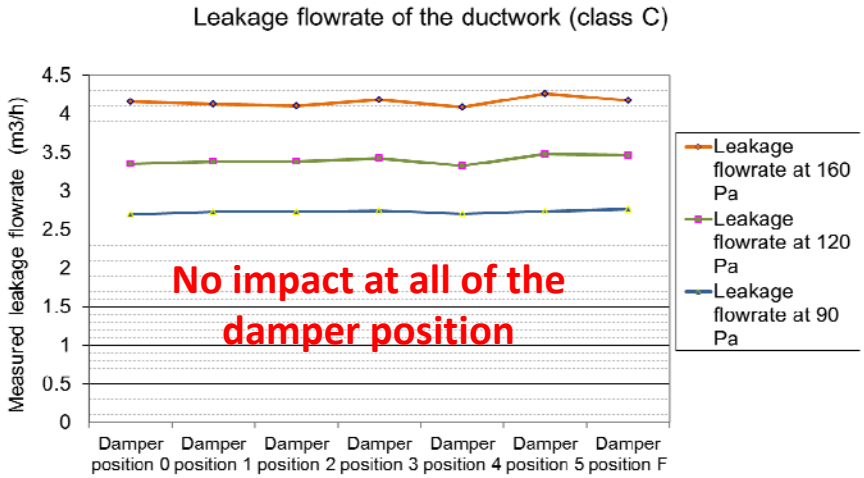
2.1 Impact of pressure drop in the ductwork on the test result



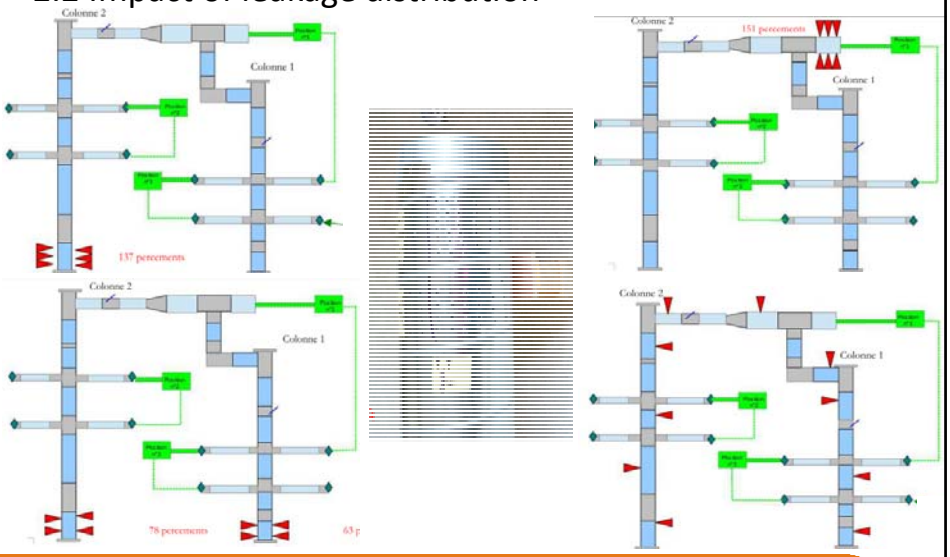
2.1 Impact of pressure drop in the ductwork on the test result



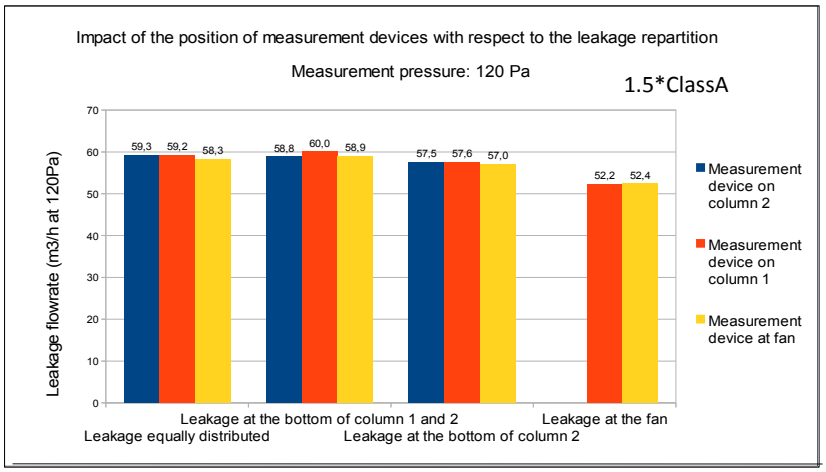
2.1 Impact of pressure drop in the ductwork on the test result



2.2 Impact of leakage distribution



2.2 Impact of leakage distribution



No impact at all of the measurement device position

Main conclusions

Part. 1: Impact of airtightness

- Some elements of the ductwork lead to big leakage
- Bad ductwork airtightness can lead to a 40% overconsumption of the fan

Part. 2: Reliability of ductwork airtightness test

- The pressure drop in the ductwork and the position of devices with respect to leakage has almost no impact on the measurement result

Thank you for attention

- Valérie Leprince - PLEIAQ
- Sylvain Berthault - CEREMA

Cerema 19

Lindab Group

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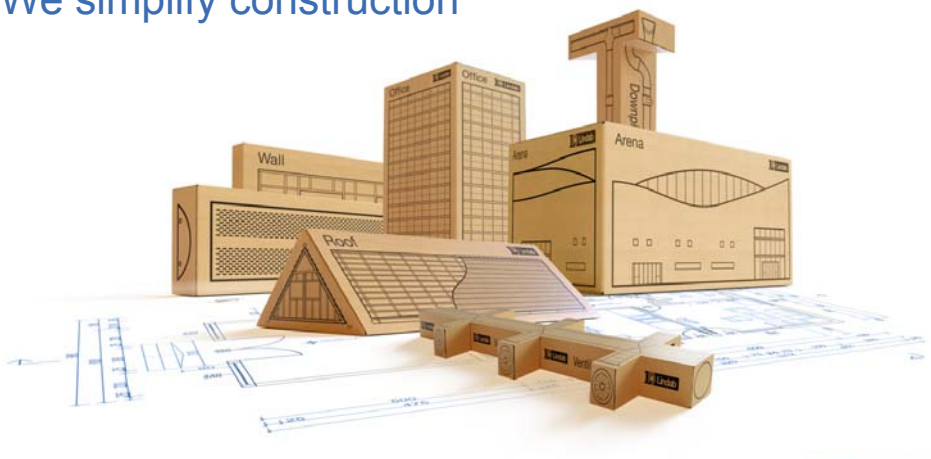

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Practical solutions for airtight ductwork

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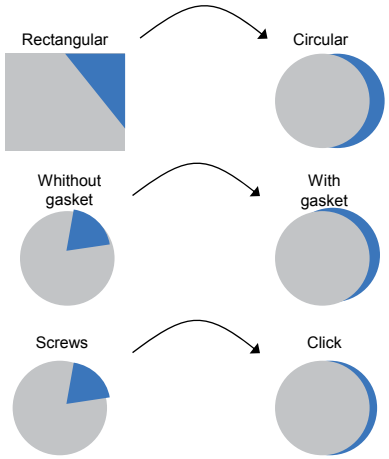
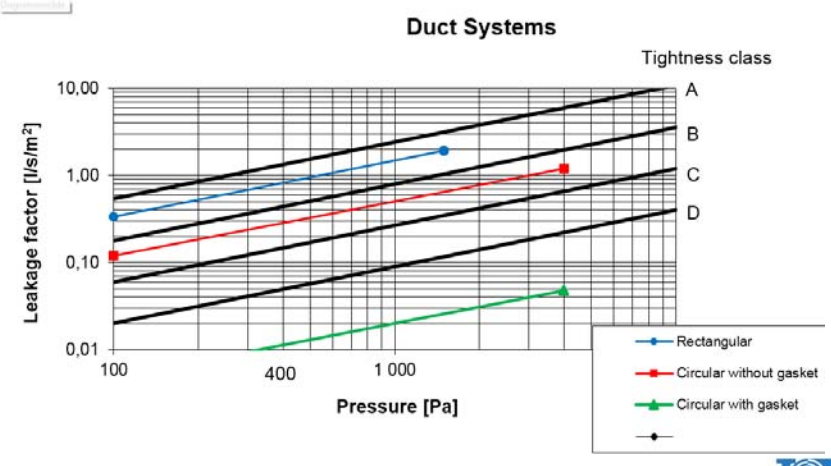
Solution



Air tightness



Measure the result

- Measuring will raise the standard for the installation work

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Inside

- Residential ventilation

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Indomo

- Mechanical supply and exhaust with heat recovery

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Incapsa

Lindab

Airy

- Design supply air

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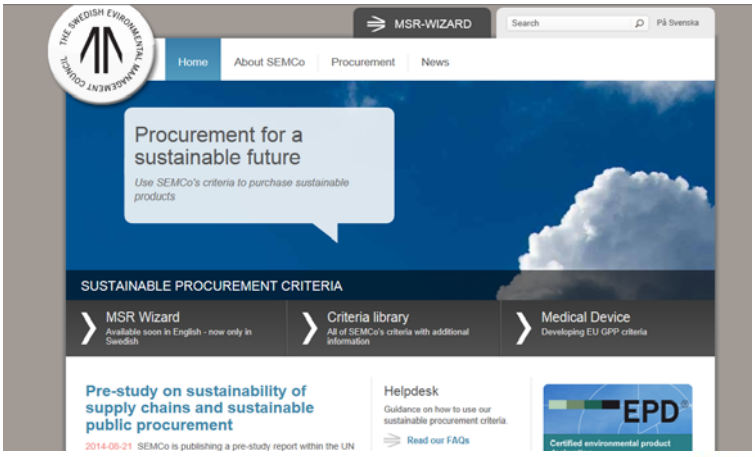
Governmental initiative



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Procurement criteria

MILJÖSTYRNINGSRÅDETS

UPPHANDLINGSKRITERIER FÖR

ENERGIPRESTANDA

VID NYBYGGNATION AV FLERBOSTADSHUS

MED

UTFÖRANDEENTREPRENADER

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INNEHÅLL

Omfattning

Kriteriedokumentet

Krav i tre nivåer

Vem står bakom kriterierna?

NBF-E1: System för uppföljning av energikrav

NBF-E2: Lufttäthet

NBF-E3: Samråd för Lufttäthet

NBF-E4: Läckagesökning och provning

NBF-E5: Uppvärmning av serviceutrymmen

NBF-E6: Ytor i bostad som vetter mot mark eller annan lokal i samma byggnad

NBF-E7: Kanaler, täthet

NBF-E8: Kanaler, isolering

NBF-E9: Rör, isolering

NBF-E10: Energieffektiva fönster

NBF-E11: Energieffektiva glaspartier

NBF-E12: Belysningsprodukter, inomhus

NBF-E13: Belysningsprodukter, utomhus

NFB-E14: Pumpar utan axeltätning, energieffektivitet

NFB-E15: Rotodynamiska vattenpumpar, energieffektivitet

NFB-E16: Specifik fläkteleffekt för fläktaggregat i ett system med värmeåtervinning

NFB-E17: Specifik fläkteleffekt för fläktaggregat i ett system med värmepump

NBF-E18: Verkningsgrad för värmeväxlare i från- och tilluftssystem

NBF-E19: Vitvaror

NFB-E20: Mätare

NBF-E21: Överlämning

NBL24: Luftfilter

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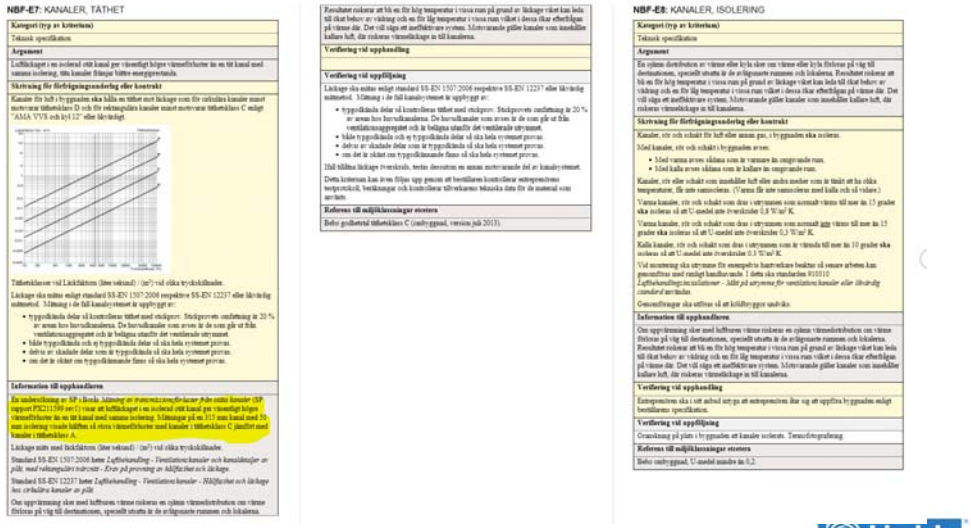

NBF-E7: KANALER, TÄTHET

Kategori (typ av kriterium)
Teknisk specifikation
Argument
Luftläckaget i en isolerad stål kanal per väsentligt högre värmeförluster än en tät kanal med samma isolering, vilka kanaler förtjänar bättre energiprestanda.
Skrivning för förfrågningsunderlag eller kontrakt
Kanaler för luft i byggnaden ska hålla en täthet mot läckage som för cirkulära kanaler minst motsvarar täthetsklass D och för rektangulära kanaler minst motsvarar täthetsklass C enligt "AMA VVS och kyl 12" eller likvärdigt.
Tätheten klasser vid Läckfaktorn (liter/sekund) / (m²) vid olika tryckskillnader.
Läckage ska mätas enligt standard SS-EN 1507:2006 respektive SS-EN 12237 eller likvärdig mätmetod. Mätning i de fall kanalsystemet är uppbyggt av:
• typgodkända delar så kontrollera tätheten med stickprov. Stickprovets omfattning är 20 % av arean hos huvudkanalerna. De huvudkanaler som avses är de som går ut från ventilationsaggregatet och är belägna utanför det ventilerade utrymmet. • både typgodkända och ej typgodkända delar så ska hela systemet provas. • delvis av skalade delar som är typgodkända så ska hela systemet provas. • om det är okänt om typgodkännande finns så ska hela systemet provas.
Information till upphandlaren
En undersökning av SP i Borås Mätning av tryckstegsförluster från enkla kanaler (SP rapport PX2211589 sm G) visar att luftläckaget i en isolerad stål kanal per väsentligt högre värmeförluster än en tät kanal med samma isolering. Mätningar på en 315 mm kanal med 50 mm isolering visade hälften så stora värmeförluster med kanaler i täthetsklass C jämfört med kanaler i täthetsklass A.
Läckage mätt med läckfaktorn (liter/sekund) / (m²) vid olika tryckskillnader.
Standard SS-EN 1507:2006 heter *Luftförsörjning - Ventilationskanaler och kanalstänglar av plåt, med rektangulärt tvärsnitt - Krav på provning av täthetsklass och läckage.*
Standard SS-EN 12237 heter *Luftförsörjning - Ventilationskanaler - Täthetsklass och läckage hos cirkulära kanaler av plåt.*
Om uppvärmning sker med luftburen värme reduceras en sjöns värmedistribution om värme förloras på väg till destinationen, speciellt utsatta är de avlägsnaste rummen och lokalerna.

Resultatet reduceras att bli en för hög temperatur i vissa rum på grund av läckage vilket kan leda till ökat behov av värkning och en för låg temperatur i vissa rum vilket i dessa fäller efterfrågan på värme där. Det vill säga ett ineffektivare system. Motsvarande gäller kanaler som innehåller kallare luft, där reducera värmeläckage in till kanalerna.
Verifiering vid upphandling
Verifiering vid uppföljning
Läckage ska mätas enligt standard SS-EN 1507:2006 respektive SS-EN 12237 eller likvärdig mätmetod. Mätning i de fall kanalsystemet är uppbyggt av:
• typgodkända delar så kontrollera tätheten med stickprov. Stickprovets omfattning är 20 % av arean hos huvudkanalerna. De huvudkanaler som avses är de som går ut från ventilationsaggregatet och är belägna utanför det ventilerade utrymmet. • både typgodkända och ej typgodkända delar så ska hela systemet provas. • delvis av skalade delar som är typgodkända så ska hela systemet provas. • om det är okänt om typgodkännande finns så ska hela systemet provas.
Hål tillåtna läckage överskrids, testas dessutom en annan motsvarande del av kanalsystemet.
Detta kriterium kan även följas upp genom att beställaren kontrollerar entreprenörens tarpetsskrift, beräkningar och kontrollerar tillverkarens tekniska data för de material som används.
Referens till miljöklassningar etcetera
Bebo godkännd tätheteklass C (miljöpgrad, version juli 2013).

NBF-E8: KANALER, ISOLERING

Kategori (typ av kriterium)
Teknisk specifikation
Argument
En sjöns distribution av värme eller kyla sker om värme eller kyla förloras på väg till destinationen, speciellt utsatta är de avlägsnaste rummen och lokalerna. Resultatet reduceras att bli en för hög temperatur i vissa rum på grund av läckage vilket kan leda till ökat behov av värkning och en för låg temperatur i vissa rum vilket i dessa fäller efterfrågan på värme där. Det vill säga ett ineffektivare system. Motsvarande gäller kanaler som innehåller kallare luft, där reducera värmeläckage in till kanalerna.
Skrivning för förfrågningsunderlag eller kontrakt
Kanaler, rör och schakt för luft eller annan gas, i byggnaden **ska** isoleras. Med kanaler, rör och schakt i byggnaden avses: • Med värma avses sådana som är varmare än omgivande rum. • Med kalla avses sådana som är kallare än omgivande rum.
Kanaler, rör eller schakt som innehåller luft eller andra medier som är tänkt att ha olika temperaturer, får inte samsiteras. (Värma får inte samsiteras med kalla och så vidare.)
Värma kanaler, rör och schakt som dras i utrymmen som normalt inte värms till mer än 15 grader **ska** isoleras så att U-medel inte överskrider 0,8 W/m² K.
Kalla kanaler, rör och schakt som dras i utrymmen som är värmda till mer än 10 grader **ska** isoleras så att U-medel inte överskrider 0,3 W/m² K.
Vid nyckeriarbete ska utrymme för exempelvis hantverkare beaktas så senare arbeten kan genomföras med enkelt handlarande. I detta ska standarden SS3310 *Luftbehandlingssystemkomponenter - Allmänt för utrymme för ventilation kanaler eller likvärdig standard* användas.
Genomföringar ska utföras så att köldbryggor undviks.
Information till upphandlaren
Om uppvärmning sker med luftburen värme reduceras en sjöns värmedistribution om värme förloras på väg till destinationen, speciellt utsatta är de avlägsnaste rummen och lokalerna. Resultatet reduceras att bli en för hög temperatur i vissa rum på grund av läckage vilket kan leda till ökat behov av värkning och en för låg temperatur i vissa rum vilket i dessa fäller efterfrågan på värme där. Det vill säga ett ineffektivare system. Motsvarande gäller kanaler som innehåller kallare luft, där reducera värmeläckage in till kanalerna.
Verifiering vid upphandling
Entreprenören ska i sitt anbud intyga att entreprenören åtar sig att uppföra byggnaden enligt beställarens specifikation.
Verifiering vid uppföljning
Granskning på plats i byggnaden att kanaler isolerats. Termofotografering.
Referens till miljöklassningar etcetera
Bebo miljöpgrad, U-medel måste in 0,2.

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Technical ductwork products

- Dampers
- Silencers
- Filterbox
- Heaters
- Etc.

Standards/Regulation

EN 15727:2010 (E)

1 Scope

This European Standard applies to technical ductwork products, intended for installation in ductwork conforming to EN 1505 and EN 1506, used in air conditioning and ventilation systems defined in the scope of CEN/TC 156. This document specifies the leakage requirements for technical ductwork products, i.e. components in the ductwork that has more functions than conveying air, such as sound attenuators, filter boxes and duct fans, etc.

The following products are not within the scope of this document:

— ductwork components like bends, reducers, ducts and T-pieces. EN 12237 and EN 1507 apply;

— flexible ducts according to EN 13180;

— ducts made of insulation ductboards according to EN 13403;

— dampers according to EN 1751;

— air handling units according to EN 1886.

This document is a parallel standard to EN 12237, EN 1507 and EN 1751, based on the same leakage classification.

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Goal 20-20-20 Build tight ventilate right

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Penetration trough the roof/ wall

Membrane lead-through MG

Description

The product is based on a special flexible 2-component rubber (1) that is integrated with a 1 mm aluminium plate (2).

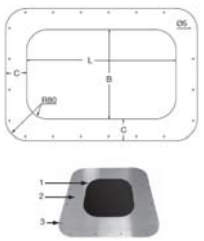
Used for sealing of the building envelope for all types of pipes and ducts, wich is lead trough a vapour barrier of roofing underlay.

The product can be used as a roofing underlay transition or as a vapour barrier sheet, in the ridge as well as on the inclinad roof area.

You will also find screwholes (3) ready for fixed roofing underlay, concrete floor or floor structures.

A special mounting instruction exists for this product.

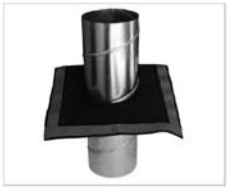
Dimensions



Special transition designet for ceiling, shaft etc. used for ducts from Ø100 - Ø160

Type	Max. duct measure □ / Ø mm	B × L × C mm	m kg
MG 1016	160	200 × 200 × 50	0,32

Membrane lead-through MGL



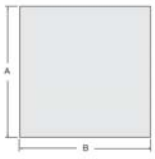
Description

Made from a special flexible syntetic rubber and provided with tape with adhesive on both sides.

Is used for sealing of the climate shield to all sorts of pipes and ducts, which passes through moisture barrier or roofing underlay.

A special mounting instruction exists for this product.

Dimensions



Type	Max. duct dimension □ / Ø mm	A × B mm	m kg
MGL 80	80	200 × 200	0,10
MGL 125	125	250 × 250	0,10
MGL 160	160	300 × 300	0,15
MGL 250	250	400 × 400	0,20
MGL 355	355	500 × 500	0,25

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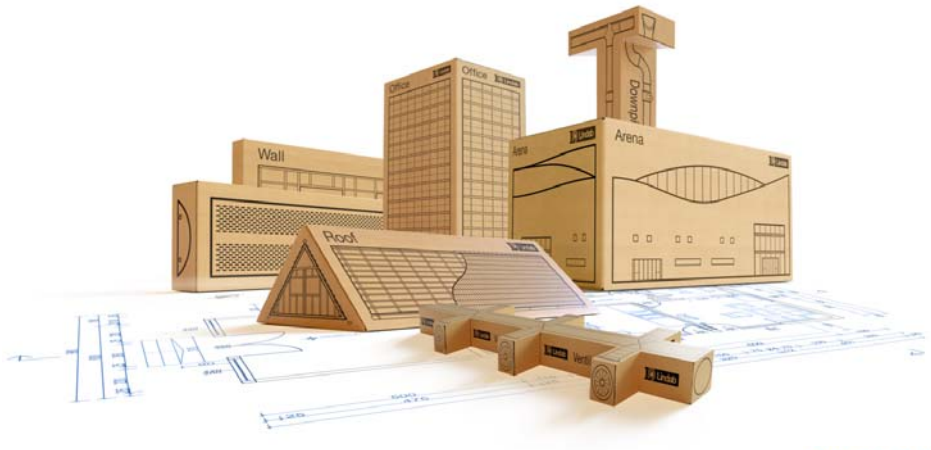

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COMPARISON OF TWO VENTILATION STRATEGIES IN THE FIRST NORWEGIAN SCHOOL WITH PASSIVE HOUSE STANDARD

Axel Cablé[1], Hugo Lewi Hammer[2] ,Mads Mysen[1]
1 SINTEF, Norway
2 Oslo and Akershus University College, Norway

MARIENLYST SCHOOL

- First school in Norway built according to the passive house standard (NS 3701, 2012)
- Operational since 2010
- 500 pupil from age 13 to 15
- Demand-Controlled Ventilation
- District heating
- Automated shadings
- Free cooling on warm days

CONTEXT

- Airtight envelope (0.6 vol/h under 50 Pa)
- Efficient insulation (U-values: 0.05 to 0.12 W/m²K)

➢ IAQ/overheating: efficient ventilation strategy required

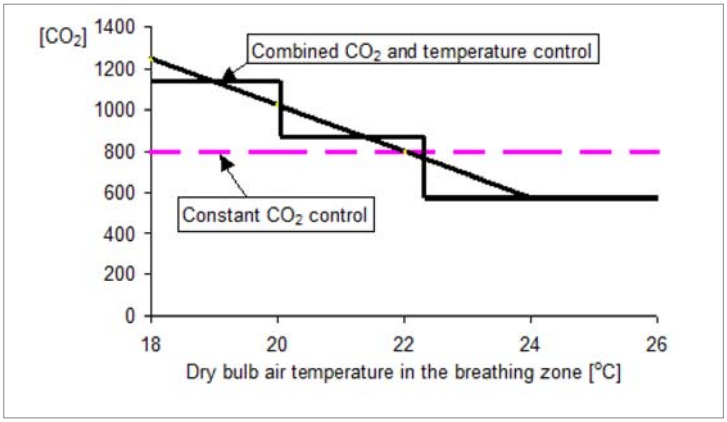
- Educational building: large variations of heat and pollution load

➢ Demand-controlled ventilation particularly fitted (up to 50% energy saved compared to CAV)

DEMAND-CONTROLLED VENTILATION

Existing ventilation strategy: constant CO_2 DCV (800ppm)

Overheating mode (damper 100% open): When T > 23.8°C until T < 23°C

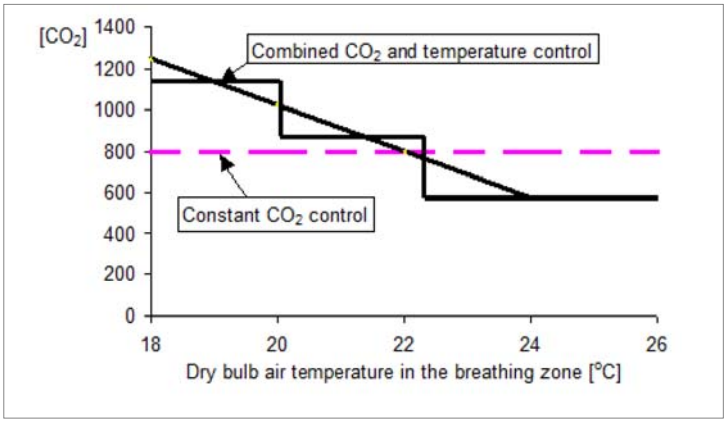


DEMAND-CONTROLLED VENTILATION

Existing ventilation strategy: constant CO_2 DCV (800ppm)

Overheating mode (damper 100% open): When T > 23.8°C until T < 23°C

Complaints from the pupils regarding thermal comfort



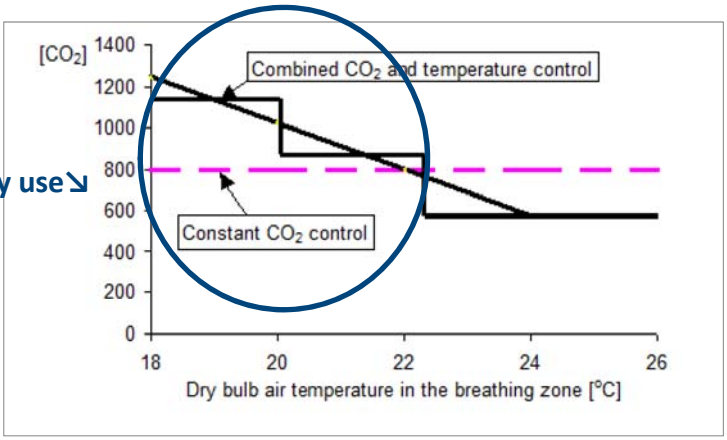
DEMAND-CONTROLLED VENTILATION

New tested ventilation strategy:

Combined CO_2 and temperature control (Mysen, 2005)

Energy use↘

IAQ =



DEMAND-CONTROLLED VENTILATION

New tested ventilation strategy:

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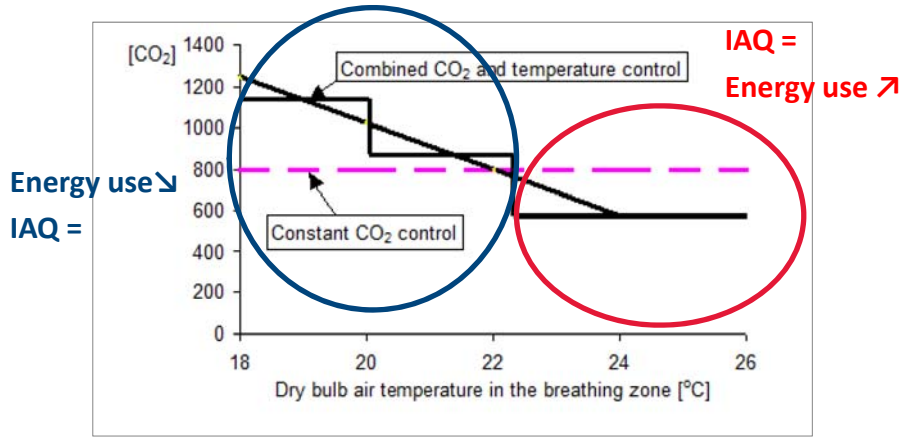


DEMAND-CONTROLLED VENTILATION

New tested ventilation strategy:

Combined CO_2 and temperature control (Mysen, 2005)

Improved perceived indoor climate by fitting better to the demand ?

➡ Questionnaires

PLAN FOR THE INTERVENTIONS

Date	20 February 2012	14 March 2012	30 May 2012
Ventilation control	Constant CO_2 with "overheating mode"	Combined CO_2 and temperature	Combined CO_2 and temperature

QUESTIONNAIRES

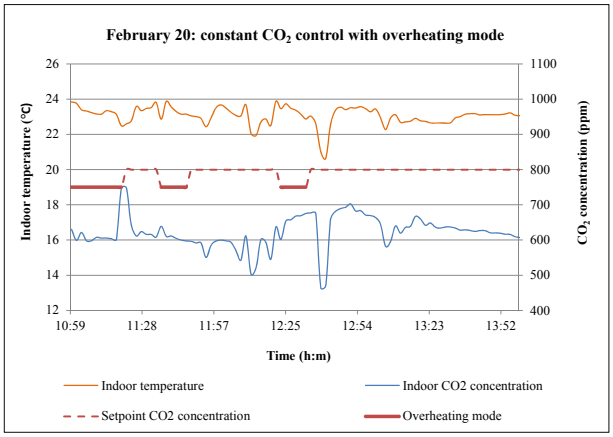
19 questions:

- Perceived thermal comfort
- Sick Building Syndrome-symptoms (SBS)
- Scale of 0 (satisfied) to 1 (unsatisfied)

= indicator of the well-being

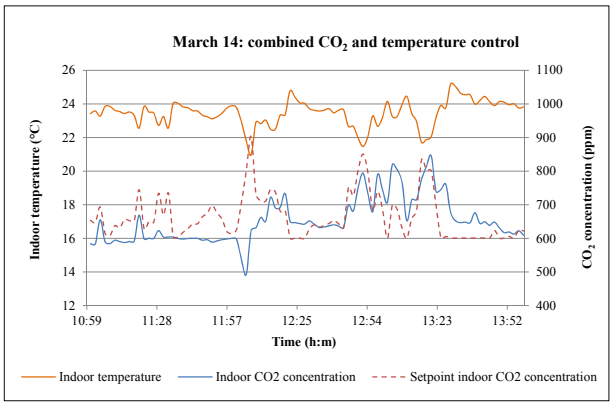
Examples:
Do you have a headache ?
Is there bothersome warmth because of sunshine?
Do you feel bothersome draught around your feet or your neck?
Is there is a unpleasant smell? …

RESULTS: MEASUREMENTS ON FEB 20



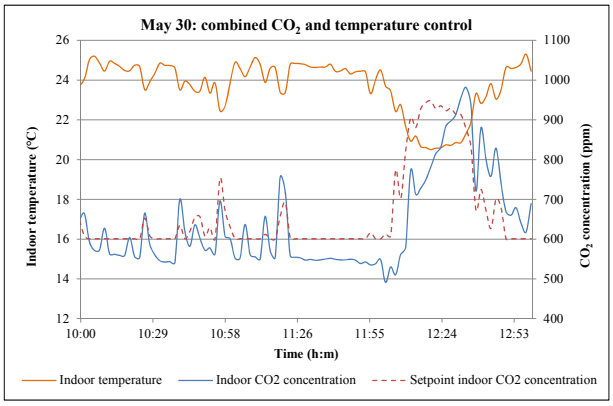
- T reached 23.8°C on three occasions, causing the "overheating mode" to override the constant CO_2 control of the ventilation.
- Low CO_2 concentration

RESULTS: MEASUREMENTS ON MARCH 14



- Good agreement setpoint/measured CO_2 concentration
- T exceeded 22.5°C. Control towards a lower concentration of CO_2 (red dots), down to 600 ppm.

RESULTS: MEASUREMENTS ON MAY 30

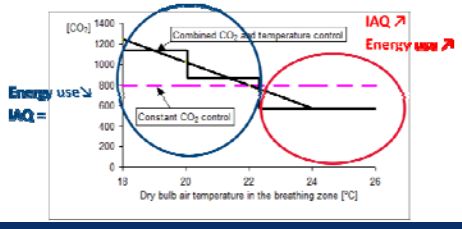


- Good agreement
- Classroom was empty from 12:00 to 12:30: energy savings

TEMPERATURE/CO2 LEVEL

	Average indoor temperature (°C)	Average indoor CO_2 concentration (ppm)
20 February (constant CO2 control with overheating mode)	23,1	622
14 March (combined CO_2 and temperature control)	23,5	652
30 May (combined CO_2 and temperature control)	23,7	635

- Relatively high temperatures; similar in all cases
- Low indoor CO_2 concentration for all cases
- The strategy could only be tested for the right side of the curve



QUESTIONNAIRES: AVERAGE SCORES

	Too warm	Bothersome warmth from sun	Bothersome variations of temperature	Heavy/ Poor air	Dry air	Dry throat
30may COMBINED	0,17	0,25	0,15	0,43	0,35	0,29
14mar COMBINED	0,19	0,25	0,19	0,46	0,47	0,18
20feb CONSTANT	0,40	0,30	0,56	0,55	0,48	0,35

- 39 pupils answered to the questionnaires.

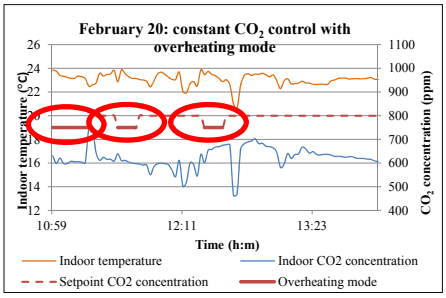
REGRESSION ANALYSIS

Variables	Estimate	Std. Error	Df	T-value	P-value
Combined CO_2 and temperature control (reference: constant CO_2 control)	–0.28	0.11	26.24	–2.53	0.018 *
Gender male (reference: female)	–0.22	0.14	19.33	–1.62	0.121
Has a cold (reference: Does not have a cold)	0.15	0.12	34.45	1.21	0.238

Signif. codes: p-value < 0.01:**, p-value < 0.05:*

- 39 pupils answered to the questionnaires. 19 answered to all three questionnaires and were considered in the analysis.
- “Are there uncomfortable variations of temperature in the room?” New strategy significantly better.
- The other questions did not reveal any significant difference between both control strategies.

DISCUSSIONS



- Existing strategy: large variations of the dampers opening ("rough" control): from MIN to MAX open position
- Combined CO_2 and temperature control provides a finer control of the dampers
- No correlation with draught or warmth from the sun

CONCLUSIONS

- A combined CO_2 and temperature ventilation control strategy was efficiently implemented
- Finer control: discomfort resulting from too large variations of temperature significantly reduced
- Overheating
- Limited number of answers

MONICAIR

Presentation first results MONICAIR field-research at

35th AIVC Conference, Poznan

Titel:

"Monitoring the energy- and IAQ performance of ventilation systems in Dutch residential dwellings"

By :
Rob van Holsteijn, partner in VHK
VHK is a Dutch *research design & engineering company*, specialized in energy using products

MONICAIR

TOPICS

1. Introduction to MONICAIR
2. Rationale behind the project
3. Project details
4. Some results of individual dwellings
5. Overall results CO2-concentrations
6. Overall results RH-levels
7. First results energy performance ventilation systems
8. Preliminary conclusions and discussion

MONItoring & Control of Air quality in Individual Rooms

MONICAIR

MONICAIR:

MONItoring & Control of Air quality in Individual Rooms

MONICAIR is a pre-competitive field research project, investigating :

a) The real life IAQ- and energy performance of 9 different residential ventilation systems. Projectleader : VHK, Rob van Holsteijn

b) The overall energy performance of dwellings in relation to building- and installation quality, comfort levels and resident behavior . Projectleader : OTB / TUDelft, Laure Itard

With as final goal further improvement of residential ventilation systems and if proven necessary, adjustment of assessment- and calculation methods on IAQ- and energy performance

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MONICAIR CONSORTIUM

Participating parties:

Manufacturers: :

BRINK Climate Systems, ClimaRad Indoor Air Quality, ithodaalderop, zehnder, Honeywell Customized Comfort Products

Consulting agencies :

Nieman, VHK

Research institutions :

TU Delft, TNO Innovation for life

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MONICAIR PROJECT FUNDING

Total project costs	**: 1,57 million euro**
Contribution Dutch Ministry of Economic Affairs*	: 0,86 million euro
Contribution Consortium Members	: 0,63 million euro
Contribution Housing Corporations	: 0,08 million euro

** Within the framework of TKI (Top Consortia for Knowledge & Innovation)*

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1.
Manufacturers want to know *how* their ventilation systems perform in real life. Detailed knowledge on IAQ-performance per room (during presence) can help them further improve their systems

2.
Consultancy firms want to know *to what extend* the real life performance of ventilation systems on IAQ en energy consumption, complies with standards and legislation

3.
Legislator wants to know if applied assessment and calculation methods are in line with the real life IAQ- and energy performance of ventilation systems

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4.
Existing research has mainly focused on compliance with standards at nominal conditions (and improvements are certainly necessary here) , but research on IAQ- and energy performance at real life conditions *in individual rooms* of dwellings that comply with current building codes is scarce.

5.
With a housing stock that is being improved in terms of insulation and air tightness, further detailed knowledge on real life performance of ventilation systems is essential

6.
The exploratory field research study MONICAIR can help giving direction to future monitoring and field research projects

MONICAIR

Type of ventilation systems

System type		Section of the house that is served	Air exchange provisions			Controls	
			Exhaust	Supply	Heat Rec.	Exhaust	Supply
MEV (type C) Systems	C.1	Whole house	Mech. extraction in wet-rooms	Stnrd nat.supply vents in hab.rooms	No	Manual 3-pos. switch	Manual
	C.2c	Whole house	Mech. extraction in wet-rooms	wind contrl. nat. supply in hab.rooms	No	Manual 3-pos. switch	Manual
	C.4a	Whole house	Mech. extraction in wet-rooms	wind contrl. nat. supply in hab.rooms	No	CO_2-sensor in living room	Manual
	C.4c	Whole house	Mech. extraction in all rooms	wind contrl. nat. supply in hab.rooms	No	CO_2-control on all hab.rooms	Manual
MVHR (type D) systems	D.2	Whole house	Mech. extraction in wet-rooms	Mech. supply in hab.rooms	Yes	Manual 3-pos. switch	
	D.5a	Whole house	Mech. extraction in wet-rooms	Mech. supply in hab.rooms	Yes	Manual 3-pos. switch with CO_2-contrl in 2 zones	
	D.5b	Whole house	Mech. extraction in all rooms	Mech. supply in hab.rooms	Yes	CO_2 and RH -controlled ventilation rate in all rooms	
	D.x	Whole house	Mech. extraction in all rooms	Mech. supply in corridor	Yes	CO2-control	
Combined systems	X1/C	Living section: D.5b	Mech. extraction in hab.rooms	Mech. supply in hab.rooms	Yes	CO_2 and RH -controlled ventilation rate in living room	
		Sleeping section:C.2c	Mech. extraction in wet-rooms	wind contrl. nat. supply in bedrms	No	Manual 2-pos. switch	Manual
	X1/A	Living section: D.5b	Mech. extraction in hab.rooms	Mech. supply in hab.rooms	Yes	CO_2 and RH -controlled ventilation rate in living room	
		Sleeping section: A	Nat. extraction in wet-rooms	wind contrl. nat. supply in bedrms	No	No control	Manual

3. PROJECT DETAILS

MONICAIR

Number of dwellings	: 62
Type of dwellings	: terraced houses / semi detached houses
Airtightness dwellings	: 10 dwellings $q_{v;10;kar} \geq 1,5$ dm3/s/m^2 52 dwellings $q_{v;10;kar} < 1,5$ dm3/s/m^2, of which 21 dwellings $q_{v;10;kar} < 1,0$ dm3/s/m^2
Ventilation systems	: Supply and exhaust provisions and system airflow all tuned acc. to building code specifications
Number of rooms	: 342
Sensors	: measuring CO_2, RH, Temp, PIR in all habitable rooms measuring RH in all bath- and utility rooms measuring power consumption all ventilation units
Other monitoring	: Logging data Combi-boiler (on/off, CH/DHW, energy cons.) Logging KNMI data of nearby weather stations (temp., RH, Pressure, wind direction & wind speed)

3. PROJECT DETAILS

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Data logging frequency	: CO2-, RH- and Temp sensors : every 5 minutes PIR-sensors: every movement registered by sensor Power consumption: every power-change, every 10 min.
Other monitoring	: Logging data Combi-boiler : (every 5 minutes) Logging data weather stations : every hour

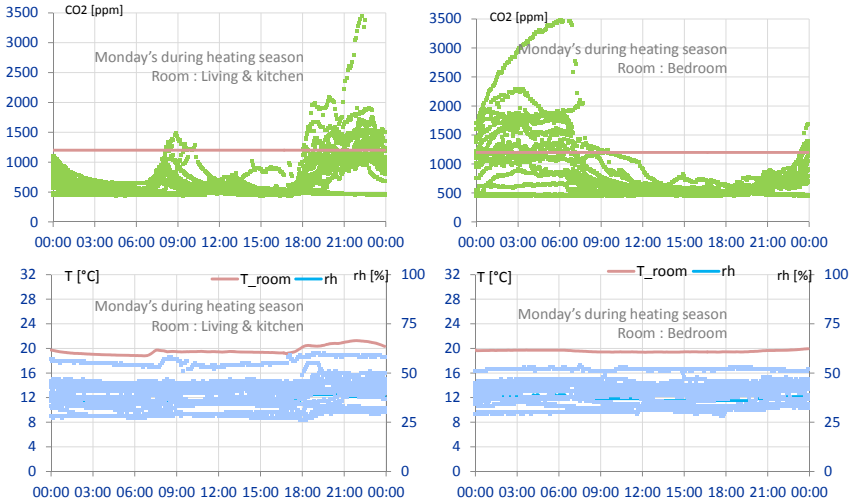
After more then 1 year monitoring this has resulted in an SQL-data base with over 100 million data records

MONItoring & Control of Air quality in Individual Rooms

4. RESULTS INDIVIDUAL DWELLING

MONICAIR

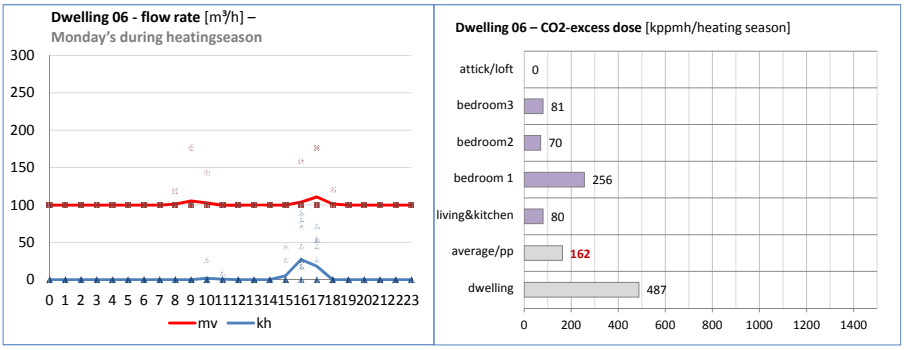
Dwelling with MEV system type C.2c. Number of inhabitants : 3



4. RESULTS INDIVIDUAL DWELLING

MONICAIR

Dwelling with MEV system type C.2c. Number of inhabitants : 3



CO_2 excess dose = $\sum ((C_{CO2} > 1200 - 1200) * t_{>1200}) / 1000$ in kppmh per heating season

Explanation : CO2 excess dose pp = **162** kppmh during heating season (= 5088 h).
IF average CO2 excess value is 300 ppm, then during **540** hours ventilation rate is insufficient
IF person is home 60% of the time, then **18%** of this time spent at home, ventilation is insufficient

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4. RESULTS INDIVIDUAL DWELLING

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Dwelling with MEV system type C.2c.

Dwelling Nr.	Inhabitants	CO_2 excess dose pp in kppmh/h.season	Hours [h] insuff. ventilation @ CO2 excess value = 300 ppm	% of time spent at home ventilation is insufficient @ 60% presence
1	1	86	287	9%
2	3	162	540	18%
3	4	141	470	15%
4	3	201	760	25%
5	5	198	660	22%
6	4	675	2250	74%

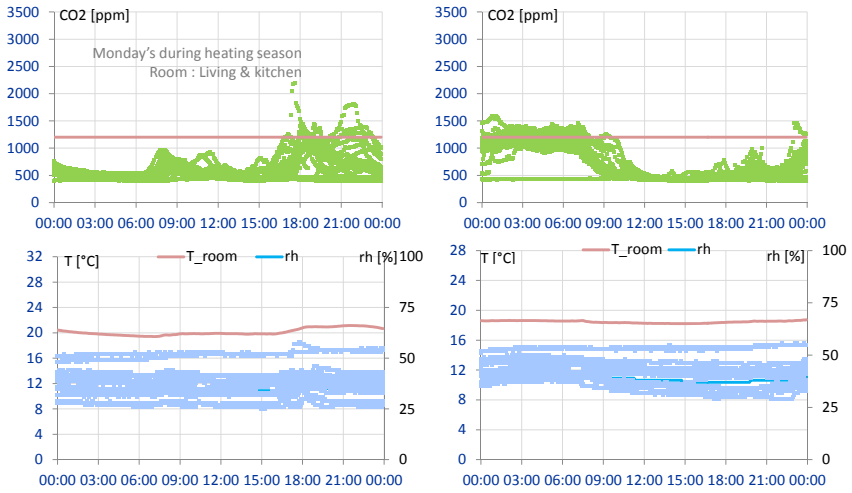
Explanation

CO2 excess dose pp = **162** kppmh during heating season (= 5088 h).
IF average CO2 excess value is 300 ppm, then during **540** hours ventilation rate is insufficient
IF person is home 60% of the time, then **18%** of this time spent at home, ventilation is insufficient

4. RESULTS INDIVIDUAL DWELLING

MONICAIR

Dwelling with MVHR system type D.2. Number of inhabitants : 5



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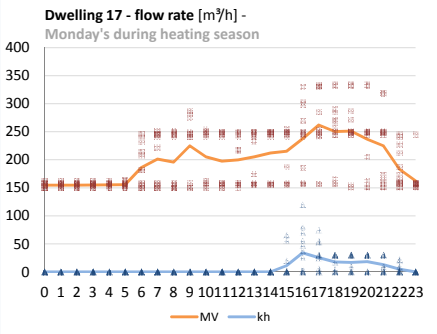
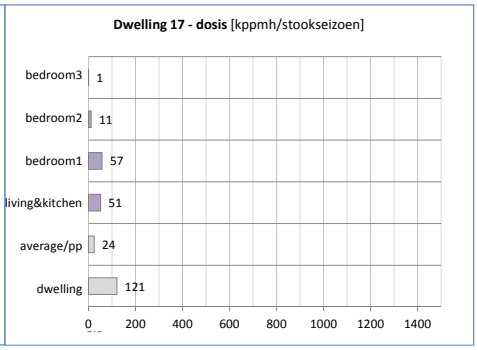
Dwelling with MVHR system type D.2. Number of inhabitants : 5





CO_2 excess dose = $\sum ((C_{CO2} > 1200 - 1200) * t_{>1200}) / 1000$ in kppmh per heating season

Explanation : CO2 excess dose pp = **24** kppmh during heating season (= 5088 h).
IF average CO2 excess value is 300 ppm, then during **80** hours ventilation rate is insufficient
IF person is home 60% of the time, then **2,6%** of this time spent at home, ventilation is insufficient

4. RESULTS INDIVIDUAL DWELLINGS

MONICAIR

Dwelling with MVHR system type D.2.

Dwelling Nr.	Inhabitants	CO_2 excess dose pp in kppmh/h.season	Hours [h] insuff. ventilation @ CO2 excess value = 300 ppm	% of time spent at home ventilation is insufficient @ 60% presence
1	2	51	170	5,6%
2	5	24	80	2,6%
3	2	69	230	7,5%
4	4	66	220	7,2%
5	4	79	263	8,6%
6	3	121	403	13,2%

Explanation
CO2 excess dose pp = **24** kppmh during heating season (= 5088 h).
IF average CO2 excess value is 200 ppm, then during **80** hours ventilation rate is insufficient
IF person is home 60% of the time, then **2,6%** of this time spent at home, ventilation is insufficient

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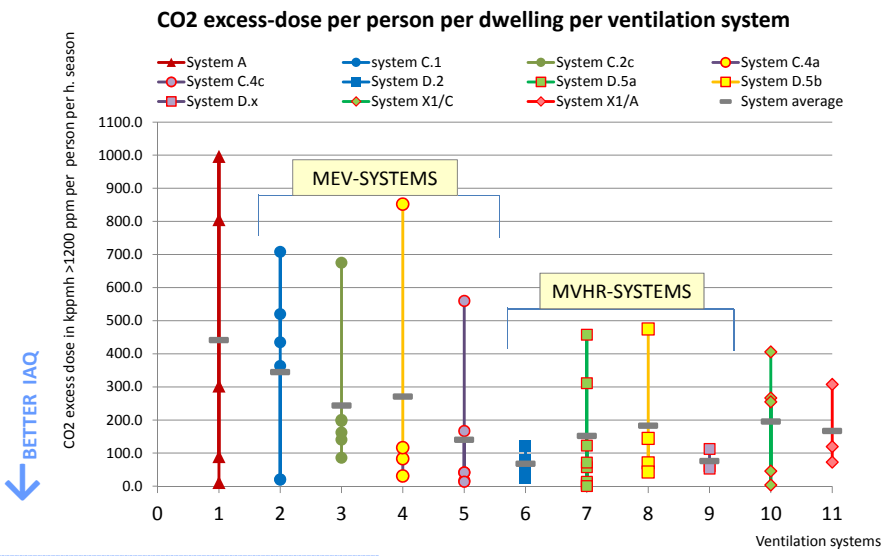
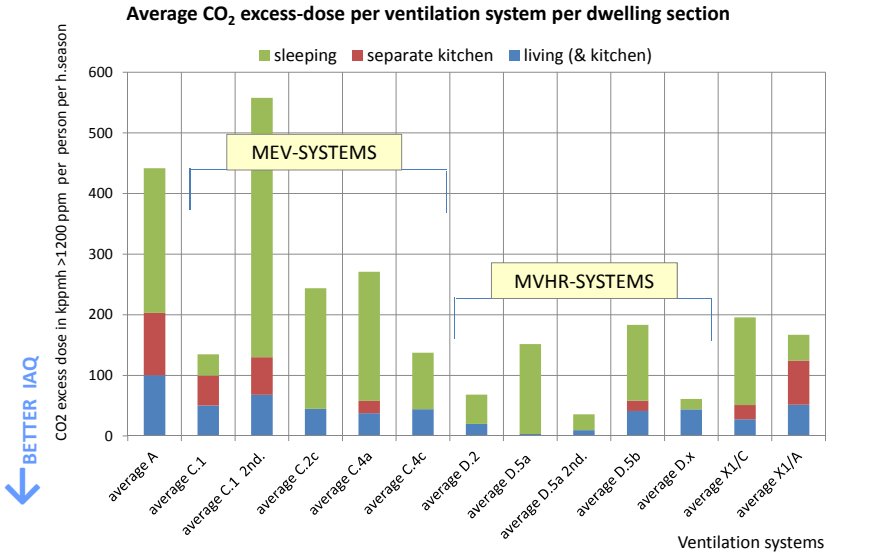
5. OVERALL RESULTS CO2 CONCENTRATIONS

MONICAIR



5. OVERALL RESULTS CO2 CONCENTRATIONS

MONICAIR

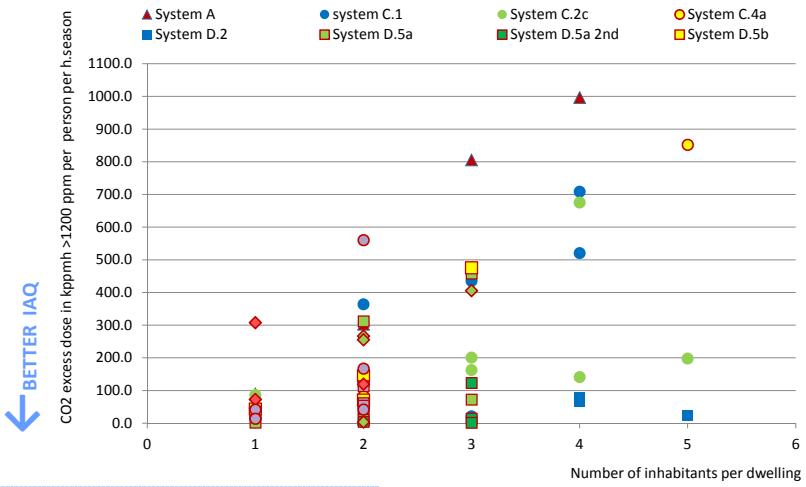


5. OVERALL RESULTS CO2 CONCENTRATIONS

MONICAIR

CO2 excess-dose versus number of inhabitants

(in kppmh above 1200 ppm per person per heatingseason versus number of inhabitants)



BETTER IAQ

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5. OVERALL RESULTS CO2 CONCENTRATIONS

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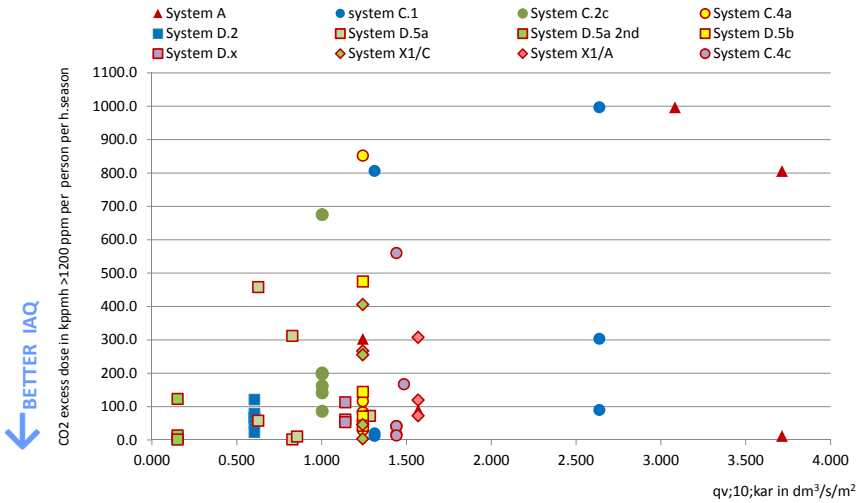
CO_2 excess-dose versus airtightness dwelling

(in kppmh above 1200 ppm *per person* per heatingseason versus $q_{v;10;kar}$ in $dm^3/s/m^2$)



BETTER IAQ

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6. OVERALL RESULTS RH-LEVELS

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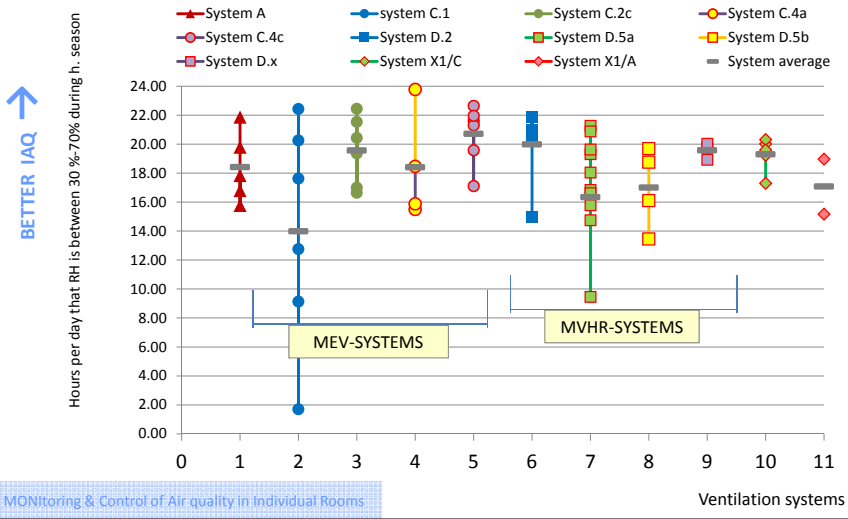
Number of hours per day with RH between 30 -70%
(dwelling average during heating season)



6. OVERALL RESULTS RH-LEVELS

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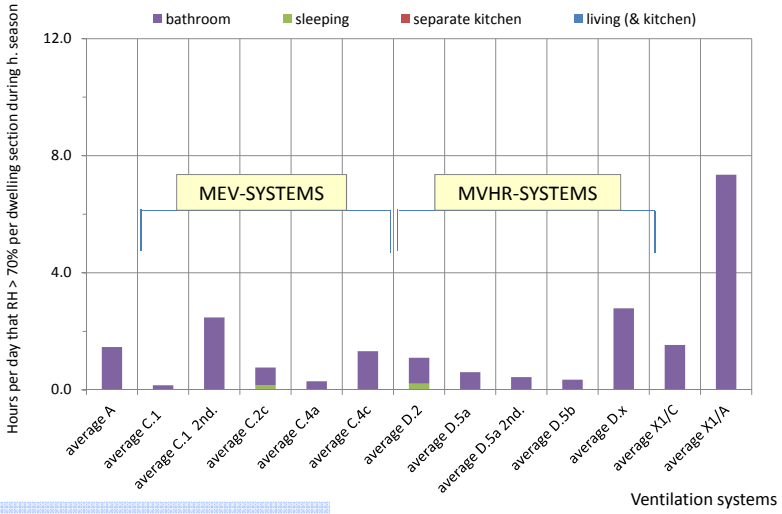
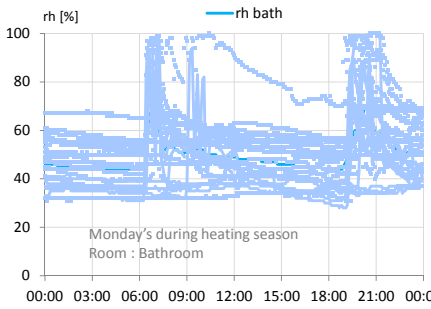
Number of hours per day with RH>70% per dwelling section
Ventilation system average during heating season



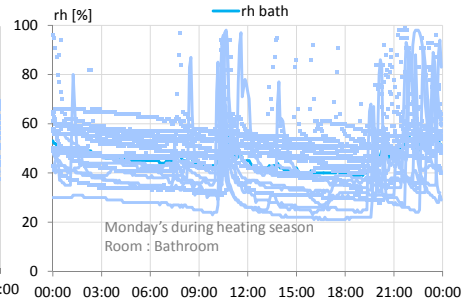
6. OVERALL RESULTS RH-LEVELS

MONICAIR

Dwelling with MEV system type C.2c.
Number of inhabitants : 3



Dwelling with MVHR system type D.2
Number of inhabitants : 5

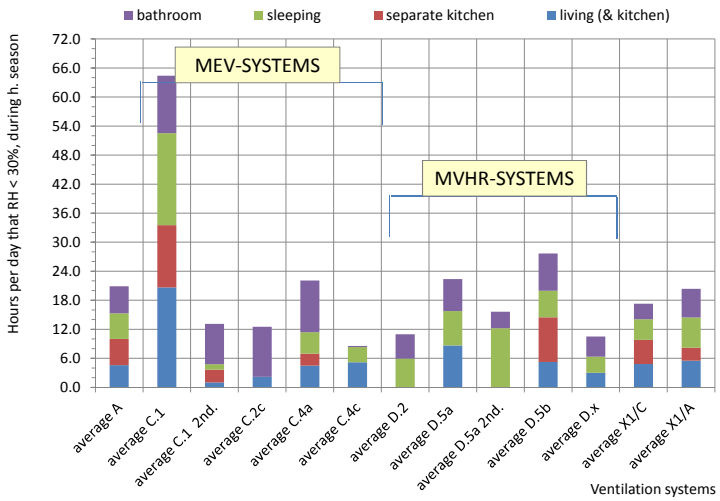


6. OVERALL RESULTS RH-LEVELS

MONICAIR

Number of hours per day with RH<30% per dwelling section

Ventilation system average during heating season



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7. FIRST RESULTS ENERGY PERFORMANCE VENTILATION SYSTEMS

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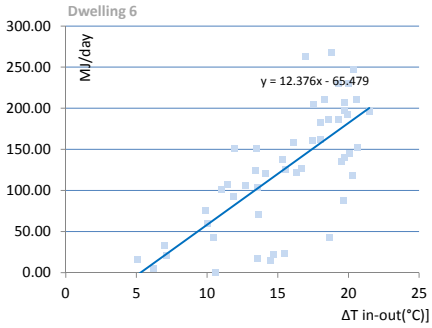
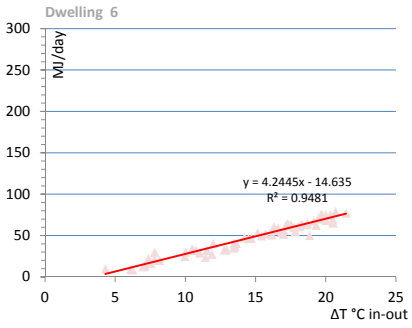
Dwelling with MEV system type C.2c.

Gas consumption space heating
(MJ/day)/ΔT°C in-out



Thermal energy content mech. induced ventilation
(MJ/day)/ΔT°Cin-out

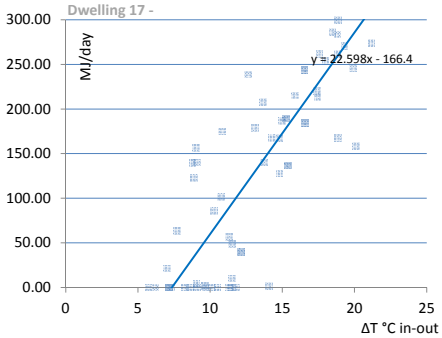


7. FIRST RESULTS ENERGY PERFORMANCE VENTILATION SYSTEMS

MONICAIR

Dwelling with MVHR system type D.2

Gas consumption space heating
(MJ/day)/ΔT°Cin-out



Thermal energy content mech. induced ventilation
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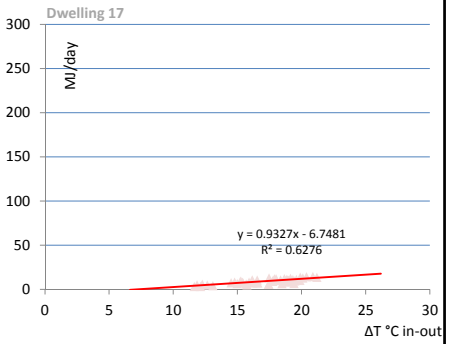
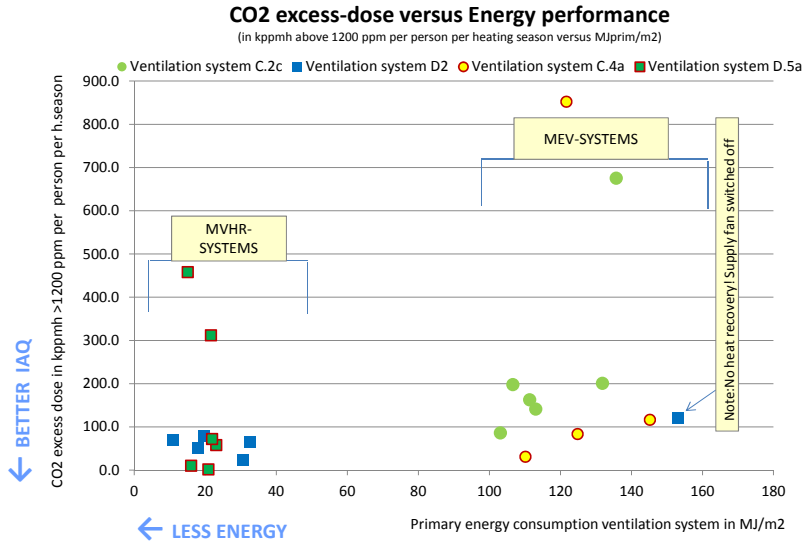


MONItoring & Control of Air quality in Individual Rooms

7. FIRST RESULTS IAQ & ENERGY PERFORMANCE VENTILATION SYSTEMS

MONICAIR



8. PRELIMINAY CONCLUSIONS & DISCUSSION

MONICAIR

- Real life IAQ- performance of ventilation systems, that fully comply with current building codes and relevant standards, show big differences
- Real life CO_2-excess dose may vary from 10 to 850 kppmh/pp/heating season, resulting in a situation in which appr. 1% to 85% of the time at home, ventilation is not sufficient the room that one occupies
- More than half of the dwellings investigated (32 of 62) have a CO_2-excess dose of > 100 kppmh/pp/heating season ; almost 30% (17 dwellings) have >250 kppmh (corresponding to resp. >10% and >25% of time spent at home with insufficient ventilation)
- Current standards & building codes for ventilation systems result in very different IAQ levels (question: do they suffice to secure acceptable IAQ-levels in residential dwelling?)
- Also the real life *energy* performance of ventilation systems show big differences, with an average primary energy consumption of 22 MJ/m2 for MVHR systems to an average of 125 MJ/m2 for MEV systems (this is excluded the energy related to cross ventilation)
- MEV-systems with an IAQ sensor do not necessarily have a better IAQ- or a better energy performance

8. PRELIMINAY CONCLUSIONS & DISCUSSION

MONICAIR

- There is a significant improvement potential, both in ventilation systems design as in the assessment- and calculation methods with which the IAQ- en energy performance of ventilation systems are valued
- Key issue in improving ventilation system design is “securing the necessary air exchange *per room* under all circumstances” (despite variations in façade wind pressure, position of internal doors, opening of vents or windows, number of inhabitants, etc.)
- Assessment- and prediction methods on real life IAQ and energy performance of ventilation systems should also be based on real life tests under various circumstances, and not only on computer simulations
- A clear limit or standard should be set, defining the maximum CO_2 excess dose (kppmh/pp/hs) that is allowed per IAQ-class (or a % of time the IAQ may be outside limits of the given IAQ class)
- More monitoring- and field research projects are necessary to further substantiate the preliminary findings of MONICAR

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Thanks for your attention

MONItoring & Control of Air quality in Individual Rooms

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MONICAIR : DISSEMINATION RESEARCH DATA

Level 1 : detailed logdata per ventilation systeem	Indiv. manufacturers
Level 2 : first level of data aggregation	Consortium members
Level 3 : second level of data aggregation	External parties

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PLANNING PART A: FIELD RESEARCH VENTILATION

Workingplan	*Main task*	*Planning*
WP1a. Data collection	Monitoring & field research on IAQ- and energy performance of various commonly used ventilation systems in real life	Okt. 2012 t/m Okt. 2014
WP2a. Modelling	Improving assessment methods of ventilation systems in order to bridge the gap between theoretical and real life IAQ- en energy performance	Febr. 2014 t/m Okt. 2014
WP3a. Guidelines	Drawing up of guidelines for the development of improved ventilation systems	Okt. 2014 t/m Dec. 2014
WP4. Proof-of-Principle	Development, realisation and validation of improved ventilation systems.	Sept. 2014 t/m Dec. 2015

Predicting the optimum air permeability of a stock of detached English Dwellings

Dr. Benjamin Jones
Assistant Professor
Department of Architecture and Built Environment
University of Nottingham
benjamin.jones@nottingham.ac.uk

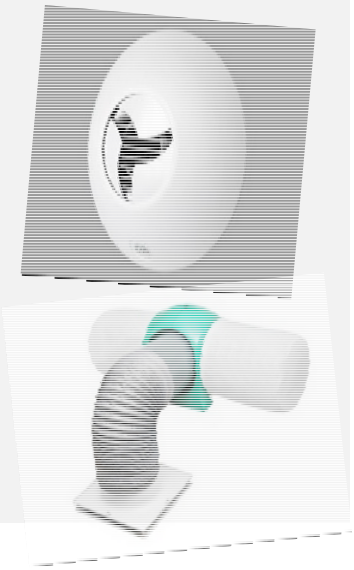
The Problem

- 22m houses in England, and 27m in UK
- 20% are government owned
- Many are *leaky* (high permeability)
- Anecdotally evidence suggests that they have IAQ problems

The Problem

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

- Mechanic extract ventilation (MEV)
  - reduce internal air pressure below ambient
  - causes fresh air to be drawn through air leakage paths (ALPs)
- Positive Input Ventilation (PIV)
  - increases internal air pressure above ambient
  - causes stale air to be extracted through ALPs



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The Problem

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- Need to reduce energy demand of all houses
- Social housing undergoing retrofitting of energy efficiency measures that **increase** air tightness
- Consequences might be:
  - Decrease of exfiltration heat losses
  - Decrease in heating demand
  - Increased resistance to airflow when using continuous MEV (CMEV) or PIV system
  - Increase in required fan power and energy demand

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Research Questions

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- An understanding of the relationships between CMEV and PIV, and infiltration and exfiltration is critical to the optimization of their performance.
- Use a theoretical approach to ask the questions:

(1) *Is there an optimum permeability for English houses ventilated using a CMEV or PIV system?*

(2) *Is it OK to continue using/installing CMEV/PIV systems into airtight dwellings?*

Method

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1. Choose theoretical model
2. Obtain sources of data inputs
3. Investigate underlying physics of the problem
   - Predict total heat lost from typical detached (single family) house in London during heating season
4. Develop simplified model of PIV/CMEV energy demand that informs the current national energy calculation method (known as SAP)
5. Predict optimum permeability of the entire stock of English detached houses during heating season

The Model

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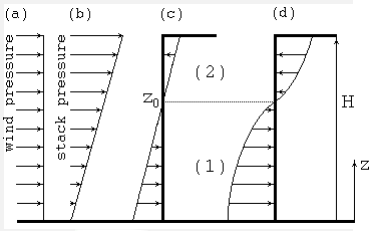
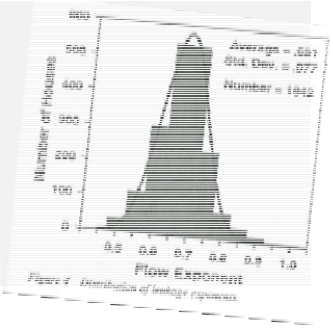
Following Persily et al. (2010) a stock model requires

1. A model
2. Knowledge of the properties of dwellings
3. Suitable statistical approach
   - Mini latin hypercube sampling
   - Boot strapping method





Persily, A., Musser, A. and Emmerich, S.J. 2010. Modeled infiltration rate distributions for U.S. housing. Indoor Air 20(6): 473-485.

Model: DOMVENT3D

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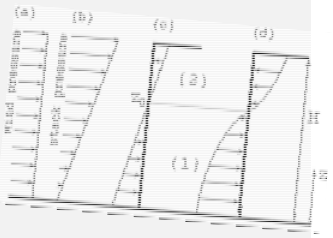
Following Jones *et al.* (2014)

- A model of infiltration and exfiltration
- Assumes uniformly porous facades
- Linear pressure distribution
- Integrates airflow in vertical plane
- Single-zone dwelling
- Dynamic neutral height



$$Q_i = \alpha(|\Delta p|/\Delta p)\int_{z_{min}}^{z_{max}} (|\Delta p|)^{\beta}\, dz$$

Jones, B.M. et al. 2014. Modelling uniformly porous façades to predict dwelling infiltration rates. Building Services Engineering Research and Technology: 35.

Knowledge of dwellings

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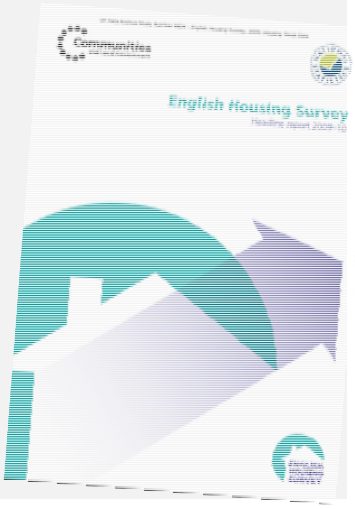
The English Housing Survey (DCLG)

1. Published by Department for Communities and Local Government every few years
2. Survey of 16,160 dwellings
3. Weighted inputs
4. Geometric, geographic, and environmental data



Knowledge of dwellings

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Meta-data	Type	Source
Geographic	Weather file	CIBSE Test Reference Year
Geometric	Dwelling dimensions	English Housing Survey (EHS), Cambridge Housing Model (CHM)
	Dwelling orientation	U(0,360)
Physical	Dwelling permeability	U(0.1,50)
	Flow exponent	Sherman (1998)
	Wind pressure coefficients	Swami & Chandra (1987)
Environmental	Terrain	EHS
	Sheltering	EHS, and Deru & Burns (2002)
	Internal air temperature	N(21.1,2.5) Shipworth et al (2009)
Ventilation	Fan airflow rate	$\pm 0.5 h^{-1}$ (constant according to system type)

Dwelling Properties

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Table 1: Properties of sample detached dwelling.

EHS sample	G0322417
Dwelling type	Detached
Location	London, England
Terrain type	Urban
Sheltering	Heavy
Orientation	North/south
Height (m)	5.1
Width (m)	6.4
Depth (m)	7.2
Volume, V (m^3)	232.7
Surface area, A_{surf} (m^2)	229.5
$A_{surf}:V$ (m^2/m^3)	1.01
β	0.6
T_{int} (°C)	21.1

Total Heating Season Heat Loss

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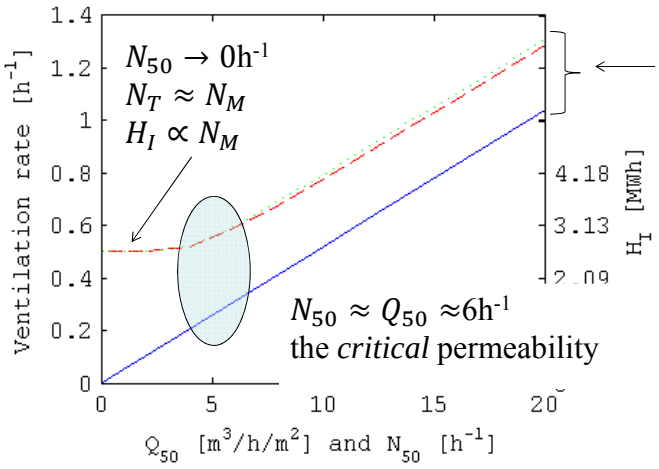

$N_{50} \rightarrow 20h^{-1}$ the ventilation rate is $N_T \approx N_{NV} + C$

$$C = \frac{N_M}{2}$$

and

$$\Delta H_I \propto \frac{N_M}{2}$$

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——, natural infiltration; ----, CMEV; ·····, PIV

Simplified model

$$N_T = \left\{ |N_M^n| + \left(N_{NV} + \frac{|N_M|}{2} \right)^n \right\}^{\frac{1}{n}}$$

N_{NV}	natural infiltration rate (h^{-1}) [RULE OF THUMB]
N_T	total ventilation rate (h^{-1})
N_M	mechanical ventilation rate (h^{-1})
n	an exponent (-)

Over range of $0<N_{50}<20$

- CMEV: n=8 gives MAE of 1%
- PIV: n=7 gives MAE of 3%

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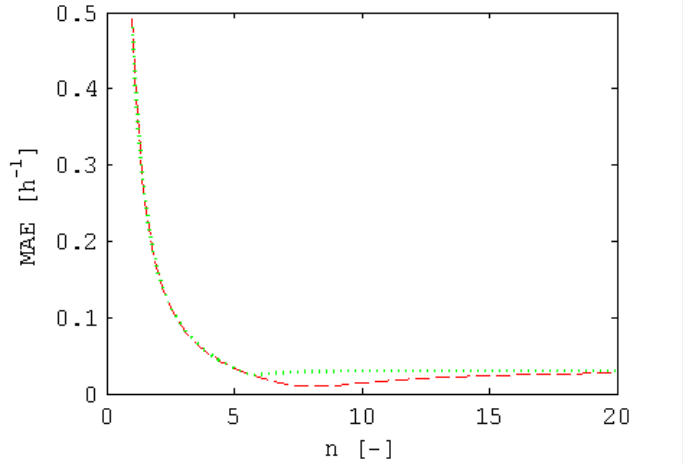
Simplified model exponent



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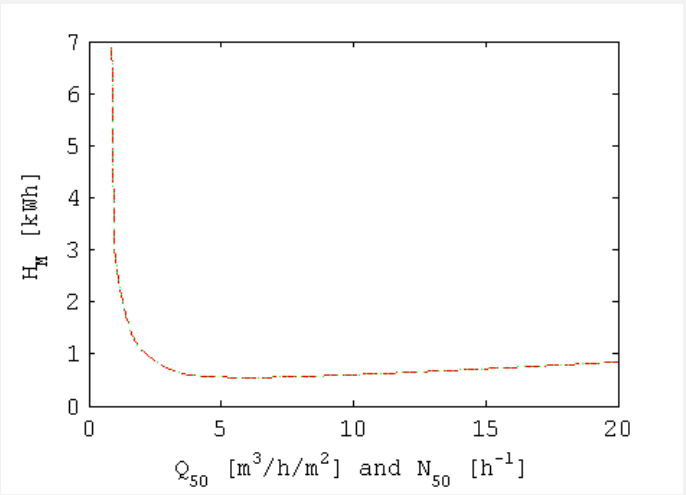
----, CMEV; ·····, PIV

Mean fan energy demand



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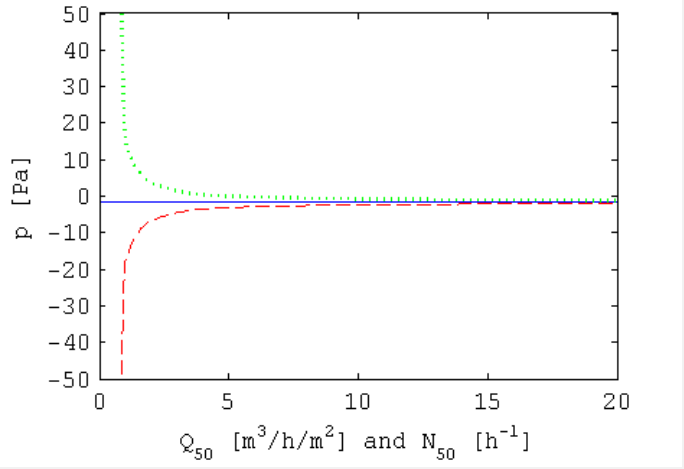
—, natural infiltration; ----, CMEV; ·····, PIV

Mean pressure difference



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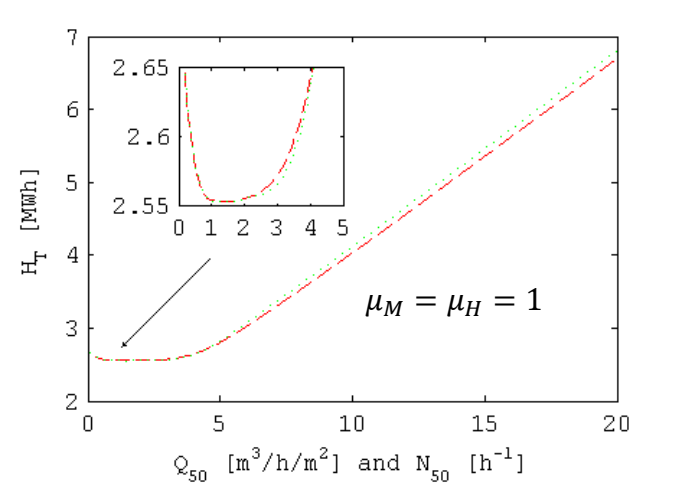
—, natural infiltration; ----, CMEV; ·····, PIV

Mean total energy demand



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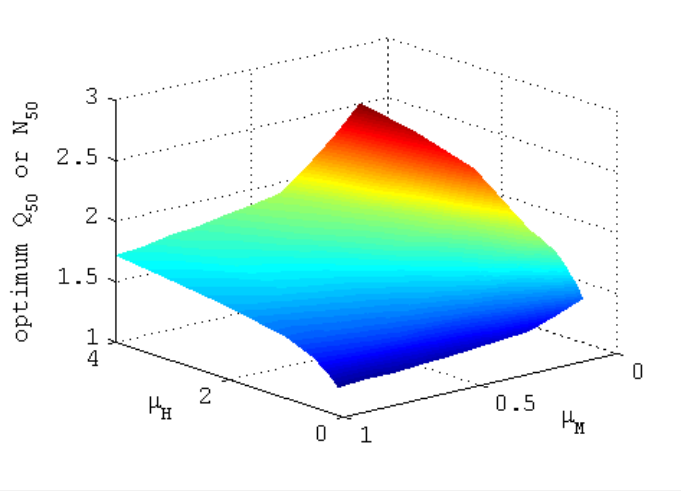
----, CMEV; ·····, PIV

Varying device efficiency



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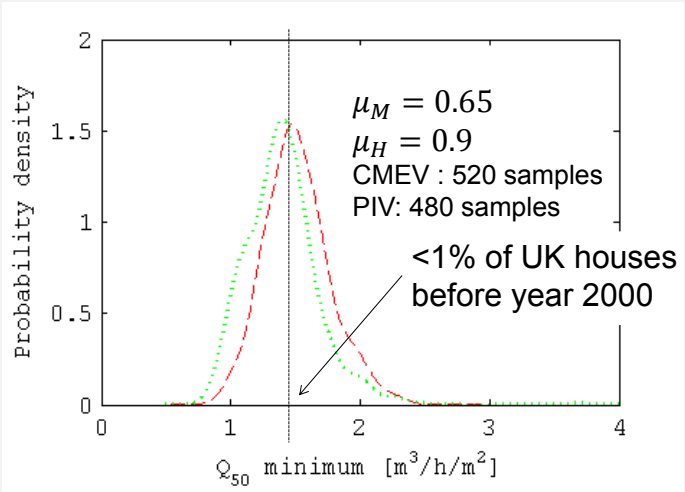
Stock optimum



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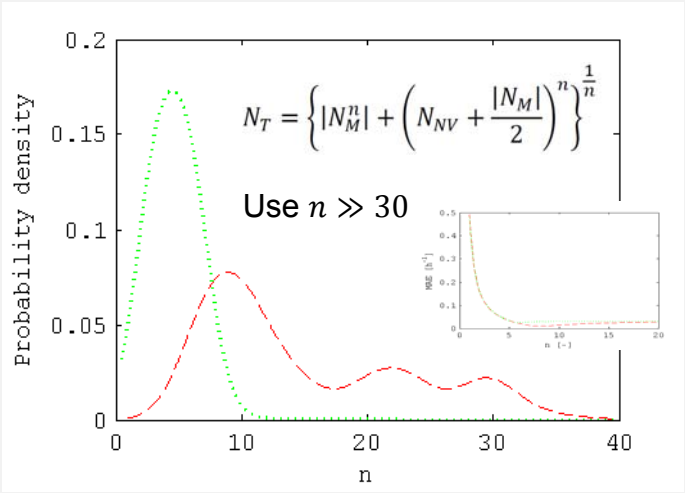
----, CMEV; ·····, PIV

Stock exponent



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----, CMEV; ·····, PIV

Summary

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- Developed simplified ventilation model of mean heating season ventilation rate in dwelling ventilated by PIV/CMEV system
  - should be of interest to simplified energy models, such as the UK's Standard Assessment Procedure
- An optimum permeability for detached houses that use PIV/CMEV systems is found between $1<N_{50}<2h^{-1}$
- Occurs in <1% of UK dwellings built before 2000
  - the reality of achieving the optimum is unlikely
- Highlights that it is difficult to make existing houses too airtight
- It is OK to use PIV/CMEV systems in existing houses

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Thank-you

Benjamin Jones
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Tuesday, September 30, 2014

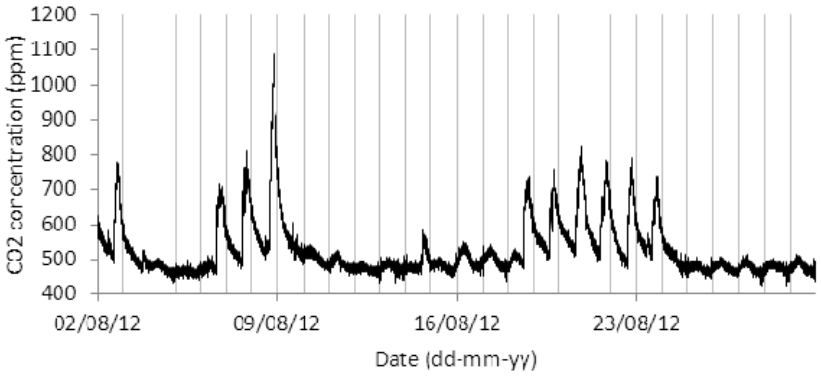
Measurement of Infiltration Rates from Daily Cycle of Ambient CO_2

João Dias Carrilho[1], Mário Mateus[1], Stuart Batterman[2] and Manuel Gameiro da Silva[1]

[1]ADAI-LAETA, Dep. Mech. Eng.
University of Coimbra
Portugal

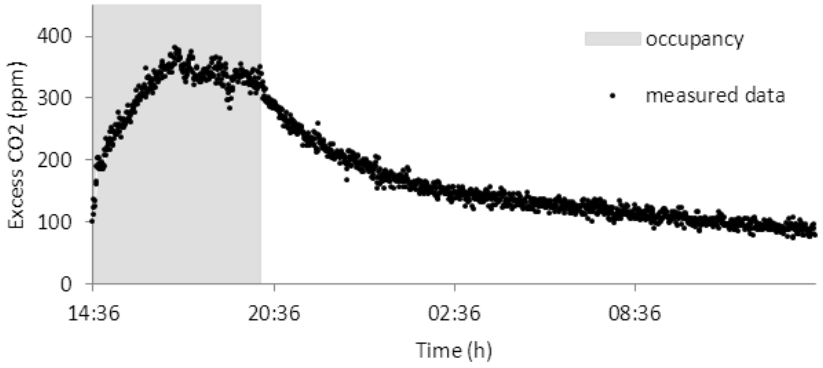
[2]Dep. of Env. Health Sciences
University of Michigan
USA

Ventilation rate time series from tracer gas time series?



Conventional analysis techniques

- Metabolic CO_2 as a tracer gas:

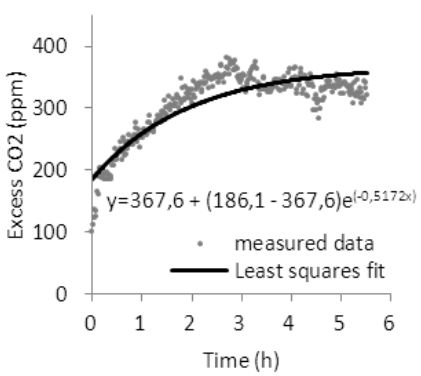


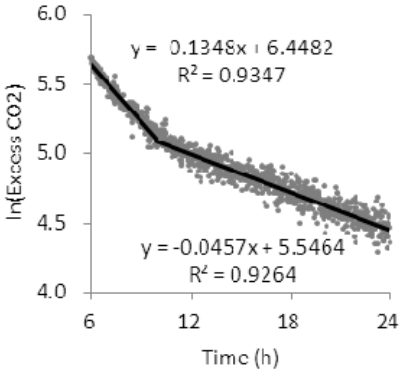
video

J. Dias Carrilho, M. Mateus, S. Batterman and M. Gameiro da Silva. *Infiltration Rates from Ambient CO2*

Conventional analysis techniques

- Fitting the exponential solution using the LS method:

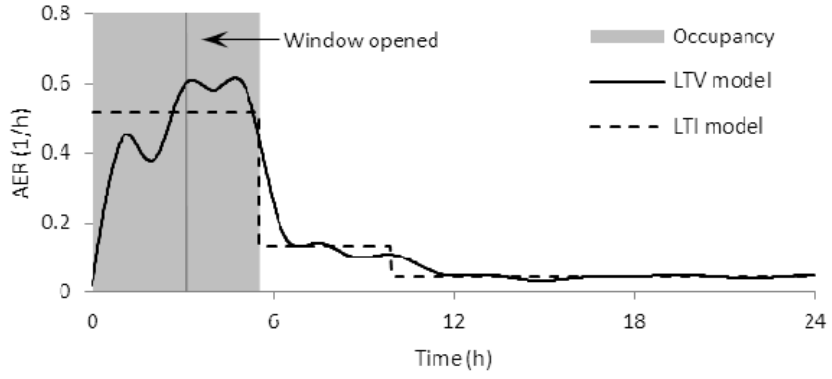




J. Dias Carrilho, M. Mateus, S. Batterman and M. Gameiro da Silva. *Infiltration Rates from Ambient CO2*

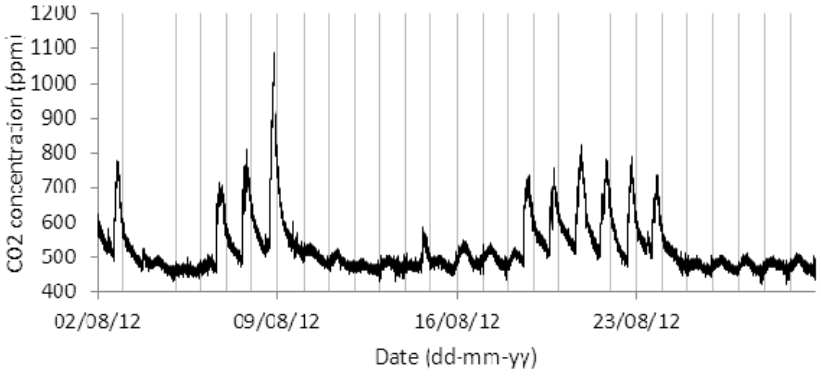
Time variant formulation + collocation of cubic splines:

J Dias Carrilho, S Batterman and M Gameiro da Silva. *Estimating Time Varying Air Exchange Rates*, presented at CLIMA 2013, Prague

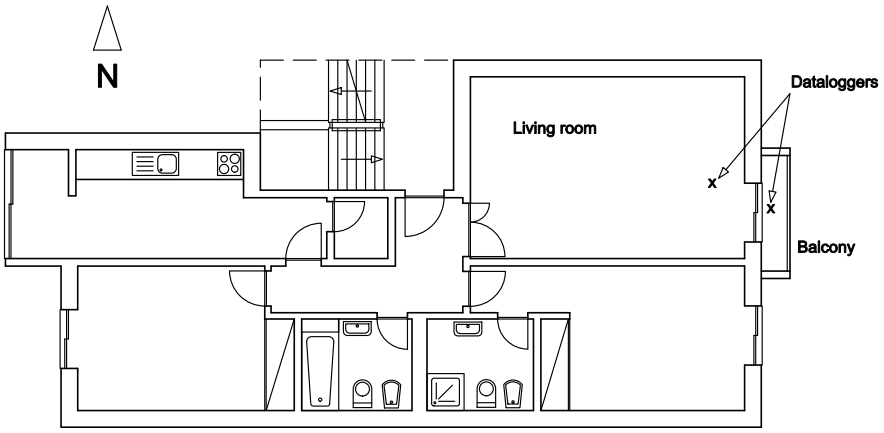


J. Dias Carrilho, M. Mateus, S. Batterman and M. Gameiro da Silva. *Infiltration Rates from Ambient CO2*

What about days without occupancy?

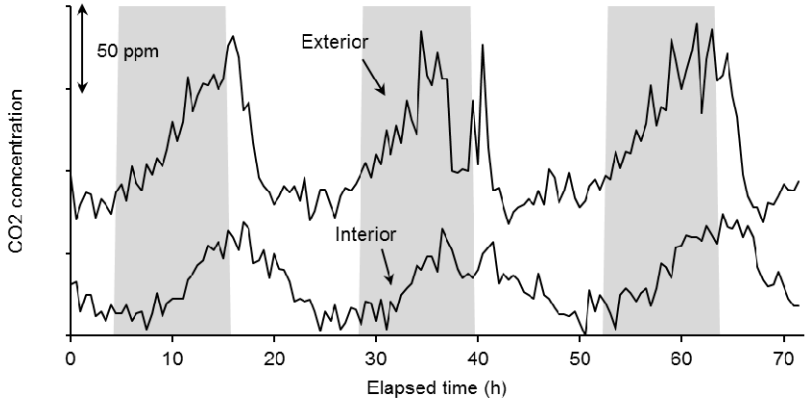


Trying out ideas...



J. Dias Carrilho, M. Mateus, S. Batterman and M. Gameiro da Silva. *Infiltration Rates from Ambient CO2*

Inside concentration follows outside concentration like a first order system!



video

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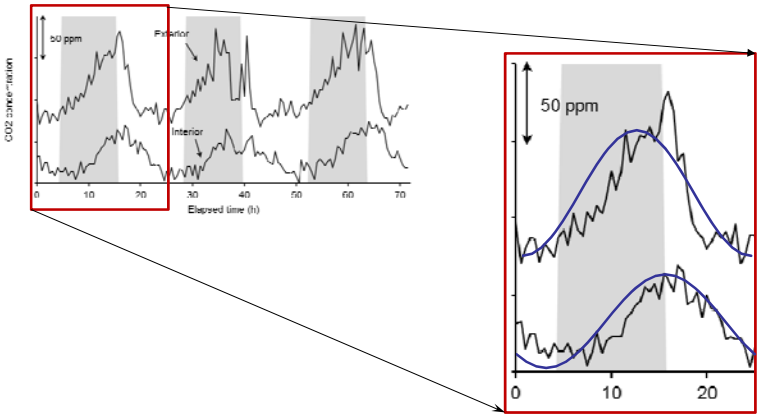
Compute 24h moving average AER from Input/Output relation of a first order system



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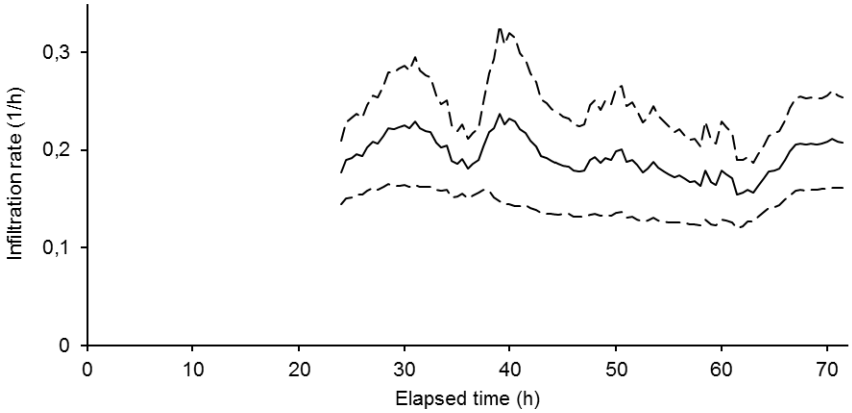
Preliminary results



J. Dias Carrilho, M. Mateus, S. Batterman and M. Gameiro da Silva. *Infiltration Rates from Ambient CO2*

Conclusion

- New tracer gas method for estimating 24h moving average AERs
- No need for tracer injection!
- Potentially works with any gas present in the surface atmosphere
- Preliminary, proof-of-concept results look reasonable
- Further (current) work on experimental validation

Thank you

joao.carrilho@dem.uc.pt

J. Dias Carrilho, M. Mateus, S. Batterman and M. Gameiro da Silva. *Infiltration Rates from Ambient CO2*

THE 35TH AIVC-4TH TIGHTVENT & 2ND VENTICOOL CONFERENCE, 2014

The impact of air-tightness in the retrofitting practice of low temperature heating

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Division of Fluid and Climate Technology
School of Architecture and Built Environment
KTH-Royal Institute of Technology

Acknowledgement: Nordic Innovation, Formas in Nordic Built for providing financial support

Background

1) A previous modeling study on the on-going project: **implementation of low temperature heating in the retrofitting practice of Swedish housing stock**

2) In Sweden, residential building stock comprises **2.5 million high/low rise multifamily houses, and 2 million semi/detached single-family houses**. 1.4 million were constructed during 1950-1975.

3) Industrialized retrofitting measures with less impacts to the occupants and easily implemented work pacakges are needed.

4) **Low temperature heating (LTH)** has shown promising advantages to improve the retrofitting efficiency, compared with conventional retrofitting:

- Easily installed solutions
- Thermal comfort contributions
- Improved coefficient of performance (COP) when supplied by heat pump

5) Existing studies show that the energy saving potentials of LTH are related to the level of existing energy demands of the building stock. **How to select the representative archetypes** and **small-scale LTH-based work packages** and **how much energy saving potentials can be achieved** are not clear.

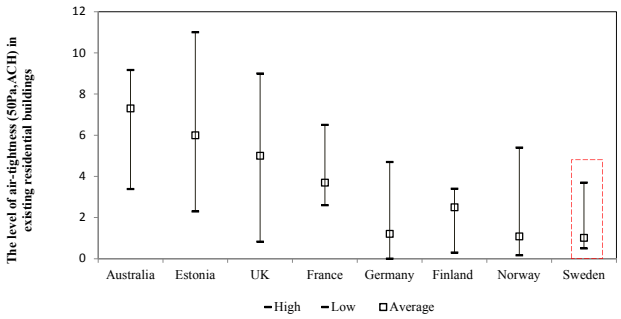
Objective

- Develope a methodology/tool to estimate the combined effect of LTH-based retrofit options from a primary purpose
- Current step: evaluate the impact of air-tightness variances to the primary operational energy (PE) saving potentials in selected archetypes

Selected housing stock types

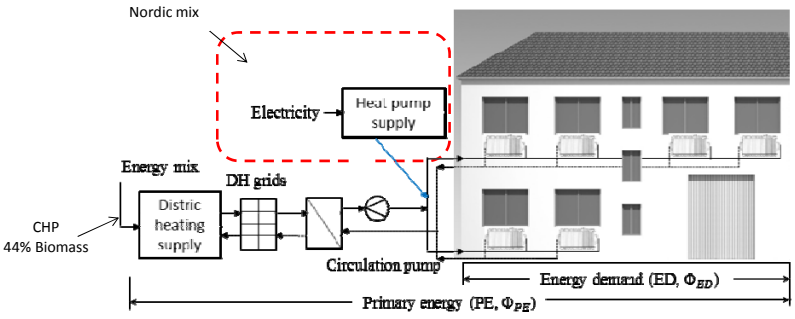
	T1	T2	T3
Archetypes			
Dwelling types	Single family house	Low-rise multifamily house	High-rise multifamily house
Age	1950- 1960	1960-1975	1960-1975
Foundation	Lightweight concrete	Concrete slab	Polished concrete
External wall	10 cm mineral wool insulation	13 cm mineral wool insulation	15 cm mineral wool insulation
Window	Double glazing, aluminium frame	Double glazing, timber frame with ventilation fan	Double glazing, aluminium frame with one-side ventilation fan
Roof /ceiling	Brick and cutter coke ash insulation	Flat roof covered with cardboard and mineral wool	Concrete foundation with galvanized sheet metals, mineral wool insulation
Ground floor	Linoleum and coke ash	Slab covered with linoleum mats or plastic board	Slab covered with mineral wool or linoleum
Heating	District heating	District heating	District heating
Radiator	Single-pipe radiator	Single-pipe hydraulic radiator	Two-pipe hydraulic radiator
Ventilation	Natural ventilation	Exhaust ventilation	Exhaust ventilation
Energy mix	Gas/oil/partly el.	CHP	CHP
Air-tightness	2 ACH	2 ACH	5 ACH

Air-tightness level of Swedish housing stock



- In 2012, the revised BBR (Swedish building regulations) provides no specific limit values in respect of tightness.
- To obtain a well performance of LTH, a good guideline minimum value for **2.88 ACH and 1.26 ACH** at a pressure difference of +/- 50 Pa are recommended for **existing and new Swedish residential buildings**.
- 1400 existing Swedish building stock statistics from derived field studies shows that the actual air-tightness level ranges **from less than 1 ACH to approximately 5.4 ACH**, at pressure difference of 50 Pa.

Methodology

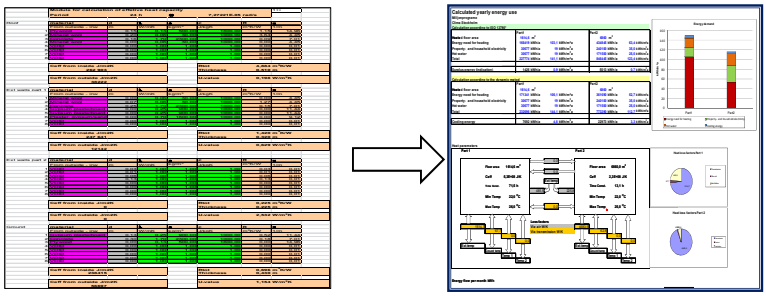


$$\Phi_{PE} = \Phi_{ED} \cdot f_{\mathrm{PE}}$$

$$\Phi_{ED} = \Phi_{Heating} + \Phi_{Domestic\ hot\ water\ (DHW)} + \Phi_{EL}$$

Combining EN ISO 13790 calculation methodologies for energy-demand modeling and European standard EN15316-4-5 boundaries for primary energy estimation

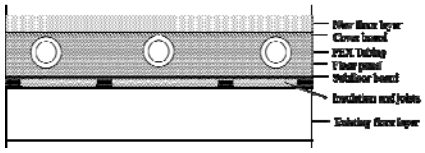
Methodology



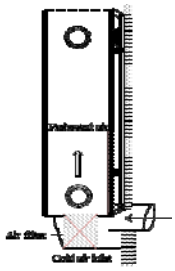
Input building parameters and energy supply/return temperature → PE saving potential

Consolis Retro is employed to model the energy saving potentials before and after retrofitting. **Two types of energy supply systems** are integrated in the model to calculate the primary energy factor (f_{PE}), depending on the **energy mix and supply/return temperature**: by district heating or heat pump. Accuracy of the errors were below 9% compared with IDA ICE and EnergyPlus. One-zone or tow-zone modeling can be performed.

Methodology



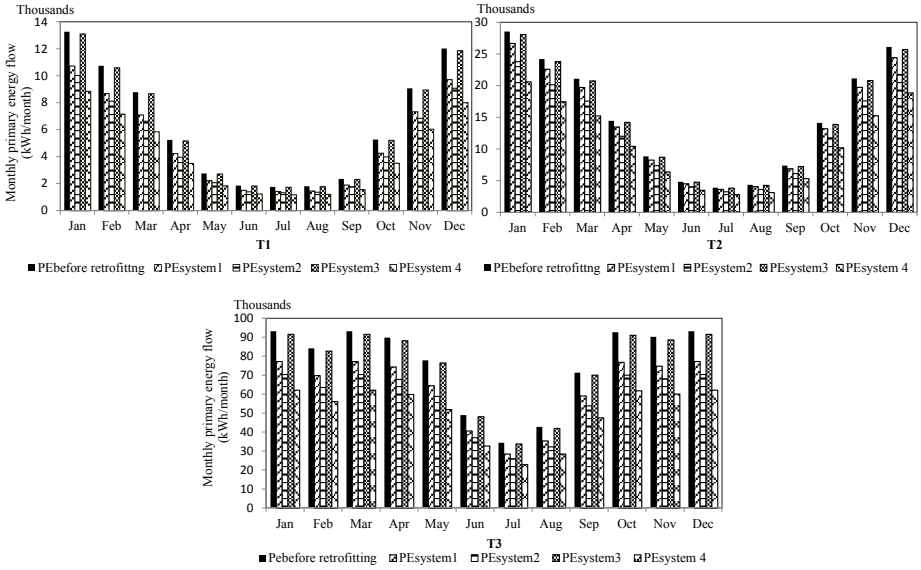
LTH- hydraulic floor heating (FH)



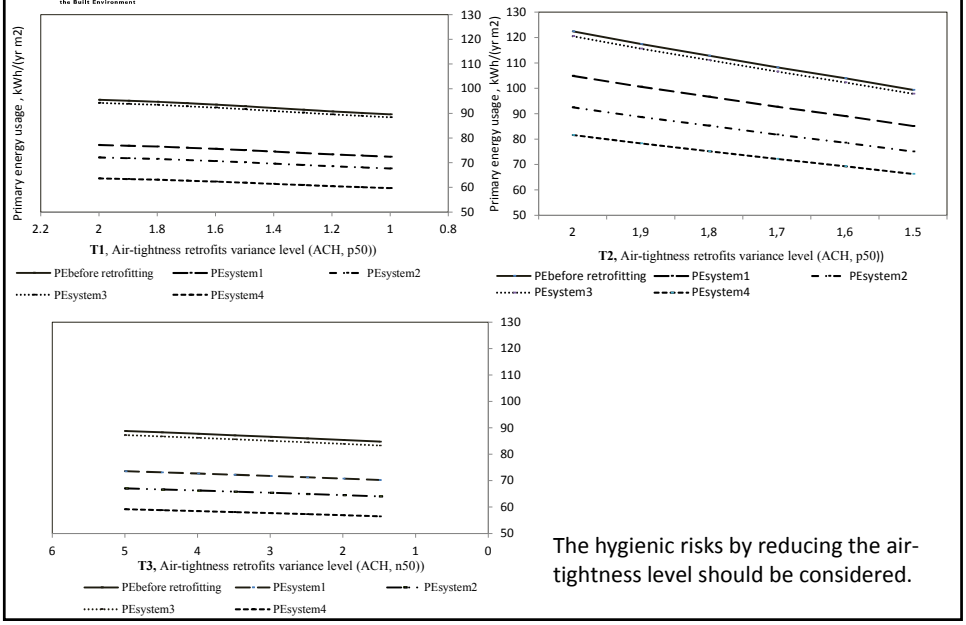
LTH-ventilation radiator (VR)

System	Retrofit room	Supply/return temperature (℃)	Non-retrofit room	Supply/return temperature (℃)
System 1	VR in living rooms	45/35	Conventional radiator	55/45
System 2	Whole building VR	45/35	-	
System 3	FH only in bathroom	35/30	Conventional radiator	55/45
System 4	Whole room FH	35/29	-	-

Results



Results



The hygienic risks by reducing the air-tightness level should be considered.

Conclusion

- The developed model is capable of performing parametric analysis and general primary energy estimations (before and after retrofitting).
- The combined effect of LTH and air-tightness retrofitting can achieve 19%-36% PE saving potentials in the selected archetypes.
- T2 low-rise multifamily houses from 1960-1975 shows high sensitivities with the proposed renovation strategy.

Limitations and future works

- A preliminary modeling work for future simulation and on-site measurements/validation.
- Primary energy saving potentials of LTH-based district heating retrofitting
- High air infiltration level in T3 are lead by the existing wind catcher beside windows, which will be considered as natrual ventilation in future works.
- Current work focus on how reduced supply temperature will increase the primary energy saving potentials, in which the heat distribution/emission efficiency model shall be further developed.
- Evaluation of both thermal comfort and primary energy saving potentials of other small-sclae retrofitting in accordance with LTH alternatives should be further investigated

KTH Architecture and the Built Environment

Thank you !

A NOZZLE PULSE PRESSURISATION TECHNIQUE FOR MEASUREMENT OF BUILDING LEAKAGE AT LOW PRESSURES

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Technology Strategy Board
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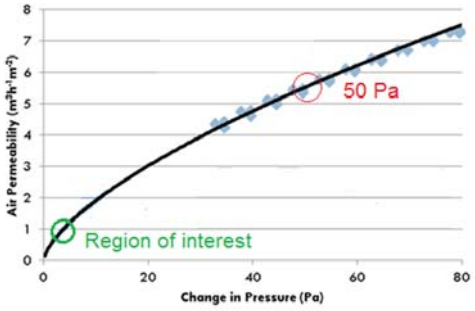
Background

- Standard for air tightness of buildings: Q50
  - European Directive on energy performance of buildings
  - UK Building Regulations
- Limitation of traditional methods
  - Unnatural test pressures
  - Errors of extrapolation



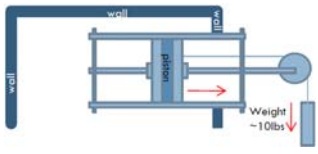
Accurate measurement of Q4 is important

Key stage

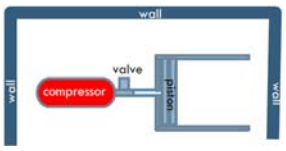
Year	Funding source	Nottingham academics/researchers (PI in bold)	External involvement
2001	Internal funding	**Etheridge** & Carey	None
2002-2006	EPSRC Industrial Case Award (PhD)	**Etheridge** & Cooper	Airflow Developments Ltd
2010	Swedish Energy Agency	**Cooper** & Etheridge	University of Gavle, Sweden
2010-2011	EPSRC First Grant	**Cooper** & Zu	None directly, various via LoS
2013-2015	TSB consortium – Scaling Up Retrofit	**Cooper**, Riffat, Gillott & Zheng	NEF, Elmhurst, EPS LTd, Air & Gas Ltd, & ANDtr
2015-2018	EU – Horizon 2020	**Cooper** & Zheng	20+ in 8 countries

Low Pressure Pulse technique

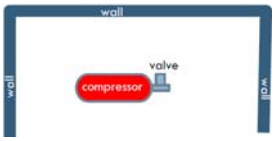
- Building leakage at ventilation pressure: Q4
- Quasi-steady technique



Carey and Etheridge 2001

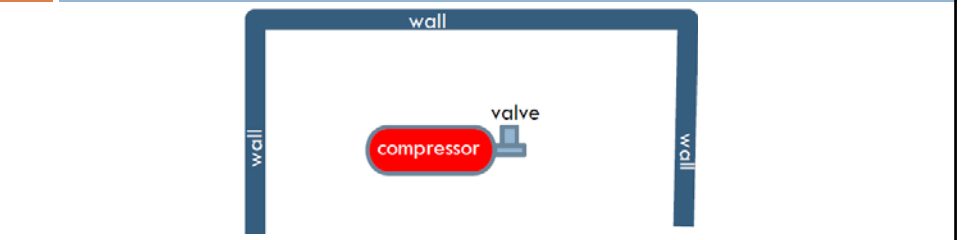


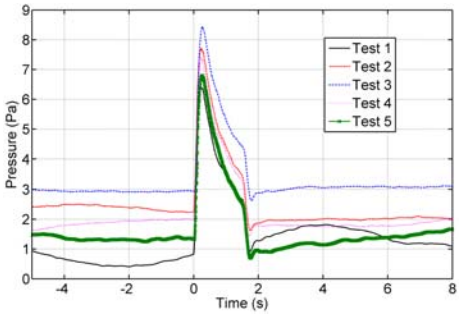
Cooper and Etheridge 2002-2006

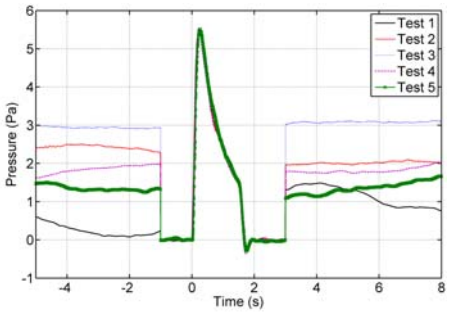


Cooper, Etheridge and Zu 2006-2011

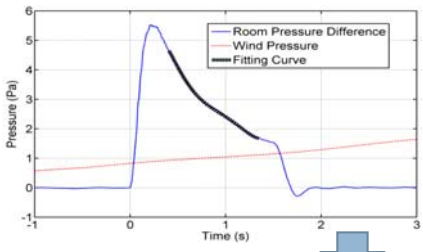
Nozzle technique

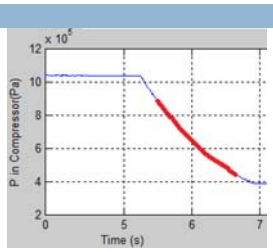


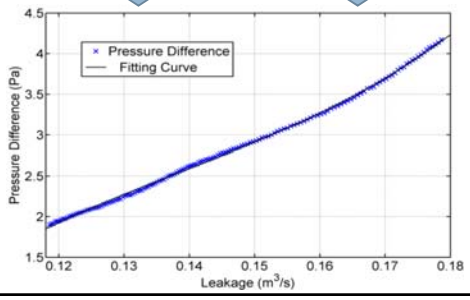




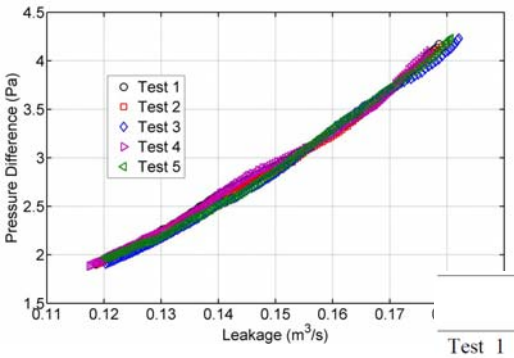
Nozzle test analysis





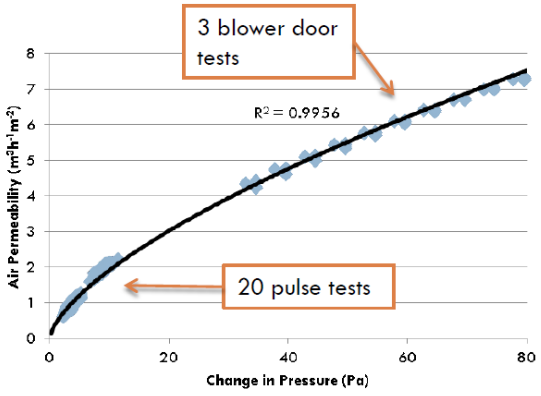


Repeatability



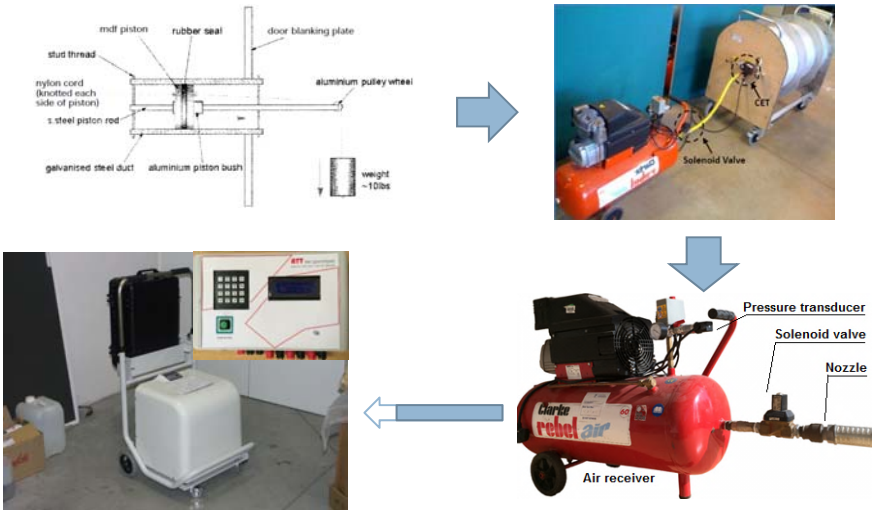
	Q4 (m^3/s)	$(Q4 - \bar{Q}4)/\ \bar{Q}4 \times 100\%$
Test 1	0.17535	-0.36%
Test 2	0.17557	-0.23%
Test 3	0.17704	0.60%
Test 4	0.17525	-0.41%
Test 5	0.17668	0.40%
Average	0.17598 ($\bar{Q}4$)	

Comparison with the blower door test



Tests including with known opening and tracer gas technique

Transformation



Key Features

- Accurate and repeatable results at typical infiltration pressures
- Measurement of the *whole* building envelope - no need to block a doorway
- Quick and easy – each test run takes only a few seconds
- Compact and portable – can test any size building
- Reduced testing cost – lower capital cost and efficient testing process
- Effects of wind and buoyancy at the time of the test are eliminated
- It can be used even in windy conditions
- Effects of envelope flexing are minimised
- User-friendly graphical interface for analysis

Uncertainties & Blower Doors

Colin Genge
colin@retrotec.com

Checking equipment and tester

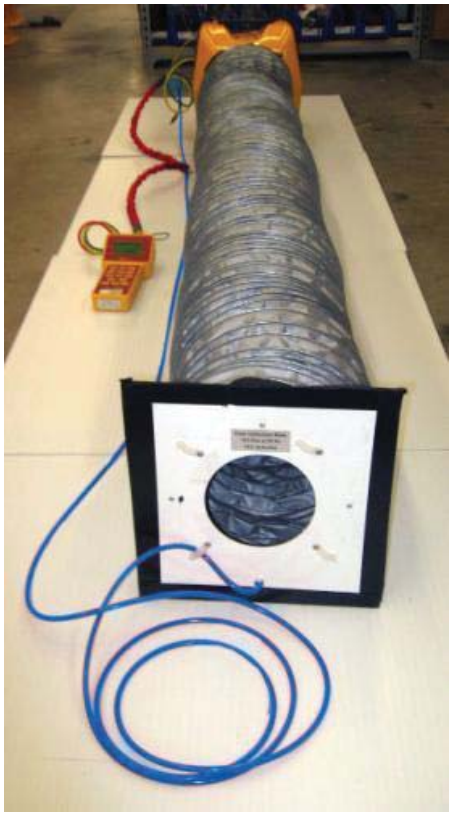
can the user troubleshoot their gauge?

Gauge with tube check

Gauge with tube check

Gauge to gauge check

Field Calibration



Field Calibration

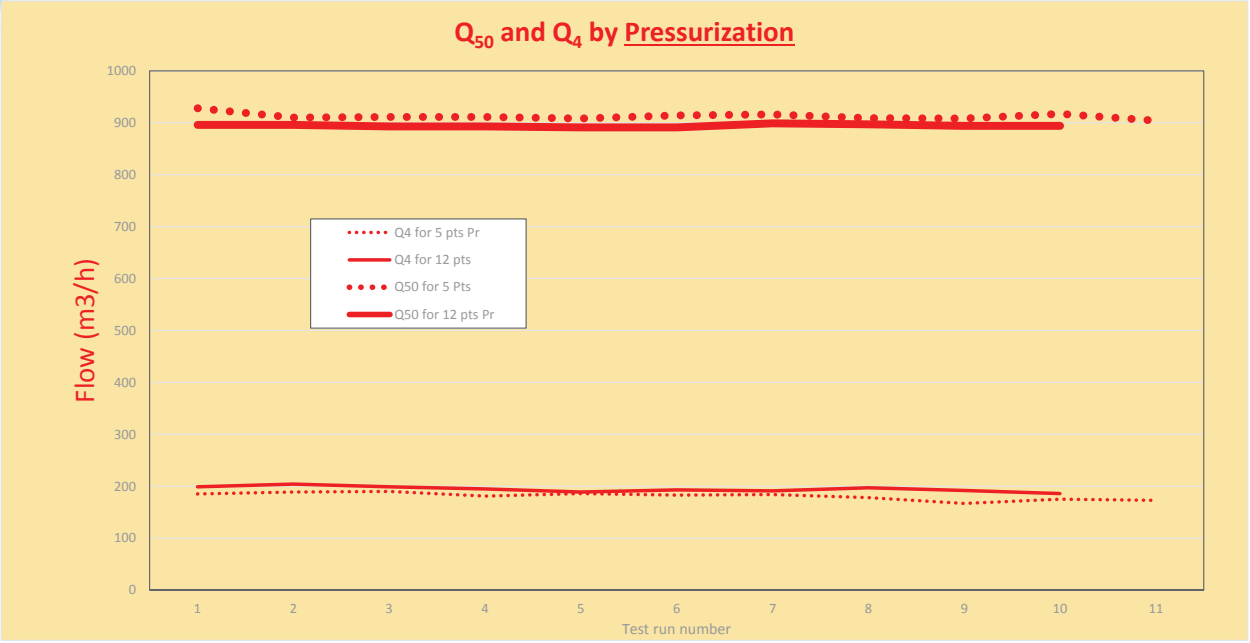
Pinched tube

Water in tube

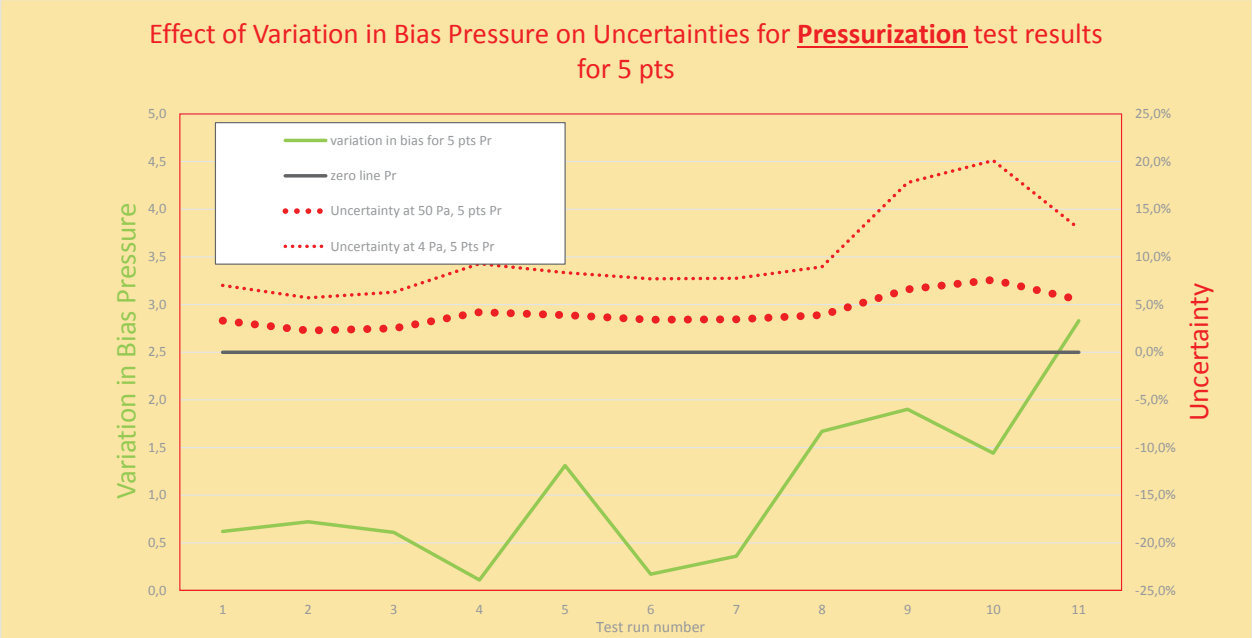
One inch of water

Repeated tests

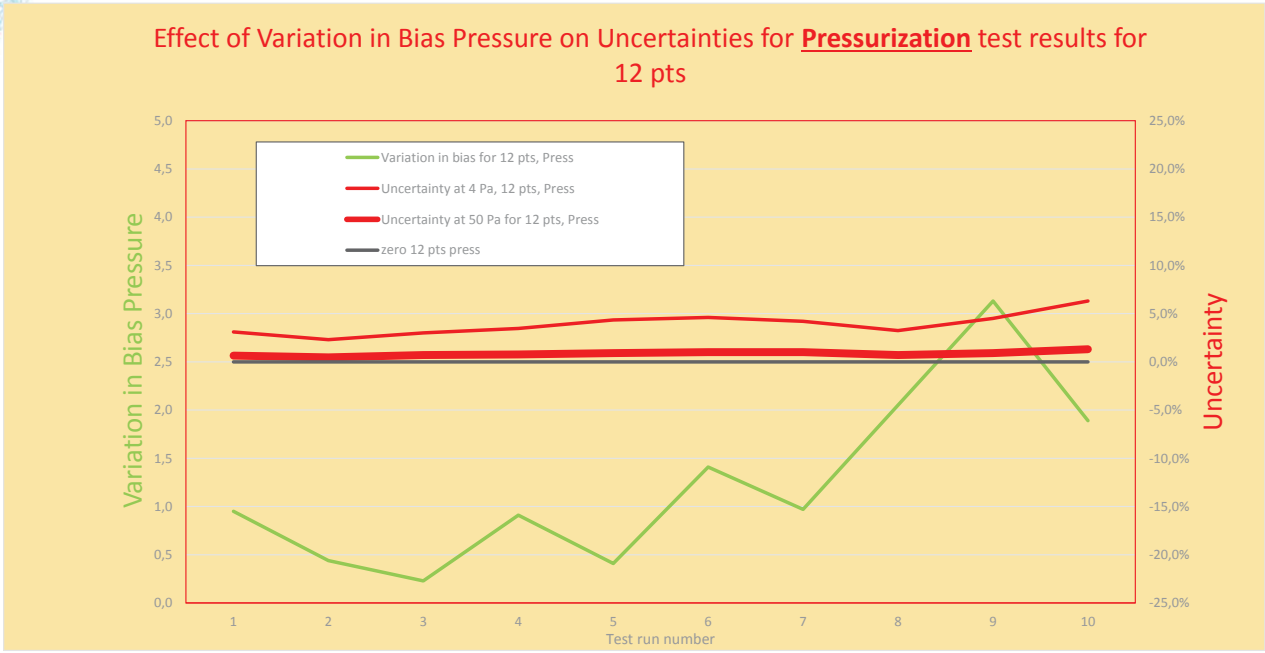
Compare Pressurization tests at 4 and 10 Pa



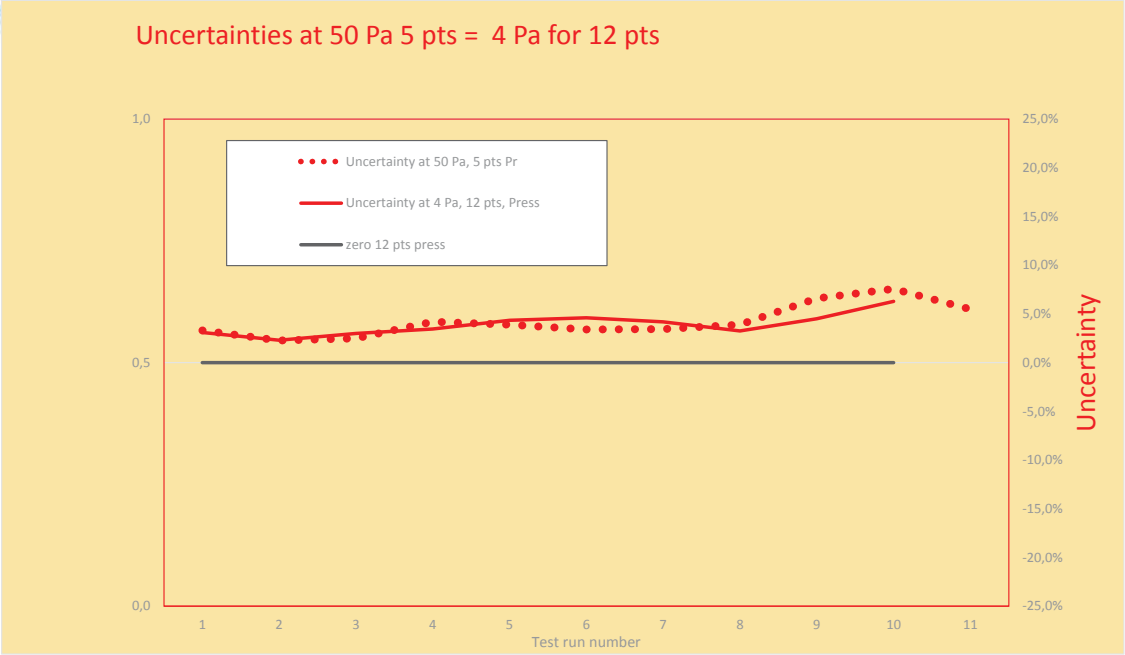
Compare **5** point Pressurization at 4 and 10 Pa



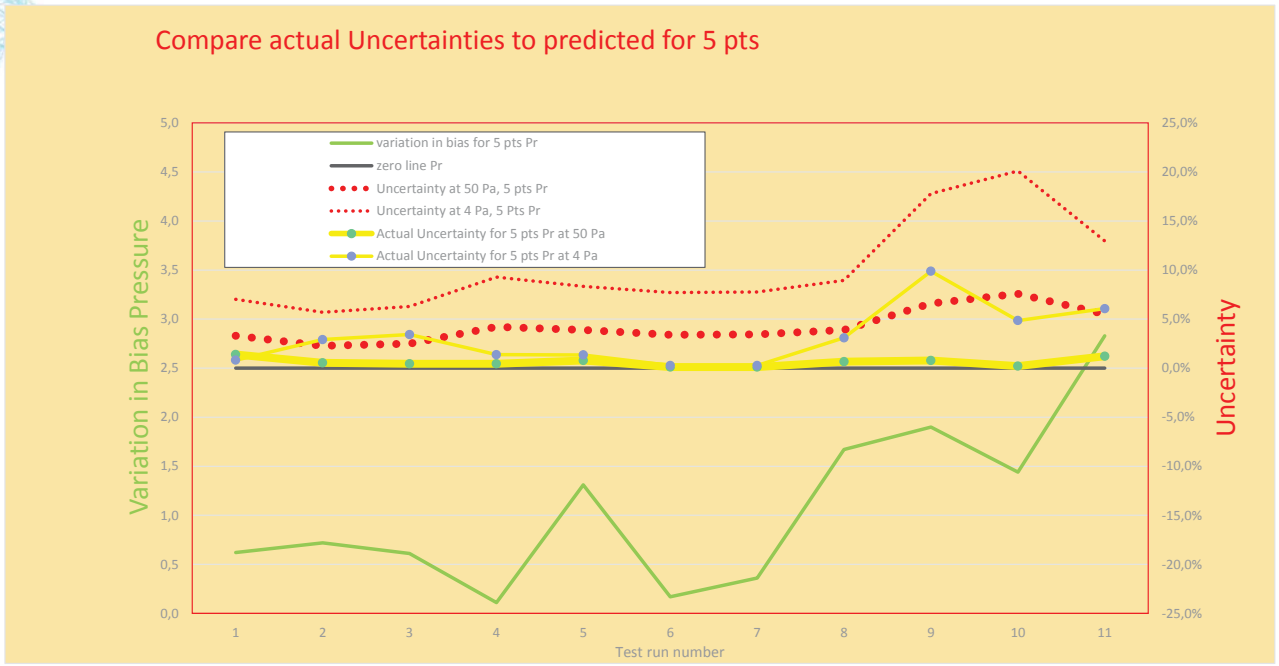
Compare 12 point Pressurization at 4 and 10 Pa



Uncertainties at 50 Pa for 5 pts = 4 Pa for 12 pts



Compare actual Uncertainties to predicted for 5 pts



- Check gauge
- ….tubes
- Fan calibration
- = checking tester
- Run maximum points

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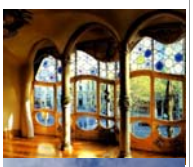
colin@retrotec.com

Gauge with tube check



35TH AIVC-4TH TIGHTVENT & 2ND VENTICOOL CONFERENCE, 2014

PROPOSED CHANGE IN SPANISH REGULATIONS RELATING TO INDOOR AIR QUALITY WITH THE AIM OF REDUCING ENERGY CONSUMPTION OF VENTILATION SYSTEMS

Poznań, 24-25 September 2014

Pilar Linares Alemparte. Architect. IETcc. CSIC

CSIC
Consejo Superior de Investigaciones Científicas

Content

- Introduction
- Current IAQ requirement
- Proposed IAQ requirement
- Proposed verification methods

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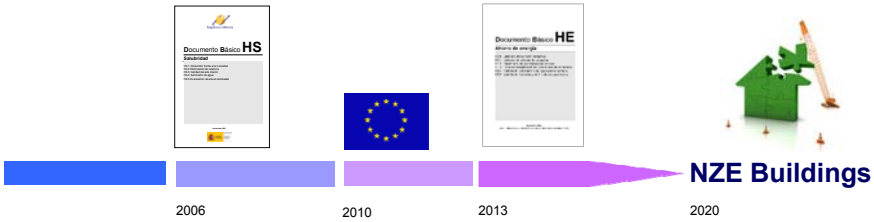
Introduction



- No IAQ regulations for dwellings
- IAQ regulations for the tertiary sector
- CTE: HS3: IAQ regulations
- Recast EPBD
- CTE: reviewed HE1: improved energy saving regulations
- Goal 2020

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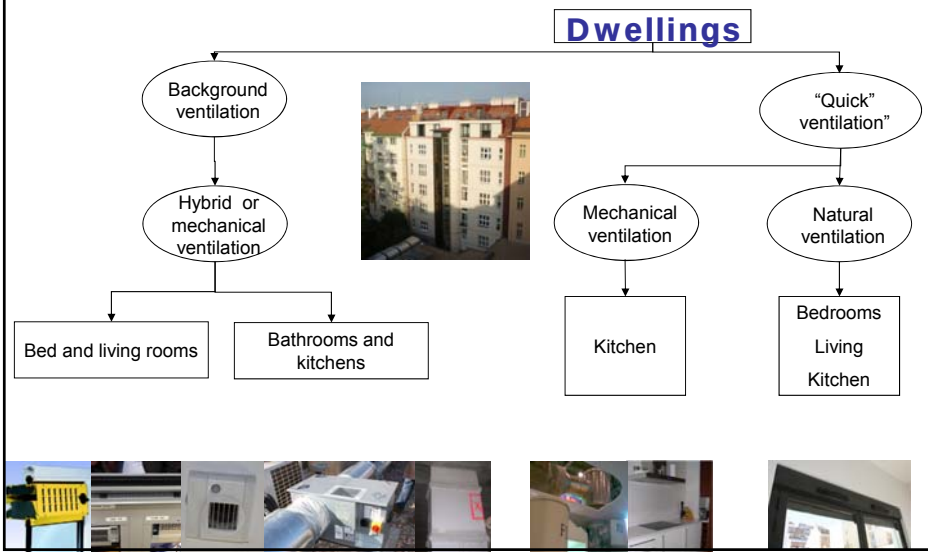
Current IAQ requirement

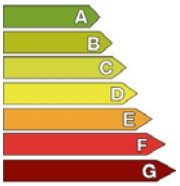


Current IAQ requirement

Table 1. Minimum ventilation rates

Rooms	Per person	Per usable floor area m^2	Per room
Bedrooms	5 l/s		
Living and dining rooms	3 l/s		
WC and bathrooms			15 l/s
Kitchens		2 l/s	

- Constant ventilation
- Variable ventilation systems are not included
- Energy efficiency, C class máx.

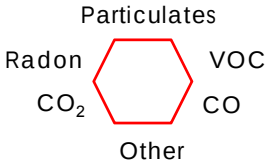


Proposed IAQ requirement

Objective: performance requirement: making easier the use of efficient ventilation systems

How: Expressing pollutant concentrations limits that affect people´s health

What pollutants: are difficult to asses: CO_2 is a good indicator



Performance requirement

In habitable rooms of dwellings outdoor aire flow must be provided in order to achieve that, in each room, CO_2 concentration year average is lower than 900 ppm and that CO_2 year accumulated over 1.600 ppm is lower than 500.000 ppm•h.

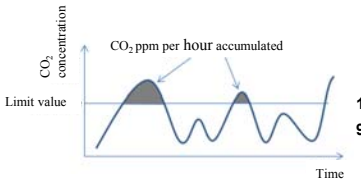


Table 2. IAQ classes according to RITE

IAQ Classification		CO2 concentration (ppm)
1	Best quality indoor air	750
2	Good quality indoor air	900
3	Medium quality indoor air	1.200
4	Low quality indoor air	1.600

Proposed verification methods

Expertise method: software

Simplified method:

Constant flow

Table 6. Results with continuous flow

Dwelling type	Continous flow (1) (l/s)	Total continous flow (l/s)	Yearly average CO_2 concentration (ppm)	Yearly accumulated over 1.600 ppm (ppm·h)
1	6	12	898	11.700
2	7	21	875	417.040
3	12	36	828	437.840
4	13	39	870	497.380
5	9	27	844	441.220

(1) In kitchen and each bathroom

Variable flow

Table 7. Results with variable flow

Dwelling type	Variable flow (1)		Yearly average CO_2 concentration (ppm)	Yearly accumulated over 1.600 ppm (ppm·h)
	MAX (during occupation) (l/s)	MIN (during no occupation) (l/s)		
1	7	5	901	0
	10	4	883	0
2	11	6	862	261.560
	14	5	892	244.660
	21	4	898	106.340
3	14	8	844	421.720
	18	7	880	380.900
	33	6	897	185.640
4	22	12	874	264.420
	30	10	884	235.820
	47	8	897	127.920
5	14	7	864	398.840
	34	4	878	307.320

(1) In kitchen and each bathroom

Draft

Simulations for simplified method. Main conditions

a) 5 dwelling types

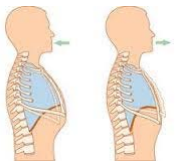
Table 3. Dwelling types

Kind and composition of dwelling	Type
Flat: Living/Kitchen+1 Bedroom+1 Bathroom	1
Flat: Living+Kitchen+2 Bedrooms+2 Bathrooms	2
Flat: Living+Kitchen+3 Bedrooms+2 Bathrooms	3
Flat: Living+Kitchen+4 Bedrooms+2 Bathrooms	4
Terrace house: Living+Kitchen+4 Bedrooms+2 Bathrooms	5

b) 400 ppm year CO_2 average concentration in outdoor air

c) No wind and no thermal difference between outdoor and indoor

d) 19l/h•person CO_2 generation, or 12 l/h•person during sleeping hours and 19 l/h•person during waking hours



e) Dwelling occupancy

Table 4. Dwellings occupancy

Bedroom number	Occupants
≤ 1	2
2	3
≥ 3	4

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f) Occupancy scenario

Table 5. Occupancy scenario for one person

Room	Monday to Friday	Room	Saturday and Sunday
Bedroom 1	0:00-8:00	Bedroom 1	0:00-8:00
Kitchen	8:00-8:30	Kitchen	8:00-8:30
Bathroom 1	8:30-9:00	Bathroom 1	8:30-9:00
	----------	Living room	9:00-10:00
Living room	17:00-18:00		----------
Bathroom 1	18:00-18:05	Living room	12:00-13:00
Living room	18:05-20:00	Kitchen	13:00-14:00
Kitchen	20:00-21:00	Living room	14:00-15:30
Bathroom 1	21:00-21:05	Bathroom 1	15:30-15:35
Living room	21:05-00:00	Living room	15:35-18:30

		Kitchen	20:30-21:30
		Bathroom 1	21:30-21:35
		Living room	21:35-00:00

Performance requirement is a design value.
In expertise method: the same conditions can be used or, instead, the real ones, if they are known or can be predicted.

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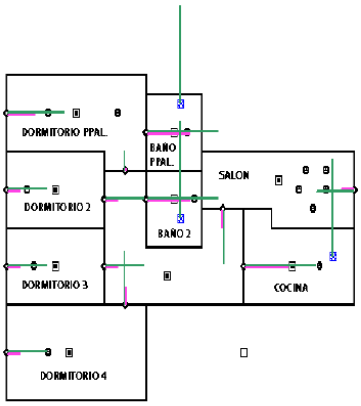
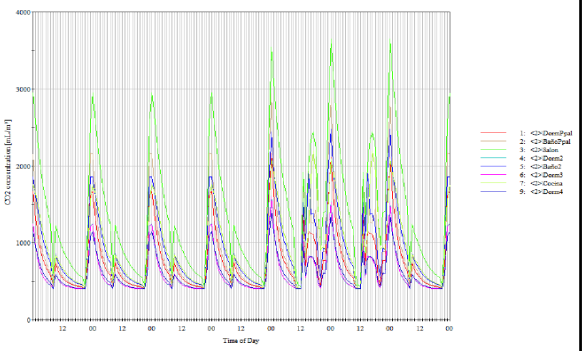
Simulations. Results





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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.

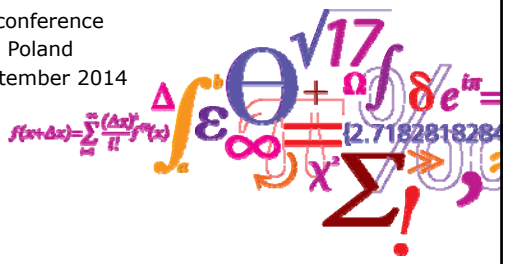
The statutory regulations for industrial safety which are dependent on other ministerial departments and that affect installations which are incorporated into buildings, will be given specific consideration.

Technical University of Denmark

Simulation of static pressure reset control in comfort ventilation

Chrysanthi Sofia Koulani, Remus Mihail Prunescu,
Christian Anker Hviid and Søren Terkildsen

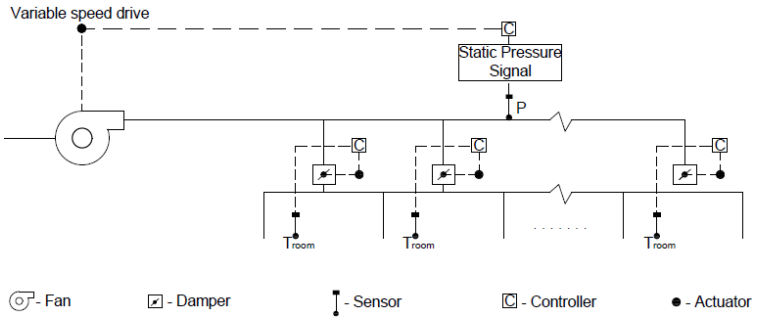
35th AIVC conference
Poznan, Poland
24-25 of September 2014



DTU Byg
Institut for Byggeri og Anlæg

Introduction

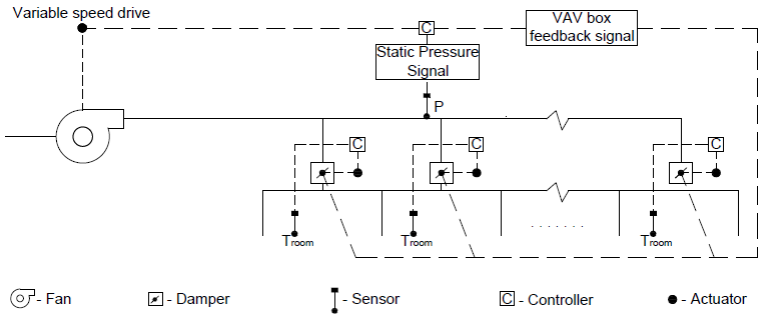
The constant static pressure control method



Fan operation set point ⟹ Fixed corresponding to full load condition

Introduction

The static pressure reset control method



Fan operation set point ⇨ Variable depending on the dynamics of the actual pressure demand

Objective

This project aims to investigate the operation of a trim and respond SPR control algorithm based on pressure alarms.

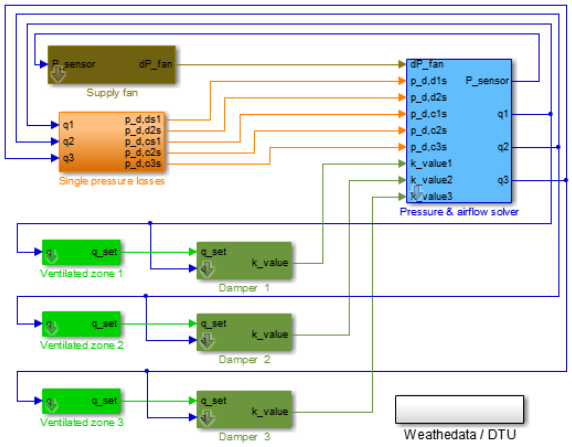
Objectives

- Investigate the dynamic behaviour static pressure control algorithm through simulations
- Disclose the key parameters and issues that needs to be addressed to optimize the control algorithm.

Methodology

- Literature review
- Mathematical modelling
- Experimental work
- Validation

Simulink model

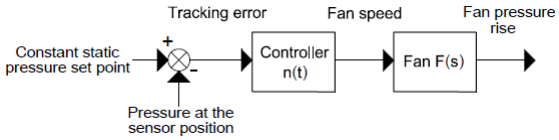


Subsystems

- Thermal zone
- Single losses
- Fan
- Damper
- Pressure & airflow solver

Simulink model

The fan subsystem



- *Controller mathematical model*: $n(t) = K_{p,f} \cdot e_f + K_{i,f} \cdot e_f \int e_f(t)dt$

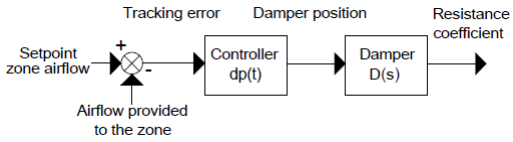
  where $K_{p,f} = 7.14$, $K_{i,f} = 17.85$ } tuned based on the simple analytic tuning rules

- *Fan mathematical model*: $\Delta P_{fan} = 0.0002 \cdot speed^2 - 0.0082 \cdot speed + 5.7401$

  where Δp_{fan}(Pa) Pressure rise provided by the fan
  speed (rpm) angular speed that the fan rotates

Simulink model

The damper subsystem



• *Controller mathematical model*: $dp(t) = K_{p,d} \cdot e_d + K_{i,d} \cdot e_d \int e_d(t)dt$

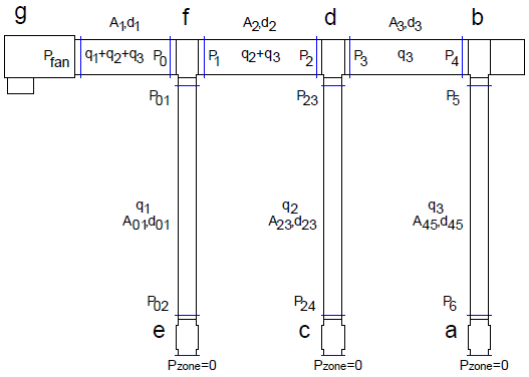
where $K_{p,d} = 1$, $K_{i,d} = 20$ } based on typical product values

• *Damper mathematical model*: $D(s) = \frac{k_d \cdot \omega_n}{s^2 + 2 \cdot \zeta \cdot \omega_n \cdot s + \omega_n^2}$ *(2nd order linear time - invariant system)*

where damping ratio, $\zeta = 1$
natural frequency, $\omega_n = 10$ rad/s
process gain, k_d opening position – resistance coefficient

Simulink model

The pressure & airflow solver subsystem ⟹ Numerical calculation



• *Friction losses*

Darcy-Weisbach: $\Delta P_{fr} = f_D \cdot \frac{L \cdot \rho}{d \cdot 2} \cdot u_{air}^2$

Swamme-Jain: $f_D = \frac{0.25}{\left[log_{10} \left[\frac{5.74}{Re^{0.9}} + \frac{\varepsilon}{3,7 \cdot d} \right] \right]^2}$

• *Single losses*

Connections: $\Delta P_{sing} = \frac{\zeta_r \cdot \rho \cdot u_{air}^2}{2}$

Damper: $\Delta P_{sing} = \left(\frac{q_{del}}{k_{value}} \right)^2$

A system of 14 non-linear equations is solved by Newton–Raphson method

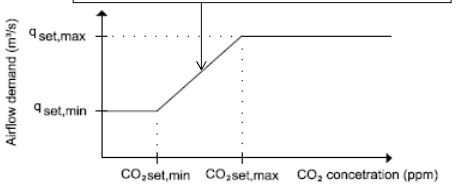
Simulink model

The ventilated zone subsystem ⟹ Based on IBPT toolbox

The ventilation demand IBPT block

- Dynamical calculation of airflow demand based on the CO_2-concentration.

$$q_{dem} = \frac{q_{\text{set,max}} - q_{\text{set,min}}}{CO_{2\,\text{set,max}} - CO_{2\,\text{set,min}}} (CO_2 - CO_{2\,set,\text{max}}) + q_{set,\text{max}}$$



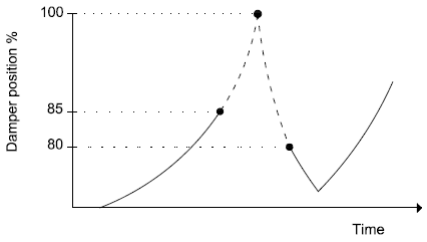
The CO_2-concentration IBPT block

- Initial concentration
- Supply air concentration
- CO_2 supplied
- Air change rate
- Room volume

$$c = (c_0 - c_i) \cdot (1 - e^{-nt}) + \frac{G}{n \cdot V} \cdot (1 - e^{-nt}) + c$$

Simulink model

The static pressure reset subsystem ⟹ Trim & respond with pressure alarms



Adjustable parameters

- Damper opening for initializing the alarm: 85%
- Damper opening for terminating the alarm: 80%
- Trim pressure decrement: 5%
- Respond pressure increment: 10%
- Timing parameter for loop iteration: 90sec
- Values were obtained from simulations of offices, where the pressure range was 8-19 Pa.

Simulation setup

• *Occupancy profiles*

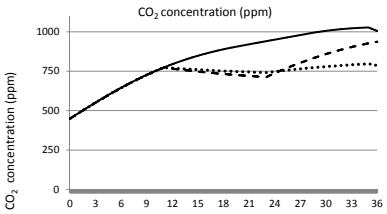
Time (min)	No. of students zone 1	No. of students zone 2	No. of students zone 3
0 - 12	20	20	20
12 - 24	20	5	3
24 - 36	20	10	20

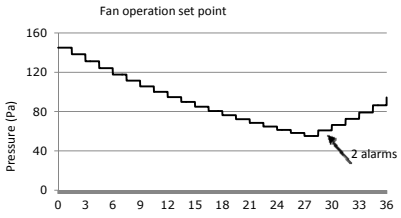
• *Pressure limits*

Lower SPR pressure set point	15 Pa
Upper SPR pressure set point	145 Pa

Results

CO_2 concentration and fan operation setpoint

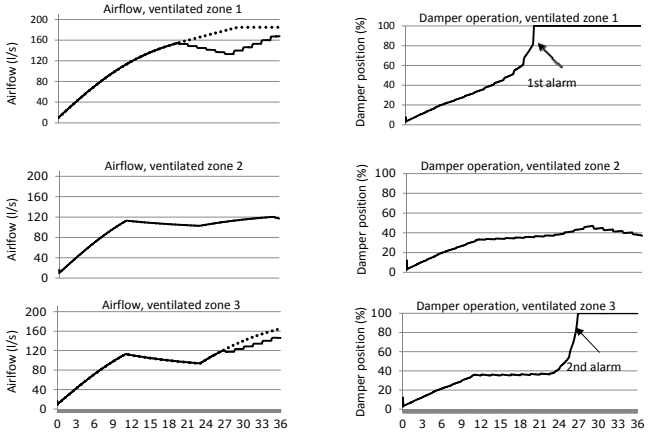




_____ Zone 1
..... Zone 2
------- Zone 3

Results

Energy savings



Conclusion

The SPR control algorithm underperformed because the following parameters did not fit to the case study examined:

- The threshold number of alarms above which the fan operation set point is reset upwards
- The trim percentage used for resetting downwards the fan operation set point
- The respond percentage used for resetting upwards the fan operation set point
- Or decrease iteration loop time

These parameters must therefore be optimised for each case.

NUMERICAL SIMULATION OF INDOOR AIR QUALITY – MECHANICAL VENTILATION SYSTEM SUPPLIED PERIODICALLY VS. NATURAL VENTILATION

Ewelina KUBACKA, Dariusz HEIM

Department of Environmental Engineering
Lodz University of Technology

AGENDA

1. Introduction
2. Aim of the study
3. Calculation method
4. Case study
5. Results
6. Conclusions

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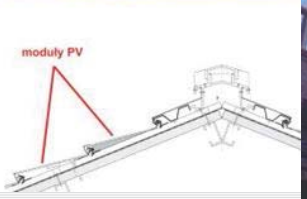
INTRODUCTION

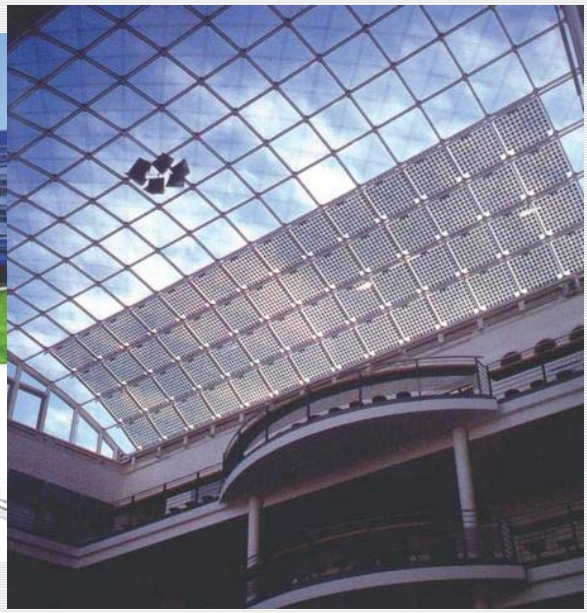
Building Integrated Photovoltaics - BIPV

INTRODUCTION

Building Integrated Photovoltaics - BIPV



The school building "Ho-Oh High School" in Kagoshima - PV modules in the role of tiles



PV modules on an overlap of the internal atrium of Munich University of Technology building [NEDO, Japan]

AIM OF THE STUDY

Comparison of indoor air quality in an office room equipped with two different ventilation systems:

1. natural ventilation system,
2. low-power, direct current mechanical ventilation system.

Evaluation of the efficiency of PV installation (capability to power the ventilation unit).

CALCULATION METHOD

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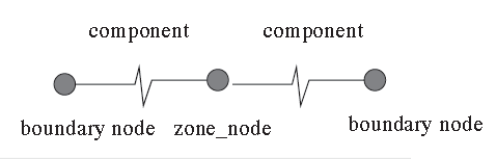
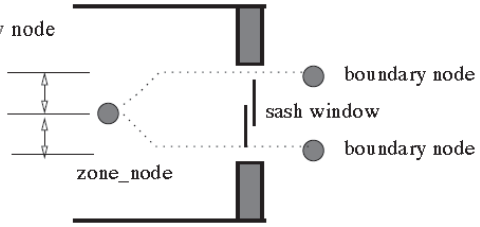
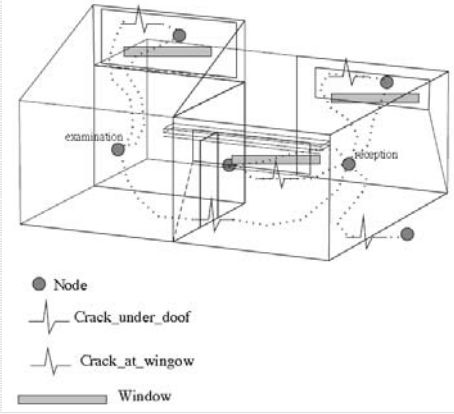
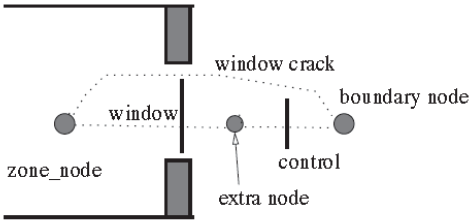
CALCULATION METHODS

Air Flow Network







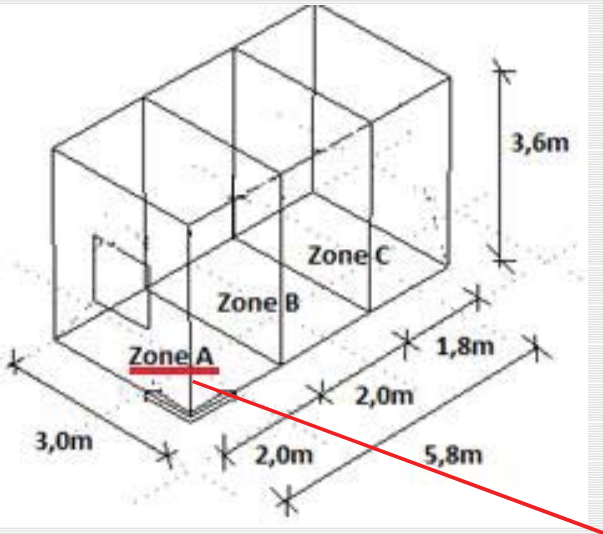


Finite-volume discretization balance method

CASE STUDY

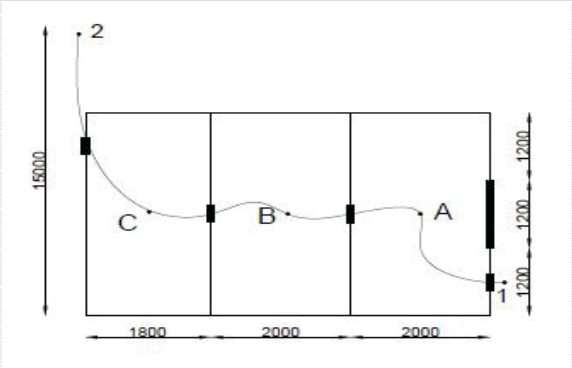
MAIN ASSUMPTIONS

A single office room defined in ESP-r



CASE STUDY

Air Flow Network model



- AFN was designed by five nodes - three internal - A, B and C and two external - 1 and 2,
- wind pressure distribution coefficient is specified as for the partially exposed walls in the inlet node, while in the outlet node as for the roof with inclination angle of less 10 ° ,
- the distance from the roof to the floor of the considered room is 15.0 m.

CASE STUDY

- Climatic data:

  LODZ - LUBLINEK - POLAND

  Latitude: 51°43'19"N Longitude: 19°23'53"E;
- one person occupying the room from Monday to Friday during office hours (8 am ÷ 4 pm);
- the total heat gains: 215 W per person, where 100 W was delivered by the equipment;
- heat gains from artificial lighting set to 10W/m^2 between 3 and 4 pm;
- the system for heating and cooling set to maintain indoor temperature in range of 20°C - 26°C;
- clothes thermal insulation in cooling season $I_{CL,cs}$=0,5clo, in heating season $I_{CL,hs}$=1,0clo;
- activity level 1,2met=70W/m^2.

CASE STUDY

Comparison of two different ventilation systems

1. Natural ventilation system

- inlet characterized by the window cracks and openings,
- efficiency strongly depends on environmental conditions.

2. Low-power, direct current mechanical ventilation system

- volume of supply air at the level of 90 m^3/h from 7 am to 5 pm
- fully supplied from the photovoltaic panels integrated with façade cladding system
- 13 PV panels, 0,72 m^2 surface area each, covers a total opaque area of external wall that equals 9.36 m^2,

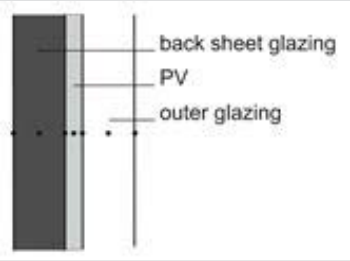
CASE STUDY

Comparison of indoor air quality for two different ventilation systems

2. Low-power, direct current mechanical ventilation system

- constant efficiency of 15%,
- battery efficiency equal to 85% and capacity of 1320 Watts.

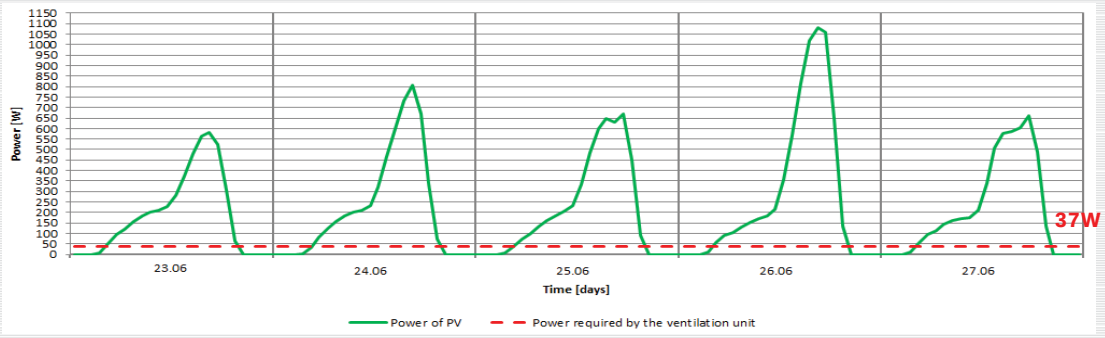
Electrical characteristics of PV panels:
Open circuit voltage: 44.02 [V];
Short circuit current: 2.5 [A];
Voltage at maximum power point: 35 [V];
Current at maximum power point: 2.3 [A].



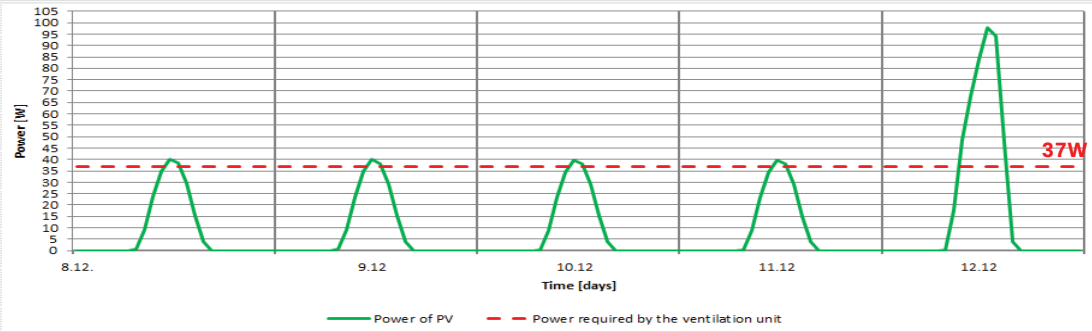
RESULTS

POWER GENERATED FROM PV PANELS

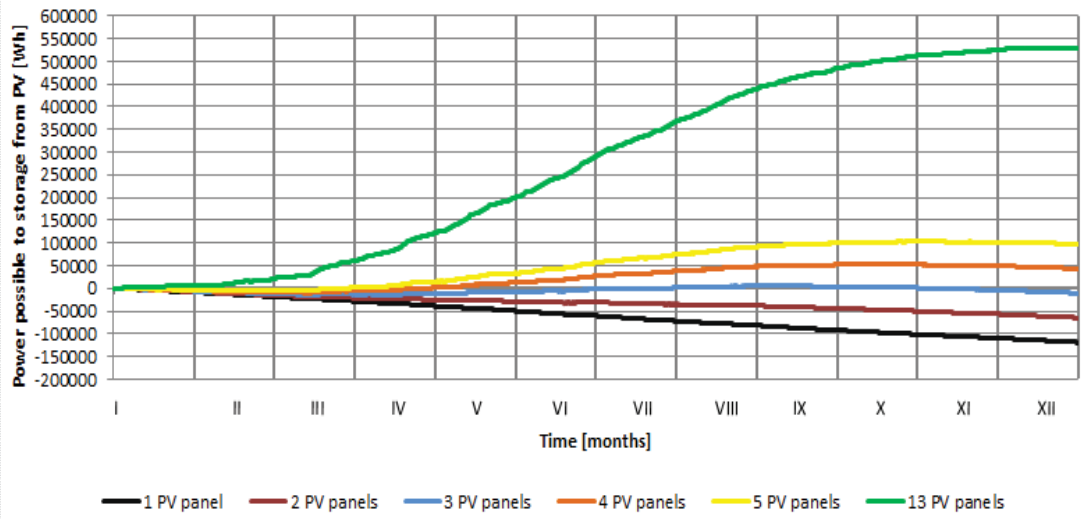
during summer week



during winter week



ENERGY BALANCE



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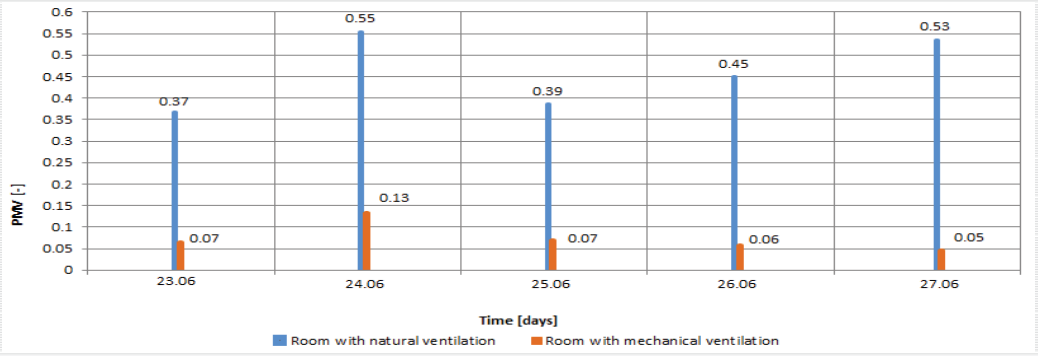
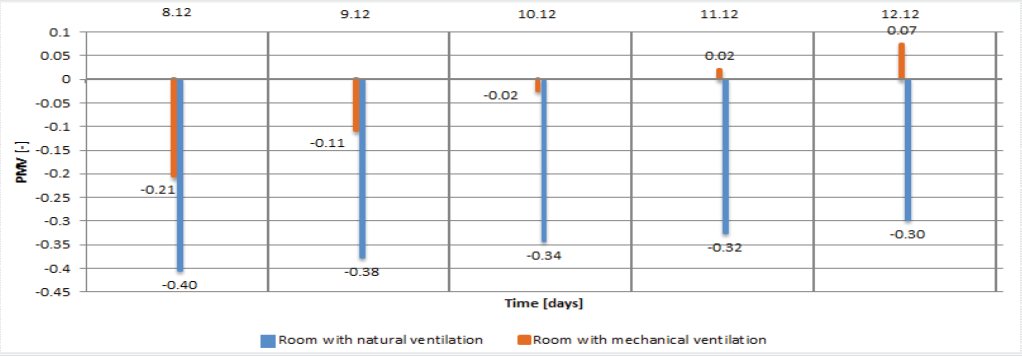
DAILY MEAN VALUES OF PMV RATE

during summer week (8am-4pm)

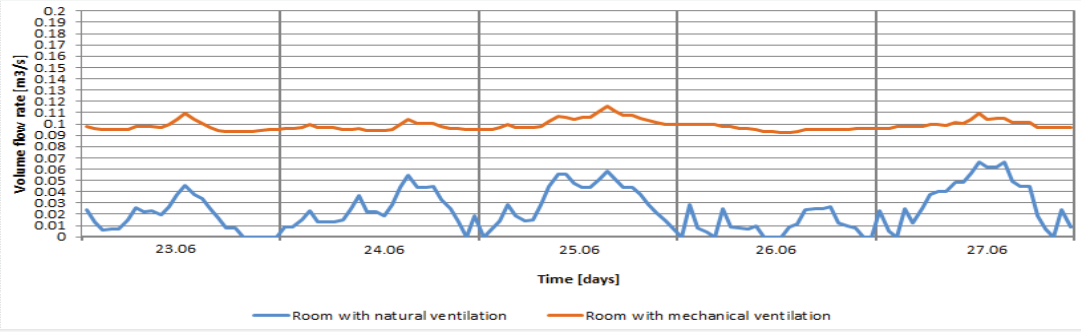


during winter week (8am-4pm)

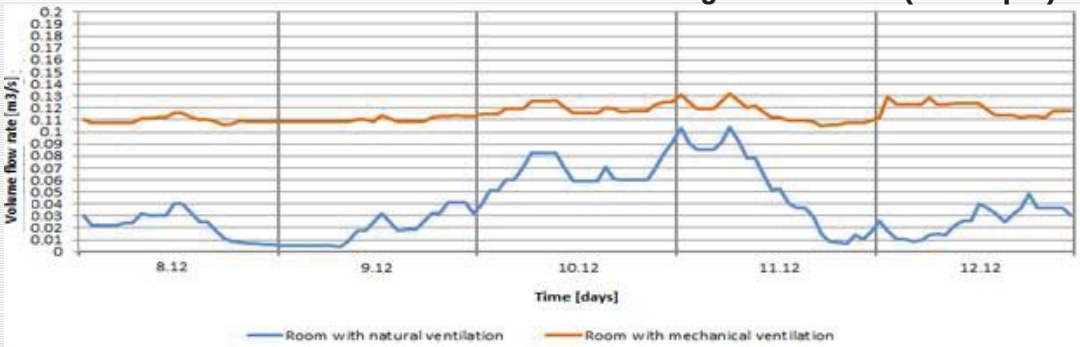


VOLUME FLOW RATE OF THE INTERNAL AIR IN ZONE A

during summer week (8am-4pm)



during winter week (8am-4pm)



CONCLUSIONS

- Installation of PV panels in the building has the potential to supply it with enough energy to power an individual mechanical ventilation device .
- Installing the appropriate number of panels gives the possibility of obtaining energy amounting to several hundred thousand Watts per hour during the calendar year.
- The results of the calculations confirm that the mechanical ventilation system works much better than the natural ventilation system, even if it is supply from renewable energy source. It provides significantly better thermal comfort and indoor air quality thanks to higher volume of the air stream supplied during the entire calendar year.

THANK YOU FOR YOUR ATTENTION!

NUMERICAL SIMULATION OF INDOOR AIR QUALITY – MECHANICAL VENTILATION SYSTEM SUPPLIED PERIODICALLY VS. NATURAL VENTILATION

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Department of Environmental Engineering
Lodz University of Technology

35TH AIVC CONFERENCE, 24-25 SEPTEMBER 2014 POZNAÑ, POLAND

MEASURED MOISTURE BUFFERING AND LATENT HEAT CAPACITIES IN CLT TEST HOUSES

Ivana Katavic
AIVC 2014

25.10.2014

Introduction

- NMBU, Aas, Norway
- Part of the WEEE project – wood, energy, emission, experience
- Can the thermal and hygroscopic properties of wood contribute to better indoor climate and energy savings?

Objective

- Measure moisture buffering and latent heat of sorption in full scale facility
- Compare the measured results to computer simulated (utilizing WUFI Plus)

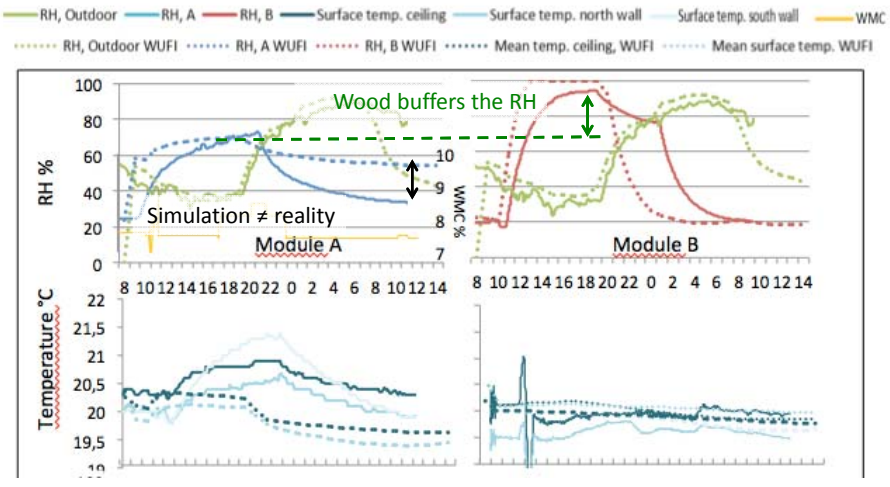
- Hygroscopic materials have the ability to accumulate and release water vapour due to changes in the surrounding humidity
- Moisture buffering – to buffer the humidity variations
- Wood – made for transporting and storing water
- The latent heat – thermal energy associated with phase change

Test facilities

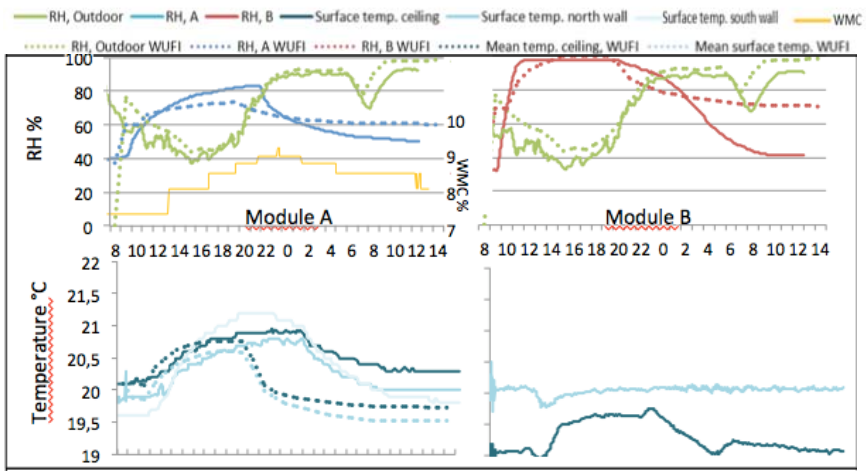
Module A

Module B

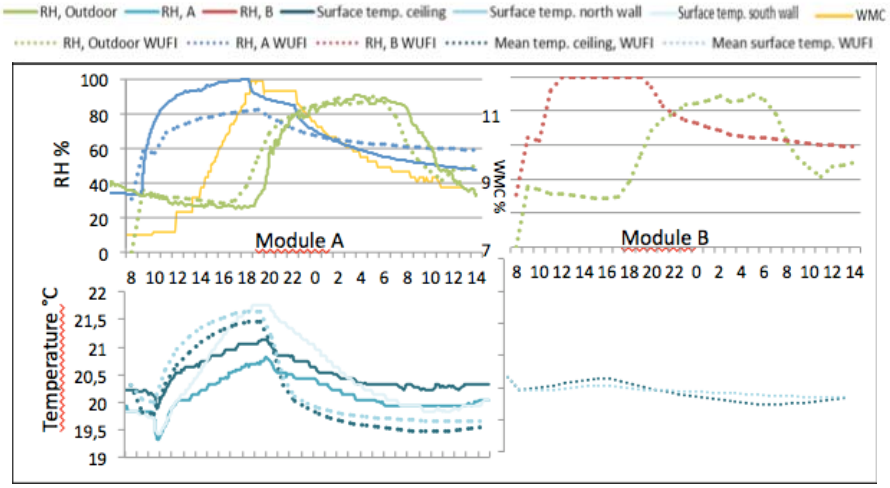
Results



Results



Results



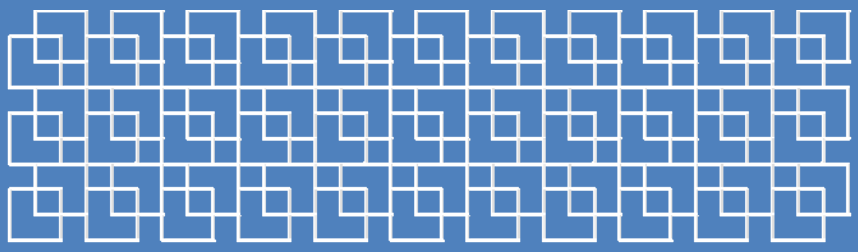
Summary

Large areas of exposed wood surfaces helps keep the relative humidity within a closer interval

Reducing the ventilation when humidity is the dimensioning factor

Wood physics – too complicated for simulation programs?

Thank you for the attention



Klemens Leutgöb
e7 Energie Markt Analyse GmbH

Integrated Design (ID)

The MaTrID-Toolkit, lessons learned and policy recommendations

MaTrID
Market Transformation Towards Nearly Zero Energy Buildings Through Widespread Use of Integrated Energy Design

Co-funded by the Intelligent Energy Europe Programme of the European Union

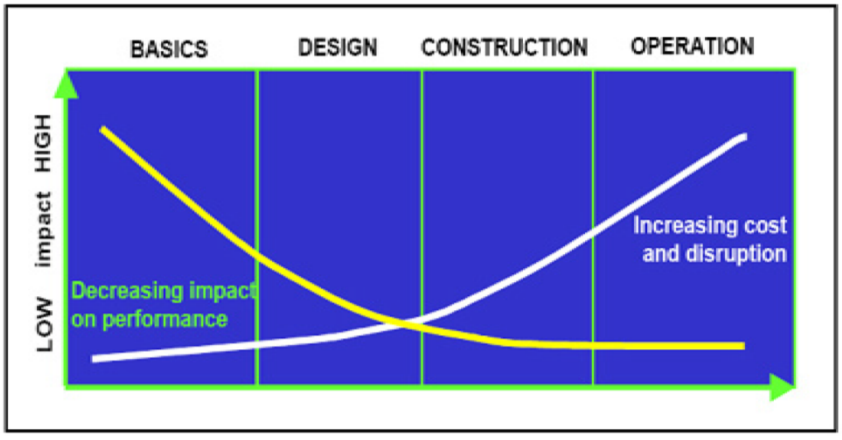
nZEB require ID

- **Nearly Zero Energy Buidlings (nZEB) are challenging**
  - increasing energy performance requirements
  - integration of renewables
  - further sustainability criteria → sustainability certificates
  - cost-optimality over the life-cycle → need for comprehensive life-cycle cost assessment
- **Integrated Design (ID) becomes indispensable for *larger and complex* nZEB**
  - non-residential buildings

ID Key points

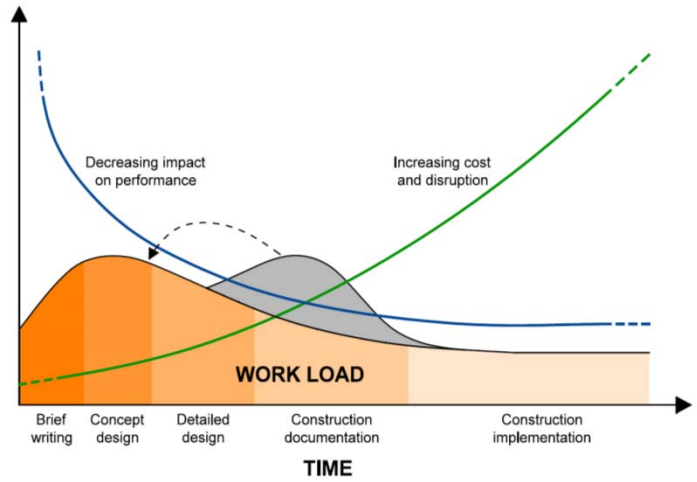
- **Integrated Design (ID) is advisable in managing the complex issues arising from planning buildings with high energy- and environmental ambitions**
- **Key issues are collaboration in multi-disciplinary teams, discussion and evaluation of multiple design concepts as well as clear goal-setting and systematic monitoring**
- **In the early design phases, the opportunities to positively influence building performance are great, while cost and disruptions associated with design changes are very small**

Why integrated design?



→ **early design phases are decisive!**

Focus on early design phases



Estimation of Costs and Benefits of ID

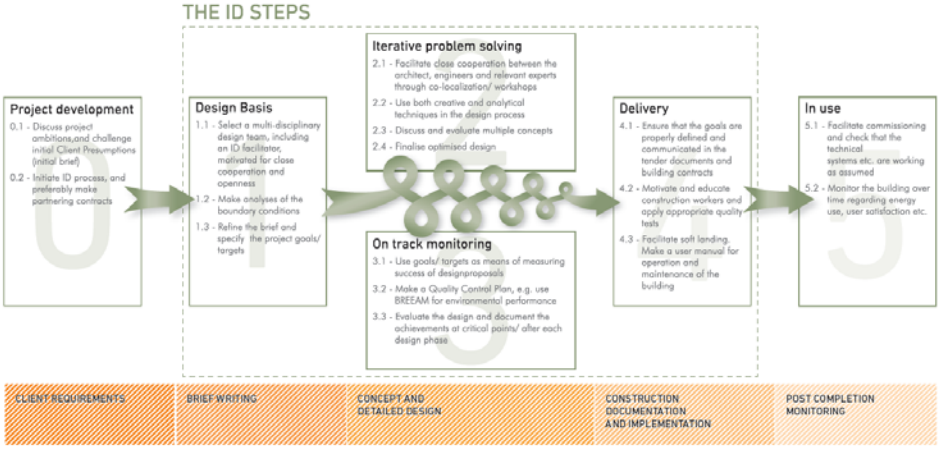
Tasks	Costs	Comments
Concept and Pre-design	5 -10 % more	Based on experience
Detailed engineering	< 5 % more the first projects 5-10% less in the next projects	Based on experience – smoother process caused by more detailed concept design
Building costs	5 – 10 % more	3-6 % for Passive houses
Operational costs	40 – 90 % less	Based on experience
Building faults	10 – 30 % less	Because of better planning and better follow up during construction

ID – let‘s try a definition

ID is defined as a combination of:

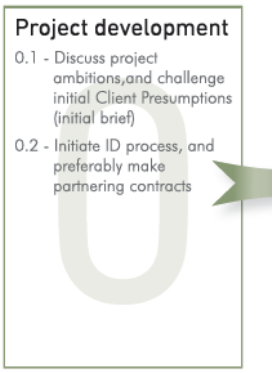
1. **Collaboration between stakeholders (client, architect and other consultants, and eventually users) from early on in the design process.**
2. **In achieving high energy/ environmental ambitions, the implementation of integrated architectural solutions or passive qualities are prioritized before active systems.**

Overview of the ID process



The creative problem solving process (2) runs parallel in time with monitoring the progress according to the goals (3). This is rarely a straightforward process, and the phase should be kept open long enough for all necessary information to be integrated in the design.

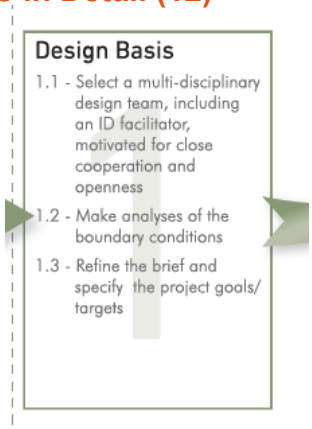
ID Process in Detail (1)



CLIENT REQUIREMENTS

r 2014

ID Process in Detail (12)



BRIEF WRITING

Kleme

ID Process in Detail (3)

Iterative problem solving

2.1 - Facilitate close cooperation between the architect, engineers and relevant experts through co-localization/ workshops

2.2 - Use both creative and analytical techniques in the design process

2.3 - Discuss and evaluate multiple concepts

2.4 - Finalise optimised design

ID Process in Detail (4)

Creative problem solving.

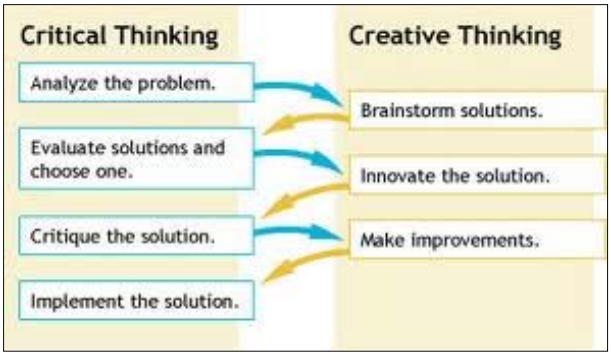
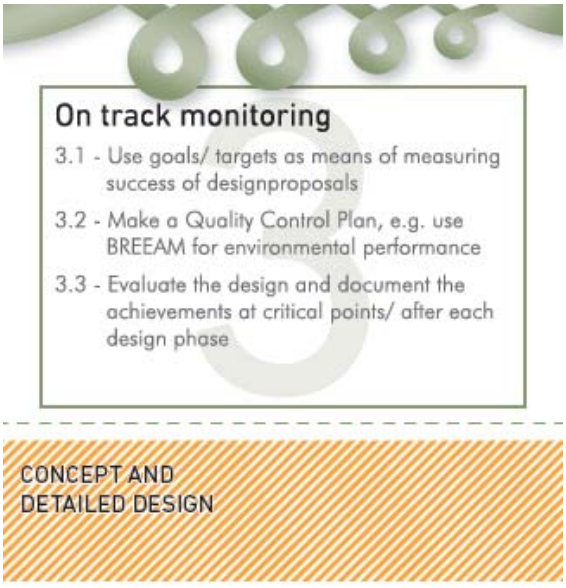


Figure 10; Creative problem solving. Both critical and creative thinking is needed in the design process. Guides and literature on creative problem solving might be useful tools in work-shops as well as in the following design process. See e.g; www.creativeeducationfoundation.org/our-process/what-is-cps

ID Process in Detail (5)



ID Process in Detail (6)

ID Process in Detail (7)

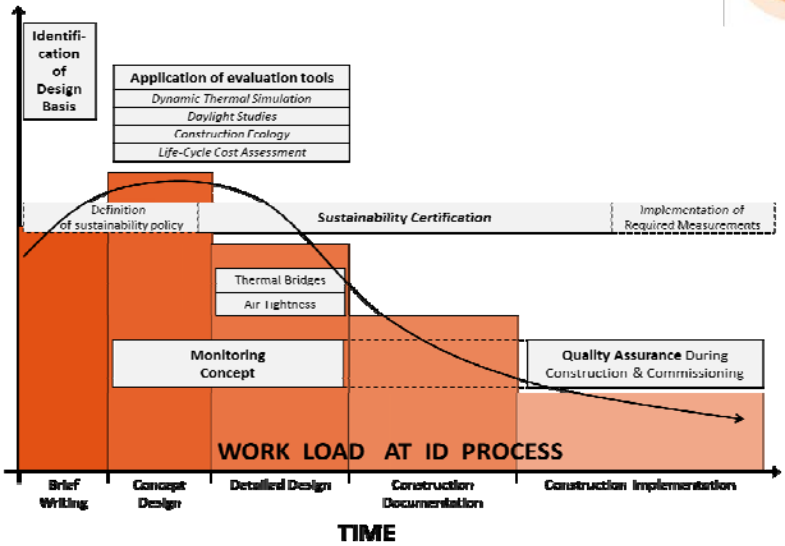
In use

5.1 - Facilitate commissioning and check that the technical systems etc. are working as assumed

5.2 - Monitor the building over time regarding energy use, user satisfaction etc.

POST COMPLETION MONITORING

Accurrate timing of ID-specific tasks



Green Building ID Award Winner: *aspern IQ*

- **WA Business & Service Center GmbH** and **ATP architects engineers**
- **Located in Vienna, Austria**
- **Technology centre (office and research facilities)**
- **11,850 m² gross floor space**
- **Plus energy building which is adapted to locally available materials**
- **More information**
  - http://www.asperniq.at/
  - http://www.integrateddesign.eu/toolkits/ID_award.php

Green Building ID Award Commendation: *Bassourakos Building-Cultural Center*

- **Municipality of Evrotas** and **National and Kapodistrian University of Athens**
- **Located in Lakonia, Greece**
- **Cultural center, mixed type (offices, exhibition, conference, restaurant)**
- **1,680 m² gross floor space**
- **More information**
  - www.evrotas.gov.gr
  - http://www.integrateddesign.eu/toolkits/ID_award.php

Green Building ID Award Commendation: *Plus Energy Business Building Kobra*

- **Kobra Team d.o.o.** and **Protim Ržišnik Perc d.o.o.**
- **Slovenia**
- **Business building**
- **1,300 m² gross floor space**
- **More information**
  - http://www.protim.si/index.php?t=projects&id=12478&l=sl
  - http://www.integrateddesign.eu/toolkits/ID_award.php

Do policies matter? The role of building codes

Generally:

- Stricter codes on energy efficiency
- Strong focus on technical measures
- More “soft” measures such as ID generally not emphasized

However:

- Although not directly supportive, the increasingly challenging standards are nevertheless a driving force for ID

Supportive framework: Environmental assessment schemes

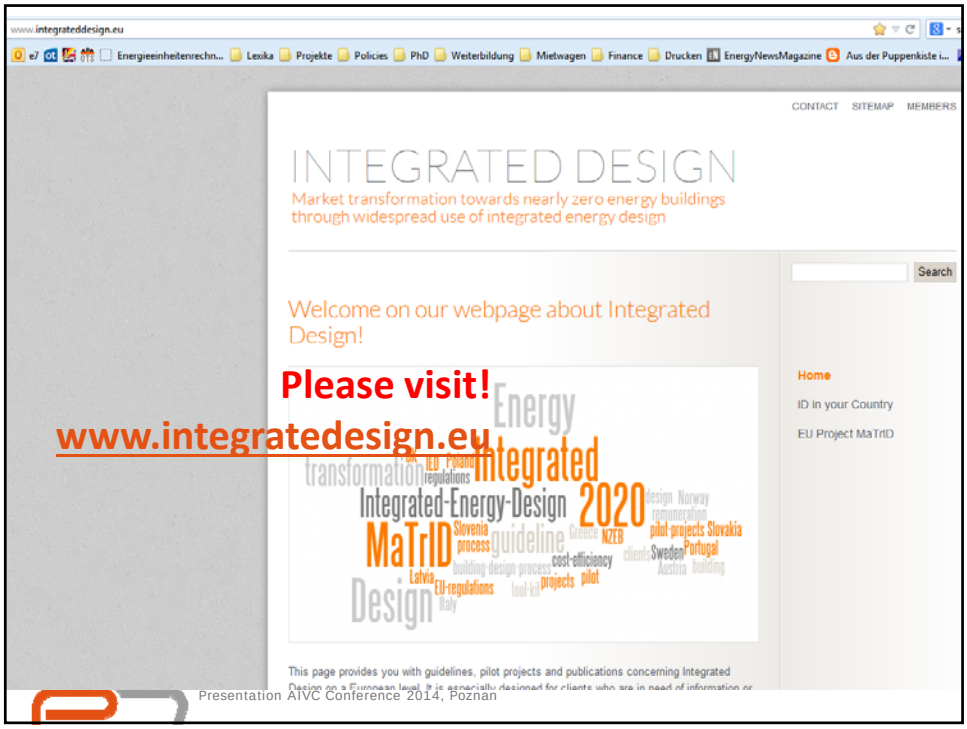
- EU GreenBuilding
- BREEAM
- LEED
- DGNB
- TQB, klima:aktiv (Austria)
- Protocollo Itaca (Italy)
- Svanen (Nordic)
- Miljöbyggnad (Sweden)
- Code for Sustainable Homes (UK)

Generally little focus on ID as a separate action to earn points. As an exception, in the Austrian TQB and ÖGNI/DGNB, and in LEED, ID is a rated criterion.

In all schemes, the inherent process resembles ID. Thus, the role of the process leader could be merged.

Supportive Framework Rules for design competitions

- **Increasingly demanding high environmental ambitions, but usually ID is not a separate requirement**
- **A multidisciplinary team is sometimes a prerequisite for entering**
- **New competition models focus on collaboration between parties, e.g. sharing of information throughout the design process in common work-shops.**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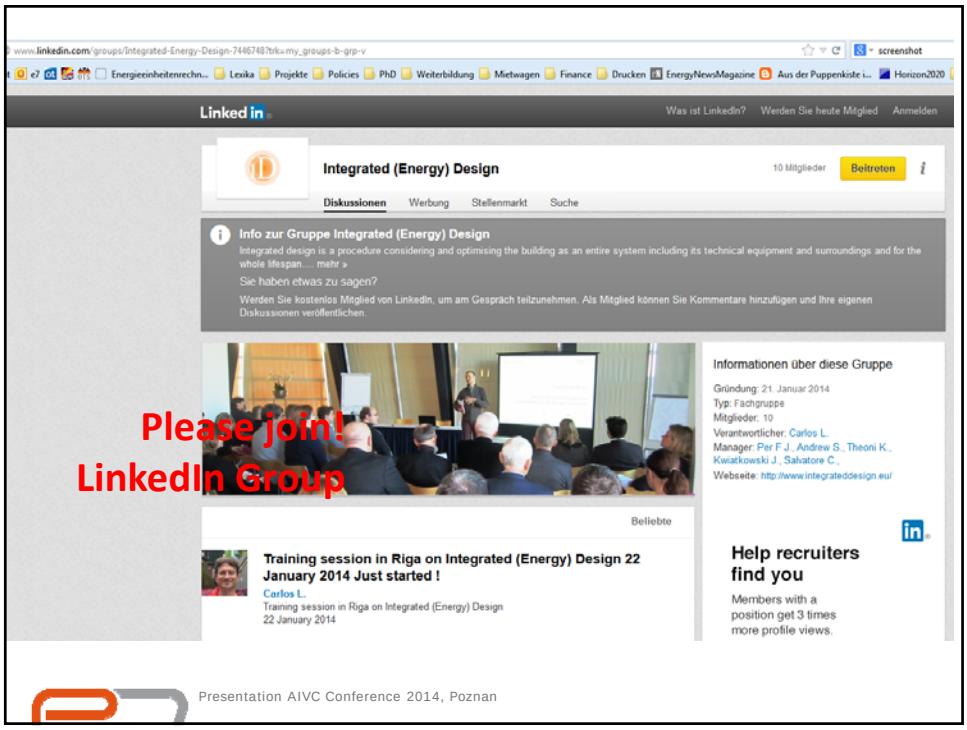
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Manager: Per F J., Andrew S., Theoni K., Kwiatkowski J., Salvatore C.,
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Project leader

e7 Energie Markt Analyse GmbH

MaTrID

Market Transformation Towards Nearly Zero Energy Buildings Through Widespread Use of Integrated Energy Design

Project number: IEE/11/989/SI2.615952
Duration: June 19, 2012 – December 18, 2014

www.integrateddesign.eu and www.integratedesign.eu

INTELLIGENT ENERGY EUROPE

Slides were created on October 1, 2012

INTELLIGENT ENERGY EUROPE

Project summary

- **MaTrID aims to support the implementation of nearly zero energy buildings (NZEB) by 2020;**
- **Design of NZEB requires an interdisciplinary approach**
  - building design phase is of particular importance;
  - Integrated Energy Design (IED) reduces complexity of the design process;
  - energy demand in the design phase can be reduced;
  - cost-efficient solution for NZEB can be identified;
  - only at the early design phases changes of the general design concept can be implemented at low cost.

Partners

Partner Institution	Country	Names
e7 Energy Market Analysis, Ltd.	Austria	Klemens Leutgöb Stefan Amann Margot Grim Katharina Thullner
National and Kapodistrian University of Athens, NKUA	Greece	Theoni Karlessi
Politecnico of Milan, eERG-Polimi	Italy	Salvatore Carlucci
CEEETA-ECO, Energy Consultants, Ltd.	Portugal	Carlos Laia
Asplan Viak AS	Norway	Per F. Jørgensen Arne Førland-Larsen
KanEnergi Sweden	Sweden	Ronnie Hollsten Mats Gustafsson
Building and Civil Engineering Institue, ZRMK	Slovenia	Marjana Sijanec Zavrl Andraz Rakuscek
Slovak Innovation and Energy Agency, SIEA	Slovakia	Pavel Starinsky Jan Magyar
National Energy Conservation Agency, NAPE	Poland	Aleksander Panek Jerzy Kwiatkowski
EKODOMA	Latvia	Agris Kamenders
Building Research Establishment, Ltd., BRE	Great Britain	Andy Sutton Zsofia Nagy

Background

- **Recast of the Energy Performance of Buildings Directive (EPBD): ambitious vision for energy performance of buildings;**
- **By 2020 all new buildings shall be NZEB;**
- **Additionally, by 2015 all new buildings and buildings undergoing major renovation must have minimum levels of energy from renewable energy sources;**
- **EU Member States draw up national action plans for increasing the number of NZEB**
  - national action plans shall include policies and measures to stimulate the transformation of existing buildings into NZEB.

Objectives

- Supporting implementation of Directive 2010/31/EU (EPBD);
- Establishing a widespread understandings among building developers and designers concerning IED;
- Strengthening the know-how in applying IED by improving availability of IED procedures, guidelines and contractual stipulations;
- Large scale tests for application of IED in early design processes in 11 participating countries;
- Broad dissemination and promotion of IED on the national level as well as on the EU level.

Expected results

- A general understanding on the advantages and requirements of IED at the side of developers and building owners;
- An improved knowhow basis on IED on the developers' side as well as on the designers' side;
- Successfully tested pilot projects in participating countries, which can be easily copied and multiplied;
- National IED tool-kits;
- Recommendations and instruments for a further market adoption of IED in the years after the end of the project.

Contact

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Simulation of night ventilation performance as a support for an integrated design of buildings

Jerzy Sowa[1)], Maciej Mijakowski[1)], Jerzy Kwiatkowski [1,2)]

Warsaw University of Technology,
Faculty of Environmental Engineering

Polish National Energy Conservation Agency - NAPE

Introduction

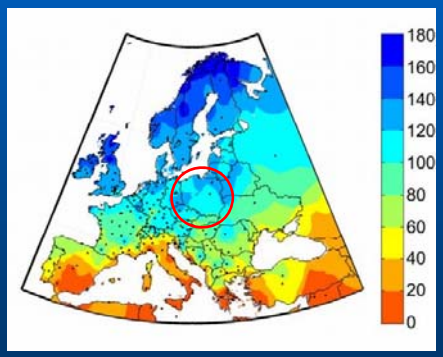
The implementation of EU policies related to energy efficiency forces scientists and technicians to pay more attention to integrated design of buildings.

Experiences from projects that applied integrated design show that the investment costs may be slightly higher about (5 %), while at the same time the annual running costs are reduced by as much as 40-90 %.

In moderate climates one of the most promising approaches to reduce cooling energy demand of office buildings is passive cooling by night ventilation. As the effectiveness of this system depends on many parameters, night ventilation is a very good example for integrated design approach.

Potential for night cooling in Europe / Poland

Map of mean Climatic Cooling Potential (CCP) in July



By Artmann, N., Manz, H., Heiselberg, P. (2007).

Virtual office building, Warsaw (Poland)

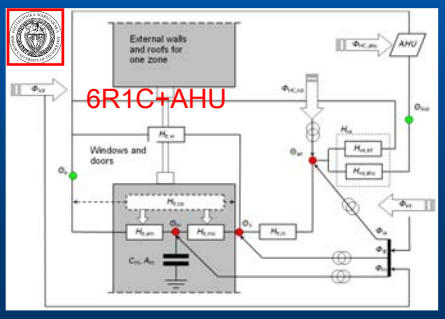
Conditioned floor area	3640	M^2
Volume	10920	m^3
Number of users	400	-
Minimal air temperature in cooling season	22	C
Maximal air temperature in cooling season	28	C
Airtightness n_{50}	2	h^{-1}
Total ventilation rate	20000	m^3/h
Peak internal heat gains	25.6	W/m^2
Operating hours (with variable profiles)	7 a.m. - 8 p.m.	-
Temperature limit outside operating hours	16	C

Applied simulation tool 6R1C +AHU

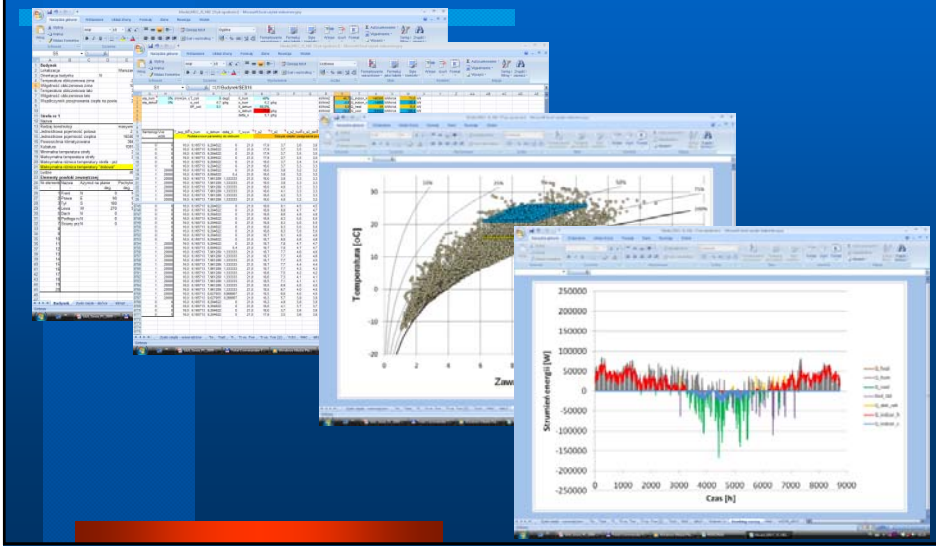
The simulations were performed using modified version of simplified hourly method (model 5R1C) described in Standard ISO 13790:2007 (ISO 2007).

The improvements developed at Warsaw University of Technology (model 6R1C+AHU) include:

- splitting thermal resistances of controlled ventilation and uncontrolled infiltration
- extension of the model by equations describing behaviour of air handling units.



Integrated 6R1C+AHU Energy Simulation Tool

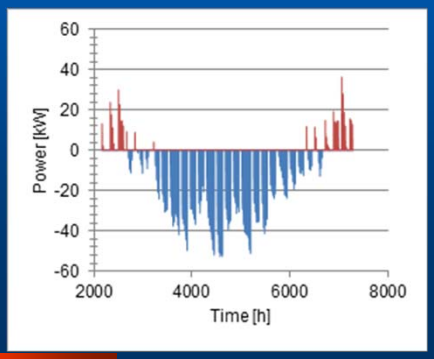


Simulation results for reference variant

The building is equipped with water based 4 pipe air conditioning system and constant air volume mechanical ventilation (e.g. active chilled beams).

Thermal capacitance is moderate and night ventilation is not used.

Heating
Cooling



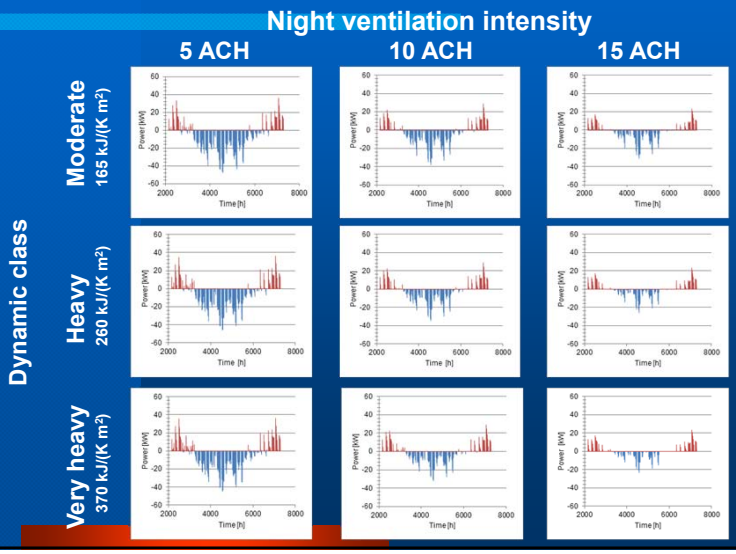
Variants for additional simulations

Additional simulations were performed for different intensity of the night ventilation 5 ACH, 10 ACH and 15 ACH and different thermal capacitances of the building corresponding to medium, heavy and very heavy classes of dynamic parameters of building, according to ISO 13790:2008.

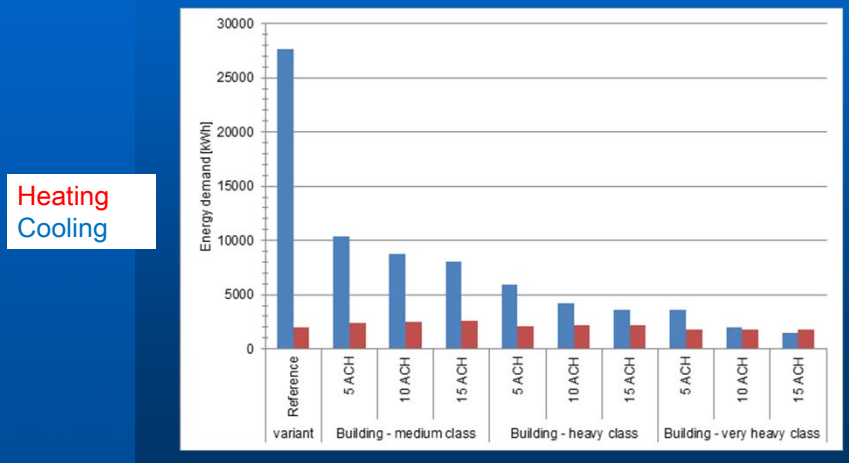
In medium class the area of effective thermal mass is 2.5 times higher than the conditioned floor area, while in heavy and very heavy classes this coefficient is equal 3 and 3.5 respectively.

Internal heat capacity divided by the conditioned floor area equals 165 kJ/(K m^2) for medium class, 260 kJ/(K m^2) for heavy class and 370 kJ/(K m^2) for very heavy class.

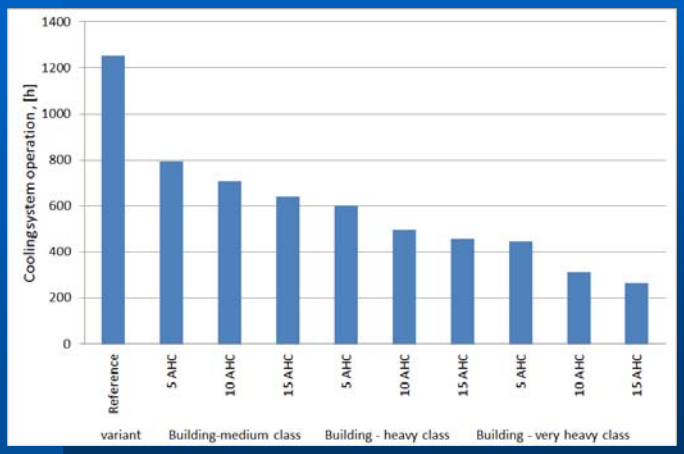
Simulation results



Comparison of the energy demand for cooling and heating

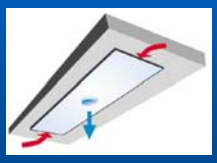


Comparison of operation time of cooling system

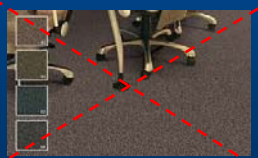


How to increase thermal capacitance of buildings?

Use



Aviod



Economic analysis in integrated design

$$C_g(\tau) = C_I + \sum_j \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) \times R_d(i) \right) - V_{f,\tau}(j) \right]$$

where:

T	the calculation period
$C_g(\tau)$	global cost (referred to starting year τ 0) over the calculation period
C_I	initial investment costs for measure or set of measures j
$C_{a,i}(j)$	means annual cost during year i for measure or set of measures j
$V_{f,\tau}(j)$	means residual value of measure or set of measures j at the end of the calculation period (discounted to the starting year τ 0).
$R_d(i)$	means discount factor for year i based on discount rate r to be calculated by equation

$$R_d(p) = \left(\frac{1}{1 + r/100} \right)^p$$

where p means the number of years from the starting period and r means the real discount rate.

Criteria for final selection of different combinations technical solutions

- the lowest energy use
- the lowest primary energy consumption
- the lowest payback time
- the highest net present value of the investment
- the lowest life-cycle cost
- or any other criteria agreed upon the designing team.

Conclusions

1. Night ventilation can be a very attractive technology for low cost cooling of office buildings.
2. Buildings with high thermal capacitance are more appropriate for application of night ventilation.
3. Achieved results confirm potential for huge energy savings during building operation.
4. Presented approach is quite universal, however one should remember that recommendations for optimal variants can be different in similar cases as economic analyses are strongly dependent on local contexts (construction technologies, local materials, prices of energy etc.).

Thank you!

Integrated approach as a perequisite for future development of urban areas

Prof. dr hab. arch.
Elżbieta D. Ryńska

Workshop on approaches, lessons learned and policy recommendations for Integrated Design

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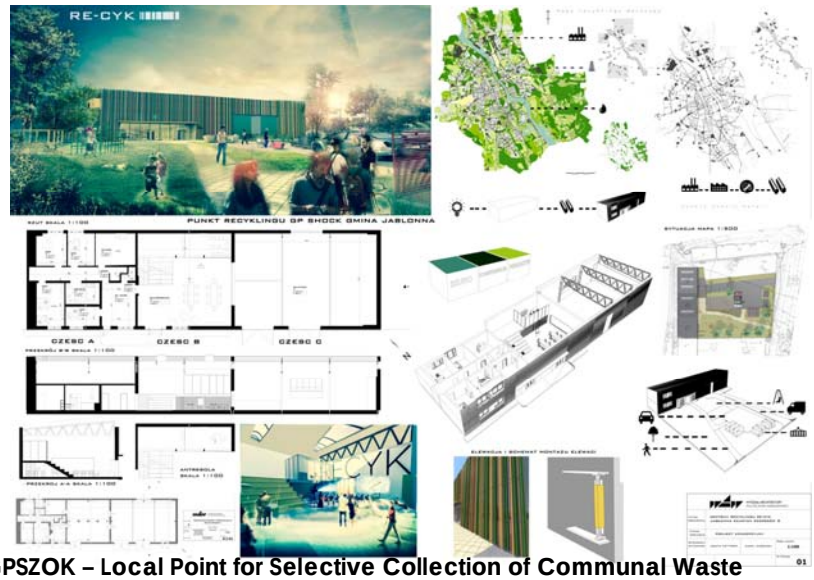

GPSZOK – Local Point for Selective Collection of Communal Waste

Integrated approach as a perequisite for future development of urban areas

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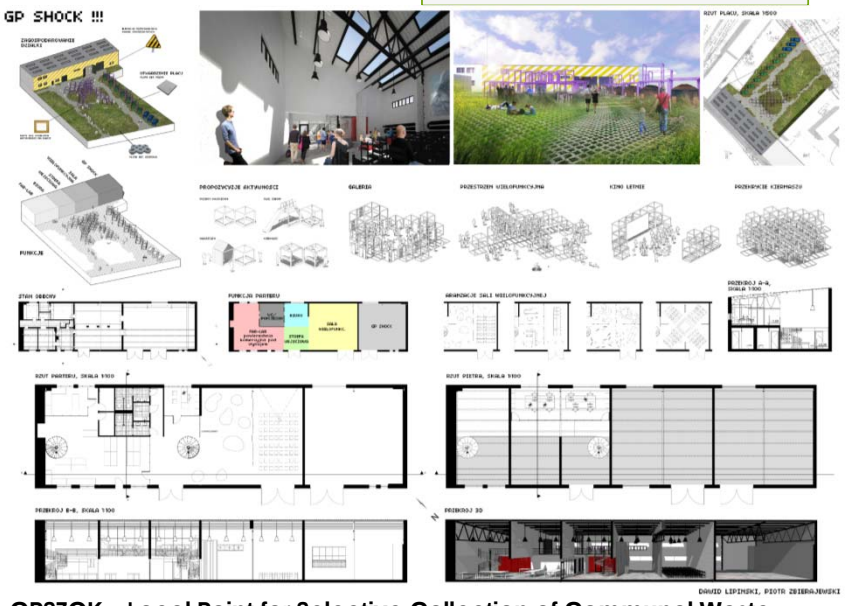

GPSZOK – Local Point for Selective Collection of Communal Waste

Integrated approach as a perequisite for future development of urban areas

RUUKKI – Energy Efficient Pavillion located in Warsaw

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Integrated approach as a perequisite for future development of urban areas

Sustainable Skyscaper, located in Warsaw

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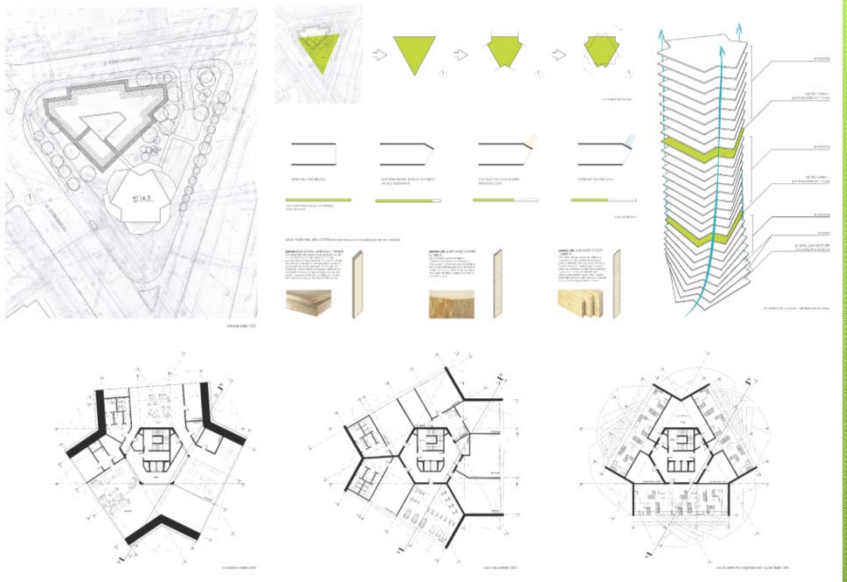
Integrated approach as a perequisite for future development of urban areas



Sustainable Skyscaper, located in Warsaw

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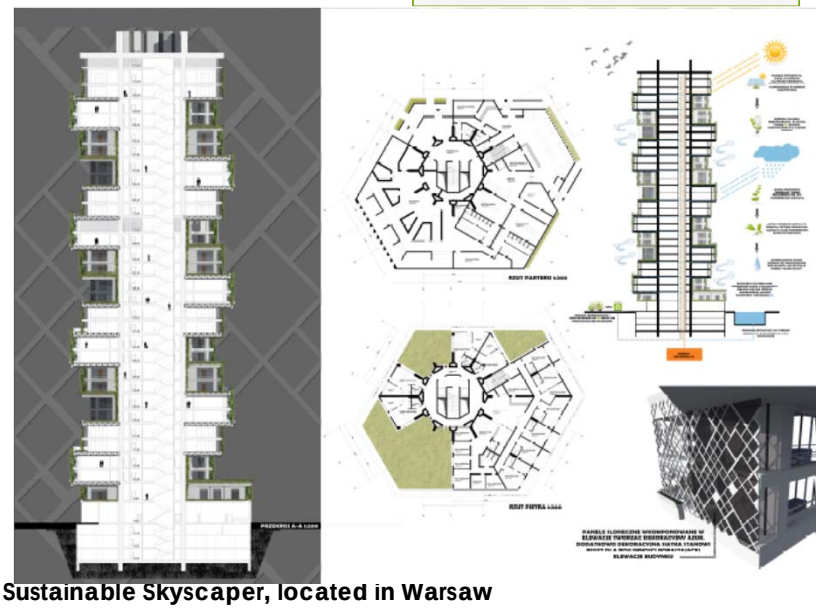

Sustainable Skyscaper, located in Warsaw

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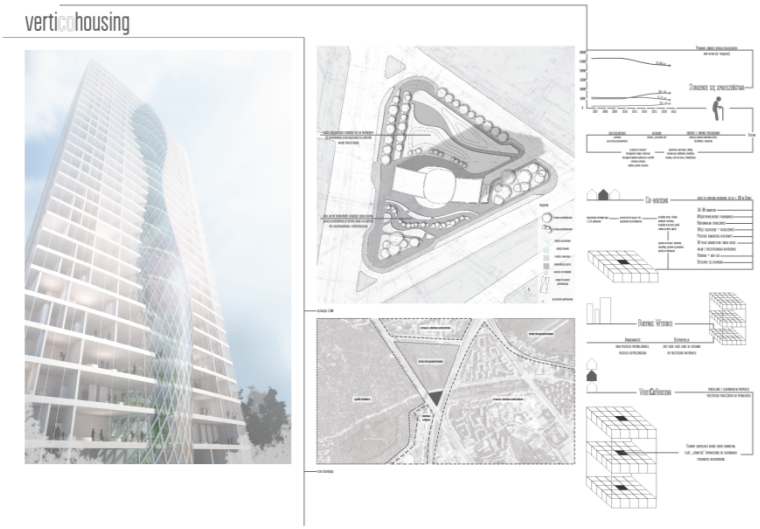

Sustainable Skyscaper, located in Warsaw

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Sustainable Skyscaper, located in Warsaw

SUMMING UP OF THE VENTILATIVE COOLING TRACK

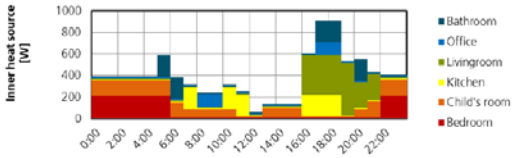
PER HEISELBERG
DEPARTMENT OF CIVIL ENGINEERING

AALBORG UNIVERSITY
DENMARK

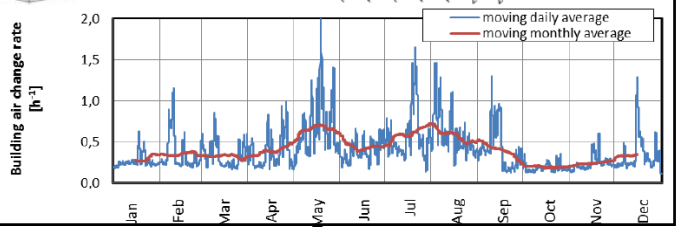
VENTILATIVE COOLING STRATEGIES (CONTROL COMFORT AND REDUCE COOLING LOAD)

THE RIGHT WINDOW OPENING STRATEGY CAN IN RESIDENCES BOTH DECREASE ENERGY USE AND IMPROVE IAQ AND THERMAL COMFORT (PAZOLD ET AL)

- Different window opening strategies will have a large impact on energy use but there is no correlation between energy use, IAQ and thermal comfort
- Supporting automatic system (demand control) can improve both energy use and comfort



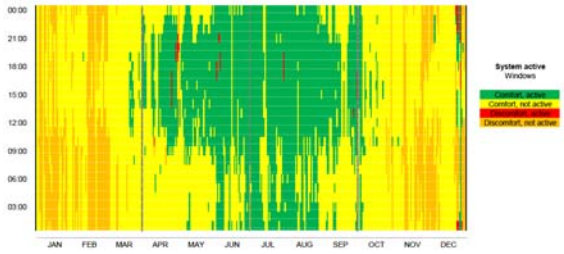
Main floor



VENTILATIVE COOLING STRATEGIES (CONTROL COMFORT AND REDUCE COOLING LOAD)

IN CASE OF PROPER DESIGN WINDOWS CAN CONTRIBUTE CONSIDERABLY TO ENSURING COMFORTABLE THERMAL CONDITIONS (HOLZER ET AL., FOLDBJERG ET AL.)

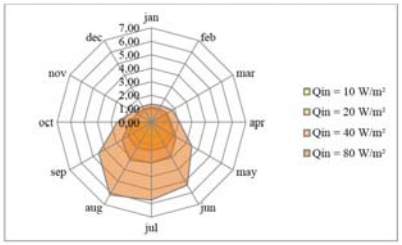
- Combination of automated window opening and automated sunblind, controlled by room temperature, outside temperature and solar irradiation do the job.
- Ventilative cooling control should be automated, with combined operation of windows and sunblinds. Individual operation won't work
- Night ventilation during heat waves reduce temperatures up to five degrees
- Automated operation of both windows and sunblinds is instantaneously visible to occupants. Unexpected 'behaviour' causes instant discomfort and complaints,

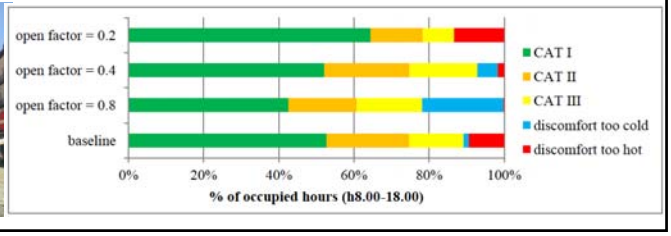


VENTILATIVE COOLING STRATEGIES (CONTROL COMFORT AND REDUCE COOLING LOAD)

VENTILATIVE COOLING POTENTIAL IN RENOVATED HISTORIC MARKET (BELLERI ET AL.)

- For Valladolid, Spain direct ventilative cooling useful up to 90% of the year
- Cooling load reduction up to 55% for temperatures below 25ºC
- Automated control important to optimize energy use and thermal comfort (avoid undercooling)

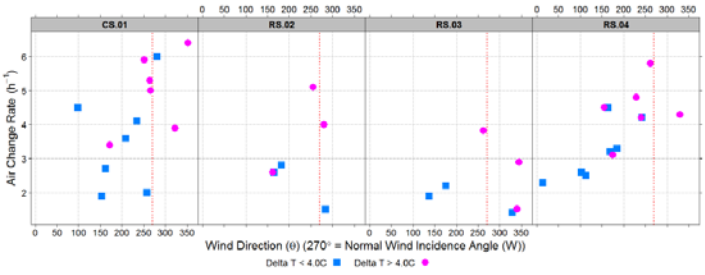


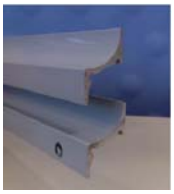


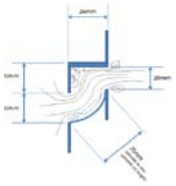
EXAMPLES OF TECHNICAL SOLUTIONS FOR VENTILATIVE COOLING

SINGLE-SIDED SLOT LOUVER SYSTEM FOR OFFICES (O'SULLIVAN ET AL.)

- Performance very dependent on wind direction and low wind pattern at building envelope
- The slot louver ventilation system has led to steadier ventilation rates.

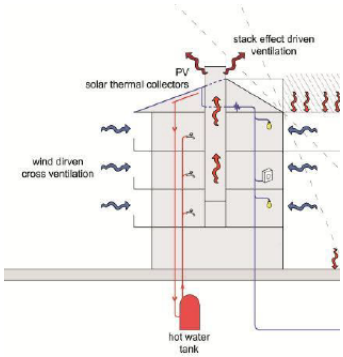




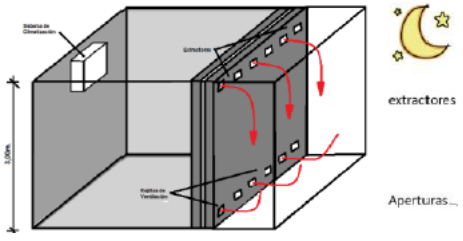


EXAMPLES OF TECHNICAL SOLUTIONS FOR VENTILATIVE COOLING

VENTILATION SHAFTS IS A USEFUL SOLUTION TO ENHANCE VENTILATIVE COOLING AND FOR CONTROL (GUARDIGLI ET AL.)



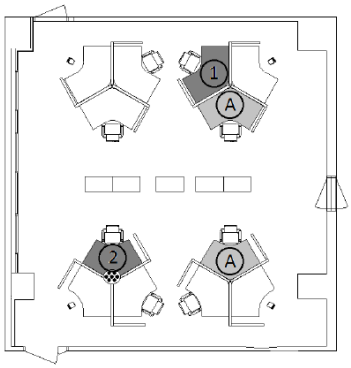
THERMAL STORAGE WALL THAT UTILIZE NIGHT COOLING SHOULD WORK WELL IN WARM CLIMATES IN THEORY. PROVE UNDERWAY (RAMOS ET AL.)



STRATEGIES TO OFFSET OF WARM SENSATION IN HIGH TEMPERATURE CONDITIONS

LOCAL COOLING WITH A SUPPLY AIR JET IMPROVED THE THERMAL COMFORT AND THE PERCEPTION OF THE WORKING ENVIRONMENT IN A WARM OFFICE (MAULA ET AL.)

- However, differences in the perception were identified between different occupants
- Further investigations will include the effect of individual control



A = Acclimatization

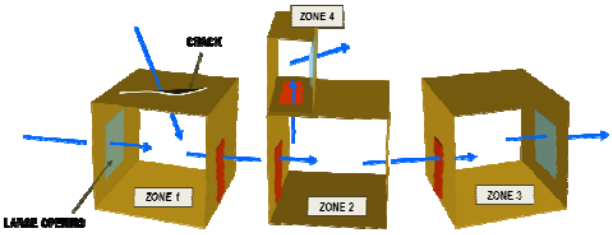
1 = Thermal condition 1; no cooling jet

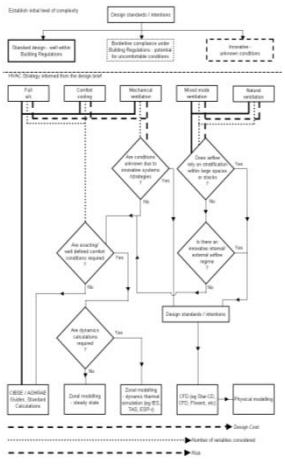
2 = Thermal condition 2; cooling jet

CALCULATION METHODS TO PREDICT VENTILATIVE COOLING PERFORMANCE

REVIEW OF ANALYSIS AND DESIGN METHODS AND TOOLS (BELLERI)

- Need for reliable simple predictions methods for energy compliance tools
- Need for guidelines for the use appropriate tools in different design stages (useful results at appropriate accuracy)

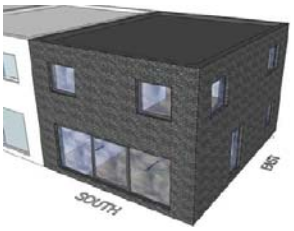


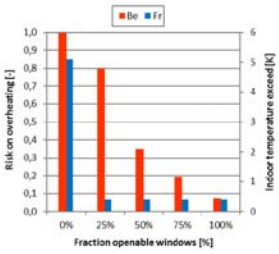


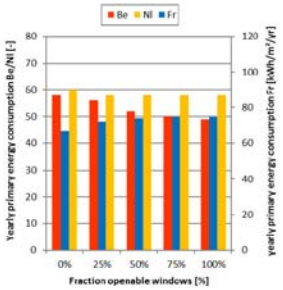
CALCULATION METHODS TO PREDICT VENTILATIVE COOLING PERFORMANCE

SENSITIVITY STUDY OF ENERGY PERFORMANCE TOOL PREDICTION OF VENTILATIVE COOLING PERFORMANCE IN B, NL, F (POLLET ET AL)

- Ventilative cooling by means of openable windows can be taken into account in all three countries. Openable windows increase heating demand in F. Increase in thermal increase heating need in NL
- Ventilative cooling decreases cooling demand (26 to 96% in B, 10 to 35% in NL), especially in combination with solar shading. Better effect for increasing thermal mass. Summer temperatures are decreased in B and F
- Reduced energy use in B, NL, increase in France?







VENTILATIVE COOLING IN STANDARDS

DO STANDARDS SUPPORT VENTILATIVE COOLING ? (OLESEN)

- No need for at separate standard for ventilative cooling
- Need for a technical guide for ventilative cooling
- Need for simple methods to predict air velocity levels in rooms

OUTCOME TO BRING HOME

VENTILATIVE COOLING EFFECTIVE TO REDUCE (OR EVEN ELIMINATE) COOLING NEED IN BUILDINGS

ELEVATED ROOM AIR VELOCITIES (CONTROLLED BY OCCUPANTS) CAN FURTHER INCREASE THIS

CORRECT CONTROL OF VENTILATIVE COOLING ESSENTIAL FOR ACHIEVING EXPECTED PERFORMANCE (WHICH IMPLIES SOME DEGREE OF AUTOMATION)

ALTHOUGH STANDARDS MIGHT SUPPORT THE USE OF VENTILATIVE COOLING BUT PERFORMANCE EVALUATION IN EPBD COMPLIANCE TOOLS ARE NOT CONSISTENT FROM COUNTRY TO COUNTRY AND INTEGRATION OF VENTILATIVE COOLING COMPONENTS OFTEN DIFFICULT.

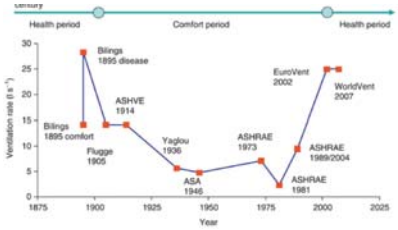
Summing Up
35st AIVC Conference
IAQ, Health and Ventilation

Willem de Gids
VentGuide NL

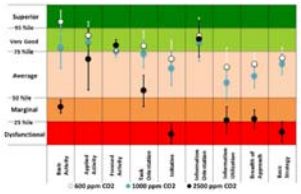
september 24/25 2014
Poznan
Poland

Opening session first day

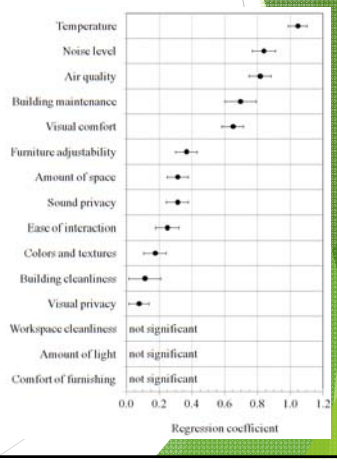
- Pawel Wargocki
  - History of ventilation requirements



  - CO2 and performance

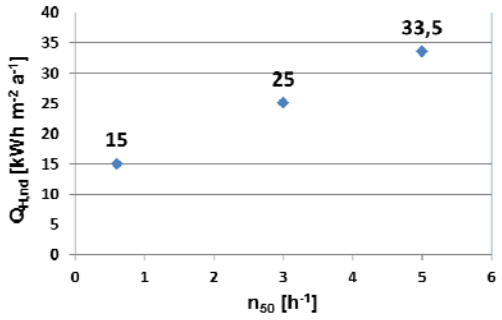


  - Self estimated performance



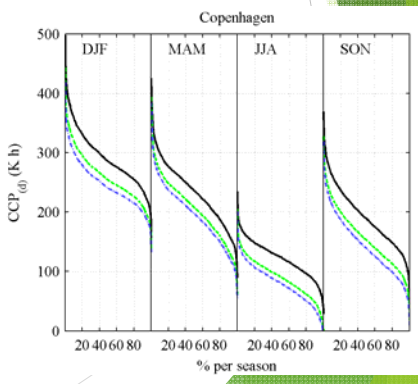
Opening session first day

- Peter Wouters Belgium
  - Housing tested on airtightness
    - Rise in tested houses with a factor of 5
- Thomas Mroz Poland
  - Airtightness and energy use



Opening session first day

- Carl Eric Hagentoft Sweden
  - Probability/risk factor
  - Moisture loads
- Severine Kirchner France
  - Opening windows
  - Socio Economic cost
- Per Heiselberg Denmark
  - Climate change and ventilative cooling potentials for different climates



Session 1C Demand Control

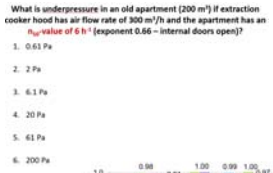
- Mads Mysen Norway
  - Handing over
  - Max/min load test
- Madeline Collet France
  - 20% of the time CO2 over about 1200 ppm in bedroom with a DCV
- Samuel Callou Belgium
  - F reduction for DCV systems for energy performance calculation
  - calculated for an apartment with has an air leakage of 0
- Arefeh Hesaraki Sweden
  - Comparison background ventilation with mechanical DCV
  - Based on 900 ppm CO2 as maximum value

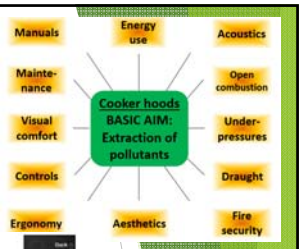
Session 2C EPBD ventilation standards

- Jaap Hogeling Netherlands
  - Revision of EPBD standards in conjunction with ISO
  - Not reaching the 20% reduction value in 2020
  - But 18 -19 %
  - Most Standards are out for formal voting by the countries
- Bjarne Olesen Denmark
  - EN 15251 revision IEQ standard
  - Not for domestic buildings
- Gerhard Zweifel Switzerland
  - Ventilation/cooling and heating
  - Commercial and domestic
- Remi Carrie France
  - Inspection
  - Interesting information in EU site Concerted Action on Inspection
  - Combining two existing standards ventilation and AC
  - Three levels of inspection

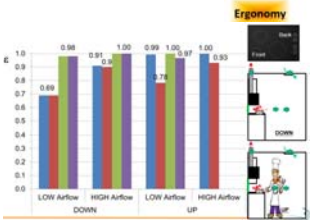
Session 5D Cooker hoods

- Peter Wouters Belgium
  - Boundary conditions

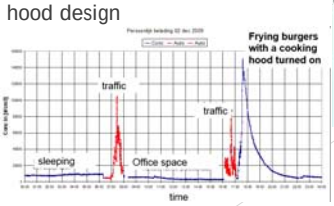


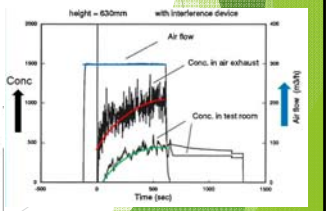


- Max Sherman USA
  - Range hoods in USA
    - Popular Microwave range hood



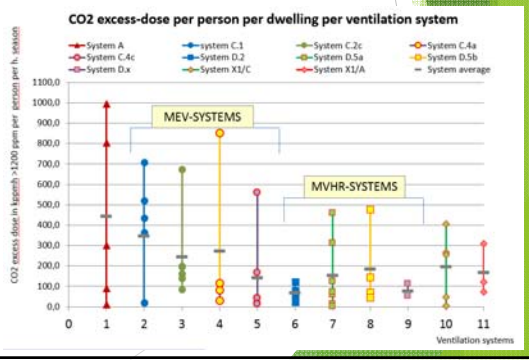
- Willem de Gids Netherlands
  - EU eco design directive and testing standards
- Wouter Borsboom Netherlands
  - Strategies for cooker hood design





Session 6C
Field performances and DCV

- Axel Cable Norway
  - DCV in schools
  - Measurements and Questionaires
- R. van Holsteijn Netherlands
  - Monitoring ventilation and energy use in 62 dutch houses
    - Over one to two years



Session 7C Ventilation/IAQ/Health and Comfort

- Pilar Linares-Alamparte Spain
  - IAQ and energy in Spanish Dwellings
- Christiani Sofia Koulani Denmark
  - Static pressure control for comfort ventilation
  - Validation is needed after carrying out measurements
- Ewelina Kubacka Poland
  - Office ventilation : Mechanical versus natural
  - Numerical simulation with ESP-r of IAQ
- Ivana Katavic Norway
  - Moisture Buffering
  - Indoor Humidity variation
  - Wood physics too complicated for simulation programs

Thank you for your attention

Ventilation and airtightness in transforming the building stock to high performance

Summing up of airtightness track

Arnold Janssens
Ghent University, Belgium

Overview airtightness track

24 September	25 September
Quality issues in airtightness testing	Characterisation of airtightness products
Durability of airtightness	Airtightness improvements in existing buildings
Building airtightness: field characterisation, energy and IAQ-impacts	Ductwork airtightness in new and renovated buildings
	Building airtightness: test methods, optimum levels

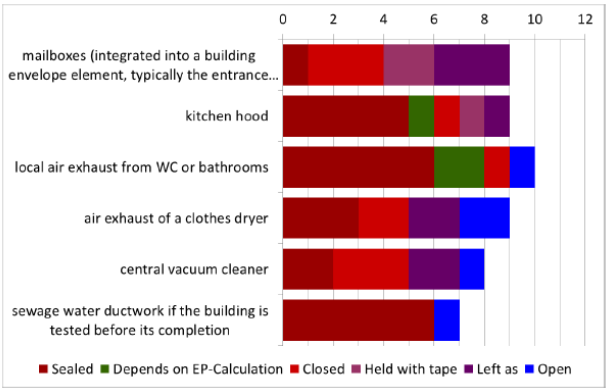
26 presentations, 27 papers

Highlights

- Quality issues in airtightness testing
- Test methods
- Renovation methods
- Durability of airtightness

Quality issues in airtightness testing

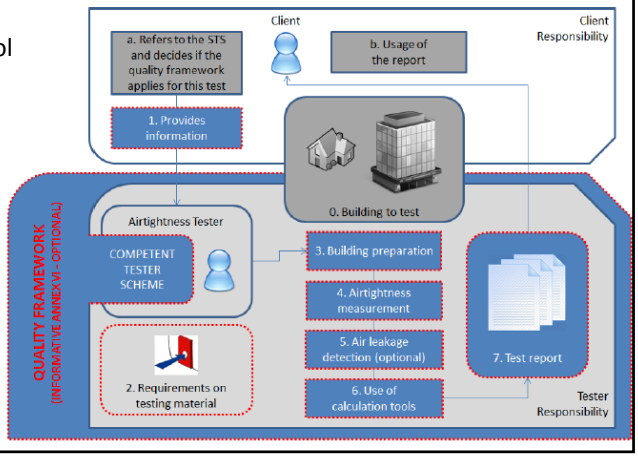
- Comparison of building preparation rules for airtightness testing
  - 7/11 countries specific preparation guidelines in addition to standard EN 13829



Leprince & Carrié

Quality issues in airtightness testing

- Framework for reliable fan pressurisation tests
  - Qualification of testers
  - Testing material
  - Technical criteria
  - Third party control



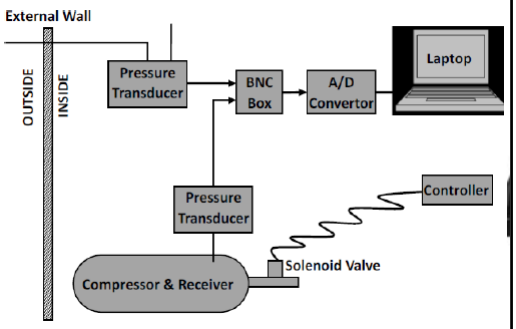
Loncour, Delmotte, Mees & De Strycker

Test methods

Large building testing using ventilation system
- Difference of 22-30% BD-MV
- More expertise and effort needed

Szymanski, Gorka & Gorzenski

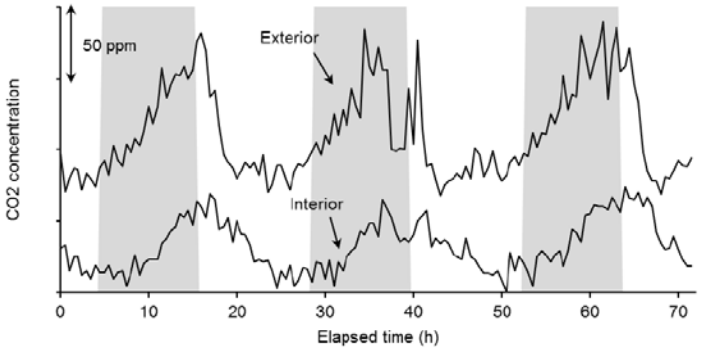
Nozzle pulse pressurisation technique
- Leakage assessment at low pressure difference



Cooper, Zheng, Gillot, Riffat & Zu

Test Methods

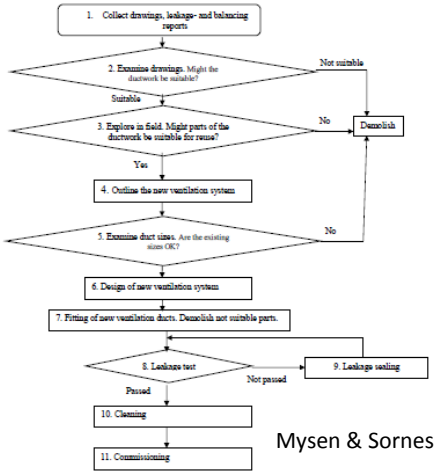
- Measurements of infiltration rates from daily cycle of ambient CO_2



Carrilho, Mateus, Batterman & Gameiro da Silva

Renovation methods

- Reuse of existing ductwork for retrofitting ventilation systems



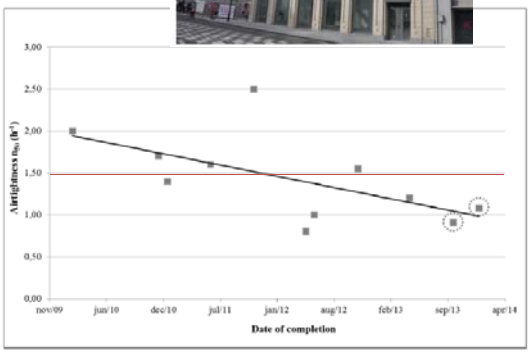
Mysen & Sornes

- Airtightness renovation of structures
  - IAQ improvement

Laine

Renovation methods

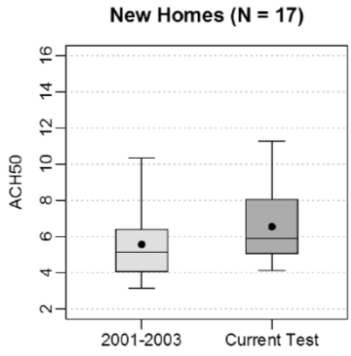
- Airtightness of renovated tertiary buildings
  - Recommended n_{50}: 1.5 h^{-1} for 'exemplary building' subsidies



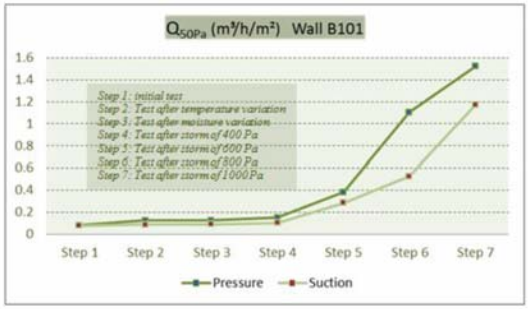
De Meester, Hermans & Steeman

Durability of airtightness

- Field measurements of airtightness
  - 1% increase/year caused by aging
- Laboratory tests
  - Materials and systems age differently depending on type of loading



Chan & Sherman



Michaux, Mees, Nguyen & Loncour

Durability of airtightness

- Aging phenomena under artificial aging
  - 80°C, 50% RH/1year

Ylmen, Hansen & Romild

Ventilation and airtightness in transforming the building stock to high performance

Summing up of airtightness track

Thank you for your attention!

Dziękuję za uwagę!

- Characterisation of sealants and foams
  - Lack of standards
  - New classes for windows
  - Air permeability testing components EN12114
    - aging

International Centre for Indoor Environment and Energy

Indoor Environmental Quality-Global Alliance: The value chain of IEQ

Professor Bjarne W. Olesen, Ph.D. FASHRAE
Vice-President ASHRAE
www.ie.dtu.dk
Technical University of Denmark

COMFORT-PRODUCTIVITY
Building costs

People	100
Maintenance	10
Financing	10
Energy	**1**

This clearly show that buildings are for

people

not for saving energy

Global impact on people

Importance of IEQ - asthma

- According to US CDC based on data collected in 2007, 2008, 2009
  - 8.2 % of population/26 million people affected
  - 10.5 million missed school days
  - 14.2 million missed work days
  - 475,000 hospital stays
  - 3,447 deaths
- Asthma triggers (CDC)
  - ETS
  - Dust mites
  - Outdoor air pollution
  - Cockroach allergens
  - Pets
  - Mold
  - Wood smoke
  - Respiratory infections

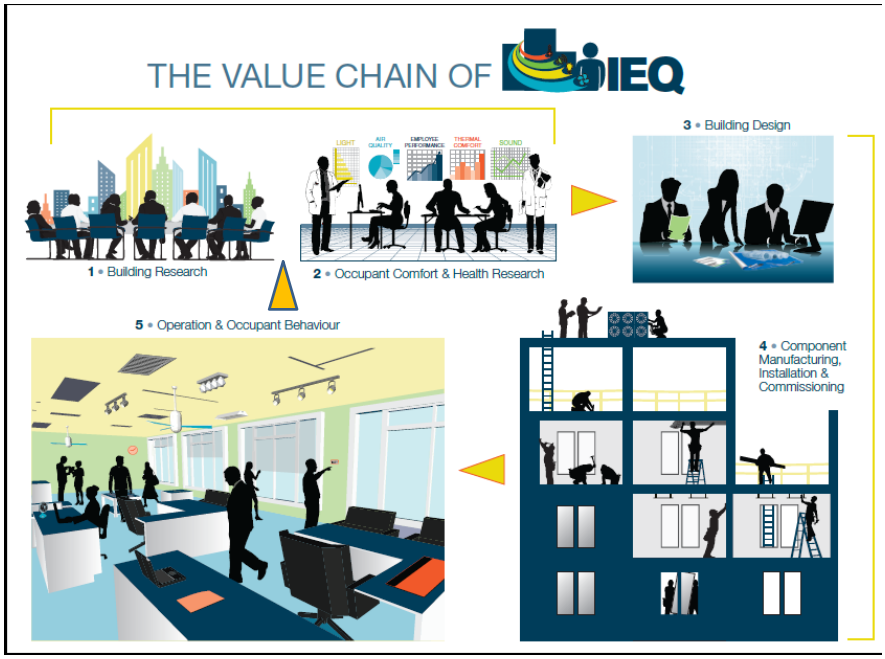
Poor IAQ/IEQ is costly – national scale

(Fisk, W. How IEQ Affects Health, Productivity. ASHRAE J., May 2000)

Source of Gain	Potential Annual Benefits	Lower $ (€) Billion (2012)	Higher $ (€) Billion (2012)
Reduced Respiratory Illness	16 - 37 Million Avoided Cases of Common Cold or Influenza	9 (6.8)	21 (15.8)
Reduced Allergies and Asthma	8% - 25% Decrease in Symptoms - 53 Million Allergy Sufferers, 16 Million Asthmatics	1 (0.8)	6 (4.5)
Reduced Sick Building Syndrome Symptoms	20% - 50% Less SBS Symptoms at Work for ~15 Million Workers	15 (11.3)	44 (33.1)
Lighting/ Thermal Gain		30 (22.6)	237 (178.2)
TOTAL		**55 (41.4)**	**308 (231.6)**

Achieving Excellence in Indoor Environmental Quality

- Physical factors
  - Thermal Comfort
  - Air quality (ventilation)
  - Noise-Acoustic
  - Illumination
  - Exposure time
- Personal factors
  - Activity
  - Clothing
  - Adaptation
  - Expectation



- Research institutes
- Universities
- Industries
  - Building Codes-Standards-Guidelines
  - Design methods
  - New Building Materials
  - New Building Service Systems

2 • Occupant Comfort & Health Research

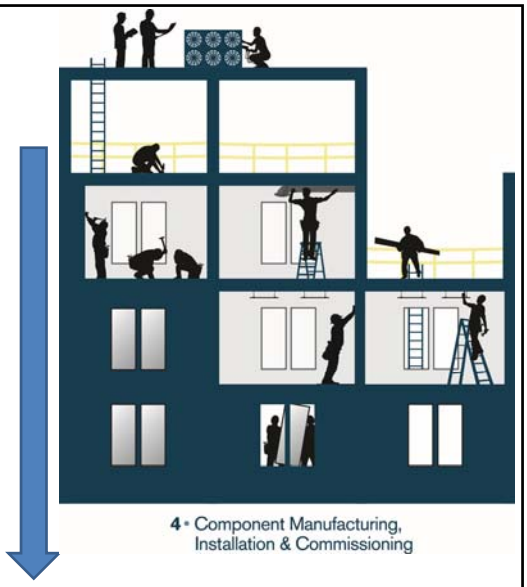
- Research institutes
- Universities
- Industries

- Health and Comfort Criteria
- Building Codes-Standards
- Prediction Methods

3 • Building Design

- Building Owner
- Architect
- Engineering Consultant
- Interior Designer

- Consultants
- Architects
- Product manufacturing
  - Building componet
  - Furnishing
  - Paint
- Construction Companies
- Installations
  - Building
  - Building Services
  - Controls
- Commissioning



4 • Component Manufacturing, Installation & Commissioning

- **Final Building**

5 • Operation & Occupant Behaviour

- Building Owner
- Facility Management
- Occupant Behaviour
- Inspections
- Maintenance

IEQ Value Chain

- Many people and organisations are responsible for the final indoor environmental quality
- They do not speak with one voice
- Energy efficiency and use is dominating the debate
- There is a need to establish a collaboration between all parts of the IEQ value chain

World Green Building Council WBGC

- **Health, Wellbeing and Productivity in Offices**
  - **The Next Chapter for Green Building**
  - http://www.worldgbc.org/activities/health-wellbeing-productivity-offices/

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

IEQ-GA

www.ieq-ga.net

- The organizations will work together to
  - Create a common understanding and messaging of research gaps
  - Identify what results of research can be transferred to practice in the form of standards and codes that support a health and performance based definition of IEQ
  - Create a legislative agenda and advocacy position.

www.ieq-ga.net

- The organizations agree:
  - To set up procedures for operation of the IEQ-GA
  - To establish a web-page for distribution of information and contacts
  - To become a broad resource on IEQ issues
  - To meet (preferably in person or optional virtual) at least two times per year during the first two years of the Alliance's existence to follow up on agreed actions and planning future actions.

www.ieq-ga.net

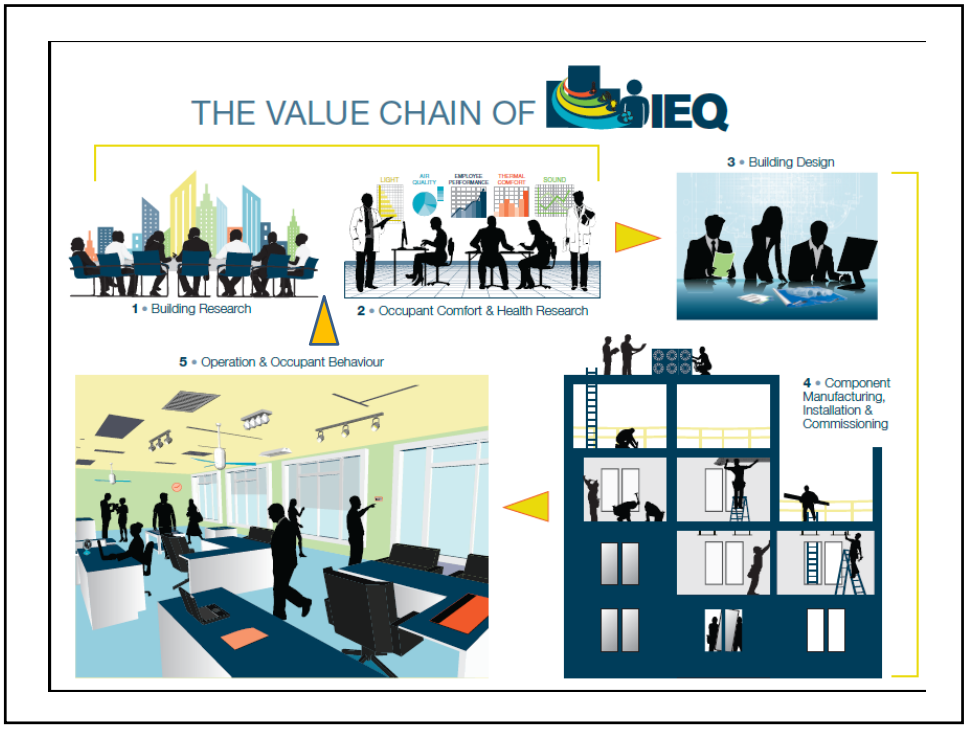
- The alliance will seek cooperation with other organizations (e.g. WHO, EPA etc.)
- The Alliance will also seek new members or collaborations with other organizations that work directly with the impact of the indoor environment on people's well-being and health.

Activities and Goals

- Advocacy
- Publications
- Education
- Coordination of Technical Activities
- Research
- Conferences and Meetings

Present Activities

- Contacting Societies for Light and Acoustic
- Set up the administration of the alliance
- Comparing Position Documents


THE VALUE CHAIN OF IEQ
1 • Building Research
2 • Occupant Comfort & Health Research
3 • Building Design
4 • Component Manufacturing, Installation & Commissioning
5 • Operation & Occupant Behaviour