Brussels, Belgium
19-20 March 2013

International Workshop

Ventilative Cooling
Need, Challenges and Solution Examples

PRESENTATIONS

This event is organized with the technical and/or financial support of the following organizations:
# International workshop

## Ventilative Cooling Needs, Challenges and Solution Examples

### Programme

**Tuesday**  
March 19, 2013

<table>
<thead>
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<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>1300 – 1400</td>
<td>Registration and sandwich lunch</td>
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<tr>
<td>1400 – 1430</td>
<td><strong>Welcome to seminar</strong>&lt;br&gt;by venticool platform, Peter Wouters and Rémi Carrié, INIVE&lt;br&gt;by Operating Agent of ECBCS Annex 62, Per Heiselberg, Aalborg University</td>
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| 1430 – 1545 | **Ventilative Cooling Needs and Potential**<br>Moderator discussion: Max Sherman, LBL, US<br>  
  - Urban heat island, climate change and impact on ventilation for cooling, Maria Kolokotroni, Brunel University, UK  
  - Personal control over indoor climate and the use of operable windows in offices, Atze Boerstra, Eindhoven University of Technology, Netherlands  
  - Ventilative cooling potential of outdoor air - now and in the future, Per Heiselberg, Aalborg University, Denmark |
| 1545 – 1600 | Break                                                                                         |
| 1600 – 1730 | **Ventilative Cooling in Buildings**<br>Moderator discussion: Per Heiselberg, Aalborg University, Denmark<br>  
  - Energy efficient design of a passive school using thermal dynamic simulations, Joerie Alderweireldt, 3E, Belgium  
  - A ventilative cooling system in a School Building, Imola, Italy, Mario Grosso, Politecnico di Torino  
  - Passive cooling with natural ventilation rate, a case study, Pier Nicola Currà, Archefice associati, Italy  
  - Examples of built naturally cooled buildings, Flourentzos Flourentzou, Estia SA, Switzerland |
| 1900       | Walking Dinner through Brussels                                                               |
Wednesday  March 20, 2013

9:00 – 10:30  Ventilative Cooling in Standards and Regulations
Moderator discussion: Rémi Carrié, INIVE Senior Consultant, France
- Ventilative cooling in relation to the CEN M/480 work, Jaap Hogeling  109
- Ventilative cooling in building regulations – Country reports by: Anne Marie Bernard (France)  135
  Karsten Duer (Denmark)  147
  Max Sherman (US)  153
  Maria Kolokotroini (UK)  157
  Bas Knoll (NL)  163
  Peter Holzer (Austria)  167

10:30 – 11:00  Break

11:00 – 12:30  Prediction of Cooling Need and Overheating Risk
Moderator discussion: Maria Kolokotroini, Brunel University, UK
- Challenges in the prediction of cooling need and overheating risk, Jan Hensen, Eindhoven University of Technology, Netherlands  175
- Is ventilative cooling an effective in light weight wooden constructions?, Hilde Breesch, KAHO St-Lieven, Belgium  189
- Natural ventilation design tools, applications in commercial buildings Stephen Ray, MIT, US  203
- Sensitivity of night cooling performance to room/system design: surrogate models based on CFD, K. Goethals, Ghent University, Belgium  217

12:30 – 13:15  Lunch break

13:15 – 14:45  New Solutions and Technologies
Moderator discussion: Jan Hensen, Eindhoven University of Technology, Netherlands
- Ventilative cooling experiences by Renson: lessons learned and solutions, Ivan Pollet, Renson Ventilation, Belgium  237
- Application of PCM-systems in ventilative cooling, Lesh Gowreesunker, Brunel University, UK  253
- Progress made in research and design of stratum ventilation, Zhang Lin, City University of Hong Kong, PR China  259
- New solution for modern passive cooling and heat redistribution, Bas Knoll, TNO, Netherlands  269

14:45 – 15:00  Break

15:00 – 15:45  Round table discussion with industry experts (EVIA, Velux, Naventa, WindowMaster, ES-SO, consultancy engineers)
Moderator: Peter Wouters

15:45 – 16:00  Closing session
Summary of workshop discussions and conclusions, Per Heiselberg, Aalborg University, Denmark
International Workshop

Ventilative Cooling: Need, Challenges and Solution Examples

Brussels, Belgium
19-20 March 2013

Peter Wouters and Rémi Carrié
INIVE EEIG
Welcome

Dear Workshop Participant,

This BUILD UP 4U issue is dedicated to the workshops organised by AIVC, TightVent and venticool on - the quality of ventilation systems in residential buildings, and - ventilative cooling, in collaboration with the new IEA Annex 62.

Find out how, in the context of AIVC, TightVent and venticool, we make use of the information and services provided by BUILD UP, the official EU portal on energy efficiency, for a wider information spread.

I wish you a pleasant and informative reading,

Peter Wouters
Manager INIVE EEIG

Günther Oettinger, EU Commissioner for Energy

... If we want to transform our society into an energy efficient and decarbonised one, energy intelligent buildings will play a vital role. Let us work together towards cleaner and more energy efficient buildings for the future. (…)
In the context of an energy efficient thermal comfort strategy…

- Ventilative cooling
- Solar control and reduction/management of internal loads
- Thermal mass
Key objective

Present situation – Poor understanding of ventilative cooling potentials

Good understanding and appropriate use of ventilative cooling

Prof. Per Heiselberg

More focusing on knowledge generation aspects

IEA Annex 62
(in preparation phase)

More focusing on market implementation

venticool

...Ventilative cooling...
Events

- 2013 AIVC conference, Athens, Greece, 25-26 September 2013
  - [www.aivc2013conference.org](http://www.aivc2013conference.org)
**Key objective of this workshop**

How and when strategies for increased ventilation with outdoor air can reduce the cooling load while maintaining good indoor environmental quality?

| Built examples to document the need and potential of ventilative cooling as well as the status of present approaches |
| Design challenges related to prediction and evaluation of the cooling need |
| Perceived barriers and challenges in standards and existing building regulations |
| New ideas |

60 participants to discuss these issues based on contributions from various countries and international organizations

*On behalf of AIVC and venticool, we wish you a pleasant and informative workshop*
Ventilative Cooling

Per Heiselberg
Aalborg University

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, especially in residences - even 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
- Utilization of the cooling potential of outdoor air can be an attractive and energy efficient solution
Why do we have overheating problem?

- A “new and increasing problem” for high performance residential buildings in cold and moderate climate
- Use of too simplified design methods – no correlation between cooling need and overheating risk
- 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”
Ventilative Cooling in Offices

- Always a cooling need during occupied hours

- 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, while the use in natural and hybrid ventilation systems is still limited in many countries

Offices in Cold Climate
Challenges in a Cold Climate

IEA ECBCS Annex 62
Ventilative Cooling
A new international project under preparation
A step on the way

In order to address these challenges we propose a new international research activity with the scope:

“How and when can strategies for energy-efficient ventilation reduce the cooling load while maintaining good indoor environmental quality?”

The Projects Definition of Ventilative Cooling

• Ventilative Cooling is application (distribution in time and space) of outdoor 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 Objectives

• To analyse, develop and evaluate suitable design methods and tools for prediction of cooling need, ventilative cooling performance and risk of overheating in buildings (Subtask A).
• To give guidelines for integration of ventilative cooling in energy performance calculation methods and regulations including specification and verification of key performance indicators (Subtask A).
• 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 (Subtask B).
• To demonstrate the performance of ventilative cooling solutions through analysis and evaluation of well-documented case studies. (Subtask C).

Annex Outcome

• Guidelines for energy-efficient reduction of risk of overheating
• 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 Organization

• Subtask A: Tools and guidelines

• Subtask B: Solutions

• Subtask C: Case studies
Urban heat island, climate change and impact on ventilation for cooling

Maria Kolokotroni
School of Engineering and Design, Brunel University

What is the difference between cities and countryside?

Urban Pollution:
air, thermal, noise
Thermal pollution causes:

- Heat capacity & conductivity
- Solar absorptivity
- Sky factor
- Wind speed
- Energy use
- Vegetation

Heat capacity & conductivity

RURAL
- ground is less dense
- has a lower heat capacity
- and has an insulating layer above

URBAN
- high density materials
- with high heat capacity
- and high thermal conductivity
Solar absorptivity

Albedo (solar reflectivity) varies in both rural and urban areas

Sky factor

reduced effectiveness of long-wave radiation for cooling
Wind speed

- Average rural wind speeds are higher than urban ones because the ground surface is smoother.
- The “rougher” urban surfaces reduce wind speeds, but there are local variations.
- Wind flowing across a deep narrow street canyon will create little disturbance at ground level.

Energy use releases heat

- Rural energy use is small compared to the energy received from the sun.
- Energy use density in urban areas is much higher.
Vegetation

- To evaporate water requires energy - this helps keep plants and the air around them cool
- Urban areas are “harder”. They have less vegetation, less evaporative cooling and less shading of the ground
- parks provide “rural” oases

What is the effect of these factors?

It is known as Urban Heat Island effect
Urban Heat Island

- Body of work in hot climates, US, Europe and Asia
- What happens in moderate climates such as London?
- We measured it!
Example of the variation in heat island intensity across London

Example of the variation in heat island intensity across London

Date: 2 August 1999
Time: 02:00
GLA report: London’s Urban Heat Island

Figure 2: The variation in the UHI intensity for London over 24 hours for summer 2000. The solid red line indicates the average UHI intensity by hour while the shaded area shows the range of UHI intensity values for 68 percent of the observations.

Mean nocturnal UHI pattern in 3 geographical zones during clear sky periods under 3 categories of wind speed

[Graph showing the mean nocturnal UHI pattern in 3 geographical zones during clear sky periods under 3 categories of wind speed.]
Hourly mean UHI value with wind speed less than 5 m/s for Core Area (zone-1)

London to be divided into three zones – consistent with CIBSE Guide A, 2006
What is the effect on night ventilation?

Effect on air temperature

Minimum Temperatures Variations (1999)

Minimum Temperatures Variations (2000)

Maximum Temperatures Variations (1999)

Maximum Temperatures Variations (2000)
Effect on night cooling strategy

![Graph showing night cooling strategy comparison between London and Rural areas in 1999 and 2000.]

Cooling demand reduction potential through night ventilation

![Bar chart illustrating the cooling demand ratio (optimum/conventional) for different scenarios.]
UHI, energy use and climate change

The challenge: to model the effect of future climate on buildings within UHI

<table>
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<tr>
<th>Factor causing change</th>
<th>change in percentage occupied hrs above 28 degC</th>
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<td>Location</td>
<td>-1</td>
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<td>Future climate</td>
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<tr>
<td>Night ventilation</td>
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</tbody>
</table>

- decrease in percentage occupied hrs >28 degC
- increase in percentage occupied hrs >28 degC
LUCID models

**LondUM**
- The citywide model, the ‘London Unified Model’ (LondUM), represents the influence of the city on the urban boundary layer using a newly-developed parameterisation called MORUSES (the Met Office-Reading Urban Surface Exchange Scheme). The model outputs temperatures at multiple 1 km x 1 km grid and is capable of describing the impact the city has on the local climate.

**ADMS – Excess Temperature & Relative Humidity**
- This neighbourhood scale model (based on the ADMS model) predicts temperature and humidity changes across an urban area as a response to the underlying land use, e.g. buildings and surfaces. Values from LondUM are used to describe the upwind boundary layer profile for this model.

**LSSAT**
- The London Site Specific Air Temperature (LSSAT) prediction model is composed of a series of Artificial Neural Network (ANN) models that predict site specific hourly air temperature within the Greater London Area.

**OutdoorROOM**
- OutdoorROOM is a dynamic thermal model that deals with radiative exchanges and comfort conditions throughout outdoor spaces and in particular within urban canyons.
Step 1- Brief description of ANN model

Air temperature dataset 2000 for sites in London + Heathrow weather data for 2000

Matlab ANN routines using back propagation method

Functions were chosen for each site using part of the data for training and part for testing

Models to predict air temp at the 77 measured sites given a Heathrow weather file – very suitable to calculate indices such as Heating Degree Days and Cooling Degree Hours

Comparison of measurement and prediction

WW1-Oct1999

Temperature degC

0 10 20 30 40

00:00 04:00 08:00 12:00 16:00 20:00 24:00


Predicted Measurements Heathrow
Using future weather files

- we used CIBSE weather files for London 2050 (medium-high scenario, according to UKCP02)
- these were constructed using the method developed by Hacker and Blecher to predict parameters on an hourly basis
- we adapted air temperature based on the results of LSSAT. Everything else was kept the same over London.

More information:
UHI, ventilation and climate change

HW-Heating load, kWh/m²/year, 2000

HW-Heating load, kWh/m²/year, 2050

y = -0.0056x + 18.739

y = 0.011x + 18.462

y = -0.0167x + 16.105

y = 0.0101x + 15.849

y = -0.0324x + 19.33

y = 0.0252x + 18.976

y = -0.0453x + 17.444

y = 0.0254x + 17.088

HW-emissions, kgCO₂/m²/year, 2000

HW-emissions, kgCO₂/m²/year, 2050

y = 0.0144x + 20.827

y = -6E-05x + 20.631

y = 0.0234x + 18.238

y = -0.014x + 18.074

y = -0.0111x + 19.983

y = -0.0149x + 19.67

y = -0.0063x + 17.748

y = 0.003x + 17.464
Some observations

- Offices with night ventilative cooling produce less CO2 in 2000 and 2050
- Difference between city and rural offices is less in 2050 with urban offices producing more CO2.
  - a 5–9% increase in CO2 emission is predicted in 2050 in the reference location and 13–15% in the city centre location.
  - In 2000, the environmental impact is up to 4% less in the city location compared to the reference location while in 2050 is 4.5% more.
- Overheating hours will increase up-to 140% in 2050 in the reference location and 110% in the city centre location. Heavy weight construction with night cooling has the highest increase but in terms of number of hours it still has the lowest number of overheating hours.
- Natural today versus AC in 2050: CO2 emissions increase between 230% and 340% in the reference location and between 480% and 670% in the city centre location.

Summary

- Urban buildings use more energy than rural buildings because of the Urban Heat Island Effect
- Less knowledge on how to improve thermal environment in cities, now and in the future, in particular moderate climates where requirements for heating fight requirements for cooling
- Challenge: How to design for ventilative cooling strategies and products taking into account future climate change predictions for the urban environment.
Thank you!
PERSONAL CONTROL OVER INDOOR CLIMATE AND THE USE OF OPERABLE WINDOWS IN OFFICES

Atze Boerstra
BBA Indoor Environmental Consultancy + Eindhoven University of Technology

THERMAL FACTORS

ENVIRONMENTAL:
- air temperature
- mean radiant temperature
- relative humidity
- air velocity

PERSONAL:
- metabolic rate
- clothing insulation

THERMAL SENSATION

THERMAL COMFORT

AVAILABLE CONTROL

ORGANIZATIONAL NORMS

HVAC SYSTEM COMPONENTS

BUILDING COMPONENTS

EXERCISED CONTROL
- MANIPULATIVE
- ADAPTIVE

PERCEIVED CONTROL

SATISFACTION with the THERMAL ENVIRONMENT

THEORY I: CONCEPTUAL MODEL PACIUK (1990)
THEORY II: CONCEPTUAL MODEL BOERSTRA ET AL (2013)

Assumption is that human responses to sensory stimuli are modified when those exposed have control over the stimuli...
(after Bell et al, 2002, Paciuk, 1990 and Brager & DeDear, 1998)

INDOOR CLIMATE
(temperature, airspeed, CO2 conc., etc.)

CONTROL
(available, exercised & perceived)

moderator

response

COMFORT, HEALTH & PERFORMANCE

AIR MOVEMENT IN WARM ENVIRONMENTS

Dr. Angela Simone, DTU, 2012:
‘Everyday experience and numerous climatic chamber and field studies show that in warm environments air movement is perceived as pleasant’

See for example:
Ishii et al (1990)
Chow & Fung (1994)
Fountain et al. (1994)
Mallick (1996)
Kubo et al. (1997)
Kitagawa et al. (1999)
Cena & DeDear (1999)
Donnini et al. (1997)
Khedari et al. (2000)
Xia YZ et al. (2000)

Brager GS et al. (2004)
Gong N et al. (2006)
Atthajariyakul & Lertsatittanakorn (2008)
Yang & Zhang (2009)
Zhang et al. (2007)
Baihan et al. (2010)
Cândido et al. (2010)
Chow et al. (2010)
and many more...

DRAFTS IN WINTER ARE PLEASURABLE BREEZES IN SUMMER!
AIR MOVEMENT PREFERENCE AND THERMAL SENSATION

Zhang et al. 2007

‘NEW’ TEMPERATURE / AIRSPEED GRAPH IN ASHRAE STANDARD 55: 2010
‘Breeze figure’ in EN-ISO 7730: 2005

Fig. 5.3 Air velocity required to offset increased temperature

LARGE INVIDIDUAL DIFFERENCES (direct control is essential)

Example results of preferred airspeed in a laboratory room of 28 °C for 6 subjects; airspeed was under direct control at workstation level and could be changed at free will

Te Kulve et al, 2013
WHAT HAPPENS IF ONE IS TOO WARM?

OPTION 1: SUE the engineer that designed the cooling system

OPTION 2: ADAPT (psychological, behavioral, physiological)

Ad 2, based on unpublished results from a field study, this is what people do when warm:

1. Open a window
2. Take of jackets, sweaters etc
3. Close blinds, curtains etc
4. Drink something cold
5. Start (table) fan
6. Move to other space where it is cooler
7. Just accept that it is warm (internal coping)
8. ....

Adaptive behavioural actions acc. to Boerstra et al (2013)

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<td>Total</td>
<td>133</td>
<td>113%</td>
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Adaptive behavioural actions acc. to Feriadi & Wong (2004)

Window opening probability in offices as a function of indoor and outdoor temperature (Haldi & Robinson, 2008)
Association between proportion of dwellings with open windows and perceived indoor air quality and outside noise situation (Andersen et al, 2009)

PROOVEN BENEFITS OF OPERABLE WINDOWS

1. Free (ventilative) cooling
2. Fast control over temperature and indoor air quality
3. Generally better thermal and olfactory comfort
4. Lower incidence of Sick Building symptoms
5. Higher productivity
6. ..... 

(specific effects in a specific building depend upon floor plan, amount of colleagues one shares the room with, design of the operable window, window interface etc.)
Access to Operable Windows (OW) and percentage of respondents ‘often experiencing air as stuffy, smelly or stale’ (Boerstra et al, 2011)

Access to Operable Windows (OW) and percentage of respondents with Personal Symptom Index > 2 (scale 0-5) (Boerstra et al, 2011)
Perceived control over ventilation and incidence of SBS symptoms (Boerstra et al, 2013)

\[ \rho = -0.36 \]
2-tailed \( p < 0.01 \)

\( n = 64 \) buildings

Building Symptom Index (BSI)

The impact of perceived control over ventilation on self reported productivity (based on: Raw, 1990)

Self reported effect on productivity

1. = No control
4. = Some control
7. = Full control
Conclusion:

- Operable windows are MORE than just tools to optimize the ventilative cooling performance of a building

- Offering (adequate) personal control over ventilation results in more comfortable and more healthy building occupants and enhanced productivity

For more information, contact:
Atze Boerstra, ab-bba@binnenmilieu.nl
Ventilative Cooling Potential of Outdoor Air
– Now and in the future

Per Heiselberg
Aalborg University

Mean Temp. Difference between Max. and Min. in July

Meteonorm Data
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:
  \[ T_b = 24.5^\circ C \pm 2.5^\circ C \]
- Ventilation period:
  7 pm – 7 am
- Minimum temperature difference:
  \[ \Delta T_{crit} = 3K \]

\[ \text{CCP} (K \ h) = \sum_{t=1}^{T_{daily}} \left( m_T \left( T_{b,d} - T_{e,d} \right) \right) \]

\[ m = \begin{cases} 
1 & \text{if } T_b - T_e \geq \Delta T_{crit} \\
0 & \text{if } T_b - T_e < \Delta T_{crit} 
\end{cases} \]
Practical significance of CCP

Example:

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

Climatic cooling potential:

$$CCP = \frac{q \cdot t_{\text{occ}}}{H \cdot ACR \cdot \eta \cdot c_p} = 80 Kh$$

Necessary CCP

As a function of heat load and ventilation air flow rate

![Graph showing CCP as a function of heat load and ventilation air flow rate with different lines for various flow rates.](attachment:image.png)
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: less than 80 Kh

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

Cumulative frequency distribution of CCP

Climatic Cooling Potential for Maritime Climate

- CCS = 80 Kh ~ 50 W/m²
Cumulative distribution

Nights per year

CCP per night (K h)

Climatic Cooling Potential for Continental Climate

- Moscow
- Zurich SMA
- Potsdam
- Dijon
- Warsaw
- Belgrade
- Prague
- Madrid Barajas
- Vienna Hohe Warte
- Ankara

Climatic cooling potential per nights, weeks and months for Zurich SMA in 2003 (ANETZ data)

Stochastic weather patterns

- High variation of CCP within few nights: ~ 100 - 200 K h
- Variation of weekly mean values: ~ 50 – 100 K h
- Heat waves with high daily cooling demand and low cooling potential during nights

Example:
- First week of August ~ 0 K h
- August mean ~ 50 K h
Adaptive comfort approach
Operative temperature as function of external running mean, EN 15251

Impact in cool climates
Denmark
Impact in warmer climate, Beijing, Shenzhen

Increase in cooling degree days

Source:
M Christenson, H Manz, D Gyalistras, 2005
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.
Summary

• Application of the CCP approach is a fast method to evaluate the night cooling potential considering both outdoor climate, building heat load and ventilation flow rate
• Application of the adaptive comfort approach increases the night cooling potential in warm periods
• According to predicted scenarios for climate change the night cooling potential will be reduced critically in the summer periods, but even in warm European climate as Greece a potential will be present more than 50% of the year.
Joerie Alderweireldt (3E)

Energy efficient design of a passive school using thermal dynamic simulations

DE VERDIEPING

De restauratie en renovatie van het ophaalmechanisme
Inclusief de bouw van een passieve school van +/- 6000 m²

AAQ

Passive-House Symposium
25 oktober 2013
De restauratie en renovatie van het voormalig mijnterrein te Zolder
In het kader van Volwassenenonderwijs
Joerie Alderweireldt (3E)

‘Ophaalmachinegebouw’ functioning as school area

‘Ophaalmachinegebouw’ functioning as reception or exhibition area

Passive school (new building project)

3D-Image of the design anno 2011
Cloud of different room types in the school:

- Offices for administration
- Fotostudio classroom
- Tasting classroom
- Refrigerator rooms
- Circulation areas
- Technical rooms
- Storage rooms
- Pc classrooms
- Cooking classrooms
- Make-up class room
- Dress rooms
- Sanitary
- Language classrooms
- Garden design classrooms
First decisions for the architectural and energy concept

- Provide active cooling in all classrooms as passive measures are kept limited
- Inplantation of the building north of the existing building
- Limit the weight of the structure by working with low weight elements
- Window-to-wall-ratio of 25% is preferred by the architects
- Follow standard passive rules for the reference building

→ Following these decisions several technical-economical optimisations are analysed by the use of dynamic simulations
Optimisation 1: Replacement of triple glazed windows by double glazed windows

<table>
<thead>
<tr>
<th>Primaire energievraag (MWhp/jaar)</th>
<th>$U_{\text{raam}} = 0.65$ W/m²K</th>
<th>$U_{\text{raam}} = 1.00$ W/m²K</th>
<th>$U_{\text{raam}} = 1.30$ W/m²K</th>
</tr>
</thead>
<tbody>
<tr>
<td>560.3</td>
<td>567.4</td>
<td>571.5</td>
<td></td>
</tr>
<tr>
<td>Primaire energievraag (kWhp/m².jaar)</td>
<td>995</td>
<td>100.8</td>
<td>101.5</td>
</tr>
<tr>
<td>Energiekost (€/jaar)</td>
<td>38 099</td>
<td>38 580</td>
<td>38 862</td>
</tr>
<tr>
<td>Energiekost (€/m².jaar)</td>
<td>6.8</td>
<td>6.9</td>
<td>6.9</td>
</tr>
<tr>
<td>Meerinvestering (€)</td>
<td>-</td>
<td>-72 618</td>
<td>-94 962</td>
</tr>
</tbody>
</table>
Optimisation 2: Increase window-to-wall ratio

<table>
<thead>
<tr>
<th>Referentie/Verhoogd glaspercentage</th>
<th>Referentie</th>
<th>Verhoogd glaspercentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primaire energievraag (MWhp/jaar)</td>
<td>560.3</td>
<td>563.7</td>
</tr>
<tr>
<td>Primaire energievraag (kWhp/m²jaar)</td>
<td>99.5</td>
<td>100.1</td>
</tr>
<tr>
<td>Energiekost (€/jaar)</td>
<td>38 099</td>
<td>38 333</td>
</tr>
<tr>
<td>Energiekost (€/m² jaar)</td>
<td>6.8</td>
<td>6.8</td>
</tr>
<tr>
<td>Meerinvestering (€)</td>
<td>-</td>
<td>244 388</td>
</tr>
</tbody>
</table>
Optimisation 3: Amount and type of heat recovery units

1 air handling unit for one floor

1 air handling unit for every class room

2 air handling units for every floor
Optimisation 4 : Control of the ventilation systems

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
<th>Scenario 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAV</td>
<td>Neen</td>
<td>Neen</td>
<td>Ja</td>
<td>Ja</td>
</tr>
<tr>
<td>CO2-gestuurd</td>
<td>Neen</td>
<td>Neen</td>
<td>Ja</td>
<td>Ja</td>
</tr>
<tr>
<td>Gepasteerd</td>
<td>Neen</td>
<td>Ja</td>
<td>Neen</td>
<td>Ja</td>
</tr>
<tr>
<td>Bezettingsgraad</td>
<td>33%</td>
<td>33%</td>
<td>33%</td>
<td>33%</td>
</tr>
<tr>
<td>Ventilatieveolume</td>
<td>100%</td>
<td>50%</td>
<td>45%</td>
<td>44%</td>
</tr>
</tbody>
</table>

Optimisation 4 : Control of the ventilation systems

![Graph showing energy consumption for different scenarios](image-url)
Optimisation 4 : Control of the ventilation systems

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
<th>Scenario 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaarlijks energieverbruik (kWh/65)</td>
<td>33</td>
<td>20</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>Investering (€)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>82</td>
</tr>
<tr>
<td>Terugverdientijd (aar)</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
<th>Scenario 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaarlijks energieverbruik (kWh/65)</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>Investering (€)</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>82</td>
</tr>
<tr>
<td>Terugverdientijd (aar)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>33</td>
</tr>
</tbody>
</table>

Moeilijk wanneer lessen uithopen
Grote afhankelijkheid van groeperen
Hoge flexibiliteit
Optimisation 5: Production, distribution and emission systems

[Diagrams and graphs related to the topic are shown here.]

Optimisation 5: Production, distribution and emission systems

[More diagrams and graphs related to the topic are shown here.]
Optimisation 5: Production, distribution and emission systems

Analysis of emission systems

- Floor heating → Too slow system
- Radiating ceilings → Condensation can occur
- Hygienic ventilation → Too low temperature required
- Ventiloconvectors → No heat/cold recovery possible
- Ceiling units → Heat recovery possible
Optimisation 5: Production, distribution and emission systems

<table>
<thead>
<tr>
<th></th>
<th>WP met WTW</th>
<th>VRV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissie</td>
<td>Warmte en koude</td>
<td>Warmte en koude</td>
</tr>
<tr>
<td>Koelmiddel</td>
<td>In klaslokaal en buiten</td>
<td>In klas, leidingnetwerk en in buiten</td>
</tr>
<tr>
<td>Flexibiliteit</td>
<td>Hoog door water in leidingnetwerk</td>
<td>Laag door koelmiddel in leidingnetwerk</td>
</tr>
<tr>
<td>COP verwarming</td>
<td>3.9</td>
<td>3.5</td>
</tr>
<tr>
<td>COP koeling</td>
<td>5.0</td>
<td>5.5</td>
</tr>
<tr>
<td>COP warmtèrecoveratie</td>
<td>Tussen bovenstaande COP's en +/-9</td>
<td>Tussen bovenstaande COP's en +/-9</td>
</tr>
<tr>
<td>Potentieel ander recupereatie</td>
<td>Zonder sanitair warm water en zonder koelcellen: 7.8%</td>
<td>Zonder sanitair warm water en met koelcellen: 10.3% Met sanitair warm water en met koelcellen: 11.0%</td>
</tr>
<tr>
<td>Acoustiek</td>
<td>Warmtepomp in klas dus extra geluid</td>
<td>Geen warmtepomp in klas dus minder geluid</td>
</tr>
</tbody>
</table>

COP = \frac{USEFULL ENERGY}{ELECTRICITY}
Optimisation 6 : Night cooling versus active night cooling

Temperature difference of 8°C is required before night cooling is more efficient than active cooling.

Temperature difference of 4°C is sufficient if night cooling is reduced below 75% of its total capacity.

Optimisation 7 : Integration of photovoltaics on roof top

The integration of photovoltaic panels allows the realisation of a Nearly Zero Energy Building.
A ventilative cooling system in a School Building, Imola, Italy

Prof. Arch. Mario GROSSO,
Associate Professor of Architectural Technology
Energy-Environmental Consultant
mario.grosso@polito.it

Two main blocks linked by a central atrium
East-West longitudinal axis

librarian, cafeteria, offices and laboratories
entrance
central atrium
classrooms

Brussels, March 19-20, 2013
Estimate of energy needs

PRELIMINARY - PHASE 1

- Focussed simulations of energy strategies and comparison to a benchmark configuration
- Calculation of annual energy needs using simplified tools

Data related to the South-West block for an occupation period from September to July

Priority to application of passive cooling systems

 Priority to application of passive cooling systems

SOLUTION D

to optimise yearly energy balance

TECHNOLOGICAL OPTIONS FOR INDOOR CLIMATE CONTROL SYSTEMS

Brussels, March 19-20, 2013

mario.grosso@polito.it
Ventilation system

Hybrid system (controlled natural/mechanical system)

Controlled natural ventilation (CNV): motorised sensor-driven openings related to IAQ and thermal comfort

Cafeteria and discontinuous-use spaces:
- Winter - mechanical
- Summer – mechanical + CNV

Atrium:
- Winter - mechanical
- Summer – mechanical

Classrooms:
- Winter - mechanical
- Summer – mech. (during occupation) + CNV

Cooling systems

Air-to-Earth Heat Exchangers

Mechanical ventilation

Vacuum Solar Collectors on roof

Radiant floor

AHU

Absorption Chiller

Ventilative Cooling

Brussels, March 19-20, 2013
mario.grosso@polito.it
Ventilative cooling

**Natural stack-driven airflow**
through the south-facing class rooms and the atrium

---

**Ventilated clerestory on the atrium glazed roof**

---

**South glazed wall with hopper window openings**

---

**Internal view of the atrium**
2-D CFD simulation in a classroom with ceiling appliances:
air temperature zones after 1 hour with a gradient of 10 °C

Brussels, March 19-20, 2013
mario.grosso@polito.it

2-D CFD simulation in a classroom with ceiling appliances:
air velocity zones after 1 hour with a gradient of 10 °C

Brussels, March 19-20, 2013
mario.grosso@polito.it
2-D CFD simulation in a classroom with ceiling appliances:
air velocity contour lines after 1 hour

2-D CFD simulation in a classroom with ceiling appliances:
radiation heat flux after 1 h as a function of distance from inlet opening
2-D CFD simulation in a classroom with ceiling appliances:
*total surface heat flux after 1 h as a function of distance from inlet opening*

![Graph showing total surface heat flux as a function of position](image)

2D CFD simulation of flows between classrooms at the different storeys and the atrium: *temperature zones for a gradient of 10 °C between inside (atrium) and outside*

![Temperature map](image)
Unbalanced flows amid the three storeys

Balanced flows amid the three storeys

Brussels, March 19-20, 2013
mario.grosso@polito.it
Night cooling of thermal mass

3D CFD simulation of flow between a classroom and the atrium: temperature zones for a gradient of 10 °C between inside (atrium) and outside

after 5 minutes

Brussels, March 19-20, 2013

mario.grosso@polito.it

3-D CFD simulations: airflow rates, enthalpic flow and global thermal exchange coefficient in the time interval 0÷800 s

3-D airflow rate, 2-D airflow rate, 3-D enthalpic flow

global thermal exchange coefficient for floor, ceiling, walls

Brussels, March 19-20, 2013

mario.grosso@polito.it
**3-D CFD simulations**: airflow rate and enthalpic flow in the time interval 500÷6500 s (linear trend)

![Graph showing airflow rate and enthalpic flow over time](image)

**Trend line equation**: \( y = (-1 \times 10^{-5})t \)

- **Portate aria [Kg/(s)]**
- **Flusso entalpico [kW]**
- **Tempo [s]**

**Thermal dynamic simulations using TRNSYS**: annual indoor air temperature profile in the south-facing classrooms with ventilative cooling

![Graph showing temperature profile over time](image)

**Temperature Profiles**:
- \( T_{est} \)
- \( T_{aula_1} \)
- \( T_{aula_2} \)
- \( T_{aula_3} \)

**Time Period**: 01/01/01 to 31/12/01

**Hours of the Day**: 00:00 to 23:59

---

**Brussels, March 19-20, 2013**

**mario.grosso@polito.it**
## Contribution to energy saving of RES & RUE technologies (prediction)

<table>
<thead>
<tr>
<th>Technology</th>
<th>Annual energy intensity [kWh/m²-gfa]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>heating</td>
</tr>
<tr>
<td>Reference configuration (a)</td>
<td>79.5</td>
</tr>
<tr>
<td>Reference configuration (b)</td>
<td>141.0</td>
</tr>
<tr>
<td>High insulation (opaque components)</td>
<td>72.7</td>
</tr>
<tr>
<td>High insulation (glazed components)</td>
<td>66.2</td>
</tr>
<tr>
<td>Time optimisation of mechanical ventilation (OMV)</td>
<td>64.9</td>
</tr>
<tr>
<td>Shading devices (fixed)</td>
<td>84.0</td>
</tr>
<tr>
<td>Shading devices (fixed and movable)</td>
<td>86.8</td>
</tr>
<tr>
<td>Total of envelope technologies (ET)</td>
<td>67.0</td>
</tr>
<tr>
<td>ET + OMV + heat recovery</td>
<td>44.3</td>
</tr>
<tr>
<td>ET+ OMV + Solarwall®</td>
<td>42.5</td>
</tr>
<tr>
<td>ET+ OMV + VC</td>
<td>54.1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>37.4</td>
</tr>
</tbody>
</table>

**ET+ OMV + heat recovery**
- **U**<sub>value</sub> (walls) = 0.45 W/m²K
- **U**<sub>value</sub> (glazing) = 2.65 W/m²K

**Mech. Vent. for 12 h/day**
- **U**<sub>value</sub> (walls) = 0.30 W/m²K
- **U**<sub>value</sub> (glazing) = 1.57 W/m²K

**As configuration (a) with Mech. Vent. for 24 h/day**

**Reference configuration (b)**
- High insulation (glazed components)
- ET+ OMV + VC

**Total**
- 179500 kWh/year
passive cooling with natural ventilation rate, a case study

Pier Nicola Currà
PASSIVE ENERGY STRATEGIES

FUNCTIONING
VENTILATION GRILLE WITH CONTROLLABLE MOTORIZED LOUVRE

U-value = 1.1 W/m\(^2\)K

Air leakage = 9.7 m\(^3\)/hour/m\(^2\) at 50 Pa pressure

DYNAMIC SIMULATION RESULTS

with IES-VEpro
BIBLIOGRAPHY

- Currà, P. N., Fabbri, K. 2012. Raffrescamento passivo con ventilazione naturale, un caso studio. Ponte, DEI Tipografia del genio civile, n° 11/12
- UNI 10339 – Impianti aeraulici a fini di benessere. Generalità, classificazione e requisiti. Regole per la richiesta d’offerta, l’offerta, l’ordine e la fornitura
- UNI EN 13779 - Ventilazione degli edifici non residenziali. Requisiti di prestazione per i sistemi di ventilazione e di climatizzazione
- UNI EN 15242 – Ventilazione degli edifici. Metodi di calcolo per la determinazione delle portate d’aria negli edifici, comprese le infiltrazioni
EXAMPLES OF NATURALLY COOLED BUILDINGS

100% ECONOMY IN CENTRAL EUROPE CLIMATE
50% ECONOMY IN MEDITERRANEAN CLIMATE

Flourentzos Flourentzou

MARS 2013

Flourentzos Flourentzou

Estia SA
Parc Scientifique EPFL
1015 Lausanne, Switzerland

*Corresponding author: flou@estia.ch

100% glazing in the East en in the South facades, with no visible opening
2

100% glazing in the East and in the South with no visible opening.

no visible duct, no visible ventilation grid.
Because

... la vision globale d'un projet est pour nous la plus importante et chaque cas est différent! Ce que les tableaux de calculs ne peuvent transcrire. L'architecture et les qualités des espaces, les atmosphères et les sensations personnelles n'entrent pas compte, car les critères sont subjectifs, ce qui prouve qu'il n'y a pas de recettes miracles et que l'on ne peut pas tout réduire par des calculs et des labels...

... nous essayons toujours de trouver des solutions les moins techniques possibles pour nos bâtiments. Nous trouvons cela beaucoup plus écologique...

patricia capua mann
graeme mann & patricia capua mann
architectes epfl fas sia
ch de monribeau 2
1005 lausanne

But how?
flash ventilation when CO2>800 ppm / night ventilation during summer

local heat discharge when sun is striking the facade
the eco-structure / dynamic solar shading / ventilation duct / acoustic absorber

the ventilation inlet grid / storage room door
building physics is part of personal sensations, atmospheres and space quality

\[ Q_1 = 2 \times 12'237 \text{ m}^3/\text{h at } \Delta T = 6^\circ \text{ C, 50\% ach in 9 minutes} \]
overheating: night ventilation cooling strategy - 55 h / no strategy 1099 h

overheating: night ventilation cooling strategy - 92 h / no strategy 1112 h
stratification strategy: cool the occupied area, avoid ceiling heat trap

Air temperature during a hot summer day

- Zone 4
- External
- Zone 3
- Zone 2
- Zone 1

Centre médical des Grangettes SA
Chemin des Grangettes
1224 Chêne-Bougeries

Architecte: Eric Durant
Physique du bâtiment: Esta SA
Projet: Parc scientifique EPFL
Réalisation: 2003
Adresse: Route de Chêne 110
Coût de construction: Fr. 3'100'000.-
one of the first eco-buildings labeled Minergie in Geneva

solar shading, color selection, external environment design
solar protection and exterior colors

T_{air} = 30^\circ C
30^\circ C
34^\circ C
29^\circ C

3 storey staircase acting like a chimney
thermal mass for cooling storage and natural light to reduce internal heat gains

architectural elements act like air ducts, inlet and exhaust devices
during the hotest days of jun internal température < 27/25° C

- Passive techniques
  - Thermal insulation
  - Solar shading
  - Window dimensionning
  - Neutral level control
  - Thermal mass
  - Night cooling ventilation
  - Free slab geo-cooling
  - Exterior cool landscape
• 10 passive technics

- 10 cm thermal insulation, double glazing low e, no thermal bridges
- Almost perfect solar shading
- High apparent thermal mass
- Optimal dimensioning of openings for passive lighting, heating, solar protection
- 70% of natural light autonomy and high efficiency artificial lighting
- 30% of surface area is outside of the thermal envelope (stairscases, toilets)
- Opening design for optimal night ventilation (summer passive cooling)
- Natural ventilation
- Use of ceiling fans
- 100% Solar hot water
• almost perfect solar shading

Permanent solar protection and glazing g-39%, TL-70%

• effect of solar protection

Solar shading and reduced g glazing value saves 37% of energy
• apparent thermal mass

➔ Unhydrid screed for the floor, apparent cladded concrete slab.

➔ Without thermal mass temperature rises to 37° C instead of 30
• Opening dimensioning

⇒ 0% east and west, 1X140X300 south, 2X140X300 north.

• Inside – outside in the Mediterranean climate

⇒ 682 m² (75%) within the thermal envelope out of a total of 900 m²
• night ventilation design

→ safe, protected, flexible openings, dissociation of air from light path

• natural ventilation design

<table>
<thead>
<tr>
<th>Opening possibilities</th>
<th>m³/h</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>40X300</td>
<td>610</td>
<td>100</td>
</tr>
<tr>
<td>40X300 grille</td>
<td>366</td>
<td>60%</td>
</tr>
<tr>
<td>40X122</td>
<td>158</td>
<td>26%</td>
</tr>
<tr>
<td>40X122.+40X122</td>
<td>499</td>
<td>82%</td>
</tr>
<tr>
<td>15X122.&amp;.la.fransaise</td>
<td>59</td>
<td>10%</td>
</tr>
<tr>
<td>7X122</td>
<td>28</td>
<td>5%</td>
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<tr>
<td>15X122+15X122.&amp;.la.Fr</td>
<td>187</td>
<td>31%</td>
</tr>
<tr>
<td>15.cm.&amp;.l'italienne.(6°)</td>
<td>49</td>
<td>8%</td>
</tr>
<tr>
<td>10.cm.&amp;.l'italienne.(4°)</td>
<td>30</td>
<td>5%</td>
</tr>
</tbody>
</table>

→ A window offering 30 to 366 m³/h stack effect
single sided airflow at ∆T 5° C
Night cooling may reduce cooling need of an already optimised building by 53%, (17 kWh/m²y instead of 36)

A light building has only 25% reduction potential

15% rise of cooling load per °C of set temperature decrease

Ceiling fans may save 30% of cooling energy consumption
• Monitoring: outside 45° C – inside 27-30° C

• Conclusions

- After solar protection and reduction of internal loads, night ventilative cooling is the only passive technique offering significant energy savings for cooling:
  - zero kWh in the central Europe climate
  - 25 - 50% reduction for the hot Mediterranean climates
- Passive cooling is not just operable windows
- Passive cooling design needs simple simulation tools (available engineering fees 5 - 10 000 €)
- There is a need of accounting the energy savings in the national energy regulations. It is the only way to make this technique able to penetrate the market, because there is nothing to sell other than engineering fees.
Ventilative Cooling:
the holistic approach on buildings and systems developing the EPBD standards under Mandate 480

Jaap Hogeling
Manager international projects and standards
Chair CEN TC 371 Program Committee on EPBD
Fellow ASHRAE and REHVA
j.hogeling@isso.nl
ISSO; Kruisplein 25; Rotterdam The Netherlands

International Workshop
Ventilative Cooling Needs, Challenges and Solution Examples

Definition of “Ventilative” cooling?

• Passive cooling: definition? “Natural and free ventilation for passive cooling “: quoted from OA

• Ventilative cooling:
  – Cooling by ventilation air from outside without any mechanical pre-cooling (natural or by a central or local system( allowing filtering and outside noise reduction))
  – Cooling by air entering a room by natural ventilation
**Extended Ventilative Cooling definition needed?**

- Cooling by ventilation air entering a room by a mechanical ventilation device or system without mechanical-cooling but allowing adiabatic / evaporative cooling (with or without HXS) or other “free” not primary energy using cooling principles (apart from the fan energy)
- Cooling by air entering a room trough a non conditioned space (ground HXG, cellar( building mass))?
- etc?

---

**Quotes in the Over-Arching standard**

- “Natural and free ventilation for passive cooling “: to be indicated as *Ventilative cooling*
- More focus on “passive” cooling techniques and for the assessment of the energy performance of cooling systems: “passive” means using building mass and additional techniques as referred to as “extended ventilative cooling” ?
Current existing EPBD standards relevant to “ventilative cooling”

EN 13791 Performance requirements for temperature calculation procedure without mechanical cooling (Detailed) and EN 13792 (Simplified)

EN 15255 Sensible room cooling load calculation - General criteria and validation procedures

EN 15265 Calculation of energy needs for space heating and cooling using dynamic methods – General criteria and validation procedures

EN 15242 Calculation methods for the determination of air flow rates in buildings including infiltration

EN 15241 Calculation methods for energy losses due to ventilation and infiltration

EN 15251 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics
These current standards are already applicable for ventilative cooling

- However this terminology has not been used in these standards
- The next presentations will, as I expect illustrate amongst others the use of these standards.

EN15242 Calculation methods for the determination of air flow rates in buildings including infiltration

- Describes method to calculate the ventilation air flow rates for buildings to be used for applications such as energy calculations, heat and cooling load calculation, summer comfort and indoor air quality evaluation. Applies to mechanically ventilated buildings; passive ducts; hybrid systems switching between mechanical and natural modes; window opening by manual operation for airing or summer comfort issues.
EN15241 Calculation methods for energy losses due to ventilation and infiltration

• Describes method to calculate the energy impact of ventilation systems (including airing) in buildings to be used for applications such as energy calculations, heat and cooling load calculation. Its purpose is to define how to calculate the characteristics (temperature, humidity) of the air entering the building, and the corresponding energy required for its treatment and the auxiliary electrical energy required.

EN15243 Calculation of room temperatures and of load and energy for buildings with room conditioning systems

• Defines procedures to calculate temperatures, sensible loads and energy demands for rooms; latent room cooling and heating load, the building heating, cooling, humidification and dehumidification loads and the system heating, cooling, humidification and dehumidification loads. Gives general hourly calculation method, and simplified methods.
M480: EPBD Recast Revision of EN15241
Calculation methods for energy losses due to
ventilation and infiltration

- Consider rearrangement of content versus EN 15242
- Consideration of ISO work
- Add a TR (split normative text and informative explanations)
- Formatting according to new rules
- Provide EXCEL sheet, make the standard “software proof”
- Should include:
  - Passive cooling
    - Improved fan energy calculation, taking into consideration control strategies according to TC 247 and fan product standards / data
  - Improved calculation of different types of heat recovery devices (air-to-air HX, rotary and pumped circuit), delivering qv-dependent efficiency, auxiliary energy depending on control
  - Improved humidification calculation for different humidifier types, including auxiliary energy (see also info in EN 15243)
  - Include the effect of controls and building/system automation

M480: EPBD Recast Revision of EN15242 Calculation methods for the determination of air flow rates in buildings including infiltration

- Consider rearrangement of content EN 15242 versus the EN 15241
- Add a TR (split normative text and informative explanations)
- Consideration of ISO work
- Formatting according to new rules
- Provide EXCEL sheet, to make the standard “software proof” and check the in-/out-put connections with the connected EPBD standards.
- Effect of testing on declared value on airtightness??
M480: EPBD Recast Revision of EN15243 Calculation of room temperatures and of load and energy for buildings with room conditioning systems

- Consider rearrangement of the standard: splitting in separate parts (design and dimensioning, load calculation, energy calculation, possibly split to emission, distribution, generation...) - Making informative annexes normative text where appropriate. Integrate with the heating part as well.

- Consideration of coordination with ISO

- Add a TR (split normative text and informative explanations)

- Formatting according to new rules

- Provide EXCEL sheet to make the standard “software proof”

- Coordination of content with EN 15241

- Should include: Calculation of cooling generation, taking into account information from informative annexes, national standards, product standards and data and control

- Include the effect of controls and building/system automation

---

The revision of these EPBD standards is possible: CEN received Mandate 480

---

Mandate to CEN, CENELEC and ETSI for the elaboration and adoption of standards for a methodology calculating the integrated energy performance of buildings and promoting the energy efficiency of buildings, in accordance with the terms set in the recast of the Directive on the energy performance of buildings (2010/31/EU)
Current set of CEN EPBD (Energy Performance Buildings Directive) standards

- Presented as a “pyramid” structure

Most are used in many EU Member States, as required by national legislation based on EPBD implementation.
Main issues for the further development the current CEN EPBD standards: CEN EPBD standards need to be improved to be more fit for code intended use (more fit for regulators):

**Main Issues to be tackled**

- More consistent and in line with requirements to be specified by the Member States legislators
- More modular structure and unambiguous
- Clear split common method versus national choices e.g.: Climate data, primary energy factors, and other legal requirements are typical national/regional issues.
- Best practices
- More Focus on retrofit technics seems necessary
- Software proof: all calculation descriptions will at least be checked by available spreadsheet calculations
- Other...

**prEN15603 Energy performance of buildings — Overarching standard**

official public enquiry starts March 2013

- Common terms, definitions and symbols;
- Specifies a general framework for the assessment of overall energy use of a building,
- Calculation of energy ratings in terms of primary energy or other energy related metrics.
- The EP assessment is not limited to the building and takes the wider environmental impact of the energy supply chain into account.
prEN15603 Overarching standard

• Calculated and measured energy rating
  – Procedure, set of equations per energy use,
  – Building energy needs
  – Technical building systems losses
  – Contribution Renewable energy
• Issues like:
  • Climatic data, indoor environmental requirements
  • Time-steps (monthly, hourly, how to convert?…)
  • Operating conditions
prEN15603 Overarching standard

• Framework of assessment of EP of buildings
• Assessment of Energy Performance:
  – Energy uses
  – Assessment boundaries/ partitioning of building
• Weighted energy ratings
  – Type of weighting, factors, primary energy factor, CO2 rating etc.
• types of factors and coefficients

Conventions for the share of renewables:
For thermal solar systems the assessment boundary is option 3
(panel output)

Incident solar radiation is not part of the building balance because the energy supply cannot be controlled by the generation device.
A complex OA structure is needed Because:....
this is what we are calculating ....

The OAS provides an Overarching structure as base for:

• procedures for complex buildings
• simplified input procedures for simple small existing building cases
• Procedures for high performance (NZEB) buildings
Small existing building?

You just calculate it as one single piece …as you would eat a small pastry in one single bite..

= no partitioning required

Big building, arcade + office + residential?

… but what if there is a big cake on the table? You have to eat it slice by slice … → Partitioning required for complex buildings!
High performance or NZE-Building

The amount of energy involved is so small that any interaction may be relevant. Example domestic hot water losses and cooling...

Also localization of gains is relevant. Will solar gains of the big window in the living facing south effectively heat upstairs north rooms? Thermal zones or even room by room calculation may be required...

NZEB: Nearly Zero Energy Buildings

• Given EPBD art. 2 and 9 there is a need for definitions

• For CEN: first define and agree on all elements needed to describe NZE in a transparent and unambiguous way

• CEN published in the prEN15603 the definitions and current CEN-default values for the various elements to be included in the definition of the Energy Performance of a building, needed as basis for a NZEB declaration
The Energy balance Step by Step

• Only if the requirement of each step is reached a building can be qualified as NZEB
• To prevent underperformance on:
  – Indoor environment
  – Thermal building performance
  – Technical system performance
  – and inadequate energy balance procedures

Art 2, definition 2 EPBD Recast:

• ‘nearly zero-energy building’ means a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby;
This EPBD NZEB definition:

• distinguishes between energy from renewable sources produced “on site” or “nearby”. The following perimeters are linked to the definition of the assessment boundary:
  – the conditioned space of the assessed object;
  – the building site (“on site”);
  – nearby;
  – distant.

This EPBD NZEB definition:

• Localisation of the technical building systems: either “on site” of “nearby” impacts the energy balance.
• Primary energy conversion factors are to be defined for “onsite” and “nearby”.
• More different buildings can be “on site” (e.g. school building, office building located on the same parcel of land).
• Rules in prEN 15603 to take into account the different situations in the energy assessment of each building
Assessment boundary and perimeters

Fundamental definitions

Steps to determine boundary and perimeters

1) Determine conditioned space (CEN) building services; start of EP calculation; useful area (performance indicator)

2) Place the assessment boundary (CEN) EP balance of energy flows delivered - exported (e.g. renewables)
   Inside: all losses (e.g. boiler), unweight;
   outside: PE factor; weighted

3) Define on site (CEN) only on site production from on site renewable sources and CHP thermally
   driven can be re-exported

4) Define nearby (CEN) Plant designed depending on the needs of assesses, building, connected by a specific
   equipment, specific PE factor

5) Define distant (CEN) Plant designed depending on the available source and not on the needs of the
   connected buildings, specific PE factor

The assessment procedure prEN15603 chapter 7

Assessment steps according prEN15603

1) Identify the **object of the energy assessment**
   (several buildings, whole building, building unit ?)

2) Identify the **building categories** (e.g. residential, office building) and the related **building services** to be
   included in the energy assessment

3) Identify the **assessment boundary and related perimeters**
   (Conditioned space, assessment boundary, on site, nearby, distant)

4) Calculate the **primary energy balance**

5) Calculate additional indicators: Share of renewables (RER)

6) Calculate additional indicators: Performance technical building systems

Applications, objectives

- Minimum requirements
- Energy certificates
- Occupancy patterns
- (e.g. internal gains, opening hours)
- Performance scale
- Building needs
- Performance indicator (m2)
- Energy balance (delivered, exported)
- Primary energy factors
  - Energy performance indicator
  - Share of renewables
  - Performance indicator technical building systems
CEN structure and options prEN 15603

General CEN Structure
Common structure for defining
- conventions
- boundaries
- performance indicators (EP, RER)

Options (national annexes)
- policy
- Climate
- Building Tradition

Member State 1
Member State 2

Flexibility
- Local differences
What is the best practice?

A common backbone to
- define (Member States)
- understand (Building professionals)
  energy performance indicators

CEN default option
- Harmonization
- Reproducibility
- Transparency

Accompanying informative Technical Report to the prEN15603

- The complexity of the building energy performance calculation requires guidance and good documentation and justification of the procedures.
- Informative text is required but it is separated from actual procedures in the OAS to avoid confusion and a unpractical heavy standard. (This is the case for all standards in the EPB set)
- Parallel to the prEN15603 an accompanying Technical Report is prepared: first draft available March-2013
- The current TR is a mixture of a guidance and reference document.
Scope TR

- Information to support the correct understanding, use and implementation of prEN15603:
  - Explanation on the procedures and background information and justification of the choices
  - Reporting on validation of calculation procedures given in the standard.
  - Explanation for the user and for national standards writers involved with implementation of the set of EPB standards, including detailed examples.
- Proposals for specific revisions or additions of the procedures given in current prEN 15603. When commenting during Public Enquiry of the prEN 15603, these proposals should be taken into account.
CEN TS : EPB - Basic Principles
for the developers of the set of EPB standards

- TS with basic principles that will provide guidance on the required quality, accuracy, usability and consistency of each standard and the rationalisation of different options given in the standards;
- providing a balance between the accuracy and level of detail, on one hand, and the simplicity and availability of input data, on the other. Based on the evaluation of assessed requirements for application.
- The TS basic principles is the basis for the TS detailed technical rules and the prEN15603 the over-arching standard
CEN TS: EPB *Detailed Technical Rules* for the developers of the set of EPB standards

- The Technical Specification with detailed technical rules, based on the basic principles, that will provide guidance for the over-arching standard (phase 1) and for each of the set of EPB standards under phase 2
- This TS contains detailed rules to be followed developing or reediting EPB standards.

Status and availability of the four publications:

- The prEN15603 will be officially released by CEN during March 2013.
- The two TS’s and the prEN15603 are for this moment (today) not yet officially published by CEN, but distributed as CENTC371-committee documents the TR will follow next week (the TR is needed to comment the prEN15603)
Phase 2 of M480 project

- Project Phase 2 will focus on the improvement and expansion of the current set of CEN-EPBD standards on the basis of the findings and set of requirements of Project Phase 1
- The actual revision of the standards will be carried out under the responsibility of the relevant CEN/TC’s on the basis of a clear set of common principles and rules and priorities (the OAS+TR and two TS’s) and guided by the over-arching standard.

Phase 2 includes the following issues

- General checking on the appropriateness of the current set of standard in particular for existing building given the extension of scope in the recast;
- More focus on models and input data which are suited to existing buildings;
- More focus on passive cooling techniques and for the assessment of the energy performance of cooling systems;
Phase 2 includes the following issues

• Integration of the inspection standards on systems for heating, cooling and ventilation;

• Where needed, expansion of the procedures to NZE-buildings by way of renewable sources of energy, and procedures for energy producing buildings, with consideration given to alternative systems;

• Integrated approach for calculating minimum performance requirements for technical building systems and building envelope.

Planning Phase 2

• We hope to start around summer 2013

• It is expected to reach and possibly finish the enquiry stage of the majority of EPB-standards before the end of 2014

• Keep in mind that many of the standards will not fundamentally change
Central coordination within CEN by small team of Task Leaders/experts in CEN TC 371-CAP

- CEN TC 371 organises this central coordination team in cooperation with the other relevant CEN TC’s
- Regular report to the 5 TC’s and TC371
- Project Teams on different clusters, related to the five CEN TC’s:
  - TC 89, Thermal performance of buildings and building components: CT-leader Dick van Dijk (NL)
  - TC 228, Heating systems in buildings: CT-leader Johann Zirngibl (F)
  - TC 156, Ventilation for buildings: CT-leader Gerhard Zweifel (CH)
  - TC 247, Controls for mechanical building services: CT-leader Dan Napar (F)
  - TC 169, Light and lighting: CT-Leader Sohëil Moghtader & Jan de Boer (D)
Summary

– **First phase** we produced the *Basic Principles*, prEN15603 Overarching Standard, TR to the OAS and *Detailed Technical Rules*; they are at enquiry stage or going to public enquiry the next months.

– **Second phase** to revise the set of EPB-standards is under preparation and will start summer 2013

– Also phase 2 is to be considered to be a *dynamic process*; ➔ **Transparent, practical procedures** for exchange of views and principles, cooperation and feed back of all interested parties- The *Build-up platform is used as public platform*
  
  http://www.buildup.eu/communities/epcalc

– ➔ **In Cooperation with CEN-EDMC-LC**

– ➔ **Where possible in close cooperation with ISO-TC163 and ISO-TC205** .
Free-cooling and night ventilation

How to avoid overheating?

French Energy regulation

- From 2000:
  - Indoor temperature without cooling
  - Compared to indoor temperature with a reference system
  - Weather file average on 30 years
- 2012:
  - Weather file with extreme conditions
  - Adaptative comfort as in EN15251
  - Number of hours with non comfortable temperature
French Energy regulation

Example of a standard house
90 m²
Q₄=0.4 m³/h/m² @ 4 Pa

Feasability of Free cooling

- Over-ventilation can only be efficient in an energy efficient building

Figure 7. Additional ACH needed in the reference case. Figure 8. Additional ACH needed in the modified case.
Définitions

- Night over-ventilation : increase of flow in summer at night to fresh up building
  - Cross-flow
  - Stack ventilation
  - Mechanical
- Free-cooling : increase of flow at mid-season to fresh up building
  - Commercial buildings : linked to high internal loads

Example 1
Collective Dwelling
Example: IVRY Collective Dwelling

- Owner: Habitats Solidaires (social)
- Architect: C. Binetruy
- Energy designer: TCEP
- Ventilation: ALLIE AIR

- 398 m², 6 dwellings
- 2 floors + ground
- North/South wood frame
- East/West brick

Ivry: ventilation

- Central supply and exhaust
- Double skin ducts with joints, 50mm insulation (add. cost 10 k€)
- Sound attenuator (25 dB(A) global & 20 dB @ 250 Hz in bedrooms)

<table>
<thead>
<tr>
<th></th>
<th>Nominal</th>
<th>Boost</th>
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</thead>
<tbody>
<tr>
<td>airflow (m³/h)</td>
<td>630</td>
<td>1020</td>
</tr>
<tr>
<td>Avail. Pressure (Pa)</td>
<td>150*</td>
<td>150*</td>
</tr>
<tr>
<td>Fan absorbed power (W)</td>
<td>143</td>
<td>281</td>
</tr>
<tr>
<td>Sound Power level (Lw) dB(A)</td>
<td>-</td>
<td>76</td>
</tr>
</tbody>
</table>

560 W in over-ventilation
Ivry : ground heat exchanger

- 70m
- D400 mm
- depth : 1m

Temperature after ground exchanger °C

<table>
<thead>
<tr>
<th>Month</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>11.2</td>
<td>20.7</td>
</tr>
<tr>
<td>July</td>
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<td>24.2</td>
</tr>
<tr>
<td>Aug</td>
<td>14.9</td>
<td>22.0</td>
</tr>
<tr>
<td>Sept</td>
<td>11.9</td>
<td>21.9</td>
</tr>
</tbody>
</table>

Ivry Over-ventilation

- Simulations on Pleiades Comfie
- 2 ach = around -3°C

Temperate Zone / outdoor
Impact of the temperate zone

Winter

Summer / summer double door

Example 2
Theater
Theater

- National Monuments
- Architect: Sill
- La Bergerie, Vic Nohant (France)
- Classical concert

- Runs in summer at night and afternoon
- 410 occupants, 12 kW lighting
- 24 dB(A) & 20 dB @ 250 Hz
Theater

- Displacement ventilation
  - Free cooling on a longer period
  - IAQ ++
- Supply underseats and on scene
  - Floor diffusers
- Exhaust on the ceiling (on top of scene and opposite)
**Theater**

- Supply and exhaust unit, with exhaust Air Heat Pump ETT, 20000 m³/h,
- Temperature controled by airflow
- EER=4.5 (for the same price AHU+chiller+ control EER=3.9)
- Cooling Power = 56 kW @ Text=30°C
- Heating Power = 56 kW @ Text=10°C, COP 7.5, HRU inc., CO² control
- No apparent chiller outside, technical room acoustically treated
- Free cooling = 23% of the need on a summer season (and 50% in case of night show)

**Airflow control**

- Constant supply
- Temperature (/ direct expansion)
- Control outdoor air flow
- COP improved
- Free cooling
Example 3
Supermarket in Portugal
Results

- Passive overnight ventilation -7.4% of cooling energy
- Mechanical assistance (Tout<Tin-4 et Tout>24°) : -10.6% of cooling energy
- Overall : -20% of cooling energy (which was 50% of the overall building energy)

Atriums and high rise commercial buildings

- Combination of passive stack (atrium) and mechanical (sides)
- Prefer natural air movement (ie associate with displacement ventilation),
- Use free cooling whenever it’s possible
Design rules

1. High building thermal inertia (mass)
2. Plan air transfer for 4 to 8 ach in average (inlet, transfer, exhaust)
3. Define Zones to take into account uses and loads
4. Enthapic control (humidity+temperature) is better than just temperature control
5. Bypass both flows (pressure drop in HRU)

Summary

- Use building architecture
- Check uses, orientation
- Planify summer and mid season running to avoid overheating...
Status of ventilative cooling in DK

- Ventilative cooling is possible to include in the Building energy performance in DK, also for natural ventilation – if you are very clever

- Ventilative cooling only used to small extend by building designers. It is considered difficult to evaluate

- Improvements are planned and some can be expected soon
Status of ventilative cooling in DK

PRESENT STATUS #1:

- DK Building Regulation allows in general terms to take into account the effect of ventilative cooling – but does not tell how.

- DK compliance tool *be10* is a simplified monthly-mean calculation tool. Must be used to document compliance with DK BR

- *be10* allows you to input a ventilation rate value for ventilative cooling but does not assist you in determining the value. Simple for mechanical systems, difficult for natural ventilation. *be10* does not take into account effects of elevated air velocity.

PRESENT STATUS #2:

- Danish Standard DS 447 specifies requirements for mechanical, natural and hybrid ventilation systems – and also includes ventilative cooling expressed as
  - Free cooling,
  - Night cooling,
  - Passive cooling,
  - Cooling by means of natural ventilation.
  - Effects of elevated air velocities (informative annex)
Air velocity vs reduction in temperature sensation, $\Delta T$. ISO 7730 and EN 15251. From annex in DS 447

Status of ventilative cooling in DK

PRESENT STATUS #3:

- (Too) many full scale (unintended) experiments show: Lots of over-heating in low-energy buildings have been reported
- Design without the use of simple control means such as solar shading and ventilative cooling – WHY?
  - Focus on heating energy consumption
  - Difficult to evaluate the VC performance. Lack of know-how, simple tools with realistic results
- Compliance tool focus on energy, cannot evaluate summer comfort and VC
- VC evaluation needs use of separate tools – happens sometimes in non-residential buildings, rarely in residential buildings.
Status of ventilative cooling in DK

PRESENT STATUS #4:

- Product Solutions:
  - Mechanical systems – yes but normally dimensioned for IAQ
  - Manual windows – yes
  - Electrical windows – yes, some
  - Control systems
    - Yes for non-residential buildings
    - No for residential buildings

DK status of ventilative cooling in BR

FUTURE DEVELOPMENT

- Near future (few months):
  - A new module for be10 will be launched to allow a very simple evaluation of natural ventilative cooling on the building energy performance. Will give similar results for single side, cross and stack ventilation and not very suited for design of buildings

- Future (several years?)
  - Increased legislative focus on summer comfort
  - More detailed evaluation tool of (natural) ventilative cooling is under discussion. Shall be useful also for design of buildings – destiny unknown so far.
  - Products?
DK status of ventilative cooling in BR

CONCLUSION:

- **Status**
  - Rather unclear: Ventilative cooling not well supported by building regulation or compliance tool
  - New Danish standard helps but it’s not enough
  - (Natural) Ventilative cooling is considered somewhat difficult to work with as an engineer, too little guidance and too large responsibility
  - Therefore (natural) ventilative cooling is not widely included by building designers.

- **Future**
  - Looks reasonably good for ventilative cooling in DK, simplified inclusion of natural ventilative cooling in compliance tool be10 is on its way
  - Further improvements are under discussion
  - Products hopefully will follow in parallel
Ventilative Cooling in the US

Standards and Regulations

Max Sherman, Lawrence Berkeley Laboratory

Geographical Context

• Lower latitudes in US
  • Higher sun angles; bigger diurnal differences
• Greater climate variations than Europe
  • East-to-West goes from Wet-to-Dry
  • North-to-South goes from Cold-to-Hot
  • Tropical to Arctic to Desert
• Regional variations abound
  • Regional/local regulations
  • Regional/local traditions and building practices
Occupant Expectations

- In warm/hot climates people expect air conditioning
  - Long period of warm discomfort not accepted
  - Businesses have it; people want it at home
- New homes come with air conditioning
  - In almost all parts of country. (e.g. not Maine, Alaska)
  - Even if only used a few weeks per year
- Seasonal & regional climate adaptations
  - People adapt dress, activity, expectations to climate
- Do not adapt hour-to-hour or day-to-day
  - No short-term “adaptive comfort”

Codes and Standards

- Ventilative Cooling is not a normally used term
  - Is not a requirement generally
  - Shows up in other ways
- Cooling loads considered even if no cooling installed
  - In most jurisdictions
- Energy calculation methods often assume a bit
  - Elevated air exchange when appropriate
  - Or dead-bands
- Energy calculation methods allow for options
  - Night cooling, whole-house fans, economizers
  - No adaptive comfort
What is an Economizer?

- Mechanically supplies large volume of outside air
  - 3 to 30 ACH when needed to displace cooling load
  - Typical for commercial buildings with air HVAC.
  - Operation integrated with HVAC system (dampers, controls)
- Whole-house cooling fans more typical for dwellings
  - Typically 5 to 50 ACH of exhaust; not HVAC integrated
  - Manually controlled by occupant; e.g. need for openings
- Mechanical night cooling is a form
- Valuable in dry climates with large diurnal swings
  - Care needed in humid climates: latent storage

California Adds Requirement

- 2013 regulations will require ventilative cooling
  - But not by that name
  - Not fully final yet, but should be in next few months
- Prescriptive requirement for night ventilation in some zones
  - Whole house fan or economizers complies
  - May be traded for equivalent efficiency feature if using performance path
- Not aware of other residential requirements
  - Economizers have been required for commercial buildings in appropriate climates in south-west
Thank You
Ventilative Cooling in Regulations

Building Regulations in the UK

- The Building Regulations in the UK are formulated in three sets,
  - England and Wales,
  - Scotland and
  - Northern Ireland.
- There are many similarities but also differences
- This presentation focuses on England and Wales and has used the guidance within the Approved Documents (AD).

- Building Regulations can be downloaded from:
  http://www.planningportal.gov.uk/buildingregulations/approveddocuments/
Thermal pollution causes:

- Heat capacity & conductivity
- Solar absorptivity
- Sky factor
- Wind speed
- Energy consumption
- Vegetation

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Part F - Ventilation

- Focusses on IAQ requirements
- Links with energy:
  - ventilation is linked to control of thermal comfort
  - reference is made to purge ventilation
  - building air tightness and testing is specifically addressed with associated ventilation provision (eg increased for dwellings with a design air permeability tighter then or equal to 5m³/(h m²) at 50 Pa.
- Search specifically for ‘cooling’
  - ‘The ventilation provisions will not necessary meet cooling needs’
- Search for ‘thermal comfort’
  - ‘ventilation may also provide a means to control thermal comfort but this is not controlled under the building regulation. Part L addresses minimising energy use due to the effect of solar gain in the summer’.  
  - Purge ventilation may also be used to improve thermal comfort, although this is not controlled by the building regulations’

Part L – Conservation of Fuel and Power

Focusses on energy use
- Two terms are used to describe the energy performance;
  - BER is the Building CO₂ Emission Rate and
  - TER is the minimum (Target) energy performance,
  - both expressed in mass of CO₂ emitted per year per square metre of the total useful floor area of the buildings (kg/m²/y).
  - Energy performance certificate and compliance are outlined in detail
- Cooling
  - Is not directly linked with ventilation
  - Thermal comfort is not found through a search
- Non-domestic building compliance guide
  - Section 9 – comfort cooling - on how to calculate SEER
  - Section 10 – air distribution systems – mechanical systems on specific fan power and heat recovery.
Part L - 2013 amendments and proposed changes

- 2013 - Consideration of high-efficiency alternative systems for new buildings
  - Decentralised energy supply systems based on energy from renewable sources
  - Co-generation
  - District or block heating and cooling
  - Heat pumps
- 2012 Consultation focussed on energy use – results published in Dec 2012
- iSBEM is the National Calculation Method for non-domestic building
- Ventilative cooling can be considered as part of energy performance

In summary:
- Ventilative cooling is considered as part of energy performance in the regulations (Part L)
- Ventilation regulations (Part F) focus on IAQ
- New thermal comfort guidelines are being introduced (aligned with Category II in Standard BS EN15251) which might allow more flexibility in internal environmental conditions

Thank you!
Ventilative cooling in building regulations
The Netherlands

Workshop ‘Ventilative Cooling’
Brussels March 19 – 20, 2013

Bas Knoll

Energy Performance Coefficient $EPC = \text{normative}$

Energy Performance Indicator $\text{EP for year 2000}$

$$EPC = \frac{\text{specific energy use}}{\text{acceptable energy use year 2000}} \times \text{present demand}$$

Demands for the energy performance coefficient EPC of new buildings, e.g.:

- Dwellings 0.6
- Office buildings 1.1
- Schools 1.3

EPC to be calculated according to standard NEN 7120.

Specific energy use NEN 7120

- Balance of building heating and cooling demand:
  - Conduction losses through the building envelope
  - Ventilation losses based on ventilation flow NEN 8088
  - Solar and internal heat gain
  - Hot tap water usage
  - Electrical power use, building and systems related

- Heating and cooling according to static calculation method
- Monthly averaged, corrected for dynamic effects at EPC=1
- Heating demand at 20°C inside, cooling demand at 24°C inside

- Excessive cooling demand is considered as penalty for EPC
Ventilation part – NEN 8088

Ventilation heating or cooling losses in NEN 7120 are based on an (energetic) equivalent air flow from NEN 8088:

- Total air flow × temperature correction factor

The total air flow is a sum of:
- System flow
- Infiltration flow
- Airing flow
- Additional flow through the building for combustion appliances

Temperature correction due to:
- Heat recovery
- Passive solar gain (conservatory, atrium) or active (solar collector to air)
- Ground source (preheating / precooling)

Airing / ventilative cooling in NEN 8088

Cooling demand accounts for:
- Basic airing (increased compared to heating season)
- Usage and/or control of system overcapacity
  - Natural supply systems
  - Variable (outside air) flow systems
  - Additional purge air system capacity (incl. temperature correction)
- Type and control of the heat recovery bypass
- Increased effect of night use (passive cooling)
- Presence of windows

Heat demand (effect in the heating season):
- Basic airing heat losses are taken into account
Ventilative Cooling in Standards and Regulations
Country Report from Austria

Dipl.-Ing. Dr. Peter Holzer
Danube University Krems, Austria

National Code B 8110-3 (2012)
Thermal protection in building construction
Part 3: Prevention of summerly overheating
Background and Area of Application

• Part of the OENORM B 8110 series „Thermal protection in building construction”
• Revised and relaunched in March 2012
• Valid for all types of rooms with constant human occupancy, without technical cooling

Criteria

• Max. 27°C op. Temperature in each room
• Max. 25°C op. Temp. in sleeping rooms at night
General Methodology

Dynamic Heat Balance according to EN ISO 13791

- Climate
- Geometry
- Thermal Properties
- Solar properties, including shading
- Internal load profiles
- Ventilation

Site sensitive, hourly climate data, defined as a constantly repeated mid summer design day (obligatory)

To be taken from OENORM B 8110-5 by mean day temp of 15. July plus defined day/night swing ±7K

Further Referring to

- EN 13791 (sky temp.)
- EN ISO 13370 (ground temp)
General Methodology

Dynamic Heat Balance according to EN ISO 13791

- Climate
- **Geometry**
  - Thermal Properties
  - Solar Properties, including Shading
  - Internal Load Profiles
  - Ventilation

Referring to

- EN 13786 (usable thermal mass)
General Methodology

Dynamic Heat Balance according to EN ISO 13791

• Climate
• Geometry
• Thermal Properties
• Solar Properties, including Shading
• Internal Load Profiles
• Ventilation

Default values plus referring to
• EN 13363 (shading properties)
• EN 13561 and EN 13659 and EN 13791 (wind resistance)
• EN 13791 (fixed obstacles)

General Methodology

Dynamic Heat Balance according to EN ISO 13791

• Climate
• Geometry
• Thermal Properties
• Solar Properties, including Shading
• Internal Load Profiles
• Ventilation

Mandatory lists of
hourly internal load profiles and hygienic ventilation rates
for residential, office, schools and hospitals,
[W/m²], [W/workplace], [m³/h,pers]
General Methodology

Dynamic Heat Balance according to EN ISO 13791

- Climate
- Geometry
- Thermal Properties
- Solar Properties, including Shading
- Internal Load Profiles
- Ventilation

- Window ventilation by formula, \( V \ [m^3/h] = f(A_{\text{window}}, H_{\text{window}}, dT) \)
- Mechanical ventilation
  up to 1,5 ach in occupied rooms
  up to 2,5 ach in unoccupied rooms
  including thermal load from vents

Ventilative Cooling by Window Opening

\[ \dot{V} = 0.7 \cdot C_{\text{ref}} \cdot A \cdot \sqrt{H} \cdot \sqrt{\Delta T} \]
Ventilative Cooling by Window Opening

\[ \dot{V} = 0.7 \cdot C_{ref} \cdot A \cdot \sqrt{H} \cdot \sqrt{\Delta T} \]

W = 40 cm
H = 120 cm

Learnings
Thank you
Ventilative Cooling: Modeling + Simulation Challenges
Jan Hensen
j.hensen@tue.nl

Ventilative cooling

Depends on air flow and temperature/enthalpy differences affected by dynamically interacting complex sub-systems
Air flow modeling methods

- “Simplified” expressions
- Mass flow balance network method
- Computational fluid dynamics (CFD)

Can be used separately or combined with building energy modeling (BEM)

Air flow modeling - simplified

- \( n = 0.7 \text{ ACH} \)
- \( Q = Q_{50} / K \)  
  (\( K \approx 20 \) for heating season urban NL)
- LBL-method
  \[ Q = L A_{leak} + D V^{0.5} \]
  where:
  \( Q \) = air flow rate (L/s)
  \( L \) = effective leakage area (cm²)
  \( A_{leak} \) = stack coefficient
  \( D \) = average outside air temperature difference (°C)
  \( V \) = wind coefficient
  \( \circ \) = average wind speed, measured at a local weather station.

- Etc .........
Uncertainty analysis (1984 style): variability in heating energy demand of low-energy houses due to (stochastic) occupant behaviour in terms of $T_{set}$, $Q_{int}$, ACR.

Air flow modeling – mass balance network

- for each branch
  \[ \dot{m} = \rho C \left( p_i - p_f \right) \text{ [kg / s]} \]
- for each non-boundary node
  \[ \sum \dot{m} = 0 \text{ [kg / s]} \]
- for each boundary node
  \[ p = "known" \text{ [Pa]} \]

Source: IBPSA-USA
Air flow modeling – flow network + BEM

Passive cooling
- External shading
- High thermal mass
  (exposed floor / ceiling, ribs)

Low energy cooling
- All air system
- Night ventilation
- Top cooling
- Heat recovery
**Air flow modeling – flow network + BEM**

Using calibrated building + systems model, 10 operation scenarios were simulated: 6 scenarios with various combinations of flow rates and control periods, 5 scenarios with reduced cooling coil capacity.

**Air flow modeling – CFD**

- Conservation of
  - Mass
  - Momentum
  - Energy
  - Species

Source: IBPSA-USA
Air flow modeling – CFD

“MASSLESS” PARTICLE TRACE FROM FOUR-WAY DIFFUSERS

EXISTING CONFIGURATION

OPERATING ROOM

Source: IBPSA-USA

Building components, such as balconies, can lead to very strong changes in wind pressure distribution on building facades

- CFD modeling of air flow around a building
- Computational modeling of air flow in an urban area*
- LES simulation of heat transfer around a building


Page 180
Air flow modeling – CFD + BEM

deliverables:
• prototype software
• coupling procedure
• coupling validation

Volume: 10 (m) *10 (m) * 3.33 (m)
12 surfaces
Duration = 1 day (31st of March)
2 time steps per hour
Location: Brussels
Free floating temperature
### Air flow modeling – CFD + BEM

![Image of room temperature graph]

**Contour of Static Temperature (°C)**

**Velocity: Pressure Field by Velocity Magnitude (m/s)**

- **Time (hrs)**: 0 3 6 9 12 15 18 21 24
- **Temperature (°C)**: 9.2 9.4 9.6 9.8

**Source:** Daniel Costola + Mohammad Mirdad

---

### Best modeling approach?

**Case: displacement ventilation**

<table>
<thead>
<tr>
<th>Performance Indicator</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>cooling energy</td>
<td>–</td>
<td>++</td>
<td>–</td>
</tr>
<tr>
<td>fan electricity</td>
<td>++</td>
<td>++</td>
<td>–</td>
</tr>
<tr>
<td>whole body thermal comfort</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>local discomfort, gradient</td>
<td>–</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>local discomfort, turbulence intensity</td>
<td>–</td>
<td>–</td>
<td>++</td>
</tr>
<tr>
<td>ventilation efficiency</td>
<td>–</td>
<td>0</td>
<td>++</td>
</tr>
<tr>
<td>contaminant distribution</td>
<td>–</td>
<td>–</td>
<td>++</td>
</tr>
<tr>
<td>whole building integration</td>
<td>++</td>
<td>++</td>
<td>–</td>
</tr>
<tr>
<td>integration over time</td>
<td>++</td>
<td>++</td>
<td>–</td>
</tr>
</tbody>
</table>

**Source:** Building Physics & Services
Quality Assurance (QA)

• Ensuring that our model or simulation reproduces the state and behavior of the real world object, feature or condition. (= fidelity)

• Ensuring that our simulation has meaning for the real world question being asked (= usefulness)

QA: best modeling approach?

Resource requirements

Necessary domain + modeling knowledge
QA: data uncertainty / model complexity

Figure 6 Potential errors in performance prediction vs. model complexity/ level of detail [11]

QA: measurements vs. simulation

Ruppert’s Law

Measurements essential for verification, validation and calibration!
**QA: don’t simulate when**

1. The problem can be solved using "common sense analysis".
2. The problem can be solved analytically (using a closed form).
3. It's easier to change or perform direct experiments on the real.
4. The cost of the simulation exceeds possible savings.
5. There aren't proper resources available for the project.
6. There isn't enough time for the model results to be useful.
7. There is no data – not even estimates.
8. The model can't be verified or validated.
9. Project expectations can't be met.
10. System behavior is too complex, or can't be defined.

Banks & Gibson, 1997

---

**QA: do simulate but**

**Black Belt Energy Modeling Matrix**

<table>
<thead>
<tr>
<th>Belt</th>
<th>Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>Collect modeling input data</td>
</tr>
<tr>
<td>Yellow</td>
<td>Perform input data calculations</td>
</tr>
<tr>
<td>Orange</td>
<td>Develop building geometry and zoning</td>
</tr>
<tr>
<td>Green</td>
<td>Create building input file using software wizard</td>
</tr>
<tr>
<td>Blue</td>
<td>Build minimally-code compliant building model</td>
</tr>
<tr>
<td>Purple</td>
<td>Review results for reasonableness, complete calibrations</td>
</tr>
<tr>
<td>Brown</td>
<td>Perform complex modeling, complete detailed QC, complete system level calibration</td>
</tr>
<tr>
<td>Red</td>
<td>Understand the algorithms, use supplemental analysis</td>
</tr>
<tr>
<td>Black</td>
<td>Balance modeling level of detail against accuracy of results needed to support decision making</td>
</tr>
</tbody>
</table>

E Franconi, RMI, 2011
QA: how accurate are predictions

The range 6.9 +/- 10% gives you some idea of "normal" uncertainty – and this is for a really very simple building, with no definition uncertainty.

BESTEST was used to find out why this software performs "out of range"; for details see source.

Source: Hensen and Radosevic 2004
QA: and in case of uncertainty in

- Weather (frequency, missing variables, local micro climate, climate change, …)
- Wind pressure distribution (due to shape and surroundings)
- Pressure – flow characteristics of “openings”
- Occupant behavior (operable building elements, set points, …)
- Organizational changes (company, family make-up, …)
- Behavioral changes (rebound effects, societal changes, …)
- …

Conclusions

Assuming correct and appropriate use, building performance simulation:
- Can be pretty good for relative comparisons including contrasting design solutions, sensitivity analysis, robustness analysis, (multi objective) design optimization, scenario studies, etc., but
- Is generally quite poor in absolute predictions, such as future real world energy consumption
Thank you!
Is ventilative cooling effective in light weight wooden constructions?

Hilde Breesch (KAHO Sint-Lieven)
Koen Claes (Thomas More)
Kim Goethals (UGent)
Lieven De Boever (TCHN)

**DO-IT**

- Sustainable innovation wood based applications
  - Air tightness, water & wind tightness
  - Hygrothermal performance
  - Construction and fire safety
  - Acoustics
  - Indoor air quality
  - Summer Comfort
  - Case studies
  - Sustainable management
- Financial support of IWT, BBRI, TCHN
DO-IT

• Summer Comfort
  – Development design guidelines in light weight wooden construction (KAHO, Thomas More)
    • Sensitivity analysis
    • Guidelines residential <> office buildings
  – Optimalisation existing EPBD legislation (UGent)
    • Development of overheating indicator for light weight wooden construction
    • Optimalisation overheating indicator

Summary

• Context
• Design challenges
• Reference buildings
• Method
• Results
• Conclusions
Design challenges

- Ventilative cooling in light weight constructions?
- Impact of weather data on prediction cooling need/overheating risk

Summary

- Context
- Design challenges
- Reference buildings
  - Quality levels
  - Residential <> office buildings
  - Characteristics: building – HVAC - user
- Method
- Results
- Conclusions
Reference Buildings

- 2 Quality levels: building envelop
  - Insulation level
  - Air tightness
- Flemish EPBD (2014) <> PH standard

<table>
<thead>
<tr>
<th></th>
<th>EPBD 2014</th>
<th>PH standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U [W/m²K]</td>
<td>U [W/m²K]</td>
</tr>
<tr>
<td>Façade/Roof/Floor</td>
<td>0,24</td>
<td>0,15</td>
</tr>
<tr>
<td>Window – glazing</td>
<td>1,1</td>
<td>0,8</td>
</tr>
<tr>
<td>Window – frame</td>
<td>1,8</td>
<td>0,8</td>
</tr>
<tr>
<td>External door</td>
<td>2,0</td>
<td>0,8</td>
</tr>
<tr>
<td></td>
<td>n₅₀ (h⁻¹)</td>
<td>n₅₀ (h⁻¹)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0,6</td>
</tr>
</tbody>
</table>

Reference Buildings

- Residential: detached house
  - $A_{floor, tot} = 252$ m²
  - Zone 1
## Reference Buildings

- **Office building**
  - Zone 1: $A_{\text{floor}} = 200 \, \text{m}^2$

### Characteristics: walls

<table>
<thead>
<tr>
<th>material</th>
<th>$c$ [J/(kg·K)]</th>
<th>$\rho$ [kg/m$^3$]</th>
<th>$\lambda$ [W/(m·K)]</th>
<th>$d$ [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>façade</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>structure - wood fraction (15%)</td>
<td>1600</td>
<td>500</td>
<td>0.130</td>
<td>0.300</td>
</tr>
<tr>
<td>structure - MW (85%)</td>
<td>1030</td>
<td>50</td>
<td>0.040</td>
<td>0.300</td>
</tr>
<tr>
<td>OSB</td>
<td>1700</td>
<td>950</td>
<td>0.130</td>
<td>0.015</td>
</tr>
<tr>
<td>cavity - wood fraction (15%)</td>
<td>1600</td>
<td>500</td>
<td>0.130</td>
<td>0.005</td>
</tr>
<tr>
<td>cavity - MW (85%)</td>
<td>1030</td>
<td>50</td>
<td>0.040</td>
<td>0.005</td>
</tr>
<tr>
<td>gypsum board</td>
<td>1000</td>
<td>900</td>
<td>0.260</td>
<td>0.013</td>
</tr>
<tr>
<td><strong>internal wall</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gypsum board</td>
<td>1000</td>
<td>900</td>
<td>0.260</td>
<td>0.013</td>
</tr>
<tr>
<td>structure - wood fraction (15%)</td>
<td>1600</td>
<td>500</td>
<td>0.130</td>
<td>0.100</td>
</tr>
<tr>
<td>structure - MW (85%)</td>
<td>1030</td>
<td>50</td>
<td>0.040</td>
<td>0.100</td>
</tr>
<tr>
<td>gypsum board</td>
<td>1000</td>
<td>900</td>
<td>0.260</td>
<td>0.013</td>
</tr>
<tr>
<td><strong>internal floor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>floor covering</td>
<td>1400</td>
<td>1200</td>
<td>0.190</td>
<td>0.010</td>
</tr>
<tr>
<td>OSB</td>
<td>1700</td>
<td>650</td>
<td>0.130</td>
<td>0.015</td>
</tr>
<tr>
<td>structure - wood fraction (11%)</td>
<td>1600</td>
<td>500</td>
<td>0.130</td>
<td>0.200</td>
</tr>
<tr>
<td>structure - MW (89%)</td>
<td>1030</td>
<td>50</td>
<td>0.040</td>
<td>0.200</td>
</tr>
<tr>
<td>gypsum board</td>
<td>1000</td>
<td>900</td>
<td>0.260</td>
<td>0.015</td>
</tr>
</tbody>
</table>
Reference Buildings

• Characteristics: walls

<table>
<thead>
<tr>
<th>material</th>
<th>c  [J/kg.K]</th>
<th>ρ  [kg/m³]</th>
<th>λ  [W/m.K]</th>
<th>d  [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tiles</td>
<td>1000</td>
<td>1700</td>
<td>0.810</td>
<td>0.010</td>
</tr>
<tr>
<td>light concrete</td>
<td>1000</td>
<td>1050</td>
<td>0.320</td>
<td>0.070</td>
</tr>
<tr>
<td>insulation</td>
<td>1400</td>
<td>30</td>
<td>0.035</td>
<td>0.170</td>
</tr>
<tr>
<td>light concrete</td>
<td>1000</td>
<td>1050</td>
<td>0.320</td>
<td>0.050</td>
</tr>
<tr>
<td>reinforced heavy concrete</td>
<td>1000</td>
<td>2400</td>
<td>2.200</td>
<td>0.150</td>
</tr>
</tbody>
</table>

Reference Buildings

• Characteristics: residential building
  – Solar shading
    • $g_{\text{window}} = 0.50$
    • Fixed overhang (d = 1m)
  – Hygienic ventilation rates
    • Zone 1: $n = 1 \text{ h}^{-1}$
  – Extra natural ventilation
    • Daytime ($T_i > 24^\circ\text{C}, 7\text{h}-22\text{h}$)
    • Nighttime ($T_i > T_e + 1^\circ\text{C}, T_i > 18^\circ\text{C}, 22\text{h}-7\text{u}$)
    • $n = 0 \leftrightarrow 3 \text{ h}^{-1}$
  – Thermal mass
    • Light weight wooden construction
    • Heavy weight brick internal walls
Reference Buildings

• Characteristics: residential
  – Internal heat gains (ISO 13791)


dimensions: 595.2x842.0

Reference Buildings

• Characteristics: Office building
  – Solar shading
    • $g_{\text{window}} = 0.55$
    • Fixed overhang ($d = 1\text{m}$)
  – Hygienic ventilation rates & occupancy
    • IDA 3 (29 m³/h)
    • 15 m³/pers
    • zone 1: $n = 0.67 \text{ h}^{-1}$
  – Night ventilation
    • $n = 0 \leftrightarrow 3 \leftrightarrow 6 \text{ h}^{-1}$
## Reference Buildings

- Characteristics: Office building
  - Thermal mass

<table>
<thead>
<tr>
<th>Classification (EN 13790)</th>
<th>Heat capacity $C_m$ (J/K)</th>
<th>construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very light</td>
<td>$1.13 \times 10^7$</td>
<td>All light weight wooden walls</td>
</tr>
<tr>
<td>Light</td>
<td>$2.19 \times 10^7$</td>
<td>Functional core heavy concrete</td>
</tr>
<tr>
<td>Very heavy</td>
<td>$7.91 \times 10^7$</td>
<td>Functional core heavy concrete, Internal floor + ceiling concrete slab</td>
</tr>
</tbody>
</table>

## Reference Buildings

- Characteristics: Office building
  - Internal heat gains

![Internal heat gains graph](image)
Summary

- Context
- Design challenge
- Reference buildings
- Method
  - Dynamic simulations
  - Evaluation overheating
- Results
- Conclusions

Method

- Multizone dynamic simulations
  - Design Builder (E+)
  - Time step = 1h
  - Cooling: \( T_i > 26^\circ C \)
- Evaluation overheating (EN 15251)
  - Comfort limit: PMV = 0.5 – PPD = 10%
  - Weight factor
    \[ w_f = \frac{PPD_{\text{maxPMV}}}{PPD_{\text{PMVlimit}}} \]
  - Max weighted temperature exceedings
    5% on yearly basis = 438h residential
Summary

• Context
• Design challenges
• Reference buildings
• Method
• Results
  – Impact ventilative cooling on cooling need & peak cooling load in office buildings
  – Impact ventilative cooling on overheating risk in residential buildings
  – Effect ventilative cooling in warm weather data
• Conclusions

Results

• Impact ventilative cooling on cooling need in office buildings

![Graph showing cooling need in office buildings with different ventilation rates.](image)
Results

• Impact ventilative cooling on peak cooling load in office buildings

![Graph showing peak cooling load in W/m² for different ventilation rates: 0 vol/h, 3 vol/h, and 6 vol/h. The x-axis represents different ventilation rates (very light, light, very heavy), and the y-axis represents peak cooling load. The graph shows a significant decrease in peak cooling load with increased ventilation rates.]

Results

• Impact ventilative cooling on peak cooling in office buildings

![Graph showing hourly cooling load in W/m² with markers for different ventilation rates: light, 0 vol/h, average, light, 3 vol/h, average, and light, 6 vol/h, average. The graph displays the daily variation in cooling load over a specific period.]
Results

- Impact ventilative cooling on overheating in residential buildings

![Chart showing impact of ventilative cooling on overheating in residential buildings]

Results

- Impact weather data on performances
  - Temperature
  - Solar radiation
- Meteonorm 7
  - Synthetical based on measurements
    - Temperature (2000-2009)
  - Average <> Warm weather data (1 per 10 year)
Results

- weather data: temperature

<table>
<thead>
<tr>
<th>Month</th>
<th>Average Uccle (B)</th>
<th>Warm Uccle (B)</th>
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<tbody>
<tr>
<td></td>
<td>KMI 04-08 Meteonorm 7</td>
<td>Max KMI 04-08 Meteonorm 7</td>
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<tr>
<td>1</td>
<td>4.83 4.00</td>
<td>7.16 6.70</td>
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<td>2</td>
<td>4.58 4.90</td>
<td>6.77 7.20</td>
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<tr>
<td>3</td>
<td>6.57 7.10</td>
<td>8.02 8.60</td>
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<td>4</td>
<td>10.86 10.70</td>
<td>14.28 13.00</td>
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<td>5</td>
<td>14.20 14.40</td>
<td>16.46 15.70</td>
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<td>17.03 17.20</td>
<td>18.20 18.50</td>
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<td>7</td>
<td>18.76 18.60</td>
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<td>8</td>
<td>17.33 18.50</td>
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<td>9</td>
<td>15.80 15.50</td>
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<td>10</td>
<td>12.23 11.80</td>
<td>14.23 14.50</td>
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<td>11</td>
<td>7.14 7.80 9.20 9.50</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>3.93 4.10 5.94 5.80</td>
<td></td>
</tr>
<tr>
<td>Annual average</td>
<td>11.11</td>
<td>11.22</td>
</tr>
</tbody>
</table>

Results

- Warm weather data: cooling need in office

![Cooling need chart](chart.png)
Summary

• Context
• Design challenge
• Reference buildings
• Method
• Results
• Conclusions

Conclusions

• Is ventilative cooling effective in light weight wooden constructions
  – Office buildings: night ventilation
    • Cooling need: very effective
    • Peak cooling load: less effective - larger impact thermal mass
  – Residential buildings: day & night ventilation
    • Overheating: day ventilation effective
• warm weather data: impact ventilative cooling
  – Office buildings: night ventilation effective
  – Residential buildings:
    • Only day ventilation not effective
    • Need automatically controlled shading device -> good thermal comfort
Overview

Natural ventilation design tools, applications in commercial buildings

MIT Building Technology Laboratory, Cambridge, USA
Stephen Ray, postdoc
Airflow Network (AFN) models divide space into large zones

Flow pathways connect zones through openings
Conservation equations are used to calculate flow rates and temperatures

Conservation of Momentum (Bernoulli)

Orifice Equation

Conservation of Energy

\[ \Delta P(T, \text{wind}) \]

\[ V(\Delta P, \text{losses}) \]

\[ \Delta T(V, \text{loads}) \]

Many AFN models exist, both commercially available and in-house models
Strength 1: CoolVent easily usable in early design stage

Strength 2: CoolVent provides quick, informative results – temperatures & ACH
Strength 2: CoolVent provides quick, informative results – thermal comfort
Strength 3: CoolVent predicts zonal vertical temperature distribution – CFD verified

Strength 4: CoolVent models air momentum in ventilation shafts – CFD and model verified
Strength 5: CoolVent easily accounts for low-power auxiliary fans

Full scale monitoring of 10 story NV office building in Tokyo w/ 2000+ instruments
Rooftop weather stations not always useful

22.9°C

24.3°C

Up to 3°C difference between $T_{\text{inlet}}$ and $T_{\text{roof}}$ in October
3 week horizontal temperature distribution – measurements at desk level

Positive gradient from inlets to back of occupied zone
Similar temperatures at similar distances from inlet
Similar temperatures at similar distances from inlet

Largest difference < 2 C between copy room and window
Occupants can bring strong biases to certain systems: uncomfortable = NV problem

Mech cooling: uniform vertical temps
NV: linear increase in vertical temps
Operation of “non-system” components can be important.

Reasonable agreement between CoolVent and measured airflow rates.
Reasonable agreement between CoolVent and measured air temperatures

Steve Ray – sdray@mit.edu

Intro

CoolVent

JP bldg
SENSITIVITY OF NIGHT COOLING PERFORMANCE TO ROOM/SYSTEM DESIGN: SURROGATE MODELS BASED ON CFD

Kim Goethals and Arnold Janssens
Laboratory of Building Physics, Construction and Services

Three basic elements of night cooling

Supply of cool air
Three basic elements of night cooling

Supply of cool air

Heat storage

Three basic elements of night cooling

Supply of cool air

Heat transfer

Heat storage
Convective heat transfer in...

... reality

... Building Energy Simulation (BES)

\[ q_c = h_c \cdot (T_w - T_a) \quad \text{(correlations)} \]

natural/forced/mixed • laminar/turbulent • surface location, surface orientation...

Correlations are case-specific

\[ h_c = \frac{C}{D_{eq}} \cdot \left( T_w - T_{a,\text{local}} \right)^2 \]

Awbi and Hatton
(natural convection)
Is the current BES approach sufficient to model night cooling? No!
   Part 1: Importance of the choice of correlation (BES)
   Part 2: Applicability of current correlations (experiments)

What possibly is a proper way? BES + CFD-based surrogate models!
   Part 3: Methodology to derive CFD-based surrogate models

Importance of choice of correlations?
Impact of the choice of correlation

![Bar chart showing the impact of the choice of correlation](Image)

- **Correlations**:
  - NBN EN ISO 13791
  - Alamdari and Hammond
  - Beausoleil-Morrison

**Design Parameters**

- **TE(PM>0.5)**

**Page 221**
Is convective heat transfer modelling of minor importance? No!

Applicability of current correlations?

(Part 2)
Comparison to correlations

![Diagram showing the comparison between measurements and correlations]
Are the currently available convection correlations always usable? No!
BES + more empirical correlations
BES + CFD
Methodology to derive CFD-based surrogate models?

- BES + more empirical correlations
- BES + CFD
- BES + CFD-based surrogate models

input → output = f(input) → output

Page 226
Methodology to derive CFD-based surrogate models?

\[ \text{input} \rightarrow \text{output} = f(\text{input}) \rightarrow \text{output} \]

Methodology to derive CFD-based surrogate models?

\[ \text{input} \rightarrow \text{output} = f(\text{input}) \rightarrow \text{output} \]
Methodology to derive CFD-based surrogate models?

input \rightarrow \text{output} = f(\text{input}) \rightarrow \text{output}

Methodology to derive CFD-based surrogate models?

input \rightarrow \text{output} = f(\text{input}) \rightarrow \text{output}
Methodology to derive CFD-based surrogate models?

input \rightarrow \text{output} = f(\text{input}) \rightarrow \text{output} 

(Part 3)
Pilot study on night cooled landscape office

Night cooling in offices
- Usually in oblong landscape offices
- Often line-shaped diffusers/band windows
- So, roughly speaking, 2-D airflow

Design parameters
- Ventilation concept
- Mass distribution
- Geometry
- Driving force for convective heat transfer

Stirring up the Annex 20 2-D case

[Image of cfd-benchmarks.com]
Parameterizing Annex 20 2-D case

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilation concept</td>
<td>Single-sided/cross/under floor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass distribution</td>
<td>Floor/ceiling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L_r (m)</td>
<td>Geometry</td>
<td>4.5</td>
<td>9</td>
</tr>
<tr>
<td>H_sup (m)</td>
<td></td>
<td>0+BL</td>
<td>2.6-2.6 (L_r-0.5m)</td>
</tr>
<tr>
<td>h_sup (m)</td>
<td></td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>α (°)</td>
<td></td>
<td>60</td>
<td>120</td>
</tr>
<tr>
<td>n (R^-1)</td>
<td>Driving force</td>
<td>1.5</td>
<td>10</td>
</tr>
<tr>
<td>T_w (°C)</td>
<td></td>
<td>16</td>
<td>25</td>
</tr>
</tbody>
</table>

Gambit + Fluent + SUMO = surrogate model

- Controlled by Matlab (fully automated)
- Estimate airflow on base grid
- Grid refinement
- Calculate average convective heat flux

Monitoring residuals and quantities is contestable
SUMO: global Surrogate-Based Optimization

Interpolation modelling (kriging)  
Adaptive sampling (expected improvement)

Sensitivity: position of thermal mass more important than ventilation concept

Solution interval  -  min/max  -  ref  

$(L, r, 5m, (T_u - T_{sup}) = 10°C and n=10h)$
Typical contour plots of the convective heat flux $q_c$

$H_{\text{in}}$ $H_{\text{exh}}$

Typical contour plots of the prediction variance $\hat{s}^2$

$H_{\text{in}}$ $H_{\text{exh}}$
These CFD-based surrogate models can provide insight (now) advance BES-modelling (later)

### Advancement of BES modelling

<table>
<thead>
<tr>
<th>Surrogate models</th>
<th>Indicate optimal solutions for which new correlations can be derived empirically Make a basis for more globally accurate surrogate models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Framework (in Matlab)</td>
<td>Can be used to derive more surrogate models for different sets of room/system design parameters Can be extended to enable co-kriging (few high-res simulations and many low-res simulations)</td>
</tr>
</tbody>
</table>
SENSITIVITY OF NIGHT COOLING PERFORMANCE TO ROOM/SYSTEM DESIGN: SURROGATE MODELS BASED ON CFD

Kim Goethals and Arnold Janssens
Laboratory of Building Physics, Construction and Services

Further reading:
K. Goethals, Convective heat transfer modelling in offices with night cooling (Ph.D.), Ghent University, 2012
Ventilative cooling experiences by Renson: lessons learned and solutions

International Workshop AIVC-Venticool – Brussels – 19-20 March 2013
Ivan Pollet - Renson Ventilation

Healthy Concepts: for residential and non-residential applications

3 systems:
- Demand controlled hygienic ventilation (DCV)
- External solar protection
- Intensive nightcooling

Several sectors:
- Dwellings and apartments
- Health Care
- Schools
- Offices ...

- Indoor air quality
- Acoustic comfort
- Thermal summer comfort
- Visual comfort
1. Process of applying ventilative cooling
2. Ventilative cooling in practice

Process of applying ventilative cooling

Specifications
Design
System/ installation
Commissioning
Maintenance

Legislation and standards on European, national, regional and community level
Process of applying ventilative cooling

**European EPB-directive**

Not explicitly mentioned to consider into the calculation methodology (annex I)

⇒ not or slowly taken up by countries
⇒ no benefits on paper / EP-certificate
⇒ not or little applied

= great barrier

Legislation and standards on European, national, regional and community level

Impact of EPBD on the market: DCV

**EPBD: impact of demand controlled residential ventilation in different countries**

- The Netherlands - CO2-control
- France - Aldes hygro B (F3)
- Germany - Fixed small effect
- UK - not considered
- Belgium - Renson Crevo II
- Belgium - Duco - Ducotronic

Significant effect = Great market
No or small effect = Great market

Percentage of constant air flow rate (%)
Impact of EPBD on the market: DCV

EPBD: impact of demand controlled residential ventilation in different countries

= unfair competition?

Important issue for European commission, but not in relation to the EPBD ... ?

Process of applying ventilative cooling

Fire/ smoke regulation

- Fire compartment of a building
  = fire resistant air transfer devices
    = barrier
- Smoke evacuation used as ventilative cooling
  = opportunity

Legislation and standards on European, national, regional and community level
Process of applying ventilative cooling

**Specifications**

- Operable windows often required
  - opportunity
- Protection/securing of openings
- Maximum indoor temperature < 25°C
  - no guarantee if only ventilative cooling
  - barrier (EN15251)

**Design**

Lack of simple design rules within standards

- cooling capacity ? 5 W/m²/air exchange rate
- ventilation principles ? single sided, cross, ...
- pressure difference across façade opening ?
  - 1 – 2 – 5 Pa
  - barrier
Process of applying ventilative cooling

Design

Lack of simple design rules within standards
- protection/securing of openings: K of $\xi$-factor
- mechanical ventilation:
  - maximum air speed in ducts ?
  - maximum SFP (W/m³/s) ?
- $\text{COP} = \frac{\text{cooling power}}{\text{fan power}} = \frac{1200 \Delta T \text{ (in-out)}}{\text{SFP}}$

Mechanical ventilative cooling

COP of mechanical ventilative cooling

Working area of standard airco
Process of applying ventilative cooling

**System/ installation**
- Simplicity ↔ automation
- Integration: - nightcooling / solar shading
  - hygienic and intensive ventilation
  - within the façade elements
- Acoustic insulated openings
- Mechanical support on exhaust

**Commissioning and maintenance**
- “Guarantee on correct performance”
- The more automated (sensors, actuators, fan), the more necessary
- A real “as-built” dossier and not “should built”
- An internal responsible

Legislation and standards on European, national, regional and community level
Process of applying ventilative cooling

Commissioning and maintenance

• **Soft Landings** means designers and constructors staying involved with buildings beyond practical completion. This will assist the client during the first months of operation and beyond, to help fine-tune and de-bug the systems, and ensure the occupiers understand how to control and best use their buildings.

Legislation and standards on European, national, regional and community level

Ventilative cooling in practice

**Offices**
- **Renson offices** (Waregem - Belgium)
- **BBL office** (Brussels - Belgium)
- **Green office** (Paris - France)
- **Tour Elithis** (Dijon - France)

**Residential sector**
- **Healthbox II system**
Renson offices (Waregem – Belgium, 2002)

- Passive stack nightcooling
- Average air exchange rate: 6 h⁻¹
- Free area of air supply: 2% of floor area
- Occupancy: 12 m²/person
- Controlled by BMS
- Combined with external adjustable solar shading and exposed ceiling as thermal mass
- Summer of 2006: 76 nights in operation (20%)
Renson offices (Waregem – Belgium, 2002)

Number of occupants more than doubled
Number/power of computer(screens) strongly increased

Renson showroom (Waregem – Belgium, 2013)

- Located under the offices
- Vertical screens as solar protection
- Hybrid nightcooling system: natural cross ventilation, supported by mechanical exhaust (5 h⁻¹)
- Floor cooling on reversible heat pump – 30 W/m²
**Natural air supply - exhaust:**
- acoustic insulating automated window vents at the top of the windows (also used for hygienic ventilation)
- automated windows integrated in the plenum above the entrance doors
Renson showroom (Waregem – Belgium, 2013)

• **Half open ceiling covered by acoustic absorption profiles**
  - thermal mass available
  - acoustic absorption
  - integration of lightings, loudspeakers, ducts, ...

Renson showroom (Waregem – Belgium, 2013)

• **Mechanical exhaust if needed**
  - SFP = 800 W/m³/s
BBL office (Brussels – Belgium, 2012)

- Renovation and extension of an office – 4 floors
- Nightcooling with mechanical extract – 6 h⁻¹
- Half open ceiling

BBL office (Brussels – Belgium, 2012)

- Facade openings – manually operated
- Protected/ secured by sliding solar protection louvres
  ⇒ multifunctionality: window protection
Green office (Paris – France, 2011)

- **Positive energy building - 23,300 m² over 6 floors:**
  - Total energy consumption: 62 kWh/m²/year
  - Total produced energy: 64 kWh/m²/year
    - Photovoltaic: 4200 m²
    - Cogeneration (CHP) on bio-diesel

Green office (Paris – France, 2011)

- **Solar protection: sliding louvres - screens**
  - Solar heat control
  - Daylight control
  - Protection/security of openings for nightcooling
- **Concrete slabs** as thermal mass
- **Ceiling fans** to increase summer comfort
Tour Elithis (Dijon – France, 2009)

- **Positive-energy building - 5.000 m² over 10 floors:**
  - Total energy consumption: ~100 kWh/m²/year
  - Total energy production:
    - Photovoltaic: 40 kWh/m²/year (560 m²)
    - Boiler on wood granulates
  - External solar shading shield

- **Ventilative cooling** with natural supply (acoustic vents) and low pressure mechanical exhaust ventilation from atrium during **daytime** (T > 10 °C) or **nighttime** (3 h⁻¹)
- **Occupancy:** 15 m²/person
- Adiabatic + compressor cooling ~ 7 kWh/m²/year
- **Lighting:** 2 W/m² + occupancy and daylight control
Renson Healthbox II (residential sector)

Demand controlled mechanical extract ventilation (MEV)

Control valves
Air flow rate of each room (living and/or functional rooms) controlled on internal and external air temperature

• Cooling rate is automatically increased during hot periods with lower outdoor air temperature

Burglary resistant louvre WK2
before operable window

Thanks for your attention

Page 252
Application of PCM-systems in Ventilative Cooling

Lesh Gowreesunker, Maria Kolokotroni, Savvas Tassou

Centre for Sustainable Energy Use in Food Chains
Brunel University, UK

20th March 2013 - Brussels
IEA Workshop Annex-62: Ventilative Cooling

Ventilative Cooling

- Use of low temperature outdoor air for cooling
- Very dependent on unpredictable ambient conditions
- Use of outdoor air does not always guarantee cooling during the day

Proposed solution:
→ Shift low night-time temperatures to occupied day-time
→ Via Energy Storage – Phase Change Materials (PCM)
Phase Change Materials (PCM)

Sensible + Latent heat capacities → Increased Energy Storage

Thermal Comfort requirements → Narrow range of temperature

Damping of indoor temperature due to increased thermal inertia (by absorption/release of energy) → Prolonged thermal comfort without energy consumption

PCM Recharge (Night Ventilation)

---

PCM + Ventilative Cooling

- Common PCM systems: PCM boards/envelopes, PCM -HX, PCM glazing

- Focus of PCM-HX in Airport Terminal Space (Heathrow T5)

  - Displacement diffuser (DV)
  - PCM plates retrofitted
  - 2 configurations studied (8/16 mm air gaps)
  - PCM: 16-25°C & 180 kJ/kg
Case Study (1) – Airport Terminal

Airport supplied by Central CAV system – Airtight building

- Conditioned Zone
- $T_f$: Temperature sensor control system

Case Study (2) – Modelling

Coupled TRNSYS-FLUENT model:
- TRNSYS models HVAC + PID control
- FLUENT models Airport airflow
Case Study (3) – Model Coupling

-Quasi-dynamic coupling, i.e. Only 1 coupled iteration between TRNSYS and FLUENT per timestep

**Diagram:**

- TRNSYS
  - Boundary Conditions -1
  - TRNSYS-Inputs

- FLUENT
  - Airport terminal
  - Boundary Conditions -1

- FLUENT
  - PCM-HX
  - Boundary Conditions -2

- TRNSYS
  - Heating/Cooling units
  - CFD Outputs -1
  - HVAC + Controls

- CFD Outputs -2

Updated Ventilation Inputs

(t+1)th time

<table>
<thead>
<tr>
<th>Boundary conditions</th>
<th>CFD Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather data (Ambient temperature, Solar gains)</td>
<td>Feedback temperature ($T_f$)</td>
</tr>
<tr>
<td>Internal heat gains</td>
<td>Return air temperature ($T_r$)</td>
</tr>
<tr>
<td>Ventilation conditions (Supply air temperature, air mass flow rate for both airport + PCM-HX)</td>
<td>PCM-HX - outlet air temperature</td>
</tr>
</tbody>
</table>

Case Study (4) - Control

**PID Control (occupied hours 04:00-24:00):**

If $18^\circ C \leq T_f \leq 23^\circ C$ → $T_m$ passes through PCM-HX and supplied to Airport (Heating/Cooling units off) → Free-Cooling

If $T_f > 23^\circ C$ → PID calculates a low $T_s$ to satisfy cooling load

If $T_f < 18^\circ C$ → PID calculates a high $T_s$ to satisfy heating load

**PCM Night Recharge Strategies (non-occupied hours 24:00-04:00):**

(Ambient air passed through PCM-HX)

1. No-night recharge
2. Full-night recharge
3. Recharge stopped when $T_{pcm} < 18^\circ C$ (limiting control)
Case Study (5) - Results

- Air movements observed in CFD model
- PCM-HX reduces temperature swing in airport
- Similar temperature trends for 3 recharge strategies

<table>
<thead>
<tr>
<th>System</th>
<th>Summer overheating (&gt;25°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DV-Only</td>
<td>6.3 %</td>
</tr>
<tr>
<td>PCM-HX No-night Recharge</td>
<td>3.9 %</td>
</tr>
<tr>
<td>PCM-HX Limiting-night control</td>
<td>3.5%</td>
</tr>
<tr>
<td>PCM-HX Full-night Recharge</td>
<td>3.1 %</td>
</tr>
</tbody>
</table>

Case Study (6) - Results

Annual Cooling Energies obtained through Cooling Degree Days

<table>
<thead>
<tr>
<th>Systems</th>
<th>Cooling Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>DV-Only</td>
<td>100 %</td>
</tr>
<tr>
<td>PCM-HX (16mm gap) No-night Recharge</td>
<td>-12.9 %</td>
</tr>
<tr>
<td>PCM-HX (16mm gap) Limiting-night control</td>
<td>-13.9 %</td>
</tr>
<tr>
<td>PCM-HX (16mm gap) Full-night Recharge</td>
<td>-13.8 %</td>
</tr>
<tr>
<td>PCM-HX (8 mm gap) No-night Recharge</td>
<td>-16.1 %</td>
</tr>
<tr>
<td>PCM-HX (8 mm gap) Limiting-night control</td>
<td>-17.9 %</td>
</tr>
<tr>
<td>PCM-HX (8 mm gap) Full-night Recharge</td>
<td>-18.0 %</td>
</tr>
</tbody>
</table>
Summary

- TRNSYS-CFD coupled simulation used for energy evaluations
- PCM-HX reduces summer overheating by $\approx 3\%$ of the time, compared to DV-only system
- Indoor temperature trends are similar for different night recharge strategies employed
- PCM-HX Cooling Energy requirements decrease in the range of 12 - 18%, compared to DV-only system

Conclusion

Retrofitted PCM-HX system provides similar indoor temperature trends, but employs less energy to do so, compared to a DV-only system.

Acknowledgements

This study is funded by the UK Engineering and Physical Sciences Research Council

? QUESTIONS ?
Stratum Ventilation

John Z. Lin, PhD, CEng
Building Energy & Environmental Technology Research Unit
Division of Building Science and Technology
City University of Hong Kong

Presentation Outline

1. Trend in thermal comfort – ventilative cooling,
2. Concepts of Stratum Ventilation,
3. Performances of Stratum Ventilation.
• Global warming (IPCC).
• International consensus to reduce CO₂ emission.
• Recent guidelines issued by governments in East Asia:
  • Hong Kong EMSD guidelines on energy saving: the room temperature of an air-conditioned space in summer months is set to 26.5°C;
  • National Development and Reform Commission of Chinese State Council issued a guideline to set the indoor temperature to 26°C in the cooling season;
  • Room temperature in the “Presidential Office” in Taipei has been set to 27°C after Mr. Ma Ying-jeou’s inauguration;
  • Ministry of Knowledge and Economy of Korea recommend room temperature ranging from 26 to 28°C in summer;
  • Ministry of Environment of Japanese Cabinet encourages to set the temperature of offices to 28°C in summer months.

Conventional theory presumes: Occupants exposed to uniform ambience.

• Thermal neutrality (heat balance) without sweating might not longer be possible!

• Solution?

• Ventilative cooling
ASHRAE Standard 55-2004?

ASHRAE Standard 55-2010 allows elevated air movement to broadly offset the need to cool the air in warm conditions.
Stratum ventilation was proposed for small to medium rooms

Air supply stratum formed under cooling condition
Air supply stratum formed under heating condition

14/03/2013 AI/VC Workshop on Ventilative Cooling 2013
Thermal Sensation Votes of 24 Male + 24 Female subjects

![Graph showing thermal sensation votes vs room temperature]

- Mixing ventilation
  - \( y = 0.2515x - 6.3812 \)
- Displacement ventilation
  - \( y = 0.2074x - 5.2096 \)
- Stratum ventilation
  - \( y = 0.2841x - 7.7077 \)

Mixing ventilation

Displacement ventilation

Stratum ventilation

14/03/2013  AIVC Workshop on Ventilative Cooling 2013
Energy Performance

Qualitatively, 8 factors contribute to energy saving of stratum ventilation:

1. Neutral temperature of 27ºC → Higher humidity ratio for identical RH → lower latent load;
2. Smaller temperature difference between the indoors and outdoors → smaller transmission load;
3. Smaller enthalpy difference → lower ventilation load;
4. Longer free cooling period;

5. Higher ventilation effectiveness → lower ventilation load;
6. Reverse temperature gradient in the occupied zone → no over-cooling of the lower zone;
7. Elevated supply air temperature → higher evaporative temperature of the associate chiller(s); and
8. Lower cooling capacity → smaller pumps and fans.
### Year-round primary energy consumption (kWh)

<table>
<thead>
<tr>
<th>System</th>
<th>Solar-assisted?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Mixing ventilation</td>
<td>53,360</td>
</tr>
<tr>
<td>Hybrid displacement ventilation</td>
<td>39,806</td>
</tr>
<tr>
<td>Hybrid stratum ventilation</td>
<td>31,785</td>
</tr>
<tr>
<td>Saving from mixing ventilation</td>
<td></td>
</tr>
<tr>
<td>to hybrid displacement ventilation</td>
<td>25.40%</td>
</tr>
<tr>
<td>Saving from hybrid displacement</td>
<td></td>
</tr>
<tr>
<td>ventilation to hybrid stratum ventilation</td>
<td>20.15%</td>
</tr>
<tr>
<td>Saving from mixing ventilation</td>
<td></td>
</tr>
<tr>
<td>to hybrid stratum ventilation</td>
<td>40.43%</td>
</tr>
</tbody>
</table>

14/03/2013  AIVC Workshop on Ventilative Cooling 2013

### Smaller capacity of stratum ventilation leads to

(a) smaller mechanical plant and ductwork;
(b) air conditioning system occupies less indoor space;
(c) scaffolding is not necessary if the air ducts are installed in a cavity wall;
(d) substantially lower year-round energy consumption.

Qualitatively,
1. Initial cost is expected to be lower for Factors (a) to (c);
2. Operation cost is expected to be lower for Factors (a) and (d); and
3. lifecycle carbon footprint will be smaller for Factors (a) to (d).

14/03/2013  AIVC Workshop on Ventilative Cooling 2013
References

New solutions for modern passive cooling and heat redistribution

Workshop ‘Ventilative Cooling’
Brussels March 19 – 20, 2013

Bas Knoll

Normal passive cooling

- Minimal 10 to 20 x basic ventilation (2 × 0.5 m² or 1 m³/s) → additional system necessary
- Burglar-free openings (no windows but grills) or simple mechanical system
- Automatic, proportional temperature control (while you sleep)
- Silent night mode
Cooling needs in low energy houses
(results from simulations and measurements)

Summertime
› Increase of cooling demand with decrease of heating demand

Heating season
› Need for mitigation
› Time shift preferred
› Zonal temperature differentiation

→ Illustrations
Old (high energy): clearly heat demand occurs in winter and during summer night

Modern (low energy): cooling demand already in winter and even at summer nights
Zonal temperature differentiation

In bedrooms the desired temperature (optimal sleeping condition) is about 17°C, which is about 4 K lower than the living room. Due to increased energy efficiency this cannot be accomplished anymore, resulting in excess heat loss by window opening.

```
  15 °C  19 °C  17 °C  17 °C
  21 °C  21 °C  21 °C  21 °C
```

“old”  EPC = 0.8  EPC < 0.8  Zonal differentiation

High energy  Low energy

Observed window behaviour in HR ventilated low energy dwellings depending on temperature
Desired functional improvements

Summer:
- Extend cooling range
- Use ground cooling or another ‘high temperature’ buffer
- Use indirect evaporative cooling (more effective than adiabatic and no undesired humidification of indoor air)

Heating season:
- Increase damping (at least daily cycle), use short term storage
- Apply demand control for both ventilation and heat
- Differentiate in heat distribution over place and time (dynamic)

Low energy:
- Rather store than waste excess heat (load night/winter buffer)

Improved passive cooling

- Precooling by use of a ground duct →
  dew point control necessary to prevent mould growth

- Evaporative cooling 3 to 6 x basic ventilation (0.3 m³/s) will do →
  additional system necessary

- Possible combination with high volume cooker hood exhaust or with air heating system (recirculation switches to outdoor air)
Evaporative cooling

Indoor

Humidification

Heat exchanger (HR mode)

Recirculation off

Exhaust

Bypass

Control valve bypass

Outdoor

Dry cool supply

Decentral HR and LT heat distribution

Solar collector

Central exhaust

Heat exchangers

Ventilation supply CO₂-controlled

HR shower

Local humidity controlled exhaust valves

Cooker hood

LT heat distribution and collection circuit

LT Storage
Conclusions

- Low energy houses have a higher cooling demand in summer. Therefore, the use of a cold storage or more extensive natural cooling is preferred.

- The cooling needs extend to the heating season. They differ per room and in time.

- Hence, new ventilative cooling possibilities are propagated to control the temperature in low energy buildings.

- The collection of excess heat is preferred above wasting it.

- Demand control has to deal with not only ventilation but also with heat.

- The ventilation system is an ideal LT-heat distributor, while it already has the distribution function and it is the rare medium with temperatures below room level.