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**	
13^{00} – 14^{00}	**Registration and sandwich lunch**	
14^{00} – 14^{30}	**Welcome to seminar**	
	by venticool platform, Peter Wouters and Rémi Carrié, INIVE	1
	by Operating Agent of ECBCS Annex 62, Per Heiselberg, Aalborg University	7
14^{30} – 15^{45}	**Ventilative Cooling Needs and Potential**	
	Moderator discussion: Max Sherman, LBL, US	
	• Urban heat island, climate change and impact on ventilation for cooling, Maria Kolokotroni, Brunel University, UK	15
	• Personal control over indoor climate and the use of operable windows in offices, Atze Boerstra, Eindhoven University of Technology, Netherlands	35
	• Ventilative cooling potential of outdoor air - now and in the future, Per Heiselberg, Aalborg University, Denmark	45
15^{45} – 16^{00}	**Break**	
16^{00} – 17^{30}	**Ventilative Cooling in Buildings**	
	Moderator discussion: Per Heiselberg, Aalborg University, Denmark	
	• Energy efficient design of a passive school using thermal dynamic simulations, Joerie Alderweireldt, 3E, Belgium	55
	• A ventilative cooling system in a School Building, Imola, Italy, Mario Grosso, Politecnico di Torino	71
	• Passive cooling with natural ventilation rate, a case study, Pier Nicola Currà, Archefice associati, Italy	83
	• Examples of built naturally cooled buildings, Flourentzos Flourentzou, Estia SA, Switzerland	89
19^{00}	**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 Kolokotroni (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 Kolokotroni, 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
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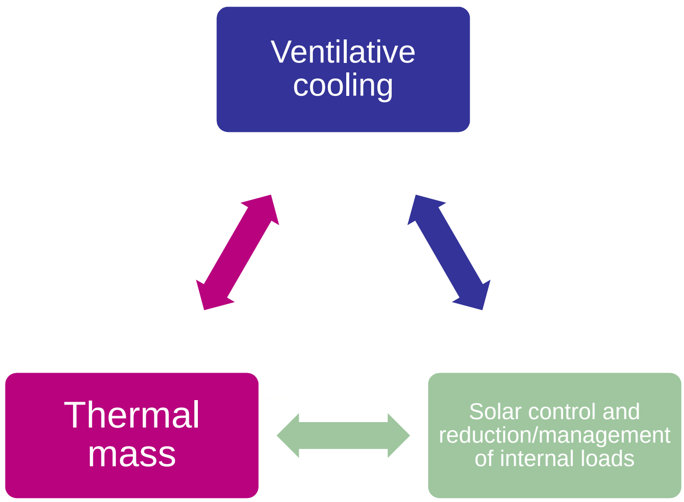
Peter Wouters and **Rémi Carrié**
INIVE EEIG

International Network for Information on Ventilation and Energy Performance

BUILD UP 4u
energy solutions
for better buildings
March 2013
AIVC/venticool/TightVent Workshops, Brussels
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 intelligent buildings for the future. (...)"
AIVC
TightVent Europe
venticool

AIVC
The IEA Information Centre on Energy Efficient Ventilation
countries
countries
countries
Newsletter
Air Infiltration and Ventilation Centre
AIVC now counts 15 members countries
In this issue

In the context of an energy efficient thermal comfort strategy…



venticool
the european platform for ventilative cooling

Newsletter
No1 • OCTOBER 2012

Welcome to **venticool**

It is with pleasure that we present to you this first newsletter of the European Ventilative Cooling Platform, **venticool.**

Are we aware about the energy saving potential of ventilative cooling? Is it sufficiently well-covered in (future NZEB) regulations to promote its adequate use? We believe that this strategy, if well designed and executed, can play a major role in the context of a drastic energy use reduction in buildings as required by the recast of the Energy Performance of Buildings Directive.

Through this newsletter, you will be regularly informed on the latest developments on ventilative cooling, including policy issues, events, innovative concepts, standardization, case studies, etc. Please, feel free to visit our website at **www.venticool.eu**

Peter Wouters, Manager of INIVE EEIG

Official Launch of the Ventilative Cooling Platform at the Copenhagen conference

an we reconcile the ambitious goals f the recast of the Energy erformance of Buildings Directive -- n particular, 2020 objective to realise early zero-energy buildings – with good thermal comfort and indoor ir quality? There are reasons to be ptimistic given the efforts undertaken y governments, industry and building rofessionals in the past few years. But t the same time, it remains extremely hallenging to effectively have all new uildings in 2020 meeting the nearly ero-energy target.

he learning process is clearly nderway and it is stimulated by the ommunication and feedback from a umber of real projects. Some of these rojects demonstrate the potential of natural or mechanical) ventilative cooling which, as part of an overall design strategy including adequate solar protections, intelligent use of thermal mass and sometimes support of active cooling, can help improve thermal comfort. Therefore, this strategy is more and more considered to reduce the cooling energy demand in summer and/or mid-season conditions, depending in particular on outdoor climate, building design and internal loads.

However, there are several concerns:

- Not all buildings function in line with the assumed performances and sometimes the real indoor climate is far away from the predicted performances;
- The national energy performance regulations not always reward the

What is ventilative cooling?

Ventilative cooling refers to the use of natural or mechanical ventilation strategies to cool indoor spaces. This effective use of outside air reduces the energy consumption of cooling systems while maintaining thermal comfort. The most common technique is the use of increased ventilation airflow rates and night ventilation, but other technologies may be considered as well. Ventilative cooling is relevant in a wide range of buildings and may even be critical to realize renovated or new NZEB.

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

venticool

the international platform for ventilative cooling

The Ventilative Cooling Platform is at present supported by:

AGORIA

ES-SO

eurima

VELUX

WindowMaster

Events

- 2013 AIVC conference, Athens, Greece, 25-26 September 2013
  - 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

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Ventilative Cooling

Per Heiselberg
Aalborg University

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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

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Why do we have a 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”

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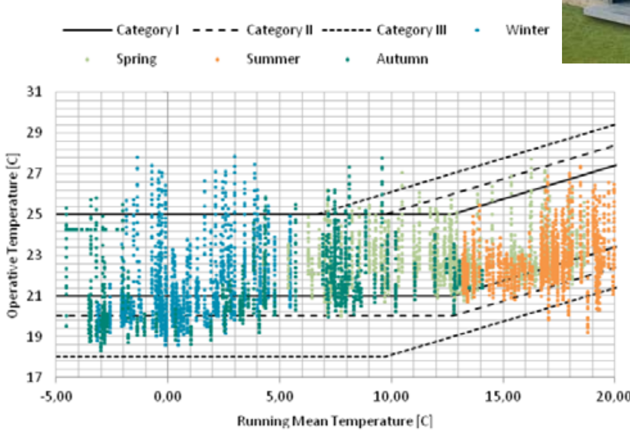
Overheating Risk – Living Room



Kilde: Esbensen

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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 system is still limited in many countries

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Offices in Cold Climate

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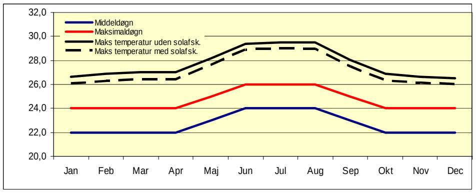
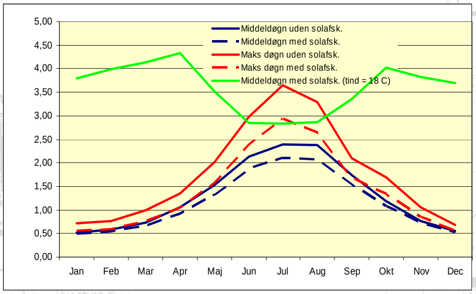
Challenges in a Cold Climate





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IEA ECBCS Annex 62

Ventilative Cooling

A new international project under preparation

International Energy Agency

International Energy Agency
Energy Conservation in Buildings and Community Systems Programme

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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?"

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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

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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).

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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

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Annex Organization

- Subtask A: Tools and guidelines
- Subtask B: Solutions
- Subtask C: Case studies

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

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

- 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

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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

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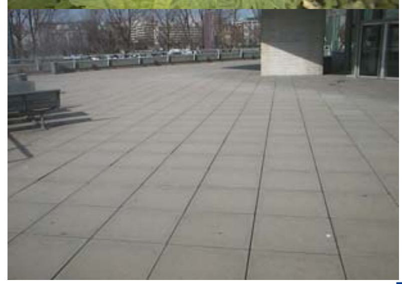
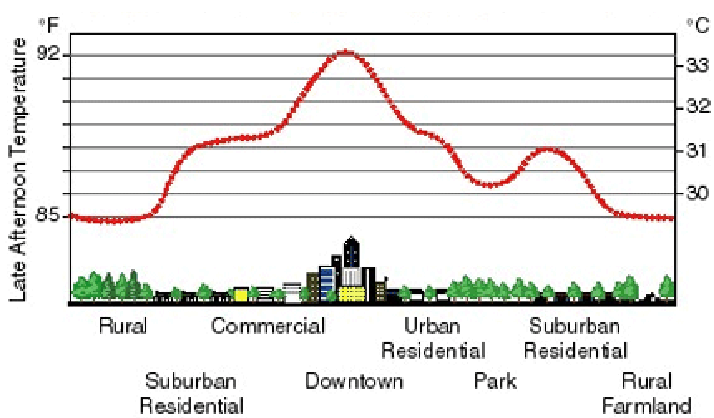
Vegetation

- 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

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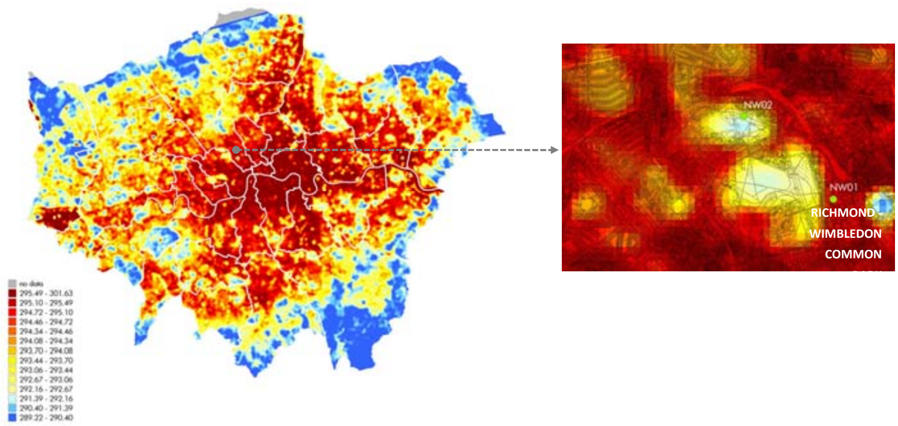
Source: The LUCID project

http://www.lucid-project.org.uk

Land Surface Temperature, 12 July 2006, 21.00 UT
ASTER satellite image



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Urban Heat Island

- Body of work in hot climates, US, Europe and Asia
- What happens in moderate climates such as London?
- We measured it!

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Measurement station

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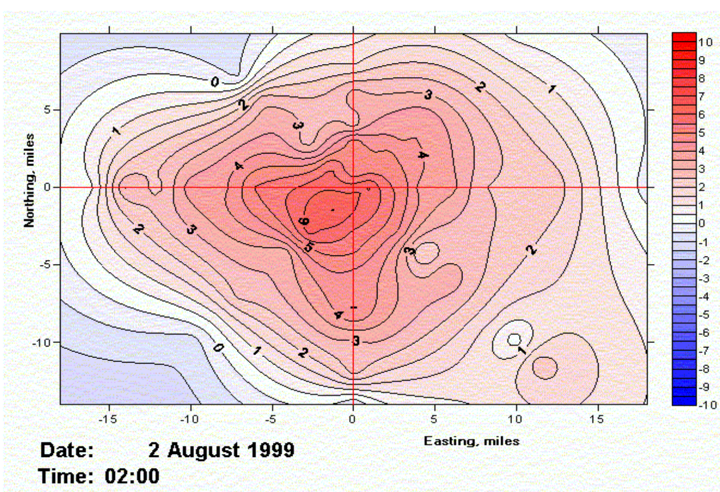
Example of the variation in heat island intensity across London



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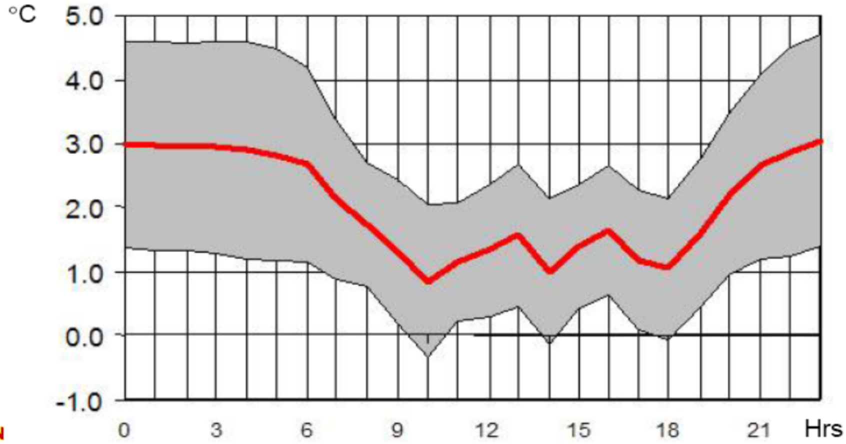
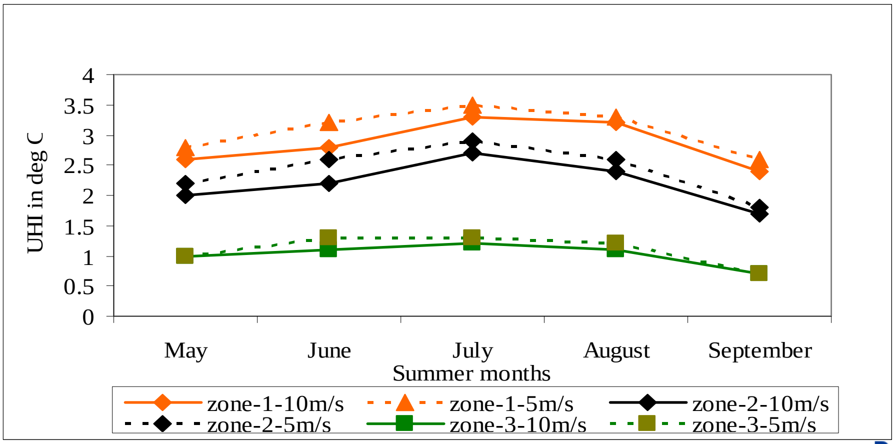
GLA report: London's Urban Heat Island

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



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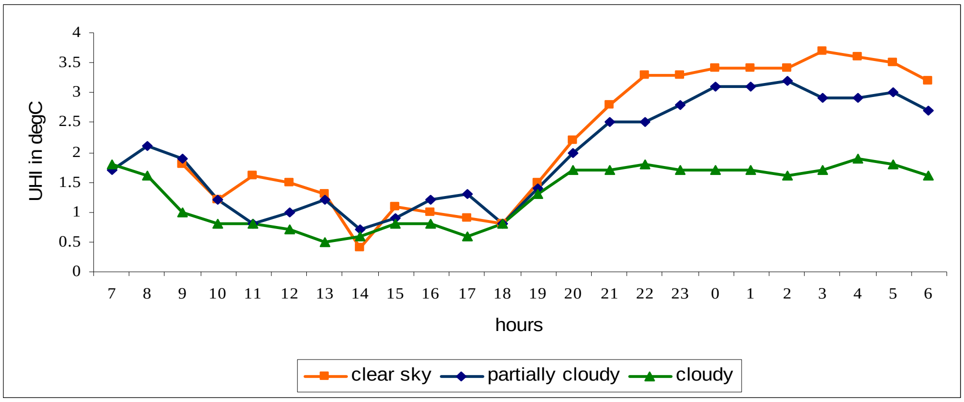
Hourly mean UHI value with wind speed less than 5 m/s for Core Area (zone-1)



London to be divided into three zones – consistent with CIBSE Guide A, 2006

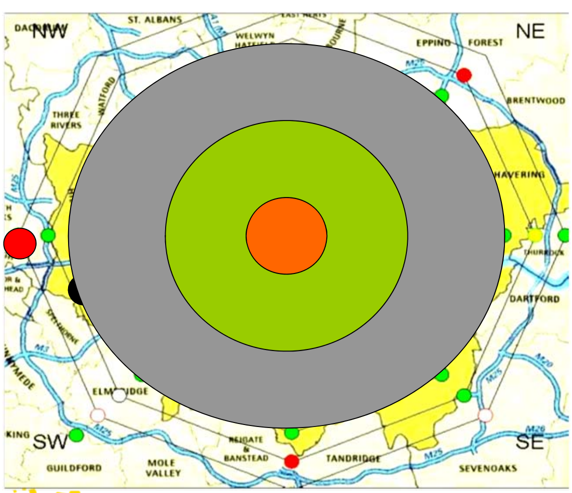


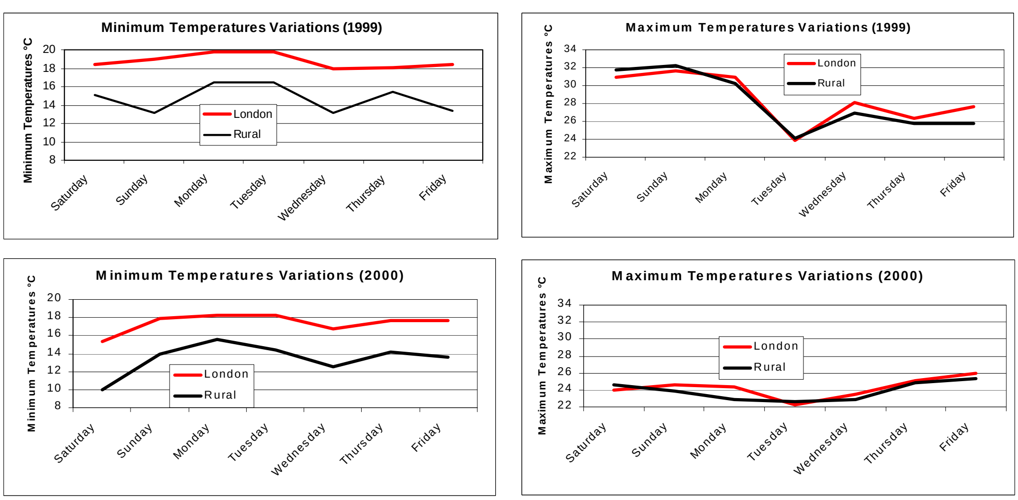
Table 2
Proposed air temperature corrections based on radial distance from city centre

Hour	Distance from city centre			Rural reference
	0–3 km	3–10 km	10–23 km	
0	1.9	1.0	−0.9	−2.3
1	1.9	1.1	−0.9	−2.5
2	1.9	1.1	−0.7	−2.0
3	1.7	0.9	−0.7	−2.3
4	1.5	0.8	−0.7	−2.3
5	1.4	0.7	−0.6	−2.3
6	1.7	1.3	−0.4	−2.5
7	1.5	1.9	0.8	−1.3
8	1.7	2.0	1.3	−0.7
9	1.8	2.2	1.5	−0.4
10	1.6	2.0	1.4	0.7
11	1.4	1.8	1.3	0.0
12	1.7	2.1	1.3	−0.2
13	1.6	2.2	1.4	−0.2
14	0.6	1.1	0.4	0.9
15	0.9	1.4	0.5	0.0
16	0.9	1.4	0.4	−0.1
17	0.7	1.0	0.2	−0.2
18	0.4	0.8	0.0	0.8
19	0.4	0.4	−0.4	−0.5
20	0.6	0.3	−0.9	−1.9
21	1.0	0.3	−1.4	−2.7
22	1.5	0.6	−1.3	−2.7
23	1.5	0.6	−1.3	−2.8
Average	1.3	1.2	0.0	−1.1

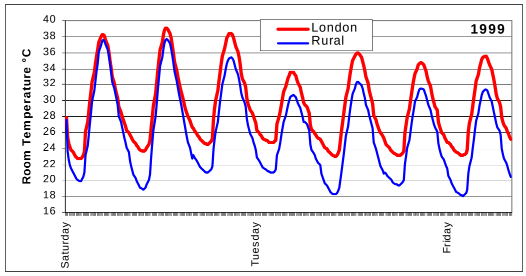
- Core
- Urban
- Semi-urban

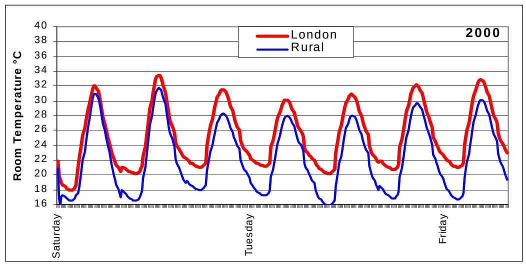
What is the effect on night ventilation?

Effect on air temperature

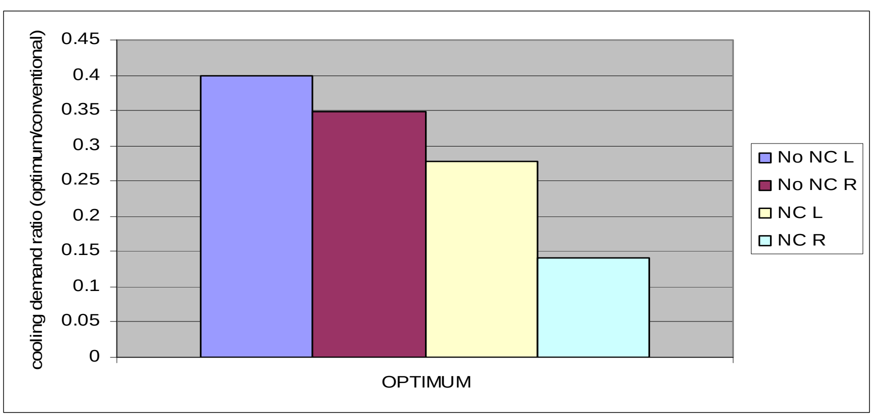


Effect on night cooling strategy





Cooling demand reduction potential through night ventilation



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UHI, energy use and climate change

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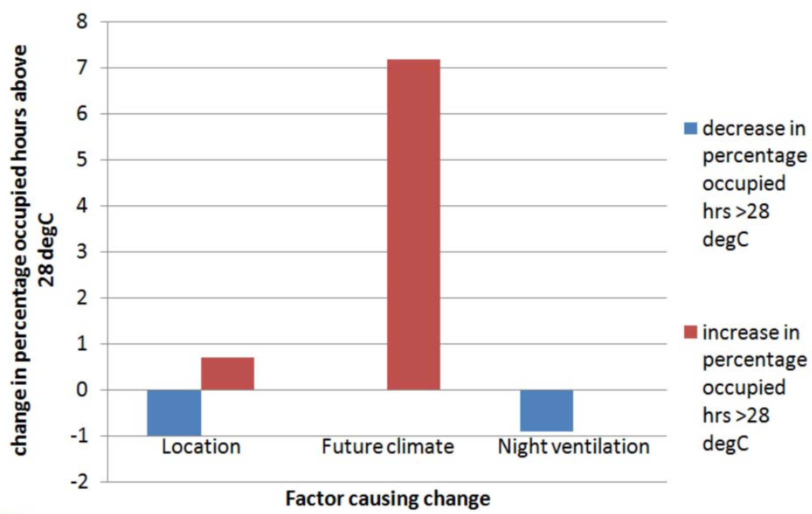
The challenge: to model the effect of future climate on buildings within UHI



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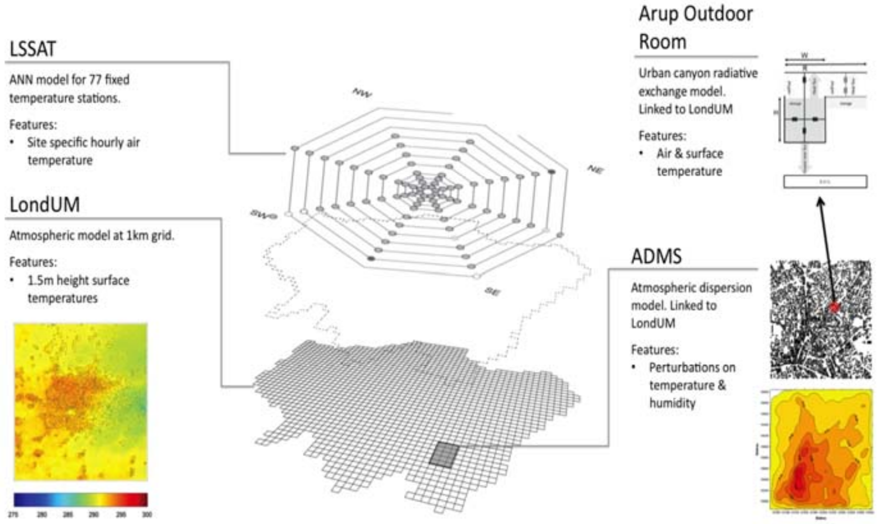
EPSRC: LUCID: The Development of a Local Urban Climate Model and its Application to the Intelligent Development of Cities, UCL/Reading/Brunel, www.lucid-project.org.uk



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 on a 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

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Step 1- Brief description of ANN model

Air temperature dataset 2000 for sites in London

+

Heathrow weather data for 2000

Mat lab 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

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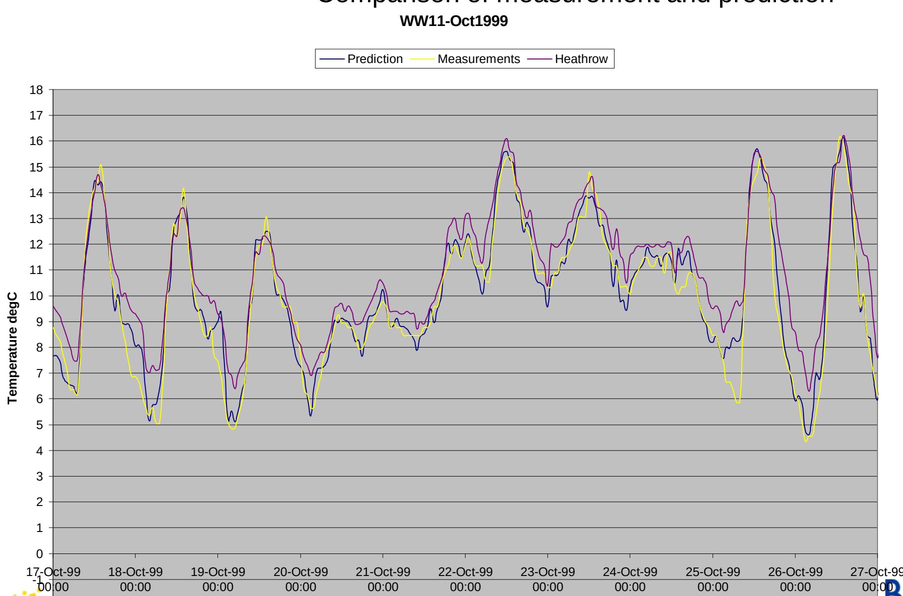
Comparison of measurement and prediction



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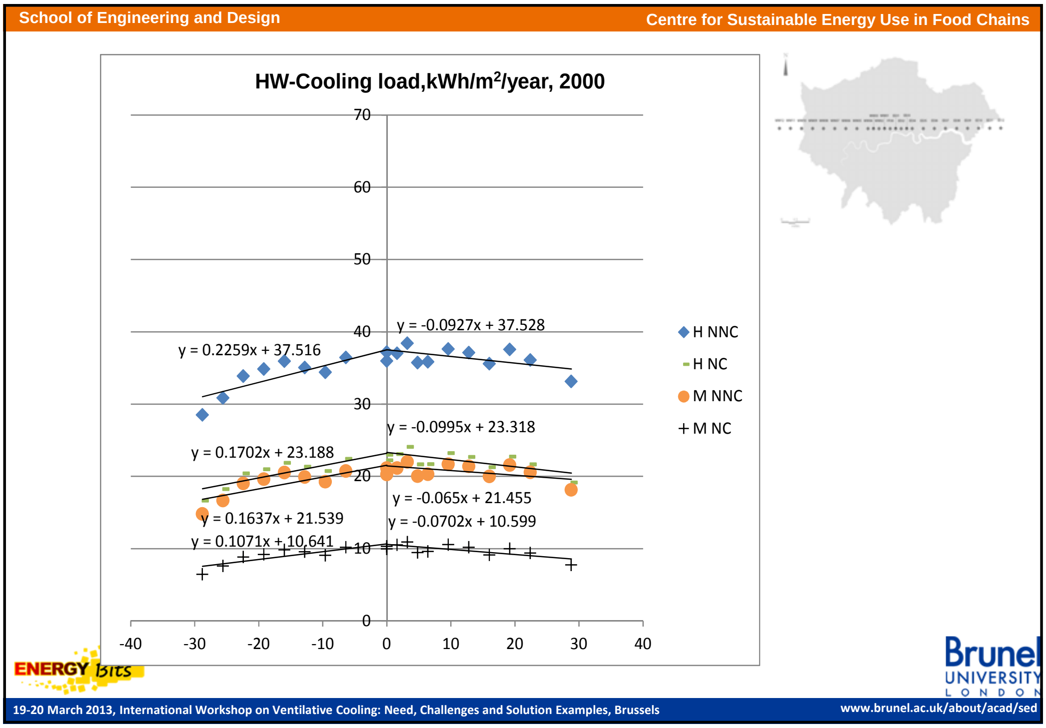
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HW-Cooling load,kWh/m2/year, 2000
y = 0.2259x + 37.516
y = -0.0927x + 37.528
y = 0.1702x + 23.188
y = -0.0995x + 23.318
y = -0.065x + 21.455
y = 0.1637x + 21.539
y = -0.0702x + 10.599
y = 0.1071x + 10.641
H NNC
H NC
M NNC
M NC
70
60
50
40
30
20
10
0
-40
-30
-20
-10
0
10
20
30
40
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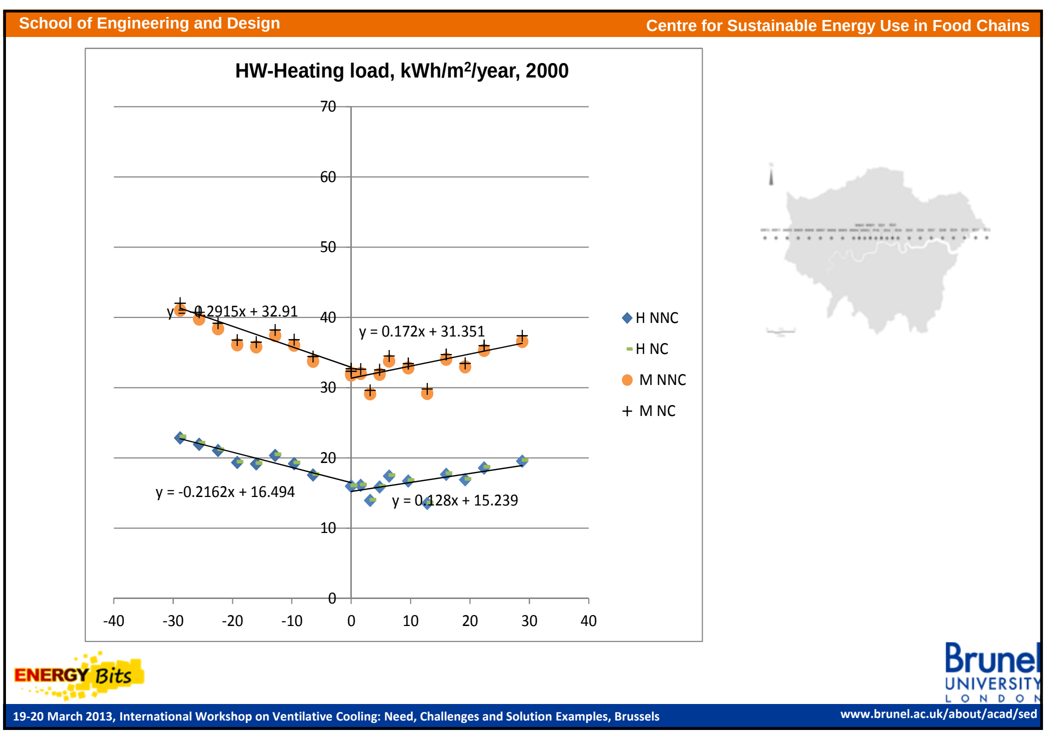
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HW-Heating load, kWh/m2/year, 2000
y = -0.2915x + 32.91
y = 0.172x + 31.351
y = -0.2162x + 16.494
y = 0.128x + 15.239
H NNC
H NC
M NNC
M NC
70
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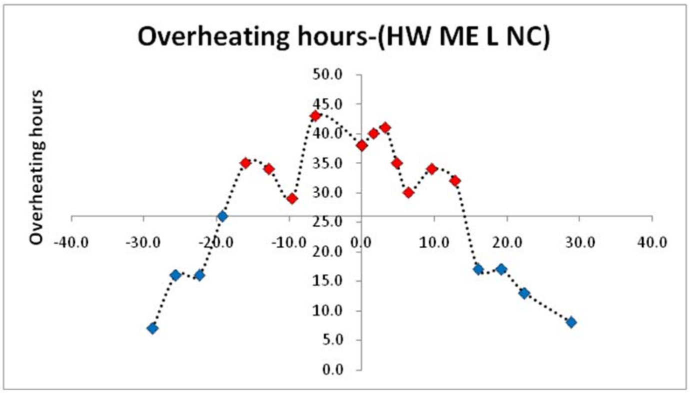
ENERGY Bits
Brunel UNIVERSITY LONDON
19-20 March 2013, International Workshop on Ventilative Cooling: Need, Challenges and Solution Examples, Brussels
www.brunel.ac.uk/about/acad/sed



Using future weather files

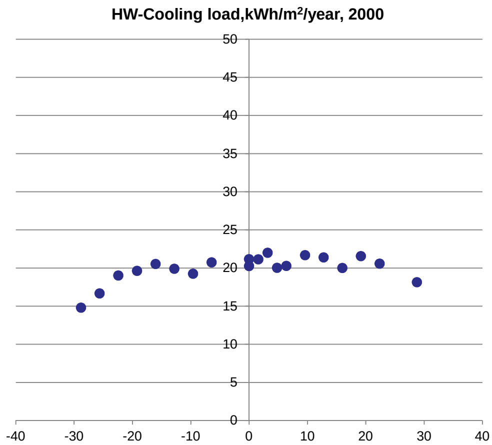
- we used CIBSE weather files for London 2050 (medium-high scenario, according to UKCP02)
- these were constructed using the method developed by Hacker and Blecher to predict parameters on an hourly basis
- we adapted air temperature based on the results of LSSAT. Everything else was kept the same over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

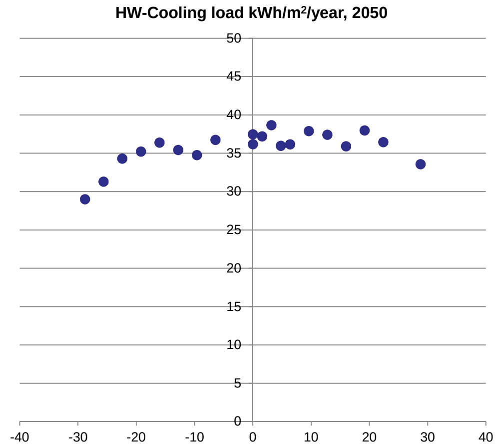
- More information:
- Demanuele C, Mavrogianni A, Davies M, Kolokotroni M, Rajapaksha I, (2012). *London's urban heat island: impact on overheating in naturally ventilated offices*. Serv. Eng. Res. Technol. 33, 4 (2012) pp. 351–369.
- Kolokotroni M., Ren X., Davies M., Mavrogianni A (2012). *London's urban heat island: impact on current and future energy consumption for heating and cooling*. Energy and Buildings, Vol 47, pp 302-311

School of Engineering and Design

Centre for Sustainable Energy Use in Food Chains

UHI, energy use and climate change





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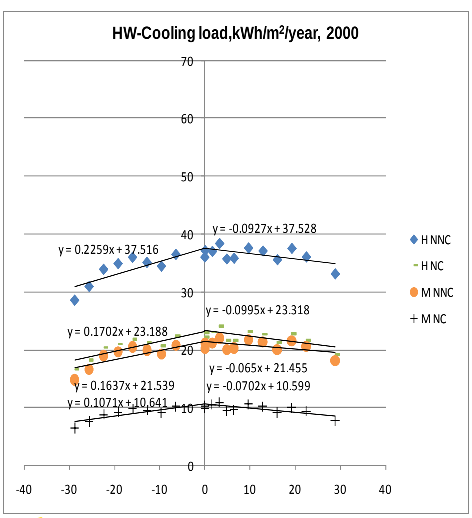
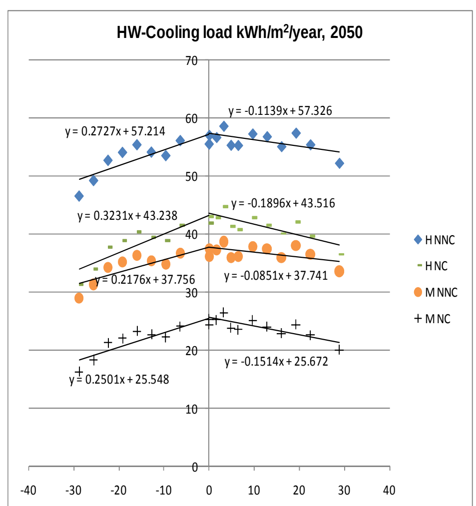
UHI, ventilation and climate change





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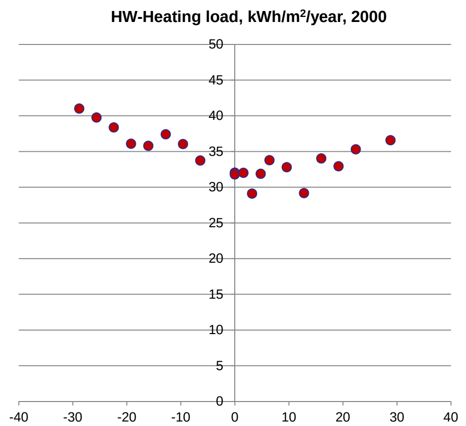
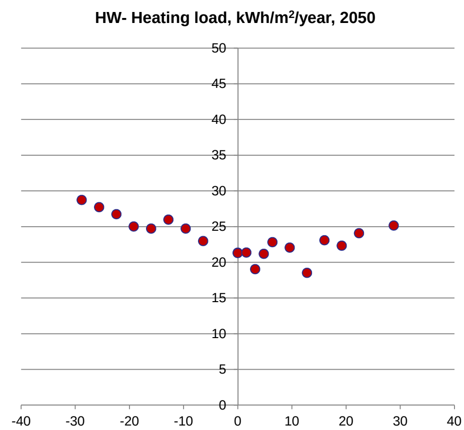
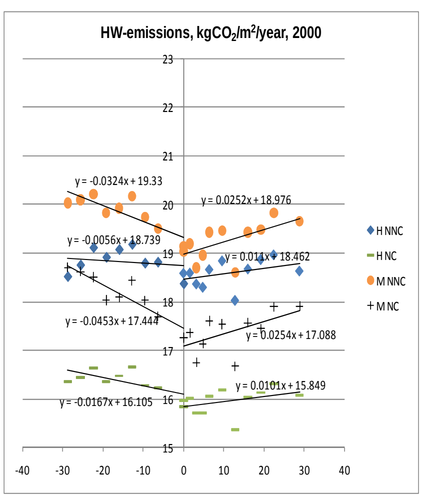
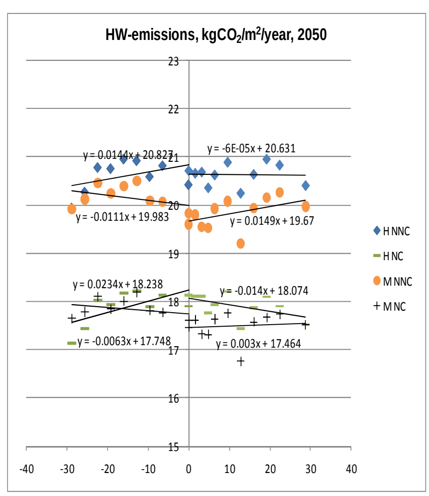
UHI, ventilation and climate change





UHI, ventilation and climate change





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!

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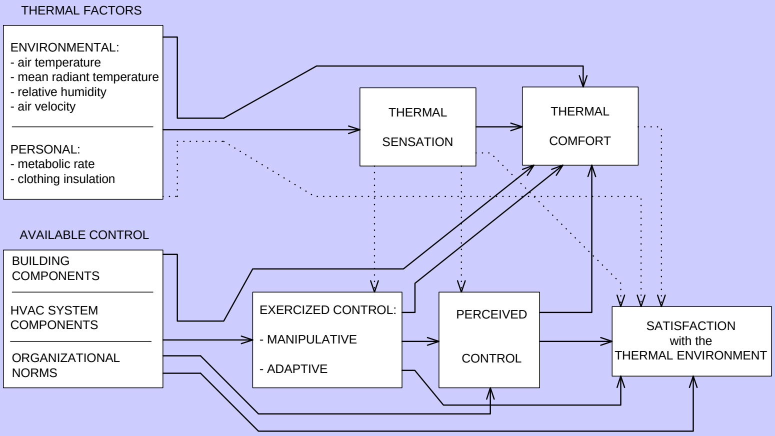
AIVC Ventilative Cooling workshop
Brussels - March 19+20, 2013

PERSONAL CONTROL OVER INDOOR CLIMATE AND THE USE OF OPERABLE WINDOWS IN OFFICES

Atze Boerstra
BBA Indoor Environmental Consultancy +
Eindhoven University of Technology

BBA www.binnenmilieu.nl

THEORY I: CONCEPTUAL MODEL PACIUK (1990)



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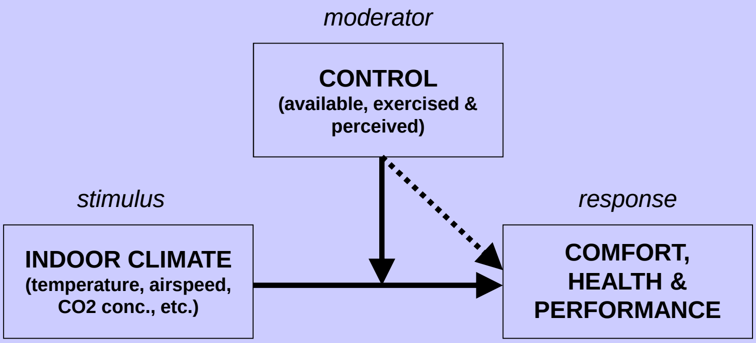
THEORY II: CONCEPTUAL MODEL BOERSTRA ET AL (2013)



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)

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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)	Brager GS et al. (2004)
Chow & Fung (1994)	Gong N et al. (2006)
Fountain et al. (1994)	Atthajariyakul & Lertsatittanakorn (2008)
Mallick (1996)	Yang & Zhang (2009)
Kubo et al. (1997)	Zhang et al. (2007)
Kitagawa et al. (1999)	Baizhan et al. (2010)
Cena & deDear (1999)	Cândido et al. (2010)
Donnini et al. (1997)	Chow et al. (2010)
Khedari et al. (2000)	and many more…
Xia YZ et al. (2000)	

DRAFTS IN WINTER ARE PLEASURABLE BREEZES IN SUMMER!

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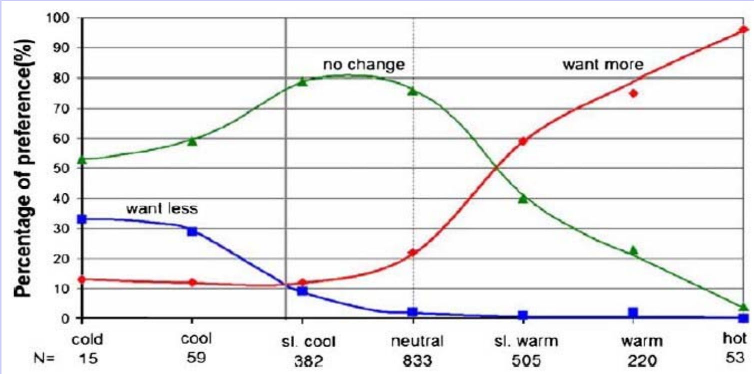
AIR MOVEMENT PREFERENCE AND THERMAL SENSATION



Zhang et al. 2007

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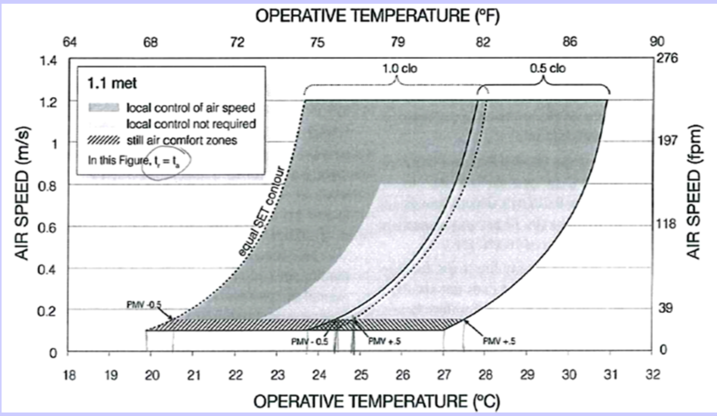
'NEW' TEMPERATURE / AIRSPEED GRAPH IN ASHRAE STANDARD 55: 2010



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‘Breeze figure’ in EN-ISO 7730: 2005

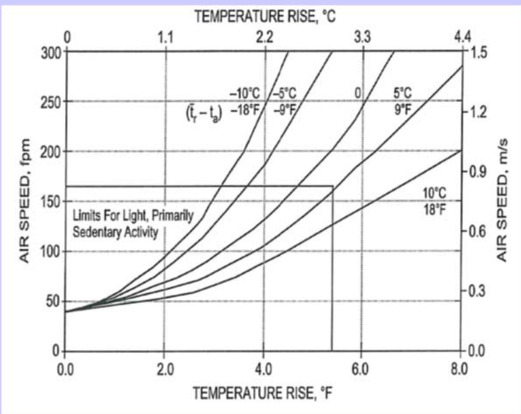

Fig. 5.3 Air velocity required to offset increased temperature

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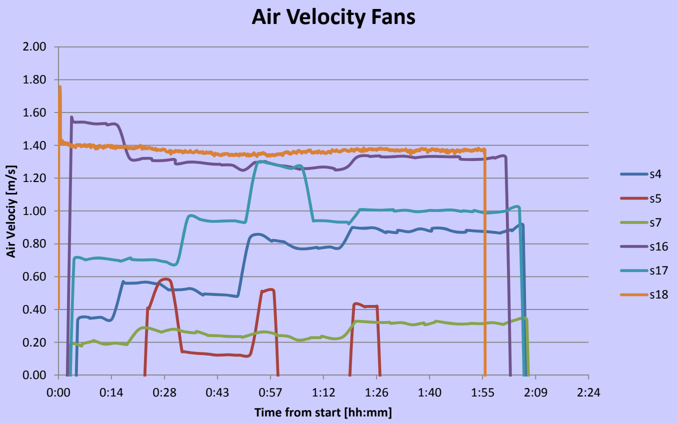
LARGE INVIDIDUAL DIFFERENCES (direct control is essential)

Example results of preferred airspeed in a laboratorium room of 28 ºC 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. .....

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

Use of controls - WINTER

		Count	Perc.
Operable window use	daily	30	19%
	weekly	38	24%
	monthly	23	14%
	less than monthly / never	48	30%
	not applicable	20	13%
	Total	159	100%
Temperature knob use	daily	16	10%
	weekly	18	11%
	monthly	31	19%
	less than monthly / never	48	30%
	not applicable	48	30%
	Total	161	100%
Clothing adjustment	daily	33	23%
	weekly	38	26%
	monthly	26	18%
	less than monthly / never	48	33%
	Total	145	100%

Use of controls - SUMMER

		Count	Perc.
Operable window use	daily	76	48%
	weekly	17	11%
	monthly	27	17%
	less than monthly / never	15	9%
	not applicable	24	15%
	Total	159	100%
Temperature knob use	daily	1	1%
	weekly	5	3%
	monthly	7	4%
	less than monthly / never	95	60%
	not applicable	51	32%
	Total	159	100%
Clothing adjustment	daily	33	24%
	weekly	26	19%
	monthly	30	22%
	less than monthly / never	50	36%
	Total	139	100%

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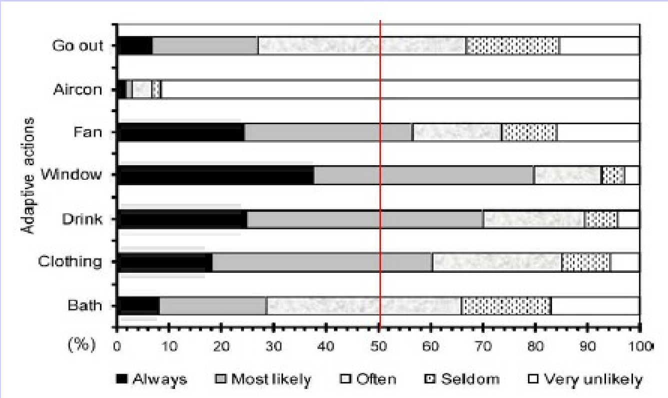
Adaptive behavioural actions acc. to Feriadi & Wong (2004)



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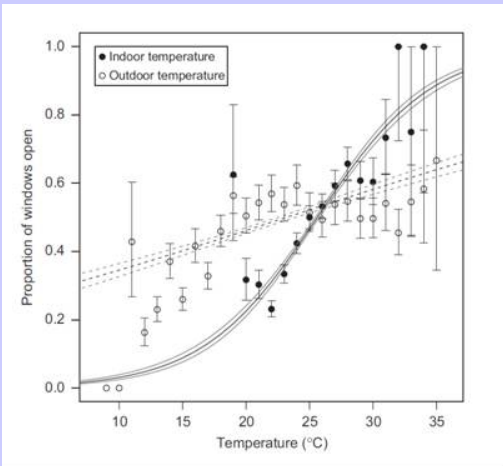
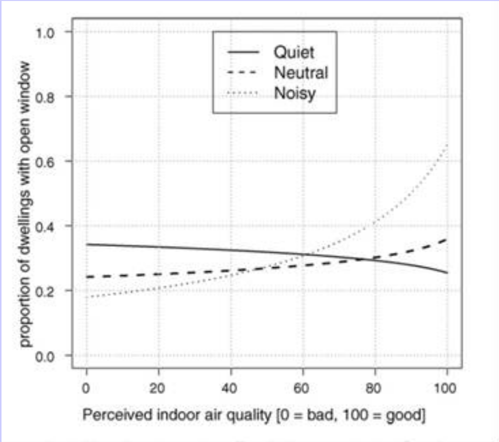
Window opening probability in offices as a function of indoor and outdoor temperature (Haldi & Robinson, 2008)



Association between proportion of dwellings with open windows and perceived indoor air quality and outside noise situation (Andersen et al, 2009)



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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 collegues one shares the room with, design of the operable window, window interface etc.)

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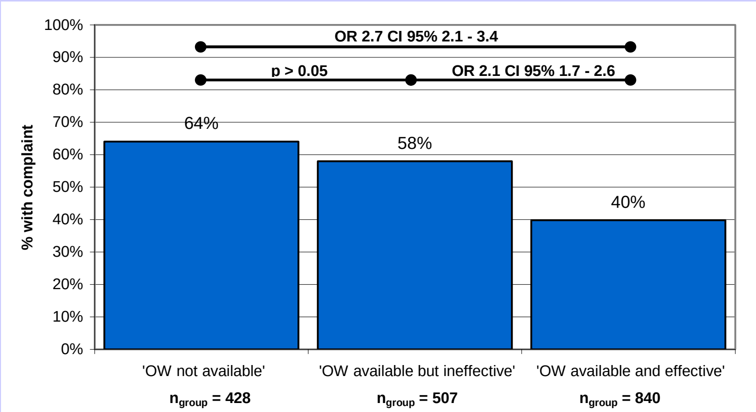
Access to Operable Windows (OW) and percentage of respondents 'often experiencing air as stuffy, smelly or stale' (Boerstra et al, 2011)



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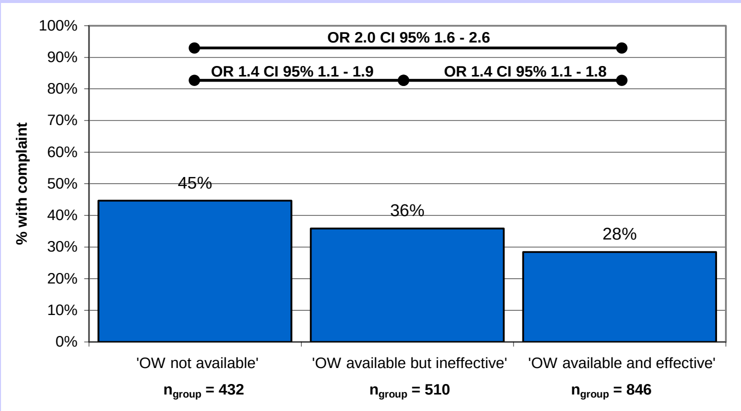
Access to Operable Windows (OW) and percentage of respondents with Personal Symptom Index > 2 (scale 0-5) (Boerstra et al, 2011)



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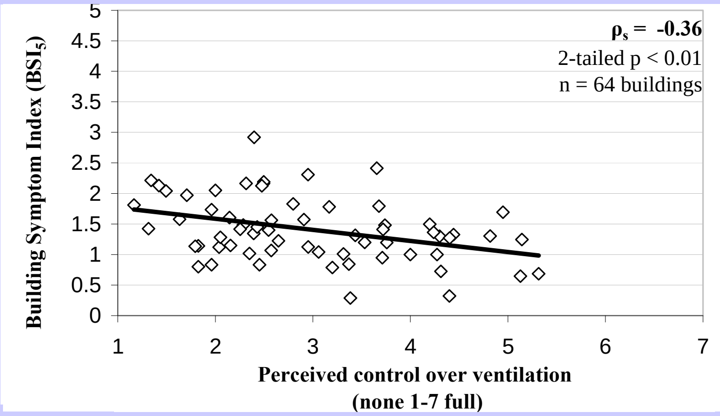
Perceived control over ventilation and incidence of SBS symptoms (Boerstra et al, 2013)



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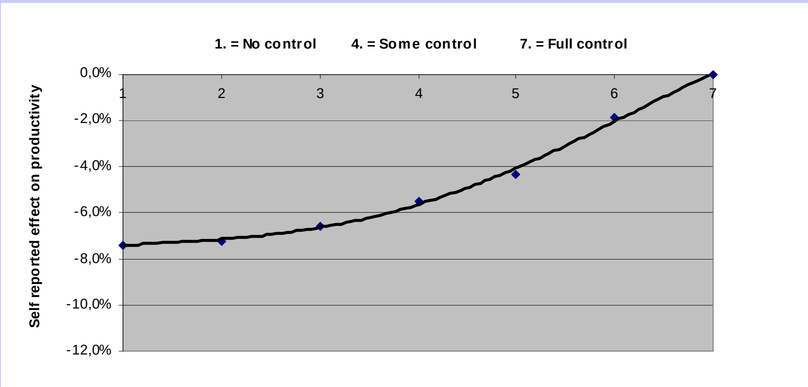
The impact of perceived control over ventilation on self reported productivity (based on: Raw, 1990)



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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

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Ventilative Cooling Potential of Outdoor Air – Now and in the future

Per Heiselberg
Aalborg University

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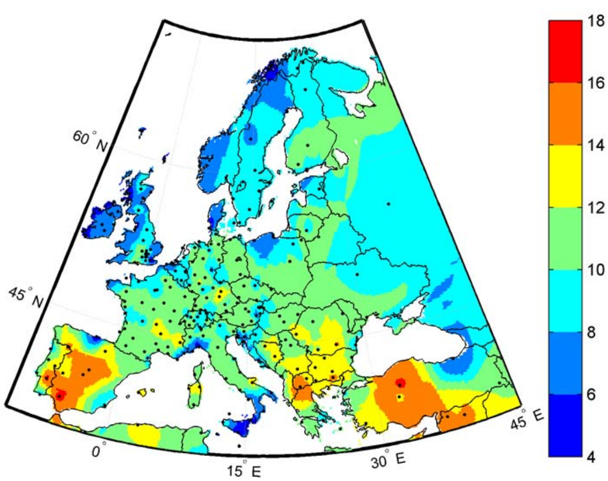
Mean Temp. Difference between Max. and Min. in July



Meteonorm Data

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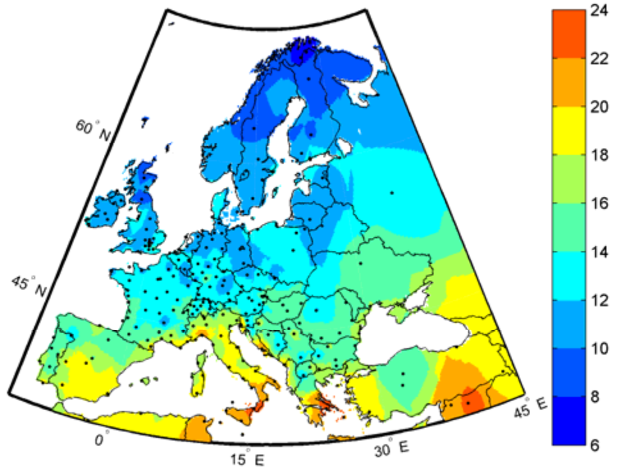
Daily Minimum Temperature July



Meteonorm Data

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Climatic potential for night-time cooling

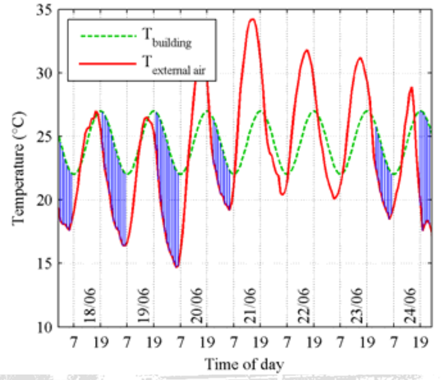
- Degree hours method to quantify the climatic cooling potential (CCP)
- Harmonically oscillating building temperature within a range of thermal comfort:

  $T_b = 24.5°C \pm 2.5°C$
- Ventilation period: 7 pm – 7 am
- Minimum temperature difference:

  $\Delta T_{crit} = 3K$

➔ *CCP* (K h)

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



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

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Practical significance of CCP

Example:

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

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

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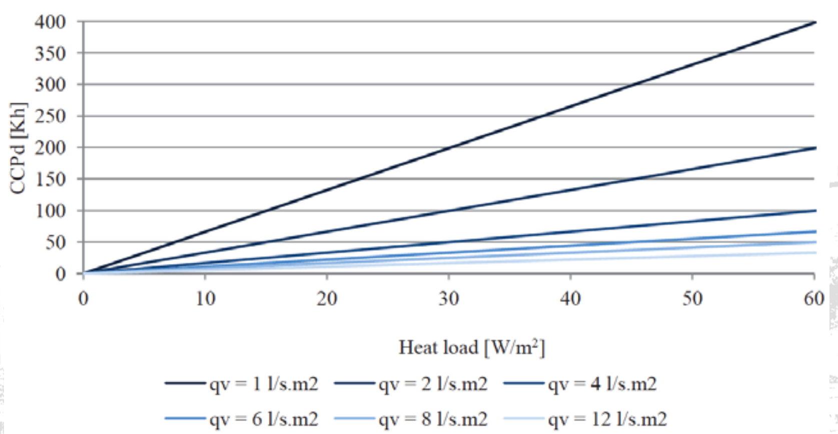
Necessary CCP

As a function of heat load and ventilation air flow rate



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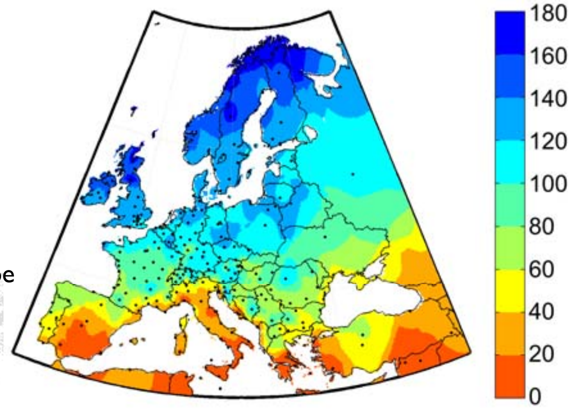
Local variability

Semi-synthetic data (Meteonorm) from 259 locations in Europe

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



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

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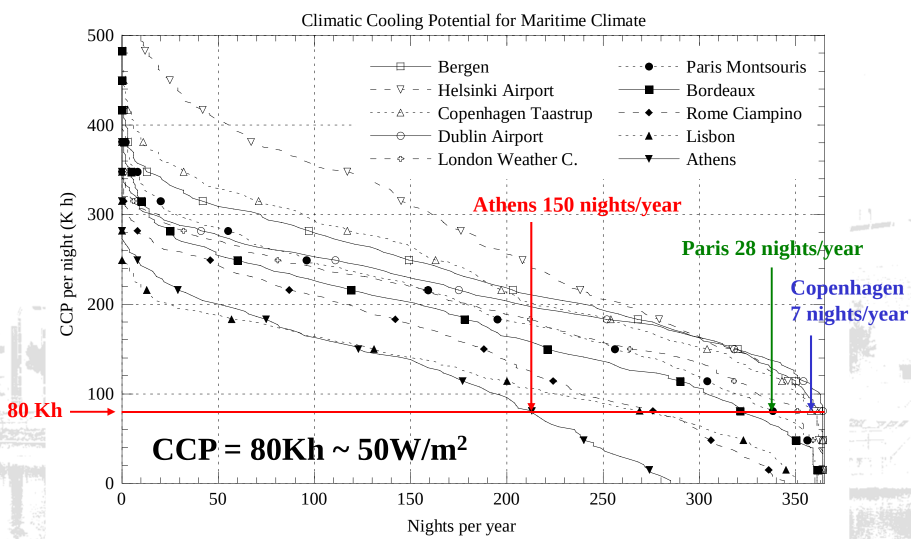
Cumulative frequency distribution of CCP



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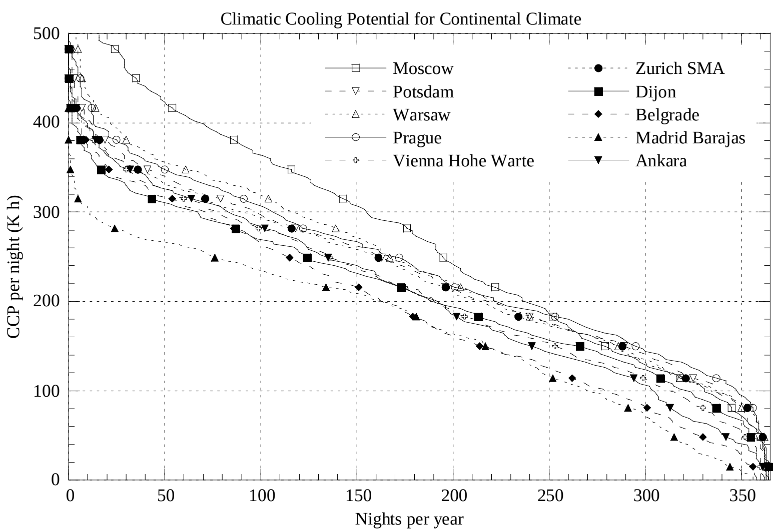

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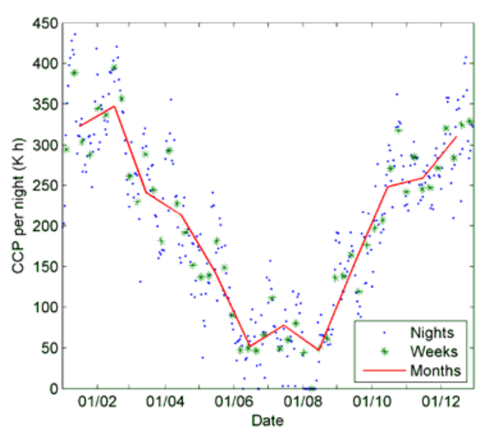
CCP in different time

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**



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

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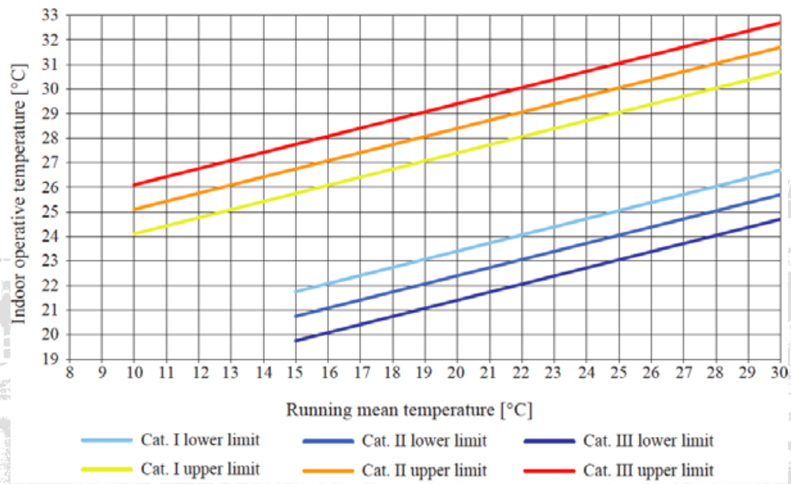
Adaptive comfort approach

Operative temperature as function of external running mean, EN 15251



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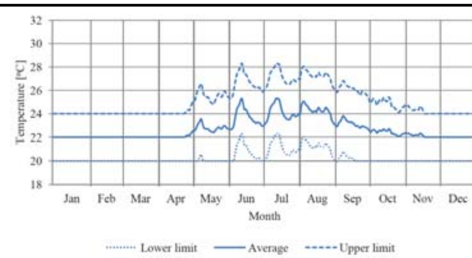
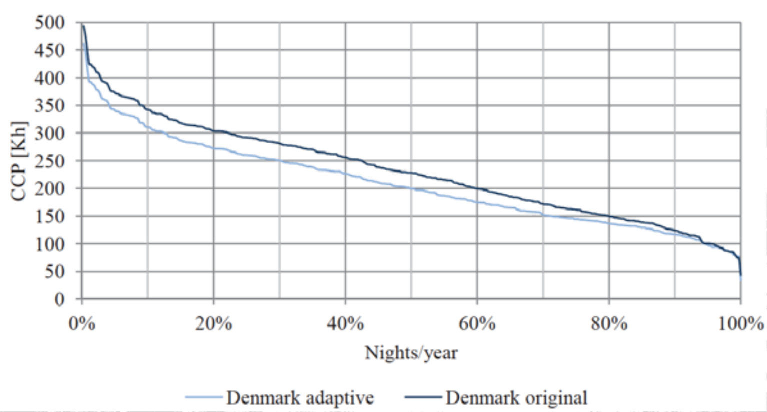
Impact in cool climates Denmark





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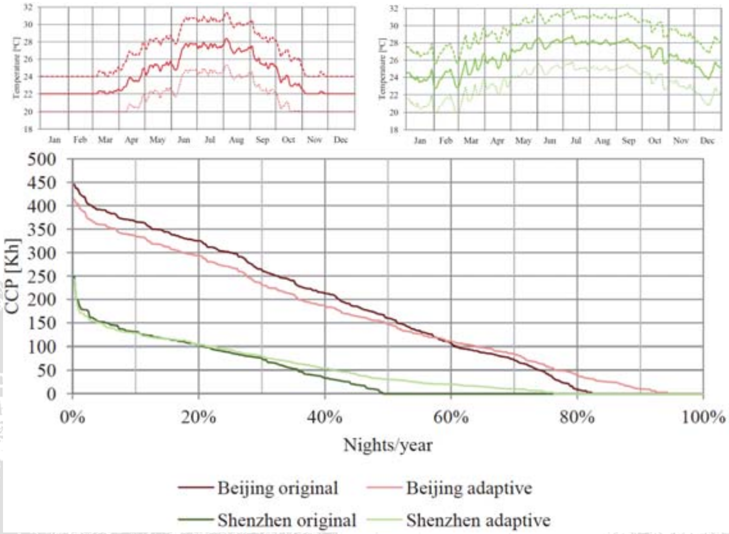
Impact in warmer climate, Beijing, Shenzhen



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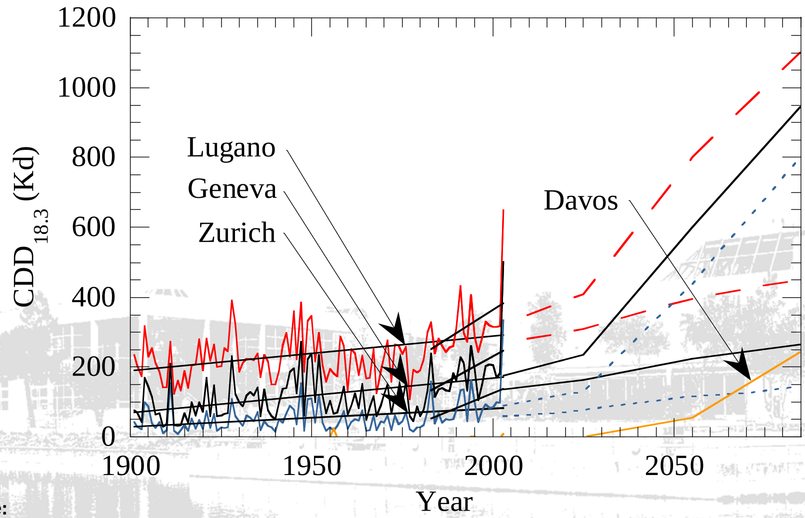
Increase in cooling degree days



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

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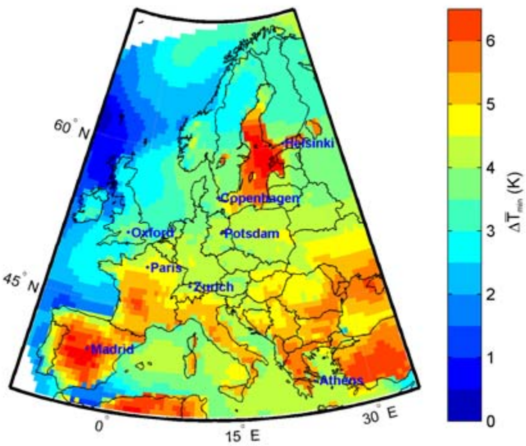
Change in long-term mean daily minimum temperature in summer (JJA)

- “A2” emissions scenario for the years 2071-2100 relative to the baseline 1961-1990, as simulated by the Danish Meteorological Institute regional climate model. Simulations were based on boundary conditions from the HadAM3H atmospheric general circulation model (Table A1: Scenario No S1). Data from PRUDENCE (2006).



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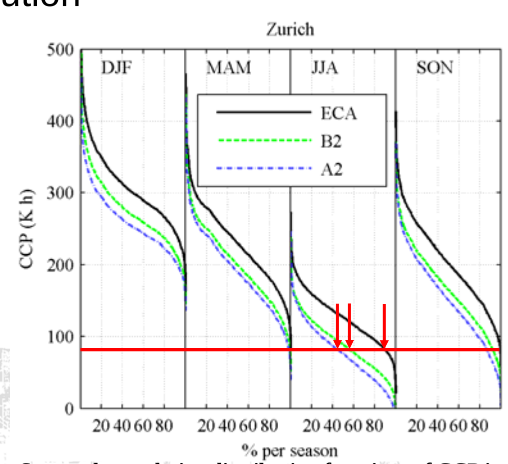
Cumulative distribution

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

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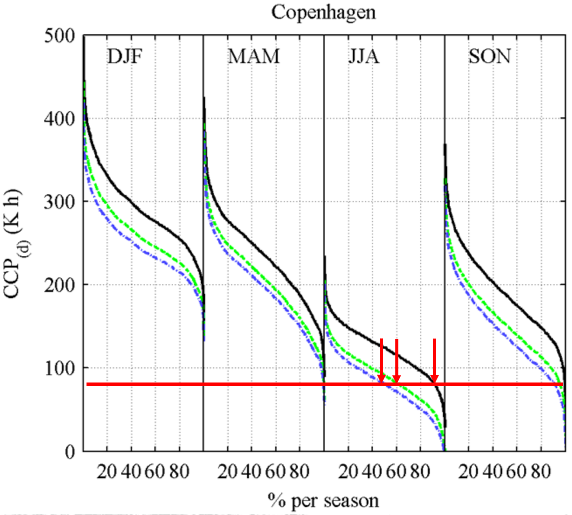
Passive Cooling Potential



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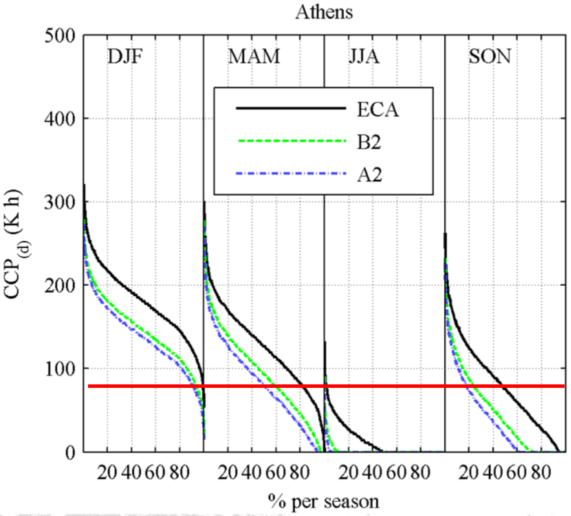
Passive Cooling Potential



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Summary

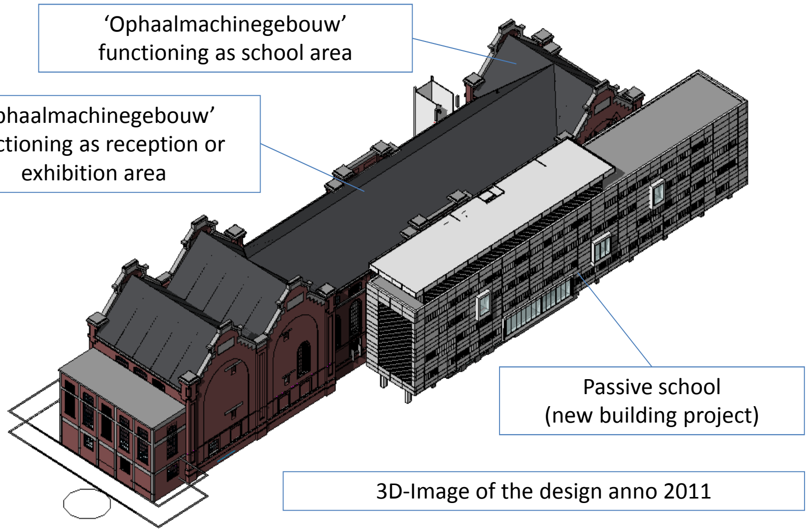
- Application of the CCP approach is a fast method to evaluate the night cooling potential considering both outdoor climate, building heat load and ventilation flow rate
- Application of the adaptive comfort approach increases the night cooling potential in warm periods
- According to predicted scenarios 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

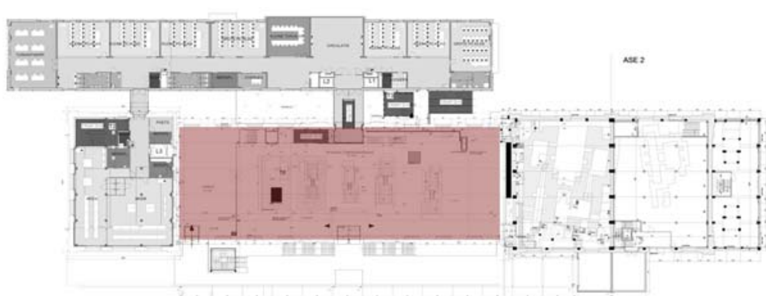
Joerie Alderweireldt (3E)

Joerie Alderweireldt (3E)



3D-Image of the design anno 2011

Joerie Alderweireldt (3E)



Joerie Alderweireldt (3E)

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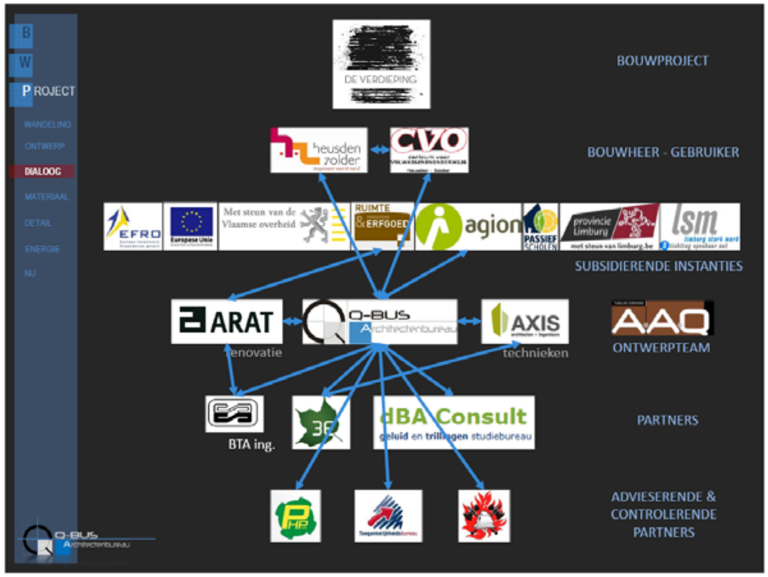
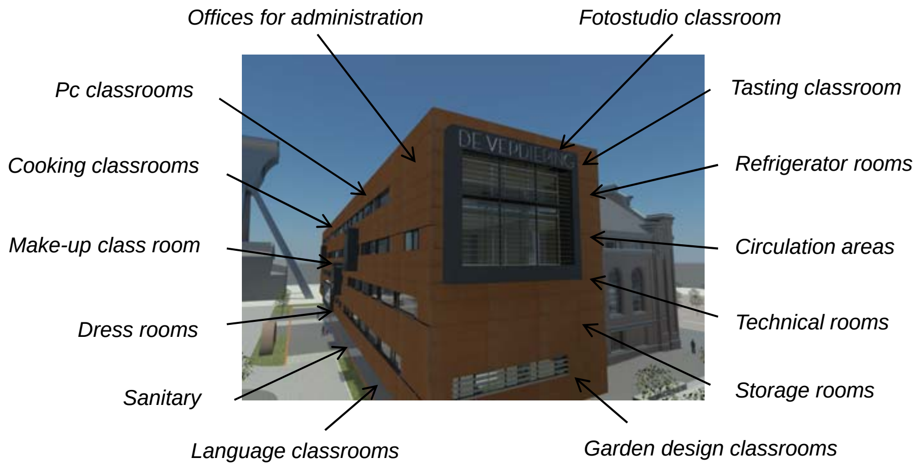


Joerie Alderweireldt (3E)

Cloud of different room types in the school:



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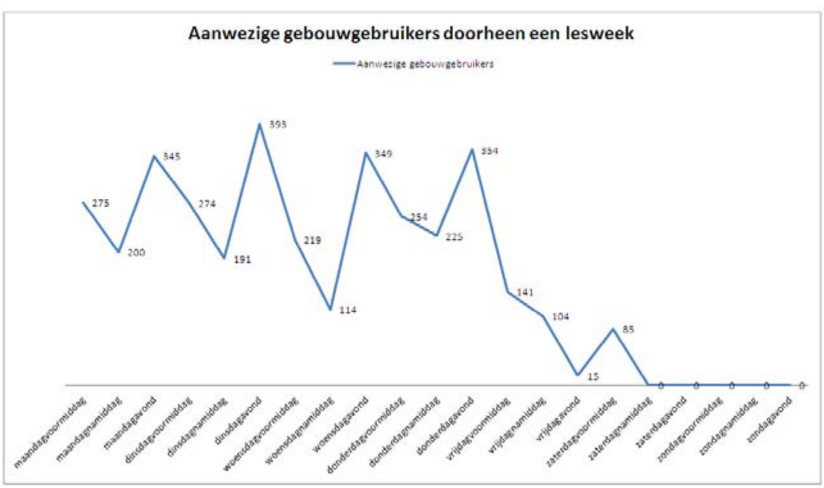
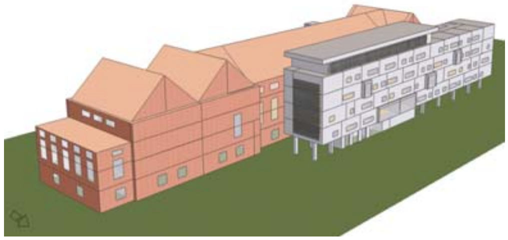
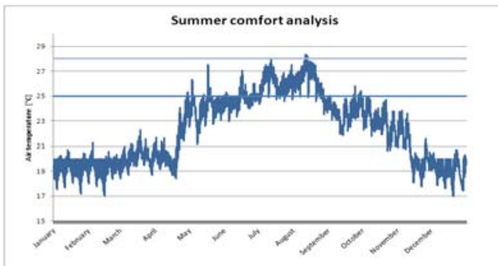


Joerie Alderweireldt (3E)





Summer comfort analysis	Hours > 25 °C	Maximum allowed
Administrative room	648 h	120 h
Language classroom (east orientation)	508 h	158 h
Language classroom (west orientation)	454 h	158 h
Language classroom (north orientation)	221 h	158 h
Language classroom (north orientation)	167 h	158 h

Joerie Alderweireldt (3E)

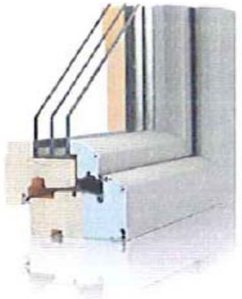
First decisions for the architectural and energy concept

- 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 weigth elements
- Window-to-wall-ratio of 25% is preferred by the architects
- Follow standard passive rules for the reference building

→ Following these decisons several technical-economical optimisations are analysed by the use of dynamic simulations

Joerie Alderweireldt (3E)

Optimisation 1 : Replacement of triple glazed windows by double glazed windows



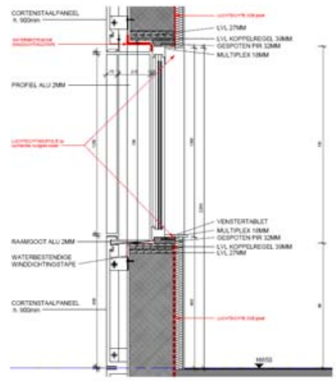
Joerie Alderweireldt (3E)

Optimisation 1 : Replacement of triple glazed windows by double glazed windows

	U_{raam}=0.65 W/m²K	U_{raam}=1.00 W/m²K	U_{raam}= 1.30 W/m²K
Primaire energievraag (MWhp/jaar)	560.3	567.4	571.5
Primaire energievraag (kWhp/m².jaar)	995	100.8	101.5
Energiekost (€/jaar)	38 099	38 580	38 862
Energiekost (€/m².jaar)	6.8	6.9	6.9
Meerinvestering (€)	-	-72 618	-94 962

Joerie Alderweireldt (3E)

Optimisation 2 : Increase window-to-wall ratio



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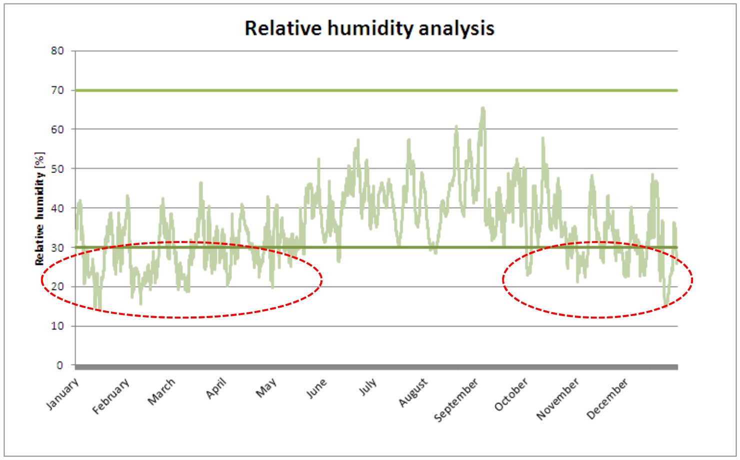
Optimisation 2 : Increase window-to-wall ratio

	Referentie	Verhoogd glaspercentage
Primaire energievraag (MWhp/jaar)	560.3	563.7
Primaire energievraag (kWhp/m².jaar)	99.5	100.1
Energiekost (€/jaar)	38 099	38 333
Energiekost (€/m².jaar)	6.8	6.8
Meerinvestering (€)	-	244 388

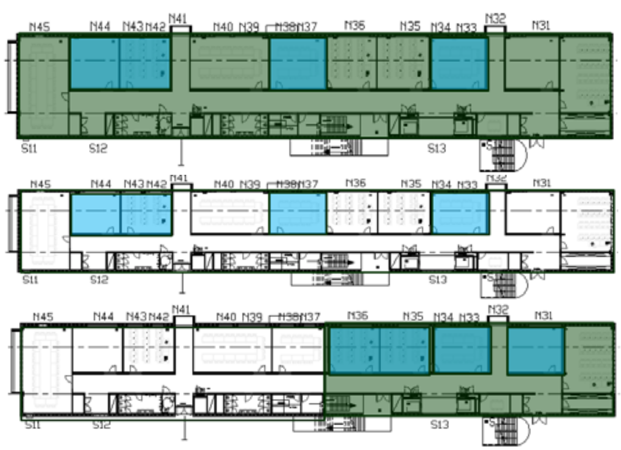
Joerie Alderweireldt (3E)

Optimisation 3 : Amount and type of heat recovery units



Joerie Alderweireldt (3E)

Optimisation 3 : Amount and type of heat recovery units



1 air handling unit for one floor

1 air handling unit for every class room

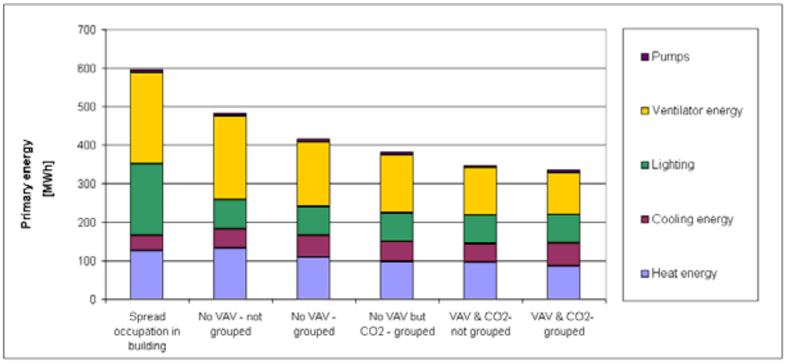
2 air handlings units for every floor

Optimisation 4 : Control of the ventilation systems

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
VAV	Neen	Neen	Neen	Ja	Ja
CO_2-gestuurd	Neen	Neen	Ja	Ja	Ja
Gegroepeerd	Neen	Ja	Ja	Neen	Ja
Bezettingsgraad	33%	33%	33%	33%	33%
Ventilatievolume	100%	50%	45%	44%	34%

Joerie Alderweireldt (3E)

Optimisation 4 : Control of the ventilation systems



Joerie Alderweireldt (3E)

Optimisation 4 : Control of the ventilation systems

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Jaarlijkse energiekost (k€/jaar)	33	28	26	24	23
Investering (k€)	0	0	9	82	82
Terugverdientijd (jaar)	-	-	1	5	5

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Jaarlijkse energiekost (k€/jaar)	-	-	26	24	23
Investering (k€)	-	-	9	82	82
Terugverdientijd (jaar)	-	-	-	33	33

Joerie Alderweireldt (3E)

Optimisation 4 : Control of the ventilation systems

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
VAV	Neen	Neen	Neen	Ja	Ja
CO_2-gestuurd	Neen	Neen	Ja	Ja	Ja
Gegroepeerd	Neen	Ja	Ja	Neen	Ja
Bezettingsgraad	33%	33%	33%	33%	33%
Ventilatievolume	100%	50%	45%	44%	34%

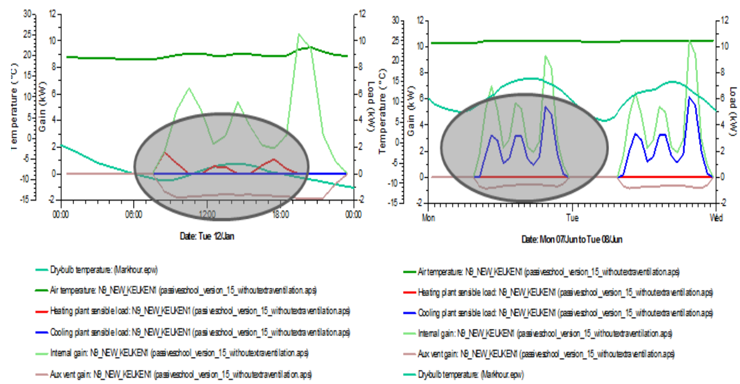
Moeilijk wanneer lessen uitlopen

Grote afhankelijkheid van groeperen

Hoge flexibiliteit

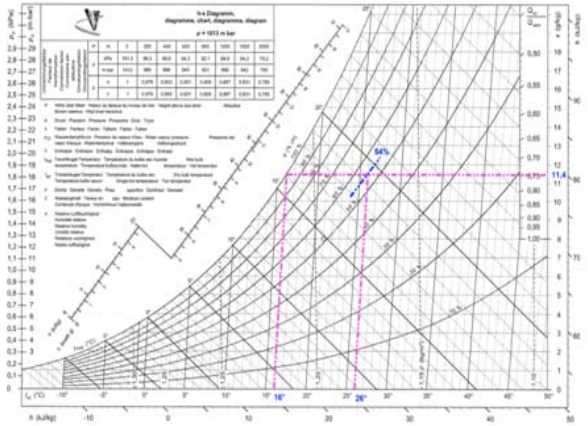
Joerie Alderweireldt (3E)

Optimisation 5 : Production, distribution and emission systems



Joerie Alderweireldt (3E)

Optimisation 5 : Production, distribution and emission systems



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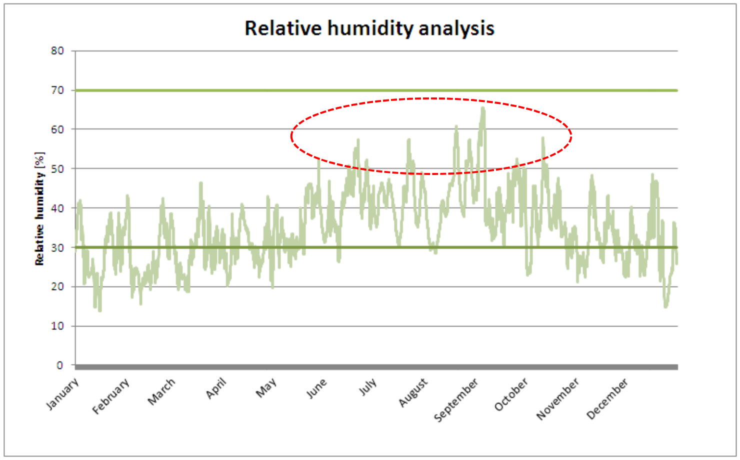
Optimisation 5 : Production, distribution and emission systems



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Optimisation 5 : Production, distribution and emission systems

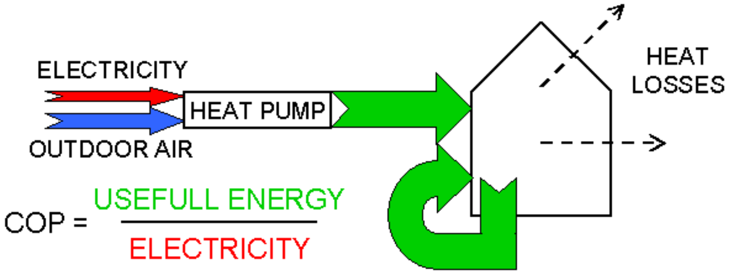
Analysis of emission systems

- 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

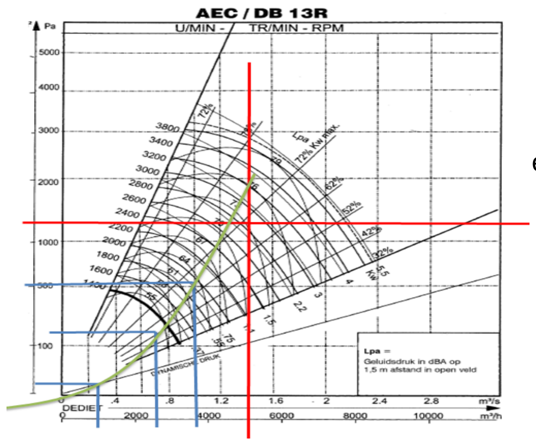
	WP met WTW	VRV
Emissie	Warmte en koude	Warmte en koude
Koelmiddel	In klaslokaal en buitenunit	In klassen, leidingnetwerk en in buitenunit
Flexibiliteit	Hoog door water in leidingnetwerk	Laag door koelmiddel in leidingnetwerk
COP verwarming	3.9	3.5
COP koeling	5.0	5.5
COP warmterecuperatie	Tussen bovenstaande COP's en +/- 9	Tussen bovenstaande COP's en +/- 9
Potentieel andeel recuperatie	Zonder sanitair warm water en zonder koelcellen: 7.8% Zonder sanitair warm water en met koelcellen: 10.3% Met sanitair warm water en met koelcellen: 11.0%	
Akoestiek	Warmtepomp in klas dus extra geluidsbron	Geen warmtepomp in klas dus minder geluid

Optimisation 5 : Production, distribution and emission systems



Joerie Alderweireldt (3E)

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

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Optimisation 7 : Integration of photovoltaics on roof top

Heat demand kWh/m².y	17.4
Cooling demand kWh/m².y	7.0
Heat energy kWh/m².y	5.8
Cooling energy kWh/m².y	1.5
Lighting kWh/m².y	6.8
Ventilator energy kWh/m².y	15.2
Pumps kWh/m².y	0.4

Primary energy kWhpr/m².y	54.0
Energy cost €/m².y	6.5

RE kWhpr/m².y	19.4
RE %	35.9

The integration of photovoltaic panels allows the realisation of a Nearly Zero Energy Building

A ventilative cooling system in a School Building, Imola, Italy

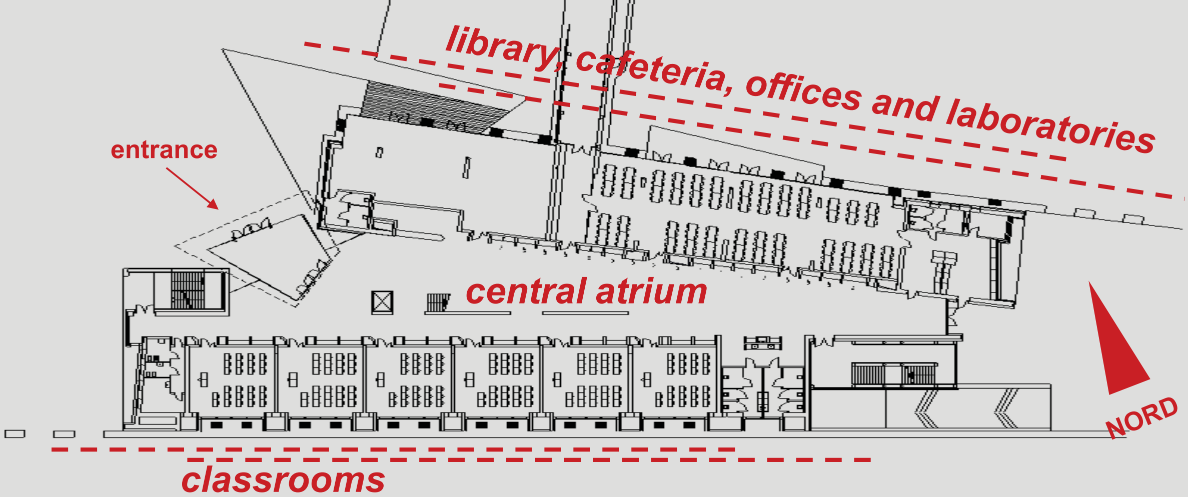
Prof. Arch. Mario GROSSO,
Associate Professor of Architectural Technology

Energy-Environmental Consultant

mario.grosso@polito.it

Building layout

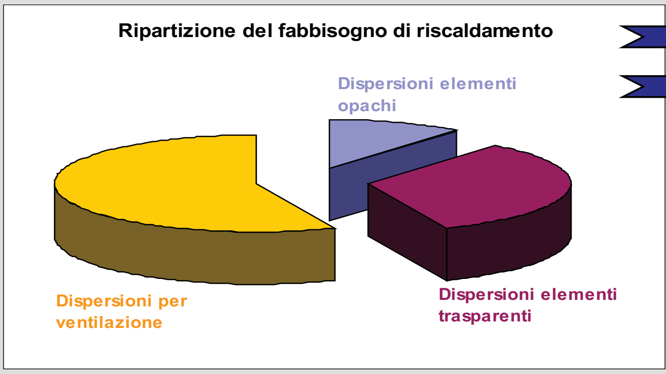
- Two main blocks linked by a central *atrium*
- East-West longitudinal axis



Estimate of energy needs

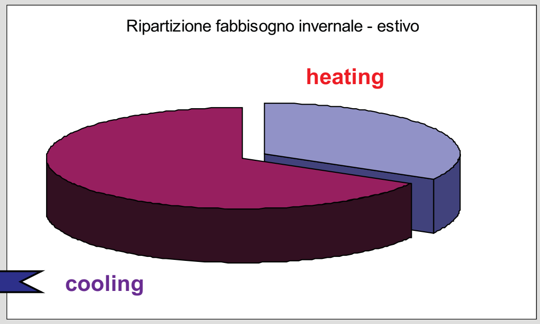
PRELIMINARY - PHASE 1

- 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

- attention to ventilation load
- need to high-performance glazing



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

priority to application of passive cooling systems

Estimate of energy needs

PRELIMINARY - PHASE 2

- Evaluation of energ-saving benefit related to alternative strategies

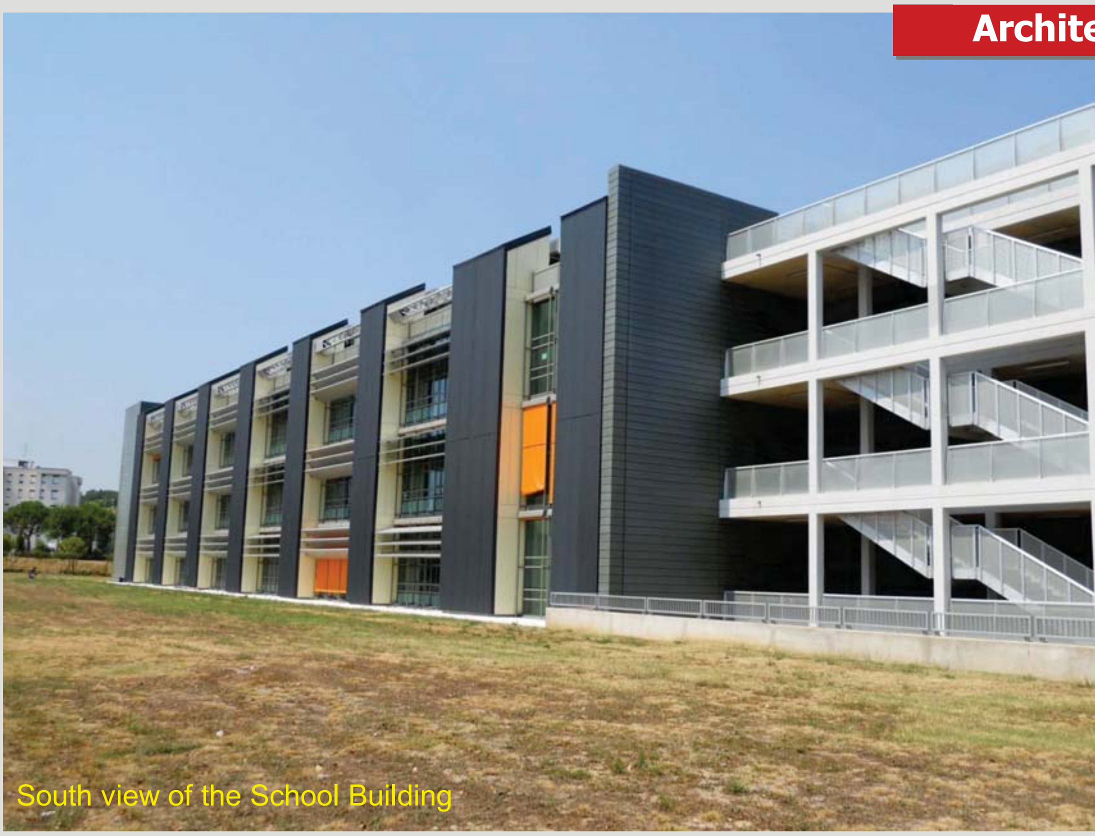
	BLOCCO AULE S-O	Fabbisogno di energia [KWh/m² anno] RISCALDAMENTO	Fabbisogno di energia [KWh/m² anno] RAFFRESCAMENTO
A	SIMULAZIONE - A - *ventilazione minima* - *struttura leggera*	13.6	-83.7
B	SIMULAZIONE - B - *ventilazione extra* - *struttura leggera*	13.6	-31.9
C	SIMULAZIONE - C - *ventilazione minima* - *struttura medio - pesante*	21.1	-41.4
D	SIMULAZIONE - D - *ventilazione extra* - *struttura medio - pesante*	21.1	-9.8

SOLUTION D

to optimise yearly energy balance

TECHNOLOGICAL OPTIONS FOR INDOOR CLIMATE CONTROL SYSTEMS

Architecture



South view of the School Building

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iea International Energy Agency venticool the european platform for ventilative cooling

Architecture

North view of the School Building

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Ventilation system

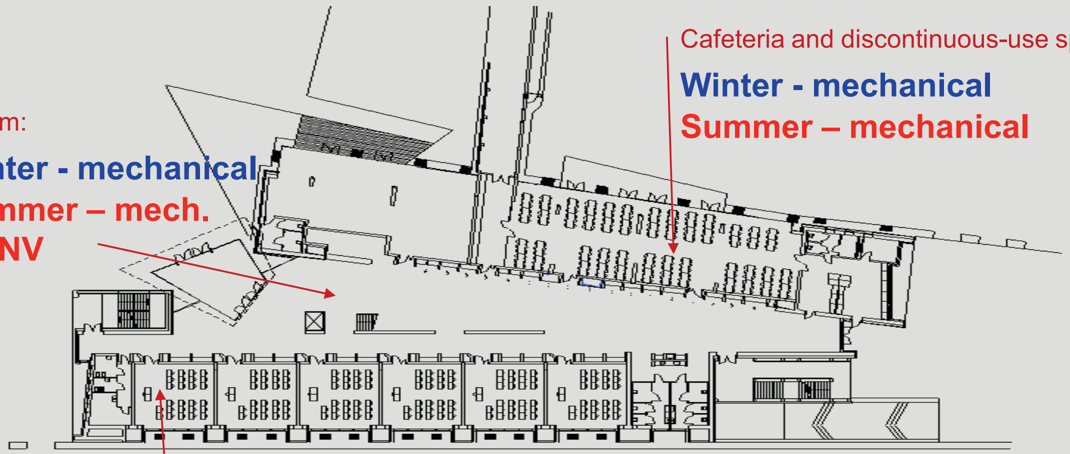
- Hybrid system (controlled natural/mechanical system)
- Controlled natural ventilation (CNV): motorised sensor-driven openings related to IAQ and thermal comfort

Cafeteria and discontinuous-use spaces:

Winter - mechanical
Summer – mechanical

Atrium:

Winter - mechanical
Summer – mech. + CNV



Classrooms:

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

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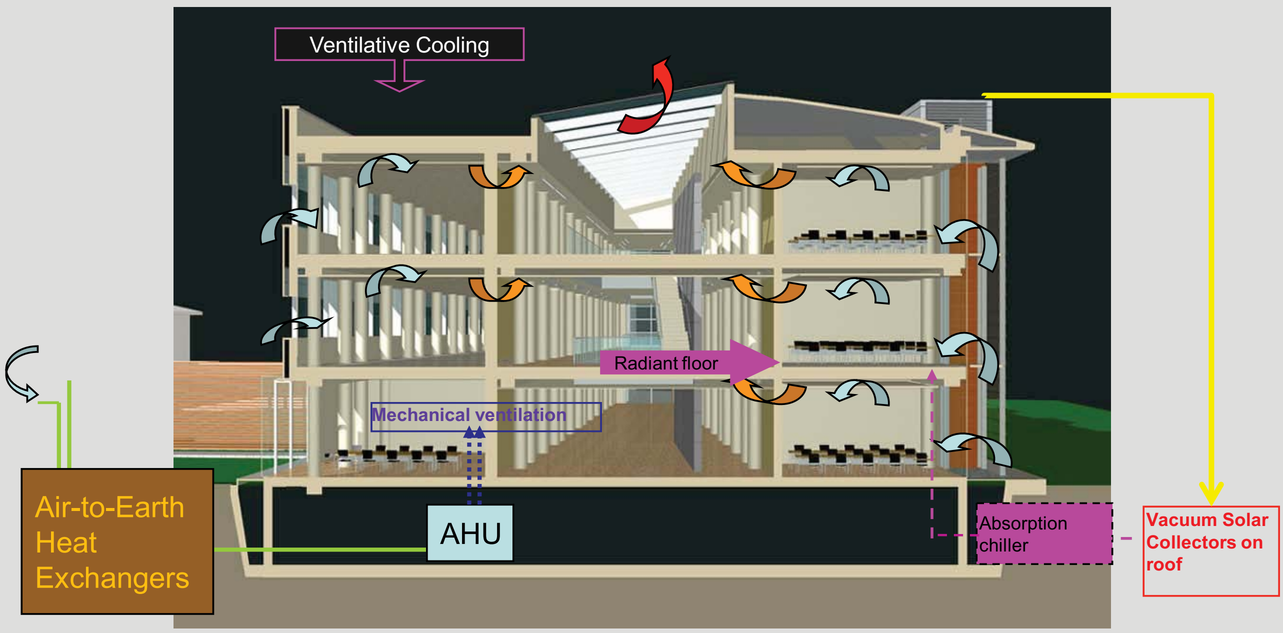
Cooling systems



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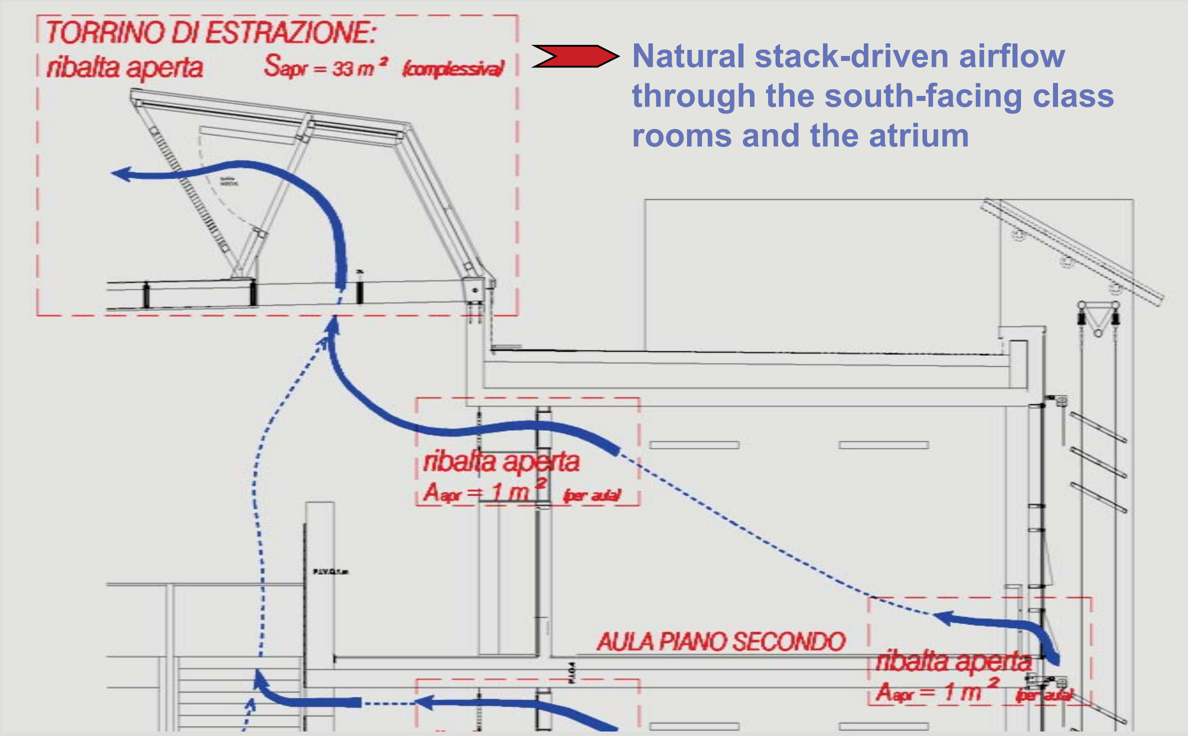
Ventilative cooling



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

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Ventilative cooling

internal view of the atrium

vented clerestory on the atrium glazed roof

south glazed wall with hopper window openings

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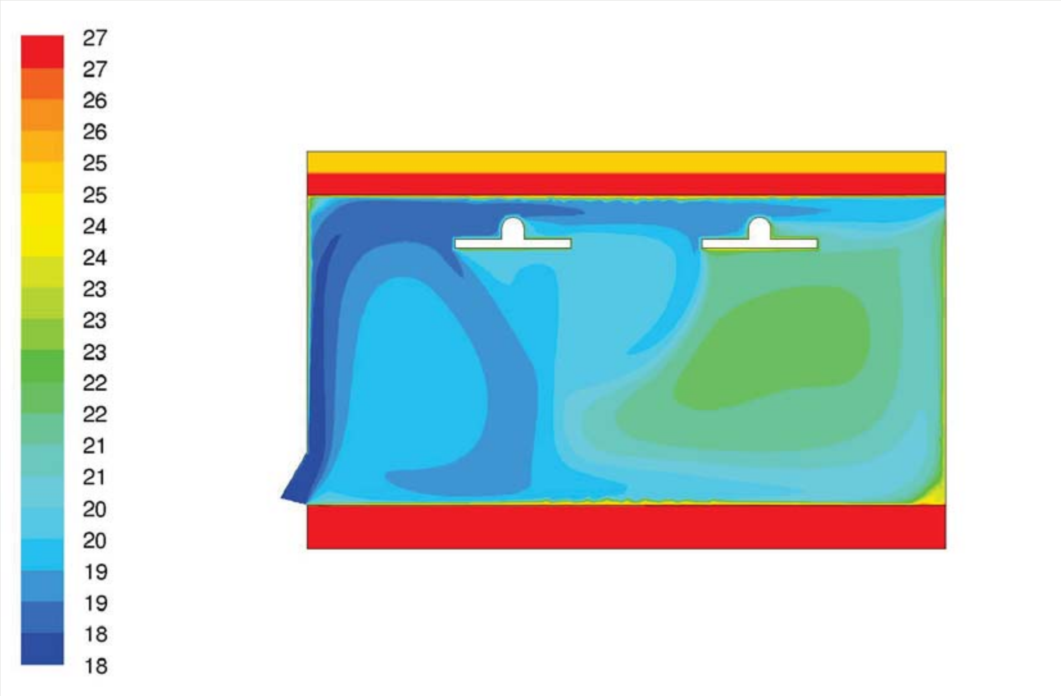
2-D CFD simulation in a classroom with ceiling appliances:
air temperature zones after 1 hour with a gradient of 10 °C



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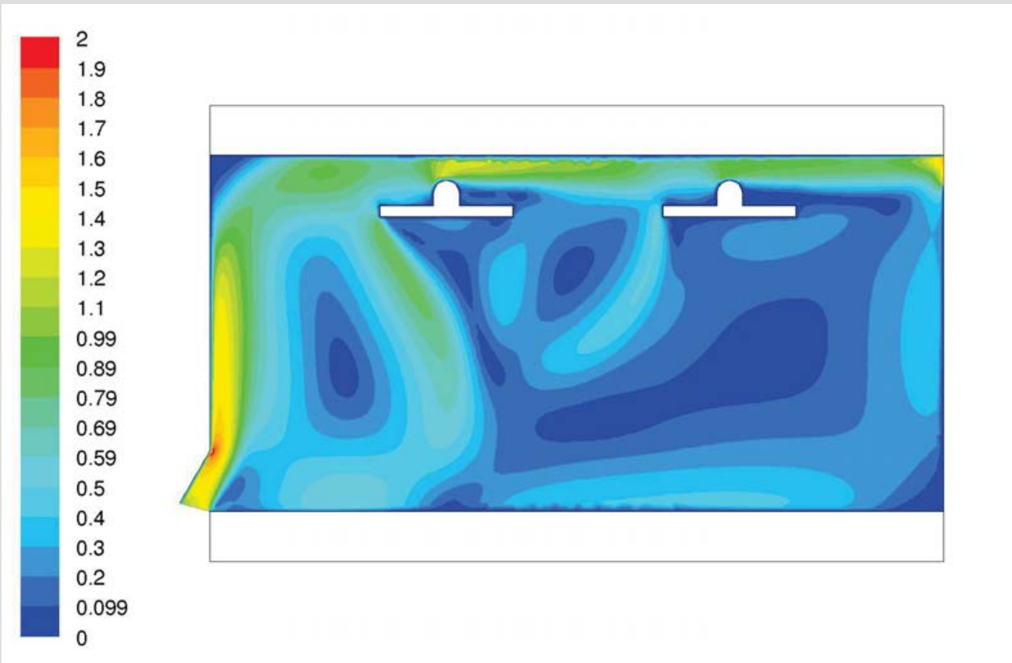
2-D CFD simulation in a classroom with ceiling appliances:
air velocity zones after 1 hour with a gradient of 10 °C



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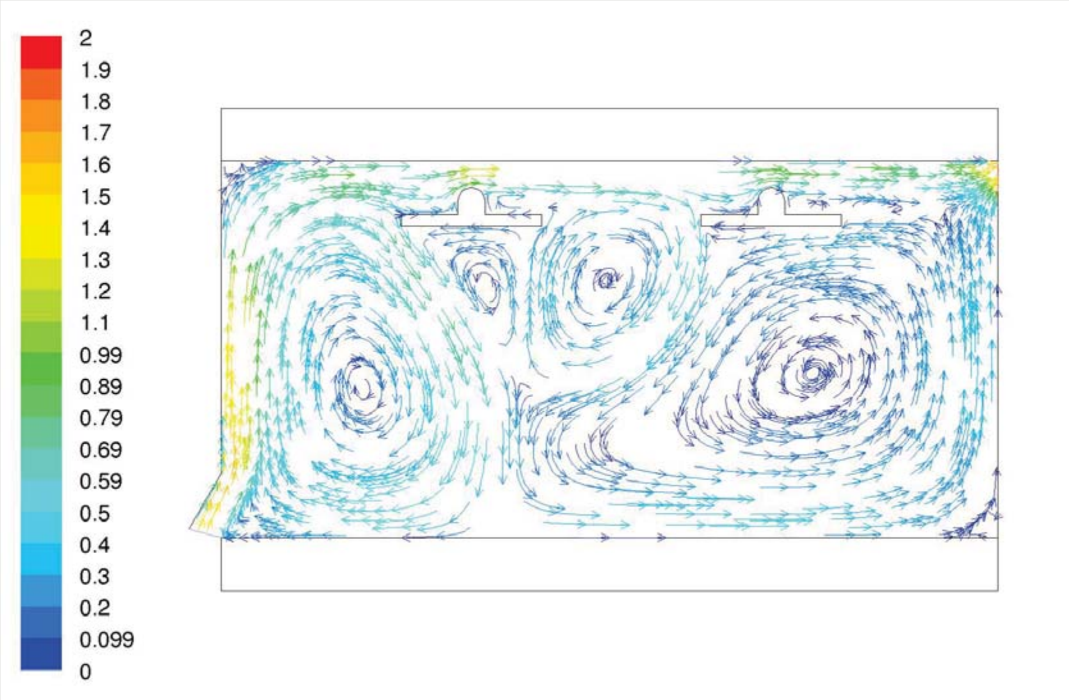
2-D CFD simulation in a classroom with ceiling appliances*: air velocity contour lines after 1 hour*



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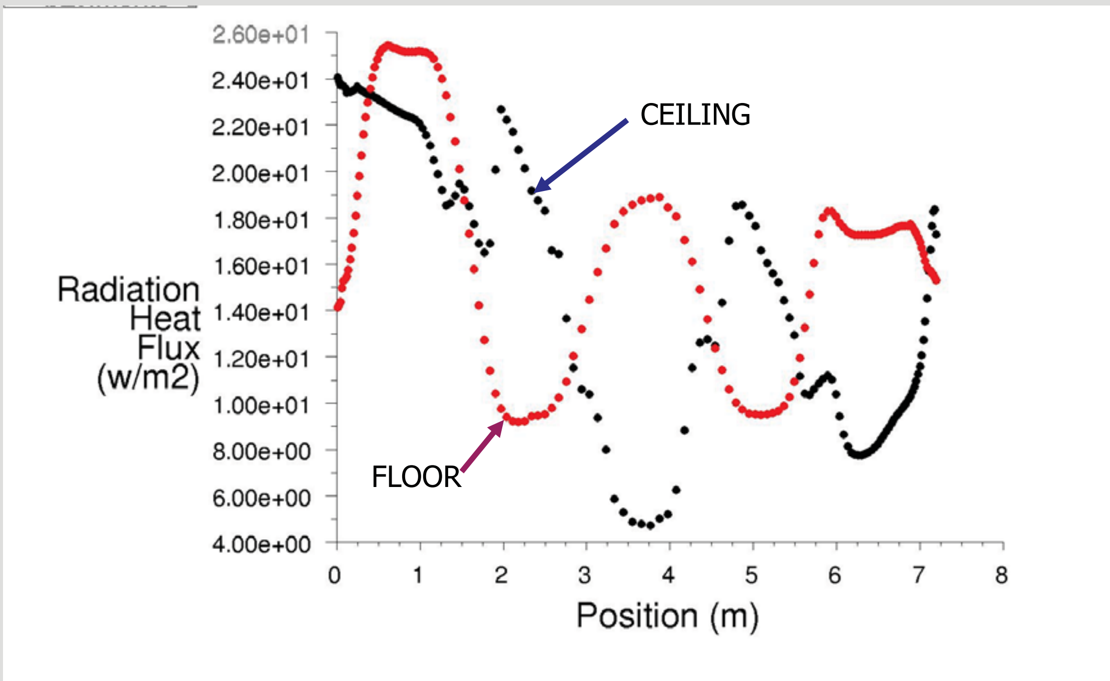
2-D CFD simulation in a classroom with ceiling appliances*: radiation heat flux after 1 h as a function of distance from inlet opening*



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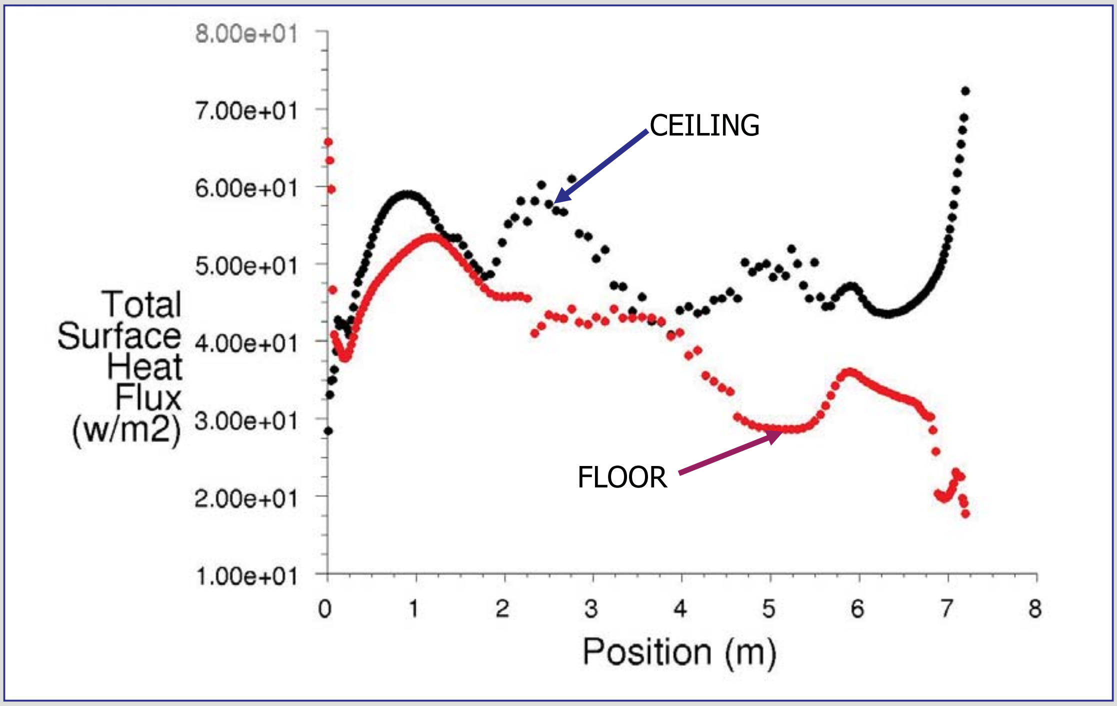
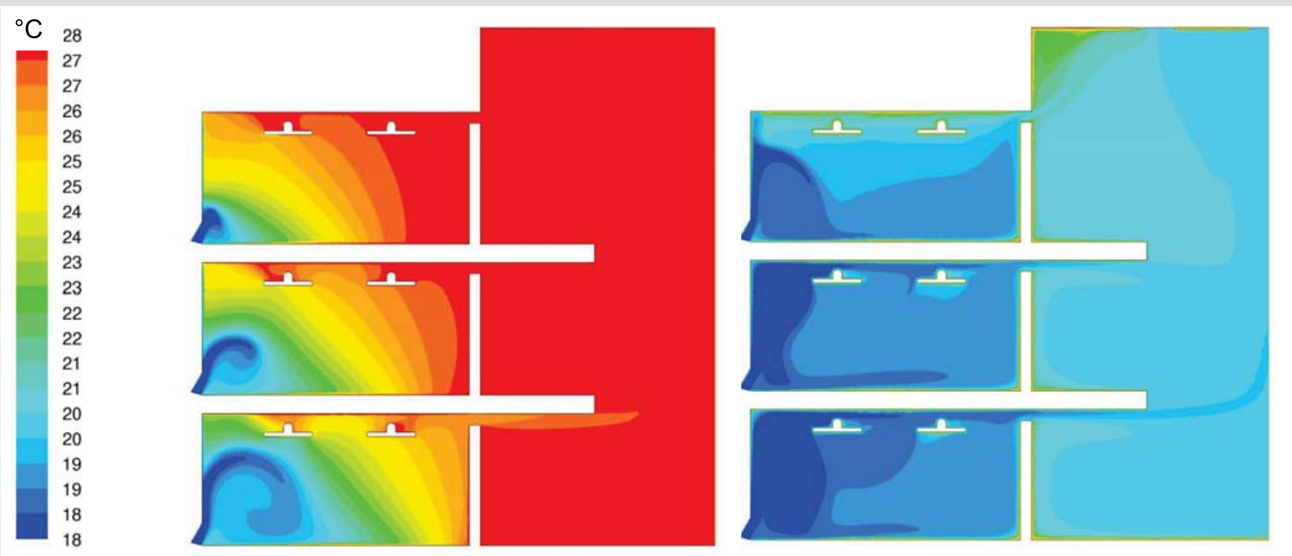
2-D CFD simulation in a classroom with ceiling appliances: *total surface heat flux after 1 h as a function of distance from inlet opening*



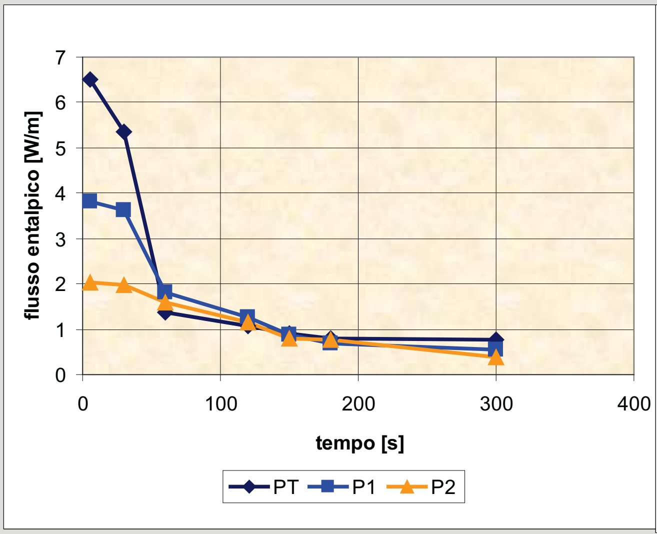
Ventilative cooling

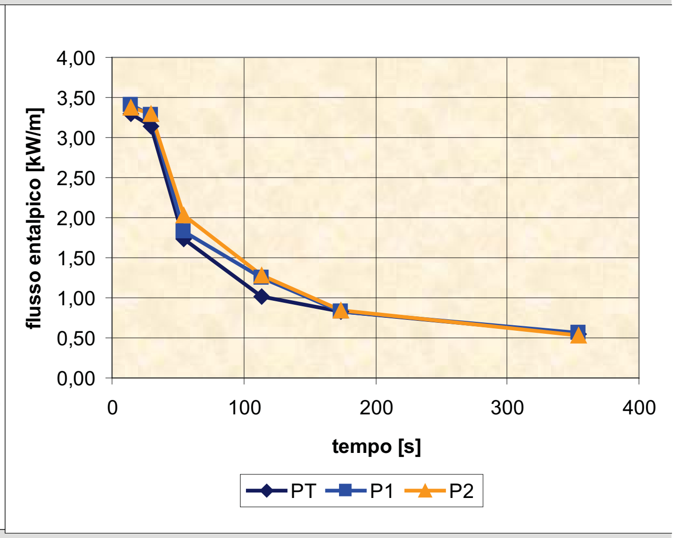
2D CFD simulation of flows between classrooms at the different storeys and the atrium: *temperature zones for a gradient of 10 °C between inside (atrium) and outside*



after 1 minute **after 10 minutes**

2-D CFD simulations: *enthalpic flows for the three storeys in the time interval 0÷400 s*





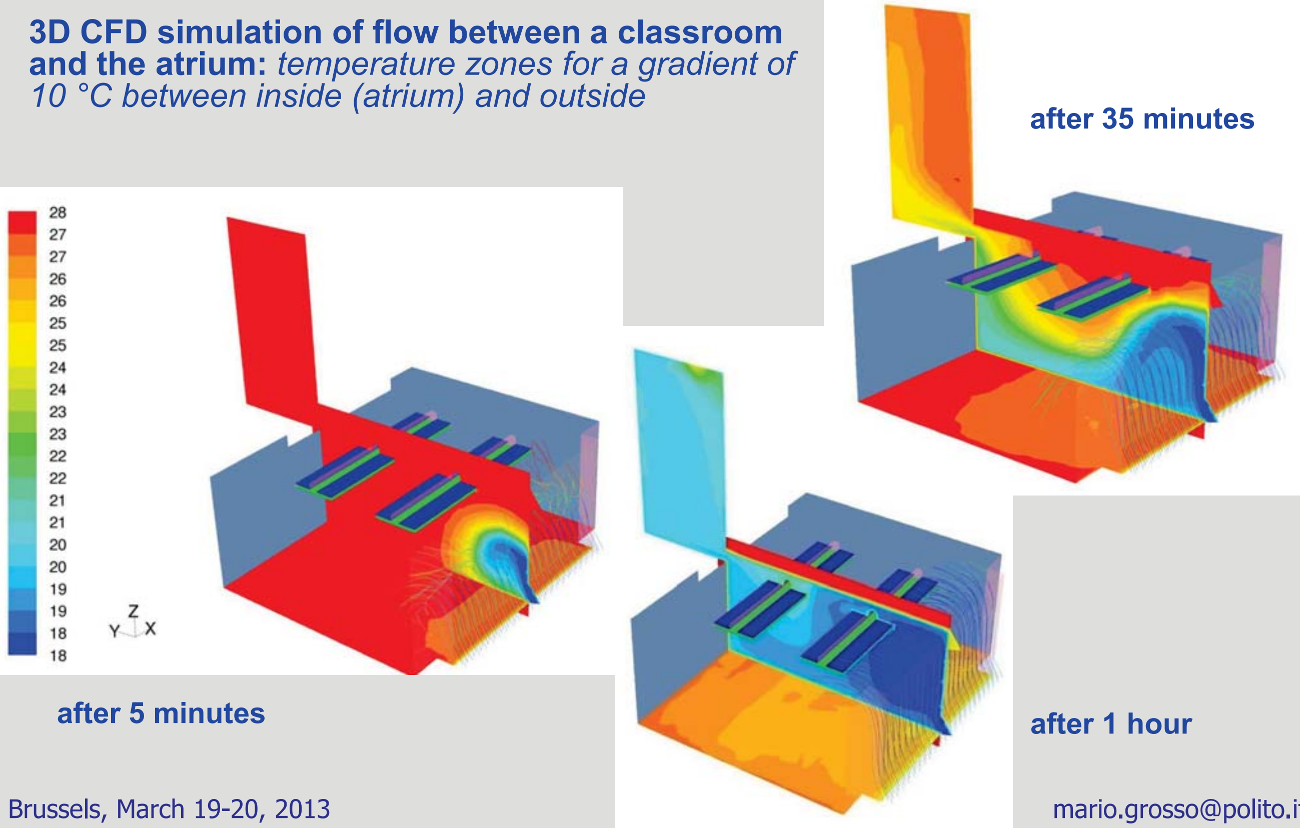
Unbalanced flows amid the trhee storeys

Balanced flows amid the three storeys

2-D CFD simulations: *enthalpic flows for the three storeys in the time interval 500÷10500 s (linear trend)*

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 35 minutes

after 5 minutes

after 1 hour

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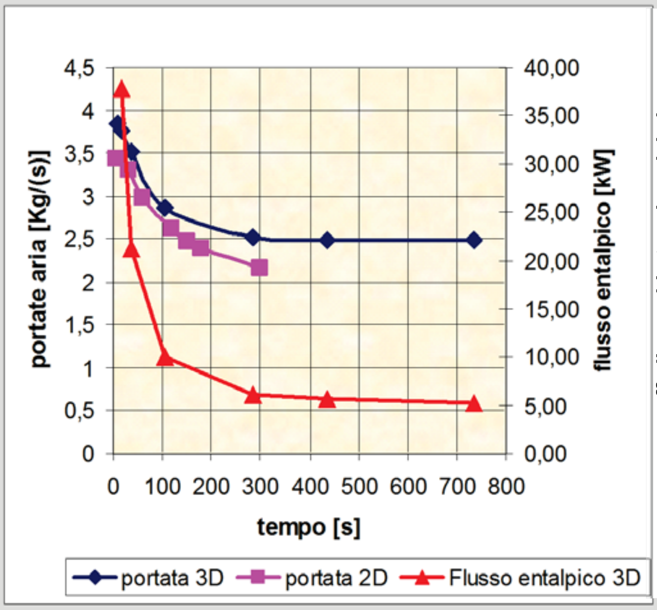
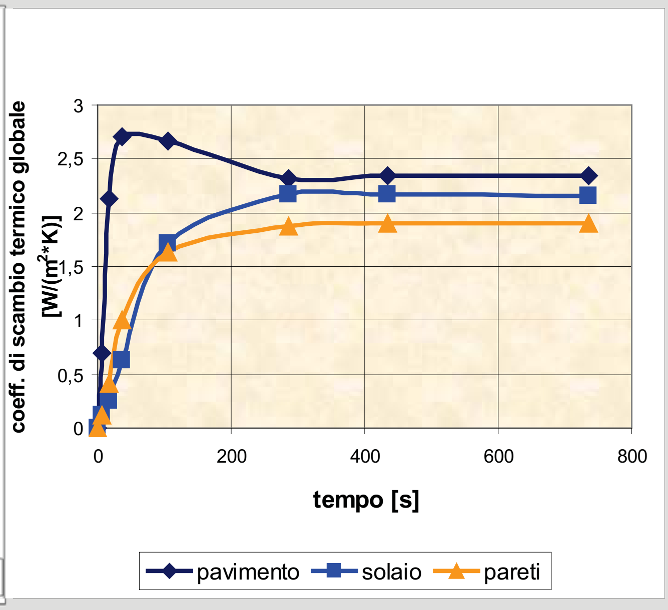
3-D CFD simulations: *airflow rates, enthalpic flow and global thermal exchange coefficient in the time interval 0÷800 s*





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

global thermal exchange coefficient for floor, ceiling, walls

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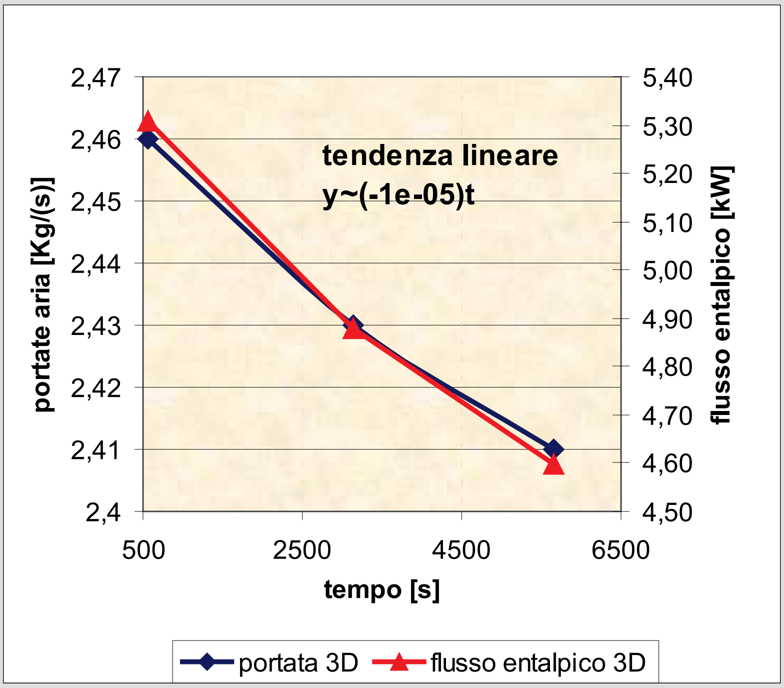
3-D CFD simulations: *airflow rate and enthalpic flow in the time interval 500÷6500 s (linear trend)*



3-D airflow rate, 3-D enthalpic flow

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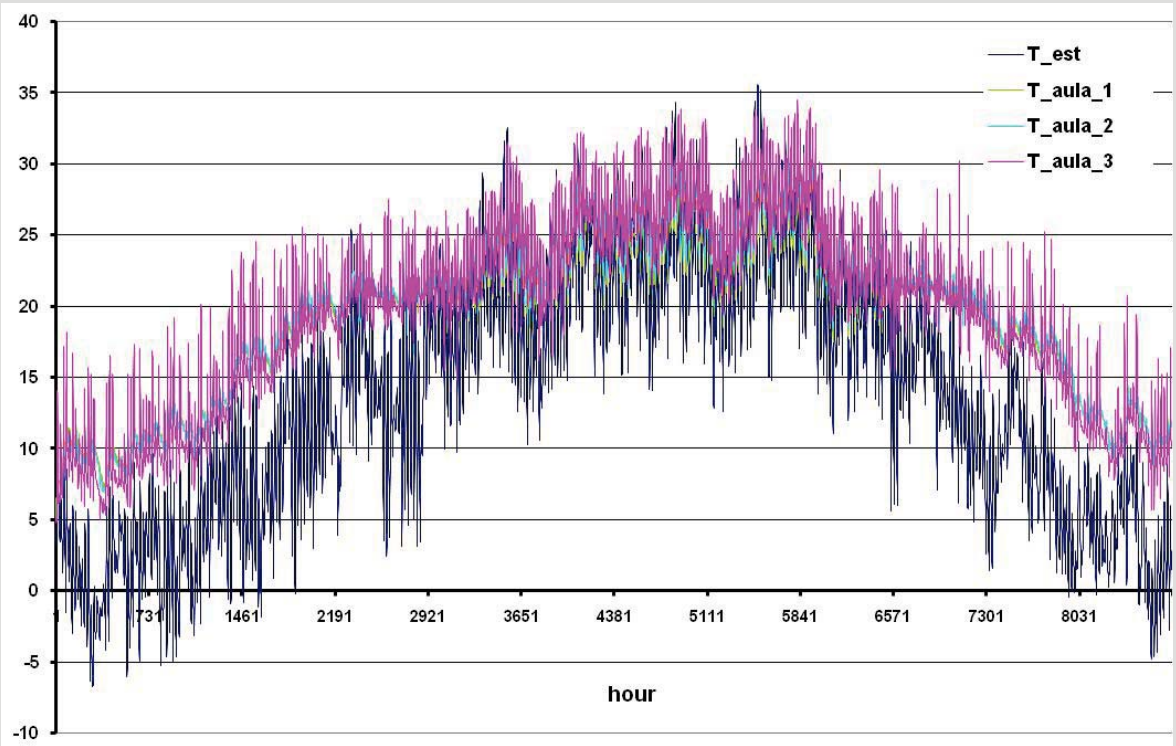
Thermal dynamic simulations using TRNSYS: *annual indoor air temperature profile in the south- facing classrooms with ventilative cooling*



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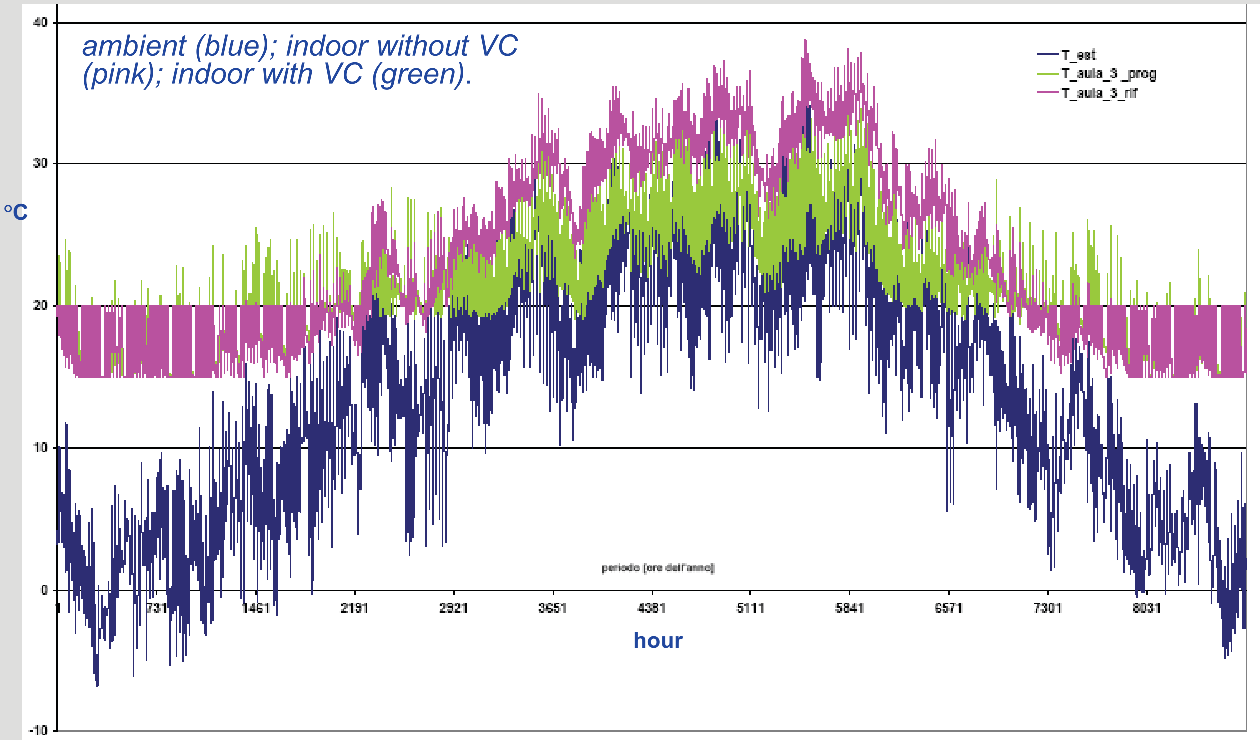
Thermal dynamic simulations using TRNSYS: *annual indoor air temperature profile in the 3° storey south- facing classroom*



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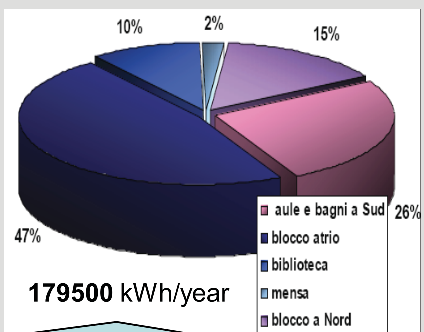
Contribution to energy saving of RES & RUE technologies (prediction)

Technology	Annual energy intensity [kWh/m²-gfa] heating	cooling
Reference configuration (a)	79.5	22.4
Reference configuration (b)	141.0	38.3
High insulation (opaque components)	72.7	25.1
High insulation (glazed components)	66.2	28.6
Time optimisation of mechanical ventilation (OMV)	64.9	15.4
Shading devices (fixed)	84.0	15.8
Shading devices (fixed and movable)	86.8	14.0
Total of envelope technologies (ET)	67.0	20.1
ET+ OMV + heat recovery	44.3	13.4
ET+ OMV + Solarwall®	42.5	13.4
ET+ OMV + VC	54.1	6.6
TOTAL	37.4	6.6

Reference configuration (a): U_{value} (walls) = **0,45** W/m²K; U_{value} (glazing) = **2,65** W/m²K; **Mech. Vent. for 12** h/day

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

High insulation: U_{value} (walls) = **0,30** W/m²K; U_{value} (glazing) = **1,57** W/m²K



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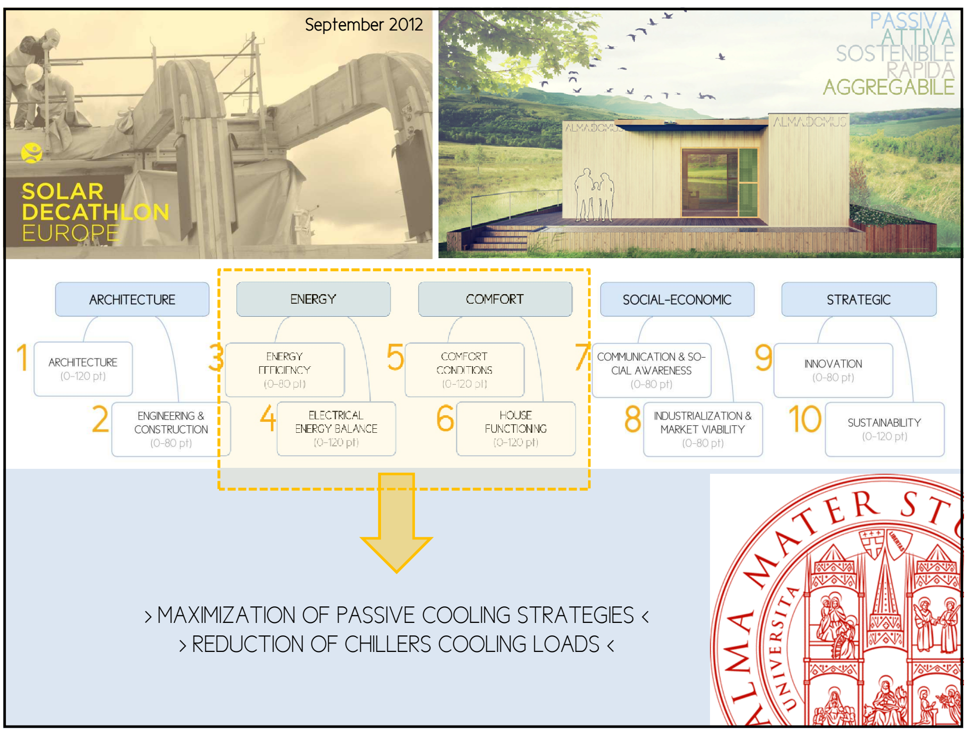
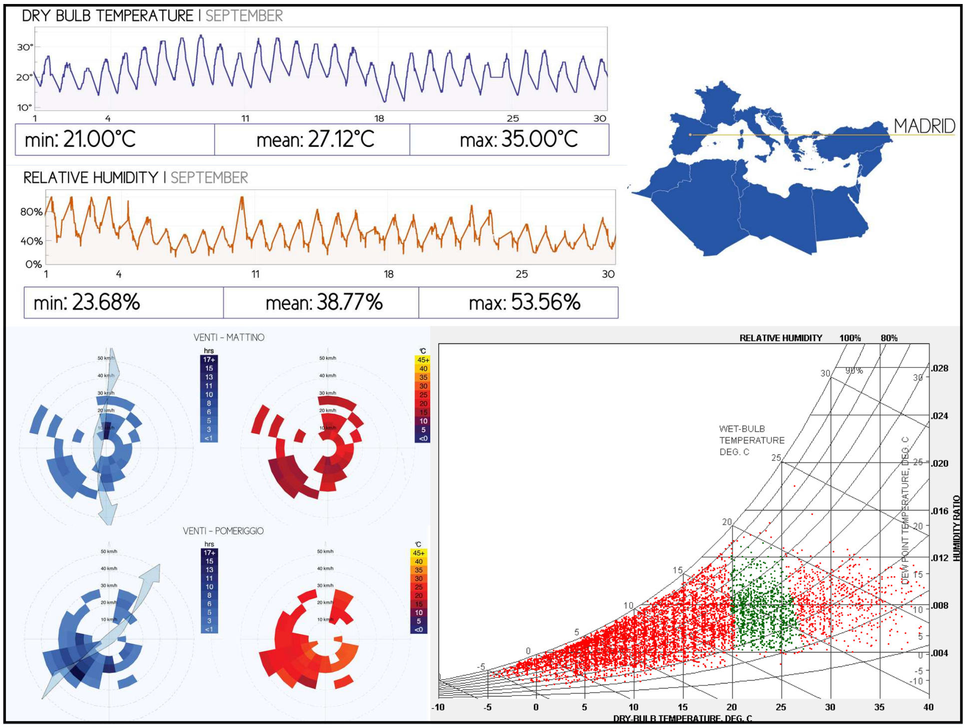
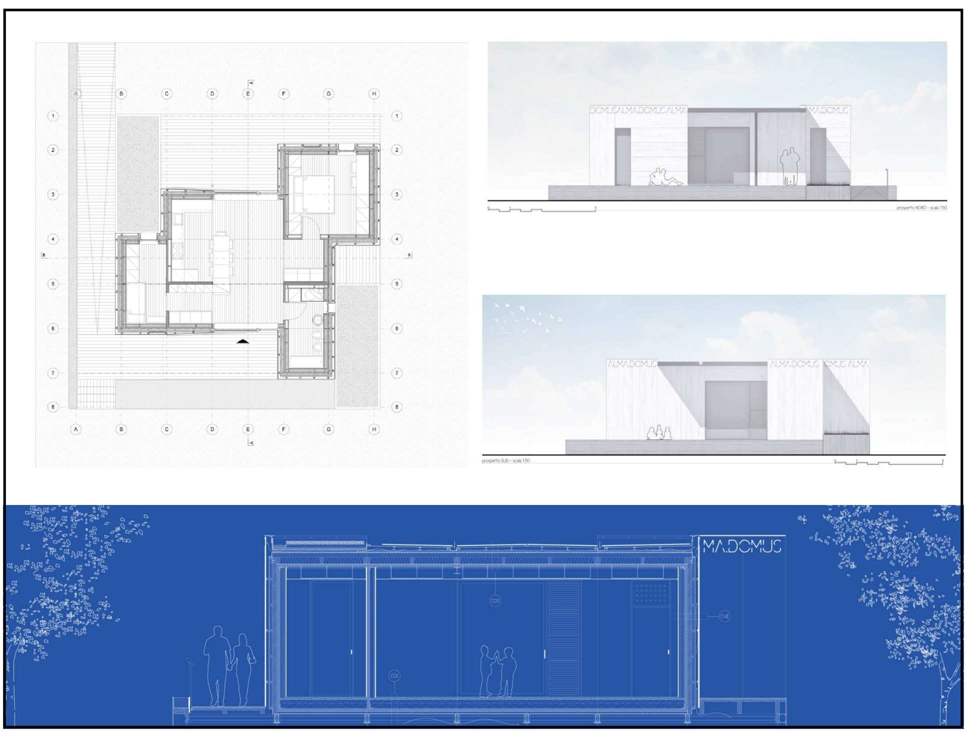
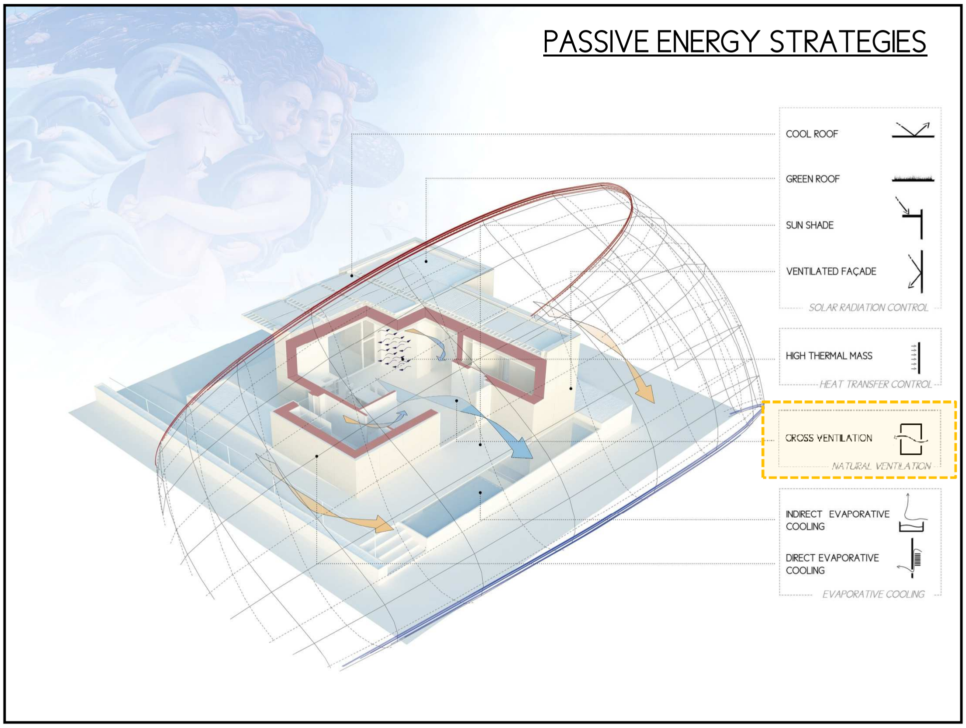
passive cooling with natural ventilation rate, a case study

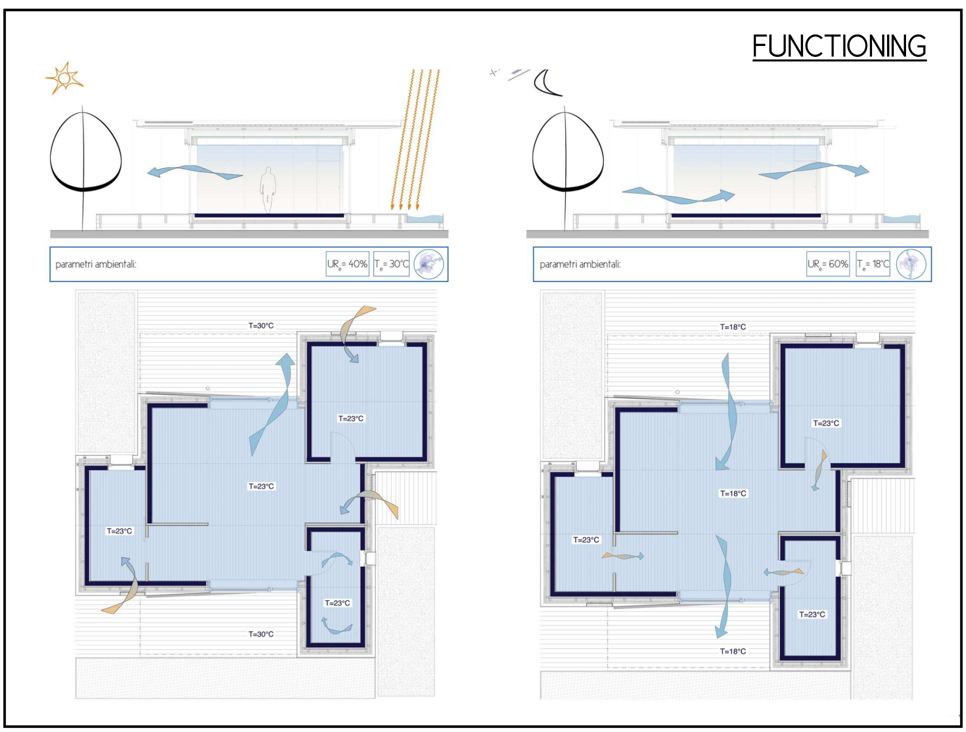
Pier Nicola Currà

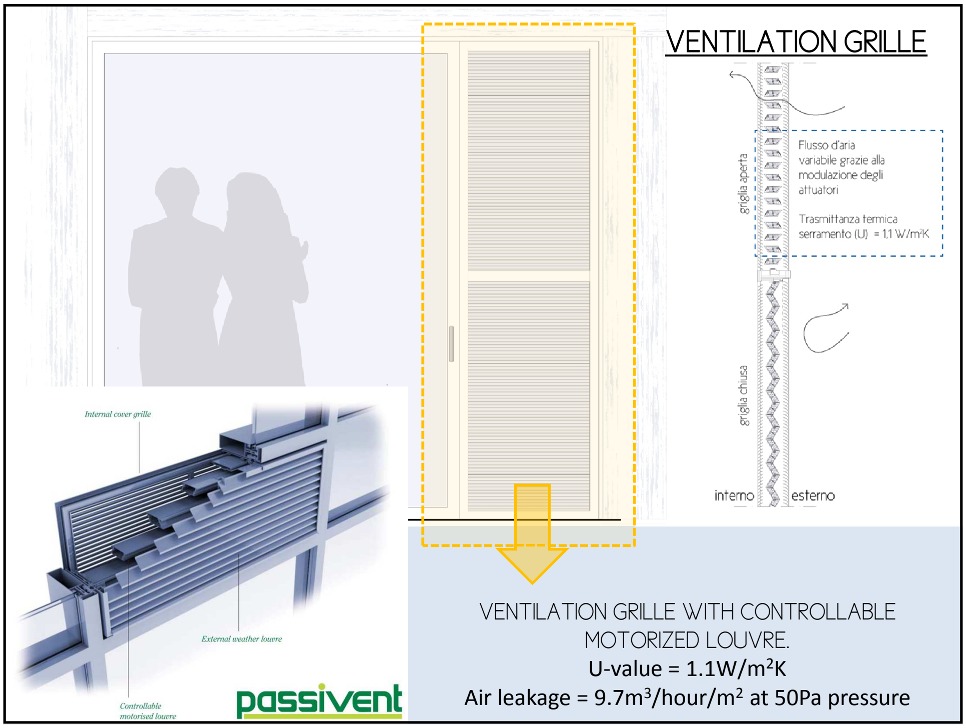


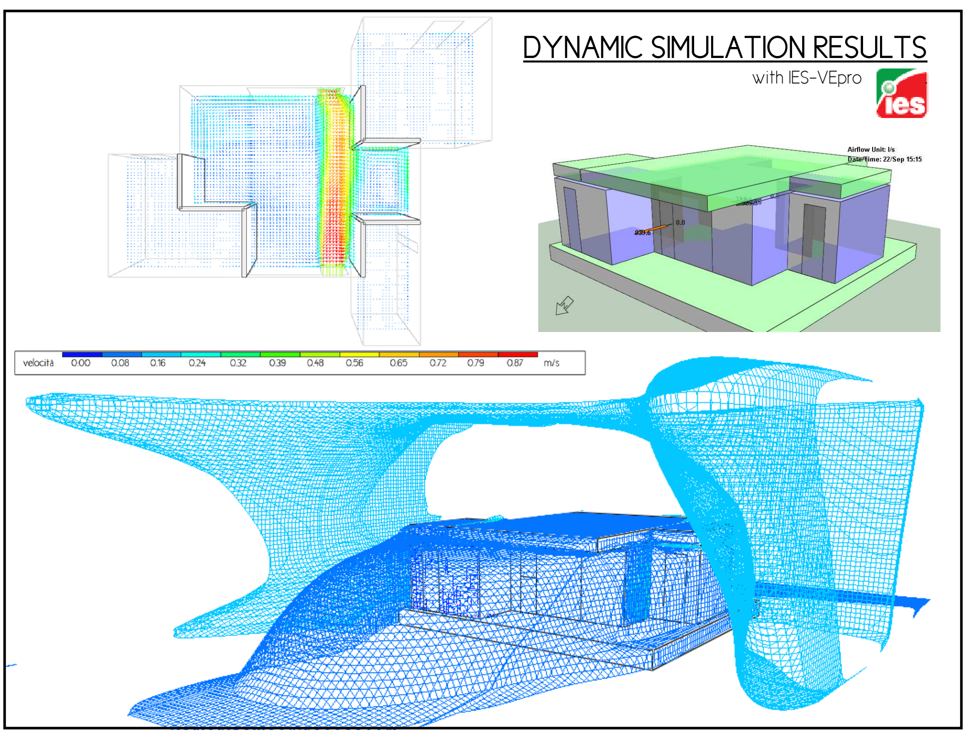

DRY BULB TEMPERATURE | SEPTEMBER
min: 21.00°C
mean: 27.12°C
max: 35.00°C
RELATIVE HUMIDITY | SEPTEMBER
min: 23.68%
mean: 38.77%
max: 53.56%
MADRID
VENTI - MATTINO
VENTI - POMERIGGIO
RELATIVE HUMIDITY
WET-BULB TEMPERATURE DEG. C
DEW POINT TEMPERATURE, DEG. C
HUMIDITY RATIO
DRY BULB TEMPERATURE, DEG. C

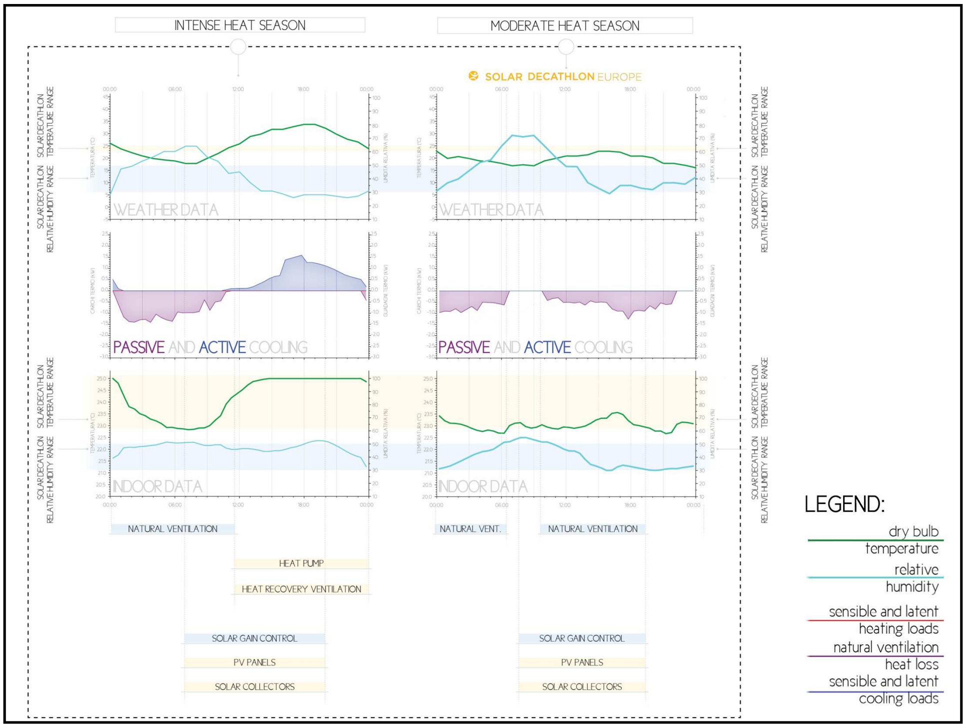

MA.DOMUS


PASSIVE ENERGY STRATEGIES
COOL ROOF
GREEN ROOF
SUN SHADE
VENTILATED FAÇADE
SOLAR RADIATION CONTROL
HIGH THERMAL MASS
HEAT TRANSFER CONTROL
CROSS VENTILATION
NATURAL VENTILATION
INDIRECT EVAPORATIVE COOLING
DIRECT EVAPORATIVE COOLING
EVAPORATIVE COOLING


FUNCTIONING
parametri ambientali:
T=30°C
T=23°C
T=23°C
T=23°C
T=23°C
T=30°C
parametri ambientali:
T=18°C
T=23°C
T=18°C
T=23°C
T=23°C
T=18°C


VENTILATION GRILLE
griglia aperta
Flusso d'aria variabile grazie alla modulazione degli attuatori
Trasmittanza termica serramento (U) = 1,1 W/m^2K
griglia chiusa
interno
esterno
Internal cover grille
External weather louvre
Controllable motorised louvre
passivent
VENTILATION GRILLE WITH CONTROLLABLE MOTORIZED LOUVRE.
U-value = 1.1W/m^2K
Air leakage = 9.7m^3/hour/m^2 at 50Pa pressure


DYNAMIC SIMULATION RESULTS
with IES-VEpro
ies
Airflow Unit: l/s
Date/time: 22/Sep 15:15
velocità 0.00 0.08 0.16 0.24 0.32 0.39 0.48 0.56 0.65 0.72 0.79 0.87 m/s



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- 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

- Cândido, C. de Dear, C., Lamberts, R. 2011. *Combined thermal acceptability and air movement assessments in a hot humid climate.* Building and Environment. Elsevier Science Ltd., Vol. 46, p. 379–385.

Estia

AIVC

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

0

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

no visible duct, no visible ventilation grid

external vue should be pure, without window frames, without accessories

Because

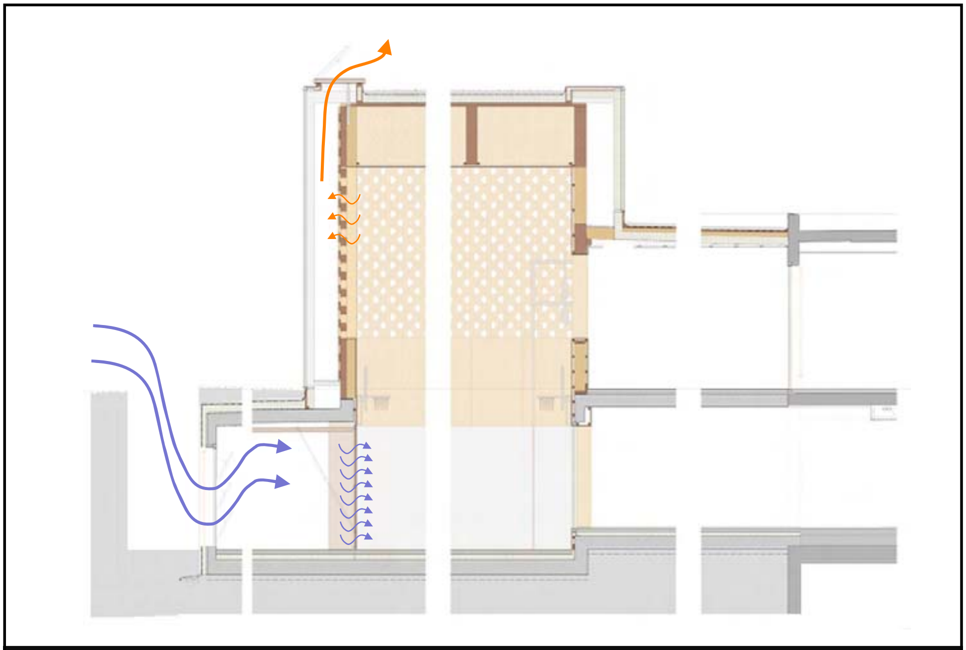
… la vision globale d'un projet est pour nous la plus importante et chaque cas est différent! Ce que les tableaux de calculs ne peuvent transcrire. L'architecture et les qualités des espaces, les atmosphères et les sensations personnelles n'entrent pas compte, car les critères sont subjectifs, ce qui 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…

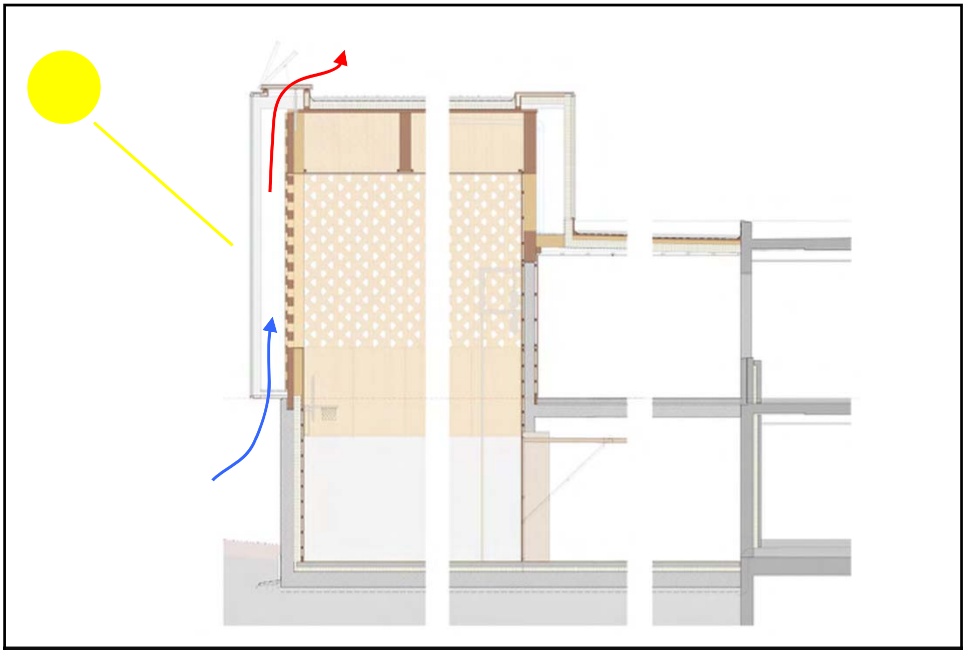
patricia capua mann
graeme mann & patricia capua mann
architectes epfl fas sia
ch de monribeau 2
1005 lausanne

But how ?

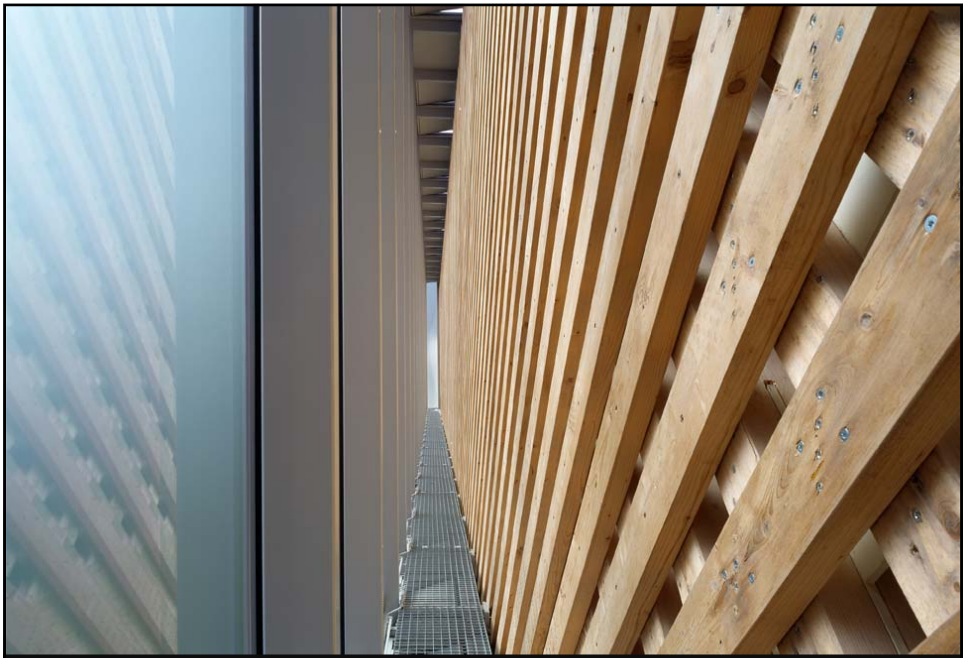
5



flash ventilation when CO_2>800 ppm / night ventilation during summer



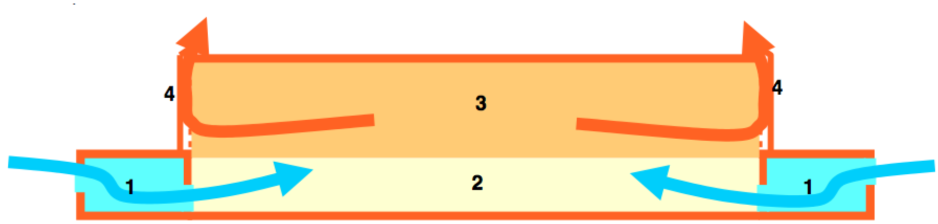
local heat discharge when sun is striking the facade

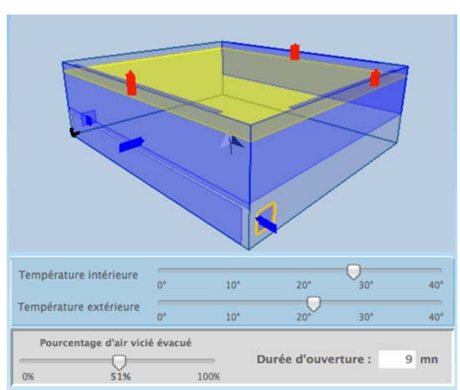


the eco-structure / dynamic solar shading / ventilation duct / acoustic absorber

the ventilation inlet grid / storage room door

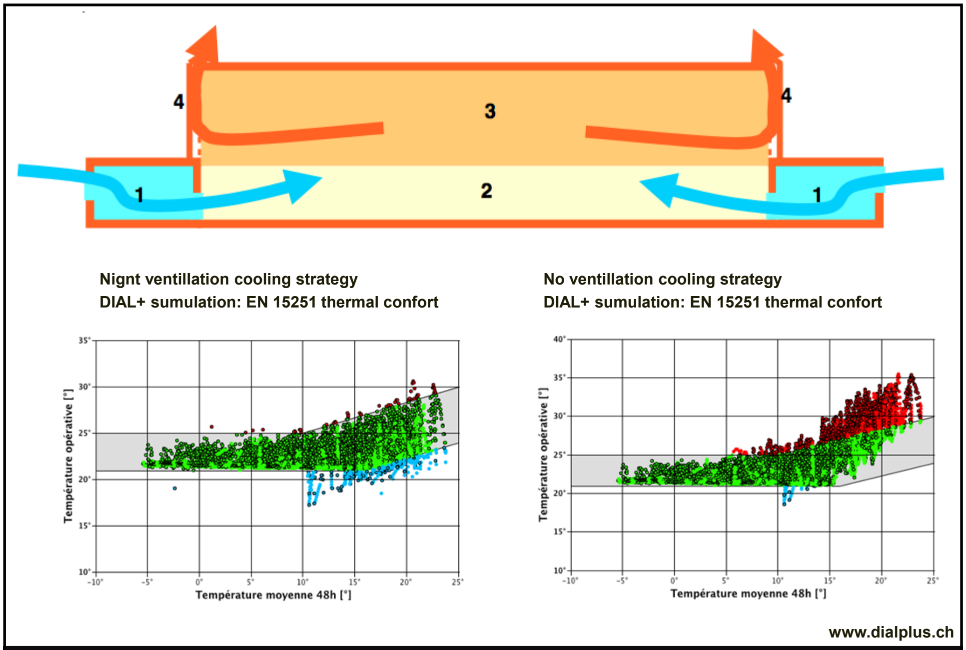
building physics is part of personal sensations, atmospheres and space quality



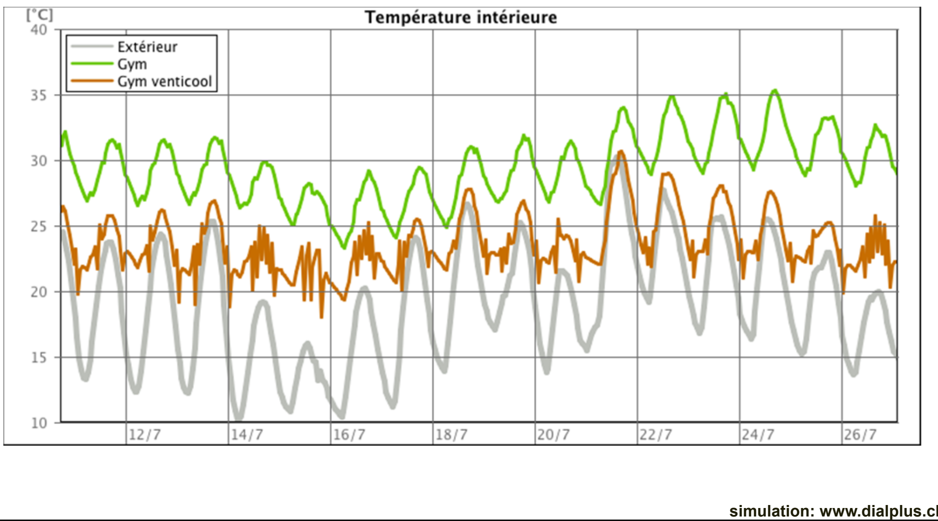


simulation: www.dialplus.ch

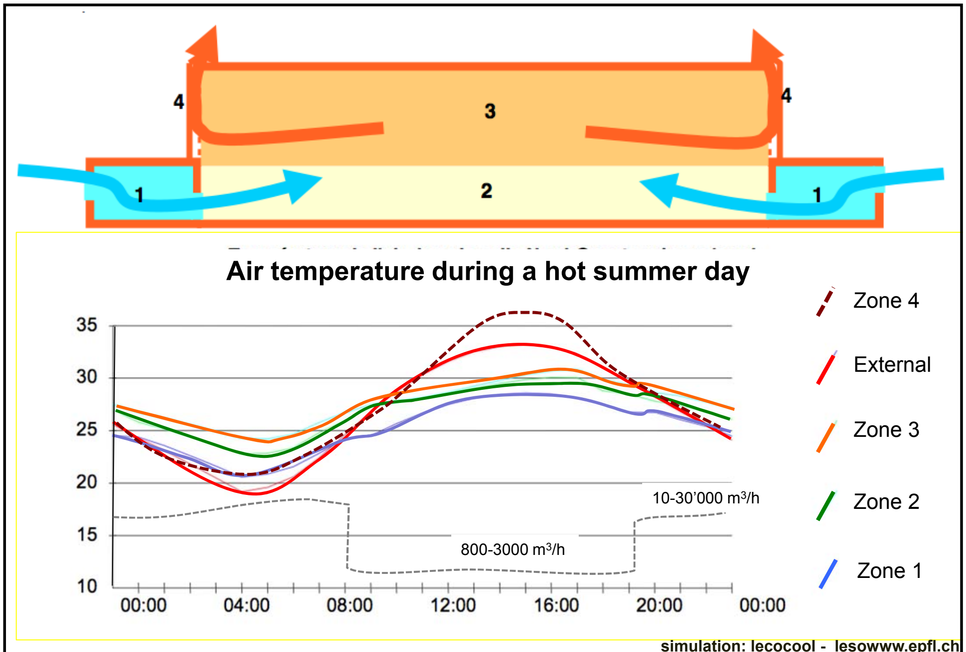
Q_1 = 2 X 12'237 m^3/h at ΔT = 6° C, 50% ach in 9 minutes



overheating: night ventilation cooling strategy - 55 h / no strategy 1099 h



overheating: night ventilation cooling strategy - 92 h / no strategy 1112 h



stratification stragegy: cool the occupied area, avoid ceiling heat trap

Centre médical des Grangettes

Construction du bâtiment d'accueil

Maître de l'ouvrage — Centre médical des Grangettes SA, Chemin des Grangettes, 1224 Chêne-Bougeries

Architecte — Eric Dunant, Pont-de-Ville 13, 1224 Chêne-Bougeries

Physique du bâtiment — Estia SA, Parc scientifique EPFL, 1015 Lausanne

Projet — 2003

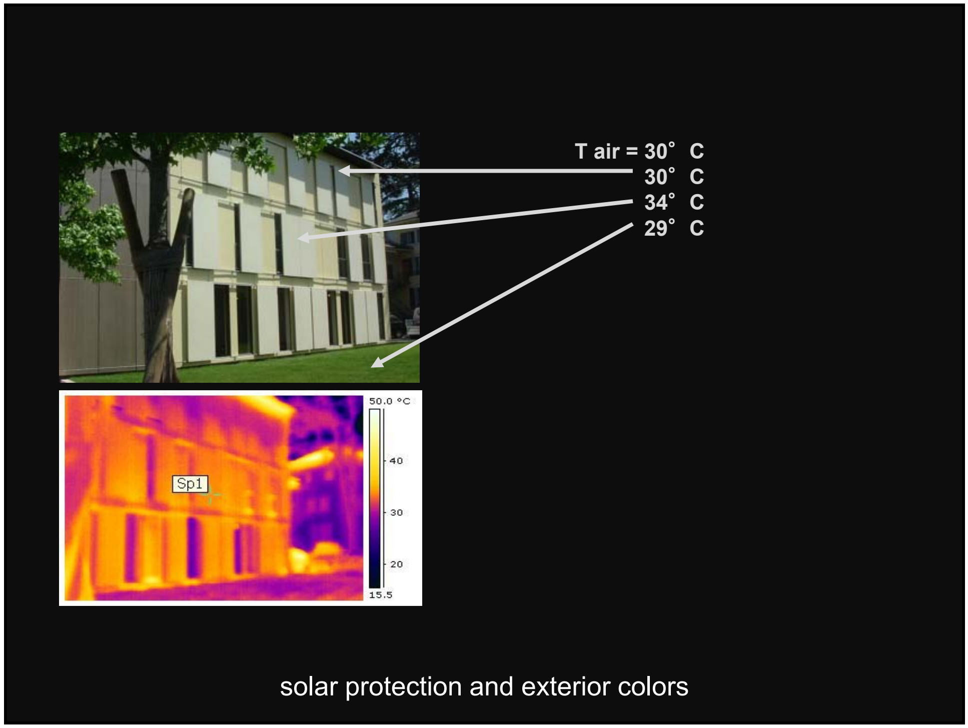
Réalisation — 2004-2005

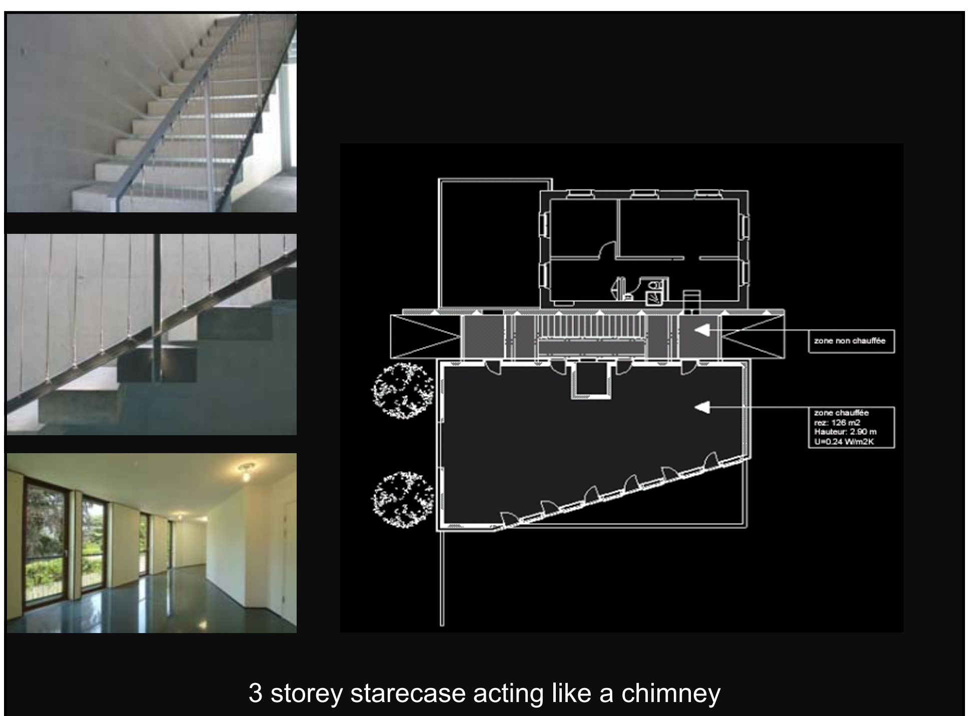
Adresse — Route de Chêne 110, 1224 Chêne-Bougeries

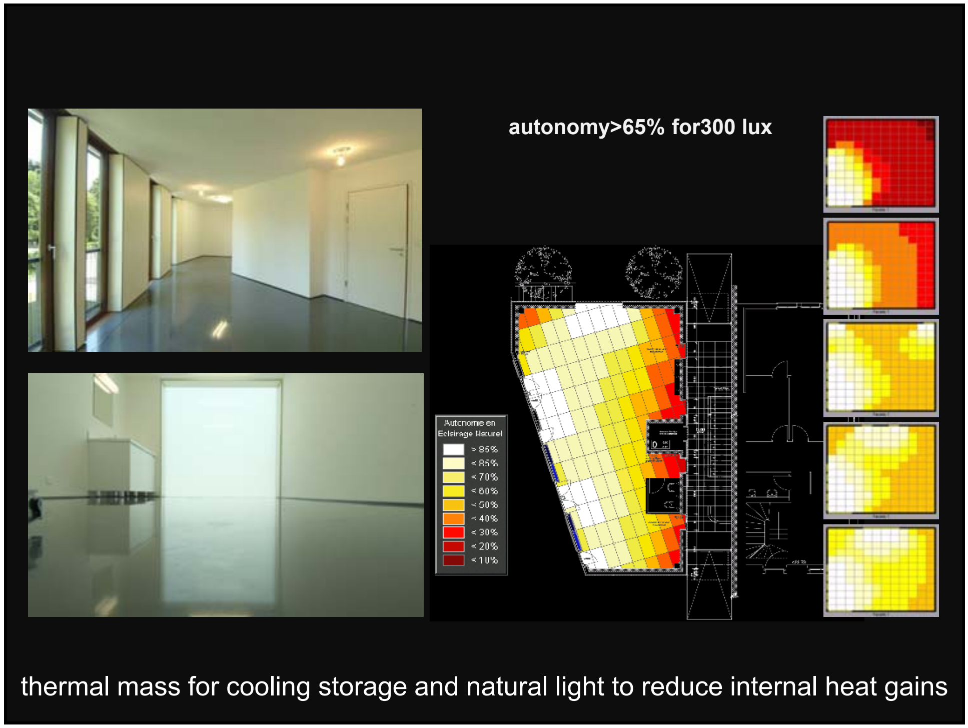
Coût de construction — Fr. 3'100'000.-

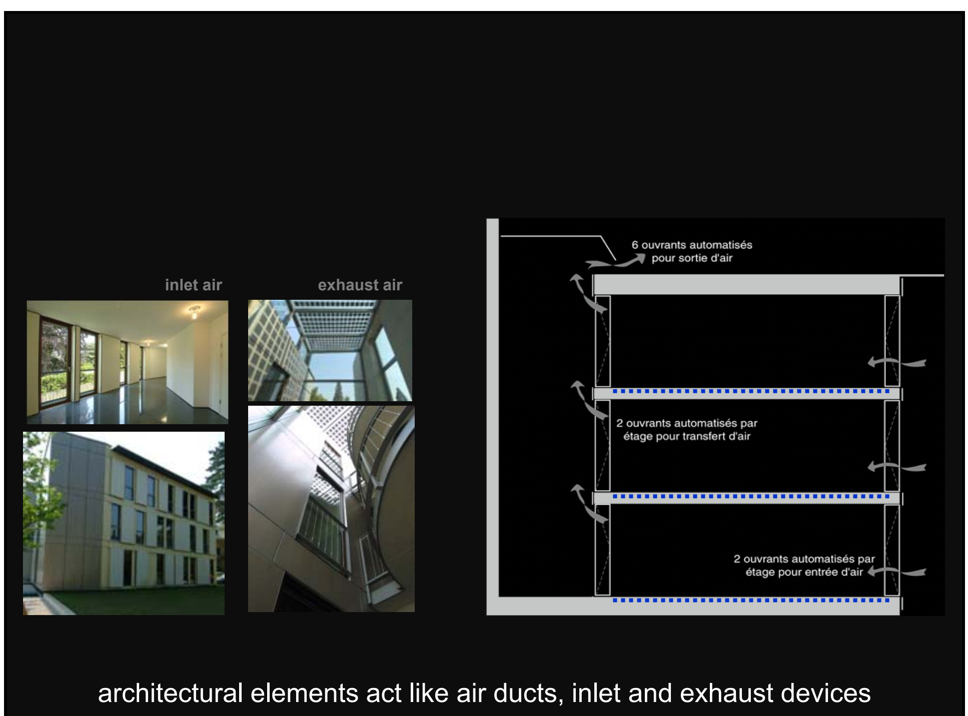
one of the first eco-buildings labeled Minergie in Geneva

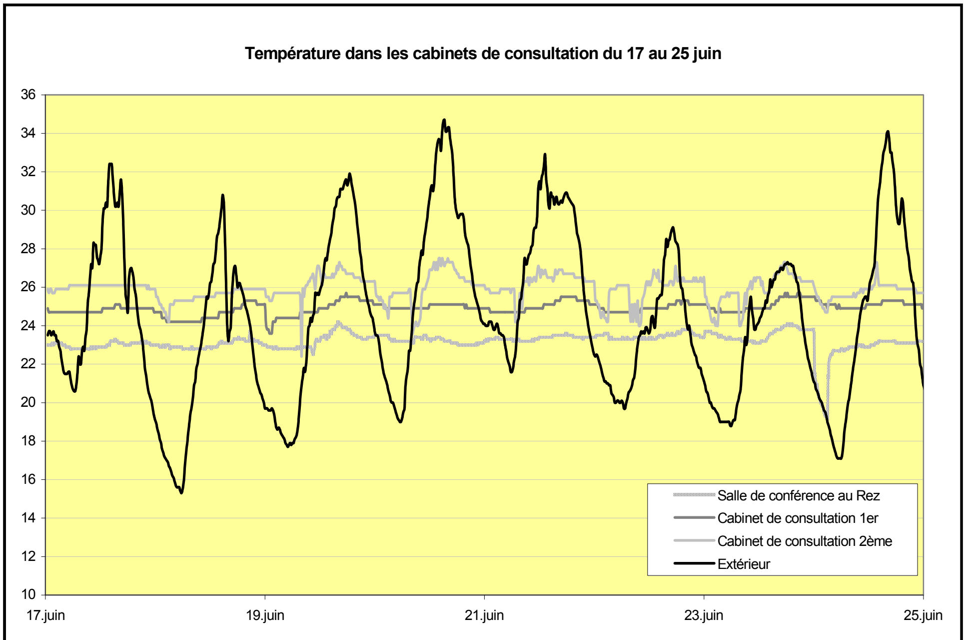
solar shading, color selection, external environment design


T air = 30° C
30° C
34° C
29° C
Sp1
50.0 °C
40
30
20
15.5
solar protection and exterior colors


zone non chauffée
zone chauffée
rez: 126 m2
Hauteur: 2.90 m
U=0.24 W/m2K
3 storey starecase acting like a chimney


autonomy>65% for300 lux
Autonomie en
Eclairage Naturel
> 85%
< 85%
< 70%
< 60%
< 50%
< 40%
< 30%
< 20%
< 10%
thermal mass for cooling storage and natural light to reduce internal heat gains


inlet air
exhaust air
6 ouvrants automatisés
pour sortie d'air
2 ouvrants automatisés par
étage pour transfert d'air
2 ouvrants automatisés par
étage pour entrée d'air
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

23

Nicosia Municipality. Finance Department - South Facade

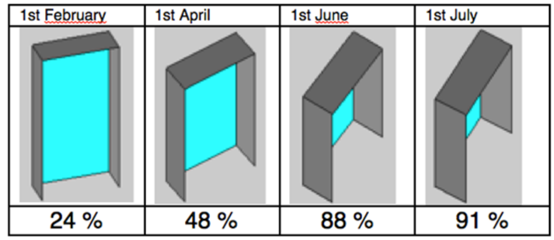
irwinkritioti.architecture

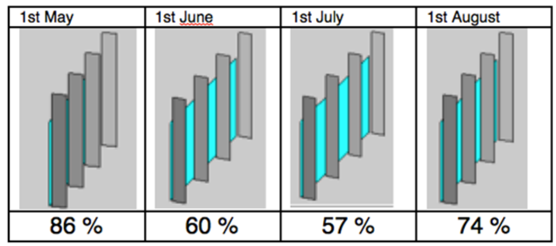
26

- **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 (staircases, toilets)
  - Opening design for optimal night ventilation (summer passive cooling)
  - Natural ventilation
  - Use of ceiling funs
  - 100% Solar hot water

27

• almost perfect solar shading

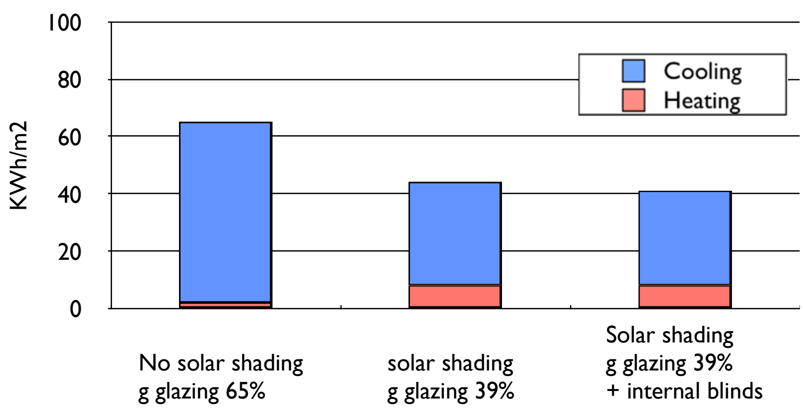




→ **Permanent solar protection and glazing g-39%, TL-70%**

28

• effect of solar protection



→ **Solar shading and reduced g glazing value saves 37% of energy**

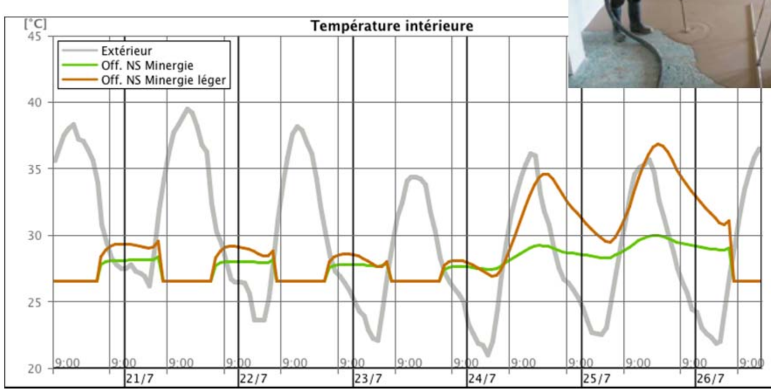
29

• **apparent thermal mass**

→ **Unhydrid screed for the floor, apparent claded concrete slab.**

30

• **apparent thermal mass**



→ **Without thermal mass temperature rises to 37° C instead of 30**

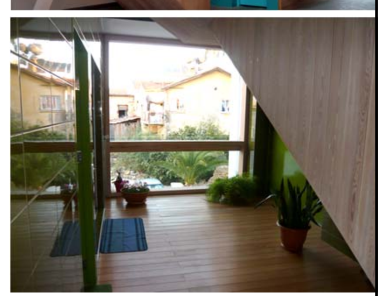
31

- Opening dimensioning

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

32

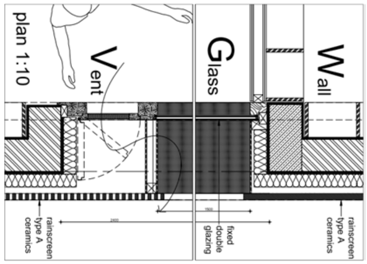
- Inside – outside in the Mediterranean climate

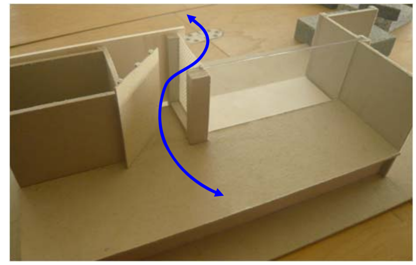


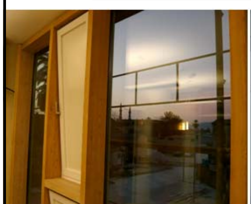
→ 682 m^2 (75%) within the thermal envelope out of a total of 900 m^2

33

- night ventilation design







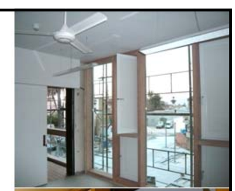

→ safe, protected, flexible openings, dissociation of air from light path

34

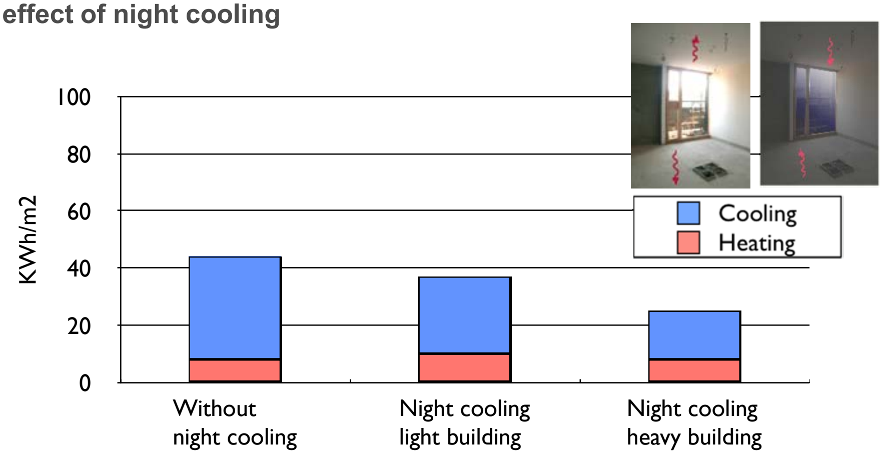
- natural ventilation design

Opening possibilities 40X300	m^3/h	
40X300	610	100
40X300 grille	366	60 %
40X122	158	26 %
40X122 + 40X122	499	82 %
15X122 à la française	59	10 %
7X122	28	5 %
15X122+15X122 à la Fr	187	31 %
15 cm à l'italienne (6°)	49	8 %
10 cm à l'italienne (4°)	30	5 %

→ A window offering 30 to 366 m^3/h stack effect single sided airflow at ΔT 5° C




• effect of night cooling

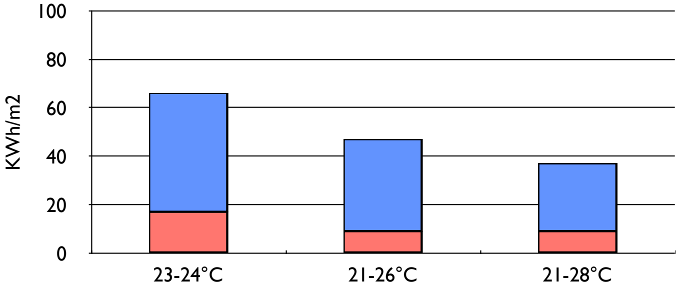


→ **Night cooling may reduce cooling need of an aready optimised building by 53%, (17 kWh/m^2y instead of 36)**

→ **A light building has only 25% reduction potential**

36

• Use of ceiling fans to keep windows closed and rise set temperature



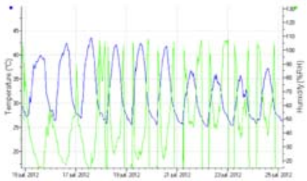
→ **15 % rise of cooling load per ° C of set température decrease**

→ **Ceiling fans may save 30% of cooling energy consumption**

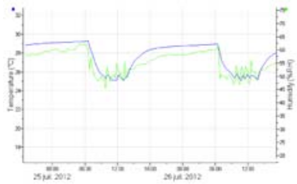
37

• Monitoring: outside 45° C – inside 27- 30° C

outside



Cooled occupied office



Unoccupied office

simulated occupied office

38

• 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 opemable 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.

39

Ventilative Cooling:

the holistic approach on buildings and systems developing the EPBD standards under Mandate 480

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Manager international projects and standards
Chair CEN TC 371 Program Committee on EPBD
Fellow ASHRAE and REHVA
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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

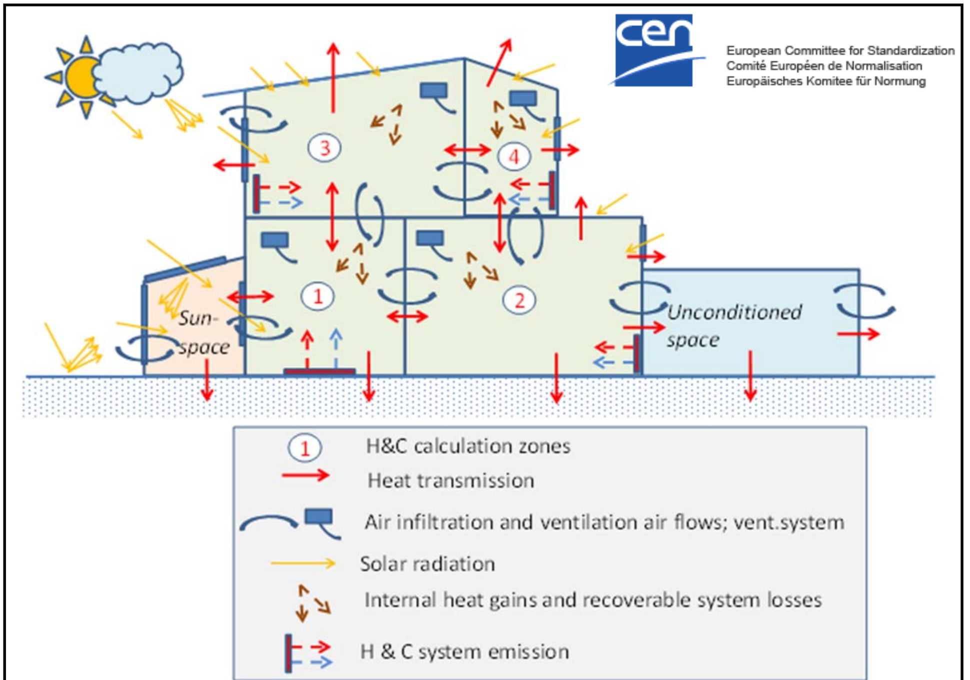
Extended Ventilative Cooling definition needed?

- 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?

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

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

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

EN15241 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

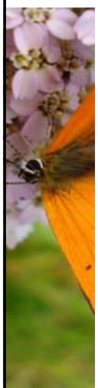
EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR ENERGY

Directorate C - New and renewable sources of energy, Energy efficiency & Innovation
C.3 - Energy efficiency of products & Intelligent Energy – Europe

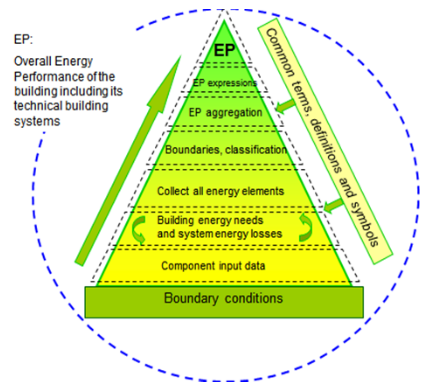
Brussels, 14th December 2010
M/480 EN

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)[1]

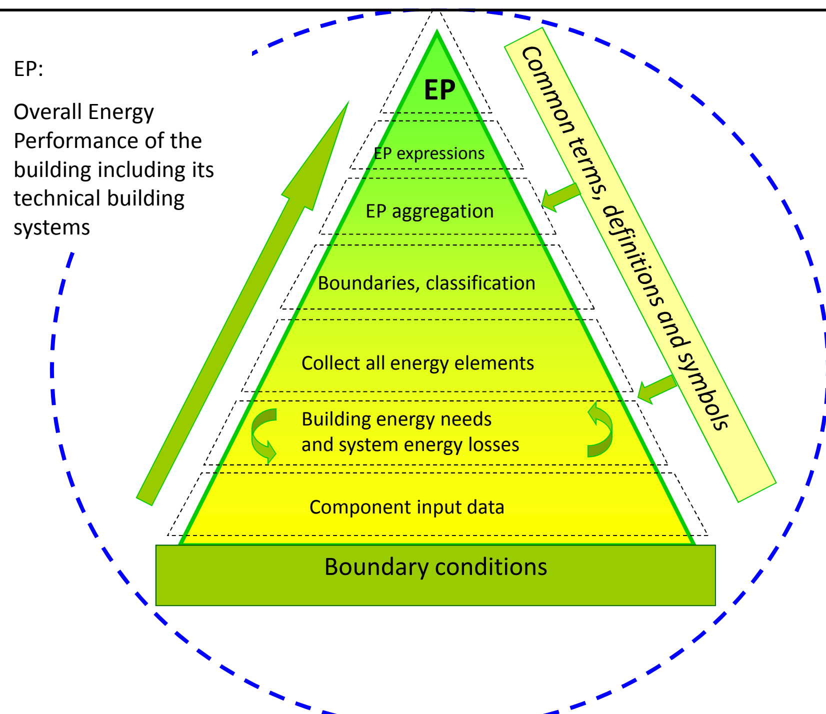
Current set of CEN EPBD (Energy Performance Buildings Directive) standards



- Total 42 standards: 31 EN- and 11 EN-ISO standards published in 2007-2008
- Presented as a "pyramid" structure



Most are **used** in many EU Member States, as required by national legislation based the 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 modular structure and unambiguous

More consistent and in line with requirements to be specified by the Member States legislators

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 spread sheet calculations

Other…

prEN15603 Energy performance of buildings — Overarching standard

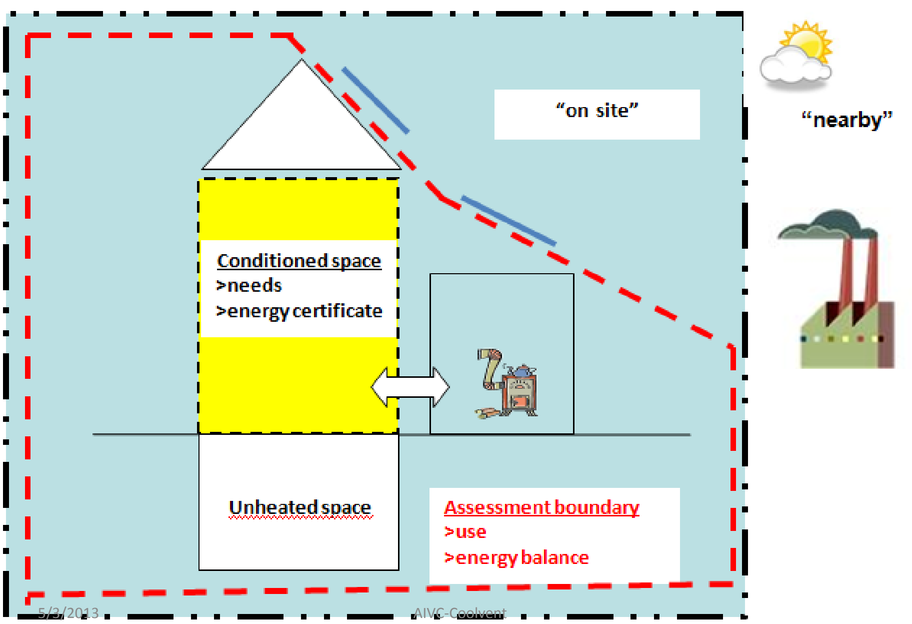
official public enquiry starts March 2013

- 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

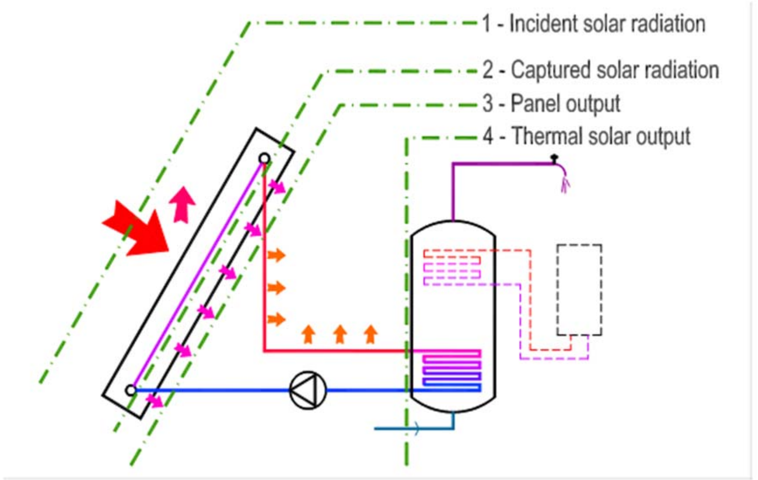
Assessment boundaries



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 ….

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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

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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

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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!

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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…

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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 NZEB 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

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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

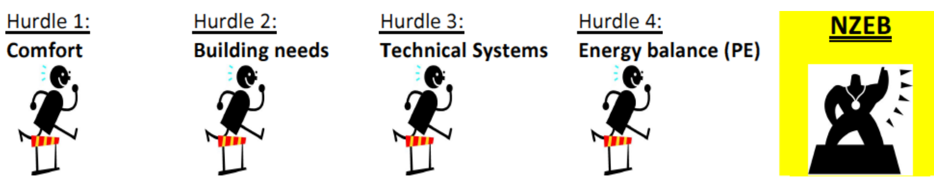

Figure: Hurdle race to NZEB

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

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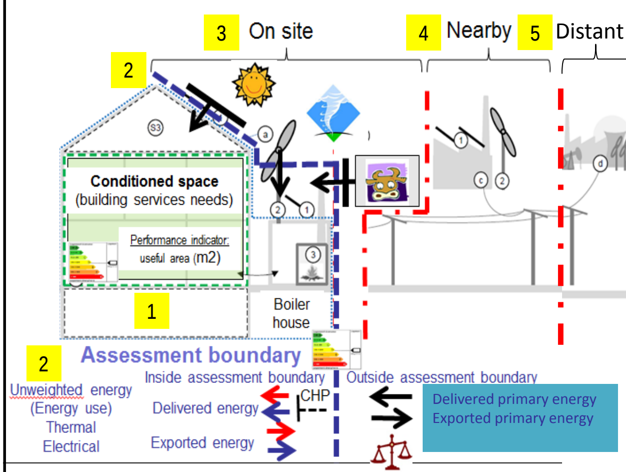
Assessment boundary and perimeters Fundamental definitions



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

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Source: Johann zirngibl@cstb.fr Page 33

The assessment procedure prEN15603 chapter 7

Assessment steps according prEN15603	Applications, objectives
1) Identify the **object of the energy assessment** (several buildings, whole building, building unit ?)	• Minimum requirements • Energy certificates
2) Identify the **building categories(s)** (e.g. residential, office buildings)and the related **building services** to be included in the energy assessment	• Occupancy patterns (e.g. internal gains, opening hours) • Performance scale
3) Identify the **assessment boundary and related perimeters** (Conditioned space, assessment boundary, on site, nearby, distant)	• Building needs • Performance indicator (m2) Energy balance (delivered, exported) • Primary energy factors
4) Calculate the **primary energy balance**	**Energy performance indicator**
5) Calculate additional indicators:: Share of renewables (RER)	**Share of renewables**
6) Calculate additional indicators: Performance technical building systems	**Performance indicator technical building systems**

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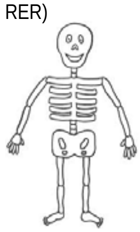
CEN structure and options prEN 15603

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?

CEN default option
- Harmonization
- Reproducibility
- Transparency

A common **backbone** to
- define (Member States)
- understand (Building professionals)

energy performance indicators

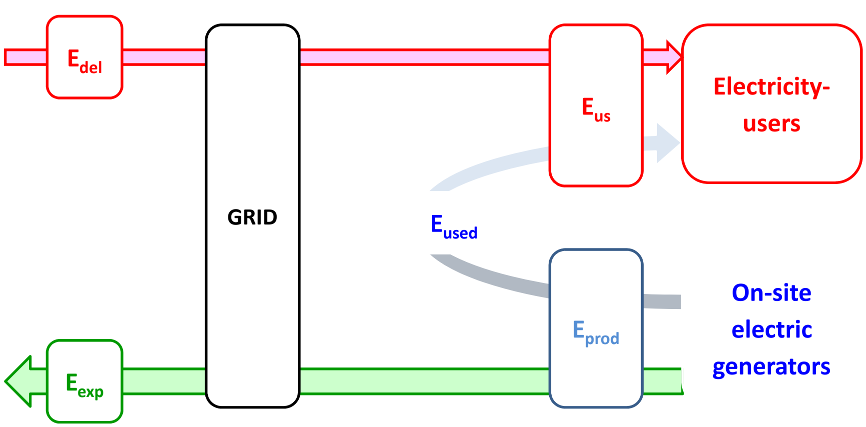
Accompanying informative Technical Report to the prEN15603

- 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

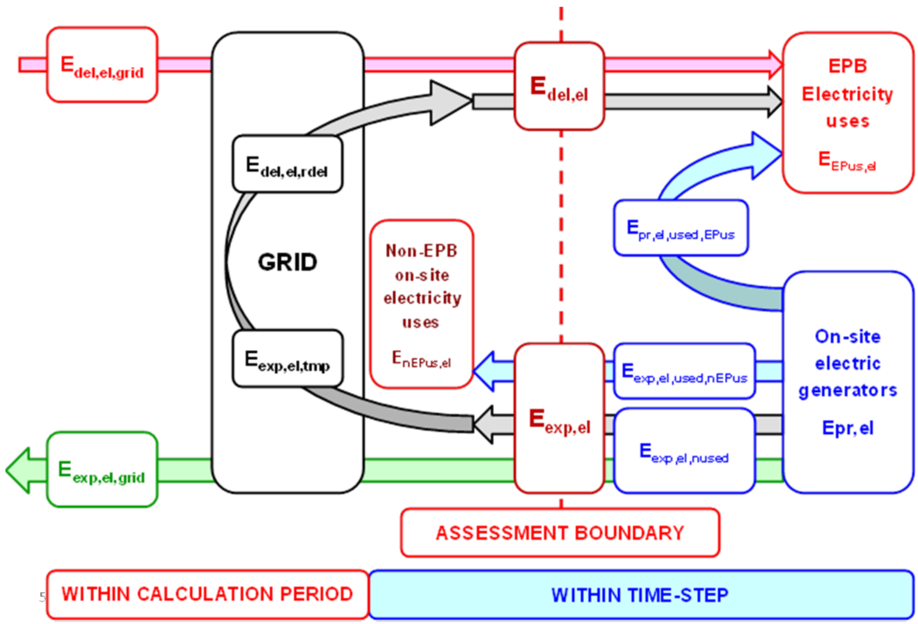
- Information to support the correct understanding, use and implementation of prEN15603:
  - Explanation on the procedures and background information and justification of the choices
  - Reporting on validation of calculation procedures given in the standard.
  - Explanation for the user and for national 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.**

It started with a **Simplified** balance (real-time)



TOWARDS A MORE COMPLETE REFERENCE DIAGRAM FOR THE ELECTRICITY BALANCE

Reference diagram for electricity balance



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.

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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;

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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 .

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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

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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 Sohéil Moghtader & Jan de Boer (D)

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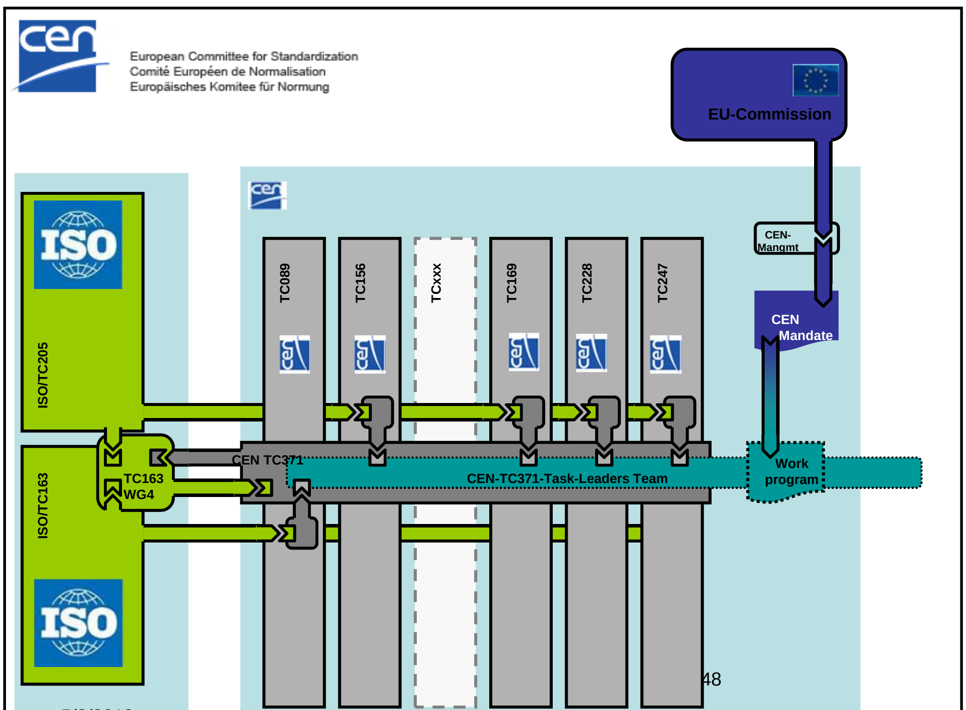

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Summary

- **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 ?

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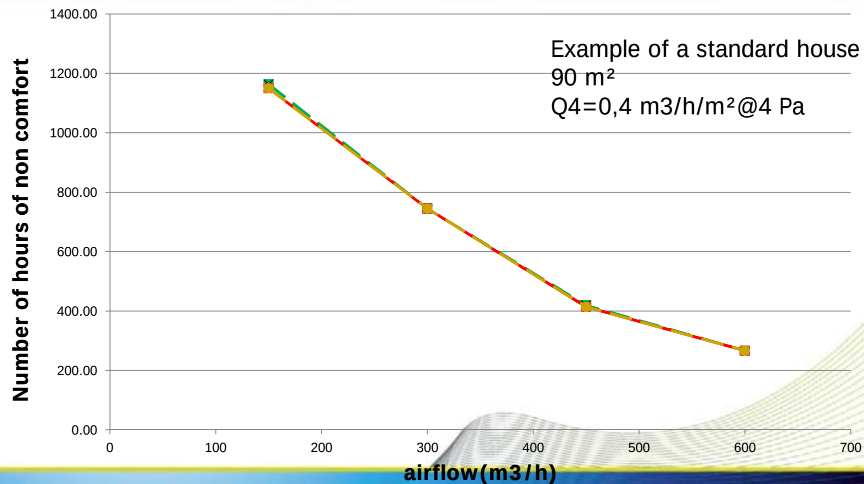
French Energy regulation

- 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 confortable temperature

French Energy regulation



Feasability of Free cooling

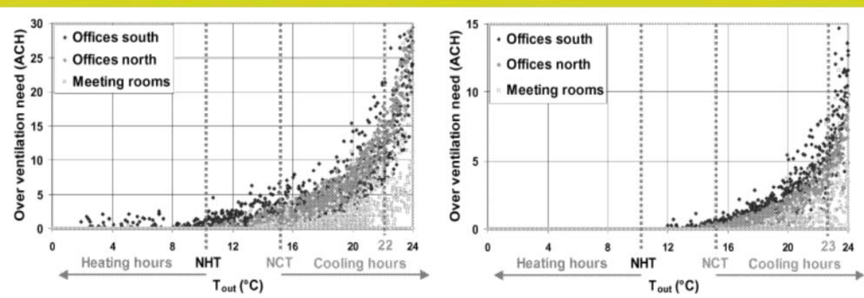
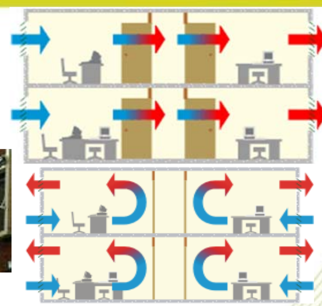


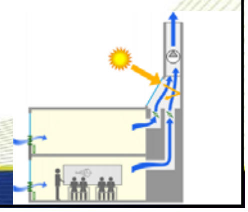
Figure 7. Additional ACH needed in the reference case. Figure 8. Additional ACH needed in the modified case.

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

Définitions

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



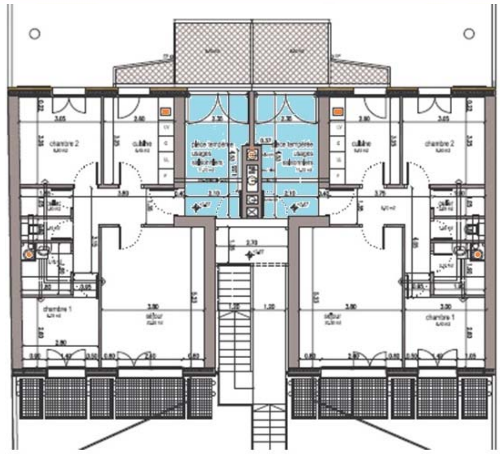


Example 1
Collective Dwelling

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)

	Nominal	Boost
airflow (m3/h)	630	1020
Avail.Pressure (Pa)	150*	150*
Fan absorbed power (W)	143	281
Sound Power level (Lw) dB(A)	-	76

560 W in over-ventilation

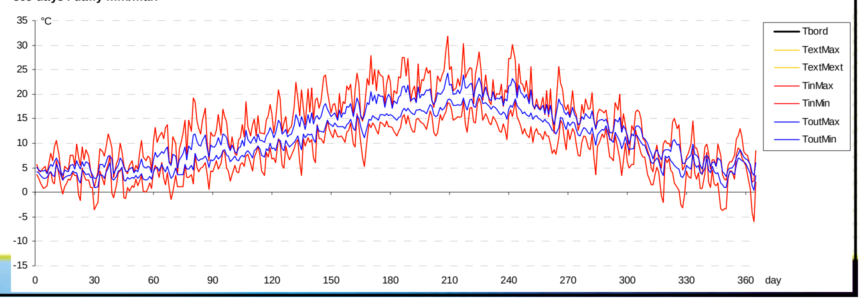
Ivry : ground heat exchanger

NOT CHOSEN

- 70m
- D400 mm
- depth : 1m

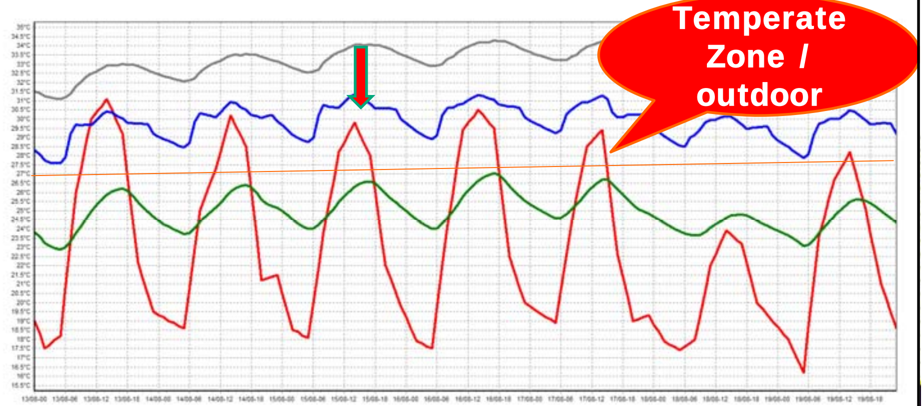
	Temperature after ground exchanger °C	
	Mini	Maxi
June	11,2	20,5
July	14,8	24,2
Aug	14,9	23,9
Sept	11,9	21,9

365 days : daily min/max



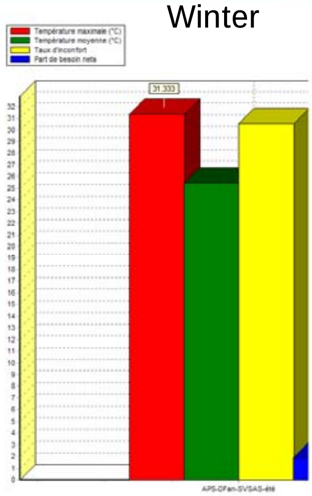
Ivry Over-ventilation

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

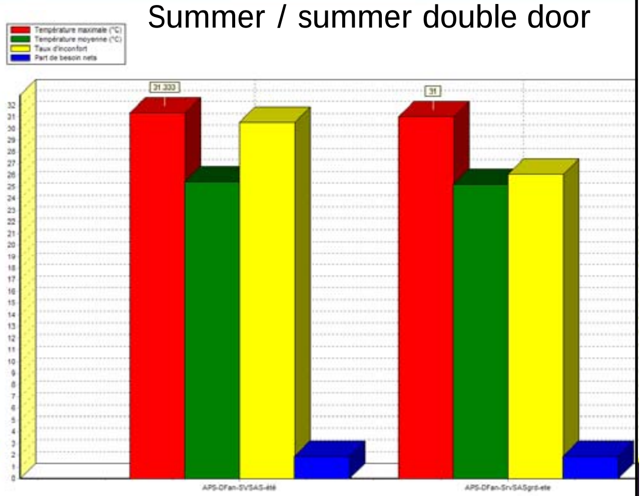


Impact of the temperate zone

Winter



Summer / summer double door



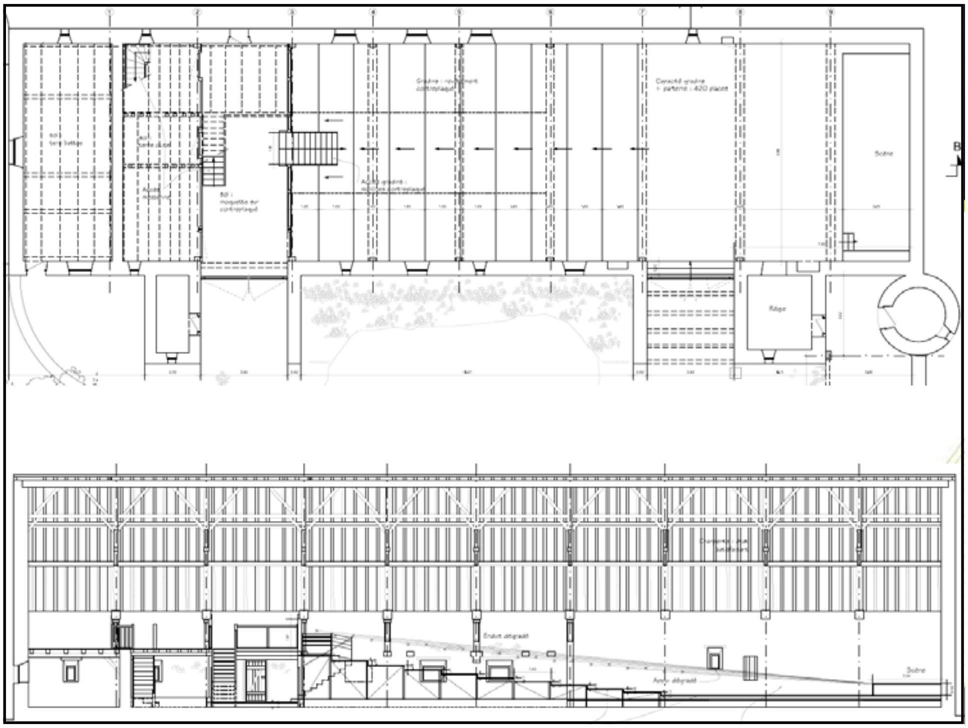
Example 2
Theater

Theater

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

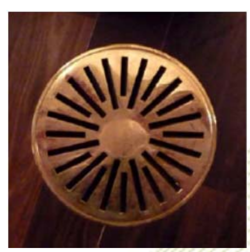
- Runs in summer at night and afternoon
- 410 occupants, 12 kW lighting
- 24 dB(A) & 20 dB @ 250 Hz

Theater



Theater

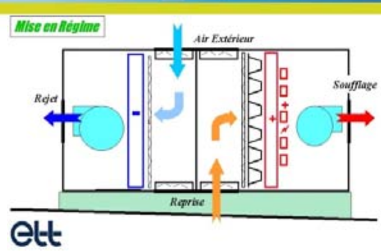
- Displacement ventilation
  - Free cooling on a longer period
  - IAQ ++
- Supply underseats and on scene
  - Floor diffusers
- Exhaust on the ceiling (on top of scene and opposite)

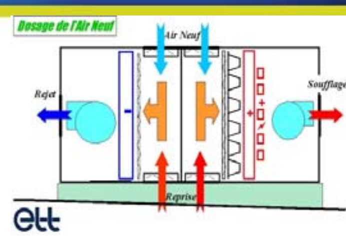


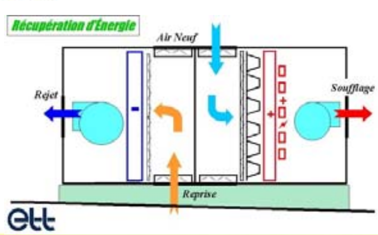
Theater

- 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., CO^2 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



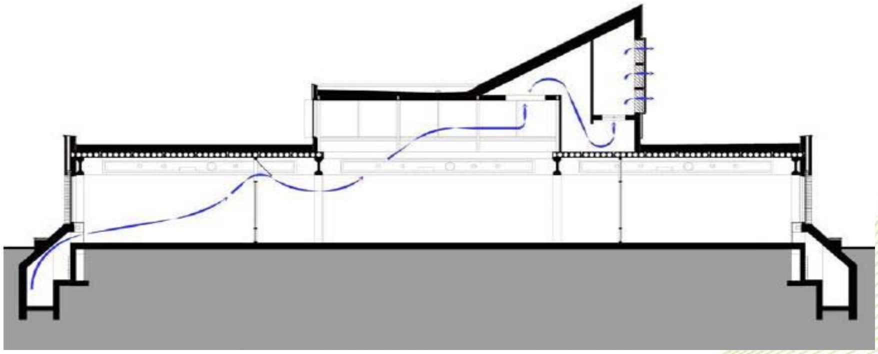




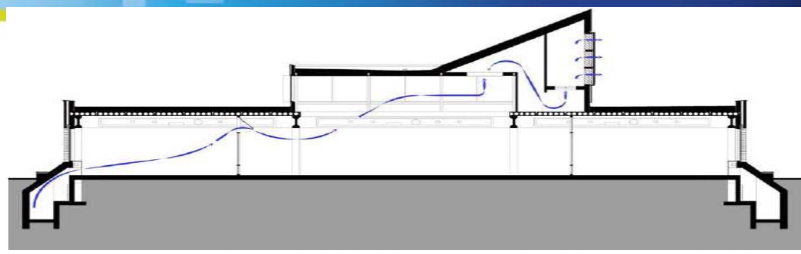
- Constant supply Temperature (/ direct expansion)
- Control outdoor air flow
- COP improved
- Free cooling

Example 3
Supermarket in Portugal

Supermarket 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
- Plannify summer and mid season running to avoid overheating...

STATUS OF VENTILATIVE COOLING IN DK

Karsten Duer
VELUX

1

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

2

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

3

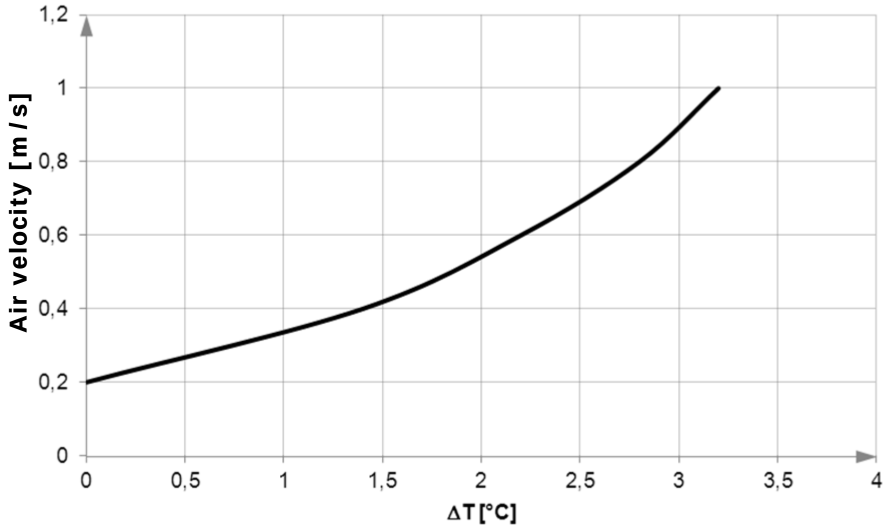
Status of ventilative cooling in DK

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)

4

Air velocity vs reduction in temperature sensation, ΔT. ISO 7730 and EN 15251. From annex in DS 447



5

VELUX

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.

6

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

7

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?

8

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

9

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

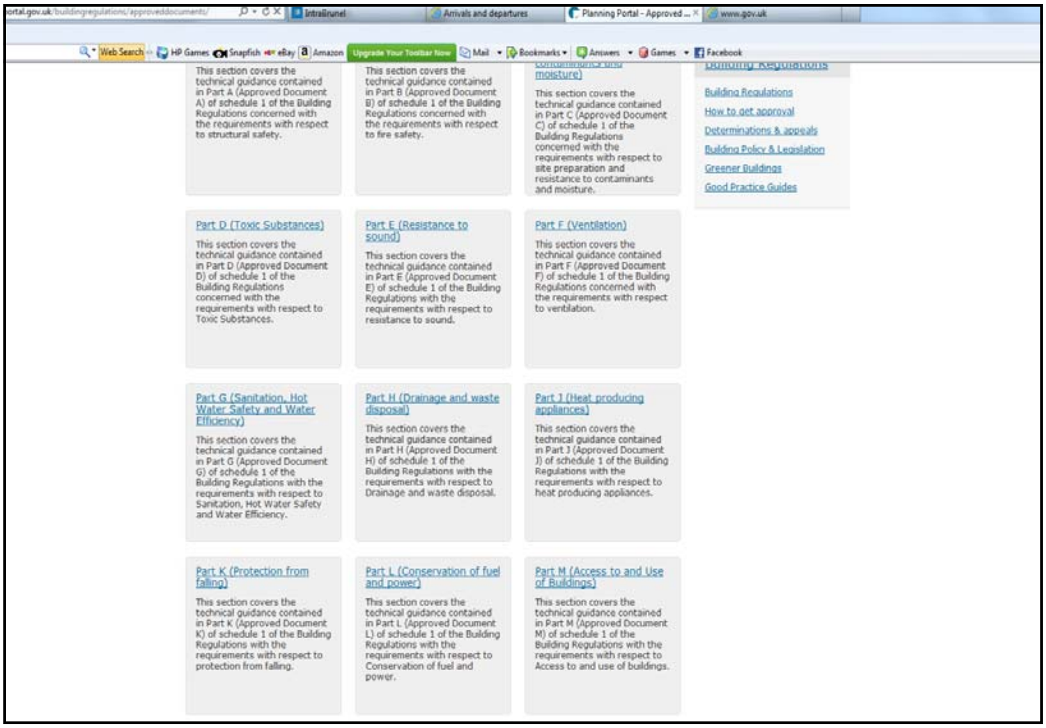
Thank You

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/



This section covers the technical guidance contained in Part A (Approved Document A) of schedule 1 of the Building Regulations concerned with the requirements with respect to structural safety.

This section covers the technical guidance contained in Part B (Approved Document B) of schedule 1 of the Building Regulations concerned with the requirements with respect to fire safety.

moisture)

This section covers the technical guidance contained in Part C (Approved Document C) of schedule 1 of the Building Regulations concerned with the requirements with respect to site preparation and resistance to contaminants and moisture.

Building Regulations
How to get approval
Determinations & appeals
Building Policy & Legislation
Greener Buildings
Good Practice Guides

Part D (Toxic Substances)

This section covers the technical guidance contained in Part D (Approved Document D) of schedule 1 of the Building Regulations concerned with the requirements with respect to Toxic Substances.

Part E (Resistance to sound)

This section covers the technical guidance contained in Part E (Approved Document E) of schedule 1 of the Building Regulations with the requirements with respect to resistance to sound.

Part F (Ventilation)

This section covers the technical guidance contained in Part F (Approved Document F) of schedule 1 of the Building Regulations concerned with the requirements with respect to ventilation.

Part G (Sanitation, Hot Water Safety and Water Efficiency)

This section covers the technical guidance contained in Part G (Approved Document G) of schedule 1 of the Building Regulations with the requirements with respect to Sanitation, Hot Water Safety and Water Efficiency.

Part H (Drainage and waste disposal)

This section covers the technical guidance contained in Part H (Approved Document H) of schedule 1 of the Building Regulations with the requirements with respect to Drainage and waste disposal.

Part J (Heat producing appliances)

This section covers the technical guidance contained in Part J (Approved Document J) of schedule 1 of the Building Regulations with the requirements with respect to heat producing appliances.

Part K (Protection from falling)

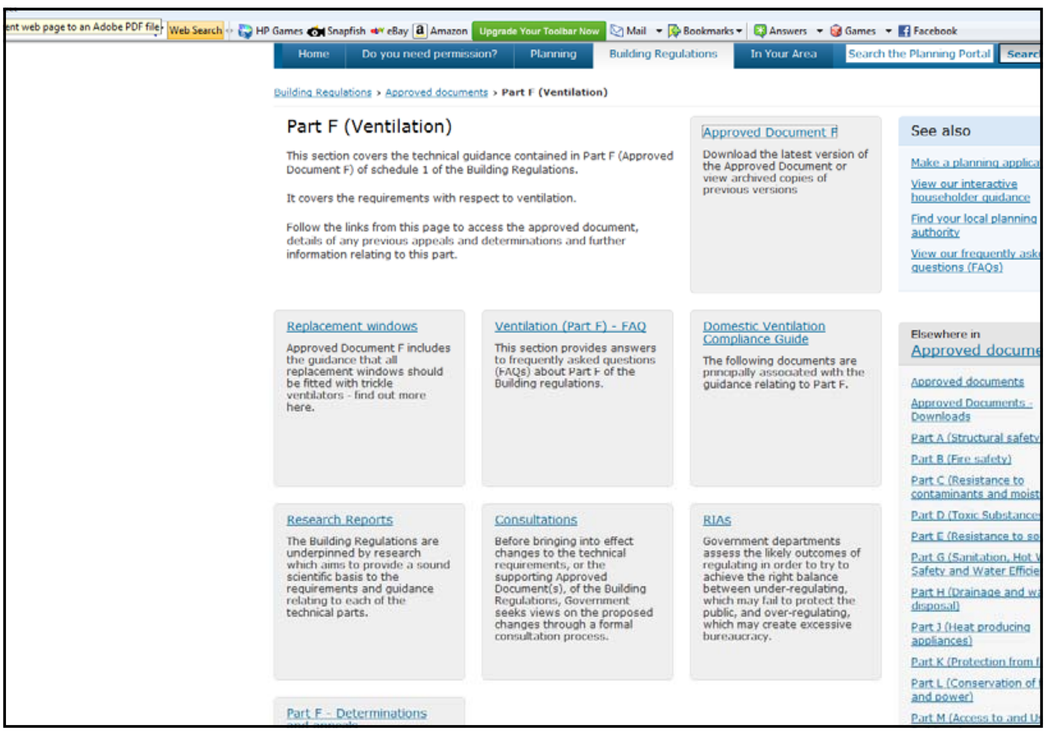
This section covers the technical guidance contained in Part K (Approved Document K) of schedule 1 of the Building Regulations with the requirements with respect to protection from falling.

Part L (Conservation of fuel and power)

This section covers the technical guidance contained in Part L (Approved Document L) of schedule 1 of the Building Regulations with the requirements with respect to Conservation of fuel and power.

Part M (Access to and Use of Buildings)

This section covers the technical guidance contained in Part M (Approved Document M) of schedule 1 of the Building Regulations with the requirements with respect to Access to and use of buildings.



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Building Regulations > Approved documents > **Part F (Ventilation)**

Part F (Ventilation)

This section covers the technical guidance contained in Part F (Approved Document F) of schedule 1 of the Building Regulations.

It covers the requirements with respect to ventilation.

Follow the links from this page to access the approved document, details of any previous appeals and determinations and further information relating to this part.

Approved Document F

Download the latest version of the Approved Document or view archived copies of previous versions

See also

Make a planning applica
View our interactive householder guidance
Find your local planning authority
View our frequently ask questions (FAQs)

Replacement windows

Approved Document F includes the guidance that all replacement windows should be fitted with trickle ventilators - find out more here.

Ventilation (Part F) - FAQ

This section provides answers to frequently asked questions (FAQs) about Part F of the Building regulations.

Domestic Ventilation Compliance Guide

The following documents are principally associated with the guidance relating to Part F.

Elsewhere in Approved docume

Approved documents
Approved Documents - Downloads
Part A (Structural safety
Part B (Fire safety)
Part C (Resistance to contaminants and moist
Part D (Toxic Substance
Part E (Resistance to so
Part G (Sanitation, Hot W Safety and Water Efficie
Part H (Drainage and wa disposal)
Part J (Heat producing appliances)
Part K (Protection from f
Part L (Conservation of f and power)
Part M (Access to and U

Research Reports

The Building Regulations are underpinned by research which aims to provide a sound scientific basis to the requirements and guidance relating to each of the technical parts.

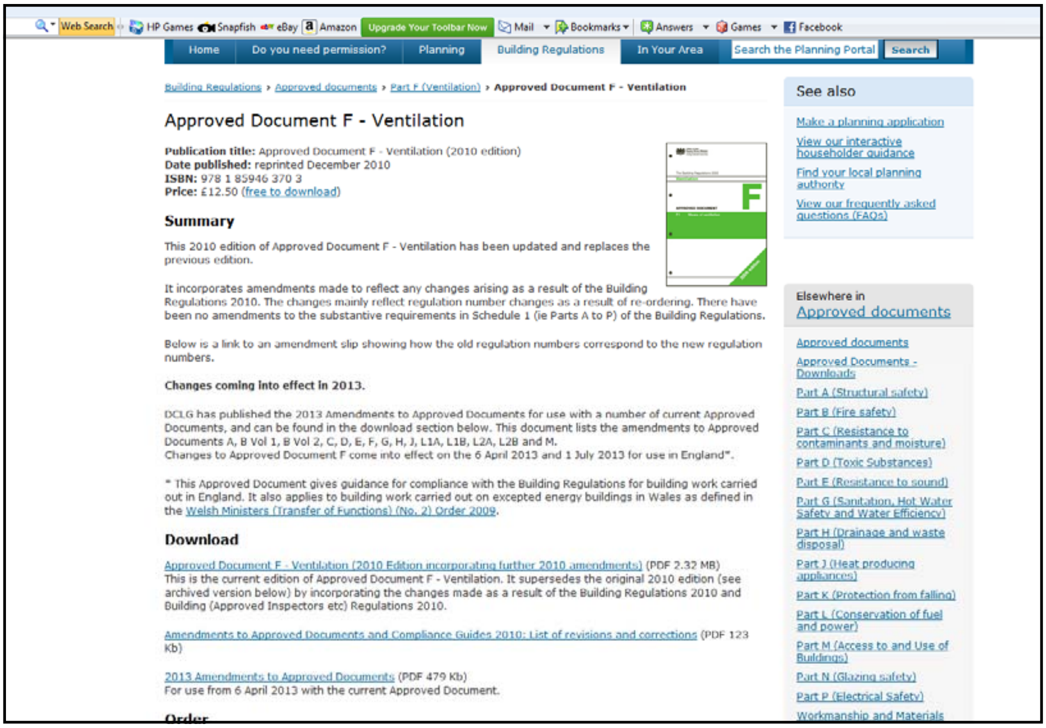
Consultations

Before bringing into effect changes to the technical requirements, or the supporting Approved Document(s), of the Building Regulations, Government seeks views on the proposed changes through a formal consultation process.

RIAs

Government departments assess the likely outcomes of regulating in order to try to achieve the right balance between under-regulating, which may fail to protect the public, and over-regulating, which may create excessive bureaucracy.

Part F - Determinations



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Building Regulations › Approved documents › Part F (Ventilation) › **Approved Document F - Ventilation**

Approved Document F - Ventilation

Publication title: Approved Document F - Ventilation (2010 edition)
Date published: reprinted December 2010
ISBN: 978 1 85946 370 3
Price: £12.50 (free to download)

Summary

This 2010 edition of Approved Document F - Ventilation has been updated and replaces the previous edition.

It incorporates amendments made to reflect any changes arising as a result of the Building Regulations 2010. The changes mainly reflect regulation number changes as a result of re-ordering. There have been no amendments to the substantive requirements in Schedule 1 (ie Parts A to P) of the Building Regulations.

Below is a link to an amendment slip showing how the old regulation numbers correspond to the new regulation numbers.

Changes coming into effect in 2013.

DCLG has published the 2013 Amendments to Approved Documents for use with a number of current Approved Documents, and can be found in the download section below. This document lists the amendments to Approved Documents A, B Vol 1, B Vol 2, C, D, E, F, G, H, J, L1A, L1B, L2A, L2B and M.
Changes to Approved Document F come into effect on the 6 April 2013 and 1 July 2013 for use in England*.

* This Approved Document gives guidance for compliance with the Building Regulations for building work carried out in England. It also applies to building work carried out on excepted energy buildings in Wales as defined in the Welsh Ministers (Transfer of Functions) (No. 2) Order 2009.

Download

Approved Document F - Ventilation (2010 Edition incorporating further 2010 amendments) (PDF 2.32 MB)
This is the current edition of Approved Document F - Ventilation. It supersedes the original 2010 edition (see archived version below) by incorporating the changes made as a result of the Building Regulations 2010 and Building (Approved Inspectors etc) Regulations 2010.

Amendments to Approved Documents and Compliance Guides 2010: List of revisions and corrections (PDF 123 Kb)

2013 Amendments to Approved Documents (PDF 479 Kb)
For use from 6 April 2013 with the current Approved Document.

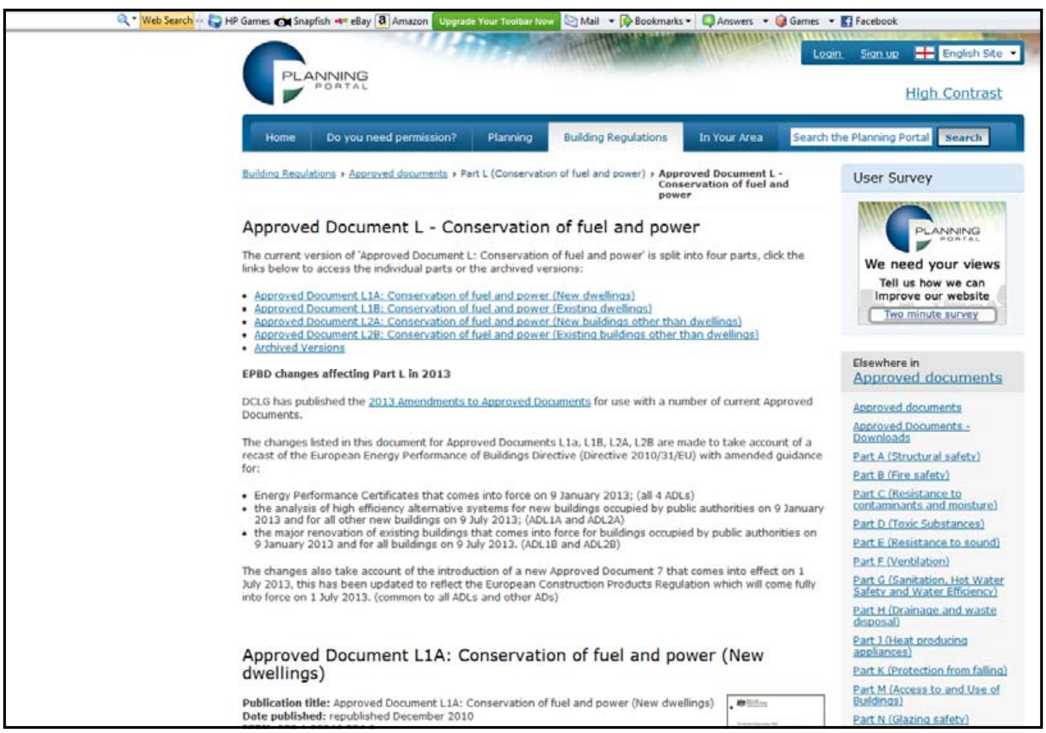
Order

See also

- Make a planning application
- View our interactive householder guidance
- Find your local planning authority
- View our frequently asked questions (FAQs)

Elsewhere in
Approved documents

- Approved documents
- Approved Documents - Downloads
- Part A (Structural safety)
- Part B (Fire safety)
- Part C (Resistance to contaminants and moisture)
- Part D (Toxic Substances)
- Part E (Resistance to sound)
- Part G (Sanitation, Hot Water Safety and Water Efficiency)
- Part H (Drainage and waste disposal)
- Part J (Heat producing appliances)
- Part K (Protection from falling)
- Part L (Conservation of fuel and power)
- Part M (Access to and Use of Buildings)
- Part N (Glazing safety)
- Part P (Electrical Safety)
- Workmanship and Materials



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Building Regulations › Approved documents › Part L (Conservation of fuel and power) › **Approved Document L - Conservation of fuel and power**

Approved Document L - Conservation of fuel and power

The current version of 'Approved Document L: Conservation of fuel and power' is split into four parts, click the links below to access the individual parts or the archived versions:

- Approved Document L1A: Conservation of fuel and power (New dwellings)
- Approved Document L1B: Conservation of fuel and power (Existing dwellings)
- Approved Document L2A: Conservation of fuel and power (New buildings other than dwellings)
- Approved Document L2B: Conservation of fuel and power (Existing buildings other than dwellings)
- Archived Versions

EPBD changes affecting Part L in 2013

DCLG has published the 2013 Amendments to Approved Documents for use with a number of current Approved Documents.

The changes listed in this document for Approved Documents L1a, L1B, L2A, L2B are made to take account of a recast of the European Energy Performance of Buildings Directive (Directive 2010/31/EU) with amended guidance for:

- Energy Performance Certificates that comes into force on 9 January 2013; (all 4 ADLs)
- the analysis of high efficiency alternative systems for new buildings occupied by public authorities on 9 January 2013 and for all other new buildings on 9 July 2013; (ADL1A and ADL2A)
- the major renovation of existing buildings that comes into force for buildings occupied by public authorities on 9 January 2013 and for all buildings on 9 July 2013. (ADL1B and ADL2B)

The changes also take account of the introduction of a new Approved Document 7 that comes into effect on 1 July 2013, this has been updated to reflect the European Construction Products Regulation which will come fully into force on 1 July 2013. (common to all ADLs and other ADs)

Approved Document L1A: Conservation of fuel and power (New dwellings)

Publication title: Approved Document L1A: Conservation of fuel and power (New dwellings)
Date published: republished December 2010

User Survey

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Elsewhere in
Approved documents

- Approved documents
- Approved Documents - Downloads
- Part A (Structural safety)
- Part B (Fire safety)
- Part C (Resistance to contaminants and moisture)
- Part D (Toxic Substances)
- Part E (Resistance to sound)
- Part F (Ventilation)
- Part G (Sanitation, Hot Water Safety and Water Efficiency)
- Part H (Drainage and waste disposal)
- Part J (Heat producing appliances)
- Part K (Protection from falling)
- Part M (Access to and Use of Buildings)
- Part N (Glazing safety)

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 $5m^3/(h\ m^2)$ 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'

School of Engineering and Design
Centre for Sustainable Energy Use in Food Chains

Part L – Conservation of Fuel and Power

Focusses on energy use

- Two terms are used to describe the energy performance;
  - BER is the Building CO_2 Emission Rate and
  - TER is the minimum (Target) energy performance,
  - both expressed in mass of CO_2 emitted per year per square metre of the total useful floor are of the buildings ($kg/m^2/y$).
  - 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.

ENERGY Bits
Brunel UNIVERSITY LONDON
19-20 March 2013, International Workshop on Ventilative Cooling: Need, Challenges and Solution Examples, Brussels
www.brunel.ac.uk/about/acad/sed

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

School of Engineering and Design
Centre for Sustainable Energy Use in Food Chains

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!

ENERGY Bits
Brunel UNIVERSITY LONDON
19-20 March 2013, International Workshop on Ventilative Cooling: Need, Challenges and Solution Examples, Brussels
www.brunel.ac.uk/about/acad/sed

Ventilative cooling in building regulations
The Netherlands

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

Bas Knoll

1
March 20, 2013
Bas Knoll
Cooling regulations NL

Energy Performance Coefficient EPC = normative Energy Performance Indicator EP for year 2000

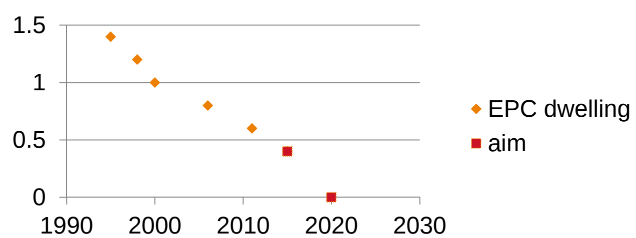
$$EPC = \frac{specific\ energy\ use}{acceptable\ energy\ use\ year\ 2000} \times present\ demand$$

Dutch Building Directive ‘Bouwbesluit’ 2012

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

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

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

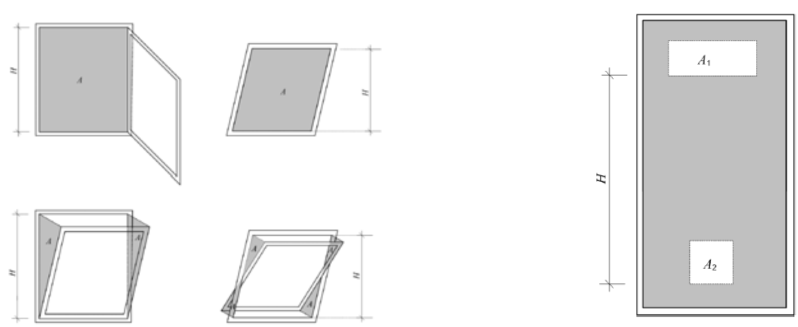
Dynamic Heat Balance according to EN ISO 13791

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

- Window ventilation by formula, V [m³/h] = f(A_{window}, H_{window}, dT)
- Mechnical 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

$$\dot{V} = 0{,}7 \cdot C_{ref} \cdot A \cdot \sqrt{H} \cdot \sqrt{\Delta T}$$

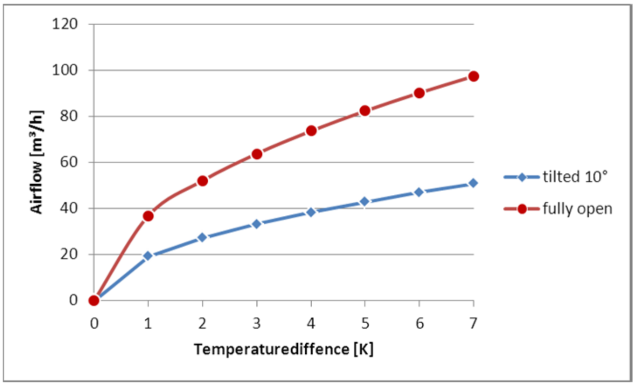


Ventilative Cooling by Window Opening

$$\dot{V} = 0{,}7 \cdot C_{ref} \cdot A \cdot \sqrt{H} \cdot \sqrt{\Delta T}$$

W = 40 cm

H = 120 cm



Learnings

Thank you

Ventilative Cooling: Modeling + Simulation Challenges

Jan Hensen

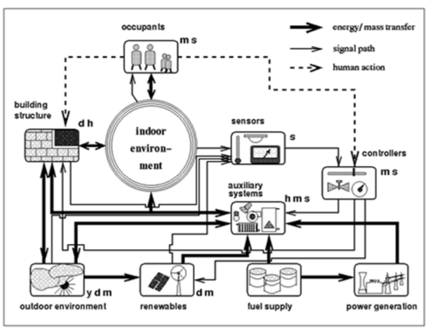
j.hensen@tue.nl

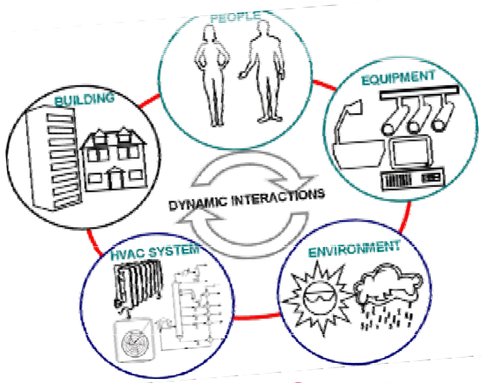
Technische Universiteit **Eindhoven** University of Technology

Where innovation starts

Ventilative cooling

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





Technische Universiteit Eindhoven University of Technology

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 = .7 ACH
- Q = Q50 / K

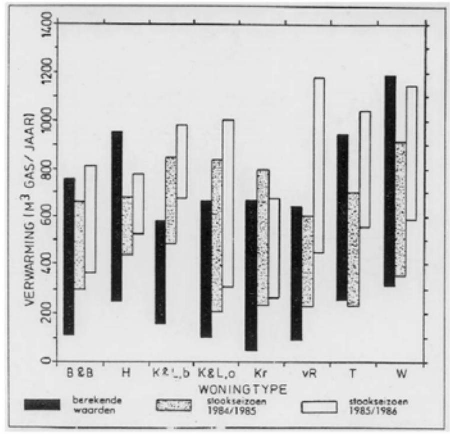
  (K ~ 20 for heating season urban NL)
- LBL-method

$$Q = L(A\Delta t + B\upsilon^2)^{0.5}$$

where Q = air flow rate (L/s)
L = effective leakage area (cm^2)
A = 'stack' coefficient
Δt = average outside/inside temperature difference (K)
B = wind coefficient
υ = average wind speed, measured at a local weather station.

- Etc ....

Air flow modeling – simplified + BEM



Uncertainty analysis (1984 style): variability in heating energy demand of low-energy houses due to (stochastic) occupant behaviour in terms of Tset, Qint, ACR

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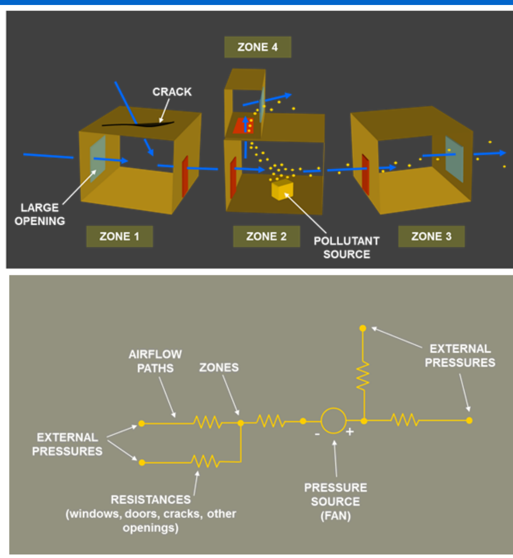
Air flow modeling – mass balance network



Source: IBPSA-USA

- **for each branch**

$$\dot{m} = \rho C_i \left(p_i - p_j\right)^n \left[kg/s\right]$$

- **for each non-boundary node**

$$\sum \dot{m} = 0 \left[kg/s\right]$$

- **for each boundary node**

$$p = "known" \left[Pa\right]$$

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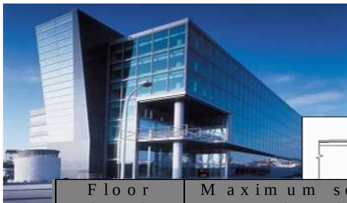
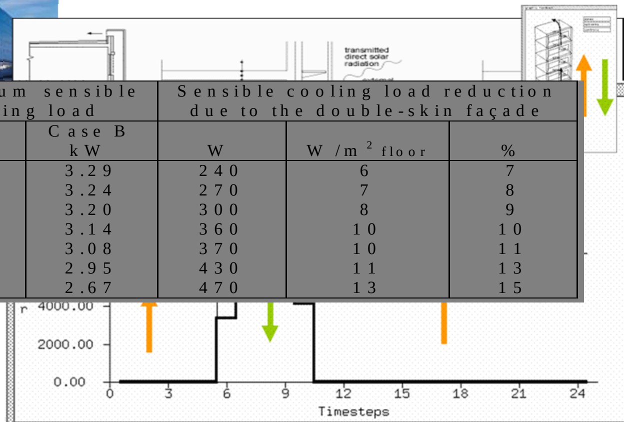
Air flow modeling – flow network + BEM



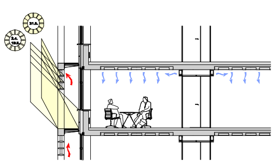


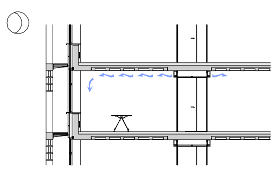
Floor level	Maximum sensible cooling load		Sensible cooling load reduction due to the double-skin façade		
	Case A kW	Case B kW	W	W/m² floor	%
8th	3.53	3.29	240	6	7
7th	3.51	3.24	270	7	8
6th	3.50	3.20	300	8	9
5th	3.50	3.14	360	10	10
4th	3.45	3.08	370	10	11
3rd	3.38	2.95	430	11	13
2nd	3.14	2.67	470	13	15

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





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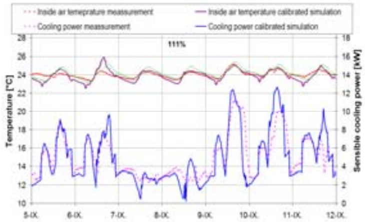
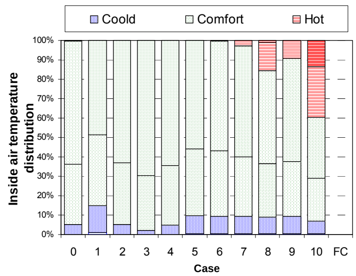
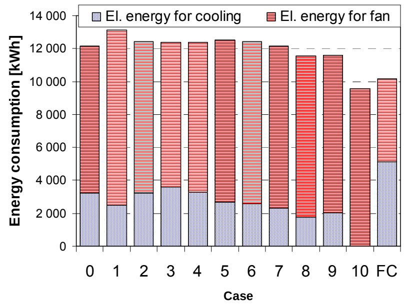
Air flow modeling – flow network + BEM



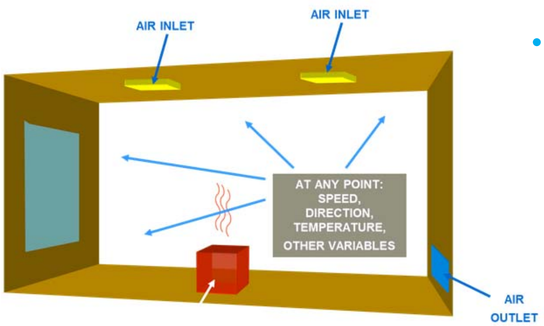
- Using calibrated building + systems model, 10 operation scenarios were simulated: 6 scenarios with various combinations of flow rates and control periods, 5 scenarios with reduced cooling coil capacity





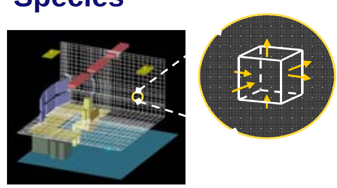
source: Milos Lain

Air flow modeling – CFD



Source: IBPSA-USA

- Conservation of
  - Mass
  - Momentum
  - Energy
  - Species



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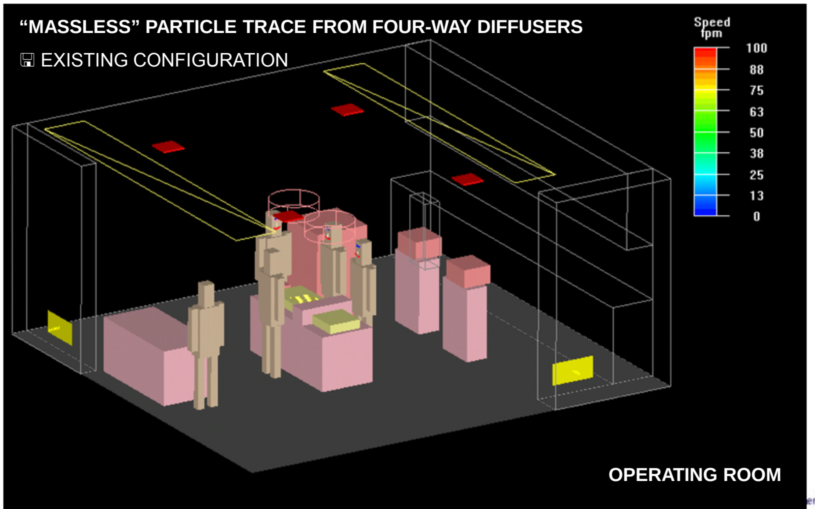
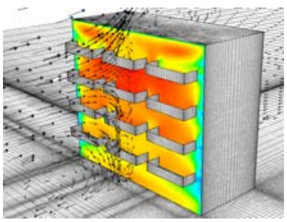
Air flow modeling – CFD



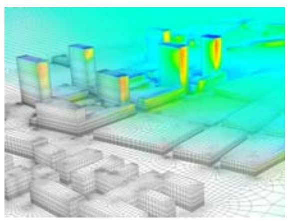
Source: IBPSA-USA

Air flow modeling – CFD

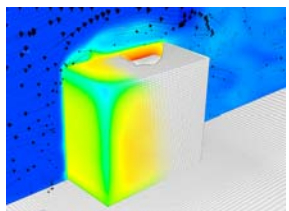
- Building components, such as balconies, can lead to very strong changes in wind pressure distribution on building facades



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

*Montazeri, H., Blocken, B., Janssen, W.D., van Hooff, T. CFD evaluation of wind comfort on high-rise building balconies: validation and application. The Seventh International Colloquium on Bluff Body Aerodynamics and Applications Shanghai, China; September 2-6, 2012.

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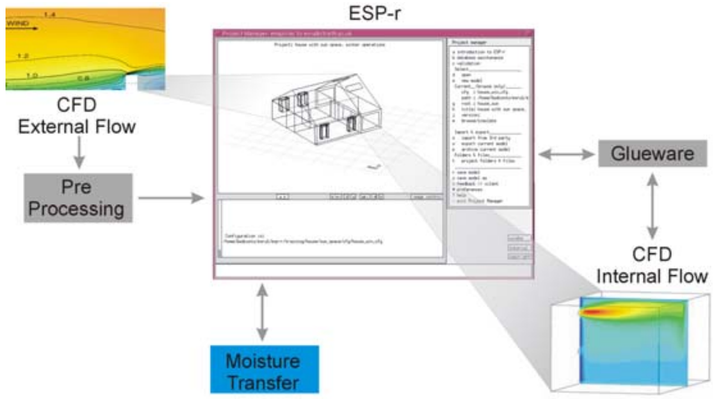
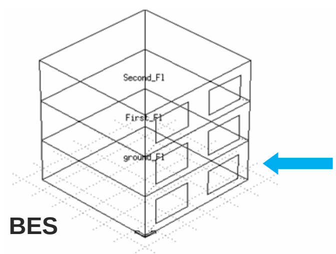
Air flow modeling – CFD + BEM



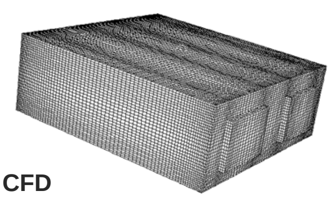
deliverables:
- prototype software
- coupling procedure
- coupling validation

Air flow modeling – CFD + BEM

- ➢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

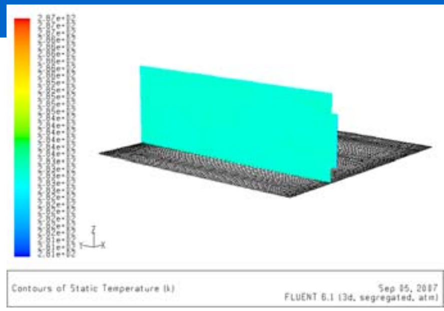


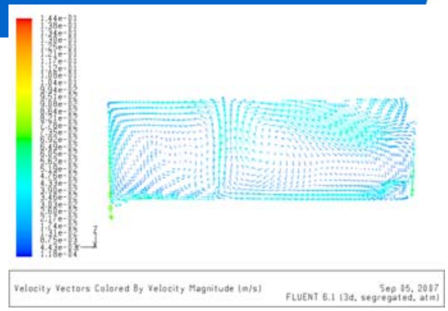
BES

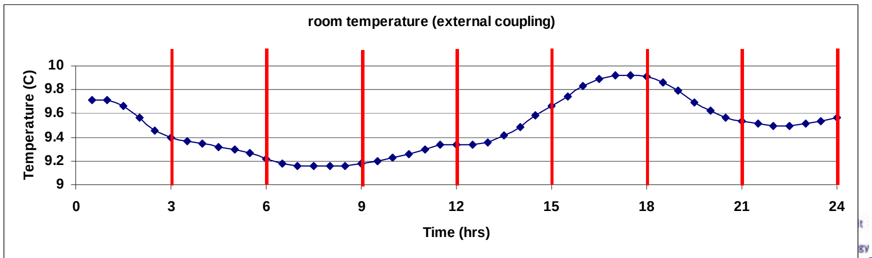


CFD

Air flow modeling – CFD + BEM







Source: Daniel Costola + Mohammad Mirsadeghi

Best modeling approach?

Case: displacement ventilation

Performance indicator	A	B	C
cooling energy	--	++	--
fan electricity	++	++	--
whole body thermal comfort	+	++	+
local discomfort, gradient	--	+	++
local discomfort, turbulence intensity	--	--	++
ventilation efficiency	--	0	++
contaminant distribution	-	-	++
whole building integration	++	++	--
integration over time	++	++	--

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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)

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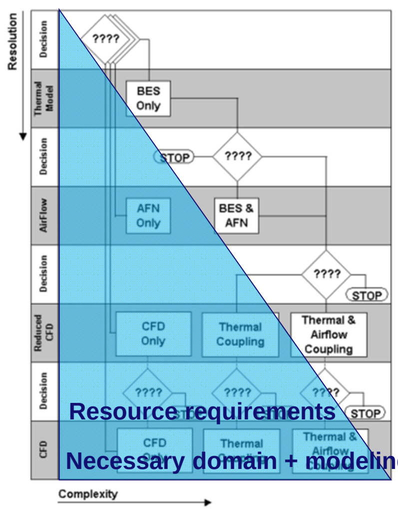
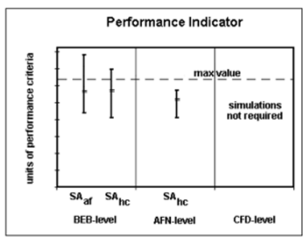
QA: best modeling approach?





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QA: data uncertainty / model complexity

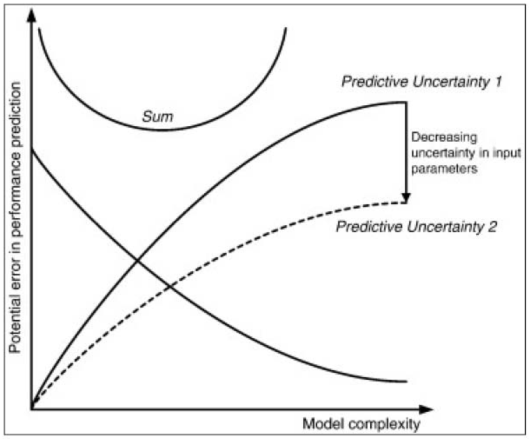
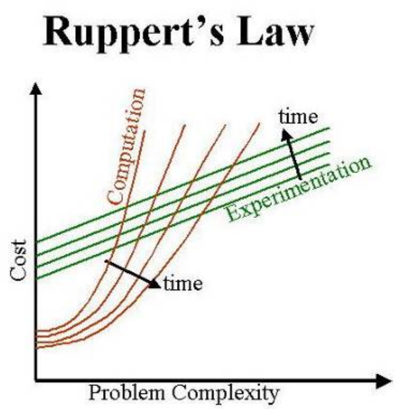


Figure 6 Potential errors in performance prediction vs. model complexity/ level of detail [11]

QA: measurements vs. simulation



Measurements essential for verification, validation and calibration !

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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

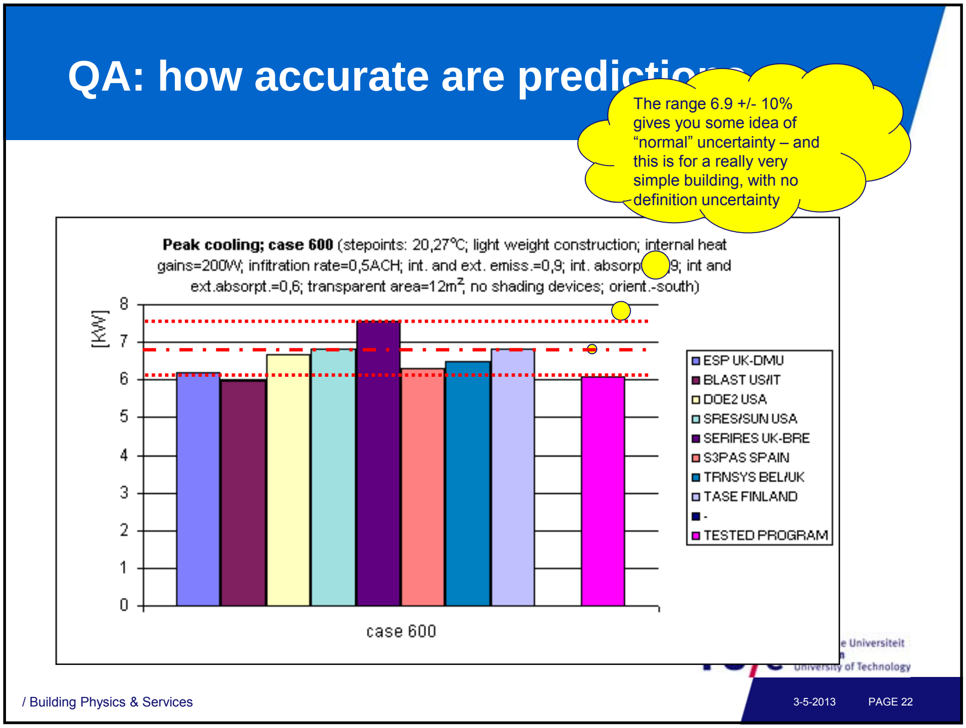
Banks & Gibson, 1997

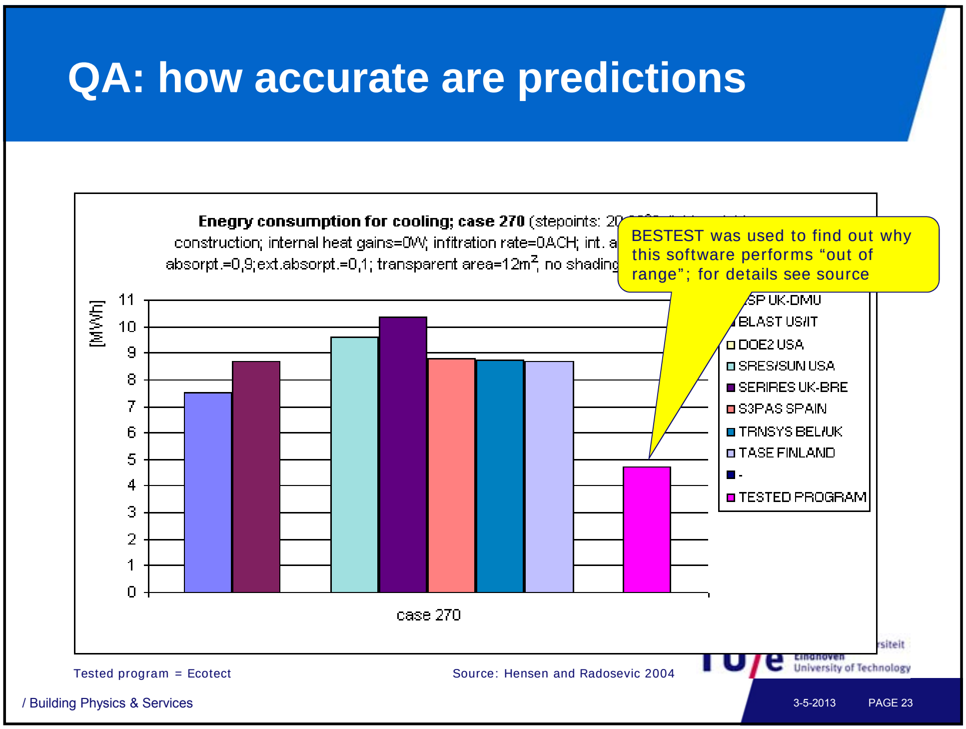
QA: do simulate but

Black Belt Energy Modeling Matrix

Belt		Capabilities
Trainee	White	• Collect modeling input data
	Yellow	• Perform input data calculations
	Orange	• Develop building geometry and zoning
Tech-nician	Green	• Create building input file using software wizard
	Blue	• Build minimally-code compliant building model
Core Analyst	Purple	• Review results for reasonableness • Complete calibrations
	Brown	• Perform complex modeling • Complete detailed QC • Complete system level calibration
Master	Red	• Understand the algorithms • Use supplemental analysis
	Black	• Balance modeling level of detail against accuracy of results needed to support decision making

E Franconi, RMI, 2011


QA: how accurate are predictio
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
Peak cooling; case 600 (stepoints: 20,27°C; light weight construction; internal heat gains=200W; infitration rate=0,5ACH; int. and ext. emiss.=0,9; int. absorp 9; int and ext.absorpt.=0,6; transparent area=12m2; no shading devices; orient.-south)
[kW]
0 1 2 3 4 5 6 7 8
case 600
ESP UK-DMU
BLAST US/IT
DOE2 USA
SRES/SUN USA
SERIRES UK-BRE
S3PAS SPAIN
TRNSYS BEL/UK
TASE FINLAND
-
TESTED PROGRAM
/ Building Physics & Services
3-5-2013
PAGE 22


QA: how accurate are predictions
Enegry consumption for cooling; case 270 (stepoints: 20
construction; internal heat gains=0W; infitration rate=0ACH; int. a
absorpt.=0,9;ext.absorpt.=0,1; transparent area=12m2; no shading
BESTEST was used to find out why this software performs "out of range"; for details see source
[MWh]
0 1 2 3 4 5 6 7 8 9 10 11
case 270
SP UK-DMU
BLAST US/IT
DOE2 USA
SRES/SUN USA
SERIRES UK-BRE
S3PAS SPAIN
TRNSYS BEL/UK
TASE FINLAND
-
TESTED PROGRAM
Tested program = Ecotect
Source: Hensen and Radosevic 2004
/ Building Physics & Services
3-5-2013
PAGE 23

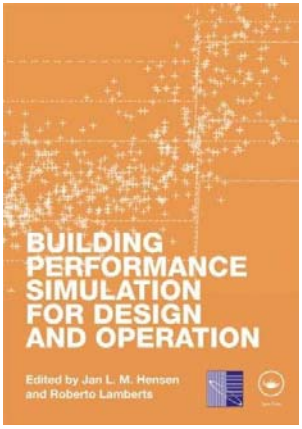
QA: and in case of uncertainty in

- 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 !

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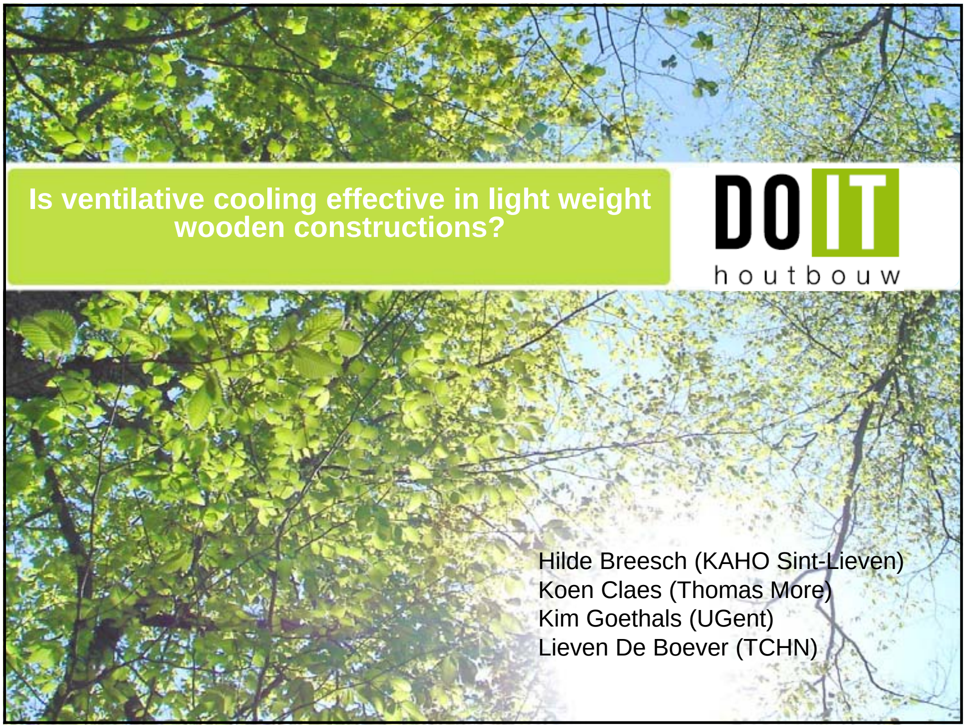


DO-IT

- 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

2

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

3

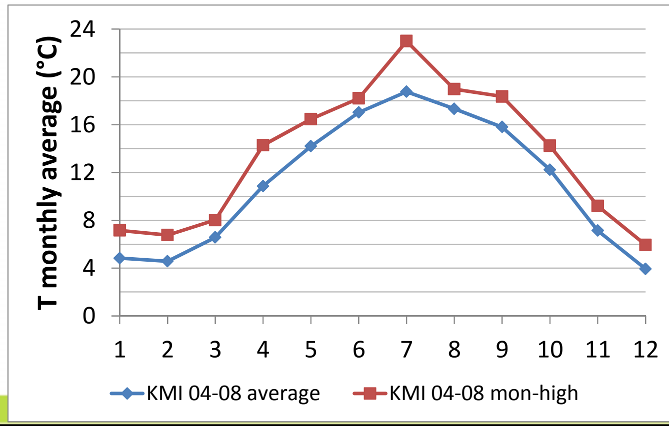
Summary

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

4

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

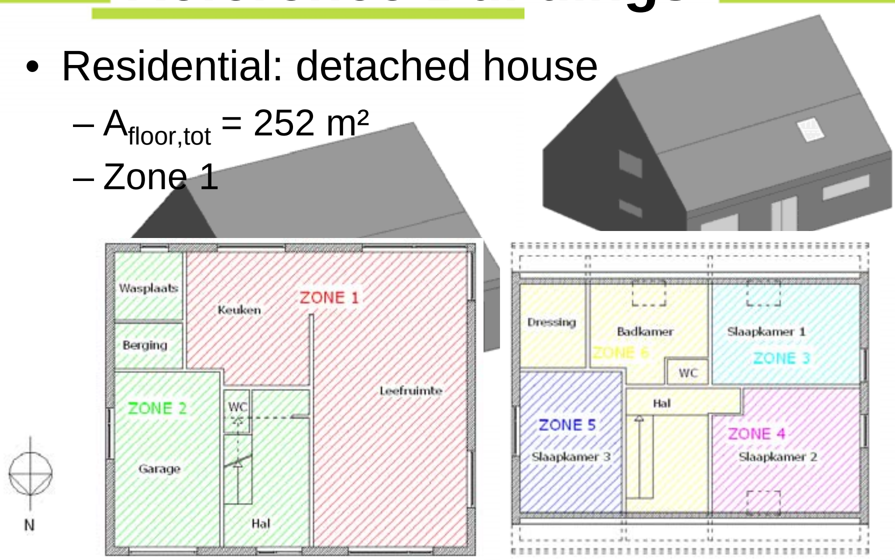
Reference Buildings

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

	EPBD 2014	PH standard
	U [W/m²K]	U [W/m²K]
Façade/Roof/Floor	0,24	0,15
Window –glazing	1,1	0,8
Window – frame	1,8	0,8
External door	2,0	0,8
	n_{50} (h^{-1})	n_{50} (h^{-1})
	3	0.6

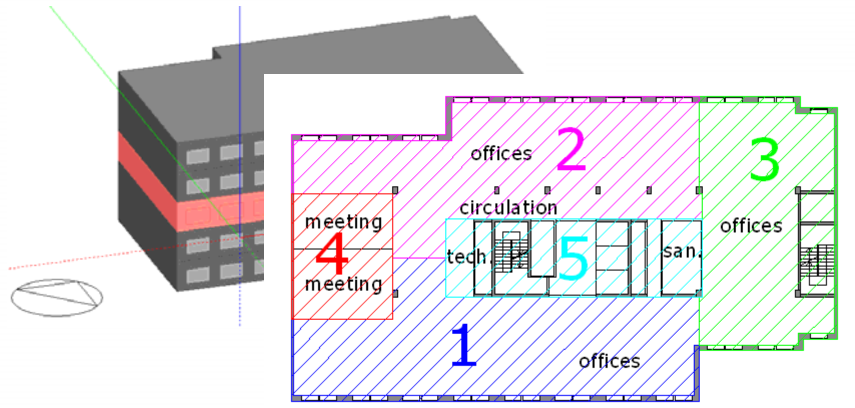
Reference Buildings

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



Reference Buildings

- Office building
  – Zone 1: A_{floor} = 200 m²



Reference Buildings

- Characteristics: walls

material	c [J/kg.K]	ρ [kg/m³]	λ [W/m.K]	d [m]
façade				
structure -wood fraction (15%)	1600	500	0.130	0.300
structure - MW (85%)	1030	50	0.040	0.300
OSB	1700	650	0.130	0.015
cavity - wood fraction (15%)	1600	500	0.130	0.050
cavity - MW (85%)	1030	50	0.040	0.050
gypsum board	1000	900	0.260	0.013
internal wall				
gypsum board	1000	900	0.260	0.013
structure -wood fraction (15%)	1600	500	0.130	0.100
structure - MW (85%)	1030	50	0.040	0.100
gypsum board	1000	900	0.260	0.013
internal floor				
floor covering	1400	1200	0.190	0.010
OSB	1700	650	0.130	0.015
structure -wood fraction (11%)	1600	500	0.130	0.200
structure - MW (89%)	1030	50	0.040	0.200
gypsum board	1000	900	0.260	0.015

Reference Buildings

- Characteristics: walls

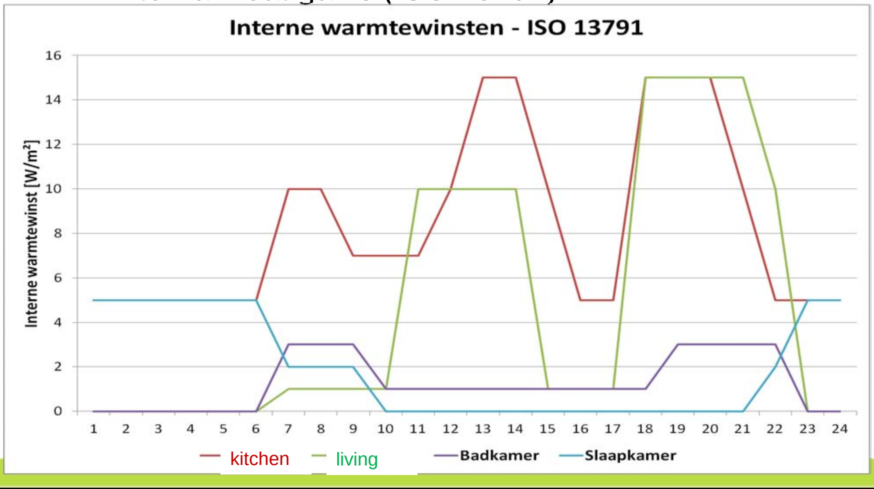
material	c [J/kg.K]	ρ [kg/m³]	λ [W/m.K]	d [m]
floor				
tiles	1000	1700	0.810	0.010
light concrete	1000	1050	0.320	0.070
insulation	1400	30	0.035	0.170
light concrete	1000	1050	0.320	0.050
reinforced heavy concrete	1000	2400	2.200	0.150

Reference Buildings

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

Reference Buildings

- Characteristics: residential
  - Internal heat gains (ISO 13791)



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Reference Buildings

- Characteristics: Office building
  - Solar shading
    - g_{window} = 0.55
    - Fixed overhang (d = 1m)
  - Hygienic ventilation rates & occupancy
    - IDA 3 (29 m³/h)
    - 15 m²/pers
    - zone 1: n = 0.67 h^{-1}
  - Night ventilation
    - n = 0 <> 3 <> 6 h^{-1}

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Reference Buildings

- Characteristics: Office building
  - Thermal mass

Classification (EN 13790)	Heat capacity C_m (J/K)	construction
Very light	1.13×10^7	All light weight wooden walls
Light	2.19×10^7	Functional core heavy concrete
Very heavy	7.91×10^7	Functional core heavy concrete Internal floor + ceiling concrete slab

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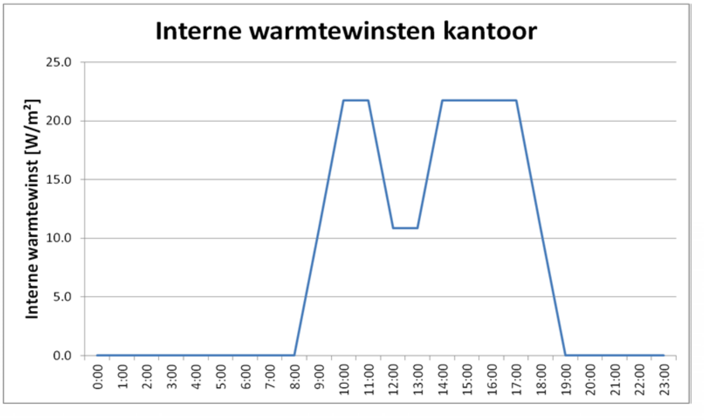
Reference Buildings

- Characteristics: Office building
  - Internal heat gains



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Summary

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

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Method

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

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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

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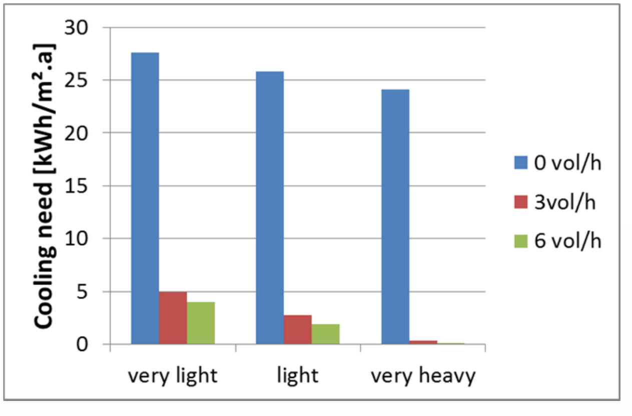
Results

- Impact ventilative cooling on cooling need in office buildings



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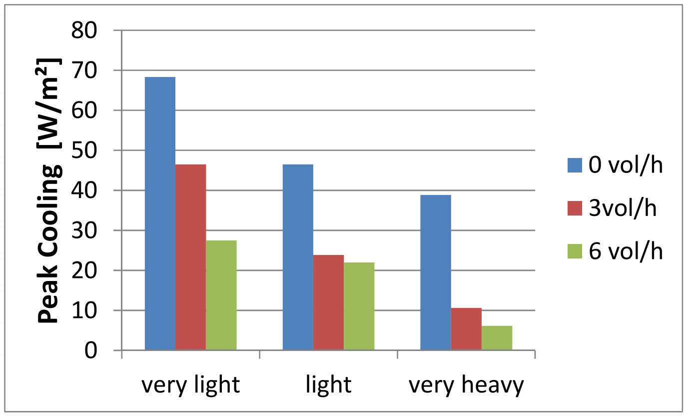
Results

- Impact ventilative cooling on peak cooling load in office buildings



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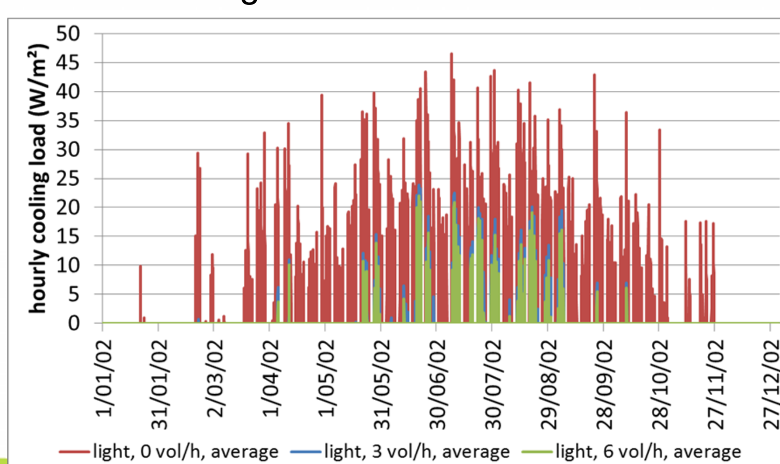
Results

- Impact ventilative cooling on peak cooling in office buildings



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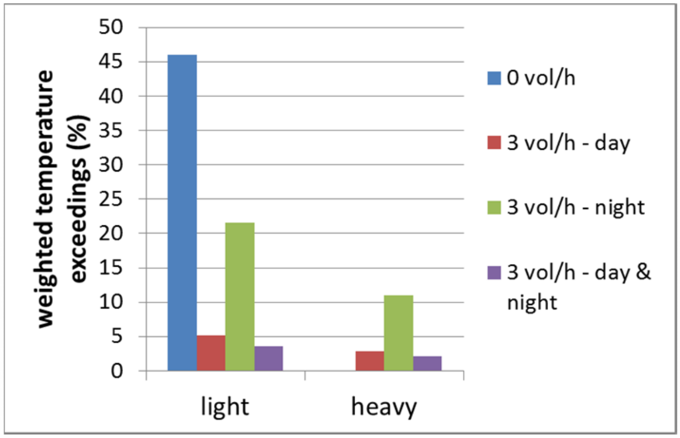
Results

- Impact ventilative cooling on overheating in residential buildings



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Results

- Impact weather data on performances
  - Temperature
  - Solar radiation
- Meteonorm 7
  - Synthetical based on measurements
    - temperature (2000-2009)
    - Solar radiation (1986-2005)
  - Average <> Warm weather data (1 per 10 year)

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Results

- weather data: temperature

Month	Average Uccle (B)		Warm Uccle (B)	
	KMI 04-08	Meteonorm 7	Max KMI 04-08	Meteonorm 7
1	4.83	4.00	7.16	6.70
2	4.58	4.90	6.77	7.20
3	6.57	7.10	8.02	8.60
4	10.86	10.70	14.28	13.00
5	14.20	14.40	16.46	15.70
6	17.03	17.20	18.20	18.50
7	18.76	18.60	22.99	21.30
8	17.33	18.50	18.97	20.20
9	15.80	15.50	18.36	17.70
10	12.23	11.80	14.23	14.50
11	7.14	7.80	9.20	9.50
12	3.93	4.10	5.94	5.80
Annual average	**11.11**	**11.22**	**13.38**	**13.23**

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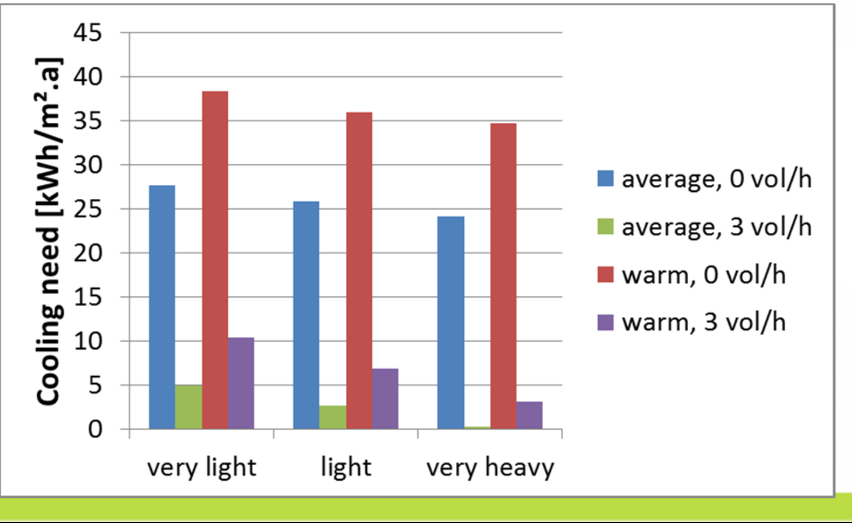
Results

- Warm weather data: cooling need in office



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Summary

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

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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

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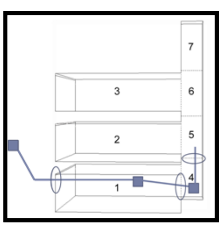
Natural ventilation design tools, applications in commercial buildings

MIT Building Technology Laboratory, Cambridge, USA
Stephen Ray, postdoc

Overview

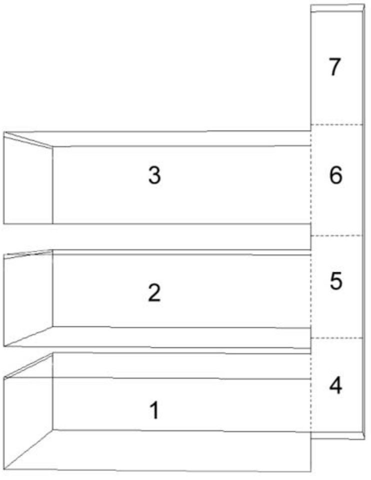


Intro

CoolVent

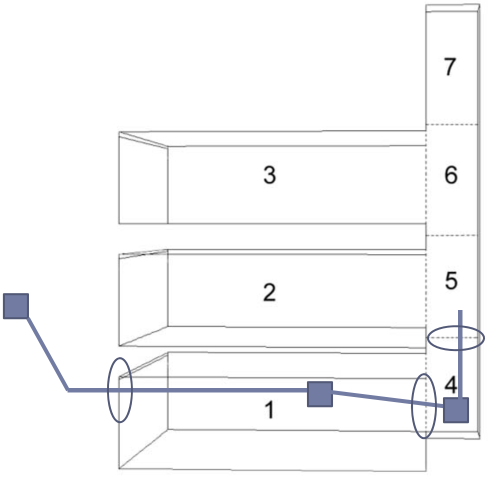
JP bldg

Airflow Network (AFN) models divide space into large zones



Intro

Flow pathways connect zones through openings



Intro

Conservation equations are used to calculate flow rates and temperatures

Conservation of Momentum (Bernoulli)

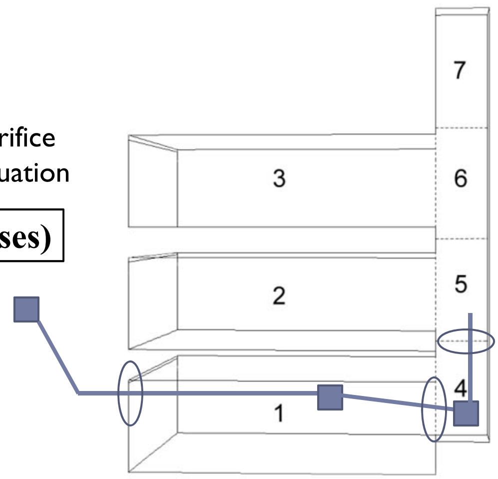
ΔP(T, wind)

Orifice Equation

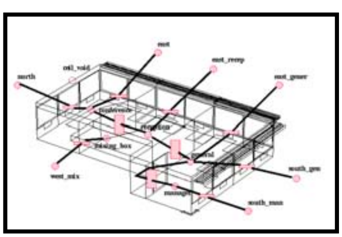
$\dot{V}$(ΔP, losses)

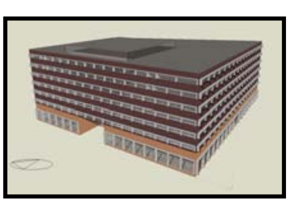
ΔT($\dot{V}$, loads)

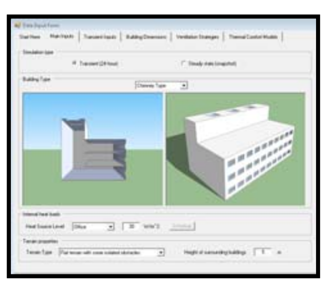
Conservation of Energy

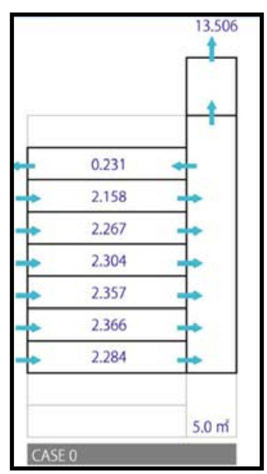


Many AFN models exist, both commercially available and in-house models

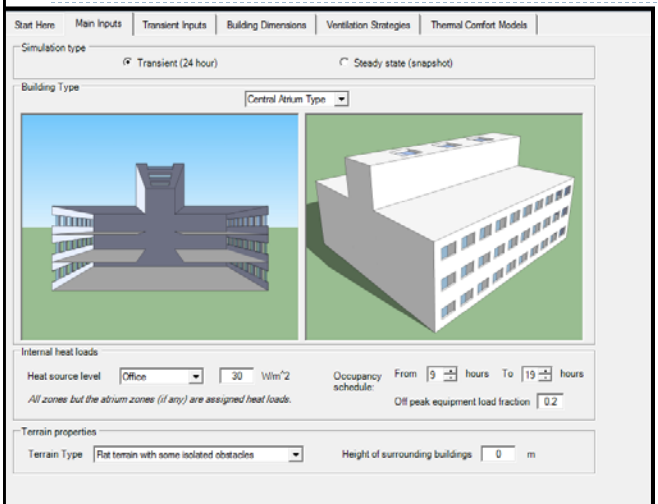


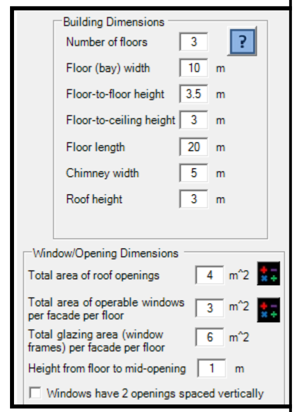






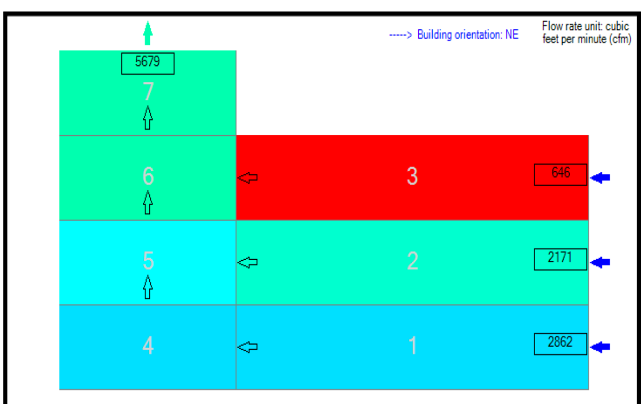
Strength 1: CoolVent easily usable in early design stage

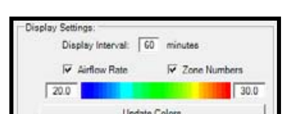




CoolVent

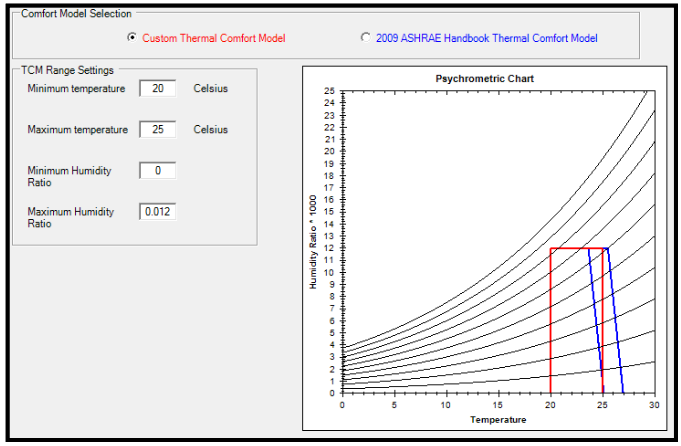
Strength 2: CoolVent provides quick, informative results – temperatures & ACH





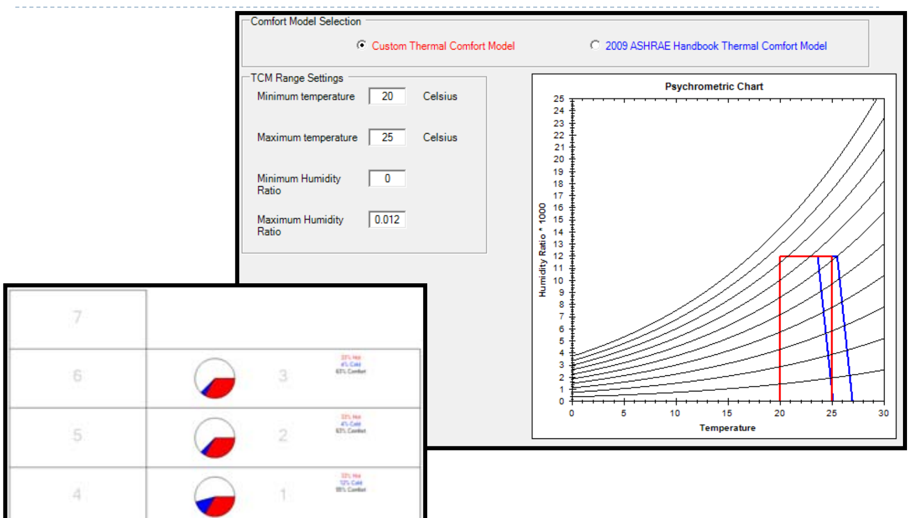
CoolVent

Strength 2: CoolVent provides quick, informative results – thermal comfort



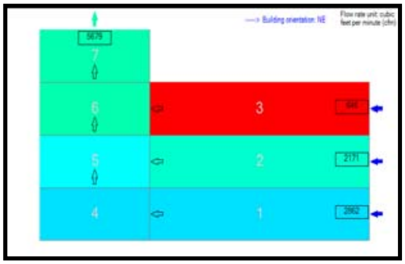
CoolVent

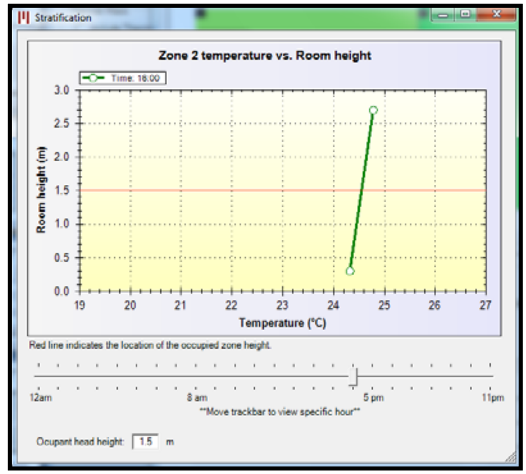
Strength 2: CoolVent provides quick, informative results – thermal comfort



CoolVent

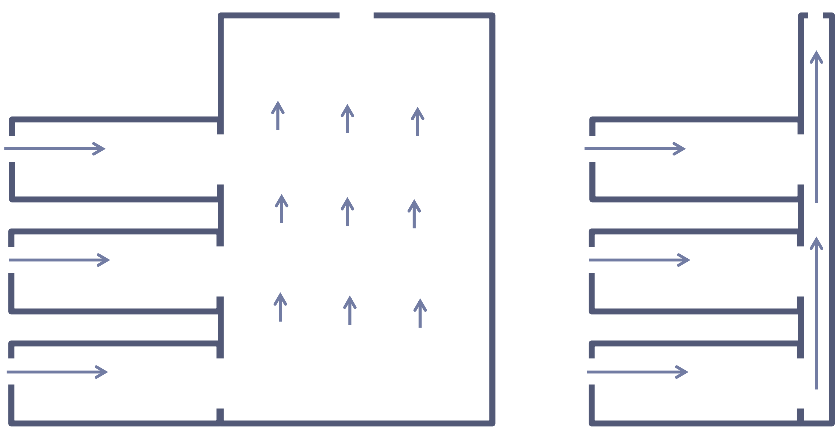
Strength 3: CoolVent predicts zonal vertical temperature distribution – CFD verified





CoolVent

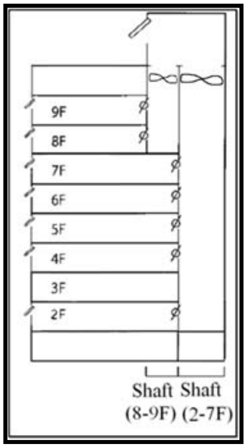
Strength 4: CoolVent models air momentum in ventilation shafts – CFD and model verified



AREA momentum area MOMENTUM

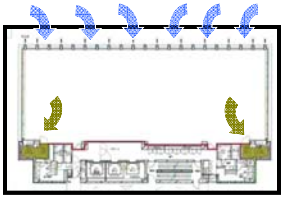
CoolVent

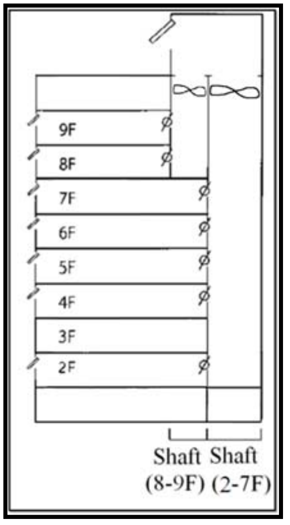
Strength 5: CoolVent easily accounts for low-power auxiliary fans



CoolVent

Full scale monitoring of 10 story NV office building in Tokyo w/ 2000+ instruments





JP bldg

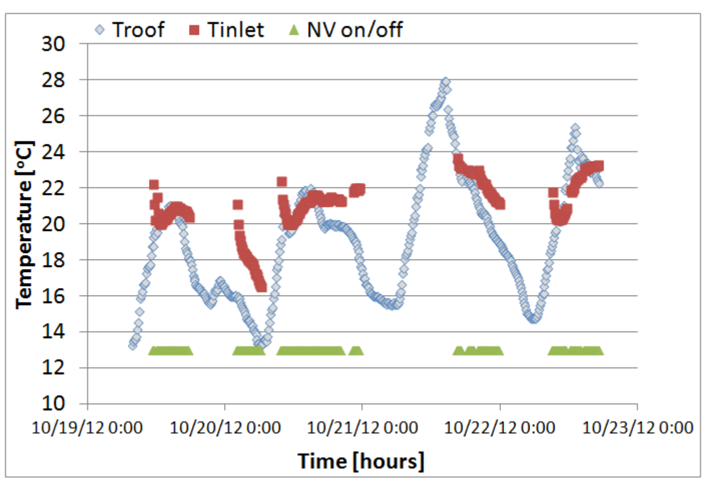
Rooftop weather stations not always useful

22.9 C

24.3 C

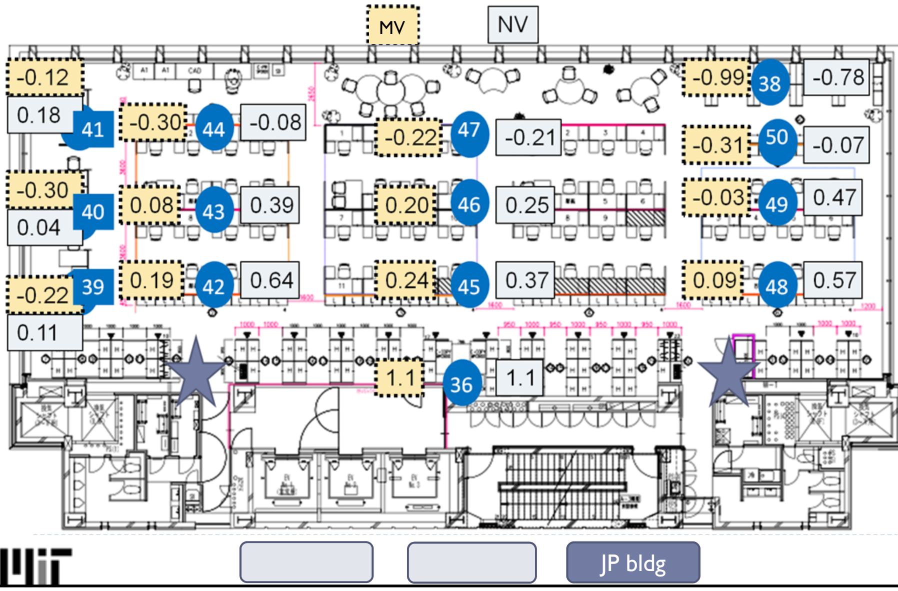
JP bldg

Up to 3 C difference between T_{inlet} and T_{roof} in October

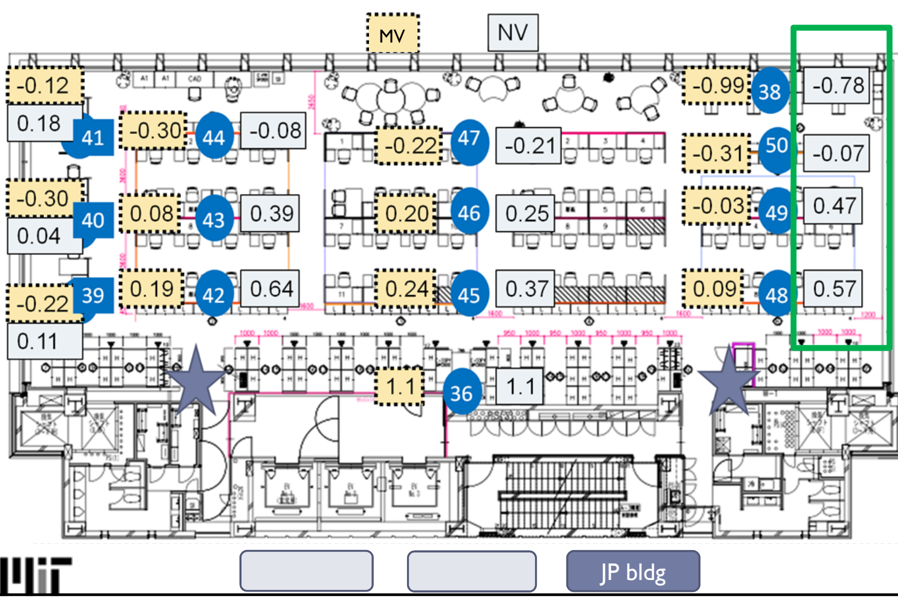


JP bldg

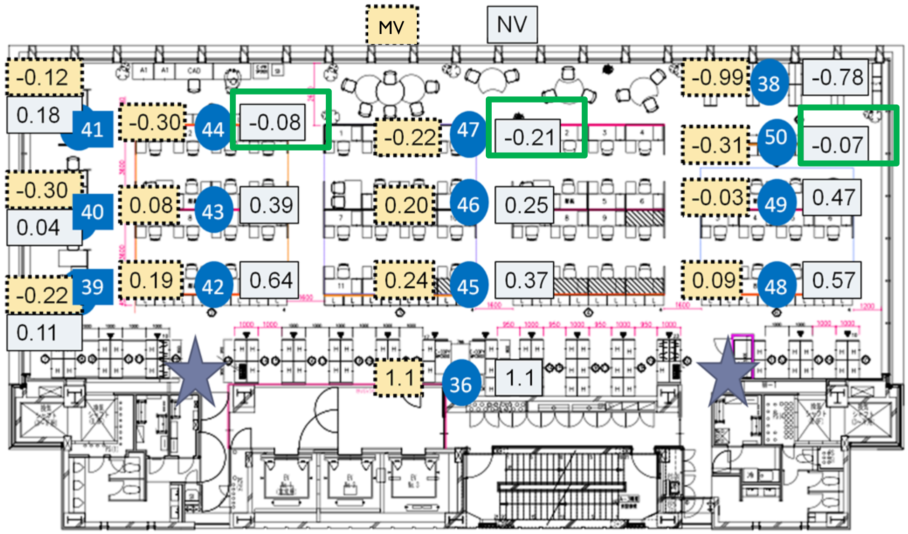
3 week horizontal temperature distribution – measurements at desk level



Positive gradient from inlets to back of occupied zone

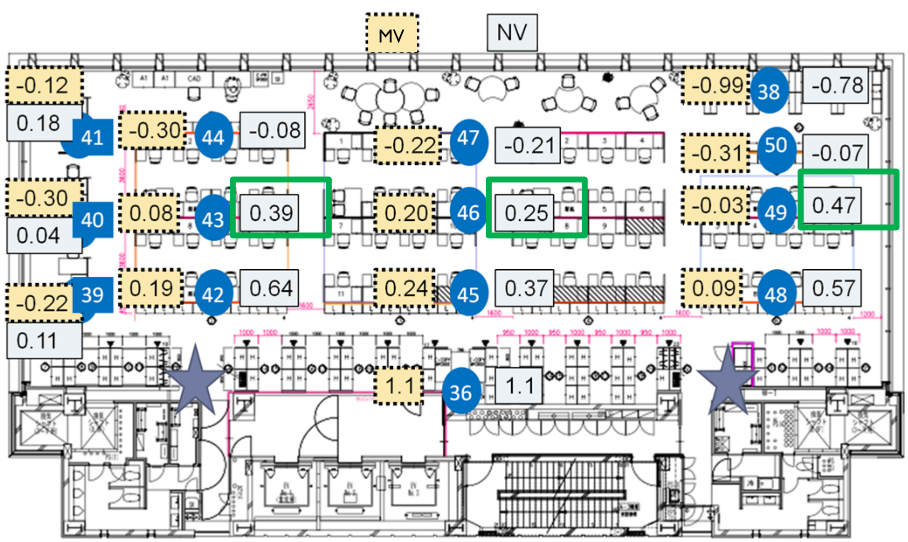


Similar temperatures at similar distances from inlet



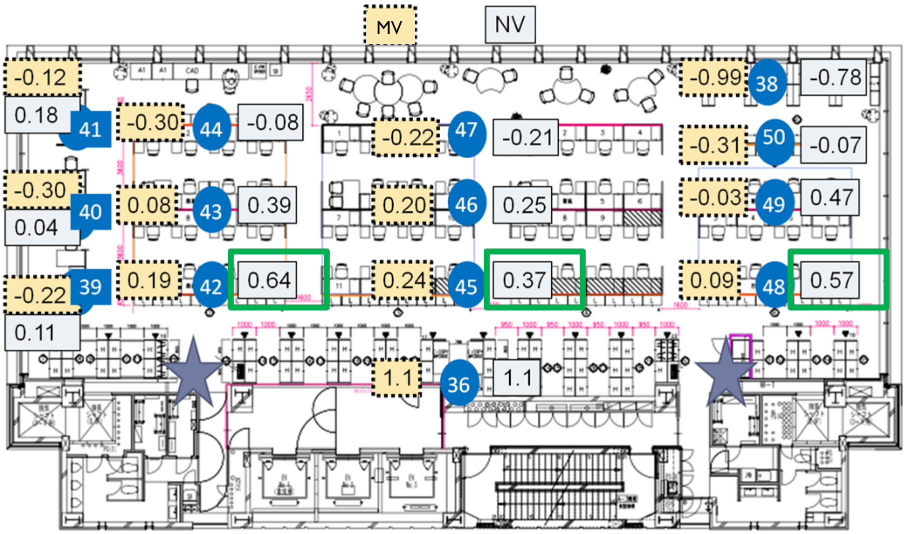
JP bldg

Similar temperatures at similar distances from inlet



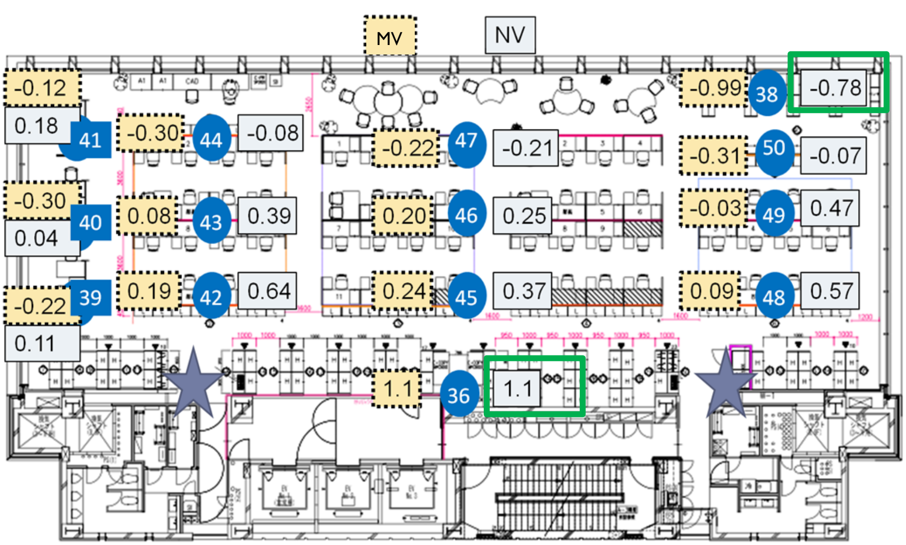
JP bldg

Similar temperatures at similar distances from inlet



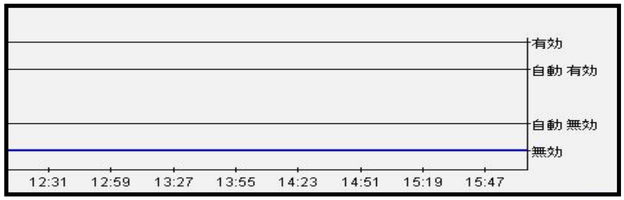
JP bldg

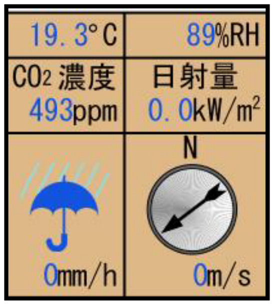
Largest difference < 2 C between copy room and window



JP bldg

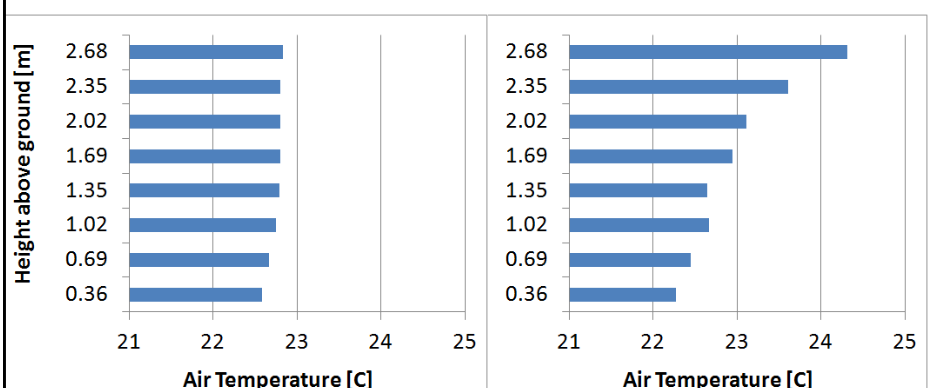
Occupants can bring strong biases to certain systems: uncomfortable = NV problem





JP bldg

Mech cooling: uniform vertical temps NV: linear increase in vertical temps

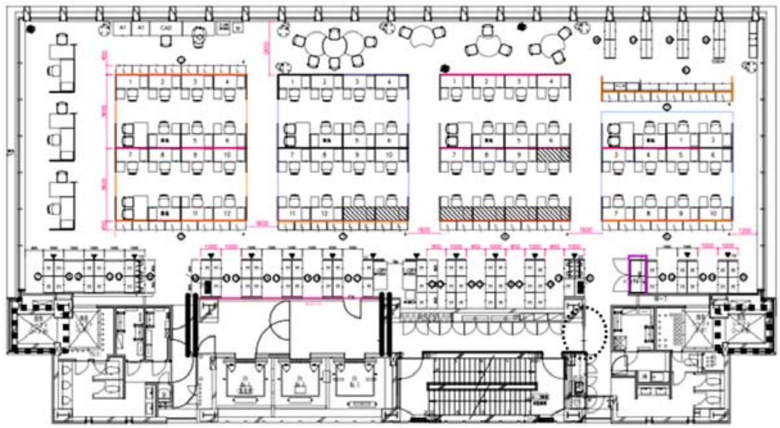


Mechanical Cooling

Natural Ventilation

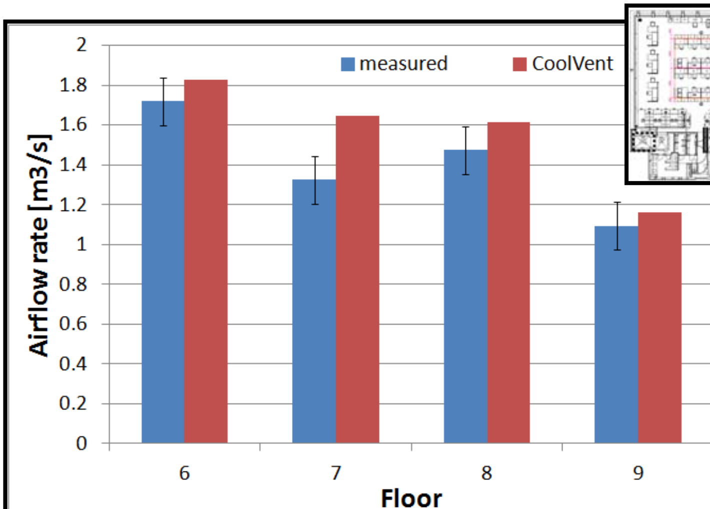
JP bldg

Operation of "non-system" components can be important



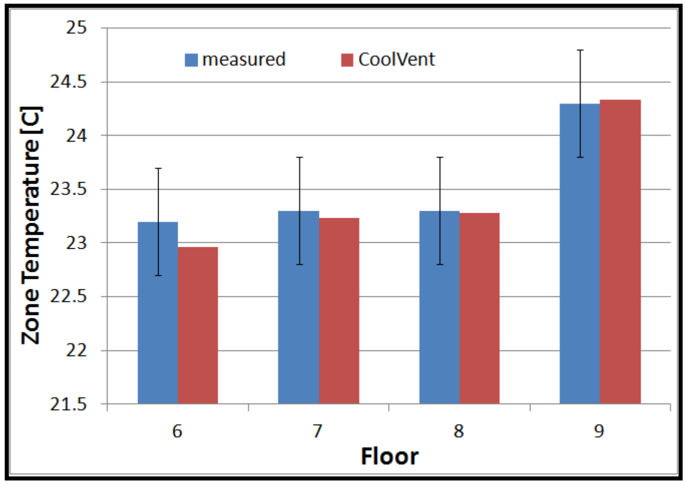
JP bldg

Reasonable agreement between CoolVent and measured airflow rates



JP bldg

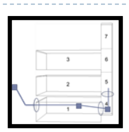
Reasonable agreement between CoolVent and measured air temperatures



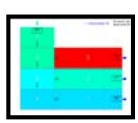
JP bldg

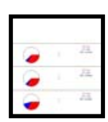
Steve Ray – sdray@mit.edu

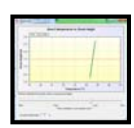
Intro

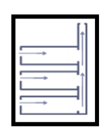


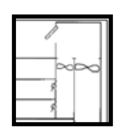
CoolVent



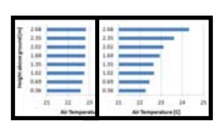


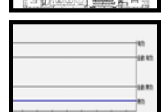


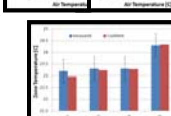




JP bldg





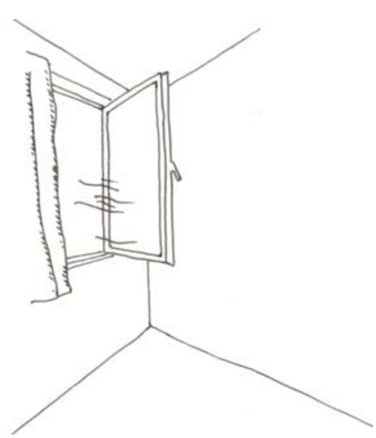


SENSITIVITY OF NIGHT COOLING PERFORMANCE TO ROOM/SYSTEM DESIGN: SURROGATE MODELS BASED ON CFD

UNIVERSITEIT GENT

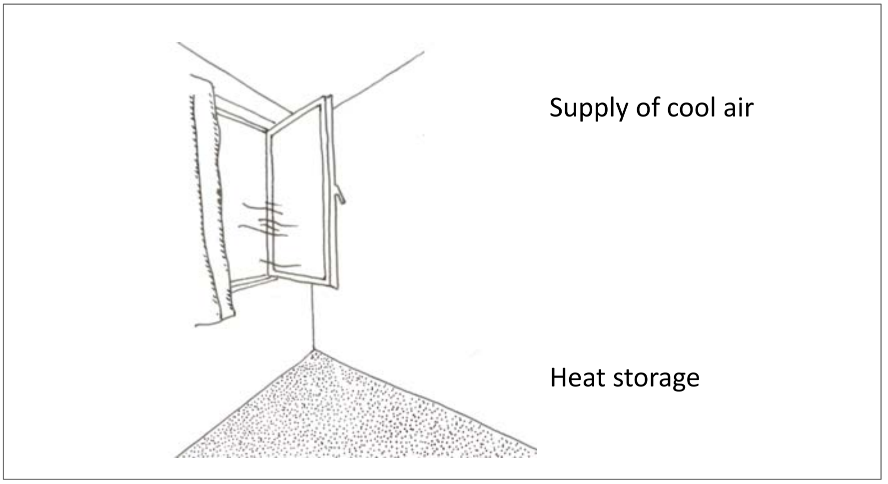
Kim Goethals and Arnold Janssens
Laboratory of Building Physics, Construction and Services

Three basic elements of night cooling

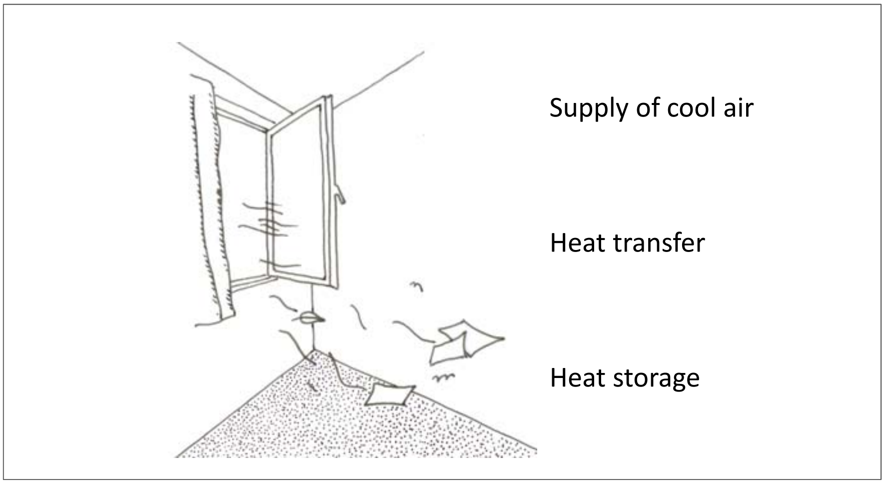


Supply of cool air

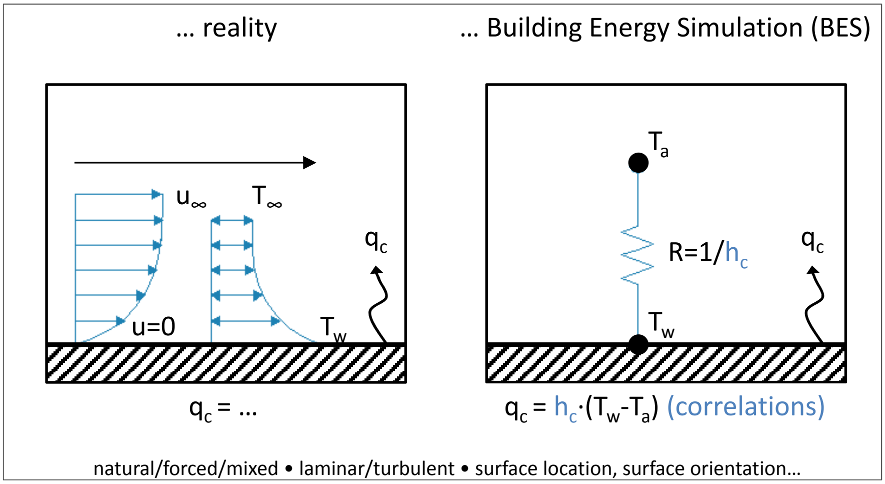
Three basic elements of night cooling



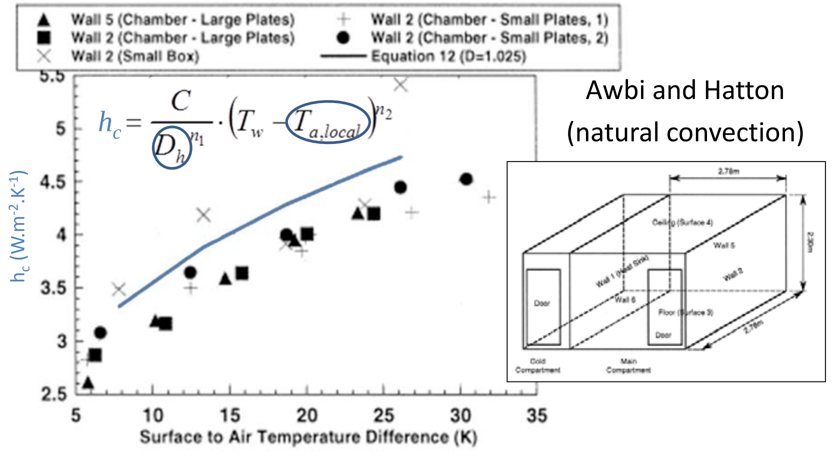
Three basic elements of night cooling



Convective heat transfer in…



Correlations are case-specific



Is the current BES approach sufficient to model night cooling? No!

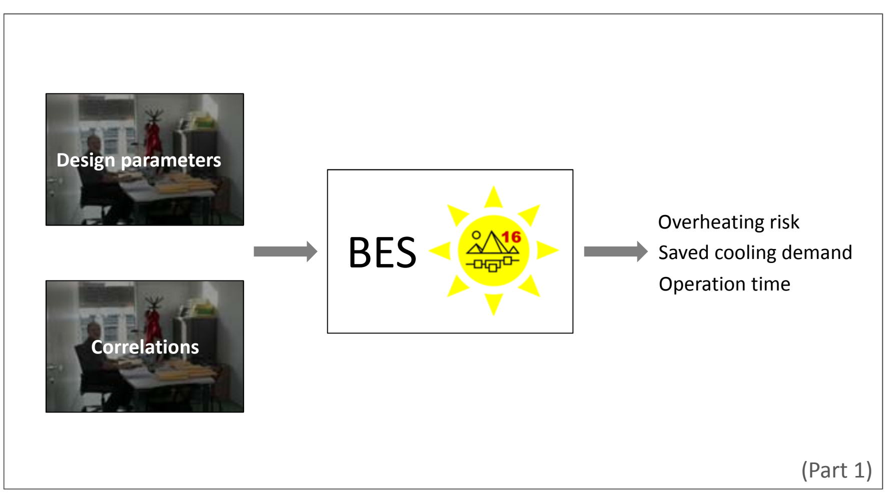
Part 1: Importance of the choice of correlation (BES)

Part 2: Applicability of current correlations (experiments)

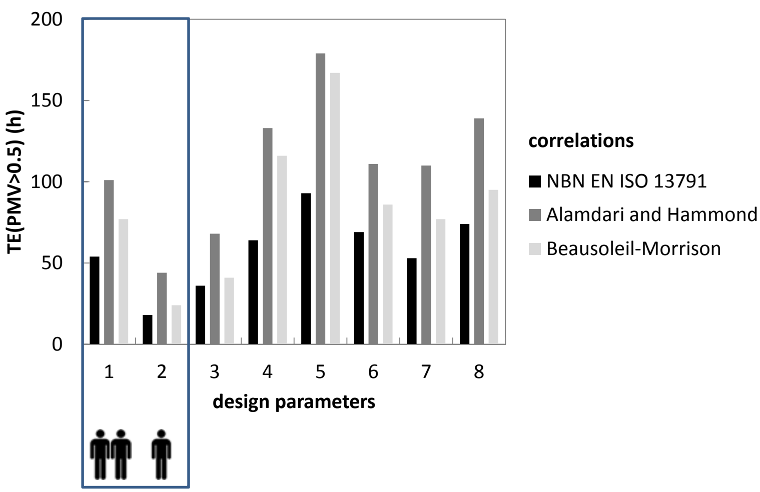
What possibly is a proper way? BES + CFD-based surrogate models!

Part 3: Methodology to derive CFD-based surrogate models

Importance of choice of correlations?

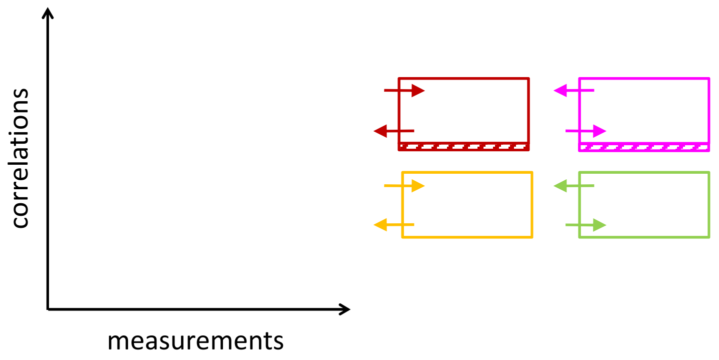


Impact of the choice of correlation



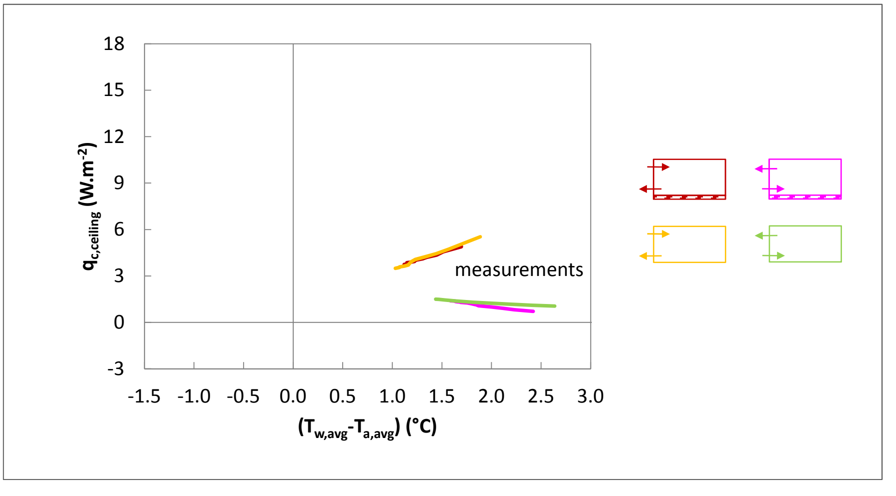
Is convective heat transfer modelling of minor importance? No!

Applicability of current correlations?

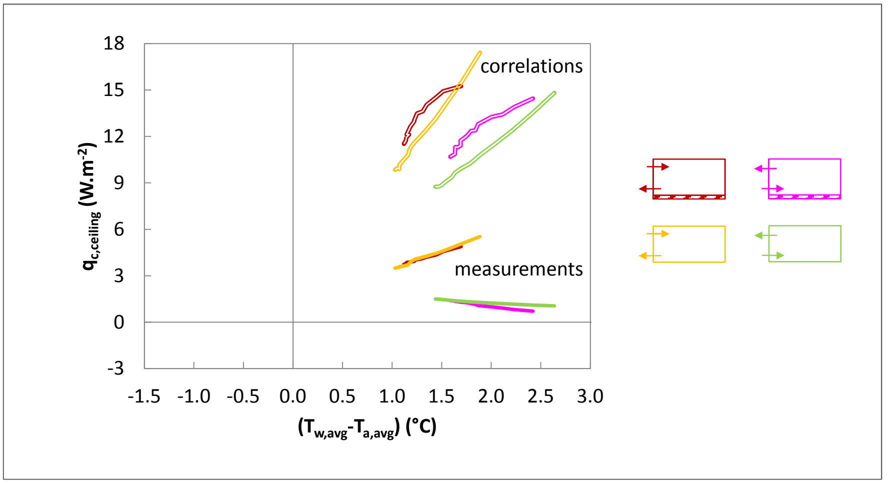


(Part 2)

Comparison to correlations



Comparison to correlations



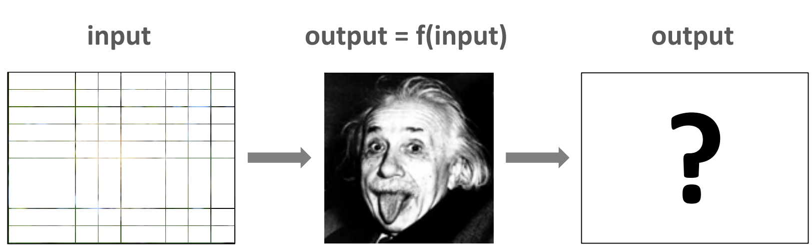
Are the currently available convection correlations always usable? No!

- ☐ BES + more empirical correlations

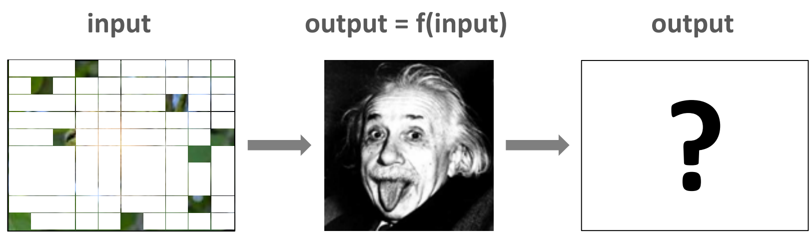
- ☐ BES + more empirical correlations
- ☐ BES + CFD

- [ ] BES + more empirical correlations
- [ ] BES + CFD
- [x] BES + CFD-based surrogate models

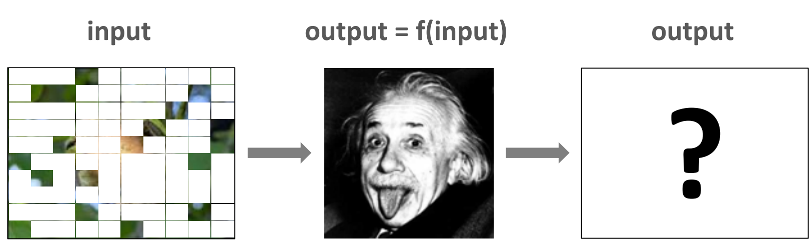
Methodology to derive CFD-based surrogate models?



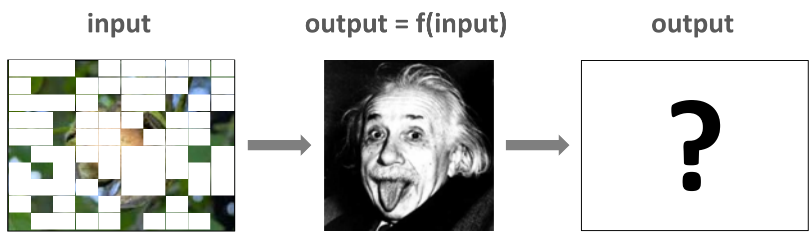
Methodology to derive CFD-based surrogate models?



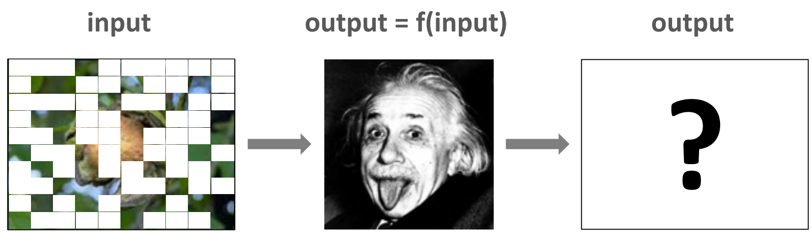
Methodology to derive CFD-based surrogate models?



Methodology to derive CFD-based surrogate models?

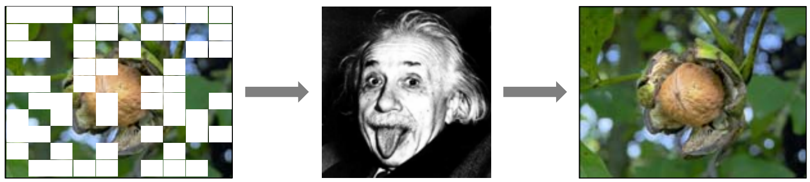


Methodology to derive CFD-based surrogate models?



Methodology to derive CFD-based surrogate models?

input output = f(input) output



Methodology to derive CFD-based surrogate models?

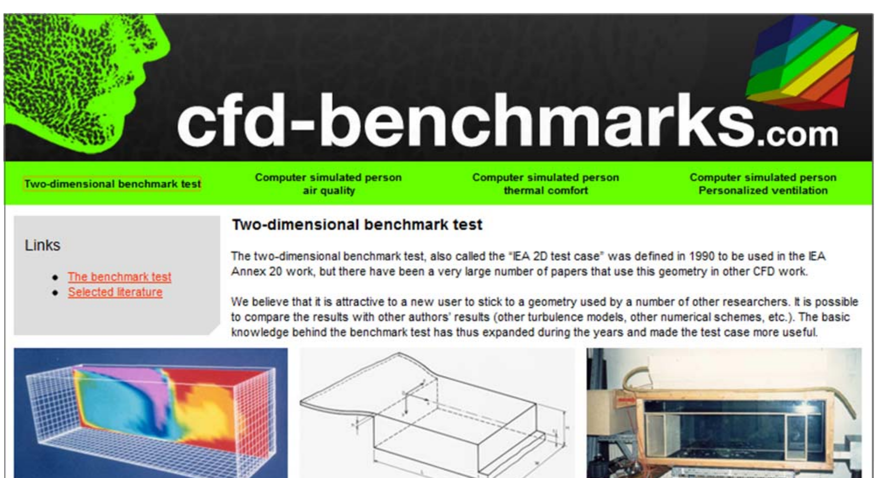
input output = f(input) output

(Part 3)

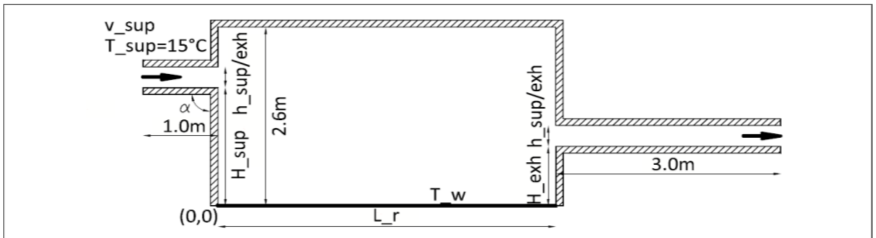
Pilot study on night cooled landscape office

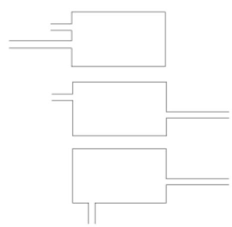
Night cooling in offices	Usually in oblong landscape offices Often line-shaped diffusers/band windows So, roughly speaking, 2-D airflow
Design parameters	Ventilation concept Mass distribution Geometry Driving force for convective heat transfer

Stirring up the Annex 20 2-D case



Parameterizing Annex 20 2-D case

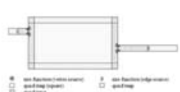




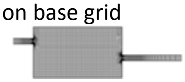
Parameter	Type	Min	Max
-	Ventilation concept	Single-sided/cross/under floor	
-	Mass distribution	Floor/ceiling	
L_r (m)	Geometry	4.5	9
H_{sup} (m)		0+BL	2.6-BL (L_r-0.5m)
H_{exh} (m)		0+BL	2.6-BL
$h_{sup/exh}$ (m)		0.1	0.5
α (°)		60	120
n (h^{-1})	Driving force	1.5	10
T_w (°C)		16	25

Gambit + Fluent + SUMO = surrogate model

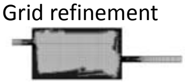
Controlled by Matlab (fully automated)



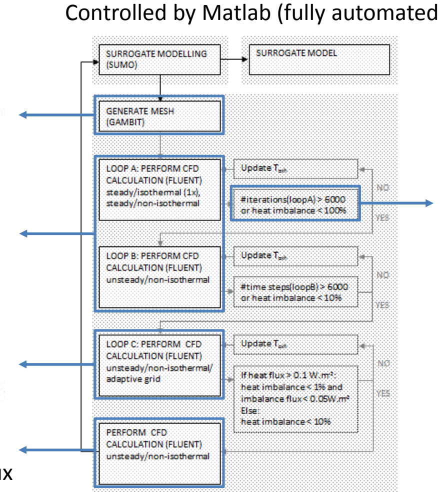
Estimate airflow on base grid

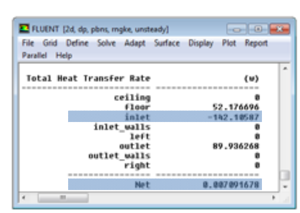


Grid refinement



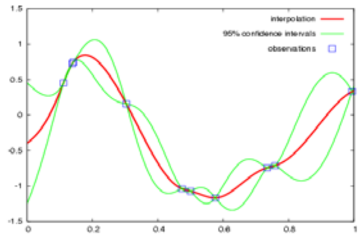
Calculate average convective heat flux



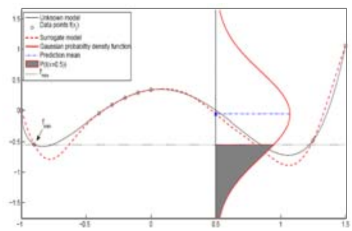


! Monitoring residuals and quantities is contestable

SUMO: global Surrogate-Based Optimization

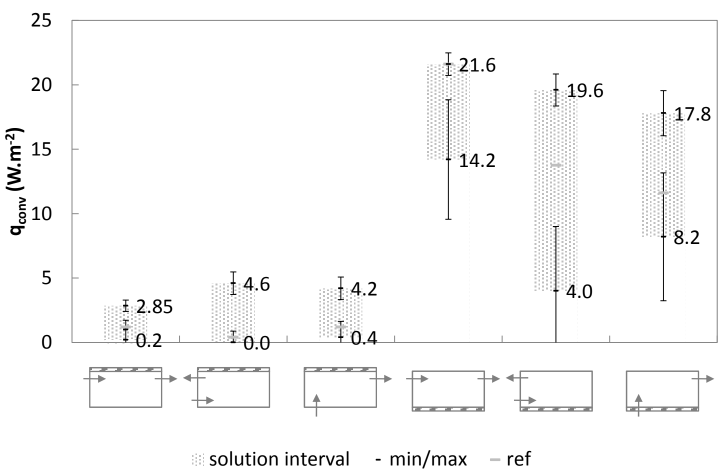


Interpolation modelling
(kriging)



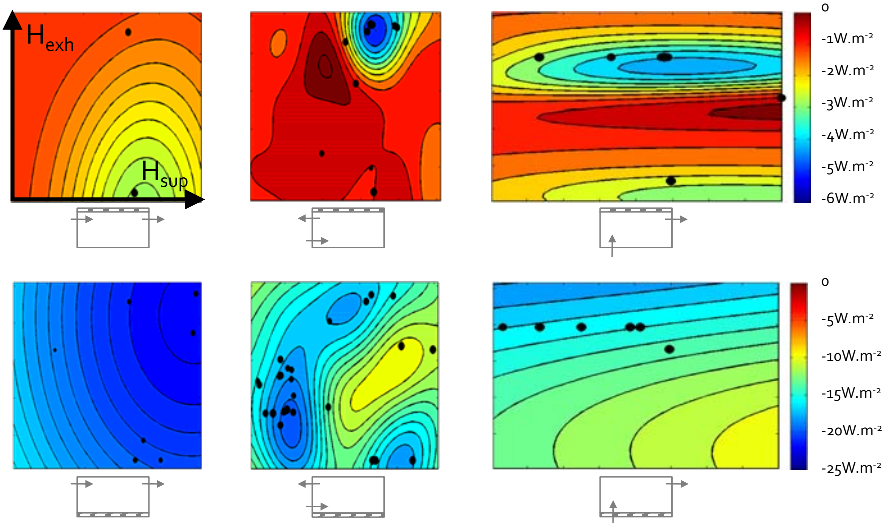
Adaptive sampling
(expected improvement)

Sensitivity: position of thermal mass more important than ventilation concept



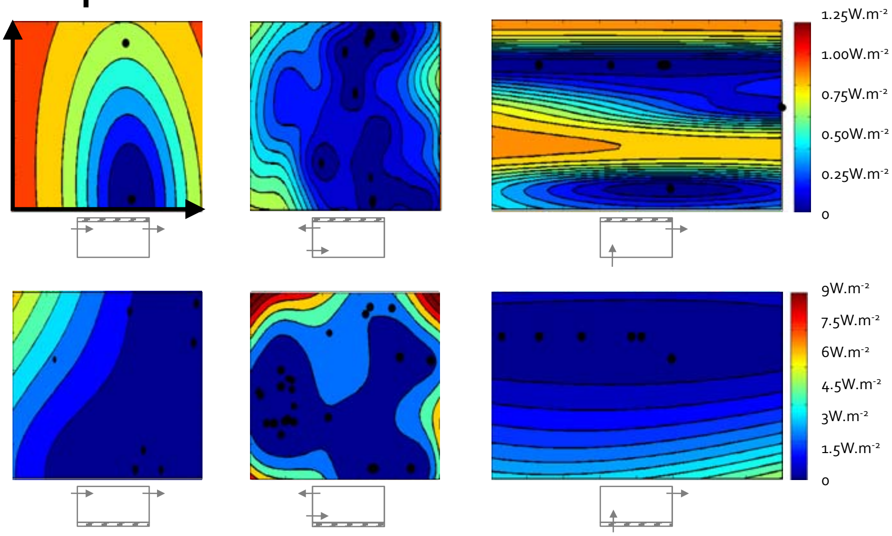
(L_r=4.5m, (T_w-T_{sup})=10°C and n=10h^{-1})

Typical contour plots of the convective heat flux q_c



(L_r=4.5m, α=90°, $h_{sup/exh}$=0.10m, (T_w-T_{sup})=10°C and n=10h^{-1})

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



(L_r=4.5m, α=90°, $h_{sup/exh}$=0.10m, (T_w-T_{sup})=10°C and n=10h^{-1})

These CFD-based surrogate models can provide insight (now)
advance BES-modelling (later)

Advancement of BES modelling

Surrogate models

Indicate optimal solutions for which new correlations can be derived empirically

Make a basis for more globally accurate surrogate models

Framework (in Matlab)

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)

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

UNIVERSITEIT GENT

Kim Goethals and Arnold Janssens

Laboratory of Building Physics, Construction and Services

Further reading:

K. Goethals, H. Breesch et al., Sensitivity analysis of predicted night cooling performance to internal convective heat transfer modelling. Energy and Buildings, 43(9) (2011) 2429-2441

K. Goethals, M. Delghust et al., Experimental investigation of the impact of room/system design on mixed convection heat transfer. Energy and Buildings, 49 (2012) 542-551

K. Goethals, I. Couckuyt et. al., Sensitivity of night cooling performance to room/system design: surrogate models based on CFD, Building and Environment, 58 (2012) 23-36

K. Goethals, Convective heat transfer modelling in offices with night cooling (Ph.D.), Ghent University, 2012

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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

RENSON®
VENTILATION
SUNPROTECTION

→

Several sectors:

- Dwellings and apartments
- Health Care
- Schools
- Offices ...

3 systems:

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

→

- **Indoor air quality**
- **Acoustic comfort**
- **Thermal summer comfort**
- **Visual comfort**

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1. Process of applying ventilative cooling

2. Ventilative cooling in practice

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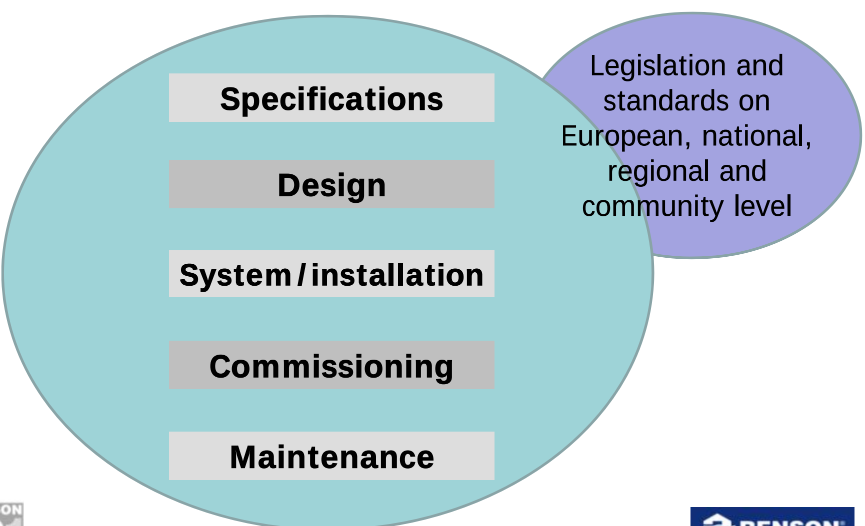
Process of applying ventilative cooling



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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

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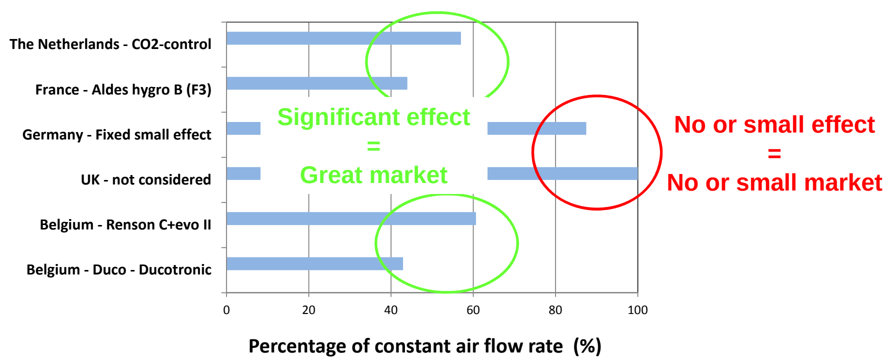
Impact of EPBD on the market: DCV

EPBD: impact of demand controlled residential ventilation in different countries



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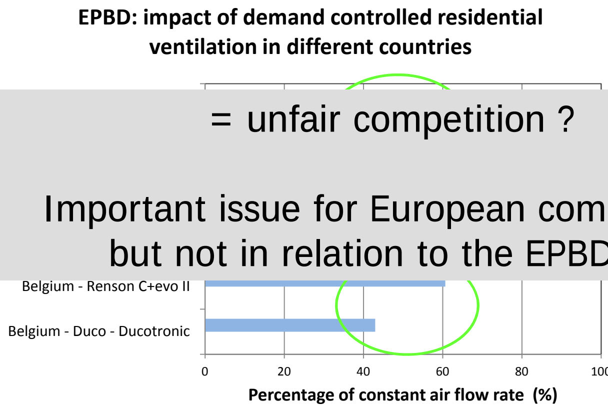
Impact of EPBD on the market: DCV



= unfair competition ?

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

ect

ket

Process of applying ventilative cooling

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

Fire / smoke regulation

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

Process of applying ventilative cooling

Legislation and standards on ...opean, national, ...gional and ...munity level

Specifications

- Operable windows often required

  = **opportunity**
- Protection/securing of openings
- Maximum indoor temperature < 25°C

  ⇒ no guarantee if only ventilative cooling

  = barrier (→ EN15251)

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Process of applying ventilative cooling

Legislation and standards on ...opean, national, ...gional and ...munity level

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

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Process of applying ventilative cooling

Design

Lack of simple design rules within standards

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

Legislation and standards on ...opean, national, ...gional and ...munity level

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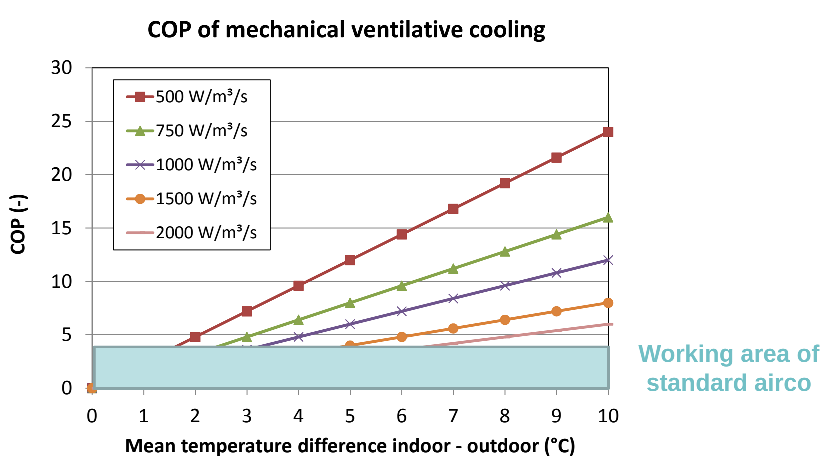
Mechanical ventilative cooling



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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

Legislation and standards on
...opean, national,
...gional and
...munity level

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Process of applying ventilative cooling

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
...opean, national,
...gional and
...munity level

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Process of applying ventilative cooling

Legislation and
standards on
opean, national,
gional and
munity level

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.

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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**

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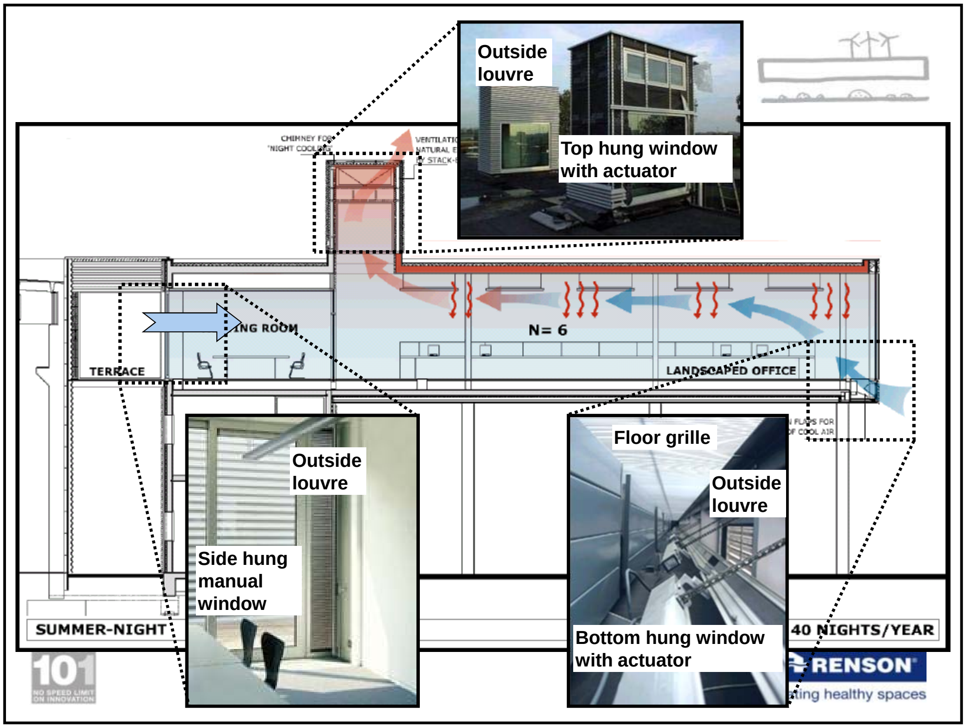
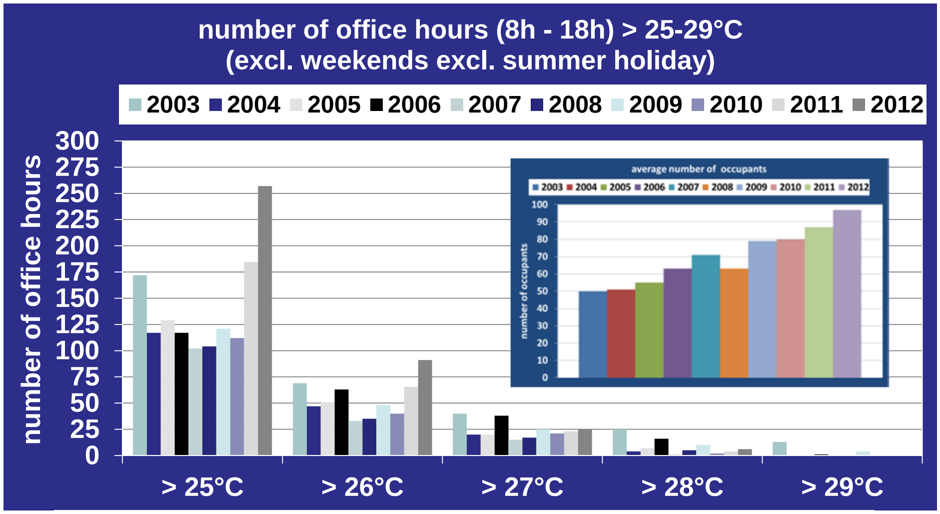
Renson offices (Waregem – Belgium, 2002)
• Passive stack nightcooling
• Average air exchange rate: 6 h-1
• Free area of air supply: 2% of floor area
• Occupancy: 12 m² / person
• Controlled by BMS
• Combined with external adjustable solar shading and exposed ceiling as thermal mass
• Summer of 2006: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


Outside louvre
Top hung window with actuator
TERRACE
N= 6
LANDSCAPED OFFICE
Outside louvre
Side hung manual window
Floor grille
Outside louvre
Bottom hung window with actuator
SUMMER-NIGHT
40 NIGHTS/YEAR
RENSON

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

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Renson showroom (Waregem – Belgium, 2013)

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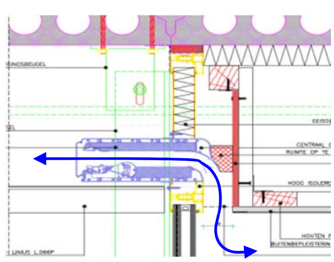
Renson showroom (Waregem – Belgium, 2013)



- **Natural air supply – exhaust:**
  - o acoustic insulating automated window vents at the top of the windows (also used for hygienic ventilation)
  - o automated windows integrated in the plenum above the entrance doors

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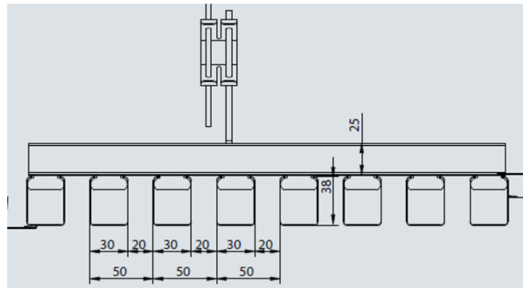
Renson showroom (Waregem – Belgium, 2013)



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

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Renson showroom (Waregem – Belgium, 2013)

- **Mechanical exhaust if needed**
- **SFP = 800 W/m³/s**

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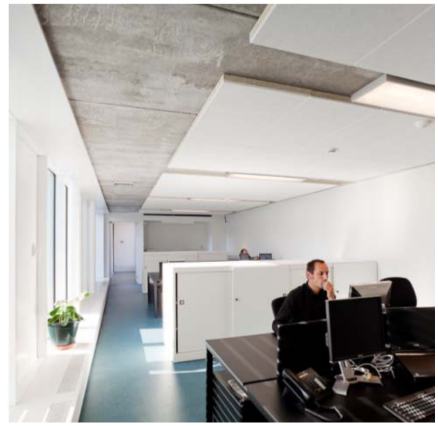
BBL office (Brussels – Belgium, 2012)



- **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 m^2 over 6 floors:**
  - Total energy consumption: 62 kWh/m^2/year
  - Total produced energy: 64 kWh/m^2/year
    - Photovoltaic: 4200 m^2
    - Cogeneration (CHP) on bio-diesel

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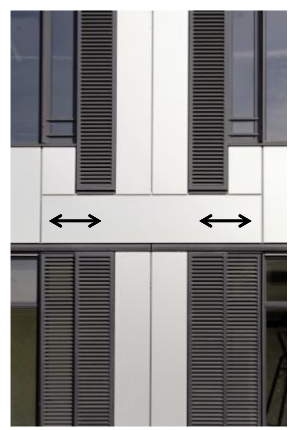
Green office (Paris – France, 2011)

- **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



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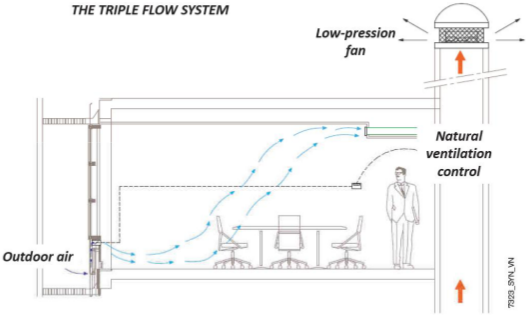
Tour Elithis (Dijon – France, 2009)

- **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

Tour Elithis (Dijon – France, 2009)

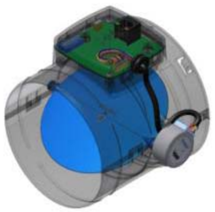
Motorized air supply by means of vents



- **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

Burglary resistant louvre WK2
before operable window

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

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Thanks for your attention

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

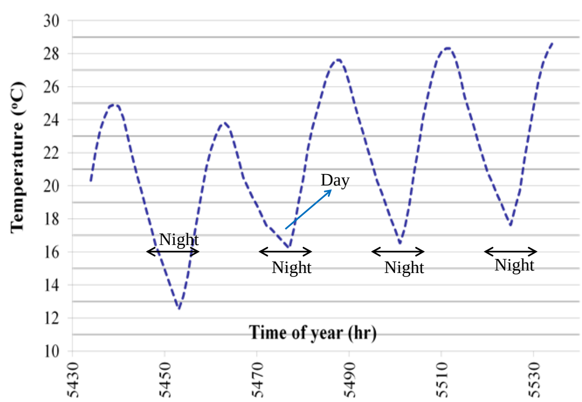
Ventilative Cooling

- 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)



Ambient Air – UK Summer

Phase Change Materials (PCM)

Sensible + Latent heat capacities → Increased Energy Storage

↓

Narrow range of temperature → Thermal Comfort requirements

↓

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

↓

PCM Recharge (Night Ventilation)

Brunel UNIVERSITY LONDON

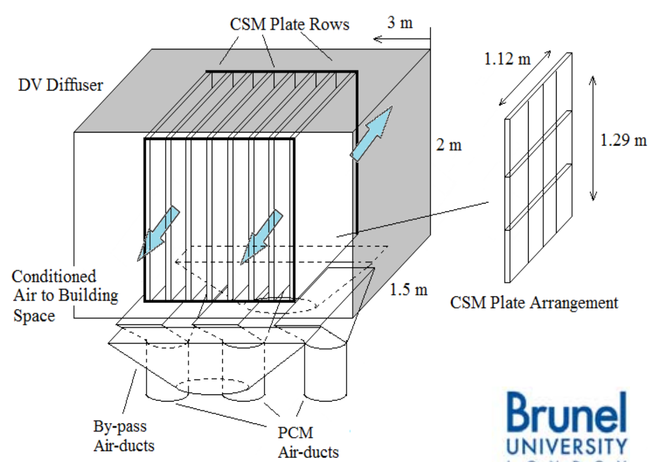
Centre for Sustainable Energy Use in Food Chains, Brunel University, UK

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
- ➢ Comfort temperature: 18-23°C (CIBSE Guide A, 2006)



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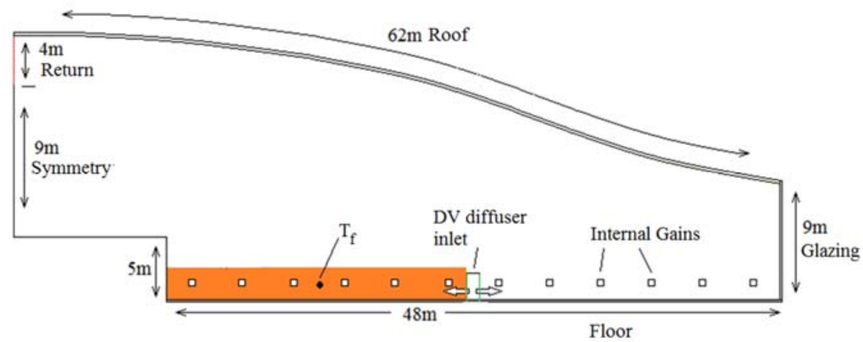
Case Study (1) – Airport Terminal



Airport supplied by Central CAV system – Airtight building

Conditioned Zone

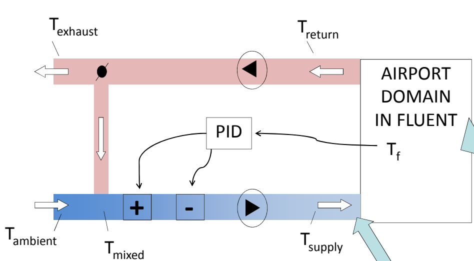
T_f: Temperature sensor control system

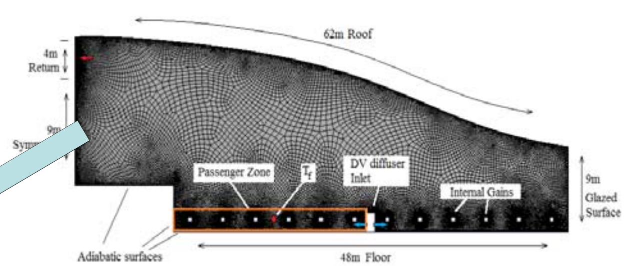
Centre for Sustainable Energy Use in Food Chains, Brunel University, UK

Case Study (2) – Modelling

Coupled TRNSYS-FLUENT model:

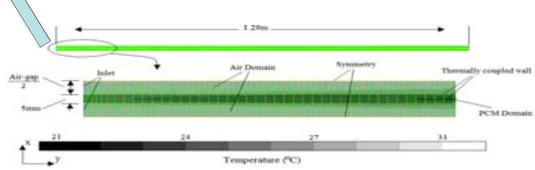
<u>TRNSYS</u> models HVAC + PID control & <u>FLUENT</u> models Airport airflow





Displacement Conditioning (DV)

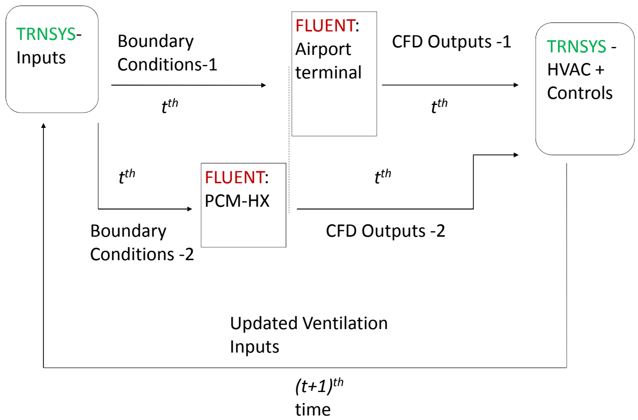
TRNSYS



FLUENT

Case Study (3) – Model Coupling

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



Boundary conditions	CFD Outputs
Weather data (Ambient temperature, Solar gains)	Feedback temperature (T_f)
Internal heat gains	Return air temperature (T_r)
Ventilation conditions (Supply air temperature, air mass flow rate for both airport + PCM-HX)	PCM-HX - outlet air temperature

Case Study (4) - Control

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

If 18°C ≤ T_f ≤ 23°C → T_m passes through PCM-HX and supplied to Airport (Heating/Cooling units off) → Free-Cooling

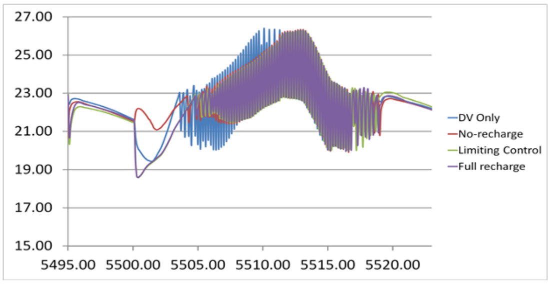
If T_f > 23°C → PID calculates a low T_s to satisfy cooling load

If T_f < 18°C → PID calculates a high T_s to satisfy heating load

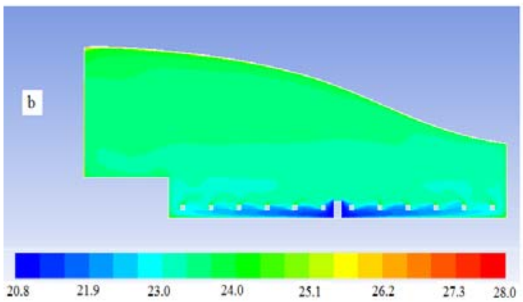
PCM Night Recharge Strategies (non-occupied hours 24:00-04:00):
(Ambient air passed through PCM-HX)

1. No-night recharge
2. Full-night recharge
3. Recharge stopped when T_{pcm} < 18°C (limiting control)

Case Study (5) - Results



Indoor Airport Temperature – One day



Temperature Contour

-Air movements observed in CFD model

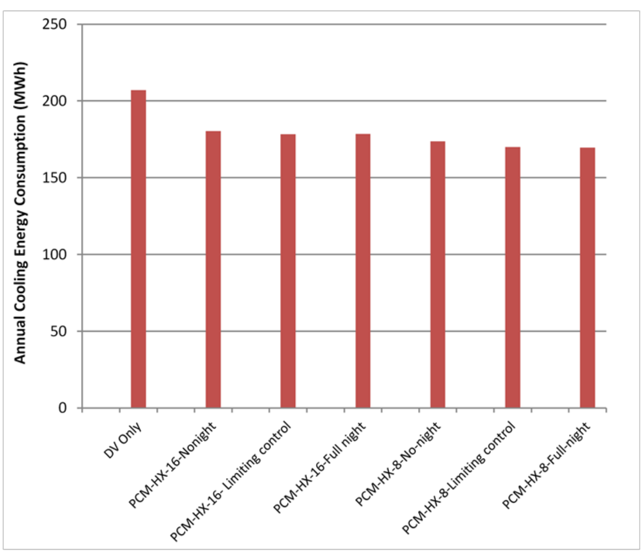
- PCM-HX reduces temperature swing in airport

- Similar temperature trends for 3 recharge strategies

	Summer overheat (>25°C)
DV-Only	6.3 %
PCM-HX No-night Recharge	3.9 %
PCM-HX Limiting-night control	3.5%
PCM-HX Full-night Recharge	3.1 %

Case Study (6) - Results

Annual Cooling Energies obtained through Cooling Degree Days



Systems	Cooling Energy Consumption
DV-Only	100 %
PCM-HX (16mm gap) No-night Recharge	- 12.9 %
PCM-HX (16mm gap) Limiting-night control	- 13.9 %
PCM-HX (16mm gap) Full-night Recharge	- 13.8 %
PCM-HX (8 mm gap) No-night Recharge	- 16.1 %
PCM-HX (8 mm gap) Limiting-night control	- 17.9 %
PCM-HX (8 mm gap) Full-night Recharge	- 18.0 %

Summary

- TRNSYS-CFD coupled simulation used for energy evaluations

- PCM-HX reduces summer overheating by ≈ 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.

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Acknowledgements

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

EPSRC
Engineering and Physical Sciences Research Council

? QUESTIONS ?

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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.

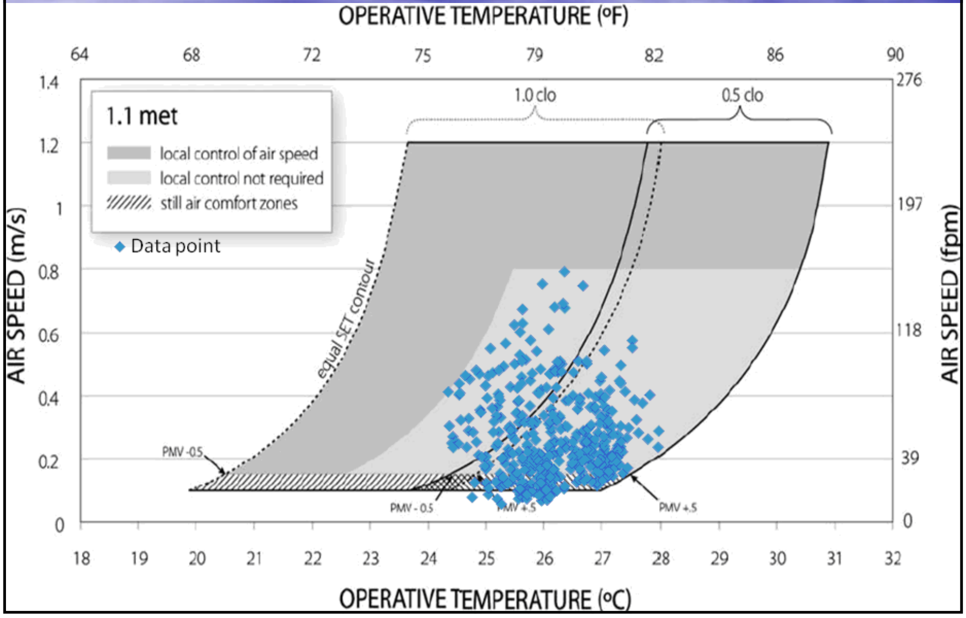
- Global warming (IPCC).
- International concensus to reduce CO_2 emission.
- Recent guidelines issued by governments in East Asia:
- Hong Kong EMSD guidelines on energy saving: the room temperature of an air-conditioned space in summer months is set to 25.5°C;
- National Development and Reform Commission 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

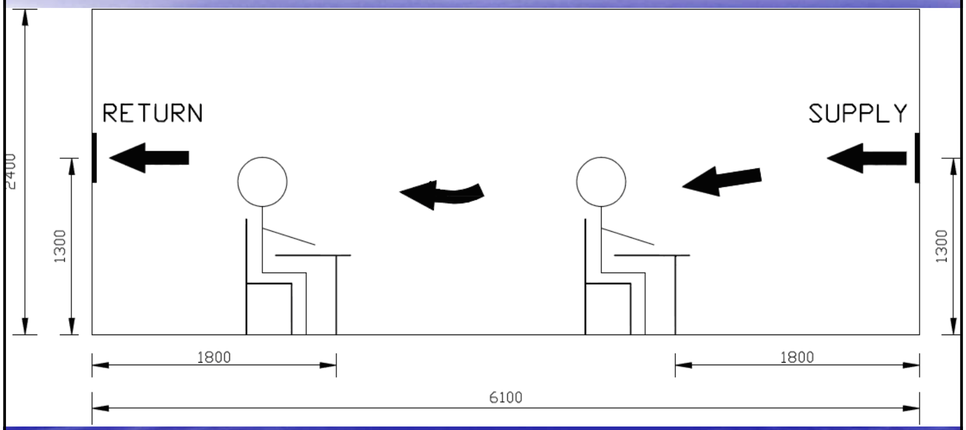
ASHRAE Standard 55-2004?

14/03/2013 AIVC Workshop on Ventilative Cooling 2013 5

ASHRAE Standard 55-2010 allows elevated air movement to broadly offset the need to cool the air in warm conditions



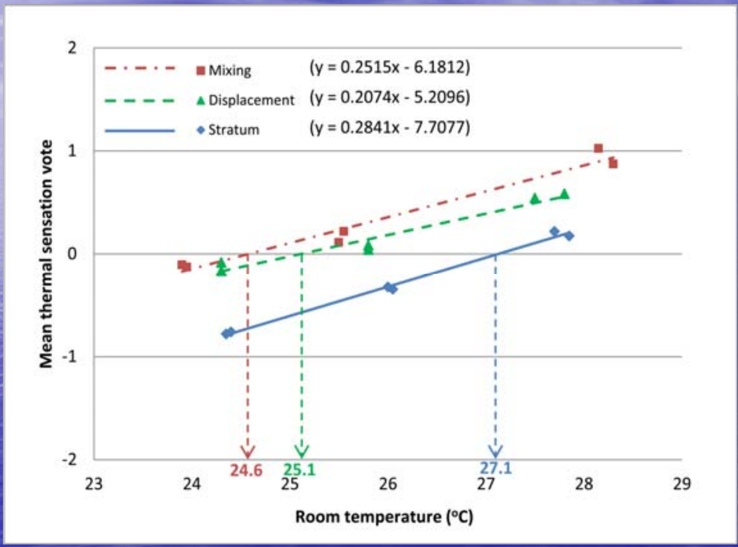
Stratum ventilation was proposed for small to medium rooms

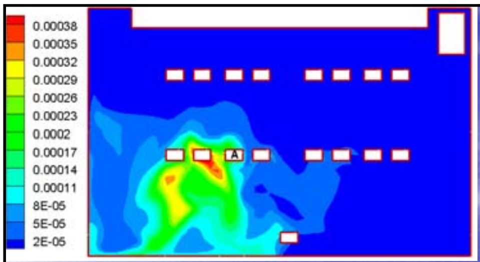


Air supply stratum formed under cooling condition

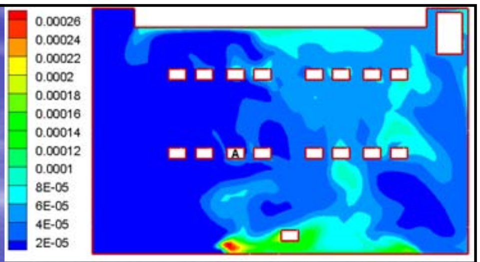
Air supply stratum formed under heating condition

Thermal Sensation Votes of 24 Male + 24 Female subjects

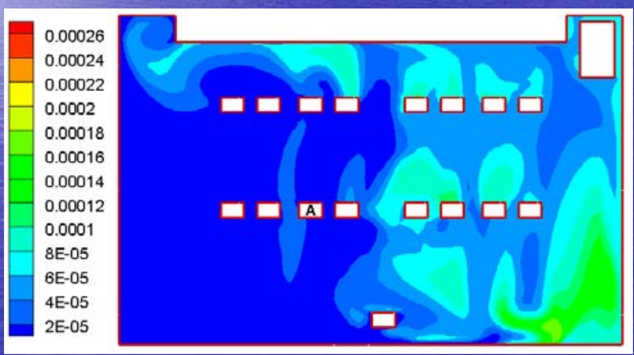




Mixing ventilation



Displacement ventilation



Stratum ventilation

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;

Energy Performance

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)

System	Solar-assisted? No	Solar-assisted? Yes
Mixing ventilation	53,360	n/a
Hybrid displacement ventilation	39,806	24,062
Hybrid stratum ventilation	31,785	19,620
Saving from mixing ventilation to hybrid displacement ventilation	25.40%	54.90 %
Saving from hybrid displacement ventilation to hybrid stratum ventilation	20.15%	18.46 %
Saving from mixing ventilation to hybrid stratum ventilation	40.43%	63.23 %

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).

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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

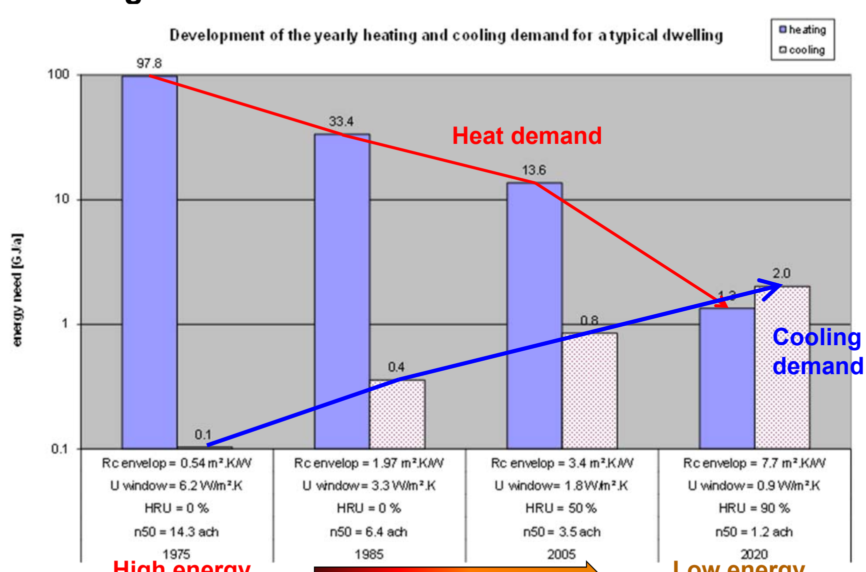
- Increase of cooling demand with decrease of heating demand

Heating season

- Need for mitigation
- Time shift preferred
- Zonal temperature differentiation

→ **Illustrations**

Cooling demand increases while heat demand decreases

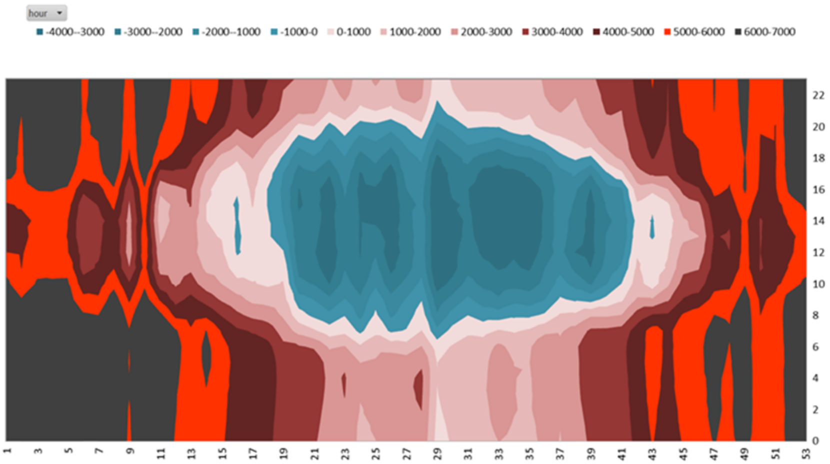


4
March 20, 2013
Bas Knoll
New cooling solutions

TNO innovation for life

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

Heating and cooling demand through the year and the daytime - 1975



5
March 20, 2013
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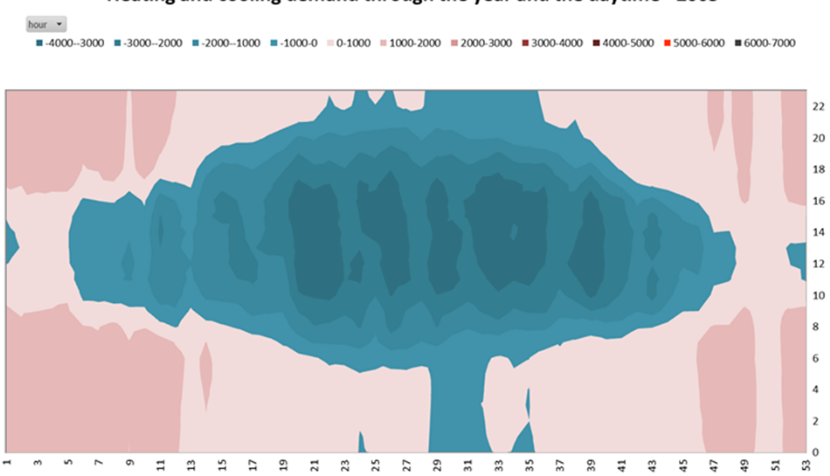
New cooling solutions

TNO innovation for life

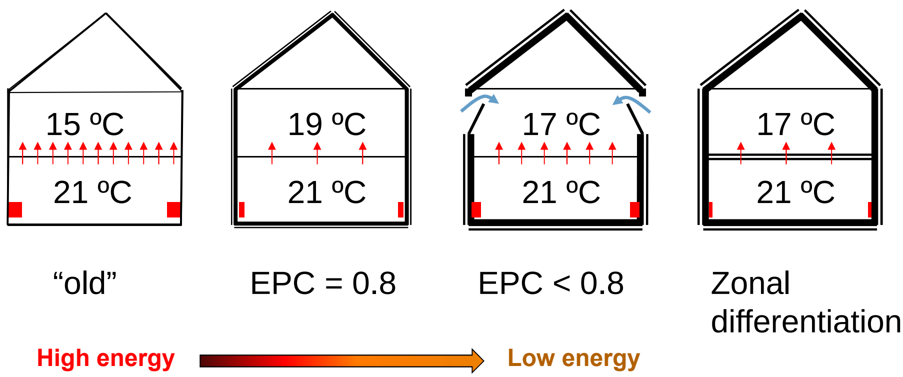
Modern (low energy): cooling demand already in winter and even at summer nights

Heating and cooling demand through the year and the daytime - 2005

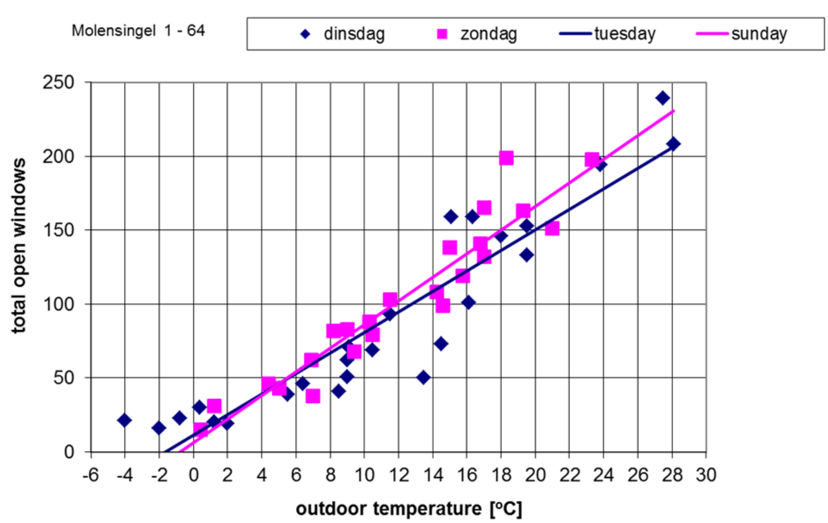


Zonal temperature differentiation

In bed rooms 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.



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



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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)

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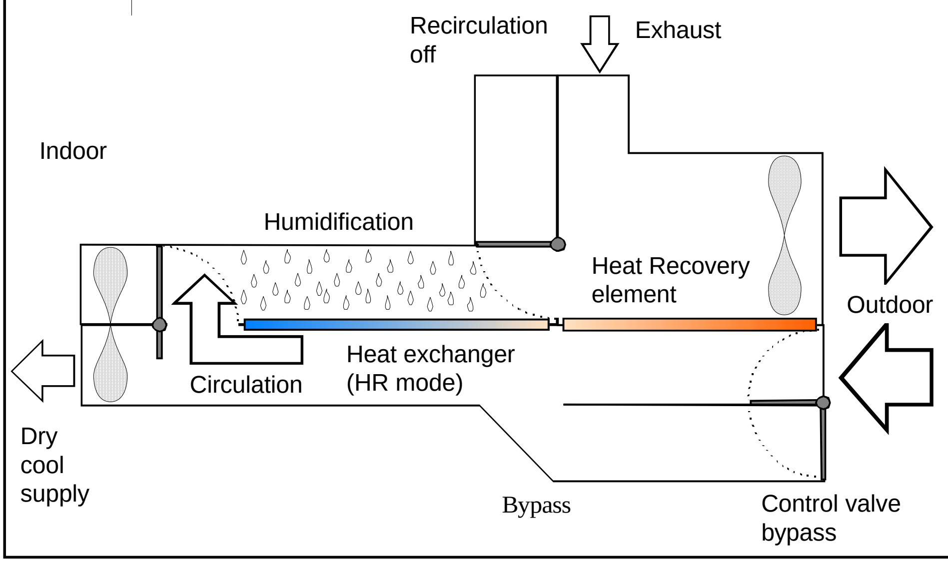
Improved passive cooling

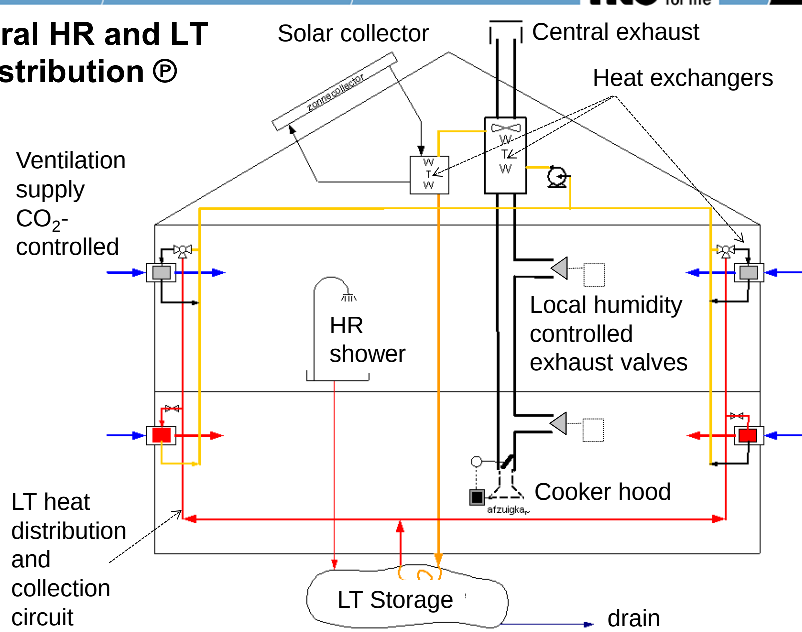
- Precooling by use of a ground duct →
  dew point control necessary to prevent mould growth

- Evaporative cooling 3 to 6 x basic ventilation (0.3 m^3/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



Decentral HR and LT heat distribution ℗



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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