Wednesday 25 September 2013

09:15-10:45: Opening – Plenary session (part 1)

Chairpersons: Peter Wouters, Denia Kolokotsa

- **Welcome on behalf of AIVC, venticool, TightVent, INIVE (**Peter Wouters, Manager of INIVE EEIG)
- **Welcome on behalf of ECRC (**Denia Kolokotsa, Professor, Technical University of Crete, Greece)
- **Model projected heat extremes and air pollution in the Mediterranean and Middle East in the twenty-first century (** Jos Lelieveld, Director, Max-Planck-Institute for Chemistry, Germany
- **Optimization of nighttime ventilation parameters to reduce buildings energy consumption by integrating DOE2 and MATLAB (**Hashem Akbari, Professor, Concordia University, Canada

Peter Wouters
Manager INIVE EEIG
AIVC – TightVent - venticool

Peter Wouters
Manager INIVE EEIG
AIVC – TightVent - venticool

INIVE

International Network for Information on Ventilation and Energy Performance

The IEA Information Centre on Energy Efficient Ventilation

2011: 12 … ntries
2012: 15 … ntries
2013: 17 … ntries

The future

Before 2020 :
Many countries will impose
near zero energy buildings

BUILD Tight
VENTILATE Right

Building Airtightness
will implicitly become a mandatory point of attention

Energy efficient
ventilation
systems will become mandatory

Tight Vent Europe
BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM

AIVC

Tight Vent Europe
BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM

1. Awareness raising about the importance
2. Awareness raising about the existing approaches
3. Identifying a long term action plan

Diamond partners

Gold partners

Associate partners

Platform facilitator

ECF – European Climate Foundation has given substantial support during the first phase of the platform.

Projects…

- Envelope air leakage databases
- Philosophy on airtightness requirements
- Quality of airtightness assessment
- How tight and insulated ducts should be?
- Durability aspects of airtightness
- Quality management of airtightness
- TAAC (TightVent Airtightness Associations Committee
- Ventilative cooling
- Ventilation needs and health
- Steps to improve the quality of residential ventilation systems

TightVent Europe
BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM

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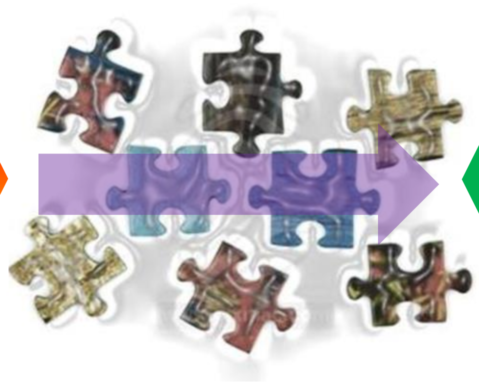
Present situation - most cases poor airtightness performances



Appropriate and durable airtighness performances of the whole stock

More focusing on knowledge generation aspects

AIVC

More focusing on market implementation

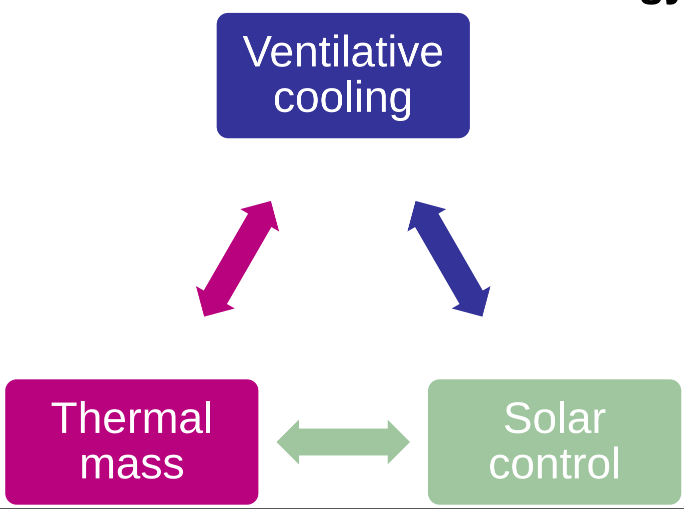
TightVent Europe
BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM

International airtightness workshop on durability issues

Washington DC
April 18-19 2013

venticool

In the context of an energy efficient thermal comfort strategy…



venticool

venticool

the international platform for ventilative cooling

Newsletter

No 2 • MAY 2013

Foreword

14 countries have expressed interest to participate in IEA ECBCS Annex 62 on "ventilative cooling"; 11 are very likely to participate and are already active in the preparation phase of the Annex.

Why? Maybe simply because these countries have identified the potential of ventilative cooling, but also barriers to field applications which call for international collaboration?

Anyways, as you will learn through this newsletter, the March Brussels workshop on "ventilative cooling—need challenges and solution examples" followed by the Annex 62 meeting have been two major milestones to answer their concerns.

This is just a start, the 34th AIVC and 1st venticool conference in Athens will be a major discussion place on ventilative cooling for researchers, professionals and policy makers as well as the 2nd project meeting. So please mark September 25-26 on your calendar for this key event.

Peter Wouters, Manager of INIVE EEIG

IEA ECBCS Annex 62 Ventilative Cooling

The Executive Committee of the IEA Energy Conservation in Buildings and Community Systems programme (IEA ECBCS) accepted the formation of a new IEA ECBCS Annex on Ventilative Cooling at their last meeting in November 2012. This new Annex 62 is given a one year preparation phase which, if successful, will continue in a four year working and reporting phase from 2014 – 2017. During the preparation phase two workshops will be arranged to define and focus the Annex's objectives, feasibility, methodology, and deliverables in detail. The 1st Annex 62 Preparation Meeting was held March 21 - 22 in the BBRI offices, Brussels, Belgium and the 2nd Preparation meeting will be held in Athens, September 23-24, 2013.

In order to address the cooling challenges of buildings the research focus of the annex will be on development of design methods and compliance tools related to predicting, evaluating and eliminating the cooling need and the risk of overheating in buildings and to develop new attractive energy efficient ventilative cooling solutions.

Annex 62 will be divided in three subtasks. **Subtask A "Methods and Tools"** will analyse, develop and evaluate suitable design methods and tools for prediction of cooling need, ventilative cooling performance and risk of overheating in buildings. The subtask will also give guidelines for integration of ventilative cooling in energy performance calculation

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.

AIVC

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BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM

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Prof. Per Heiselberg

More focusing on knowledge generation aspects

IEA EBC Annex 62 'Ventilative cooling'

More focusing on market implementation

venticool

venticool

AIVC

The Ventilative Cooling Platform is at present supported by:

PARTNERS

venticool is a market oriented platform in which involvement of industry partners is crucial. Partnership is open for all organisations with a direct or indirect interest in the topic of ventilative cooling, e.g. companies specialised in natural and mechanical ventilation, innovative cooling techniques, major architectural and consultancy companies, companies active in thermal insulation, material with high thermal capacity, phase change materials, solar control, solar control, ... At present, we have the confirmed participation of the following associations and companies:

- **AGORIA-Naventa** is the Belgian association of manufacturers of natural ventilation in residential and non-residential buildings. This group was founded within Agoria, the federation of the Belgian technological industry. As Naventa, we give special consideration to health-related issues when developing new natural ventilation, solar shading and night cooling systems. By supporting the venticool platform, Naventa wants to increase her knowhow and raise awareness that there is a huge need for CEN standards to calculate the influence of ventilative cooling on the energy performance of buildings.
- **ESSO**, the European Solar-Shading Organisation (ES-SO), is the umbrella body representing the European solar shading and roller shutter industry. Its objectives are to provide a permanent point of contact between its members (mainly the national professional trade associations) and the European authorities, and to demonstrate that solar shading can make a substantial contribution to energy savings and indoor comfort. By joining the ventilative cooling platform ES-SO underlines the importance of different technologies and strategies to be used in a multidisciplinary and integrated conceptual way to reach the target of low energy buildings' thermal comfort criteria as well as maintaining a good indoor climate and visual comfort.
- **Eurima** is the European Insulation Manufacturers Association, representing the interest of the mineral wool insulation industry. Eurima actively support venticool to develop knowledge and application of ventilative cooling solutions for a successful implementation of the EPBD recast bearing in mind comfort issues. This requires appropriate levels of insulation and well-functioning ventilation making best use of building materials in order to guarantee energy efficiency, comfort and good indoor air quality.
- The **VELUX** Group offers a wide range of solutions for daylight and fresh air through the roof – regardless of roof pitch, size and purpose of the building.The VELUX Group considers ventilative cooling to be a sustainable technology. A technology which today is not at all used to its full potential. The mission of venticool is therefore crucial. It supports the effective and knowledge-based promotion of the use of ventilative cooling, it fills in the gaps in the value chain of ventilative cooling that exist in calculation methods, standards and regulations, and it promotes the communication and awareness of ventilative cooling that could act as a catalyst in the development of the right solutions for the market when they are most needed.
- **WindowMaster A/S** is founded on a vision to create better buildings that have plenty of fresh air and excellent and safe indoor climates. We supply sustainable indoor climate solutions for all types of buildings and our solutions are based on natural and hybrid ventilation. Also natural smoke ventilation is a part of our offerings. Our expertise is built on our knowledge of regulatory standards and project development, and our experience from thousands of completed projects across Europe.

PLATFORM FACILITATOR

- **INIVE**, a registered European Economic Interest Grouping (EEIG) bringing together the best available knowledge from its members- organisations in the area of energy efficiency, indoor climate and ventilation.

TightVent Europe
BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM

venticool

AIVC

International workshop on quality of ventilation systems

Brussels

March 18 2013

International workshop on ventilative cooling

Brussels

March 19-20 2013

Welcome on behalf of the European Cool Roofs Council

Dr Denia Kolokotsa

Chair of the Board of Directors

EUROPEAN COOL ROOFS COUNCIL

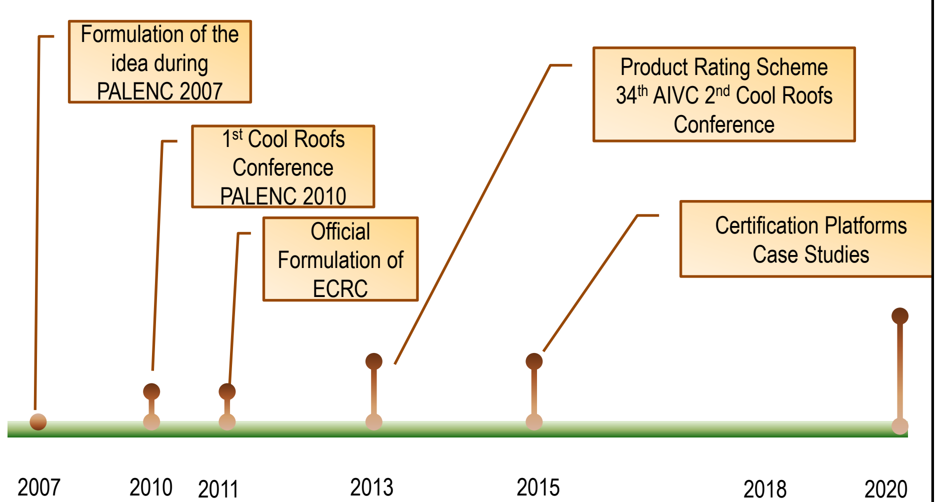
http://coolroofcouncil.eu/

Technical University of Crete

E-mail: dkolokotsa@enveng.tuc.gr

www.enveng.tuc.gr

The ECRC Story



Strategic Objectives

- ✓ Formulation of cool materials product rating programme in Europe.
- ✓ Inclusion of cool materials in European Standards, Energy Assessment Methods.
- ✓ Promote the benefits of cool materials to engineers, stakeholders, etc.

ECRC Members

- ✓ 25 members

Current ECRC Members

Below is a listing of the ECRC Members.

Companies

Universities and Research Institutes

http://coolroofcouncil.eu/

What is a Cool Roof ?

Cool Roofs allow building owners, architects, civil engineers, energy consultants and policy makers to optimise the energy and environmental performance of a single building or an urban environment, depending on the use, design, environment and the surrounding climate.
A Cool Roof minimises solar heat gain keeping roof surfaces cooler under the sun. This is due to the materials used, which both reflect the solar radiation (solar reflectance) and release the absorbed heat (infrared emittance).

A Cool Roofing product is characterised by higher solar reflectance in comparison to conventional roof materials of the same colour and high infrared emittance values.

Cool Roofing products can be applied to all types of roofs including those of residential buildings, apartment blocks, industrial structures, commercial buildings, hospitals, and offices.

The benefits of a Cool Roof products can be summarised as follows:

For building owners

- reduce the energy required for interior cooling
- reduce thermal stresses on the roof potentially improving system lifetimes

Cool roofs offer many benefits:

- Reduce energy required for cooling
- Lower related greenhouse gas emissions
- Improve thermal comfort
- Increase system lifespan
- Reduce maintenance costs
- Mitigate urban heat islands
- Reduced peak electricity demand

Ask about the benefits of Joining ECRC

ECRC News and Events

MaTrID "Market Transformation Towards Nearly Zero Energy Buildings Through Widespread Use of Integrated Energy Design" »
17/05/2013 11:52

2nd Cool Roofs Joint Conference September 25-26 2013 Athens Greece »
10/04/2013 00:20

Job Opportunity in ECRC »
09/03/2013 17:12

ECRC EUROPEAN COOL ROOF COUNCIL

Thank you

Joint Conference 34th AIVC- 3rd TightVent- 2nd Cool Roofs' - 1st venticool
25 – 26 September 2013, ATHENS, Greece

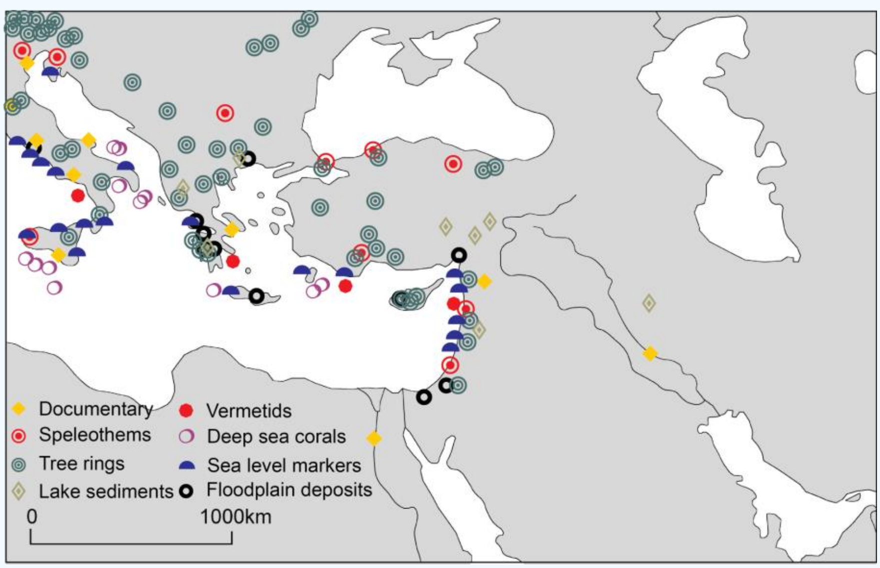
THE CYPRUS INSTITUTE

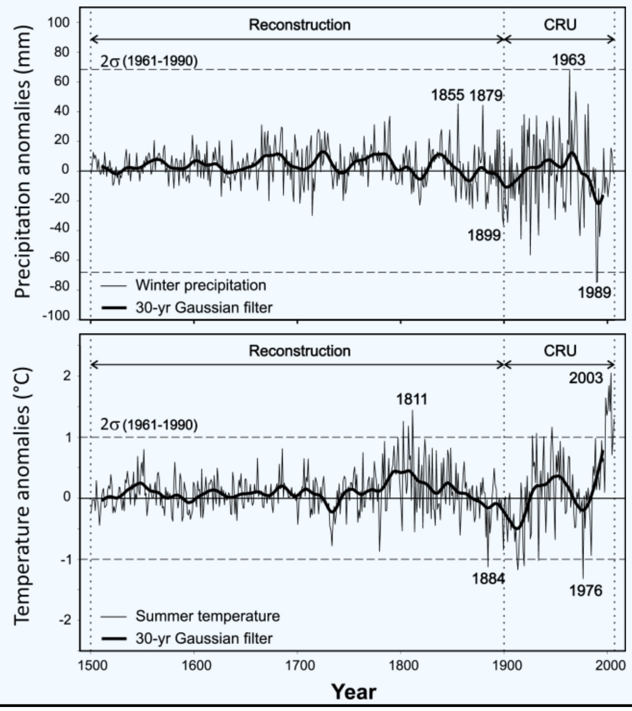
MAX PLANCK INSTITUTE FOR CHEMISTRY

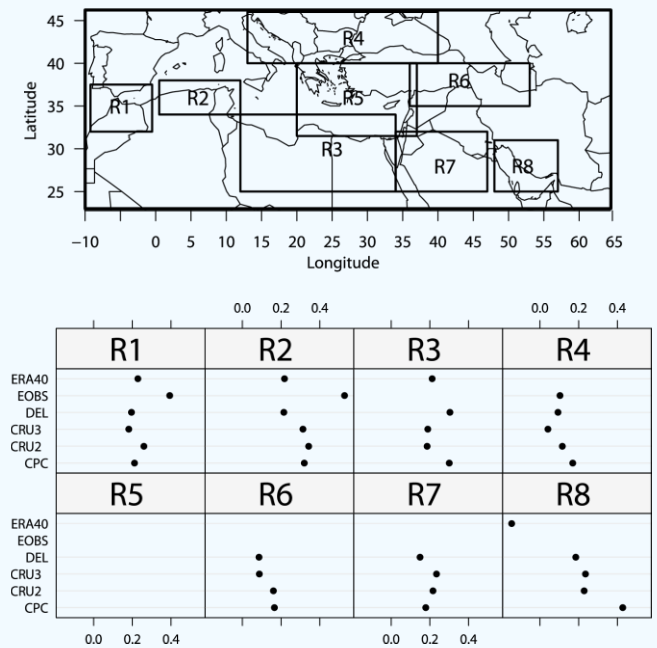
Model projected heat extremes and air pollution in the Mediterranean and Middle East in the 21st century

Jos Lelieveld

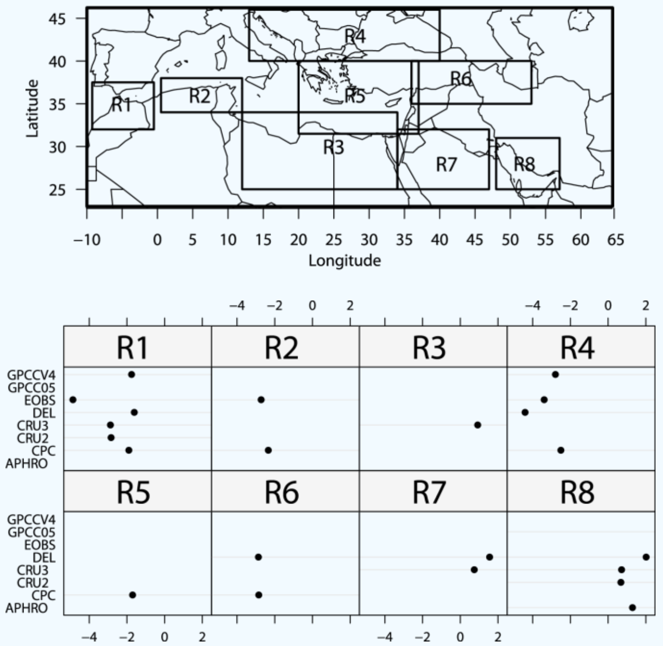
Locations of marine and terrestrial proxy data sources with seasonal to multi-decadal resolution





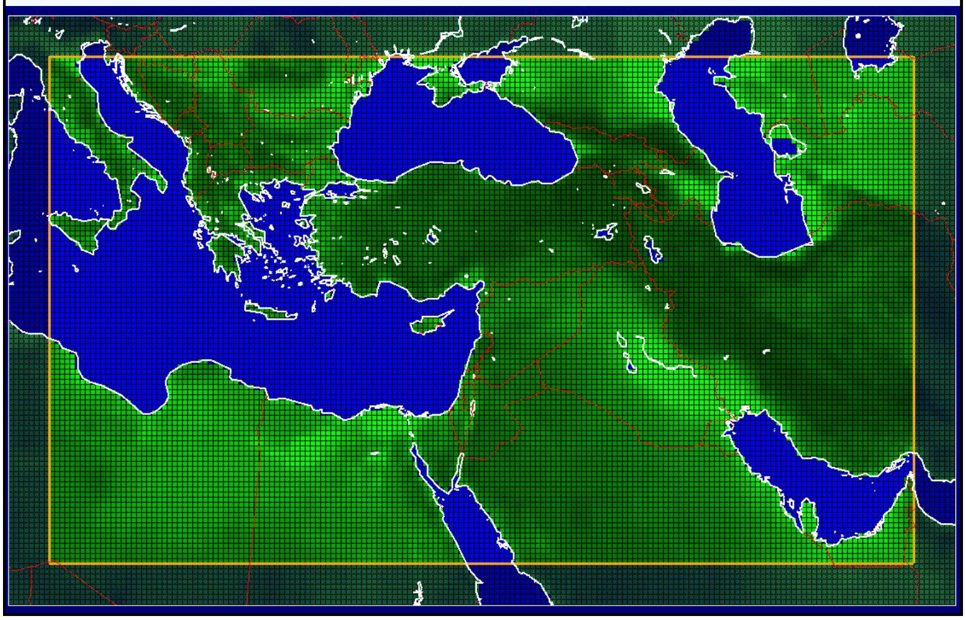


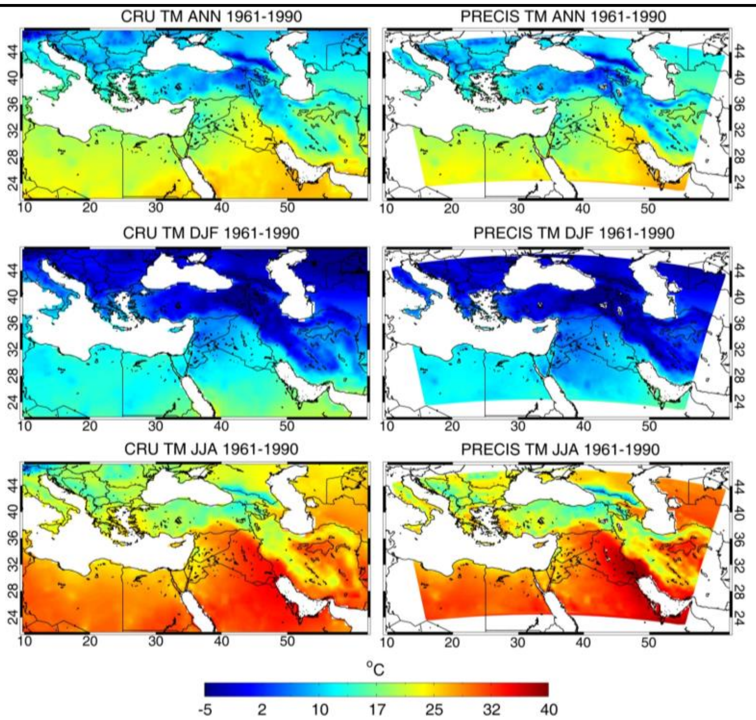
Temperature trends 1961-2000 in ° C/decade



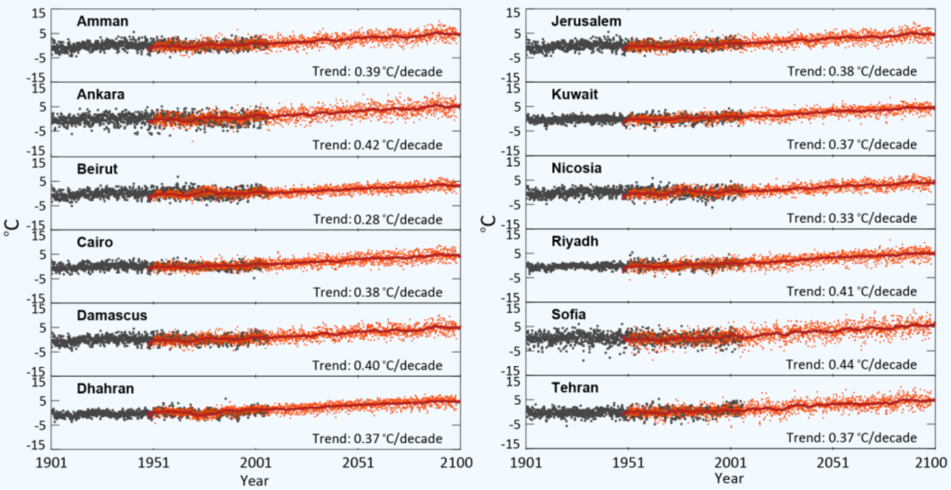
Precipitation trends 1961-2000 in %/decade

PRECIS (Providing Regional Climates for Impact Studies)
HadRM3P with HadCM3 B2, **A1B** and A2 scenarios

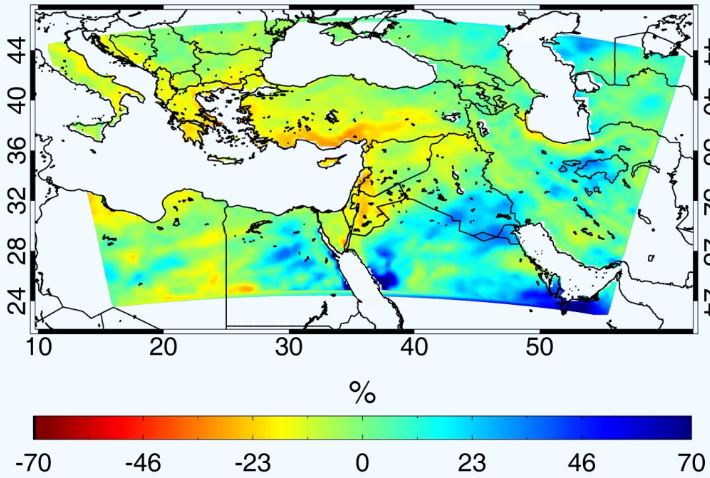




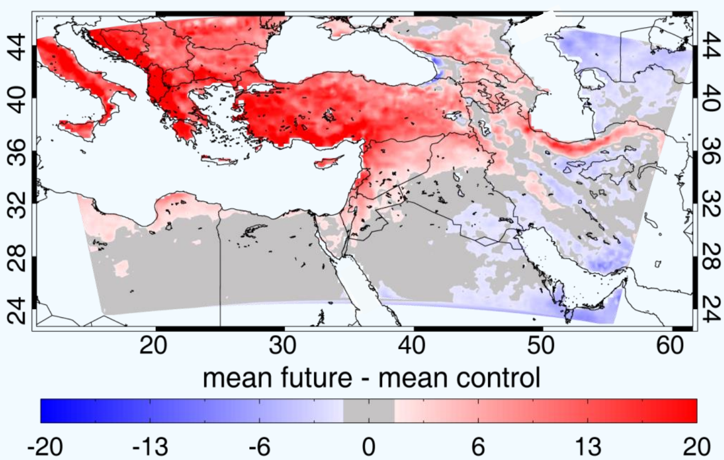
Observed (grey) and modeled (red) temperature changes relative to reference period 1961-1990



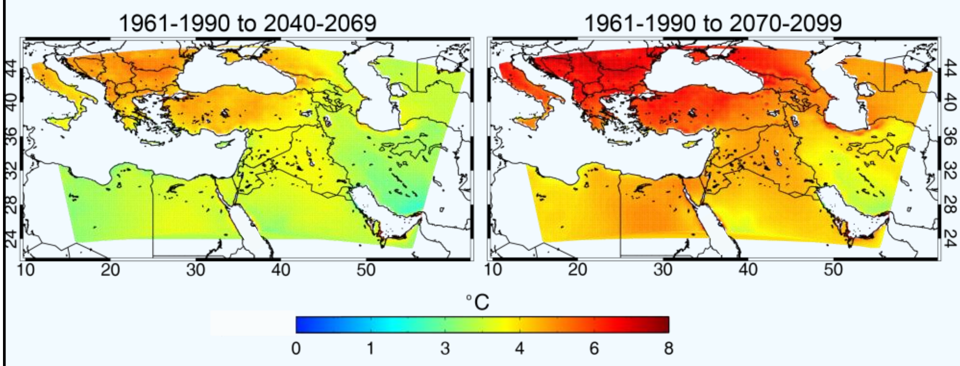
Change in annual precipitation
between 1961-1990 and 2040-2069

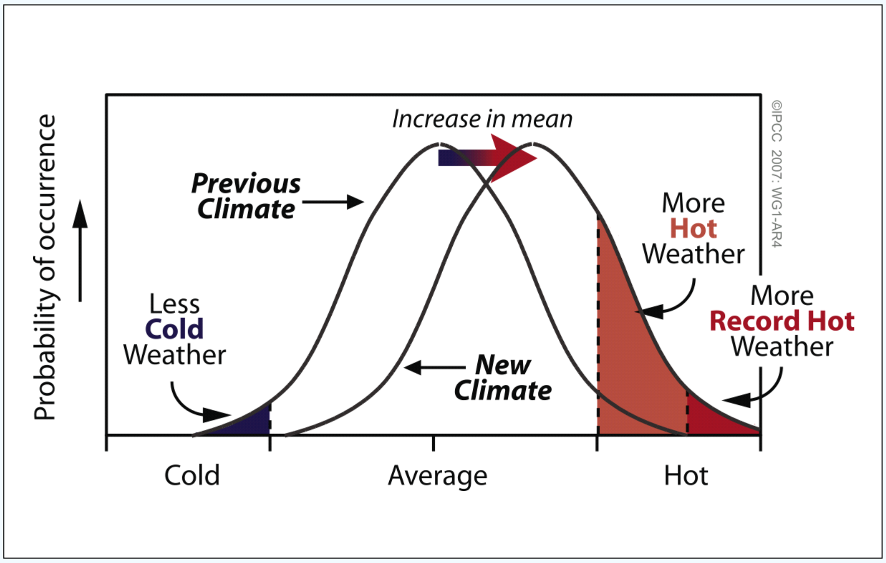


Change in number of dry days per year
between 1961-1990 and 2040-2069

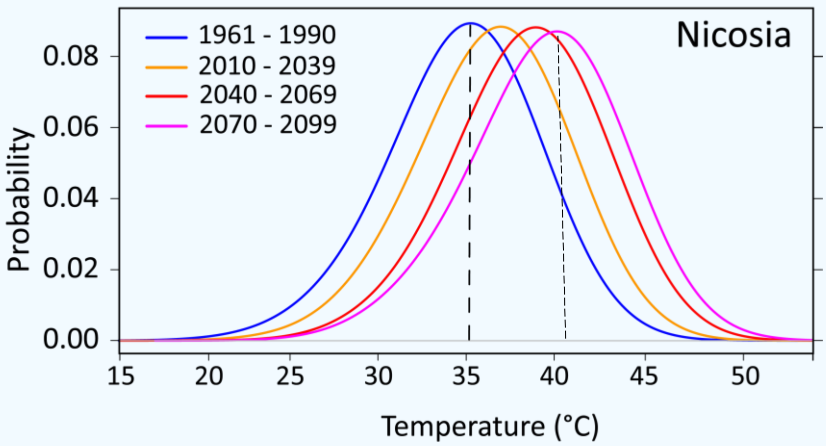


Change in daytime maximum temperature in summer (JJA) from 1961-1990 to mid-century and end-century

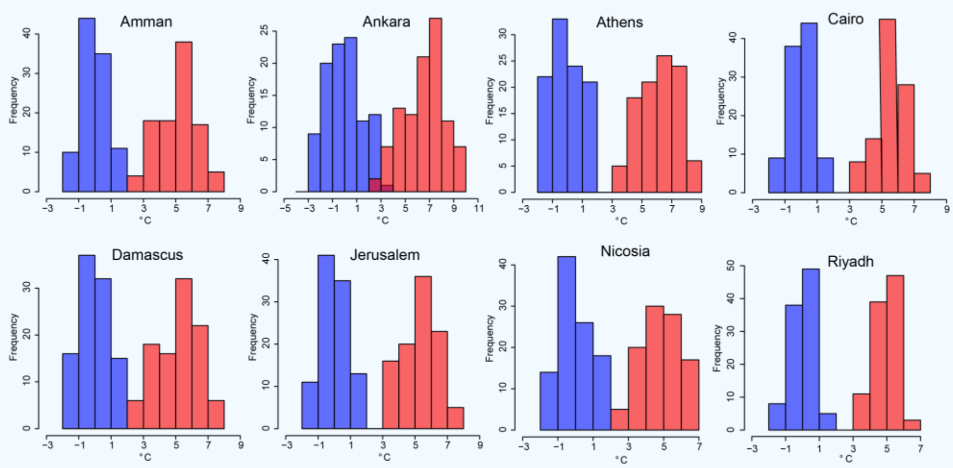




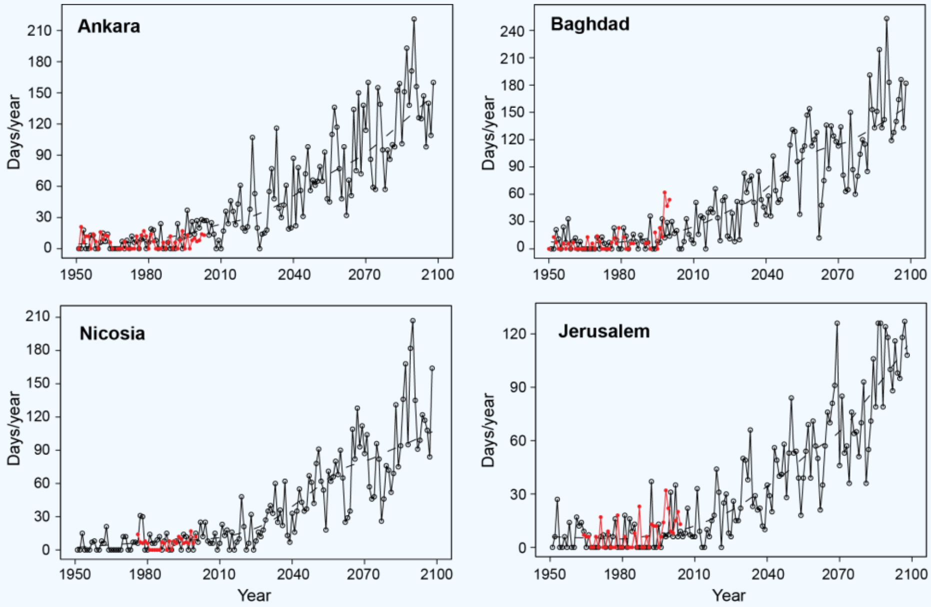
Probability distribution (PDF) of daytime maximum temperatures in summer (JJA)



Frequencies of summer (JJA) maximum temperature anomalies (%). Blue is the reference period 1961-1990 (centered around 0°C) and red 2070-2099, indicating strongly increasing hot periods



Changing number of heat wave days per year: observations (red) and model calculations (open circles)



Number of hot days per year (Tmax > 35° C)			
	Recent	End century	Change
Ankara	10	50	x 5
Athens	29	52	+ 80%
Bahrain	105	161	+ 50%
Beirut	7	57	x 8
Cairo	116	163	+ 40%
Istanbul	8	56	x 6
Nicosia	57	110	x 2

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EU air quality standards

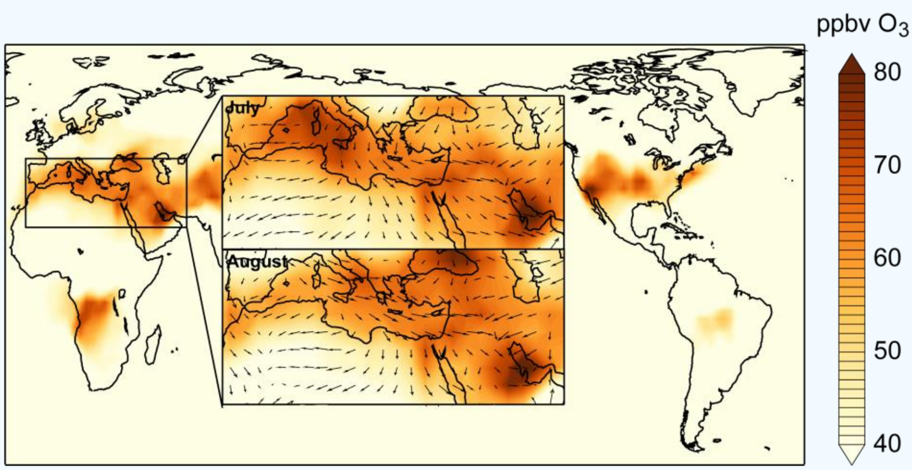
2008 Directive

Particulate matter PM2.5

Annual mean:	25 µg/m^3
WHO guideline 24-hr mean:	25 µg/m^3
WHO guideline annual mean:	10 µg/m^3

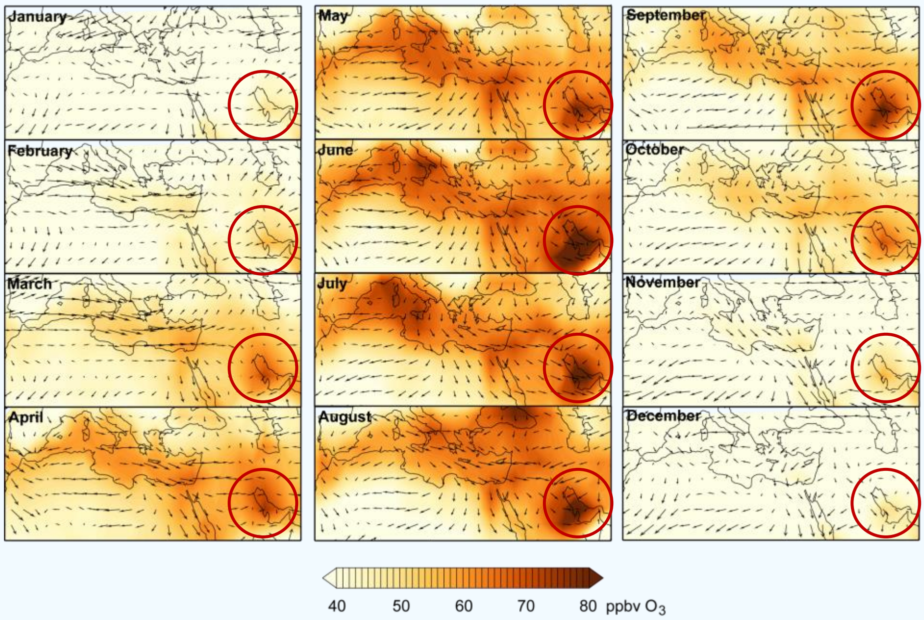
Ozone

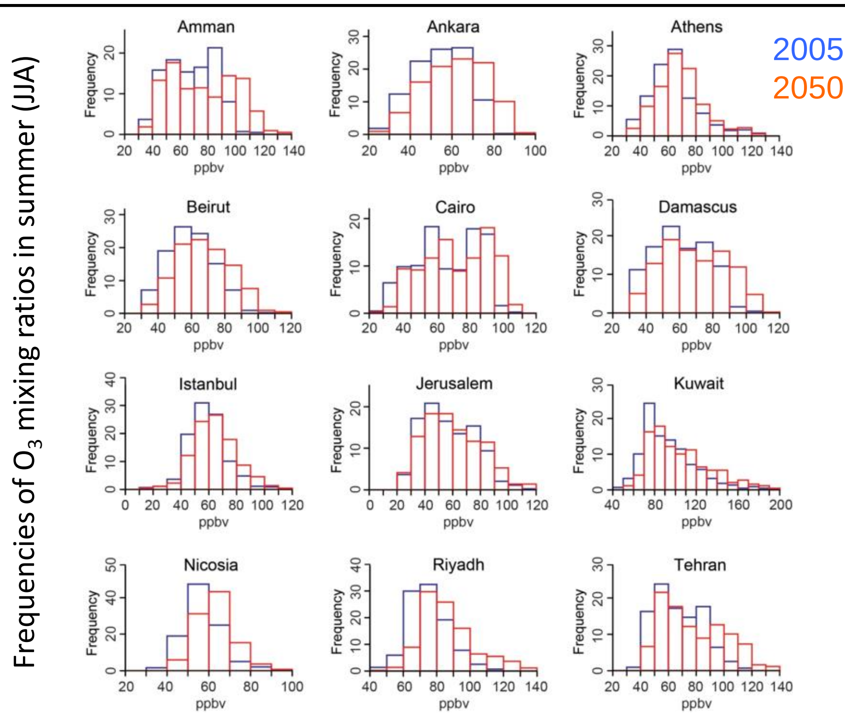
8-hr mean (< 25 days/year):	55 ppbv
WHO guideline 8-hr mean:	50 ppbv



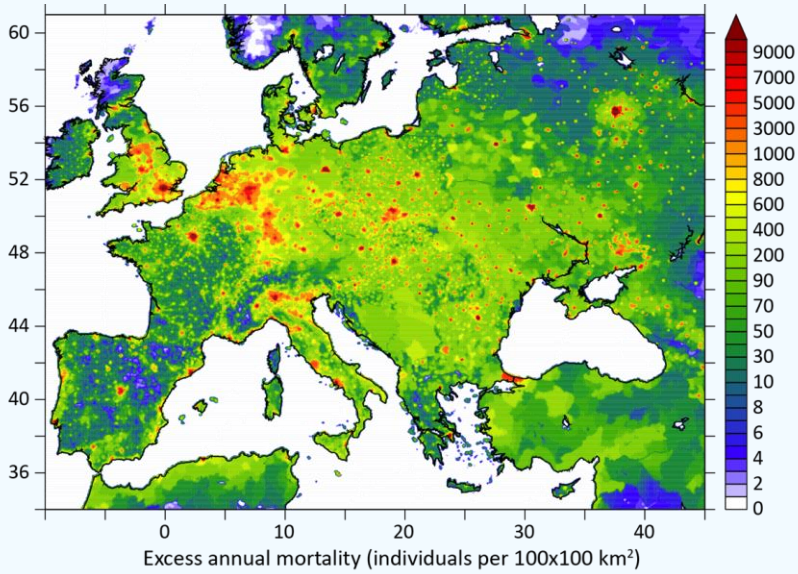
Surface ozone in July - August

Monthly mean near-surface ozone

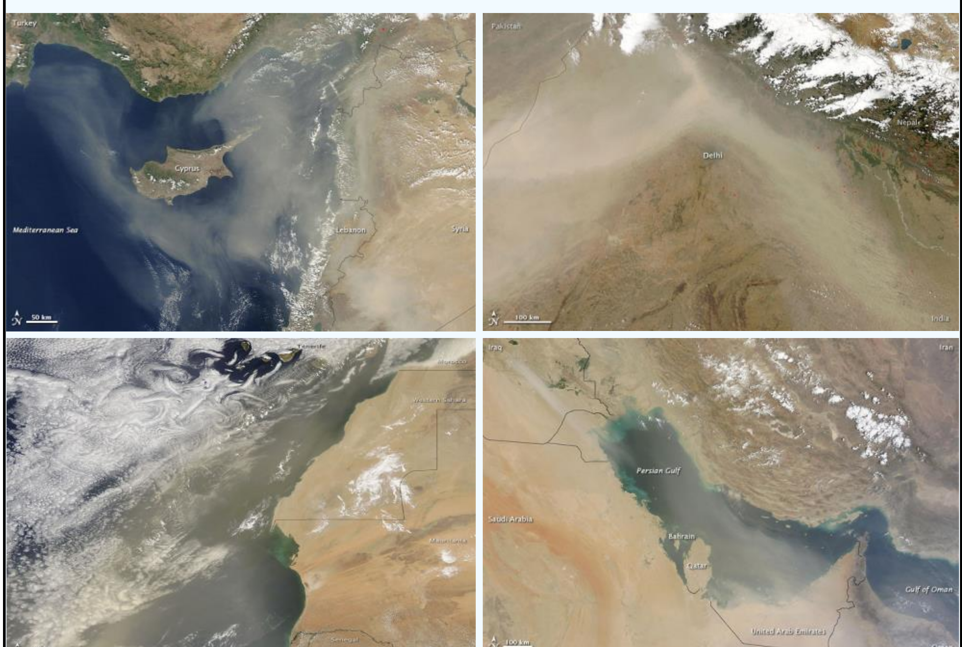


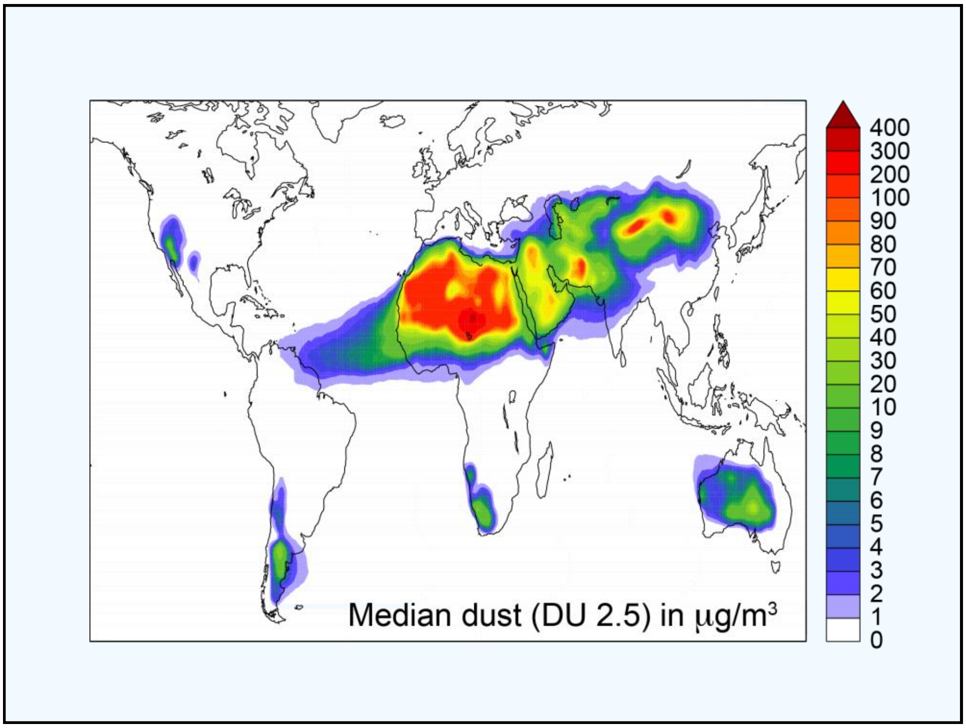


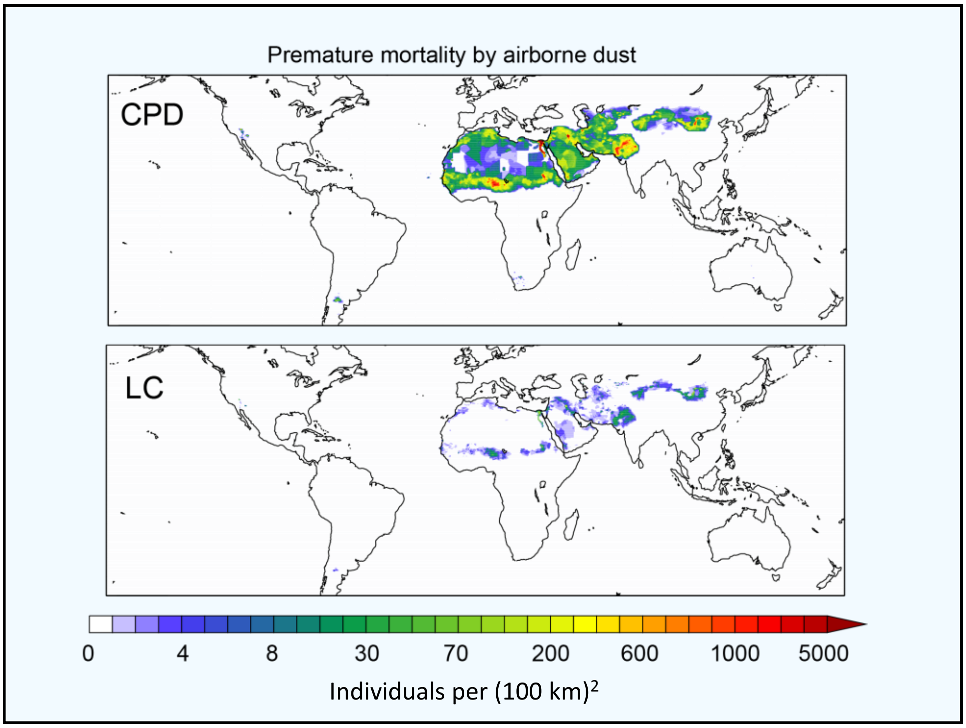
Annual premature mortality due to air pollution



Regional dust outbreaks




Median dust (DU 2.5) in μg/m3
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0


Premature mortality by airborne dust
CPD
LC
0
4
8
30
70
200
600
1000
5000
Individuals per (100 km)2

Regional climate and air quality change

- Climate change is more rapid than in other regions
- Temperature increases relatively strong in summer
- More frequent and intense heat waves (strong impacts)
- Heat stress combines with other environmental stresses in urban locations (air pollution)
- Drying in the EM (waning of cyclonic weather systems)
- Strong reductions of per capita water resources, e.g., in Syria, Cyprus, Jordan
- Health impacts by particulate matter (incl. desert dust) and high ozone levels

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Acknowledgement

Despina Giannadaki, Panos Hadjinicolaou,

Effie Kostopoulou, Andrea Pozzer,

Mereyem Tanarhte, Elena Xoplaki

Integrating building energy simulation and optimization tools to minimize energy use of a building and its application to nighttime ventilation

Hashem Akbari
Concordia University, Montreal, Canada
Hashem.Akbari@CONCORDIA.CA
514-848-2424 X3201

34th AIVC Conference, Athens, Greece
25-26 September 2013

Acknowledgment

My co-author is Hatef Aria

This work was supported by

- An internal grant from Concordia University faculty of Engineering and Computer Science
- Discovery grant from Natural Sciences and Engineering Research Council of Canada (NSERC)

Outline

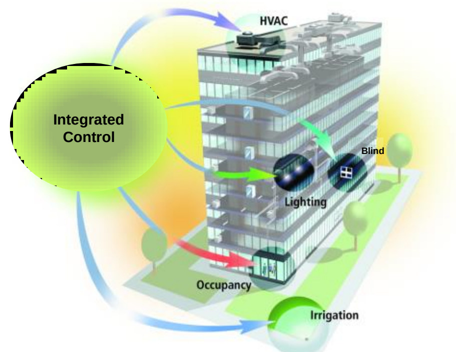
Introduction

Integrated control

Demand response

Building optimization

Example applications



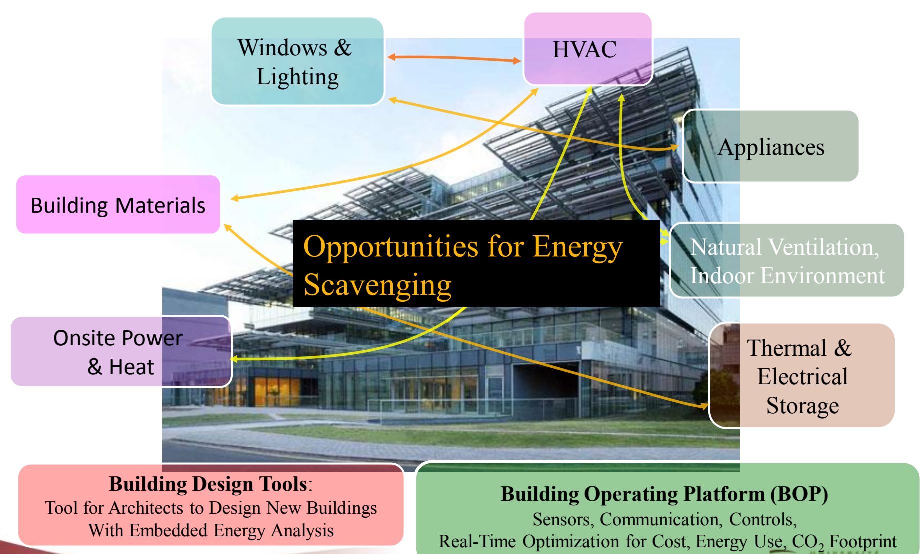
Energy efficiency domain

- Existing technologies (high potential)
  - Retrofit market
  - Integration of renewable into building
  - Fine tuning
  - Cost effectiveness, implementation, and policies
- Advanced innovation
  - Advanced materials (roofs, windows, walls, …)
  - Advanced energy-efficient systems (lighting/daylighting control, building automation, smart appliances, ...)
  - Integration of production (supply) and consumption of energy (demand)
  - Cost effectiveness, implementation, and policies

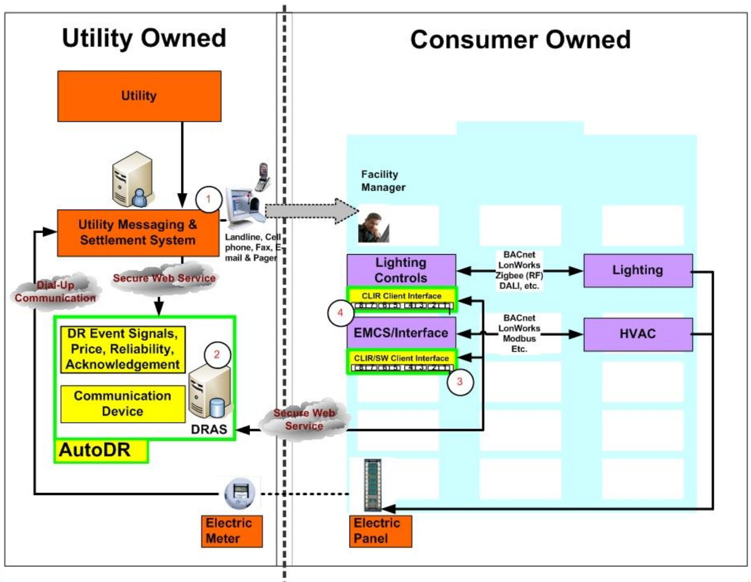
Typical building control

- Local control
  - Basic control and automation functions
  - Schedule control, PID control, and On/off control
- Supervisory control
  - Higher level controls that include local control functions
  - Integrated control and demand response
  - Reduce energy use while increasing comfort

High-performance buildings
integration of sub-systems to reduce energy consumption



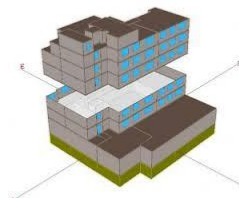
From control to demand response automation



Integrated control and building optimization

- **Optimization function**
  - Cost
  - Energy
  - Peak load
- **Optimization variables**
  - Indoor temperature
  - Outdoor air flow rate
  - Shade position
  - Light power
- **Optimization period**
  - Current hour
  - Dynamic optimization (future hours, entire day)

Optimization requires building modeling



- Simulations in building research
  - **Full-scale simulation software** (DOE2 ...)
    - Wide range of building systems and components
    - Detailed system description
    - Produce a large number of energy and comfort outputs
    - Time-consuming and data processing complex
  - **Statistics-based simulation** (artificial neural networks (ANNs) and time series models)
    - Specific inputs and outputs
    - Need the results from the other models or experimental for training
    - Not very accurate but work very fast
  - **Simplified models**
    - Approximate functional relations for components and systems under study

Optimization tools and methods

Optimization methods

- Linear and non-linear optimizatio
- Stochastic optimization
- Pattern search optimization

Optimal control

- Neural networks
- Rule-based control
- Simulation-base control
- Model predictive control

Example application 1

Integrated and dynamic optimization of an office building energy consumption with non-linear programming

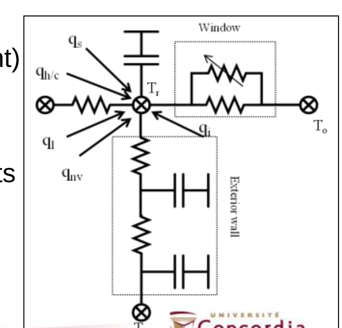
Concordia University

Building model

- RC-network model for a 5 zones

(4 perimeters and 1 center zone) office building

- Effective parameters
  - Heat transfer, solar heat gain and illuminance from window
  - Heat transfer from internal and external walls
  - External walls heat storage
  - Internal heat gain (occupants and equipment)
  - Ventilation rate
  - Cooling and heating system
  - Illuminance and heat gain from artificial lights



Concordia University

Optimization method

- Non-linear optimization with MATLAB
- Objective function: energy consumption and energy cost

$$f = \sum_{i}^{I} f_i(X) \qquad I: 1 \rightarrow N \ \ Time\ period$$

- Variables X_1, X_2, X_5 ,and X_6 are independent control variables

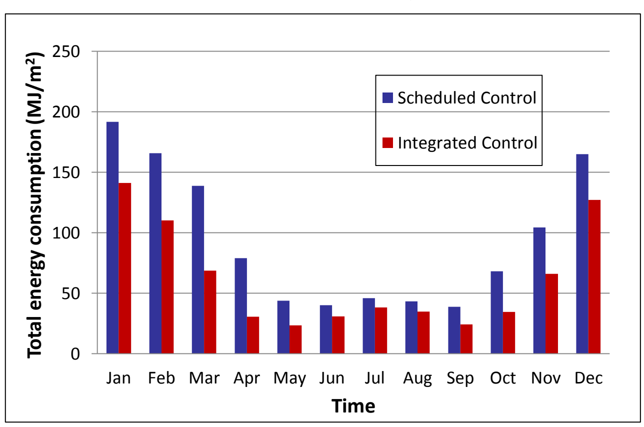
Variables	Disturbances
X_1= Light ratio	V_1= Outside air Temp.
X_2= Blind position	V_2= Solar gain
X_3= Cooling energy	V_3= Solar illuminance
X_4= Heating energy	V_4= Internal heat gain
X_5= Inside air temp.	
X_6= Outside air flow rate	
X_7= Exterior wall inside temp.	
X_8= Exterior wall outside temp.	

Integrated control vs. Schedule control

- **Integrated control**: all control variables are optimized based on current hour outdoor conditions and building schedules (N=1)
- **Scheduled control:** window shades are always closed, temperature is kept at 23.8 °C during occupied hours, and fresh air flow rate is kept at minimum flow rate for entire day

Energy savings:

20% to 50%



Dynamic optimization base on energy

Up to **6%** more energy savings by using dynamic optimization compared to using current hour optimization

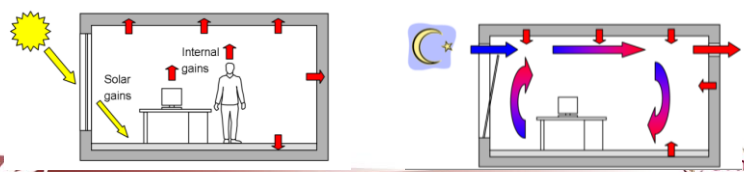
Date	Opt-current hr energy (kJ/m2)	Opt-Dyn N=2 (savings %)	Opt-Dyn N=4 (savings %)	Opt-Dyn N=8 (savings %)	Opt-Entire day (savings %)
1-Jan	4214	0.00	0.00	0.00	0.00
1-Feb	1628	0.74	1.04	1.35	1.35
1-Mar	2199	0.45	0.86	0.86	0.86
1-Apr	1885	1.43	2.71	3.13	3.13
1-May	937	0.53	1.07	2.13	2.35
1-Jun	835	0.48	0.96	2.28	2.63
1-Jul	904	0.77	1.44	2.10	2.10
1-Aug	899	0.22	0.44	1.33	1.33
1-Sep	936	0.32	0.96	2.14	2.14
1-Oct	669	0.00	0.00	0.00	0.00
1-Nov	1123	0.09	0.18	0.36	0.36
1-Dec	2840	0.00	0.00	0.00	0.00

Example application 2

Nighttime ventilation algorithm to reduce energy use and peak demand in an office building

Nighttime ventilation

- Cooling buildings (thermal mass) with outside air at night to minimize the cooling load during the day
- Ventilation methods: natural, wind, and mechanical
- Parameters effecting NV performance:
  - **Building parameters** (thermal mass, insulation)
  - **System parameters** (outdoor air flow rate, nighttime ventilation duration)
  - **Climatic parameters** (outside air temperature and humidity)



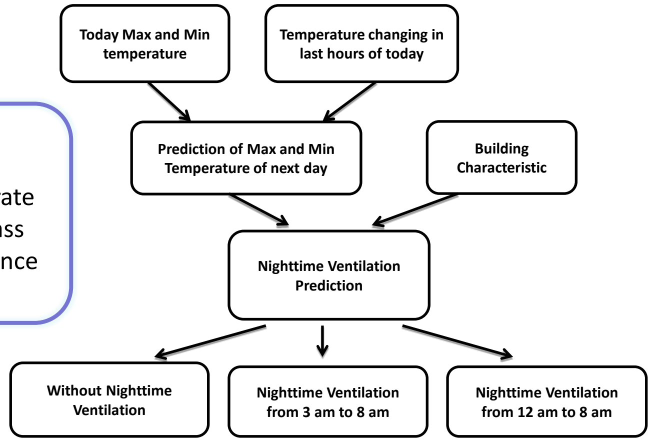
Nighttime ventilation strategies

- **Scheduled-driven method**
  - Constant flow rate and duration
  - Pre-scheduled for summer days
  - DOE2 default
- **Predictive method**
  - Prediction of next day outdoor temperature
  - Variable duration
  - Adding function to DOE2
- **Optimized method**
  - Variable fan flow rates and duration
  - Integration of DOE2 and MATLAB

Predictive method

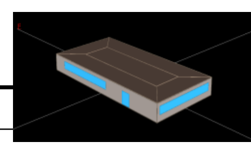
Parametric study:

- Schedules
- Nighttime fan flow rate
- Building thermal mass
- Temperature difference
- Climate



$$Predictive\ Strategy \begin{cases} \mathrm{TP-Ave} < 16\,°\mathrm{C} \rightarrow No\ Nighttime\ Ventilation \\ 16\,°\mathrm{C} < TP - Ave < 17.5\,°\mathrm{C} \rightarrow NV\ from\ 3am\ to\ 8\ am \\ \mathrm{TP-Ave} > 17.5\,°\mathrm{C} \rightarrow NV\ from\ 12am\ to\ 8\ am \end{cases}$$

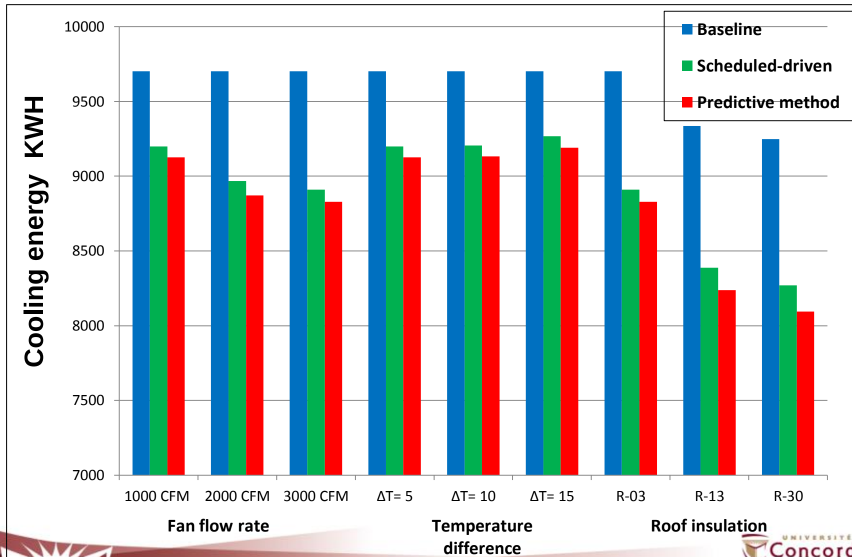
Building description



Parameters	Description
Floor area m^2	464
Wall construction	Wood shingles, plywood, R-11 fiber insulation, gypsum board
Roof construction	Roof gravel, built-up roofing,R-3 or R-30 mineral board insulation, wood sheathing ceiling
Window glass	¼ in plate double pane
Interior loads	Lighting=16 W/m^2, equipment = 10.8 W/m^2, people = 10 m^2 per person
Infiltration	0.25 ACH
Chiller	Reciprocating air cooled chiller (COP=3.65)
Boiler	Gas fired hot water boiler (EFF = 85%)

NV effective parameters

Annual cooling energy consumption in Montreal



Predictive NV savings potential

Total energy savings percentage in investigated cities

Cities	Strategy	Flow rate		
		0.47 m³/s	**0.94 m³/s**	**1.4 m³/s**
Montreal	Scheduled ventilation during summer	**4.6**	**6.9**	**7.5**
	Predictive method	**4.5**	**6.6**	**7.0**
Victoria	Scheduled ventilation during summer	**6.2**	**7.9**	**6.1**
	Predictive method	**6.3**	**8.0**	**6.2**
Portland	Scheduled ventilation during summer	**5.2**	**7.6**	**8.2**
	Predictive method	**5.9**	**8.6**	**9.0**

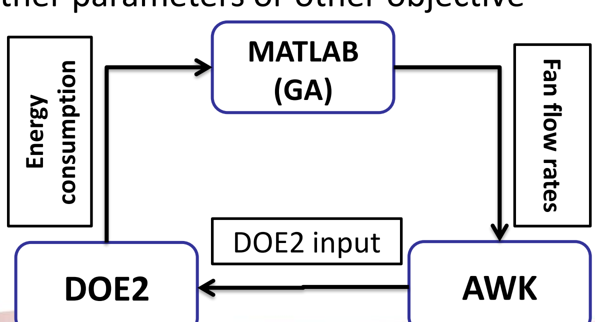
Optimization method: Integrating MATLAB and DOE2

- Optimizing 24 hours building energy consumption
- Using a Genetic Algorithm (MATLAB)
- Using DOE2.1E for building energy simulations
- Optimizing parameters: Hourly fan flow rates during the night from 3 am to 7 am
- Using AWK (text processing language) for creating DOE2 input

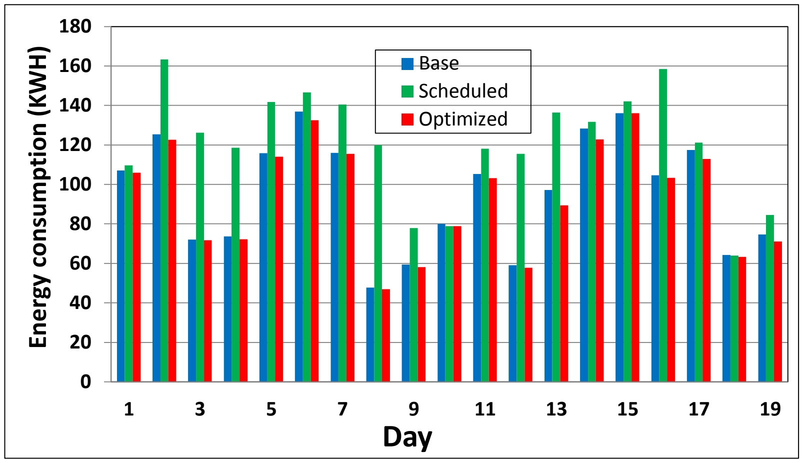
Integrating MATLAB and DOE2 advantages

Current integrated tool can be easily used to:

- Apply the NV optimization to any building model available in DOE2
- Apply any stochastic optimization method developed in MATLAB
- Optimize other parameters or other objective functions



NV energy savings



Max total energy savings:
8 %

Max cooling energy savings:
23 %

Concordia University

Conclusion

Limitation of existing work

- **Current hour optimization**
- **Single objective function**
- **Limited systems optimization**
- **One zone optimization**

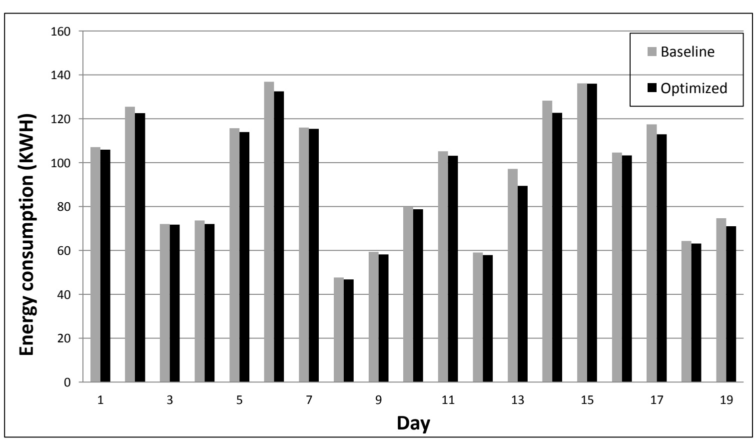
Integrated optimization

- Dynamic optimization by prediction of outdoor condition and inside loads
- Multi objective optimization for indoor comfort and energy cost
- Integrated optimization for whole building
  - All zones
  - All systems

Developing a simulation tools integrated with optimization method

Concordia University

NV energy savings



Max total energy savings:
8 %

Max cooling energy savings:
23 %

Wednesday 25 September 2013

11:15-12:45: Plenary session (part 2)

Chairpersons: Max Sherman, Yun Gyu Lee

- **High performance insulation materials** Karim Ghazi Wakili, Senior scientist, EMPA, Switzerland
- **Latent heat storage – The technology for rational energy use in buildings** Branislav Todorovic, Professor, University Belgrade, Serbia
- **Where are we today with ventilation and infiltration in buildings?** Peter Wouters, Manager of INIVE EEIG

EMPA
Materials Science & Technology

High Performance Insulation Materials

K. Ghazi Wakili

Laboratory for Building Science and Technology
Empa, Swiss Federal Laboratories for Materials Science and Technology

34th AIVC Conference 25-26 September 2013 Athens, GREECE

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Board of the ETH Domain

Eawag | Empa | EPFL | ETHZ | PSI | WSL

High Performance Insulation Materials

Materials Science & Technology

- Why high performance insulation materials:
- Energy consumption for heating and cooling is still >40% of the total energy consumption in our societies
- Retrofit of the existing building stock is the only efficient way to reduce energy consumption substantially
- Usable room becomes very expensive in steadily growing cities, i.e. slim constructions will be more beneficial
- Embodied energy including transportation has to be minimized

High Performance Insulation Materials

Materials Science & Technology

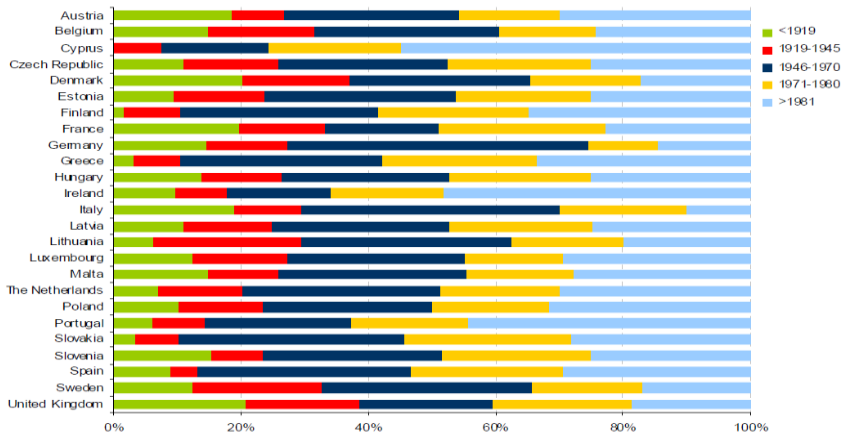


Figure 3.4 **Age distribution of the housing stock**
Source: [Boverket & MMR 2005]

High Performance Insulation Materials

EMPA Materials Science & Technology

- Products on the market and Empa's involvement:
- Vacuum Insulation Panel (VIP)
- Aerogel Containing Render (developed at Empa)
- Aerogel Containing Mats

High Performance Insulation Materials

EMPA Materials Science & Technology

- Vacuum Insulation Panel
  Reducing the thermal conductivity by evacuating the core material

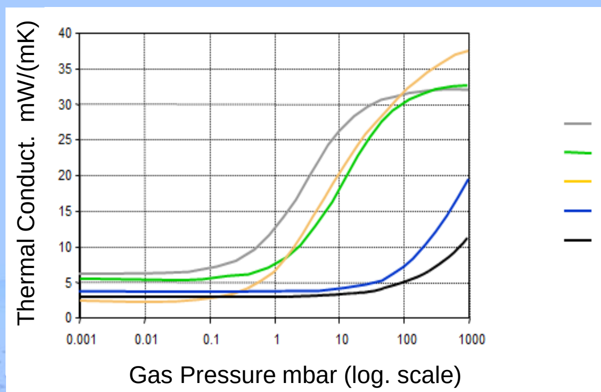


- Components: core material + air and moisture tight envelope
- Service life expectation for building applications 30 -50 years depending on the built-in conditions
- Porextherm, Vac-q-tec, Variotec, etc

High Performance Insulation Materials

EMPA Materials Science & Technology

- Vacuum Insulation Panel (core Material)



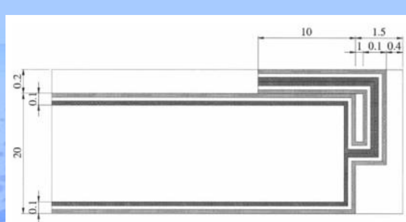
Extruded Polystyrene XPS
Polyurethane foam
Glass wool
Fumed Silica
Aerogel SiO_2

Measured by ZAE Bayern

High Performance Insulation Materials

EMPA Materials Science & Technology

- Vacuum Insulation Panel (envelope)
- Envelope contains aluminium layers
- λ_{COP} = 0.003 – 0.005 W/mK
- λ_{eff} = 0.007 -0.009 W/mK



J	PET	Polyethylene terephtalate	12 µm
I	AL	Aluminium	100 nm = 0.1 µm
H	PU	Polyurethane	2 µm
G	PET	Polyethylene terephtalate	12 µm
F	AL	Aluminium	100 nm = 0.1 µm
E	PU	Polyurethane	2 µm
D	PET	Polyethylene terephtalate	12 µm
C	AL	Aluminium	100 nm = 0.1 µm
B	PU	Polyurethane	2 µm
A	LDPE	Low Density Polyethylene	50 µm

High Performance Insulation Materials

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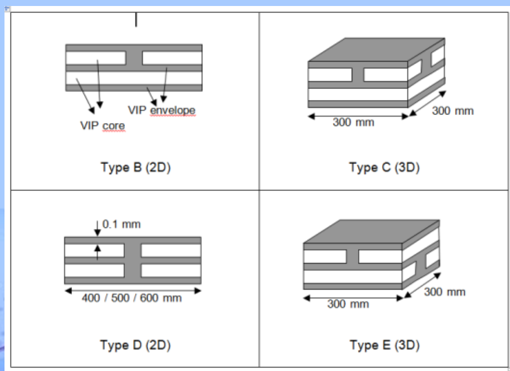
- Vacuum Insulation Panel (edge effect)
- Double layer versus single layer with doubled thickness



According configuration of samples for measurements
In the guarded hot plate
To get the corresponding
Ψ values

High Performance Insulation Materials

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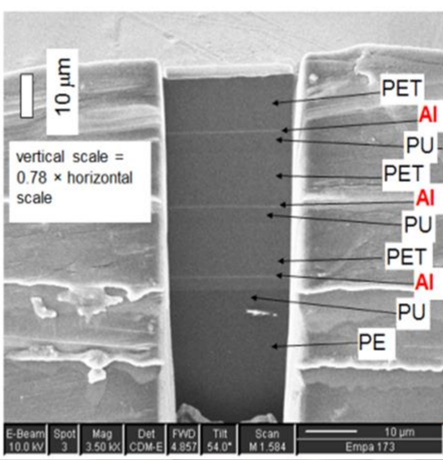
- Vacuum Insulation Panel (envelope)



- PET a relatively hard plastic with superior flat surface, an excellent substrate for the
- metallic barrier layer (Al).
- polyurethane (PU) is the glue between films
- Polyethylene (PE) is the sealable layer, lowest melting temperature

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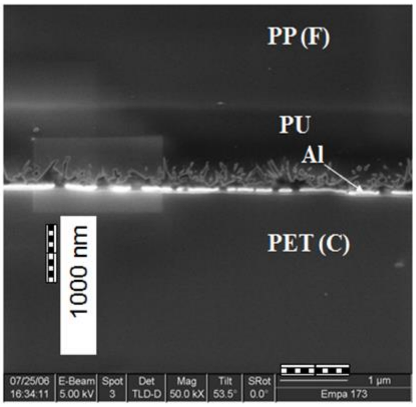
High Performance Insulation Materials

EMPA Materials Science & Technology

- Vacuum Insulation Panel (envelope, deterioration)



- Barrier layer with defects (corrosion?)

Extremely aged at 65°C, 75%r.h. for 1.9 years

aging continued long after critical pressure was reached in the panel.

S. Brunner et al., Surface & Coatings Technology 202 (2008) 6054

High Performance Insulation Materials

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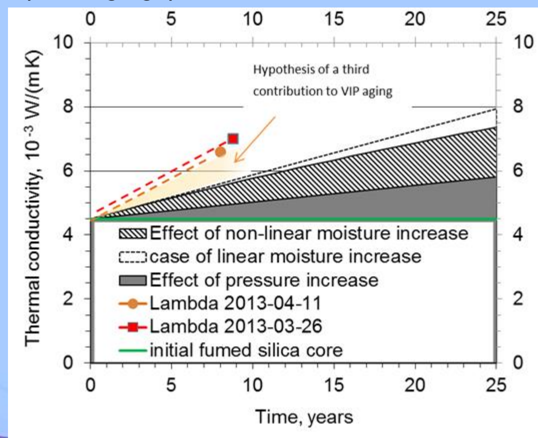
- Vacuum Insulation Panel (case study)
- Roof insulation (monitoring since 8 years and continuing)
- Reopening of a test area on the investigated flat roof

High Performance Insulation Materials

EMPA Materials Science & Technology

- Vacuum Insulation Panel (core aging?)
- Up to now: deterioration of VIP due to dry gas and moisture permeation through its envelope



- Different effects leading to an increase in the conductivity of the investigated VIP's Model and measured values in comparison

High Performance Insulation Materials

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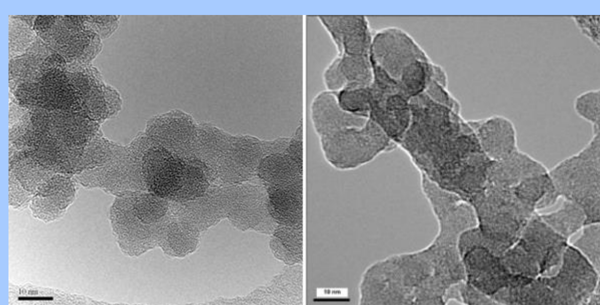
- Vacuum Insulation Panel (core aging?)
- TEM pictures of a fresh (left) and an aged (right) pyrogenic silica chain



courtesy of B. Morel
PhD Thesis, Rabelais University, France, 2008.

- A main topic of the upcoming IEA Annex 65 on Superinsulations

High Performance Insulation Materials

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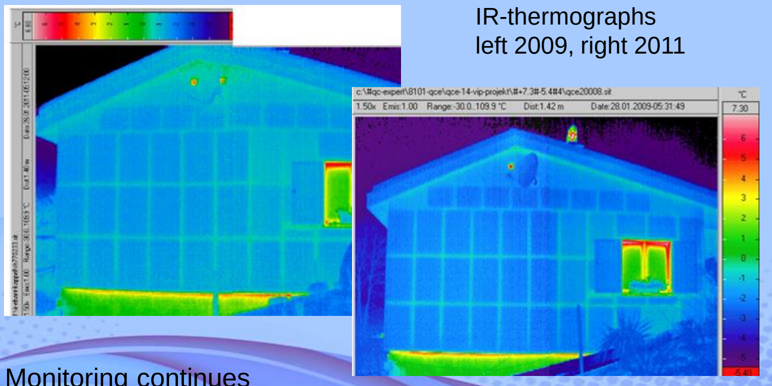
- Vacuum Insulation Panel (case study)
- Retrofitted façade in Ebnat Kappel, CH

IR-thermographs
left 2009, right 2011

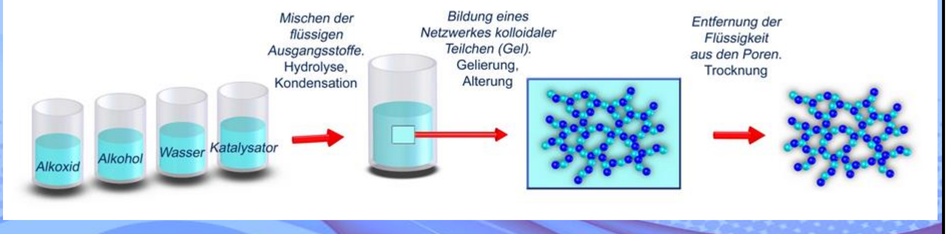


- Monitoring continues

High Performance Insulation Materials

EMPA Materials Science & Technology

- Aerogel
- Highly porous material (beyond 90%)
  made by a sol-gel process followed by a drying process
- Non organic aerogels: SiO_2, Al_2O_3, ZrO_2, TiO_2, V_2O_5
- Organic aerogels (Gelatine, Formaldehyde, ..)
- Carbon aerogels (black, opaque)



High Performance Insulation Materials

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- Aerogel containing render

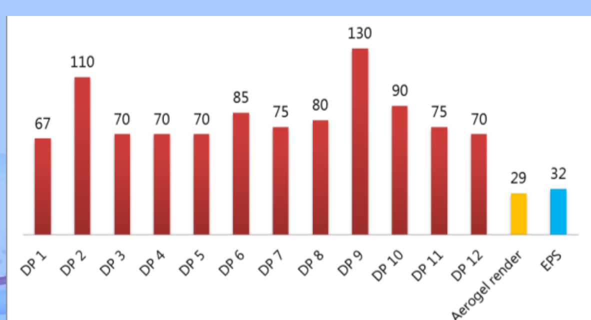
- hydraulic lime (hardens also in H_2O)
- hydrated lime (hardens by absorbing CO_2)
- white cement
- Aerogel (SiO_2)
- mineral aggregates (ex. Perlite)
- water retention agent
- air-entraining agent
- hydrophobizing agent

High Performance Insulation Materials

EMPA Materials Science & Technology

- Aerogel containing render

- Thermal conductivity determined at 20°C and 50% r.H.
- $\lambda \approx 0.029$ W/(mK) equivalent to k = 0.0167 BTU hr-1 ft-1 °F-1
- Compared to other insulation renderings at 20°C and 50% r.H.



High Performance Insulation Materials

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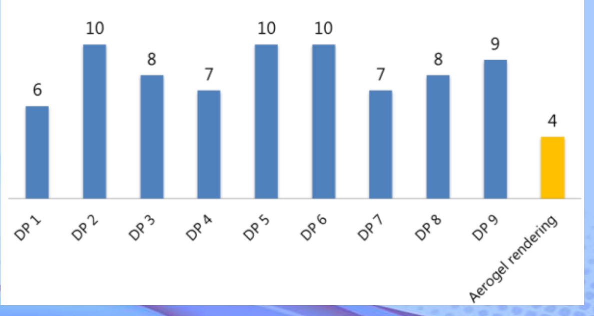
- Aerogel containing render

- Low µ-value = low resistance to water vapor transmission
- Compared to other insulation renderings at 20°C



High Performance Insulation Materials

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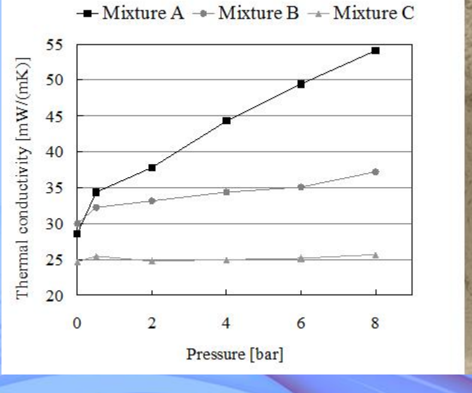
- Aerogel containing render

- Thermal conductivity versus pressure in the plastering machine for different mixtures



High Performance Insulation Materials

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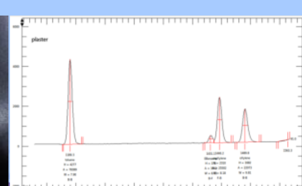
- Aerogel containing render (case study)
- Multi-family house in Sissach nearby Basel (14th century)
- External application:
  5 cm of Fixit 222 on solid masonry wall (60 cm) without insulation
- Monitored for 1.5 years (continuing)

High Performance Insulation Materials

EMPA Materials Science & Technology

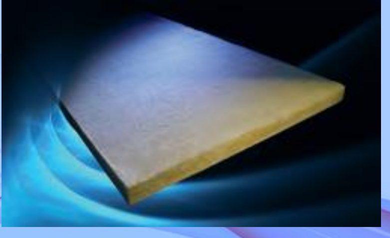
- Aerogel containing render (new case studies)
- University of Vienna (Austrian Science Foundation)
  Flexible shaped aerogel containing render for external application on historical buildings
  (Sep. 2013-2016)
- University of Harvard (monitoring)
  Test façade of 250 years old brickwork wall
  (2014-2016)
- VOC analysis for internal application
  no enhancement



High Performance Insulation Materials

EMPA Materials Science & Technology

- Aerogel containing mats (Case study: 130 Years Old Building)
- Air in the fiber insulation material is replaced by aerogel (SiO2) and the fibers are the skeleton of the very brittle aerogel
- Thermal conductivity : λ = 0.014 - 0.019 W/mK
- Ex. Aerowolle (Rockwool) Spaceloft (Aspen Aerogels)



High Performance Insulation Materials

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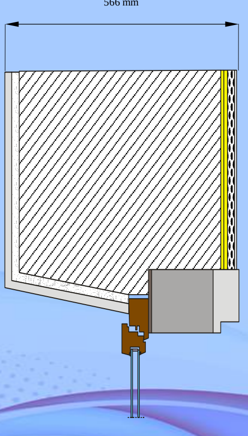
- Aerogel containing mats (Case study: 130 Years Old Building)



Wall assembly:
- White plaster
- Plasterboard
- Insulation 20 mm
- Dry stonewall
- **Aerogel mat 2 x 10 mm**
- Plaster base
- Insulation render 20 mm
- External finish

High Performance Insulation Materials

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- Aerogel containing mats (Case study: 130 Years Old Building)

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High Performance Insulation Materials

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- Aerogel containing mats (Case study: 130 Years Old Building)

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High Performance Insulation Materials

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- Aerogel containing mats (Case study: 130 Years Old Building)
- The determined U-value of the retrofitted wall by the different methods

Determination method	U-value [W/(m^2·K)]
1-dimensional **(before retrofit)**	1.2
1- dimensional (retrofitted)	0.431
Average method (retrofitted)	0.382
Average method & storage effects (retrofitted)	0.392
Dynamic method 12 days (retrofitted)	0.413
Dynamic method 79 days (retrofitted)	0.421

High Performance Insulation Materials

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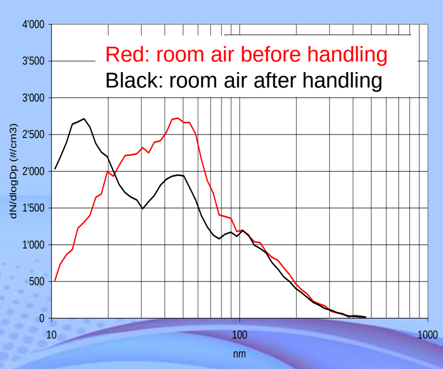
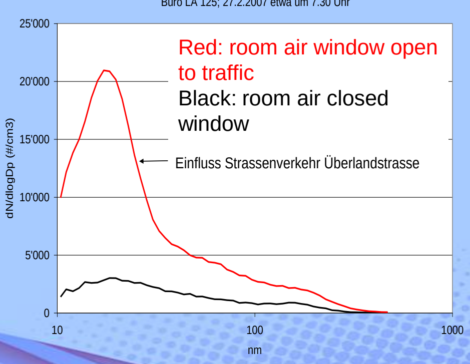
- Aerogel containing mats
- Particle size analysis of the dust due to handling





High Performance Insulation Materials

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- Aknowlegments:
  - Samuel Brunner
  - Thomas Stahl
  - Matthias Koebel
  - Roger Vonbank
  - Bruno Binder
  - Stefan Reimann

High Performance Insulation Materials

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Thank you for your kind attention

LATENT HEAT STORAGE-THE TECHNOLOGY FOR RATIONAL ENERGY USE IN BUILDINGS

Branislav Todorovic, Ph.D.

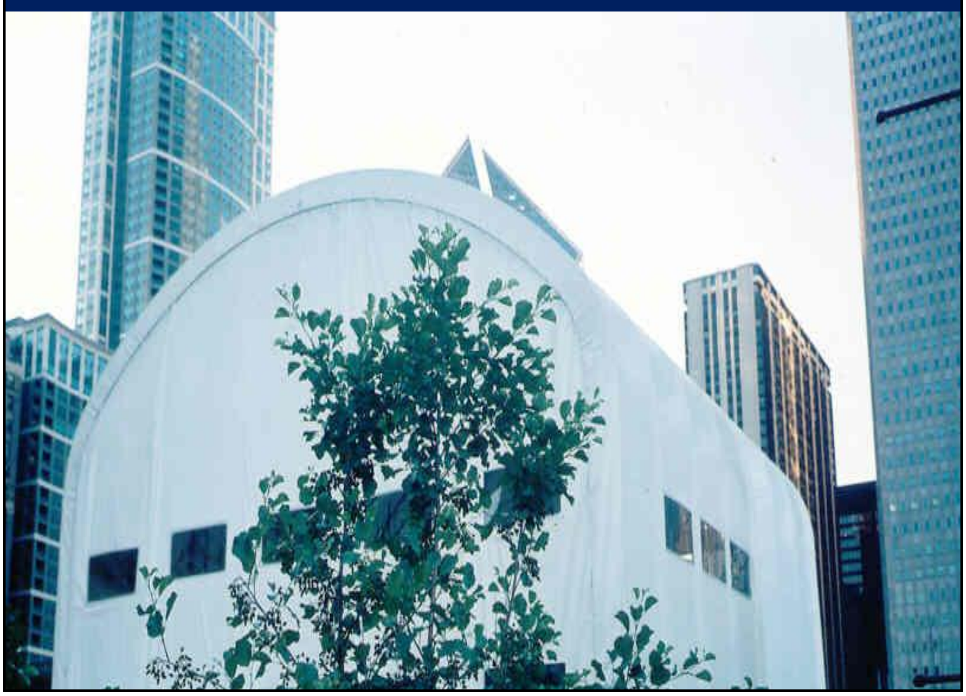
professor of University Belgrade, Dr. HC of University Timisoara, v. professor of South East university in China, former president of REHVA, ASHRAE fellow, president of Serbian HVACR Society

Athens, 2013

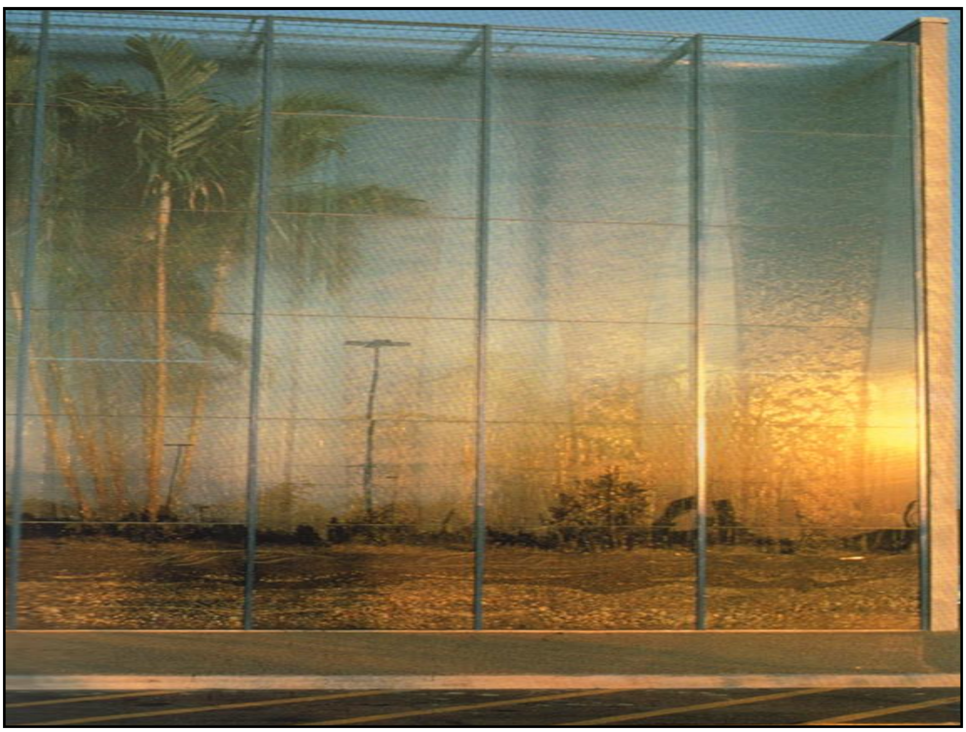
COULD NEAR ZERO COOLING LOAD BUILDING BE ACHIEVED ?

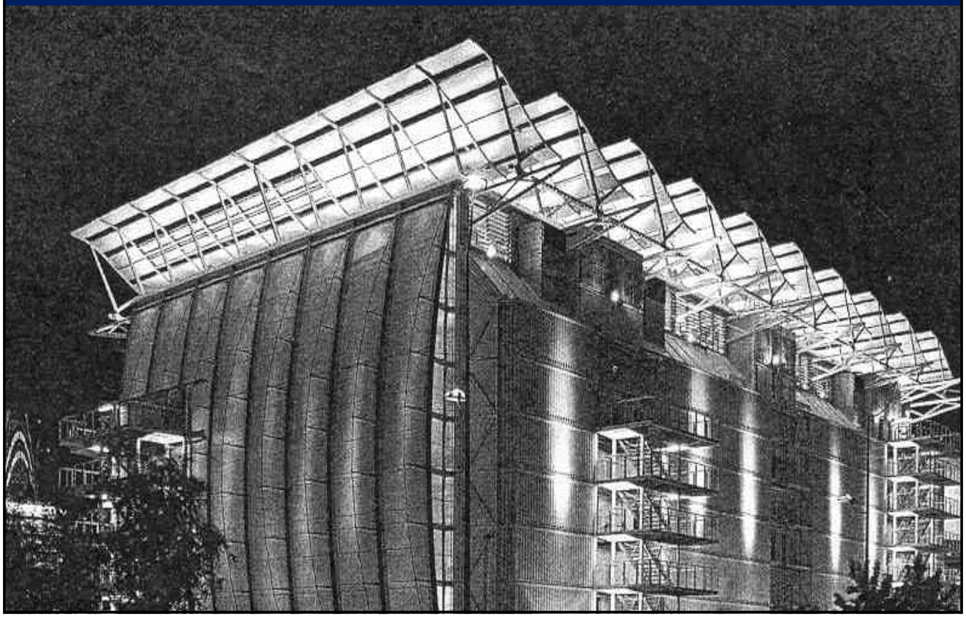
ENERGY NEEDS DURING SUMMER ARE GROWING

Summer Air Conditioning is critical.
Would it be possible to have a building which has excellent protection of heat gains from outside heat influences: from outside temperature and solar radiation, and not to have needs to neglect them by cooling? We have now zero energy houses, near zero… Could we go in such direction concerning cooling load? Of course when outside heat sources are concern.
Inside heat sources could not be zero (occupants, equipment, lighting, and also outside air for breathing.



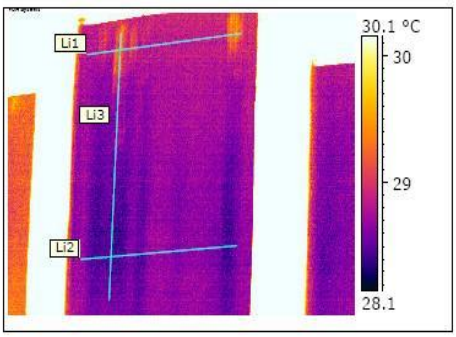
MINIMIZING ENERGY FOR COOLING IN SUMMER AIR CONDITIONING

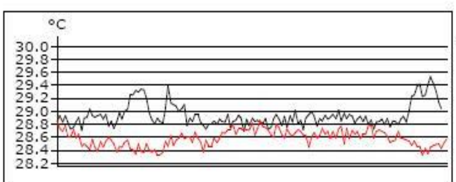




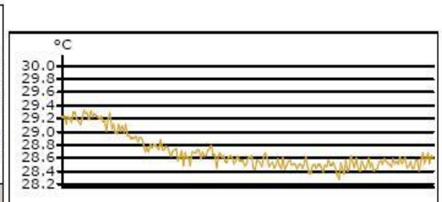
Architect Mr. GRINDSHAW

Picture 3. **Captured at: Middle glass, different angle of capturing**



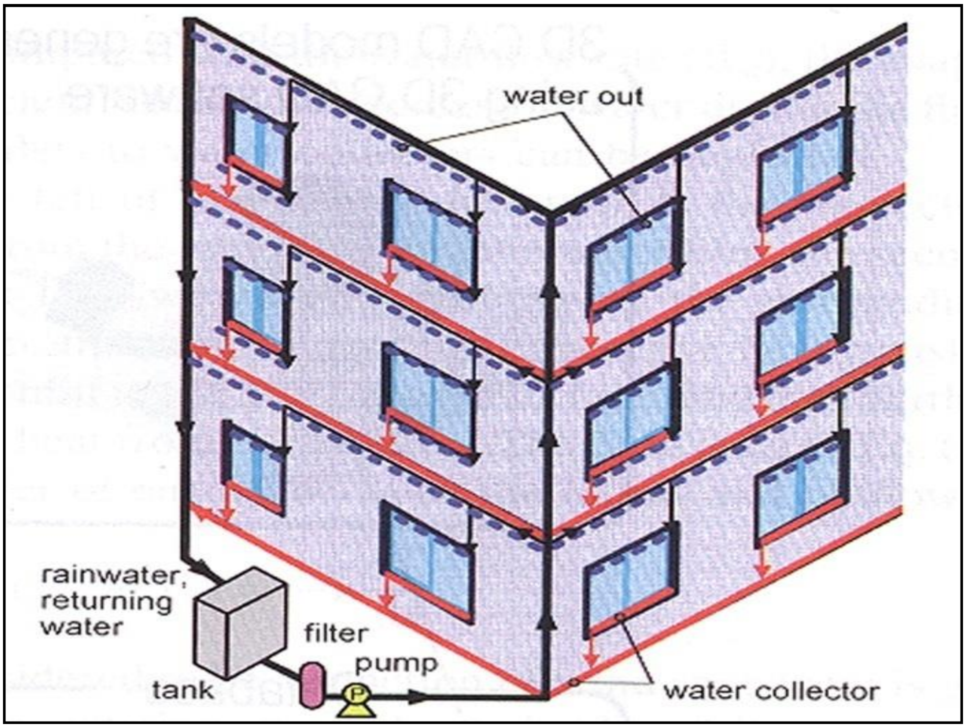


Label	Cursor	Min	Max	Avg
☑ —Li1	-	28.7	29.5	28.9
☑ —Li2	-	28.3	28.9	28.6



Label	Cursor	Min	Max
☑ —Li3	-	28.3	29.3

- Heating and heat storage of buildings envelopes by sunlight have been found to cause urban heat islands formation. Building envelopes are of materials which have high absorption and thermal capacity and absorbed solar radiation cause during night warmer envelope's surfaces then surrounding air. Reducing the heat absorbed by these surfaces or lowering the surface temperature mitigate influence of heat islands. But how to have thin water layer specially on vertical walls?
- in Japan is made possible to maintain a thin film od water using super hydropfilic coating.



Coating technology

- The coating technology has made possible to maintain a thin film of water on external surfaces coated with Titanium dioxide TiO_2
- It is controlling wetness, is antifogging, self-cleaning
- Reference: Jiang He and Akira Hoyano

Anti fogging
Self cleaning
Photo-catalytic coupled with UV lights can oxidize pollutants into nontoxic material killing some bacteria, viruses
Air purification effect, deodorizing …
It is hydro-filic oil soil,
Disinfection stronger then Ozone

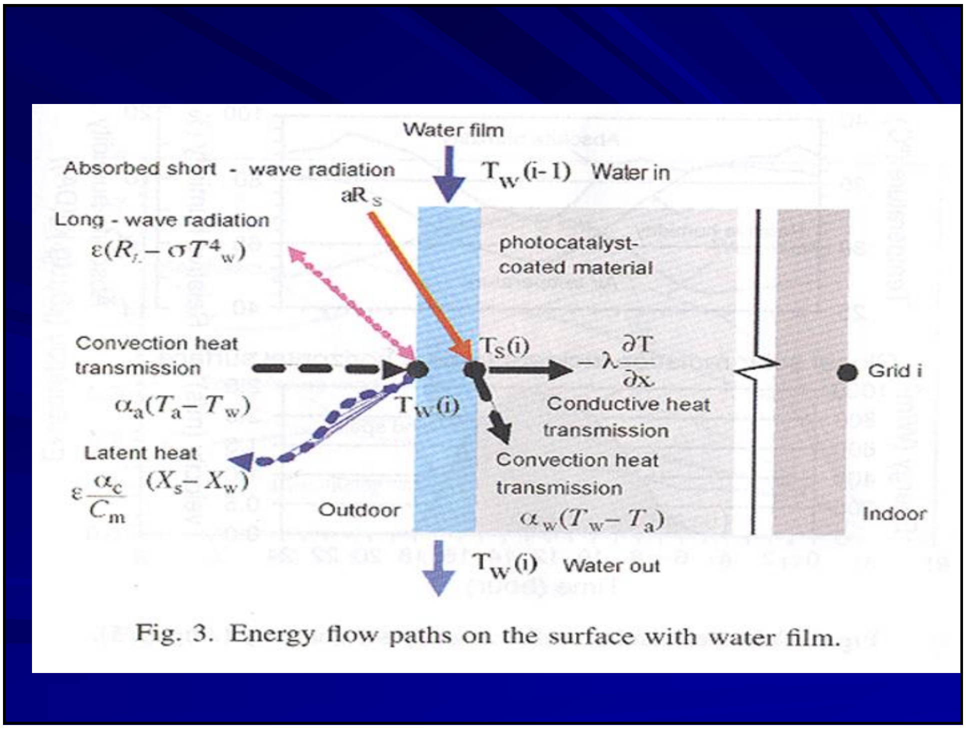
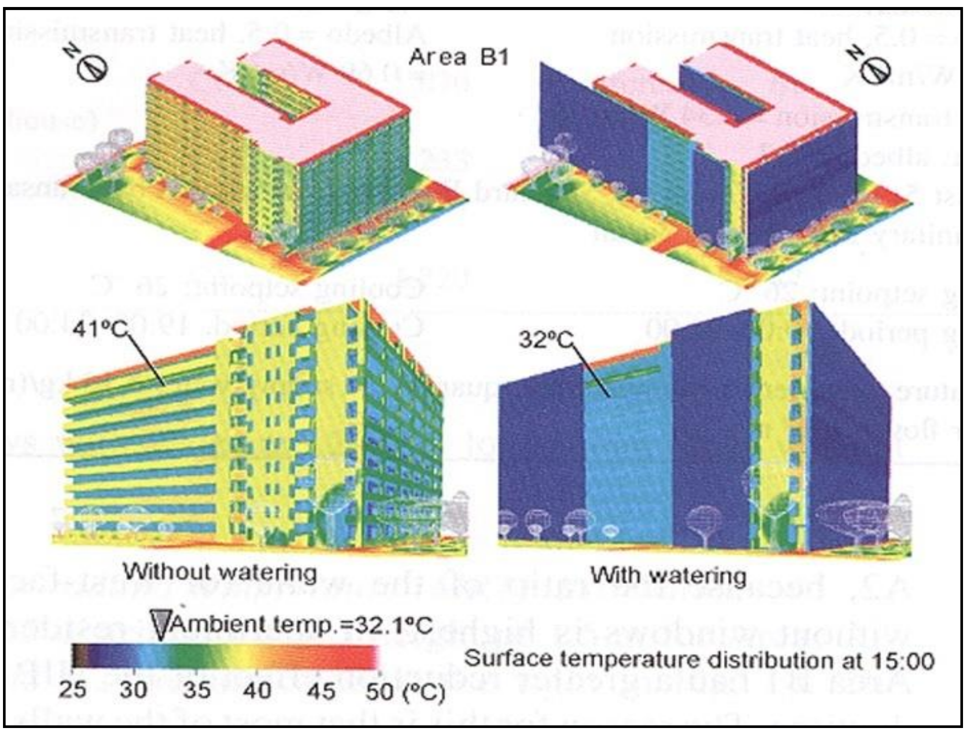


Fig. 3. Energy flow paths on the surface with water film.



THERMAL ENERGY STORAGE

“ Storing *High* or *Low* temperature energy for later use in order to bridge the time gap between energy availability and energy use “

PCM APPLICATIONS

1)Passive Cooling

2)Solar Application

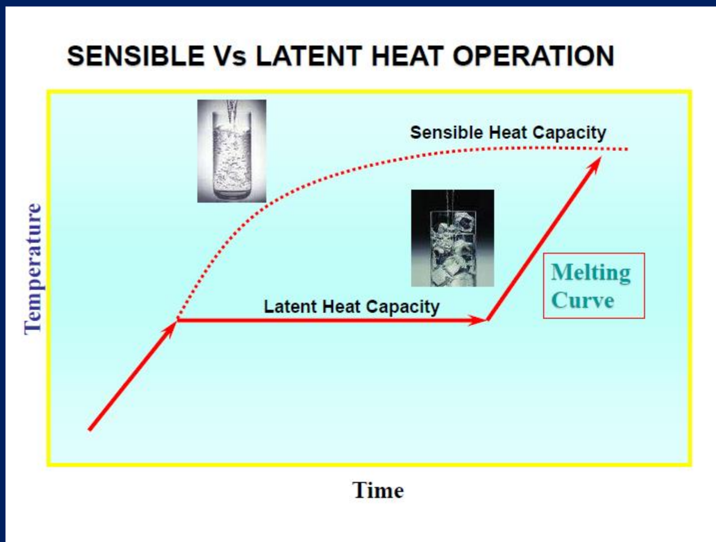
3)Air Conditioning

4)Heat Pump Applications

5)Special Applications

PCM

- A phase-change material (PCM) is a substance with a high heat of changing the phase: which when melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa; thus, PCMs are classified as latent heat storage (LHS) materials



ENCAPSULATION

- In this range of PCM materials, the latent heat material is bound within a secondary supporting structure. Encapsulating mechanism ensures that the phase change material, when in the liquid form, does not leak out of the supporting structure. The result is that the bound phase change material is always a "dry", solid product and liquid handling is eliminated.

  Another major advantage is that volume variation due to temperature excursions well above or below the working temperature is largely eliminated, thus ensuring that large quantities of thermal energy can be stored and released at a relatively constant temperature with minimum, or without any, volumetric changes.

ENCAPSULATION

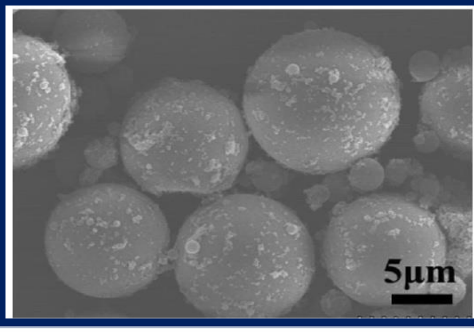
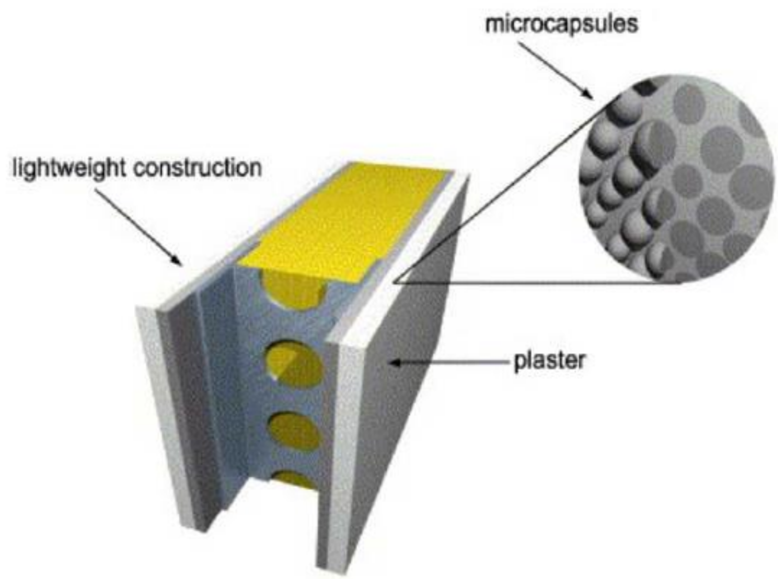


Fig. 4. Photograph of the floor panel

Figure 9
Click here to download high resolution image



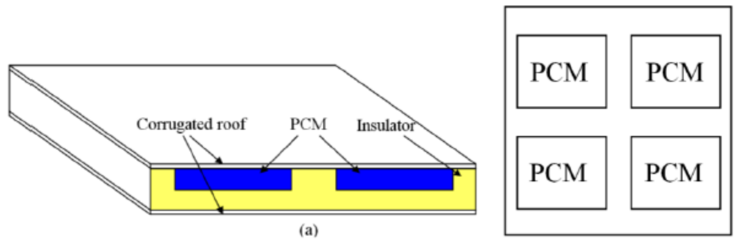
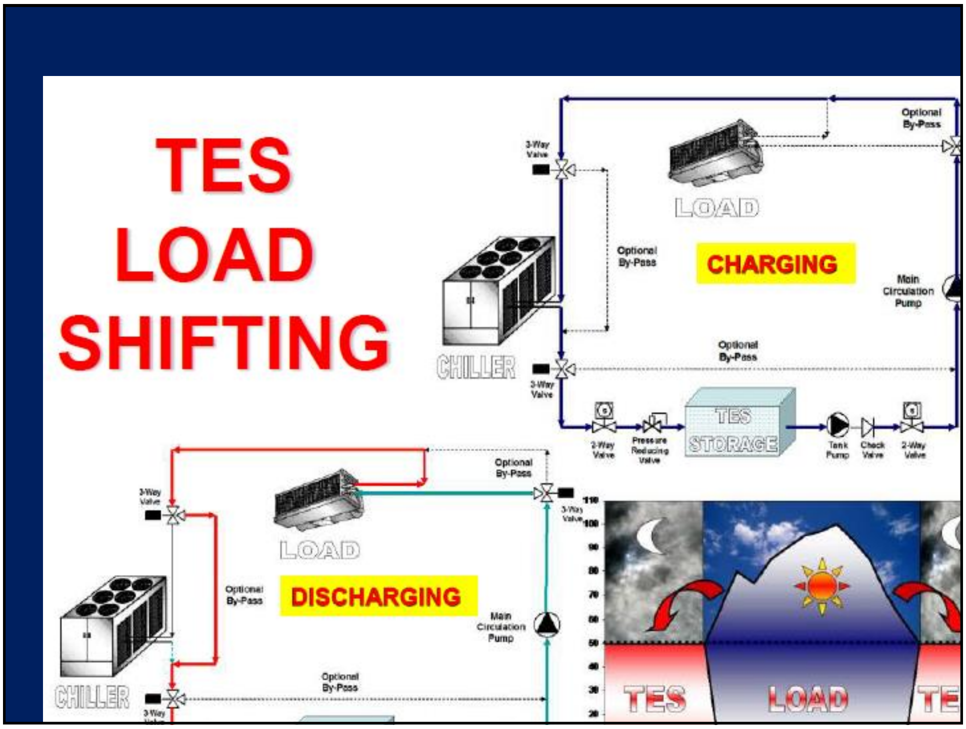


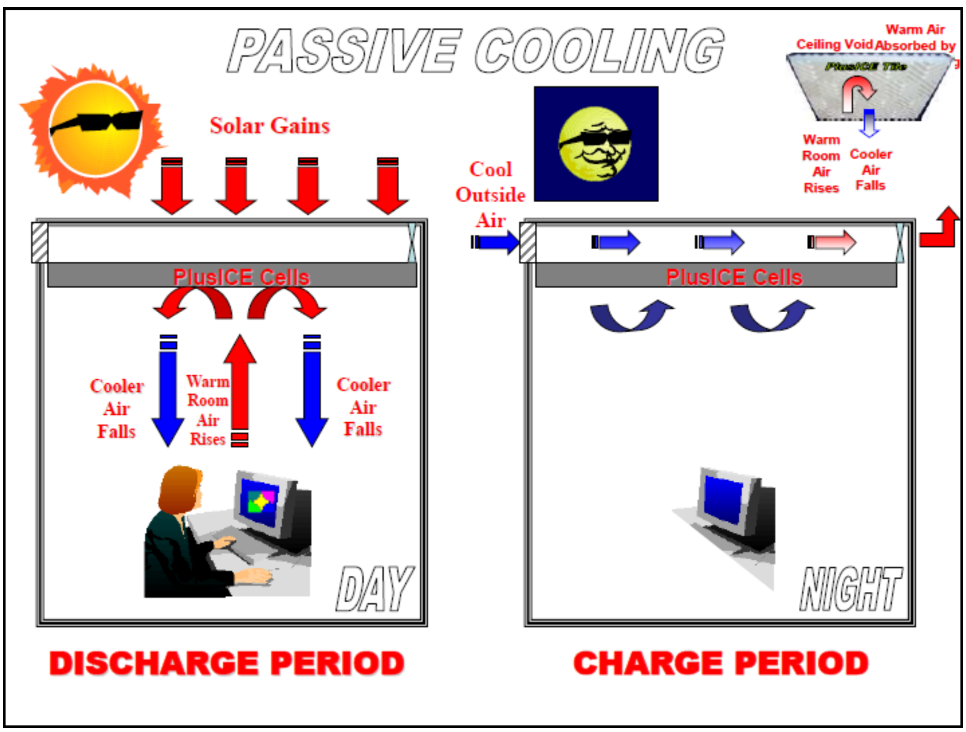
Fig. 2. Novel design structure of the corrugated roofing a) 3D view; b) Top view

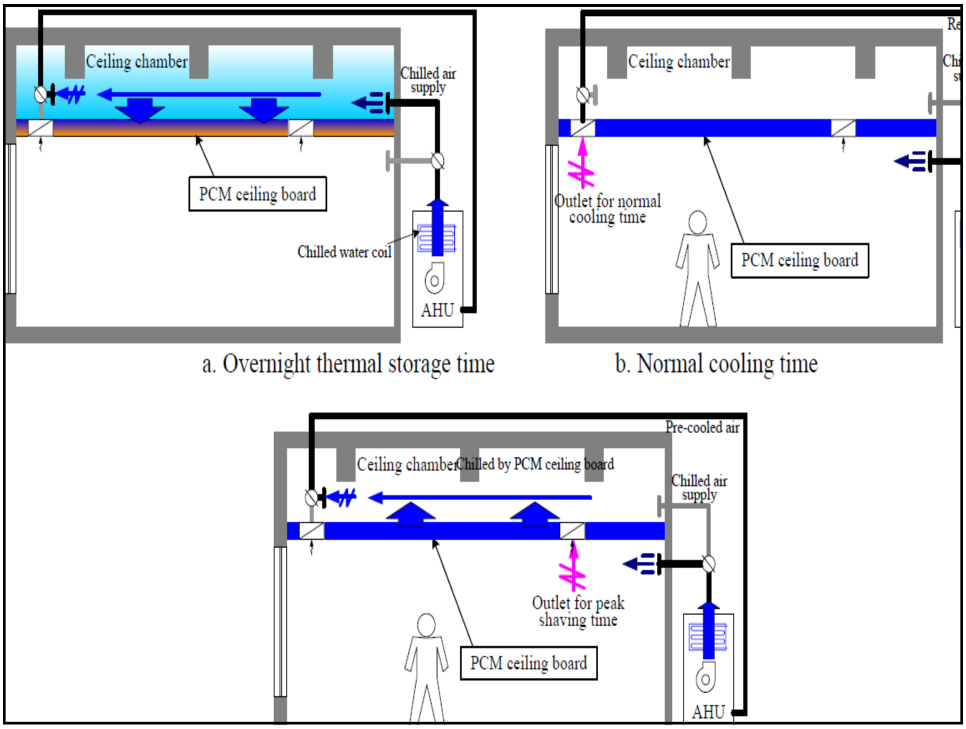
Simulation results of variation of energy saving ratio with varied external wind speed

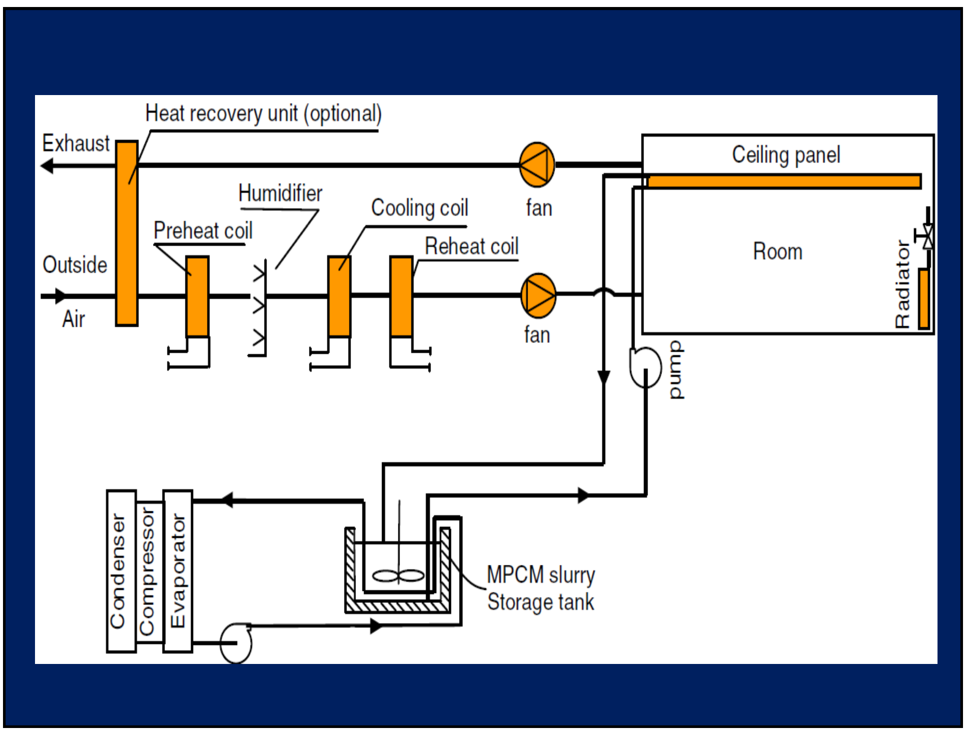
Wind speed (m/s)	Convective heat transfer coefficient h_{ex} (W/m^2K)	δ (%)	PCM thickness (mm)	$\xi_{\#2}$(%)	$\xi_{\#3}$(%)
0*	6.73*	48*	7*	43.1*	52.7*
1	8.05	48	7	57.19	68.64
2	12.25	48	7	61.24	72.90
3	23.81	48	7	67.60	73.59
4	28.34	48	7	71.23	77.88
5	32.43	48	7	75.10	80.10

* *experimental conditions/results*

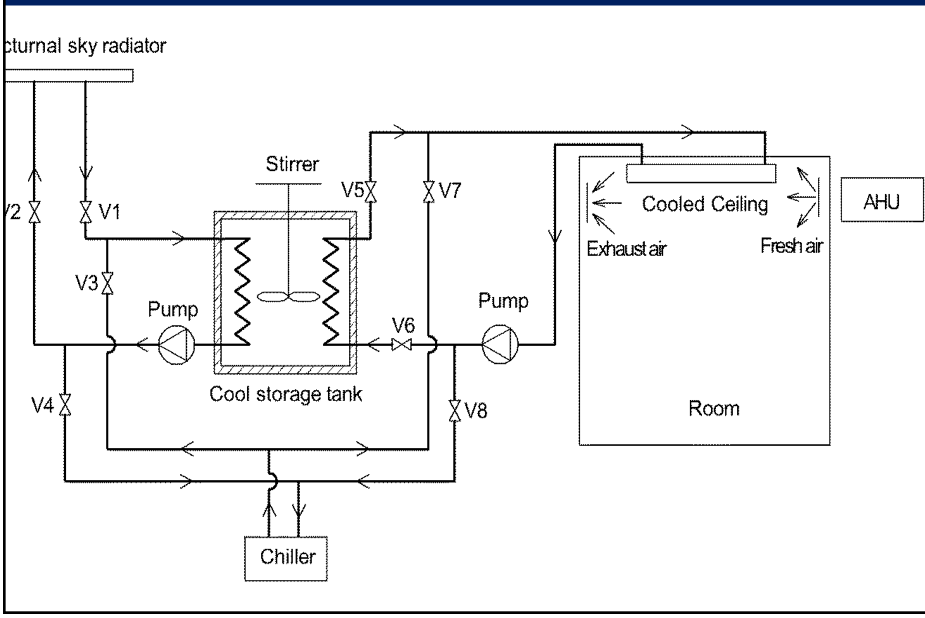

TES
LOAD
SHIFTING
LOAD
CHARGING
CHILLER
TES STORAGE
LOAD
DISCHARGING
CHILLER
TES
LOAD


PASSIVE COOLING
Solar Gains
Cool Outside Air
Warm Air Absorbed by
Ceiling Void
Warm Room Air Rises
Cooler Air Falls
PlusICE Cells
Cooler Air Falls
Warm Room Air Rises
Cooler Air Falls
DAY
PlusICE Cells
NIGHT
DISCHARGE PERIOD
CHARGE PERIOD


Ceiling chamber
Chilled air supply
PCM ceiling board
Chilled water coil
AHU
a. Overnight thermal storage time
Ceiling chamber
Outlet for normal cooling time
PCM ceiling board
b. Normal cooling time
Pre-cooled air
Ceiling chamber
Chilled by PCM ceiling board
Chilled air supply
Outlet for peak shaving time
PCM ceiling board
AHU


Heat recovery unit (optional)
Exhaust
Ceiling panel
fan
Humidifier
Cooling coil
Preheat coil
Reheat coil
Room
Outside
Radiator
Air
fan
pump
Condenser
Compressor
Evaporator
MPCM slurry
Storage tank

NOCTURNAL COOLING

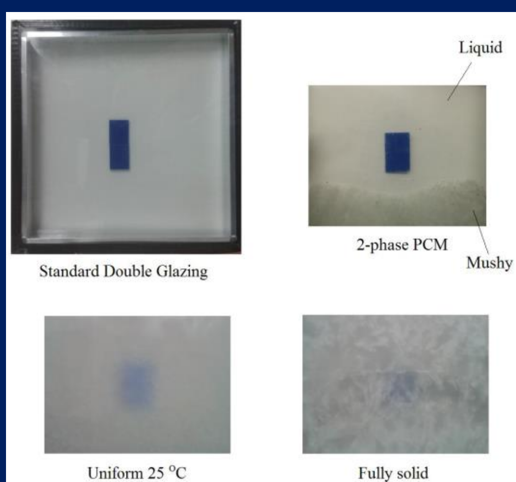


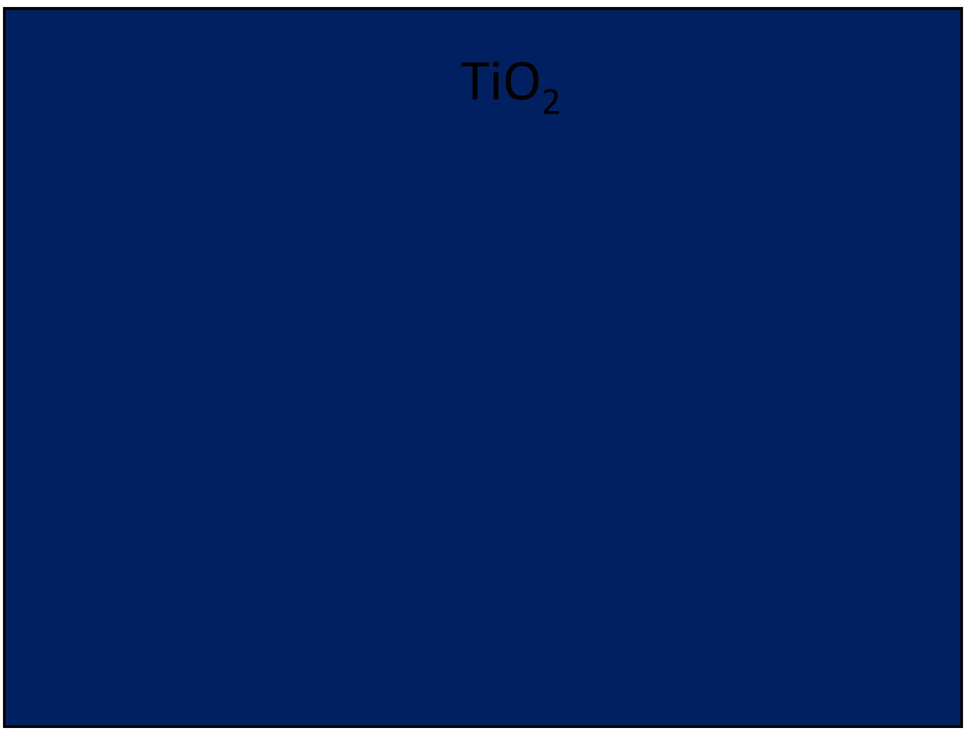
Windows are the weakest point of almost any building for thermal control. The PCM material stores heat by melting, and then radiates it back into the space at night, as the material cools and re-solidifies. As a solid, the PCM still transmits about 25% of the visible light, and more than 40% is transmitted when the PCM is in its liquid state, so day lighting is not compromised.

Given that they are so high-tech, such windows are very expensive — they weigh in at $600-900 per square meter. However the payback period on these windows is expected to be 5 to 10 years. With all the layers involved, the thickness of the windows is another obstacle, but not one that cannot be overcome to produce some attractive and energy efficient designs.

WINDOWS

- (PCM) between two of the glass panes in
  At lower temperatures, the PCM is a translucent solid. But, as it heats, the PCM melts and becomes transparent. This lets the window itself absorb heat from solar energy during the day, and then releases the energy again later on, as the material cools again.
- The combination of good insulating windows along with heat storage makes these windows very useful for passively designed buildings. PCMs are excellent heat storage materials, and the Glass windows are able to store as much heat as a 25cm thick concrete wall. Even in its solid, translucent state, the Glass windows allow more than 25% of the exterior light through, so that day lighting is not entirely lost. The windows also incorporate a diffuser that reflects high angle light from the sun in summertime, while allowing low angle light in the winter to pass through more directly.




TiO_2

EUTECTIC MATERIAL
PHASE CHANGE MATERIAL (PCM)

Mixture of two or more chemicals (inorganic salts) having a freezing / melting temperature point which is higher or lower than those of water 0 C (32F).

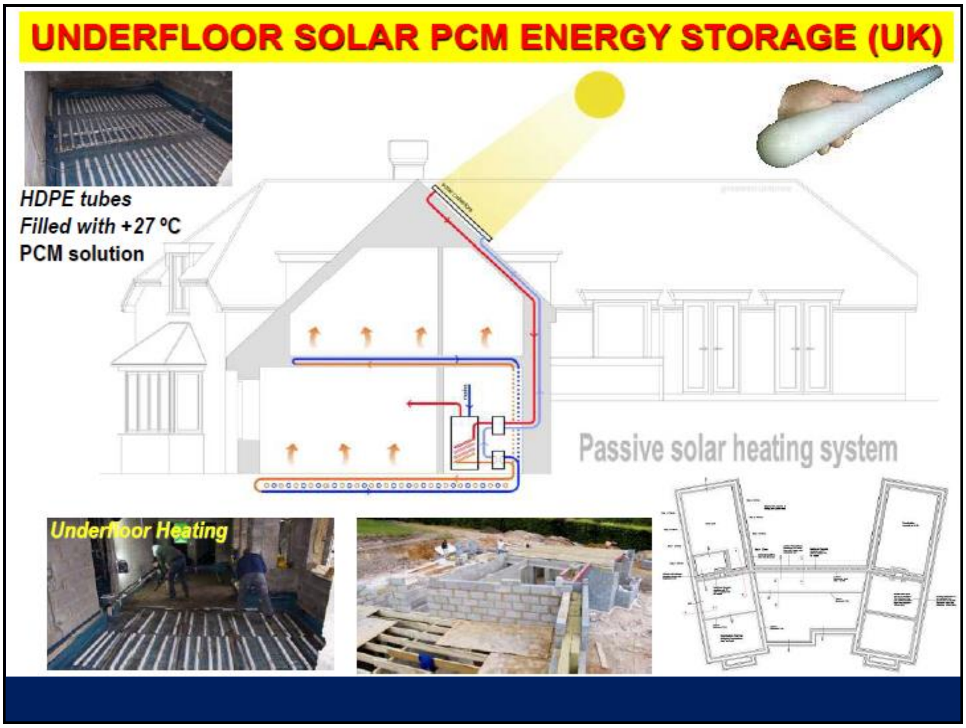
ORGANIC COMPOUNDS

- Waxes (HC Cuts)
- Vegetable Oil
- Sugar
- Fatty Acids
- Alcohol
- Polyol (Solid-Solid)

SALT-BASED SOLUTIONS

- Glauber's Salt
- Organic Salts
(Acetate / Formate based)
- Inorganic Salts
(Chloride/Nitrate based)
- Molten Salts

ORGANIC PCM VARIATIONS



UNDERFLOOR SOLAR PCM ENERGY STORAGE (UK)
HDPE tubes
Filled with +27 ºC
PCM solution
Passive solar heating system
Underfloor Heating

Where are we today with ventilation and infiltration in buildings?

Peter Wouters
Manager INIVE EEIG
AIVC – TightVent - venticool

Structure of the presentation

ASHRAE

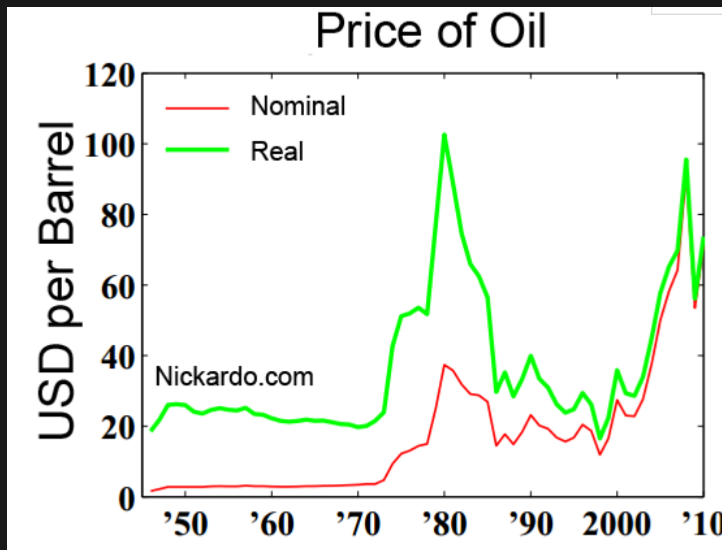
- ASHRAE was founded in 1894
  - Until 1954 it was known as the American Society of Heating and Ventilating Engineers (**ASHVE**)
- In 1954, it changed its name to the American Society of Heating and Air-Conditioning Engineers (**ASHAE**)

REHVA

- **Founded in 1963**, REHVA, The Federation of European Heating, Ventilation and Air Conditioning Associations represents **a network of more than 100 000 engineers from 26 European countries.**

40 years ago? (…1973…)

- Most countries: limited interest and almost no knowledge on ventilation, air infiltration and indoor air quality
- Few countries were ahead: SE, CAN, NL, …
- Start of IEA implementing agreement **ECBCS**: Energy conservation in Buildings and Community Systems



1973 1983 1993 2003 2013 2023 2033 2043 2053

Indoor Air conferences

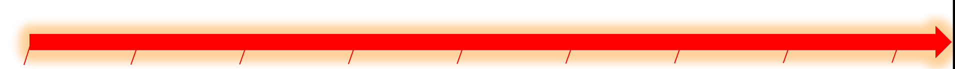
- **1978 Indoor Climate, Copenhagen, Denmark**
- 1981 Indoor Air Pollution, Health and Energy Conservation, Amherst
- 1984 Indoor Air '84, Stockholm, Sweden
- 1987 Indoor Air '87, Berlin, Germany
- 1990 Indoor Air '90, Toronto, Canada
- 1993 Indoor Air '93, Helsinki, Finland
- 1996 Indoor Air '96, Nagoya, Japan
- 1999 Indoor Air '99, Edinburgh, Scotland
- 2002 Indoor Air 2002, Monterey, California
- 2005 Indoor Air 2005, Beijing, China
- 2008 Indoor Air 2008, Copenhagen, Denmark
- 2011 Indoor Air 2011, Austin, Texas
- **2014 Indoor Air 2014, Hong Kong**

ISIAQ
INTERNATIONAL SOCIETY OF INDOOR AIR QUALITY AND CLIMATE

1973 1983 1993 2003 2013 2023 2033 2043 2053

30 years ago (1983)

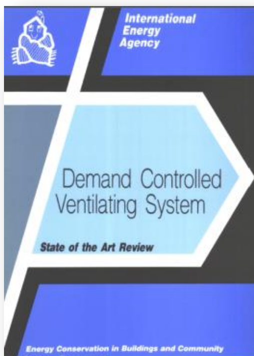
- ECBCS **AIC** (Air Infiltration Centre) operational
  → Annex 1 had indicated that many questions existed regarding air infiltration
- Policy in several countries: Built tight!
- Airtightness was research topic in some countries
- IEA annex 8 Occupants' behaviour
- IEA Annex 18 Demand Controlled Ventilation
- In research and in some countries growing interest for health and comfort

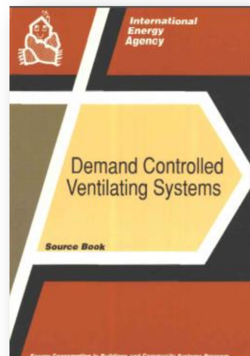


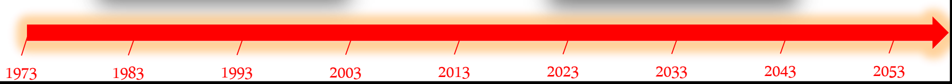
Annex 8

Annex 9

IEA EBC Annex 18
Demand Controlled Ventilation Systems
(1987-1992)







1986

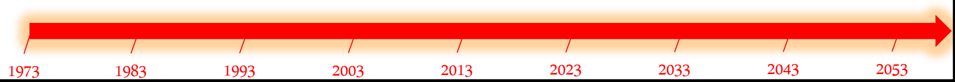
AIC became **AIVC**

The **'Air Infiltration and Ventilation Centre'**

Healthy buildings conferences

1988 Healthy Buildings '88, Stockholm, Sweden
1991 Healthy Buildings/IAQ'91, Washington, DC
1994 Healthy Buildings '94, Budapest, Hungary
1995 Healthy Buildings '95, Milan, Italy
1997 Healthy Buildings '97, Bethesda, Maryland
2000 Healthy Buildings 2000, Helsinki, Finland
2003 Healthy Buildings 2003, Singapore
2006 Healthy Buildings 2006, Lisbon, Portugal
2009 Healthy Buildings 2009, Syracuse, New York
2012 Healthy Buildings 2012, Brisbane, Australia

ISIAQ
INTERNATIONAL SOCIETY OF INDOOR AIR QUALITY AND CLIMATE



IBPSA
International Building Performance Simulation Association

- 1985: Seattle – USA
- 1989: Vancouver – Canada
- 1991: Nice – France
- …
- 2015: Hyderabad - India

ipcc INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

Environment

- **1988** The Intergovernmental Panel on Climate Change (IPCC) is formed by UNEP and the World Meteorological Organization (WMO).
- A conference held in Toronto recommends a set of political targets to reduce anthropogenic emissions of carbon dioxide.
  - The conference recommends that by 2005, industrialized countries should reduce their carbon dioxide emissions by 20 % compared to 1988 levels.

20 years ago (…1993…)

- European **Pascool** project

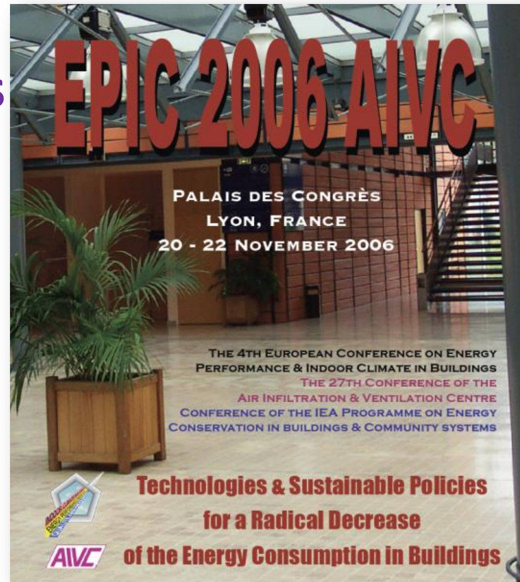
  … first time focus on summer comfort control…
- European project **NATVENT**

  … renewed attention for natural ventilation strategies…
- Annex 35 **Hybvent**

  … focus on hybrid ventilation
- **ISIAQ** created in 1992

ISIAQ
INTERNATIONAL SOCIETY OF INDOOR AIR QUALITY AND CLIMATE

EPIC conferences in Lyon (1994 – 2006)



Energy **P**erformance and **I**ndoor **C**limate

1973 1983 1993 2003 2013 2023 2033 2043 2053

Environmental concerns

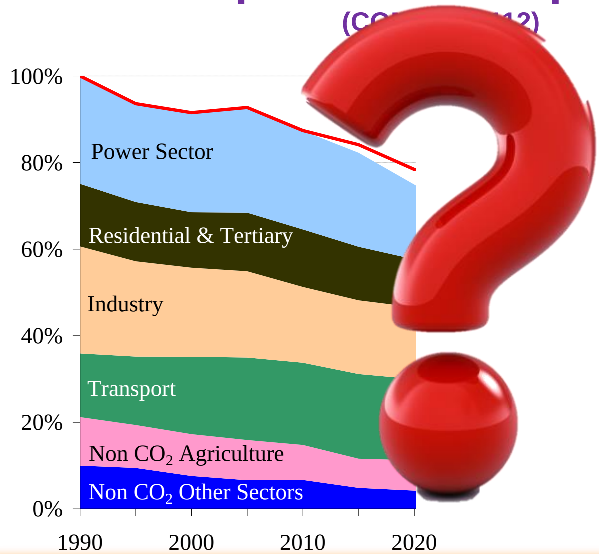
1997 Parties conclude the Kyoto Protocol in Kyoto Japan, in which they agree to the broad outlines of emissions targets.

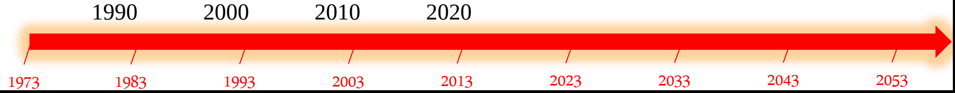
1973 1983 1993 2003 2013 2023 2033 2043 2053


2003
1973
1983
1993
2003
2013
2023
2033
2043
2053


Times
February 18th, 2009 - Late Edition
FACTS
FACTS
GLOBAL
WARMING
CLIMATE
CHANGE
Myth or reality.

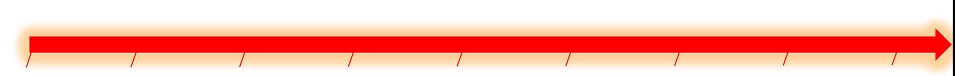
European Roadmap to 2050





During last 10 years? (2003 …)

- EPBD (European Energy Performance and Buildings Directive) (2003)
  - Also renewable energies directive and energy services directive…
- Much broader societal and political support for firm actions



Today (…2013…)

- **EPBD recast** (2010 – now under implementation)
  - Much more stringent – 'cost-optimal'
  - Towards nearly-zero energy buildings
- Millions of airtightness measurements
  - Towards systematic testing…
- Concerns about quality of systems and workmanship
- Systems: interaction of functions and technologies


Solutions
N
IN OVATION
1973
1983
1993
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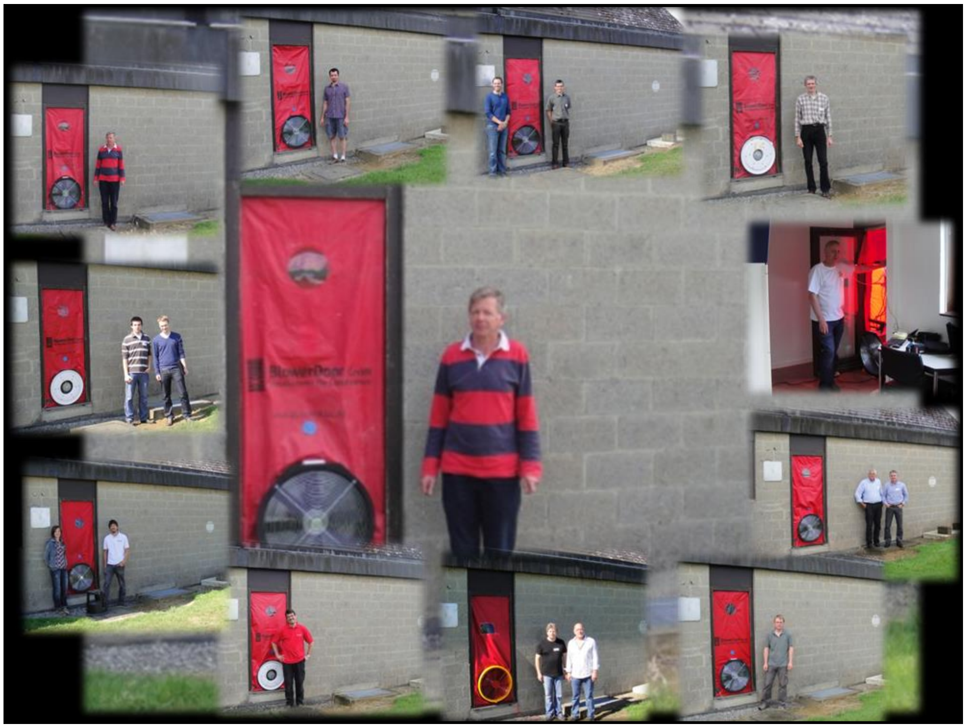
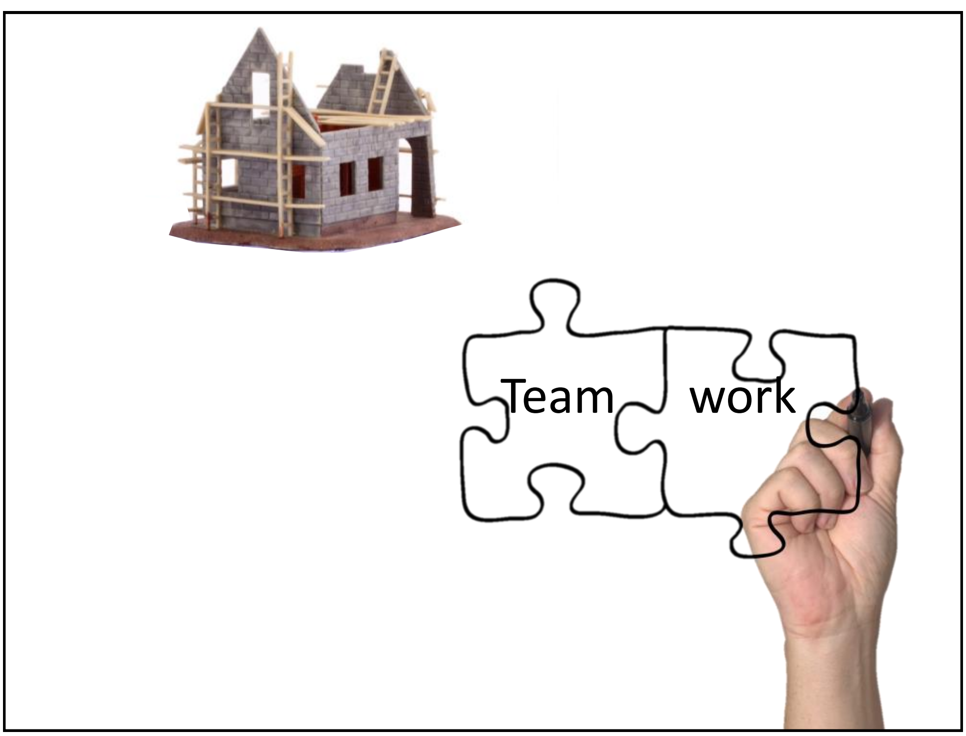
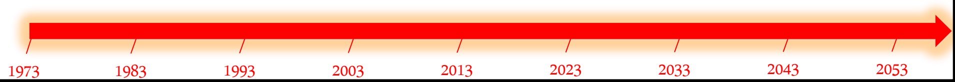
2053


Sustainable development!
1973
1983
1993
2003
2013
2023
2033
2043
2053

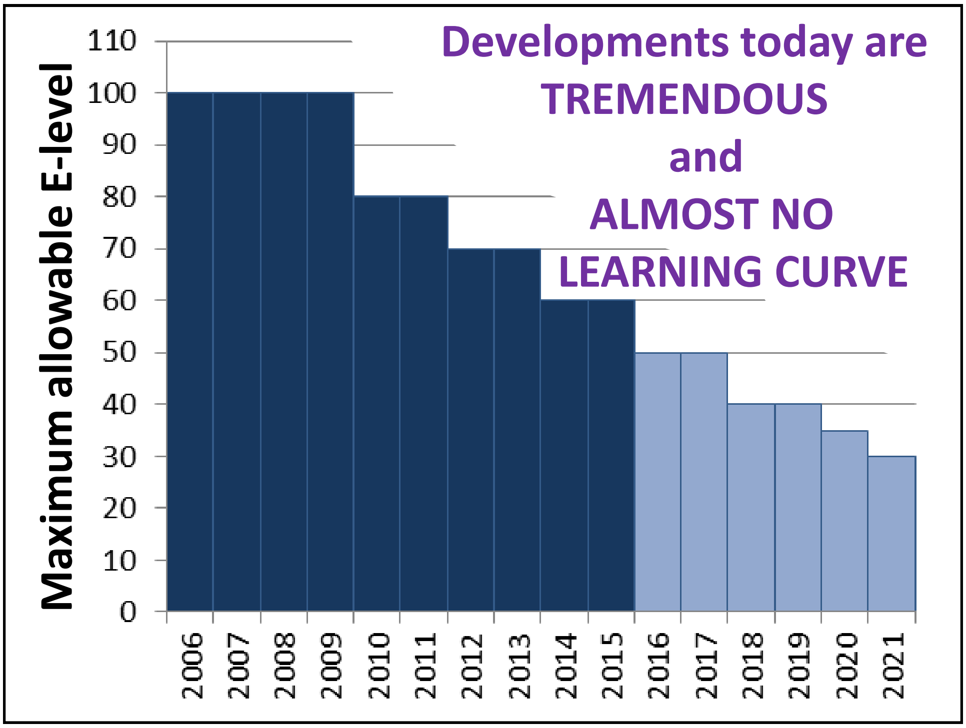



Team
work



In 10 years from now? (…2023…)

- All new buildings in Europe should be NZEB
  - Will there be a difference between theory and practice?
  - In any case strong driver for energy efficient ventilation
- Strong focus on renovation existing building stock


Developments today are
TREMENDOUS
and
ALMOST NO
LEARNING CURVE
Maximum allowable E-level
110
100
90
80
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40
30
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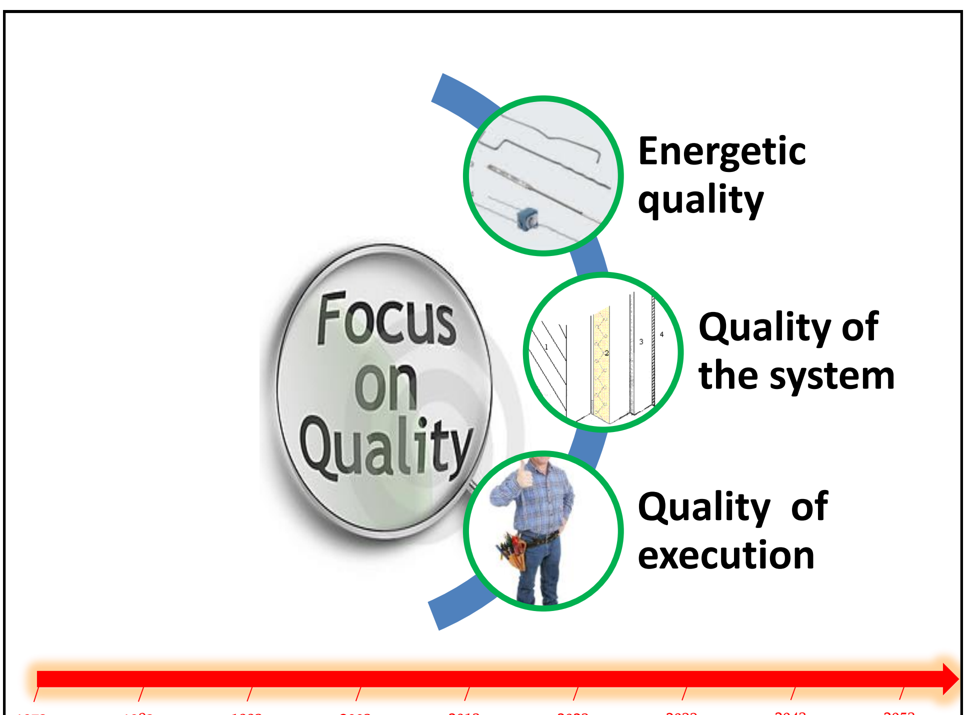
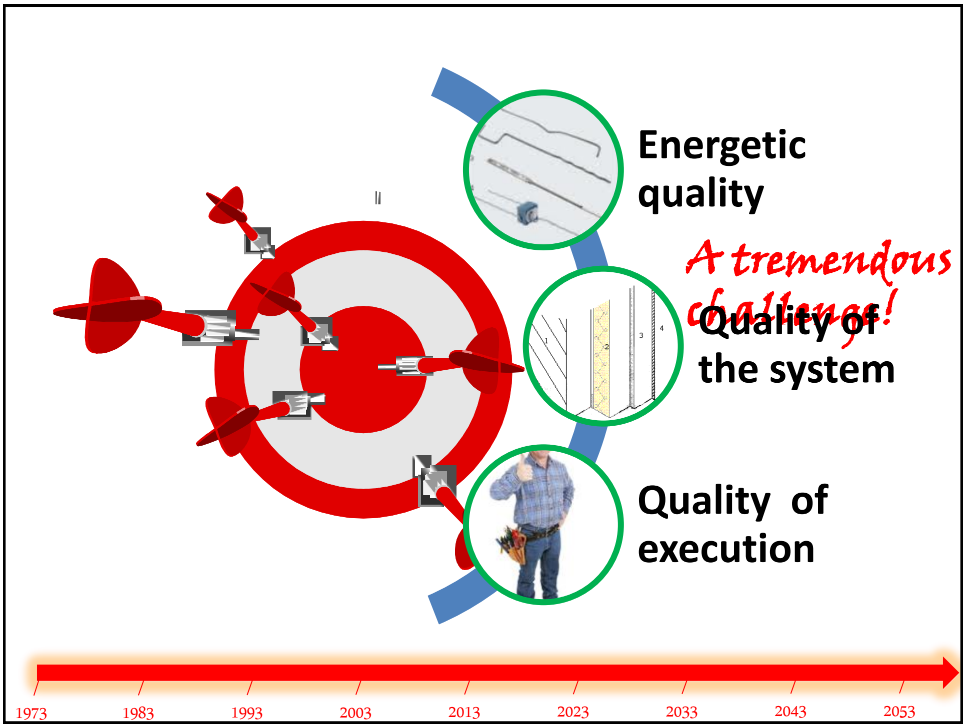

Focus on Quality
Energetic quality
Quality of the system
Quality of execution
1973
1983
1993
2003
2013
2023
2033
2043
2053


Energetic quality
A tremendous challenge!
Quality of the system
Quality of execution
1973
1983
1993
2003
2013
2023
2033
2043
2053


International collaboration
International conferences
…
1973
1983
1993
2003
2013
2023
2033
2043
2053


Lessons Learned
recognize mistakes
observe what works
document them
share them


2053
1973
1983
1993
2003
2013
2023
2033
2043
2053

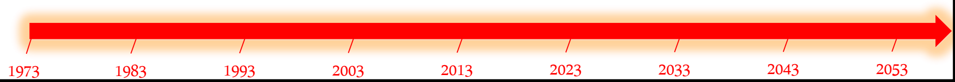
2053…

1973 | 2013 | 2053

1973 1983 1993 2003 2013 2023 2033 2043 2053

Conclusions

- We come from very far…
- Impressive acceleration in terms of energy efficiency and indoor climate requirements
- Next 5…10 years will be very challenging and uncertain
- Are there volunteers for a presentation at the 2053 AIVC conference for an update?



www.AIVC.org

www.tightVent.eu **www.venticool.eu**

Wednesday 25 September 2013

13:45-15:15: Parallel Session 1A: Short oral presentation session- Ventilation for summer comfort - Energy impacts

Chairpersons: Maria Kolokotroni, Ivan Pollet

- **Preferred air velocity and local cooling effect of desk fans in warm environments** Angela Simone, Denmark
- **Evaluating the performance of selected thermo-physiological indices on quantifying bioclimatic conditions for pedestrians in a street canyon** Katerina Pantavou, Greece
- **Individual appraisal of air conditioned surroundings** Samuel Hassid, Israel
- **A study on the thermal environment in Greek primary schools based on questionnaires and concurrent measurements** Paraskevi Dorizas, Greece
- **Combining thermal inertia, insulation and ventilation strategies for improving of indoor summer thermal comfort** Evola Gianpiero, Italy
- **The use of integrated PV shading systems for energy savings and interior comfort conditions in Mediterranean countries** Theocharis Tsoutsos, Greece
- **The thermal comfort and IAQ of recent Dutch energy efficient office buildings with Thermal Activate Building Systems** Wim Zeiler, Netherlands
- **Heat recovery ventilation with closed-loop ground heat exchange** Bart Cremers, Netherlands
- **Impact of climate change on a naturally night ventilated residential building, Greece** Theofanis Psomas, Greece

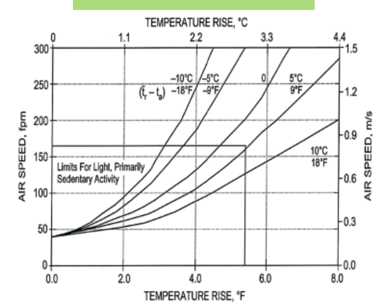
- **Energy saving effect of the ERV (Energy Recovery Ventilator) with outdoor air cooling** Doosam Song, Republic of Korea
- **Double skin system of room side air gap applied to detached house (part 1)** Kan Lin, Japan

34th AIVC Conference

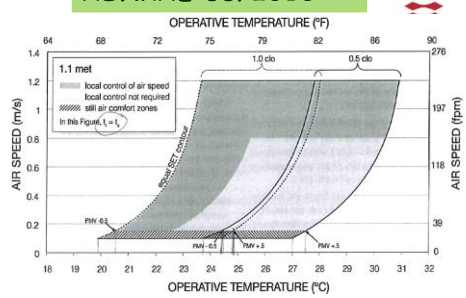
"Cooling effects on Humans by increasing local air velocity in warm environment"

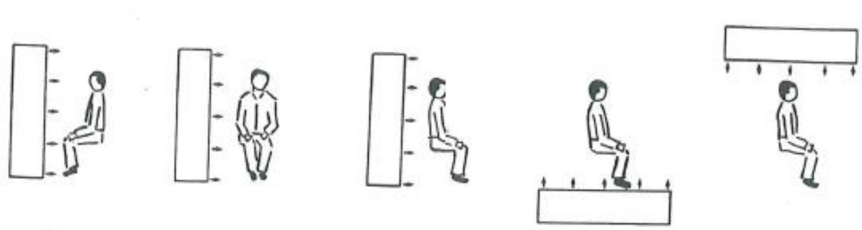
DTU Civil Engineering
Department of Civil Engineering

ISO 7730/2005

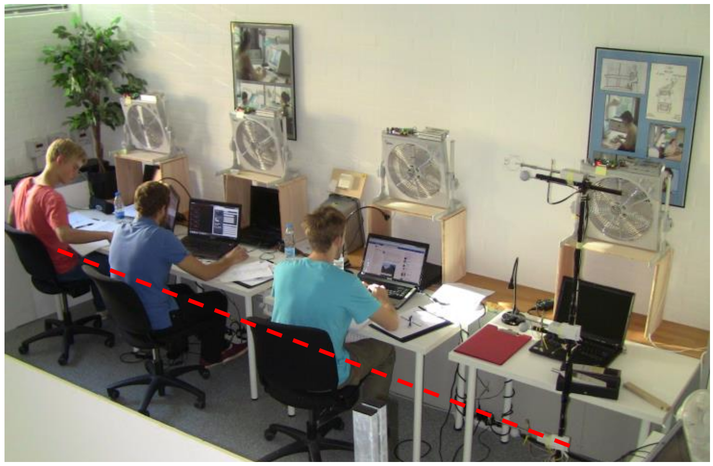


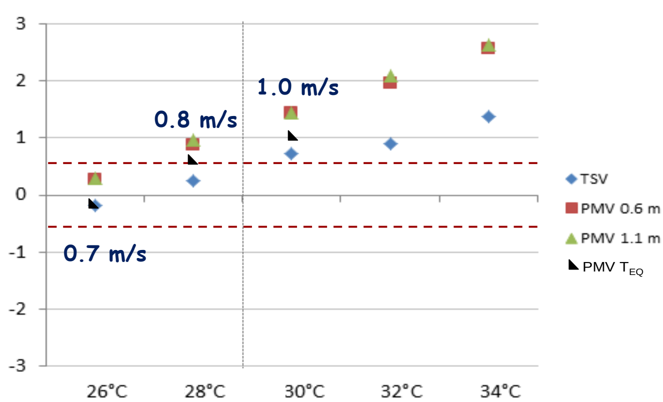
ASHRAE 55/2010

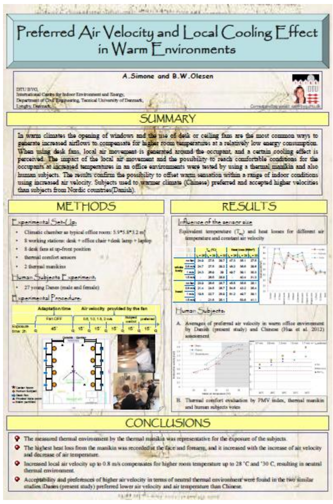




What if the air speed impact the occupant in a local body part?



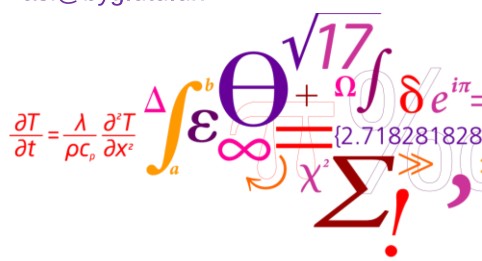




THANKS !!!

???

Angela Simone
asi@byg.dtu.dk



Evaluating the performance of selected thermo-physiological indices on quantifying bioclimatic conditions for pedestrians in a street canyon

K. Pantavou and M. Santamouris

Department of Environmental Physics and Meteorology, Faculty of Physics, University of Athens, Greece

Field Surveys

Dates and time frames:

16 July 2010	16:00-20:39
21 July 2010	10:40-14:06

Microclimatic Measurements:

At the height of 1.1 m above the ground

- air temperature (T_{air})
- relative humidity (RH)
- average wind speed (WS)
- downwelling (R_{down}) and reflected (R_{up}) solar radiation
- downwelling and upwelling total radiation (TR_{down}, TR_{up}) on a horizontal plane
- globe temperature (T_{globe})

The data were stored on a CR10X Campbell Scientific data logger at 1 min intervals.

Interviews:

► based on a structured questionnaire

- clothing, main activity during the last half hour, gender, age, height and weight
- the main question of **thermal sensation vote (TSV)** in which the respondents were asked to assess their thermal sensation based on **ASHRAE 7-point scale** **-3, cold**
  -2, cool
  -1, slightly cool
  0, neutral
  +1, slightly warm
  +2, warm
  +3, hot

► were conducted in randomly selected people

Thermo-physiological indices:

- Comfort Formula (COMFA)
- Physiological Equivalent Temperature (PET)
- Universal Thermal Climate Index (UTCI) consistent with weather measured data

Statistical criteria used for the comparison of indices:

- Spearman's rho measure of correlation between the produced index values and TSV
- Gamma measure of correlation between the predicted TSV and TSV
- percentage of correct predictions

Results

- Totally 313 interviews were performed in typical summer weather conditions.
  - 58.0% of the interviewees were males
  - 88.2% were from 18 to 64 years old
- COMFA values ranged between classes -1 and +3 in accordance to TSVs
- PET and UTCI range differed from that of TSVs, failing to predict class -1.

Indices range during the field surveys

Index	Min	Max	Mean	Std Dev
COMFA ($W \cdot m^{-2}$)	-54	288	29	66
PET (°C)	24.7	40.1	33.4	2.5
UTCI (°C)	26.4	36.9	33.0	1.8

Range of indices classes and Thermal Sensation Votes (TSV) during the field surveys

	Min	Max
COMFA	-1	3
PET	1	3
PET[1]$_{Med}$	0	3
UTCI	2	3
TSV	-1	3

[1]PET values classified according to the Mediterranean classification

- Spearman's rho and Gamma coefficients for the correlation between UTCI and TSVs (0.36 and 0.45) were the highest calculated
- The greatest percentage of correct predictions (37.2%) was estimated in the case of PET according to Mediterranean scale.

Spearman's rho and Gamma measure of correlation between predicted indices values and TSV along with the percentage of correct indices predictions

				Normalized values			
	Measures of correlation			Measures of correlation			
Index	Spearman's rho	Gamma	Correct predictions (%)	Spearman's rho	Gamma	Correct predictions (%)	Total
COMFA	0.28	0.31	15.4	0.78	0.69	0.41	1.88
PET	0.14	0.18	36.6	0.39	0.40	0.98	1.77
PET[1]$_{Med}$		0.25	37.2	0.39	0.56	1.00	1.94
UTCI	0.36	0.45	33.6	1.00	1.00	0.90	2.90

[1]PET values classified according to the Mediterranean classification

Conclusions

- According to the method followed, the criteria posed and the small sample size, **UTCI showed better applicability** in the case of Mediterranean climate compared to COMFA and PET.

- All three indices produced relatively low percentage of correct predictions, indicating that the **calibration** of the indices with empirical data is possible to provide better results.

Thank you for your attention

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Thermal Comfort and Ventilation

INDIVIDUAL APPRECIATION OF AIR CONDITIONED SURROUNINGS

Samuel Hassid, Assoc. Professor
Dept. of Environmental, Water Resources and Agricultural Eng.
Technion – Haifa - Israel

What changed in Israel (and other European and not-only Mediterranean countries) During the 90ies (from the Environmental Point of vew)?

Answer : Air-Conditioning (AC)

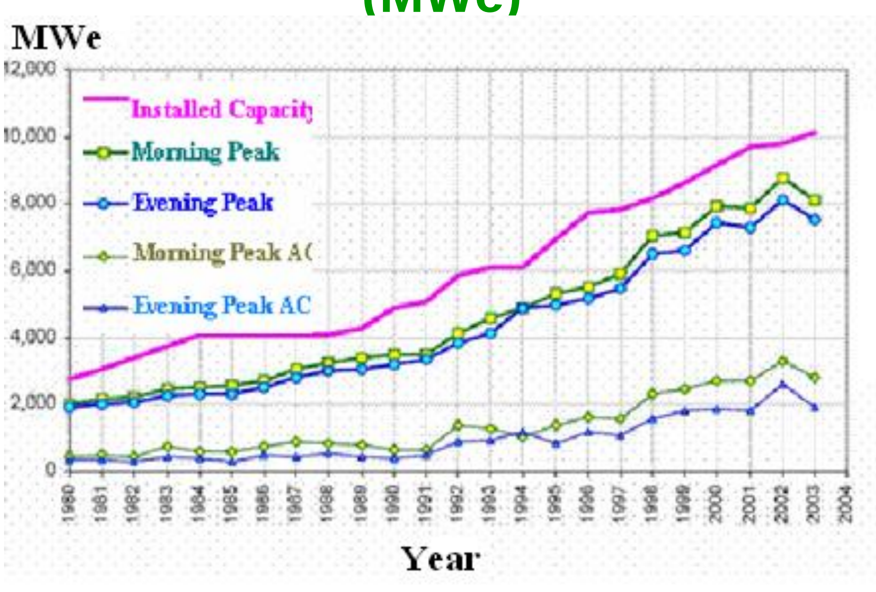
Answer : Air Conditioning

- During those year in the field of research many great things (landmark) happened – PASSCOOL and other projects on the problem of PASSIVE cooling during the summer.
- The changes in the real world were

– unfortunately - in the completely opposite direction.

- Before 1990 – AC was considered a luxury
- Today it is totally commonplace

Peak Demand and Capacity (MWe)



Changes between 1990 and 2010

- Before 1990 – AC was the exception rather than the rule
- Very uncommon in the residential sector
- Today 70 % of Israeli households have some kind of AC device.
- Shopping is in malls rather than downtown
- Cars have AC as a rule

Problems generated

- AC Power is just ahead of the increase in Demand (already above 10,000 MWe)
- Israel particularly vulnerable because of Insular Grid.
- Several Power stoppages
- Problems increasing Electricity Supply – More Power Plants opposed by Environmentalist Organization

The question:
Are People Happy About it ?

- My answer : NO !!!
- In the Mediterranean - People like OPEN WINDOWS !!!
- Experience in bus where people tried violently to keep windows open.

Several personal examples

- Sometimes in the very room you teach Climatology
- Sometimes by scientists investigating climatology
- Sometimes with scientists investigating ventilation in buildings – of all people
- Sometimes in Institutions making the rules in energy savings.

- **In Israel - civil servants in prestigious government buildings in both Jerusalem and Haifa leading a "revolt" demanding openable windows – even threatening to use whatever it takes, the implication being even by force**
- **Several strikes and work stoppages in both Jerusalem and Haifa.**
- **Senior staff admit that they try to fix meetings outside the building in pursuit of an opportunity to leave the building**
- **Experts express apparently opposing opinions, some putting the blame on the air conditioning system and other expressing a different opinion**

- **Conclusion from all these examples: There is a totally different perception of thermal comfort in an open room and a closed room.**
- **This goes beyond the suggestions of Thermal comfort as expressed from Fanger's equations and PMV. People appreciate internal environments different from external ones.**
- **Rooms with open windows are somewhere in the middle**

CONCLUSIONS and RECOMMENDATIONS

- **Thermal comfort is very much dependent on whether the environment is under natural or artificial ventilation.**
- **Proposed : repeat a program similar to RESHYVENT but focusing on summer criteria for thermal comfort**
- **Advisable to include in this study both air conditioned and non-air-conditioned environments**
- **Human appreciation of the environment – even if air-conditioning is combined with open windows –**
- **Address problems of summer thermal comfort without preconceived ideas.**

A Study on the Thermal Environment in Greek Primary Schools based on questionnaires and concurrent measurements

Paraskevi Vivian Dorizas*, Margarita-Niki Assimakopoulos, Constantinos Helmis, Mat Santamouris

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Joint Conference
34th AIVC- 3rd TightVent- 2nd Cool Roofs' – 1st venticool
25-26 September 2013, Athens, Greece

Presentation contents

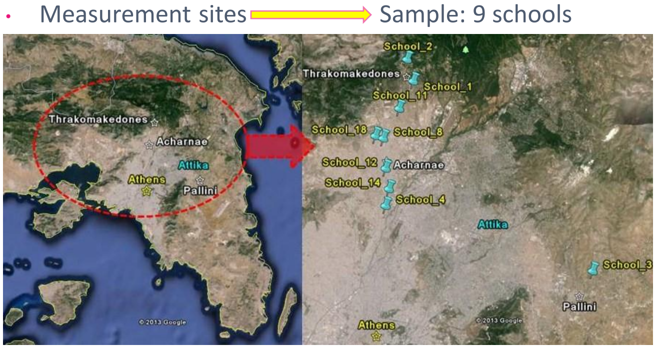
- Objectives
- Methodology
- Results & Discussion
- Conclusions

Objectives

- Investigate the thermal comfort votes of primary school students
- Assess the combination of thermal sensation versus thermal acceptability and preference
- Investigate correlations between the questionnaires and measurements

Methodology

- Measurement sites → Sample: 9 schools

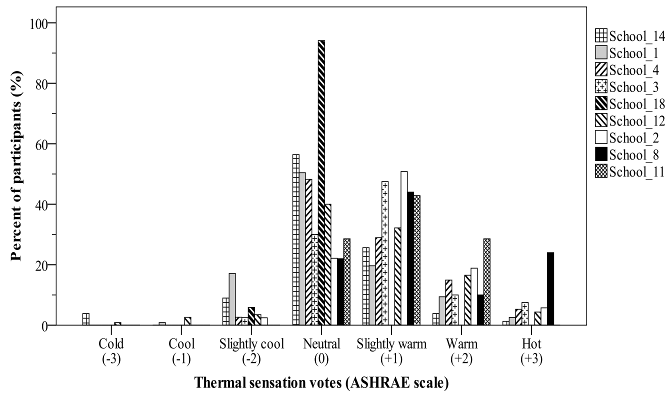


- Measurement period: April & May 2013
- Measurements from 1 to 5 days per school

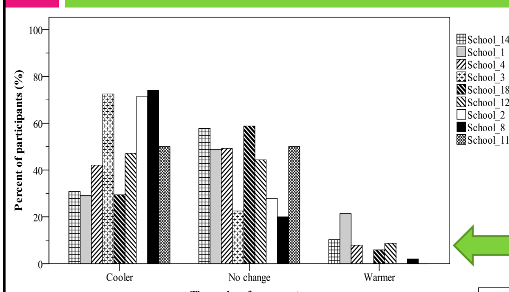
- Objective approach: Measurements →
- Subjective approach: Questionnaire survey → 7-point ASHRAE scale
- 667 collected questionnaires
- 193 students

Results & Discussion

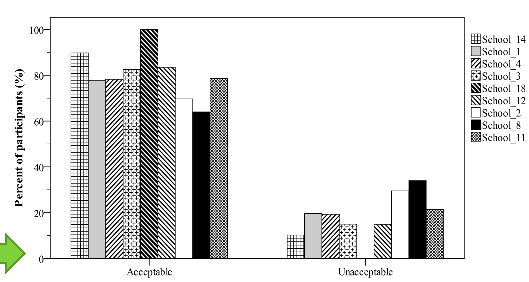
Distribution of the thermal sensation votes of students in all the schools



Results & Discussion

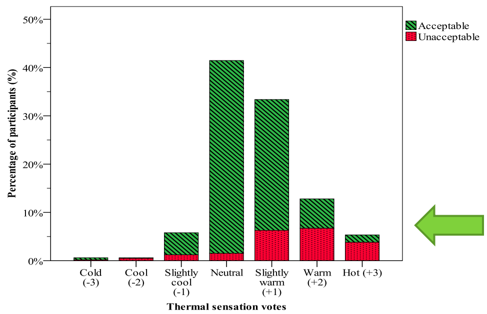


Distribution of the thermal preference votes of students in all schools

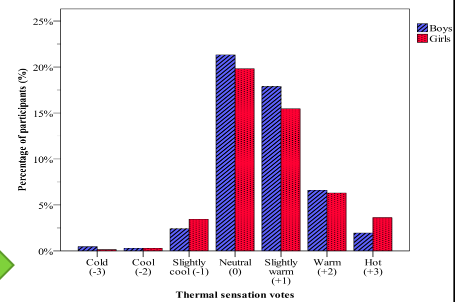


Distribution of the thermal acceptability votes of students in all schools

Results & Discussion



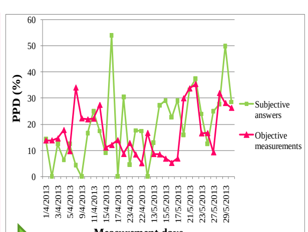
Thermal sensation votes versus students' acceptability of all schools



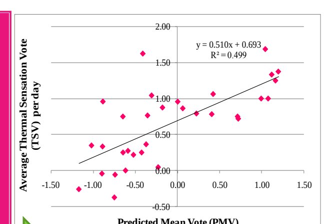
Thermal sensation votes versus gender of all schools

Results & Discussion

Temporal variation of the Objective and subjective PPD indexes



Correlation between the objective PMV & subjective TSV



Pearson and Spearman's correlation coefficients between subjective & objective indexes

	Pearson correlation coefficient				Spearman's rho correlation coefficient			
	Subjective TSV	Objective PMV	Subjective PPD	Objective PPD	Subjective TSV	Objective PMV	Subjective PPD	Objective PPD
Subjective TSV	1	0.707**	0.826**	0.146	1	0.726**	0.822**	0.055
Objective PMV		1	0.539**	0.302		1	0.611**	0.015
Subjective PPD			1	0.130			1	-0.025
Objective PPD				1				1

Conclusions

- The majority of the thermal sensation votes lied on the ‘warm’ axis of the 7-point scale
- Half of the students didn’t prefer any change in the thermal conditions
- Acceptable thermal environment for the majority of the students
- The thermal sensation of boys and girls not significantly different
- The temporal variation of the subjective and objective PPD indexes diverged a lot
- Moderate correlation found between the objective PMV and subjective TSV
- Significant correlation coefficients were found between: the subjective TSV and objective PMV, the subjective TSV and PPD and for the objective PMV and subjective PPD.
- Students at this age are capable to fully understand and evaluate the thermal environment of their classrooms.

Thank you for your attention!

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ECRC EUROPEAN COOL ROOFS COUNCIL · TightVent Europe · INIVE · venticool · AIVC

Combining thermal inertia, insulation and ventilation strategies for the improvement of indoor summer thermal comfort

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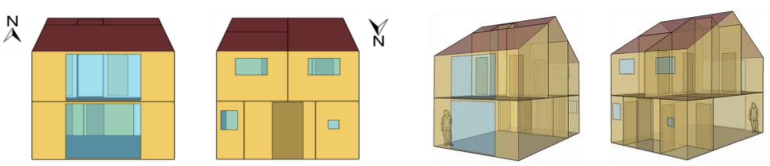
[1] Department of Industrial Engineering, University of Catania (ITALY)

[2] Department of Production and Energy Use,
Polytechnic University of Bucharest (Romania)

Case study

Real two-storey houses under construction in London (UK)

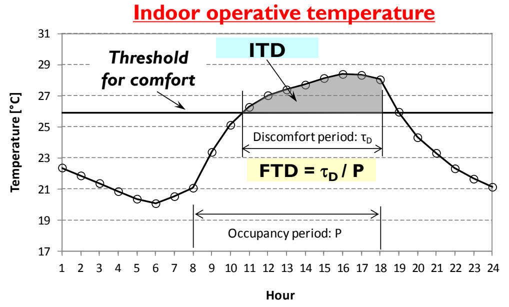


Envelope component	Features: reference configuration	U-value
Exterior walls	Concrete 20 cm - Insulation 30 cm	0.11 [W m^{-2} K^{-1}]
Ground floor	Concrete 25 cm - Insulation 30 cm	0.11 [W m^{-2} K^{-1}]
Roof	Plywood + insulation 30 cm	0.11 [W m^{-2} K^{-1}]
Internal walls	Concrete 10 cm – No insulation	3.27 [W m^{-2} K^{-1}]
Triple-glazed windows	Wooden frame	1.32 [W m^{-2} K^{-1}]

Methodology

In order to evaluate the indoor thermal comfort, some indicators recently introduced in (Sicurella et Evola, 2012) were adopted, namely the ***Intensity of Thermal Discomfort*** **(ITD)** and the ***Frequency of Thermal Discomfort*** **(FTD)**.

In this study, the definition of the threshold value is based on the **adaptive approach**, as described in (EN Standard 15251, 2007):



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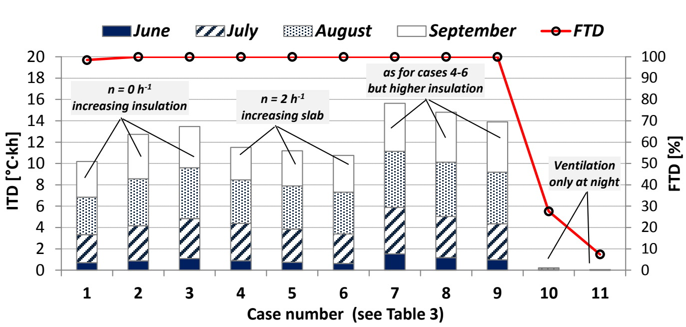
Department of Industrial Engineering – University of Catania

Results and discussion

Eleven different configurations are considered, by varying the thickness of the concrete slabs, the thickness of insulation and the ventilation strategy.

The calculation of the operative temperature is performed by means of ***dynamic simulations*** (EnergyPlus)



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Main findings

- ✓ When no ventilation is allowed (n = 0 h^{-1}), an increase in the insulation thickness implies a considerable worsening of the thermal comfort
- ✓ An increase in the thickness of the concrete slab from 100 mm to 300 mm, while keeping the same insulation layer (150 mm) and a constant ventilation rate (n = 2 h^{-1}), determines a slight reduction in the ITD
- ✓ An intense ventilation during the daytime, i.e. when the outdoor temperature is usually higher than indoor temperature, may have negative effects on the room comfort. This is more likely to occur if the insulation layer is thick.
- ✓ On the contrary, an appropriate ventilation strategy (at night, see cases n. 10 and 11) can provide optimal results.

Thank you for your attention !

Gianpiero Evola, PhD – gevola@unict.it
Department of Industrial Engineering – University of Catania

TECHNICAL UNIVERSITY OF CRETE (TUC)
ENVIRONMENTAL ENGINEERING DEPARTMENT
RENEWABLE AND SUSTAINABLE ENERGY
SYSTEMS LAB

34th AIVC Conference

Assessment of integrated PV shading systems for energy savings and interior comfort conditions in Mediterranean countries

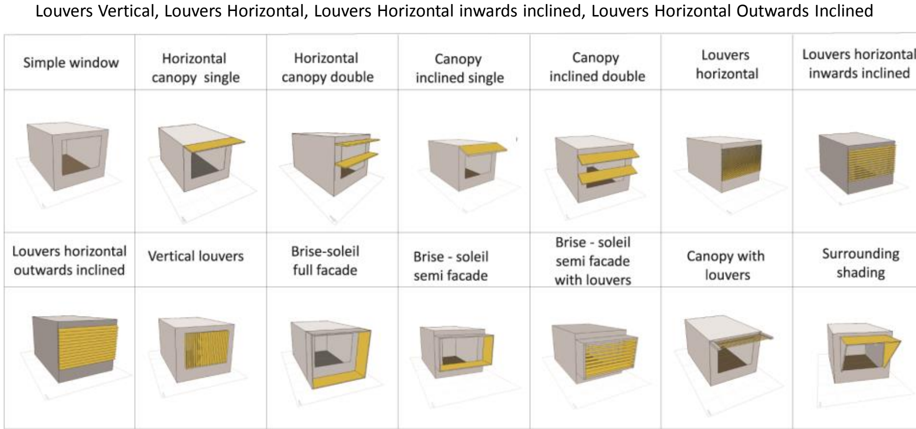
Maria Mandalaki[1], Theocharis Tsoutsos[1]
Nikos Papamanolis[2]

[1] Environmental Engineering School, Technical University of Crete
[2] Architectural Engineering School, Technical University of Crete

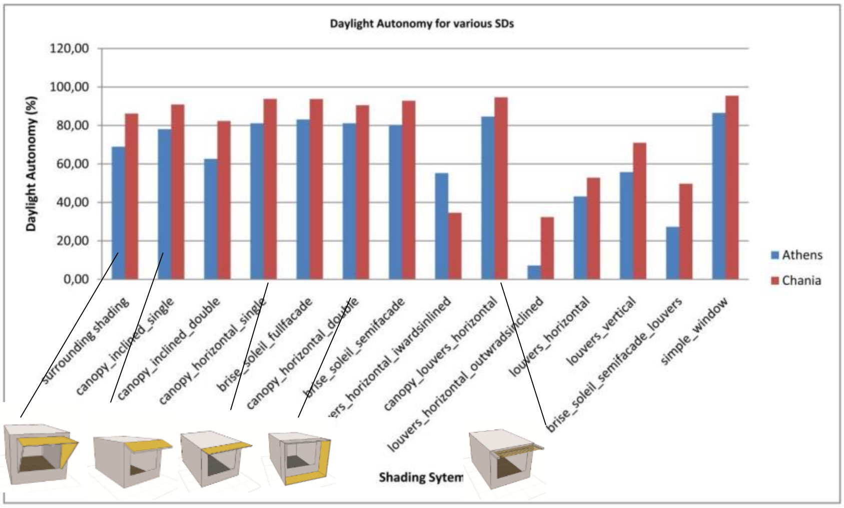
TYPES OF SHADING SYSTEMS

ASSESMENT ACCORIDNG : Visual comfort conditions AND Energy needs for cooling – heating – lighting
Two groups of Shading Systems:

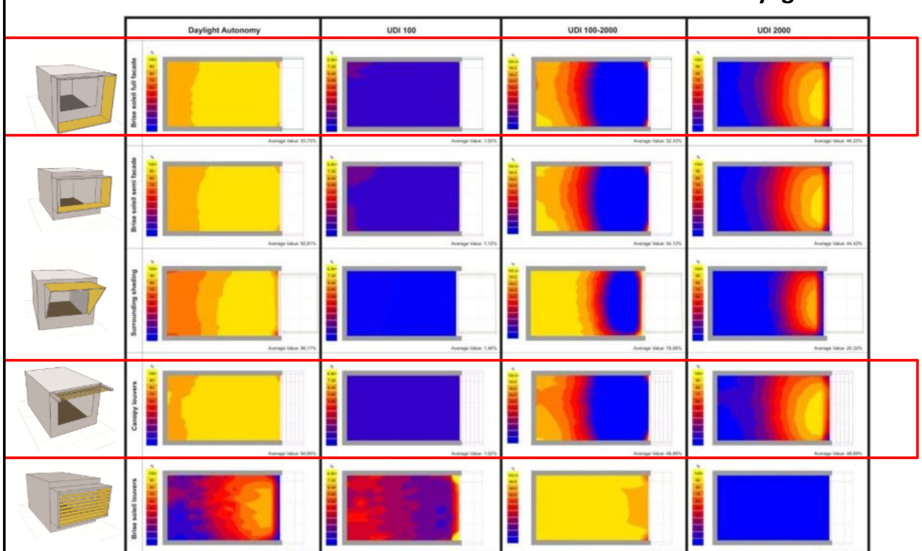
a. **Shading systems that allow transparency**: Canopy horizontal, Canopy horizontal double, Brise Soleil full façade, Brise Soleil Semi façade, Surrounding Shade, Canopy Louvers, Canopy Inclined Single and
b. **Shading systems that obstruct view to outside:** Canopy Inclined double, Brise Soleil Semi Façade with Louvers, Louvers Vertical, Louvers Horizontal, Louvers Horizontal inwards inclined, Louvers Horizontal Outwards Inclined



EVALUATING VISUAL COMFORT CONDITIONS
Daylight Autonomy Levels



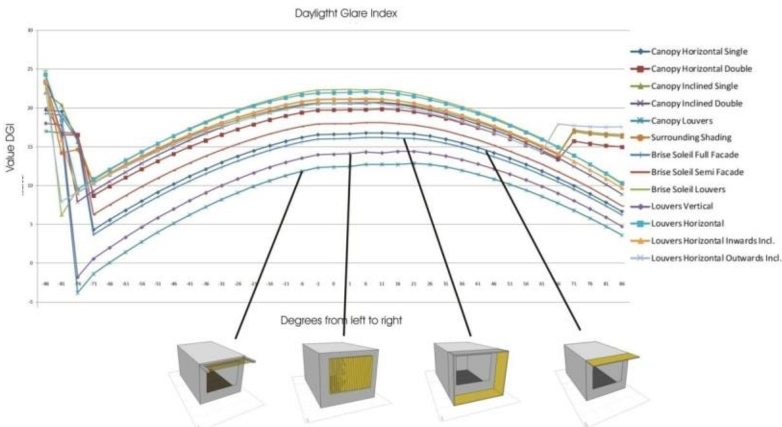
EVALUATING VISUAL COMFORT CONDITIONS
Useful Daylight Illuminance



EVALUATING VISUAL COMFORT CONDITIONS

Daylight Glare Index (DGI)

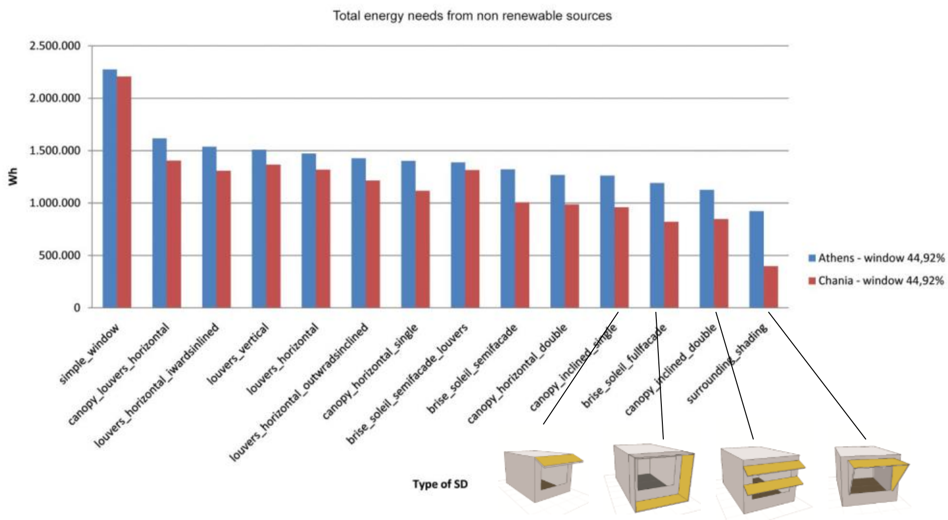
DGI values, December 21st at 12:00 in relation to the angle of view for the camera away from window



BALANCING ENERGY NEEDS AND VISUAL COMFORT

Energy saving shading systems that obtain visual comfort

BALANCING ENERGY PRODUCTION AND NEEDS
Energy for heating – cooling - lighting



12/7/2013 | 34th AIVC Conference – Athens Greece
M. Mandalaki, T. Tsoutsos, N. Papamanolis | 7

THANK YOU
FOR YOUR KIND ATTENTION!

Dr Theocharis Tsoutsos, *Associate Professor*
Ms Maria Mandalaki, *Arch. Eng., PhD Candidate*

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THERMAL COMFORT AND IAQ OF RECENT DUTCH ENERGY EFFICIENT OFFICE BUILDINGS WITH THERMAL ACTIVATE BUILDING SYSTEMS

Wim Zeiler, Koen Smelt and Gert Boxem

Technische Universiteit Eindhoven
University of Technology

Where innovation starts

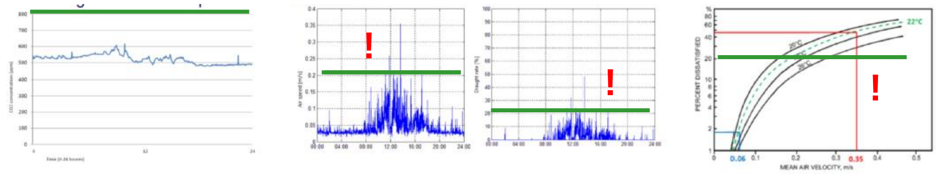
Dutch buildingswith TABS

Building A with the setup of the measurement equipment

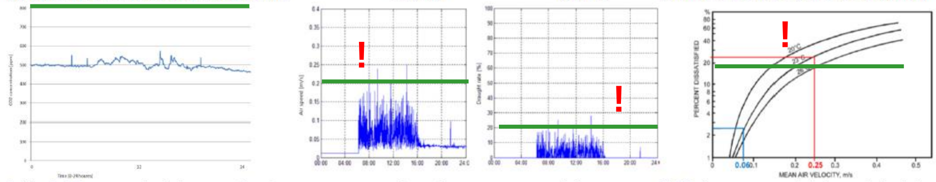
Building B with the setup of the measurement equipment

Technische Universiteit Eindhoven University of Technology

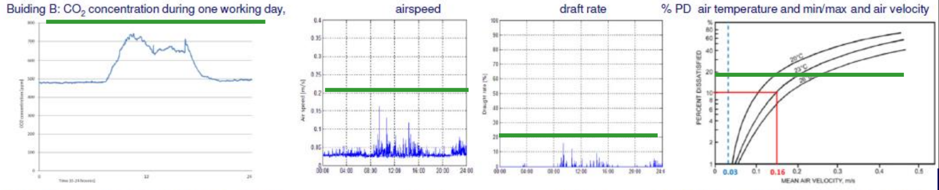
Measurement results



Buiding A: CO_2 concentration during one working day, airspeed draft rate % PD air temperature and min/max and air velocity



Buiding B: CO_2 concentration during one working day, airspeed draft rate % PD air temperature and min/max and air velocity

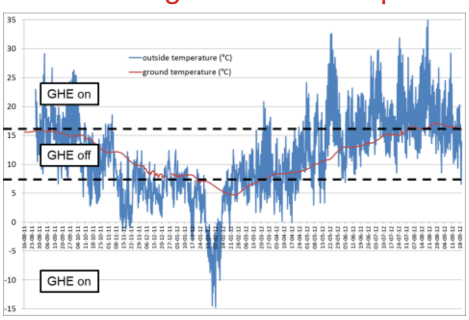


Buiding C: CO_2 concentration during one working day, airspeed draft rate % PD air temperature and min/max and air velocity

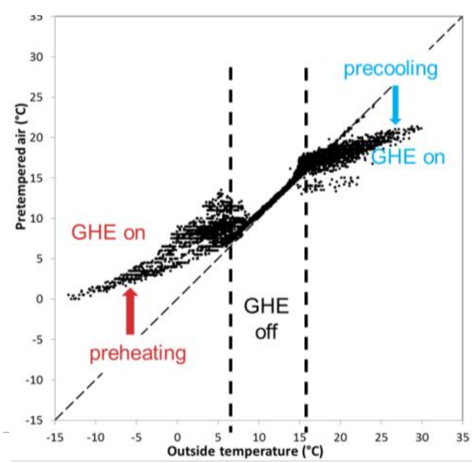
Heat recovery ventilation with closed-loop ground heat exchange

Bart Cremers, Knowledge Centre, Zehnder Group Netherlands

Preheating in winter and precooling in summer

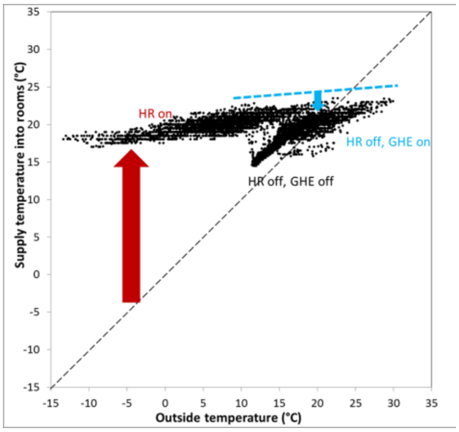


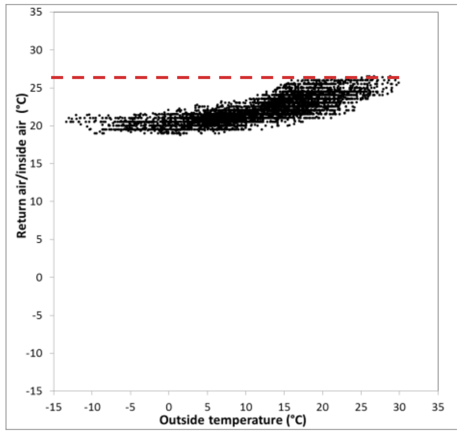
- Ground at 1.20 m depth ranges between 5°C in winter and 16°C in summer



- Preheating for outside temperatures below 7°C and precooling above 16°C

Supply and return air temperatures



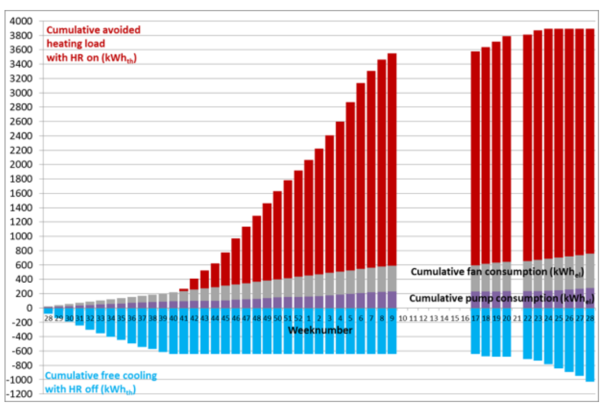


- overheating inside building is prevented because of
  - shading measures
  - precooling by ground heat exchange

zehnder group

Avoided heating & free cooling load ventilation system

- GHE off: ventilative cooling with outside air typically 500 W @ 210 m³/h
- GHE on: ventilative cooling with precooled outside air typically 250 W @ 210 m³/h



- fan + pump electrical consumption with HR on: 593 kWh_{el}
- annual avoided heating: 3899 kWh_{th} (heating SPF=7)
- fan + pump electrical consumption with HR off: 408 kWh_{el}
- annual free cooling: 950 kWh_{th} (cooling SPF=2)

zehnder group

IMPACT OF CLIMATE CHANGE ON A NATURALLY NIGHT VENTILATED RESIDENTIAL BUILDING, GREECE.

Psomas Theofanis, Holzer Peter, Santamouris Mattheos

34th AIVC Conference – Athens, 2013

OBJECTIVE – TARGET

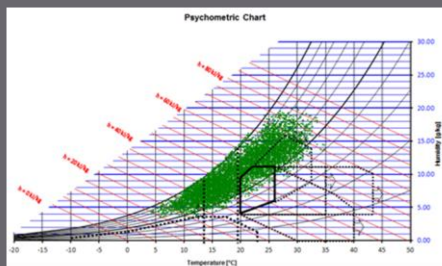
How the unequivocal climate change (A2, A1B, B1 emission scenarios until 2050) will affect the thermal demand (mainly cooling) of a single family nearly zero energy building (5 occupants), in the hottest area of Greece, Rhodos island (Mediterranean climate).

- 129/274 days over 37°C, 19/52 heat waves 1998 – 2007, last 150 years

- Climate change for Greece (IPCC):
  - ✓ Increase in average and highest summer temperature
  - ✓ Decrease in precipitation days
  - ✓ Wind patters and global radiation show no change

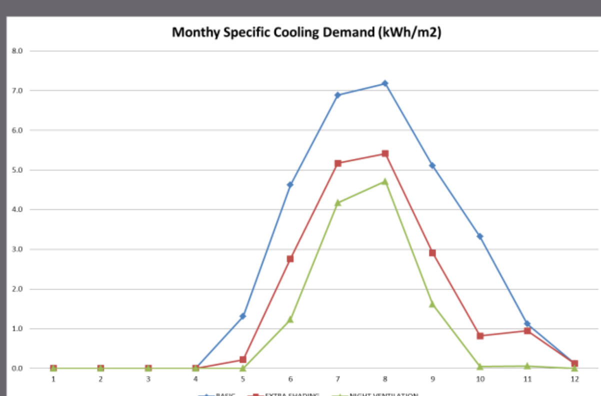
- Affect local ecosystems, economies (tourism, agriculture), low income households (economic recession)

DESIGN Nearly ZEB



- Bioclimatic and passive solar design.
- West – East long axis (no openings).
- Compactness of the building equals to 0.65.
- Continuous thermal insulation ($U_{w,r}$=0.2 W/m^{2}K – U_{gf}=0.8 W/m^{2}K).
- Constant infiltration rate of 0.7 ach.
- Wooden frames with double glazing, air filled (low-e and g equals to 0.6).
- Extended fixed south shading (double length compared with the opening).
- Occupancy and equipment loads (standards and regulations)

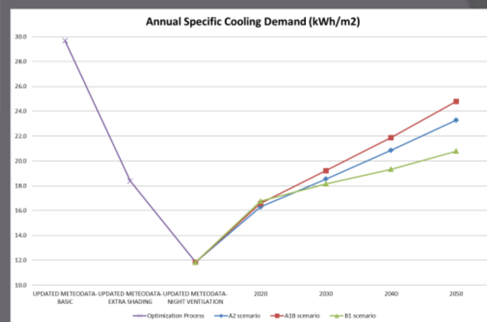
RESULTS – CONCLUSIONS



- Optimized with extra movable shadings during the morning working hours for spring, summer and autumn.
- Night natural cross ventilation, for all year (0:00 – 5:00) and all apertures, under conditions (T_{zone}>=21°C and T_{zone}>=T_{ext}).
- Decrease of the cooling demand (sensible cooling – 26°C) up to 60% and shortening of the thermal period to 4 months (no heating).

a/a	Average Temp. (°C)	Min. Temp. (°C)	Max. Temp. (°C)
Update Data	19.5	3.6	34.8
	A2		
2020	19.8	4.7	35.5
2030	20.2	5.0	36.2
2040	20.4	4.6	36.3
2050	20.8	5.5	37.0
	A1B		
2020	19.8	4.1	35.5
2030	20.2	4.6	36.3
2040	20.5	5.0	36.3
2050	**20.9**	5.3	**37.2**
	B1		
2020	19.8	4.2	35.5
2030	20.1	4.5	36.2
2040	20.2	4.6	36.2
2050	20.5	4.9	36.5

2050 → 1 ~ 1.5°C (aver.)
→1.7 ~ 2.4°C (max.)



- Climate change will increase the cooling demand in 2050, 90% on average and will extend the cooling period (8 months – no significant changes in peak cooling loads). September is included in Summer.
- A1B scenario (medium pessimistic), presents the highest increase of the cooling demand for South Greece, until 2050.

34th AIVC Conference and 1st Venticool Conference
25-26 September 2013, Athens, Greece

Energy Saving Effect of the ERV (Energy Recovery Ventilator) with outdoor air cooling

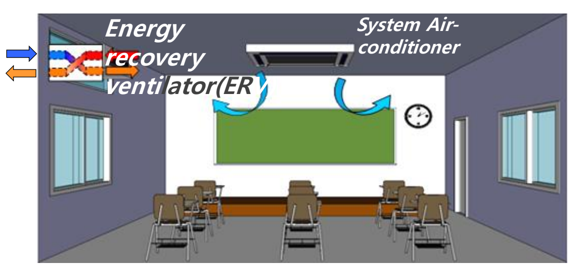
Doosam Song[1]*, Joowook Kim[2], Junghun Lee[3], Joonghoon Lee[4]

1. Professor, SungKyunKwan University, Korea
2. Graduate School (in Ph.D.), University of Colorado, USA
3. Graduate School (in M.A.), SungKyunKwan University, Korea
4. Senior Researcher, Samsung C&T, Korea

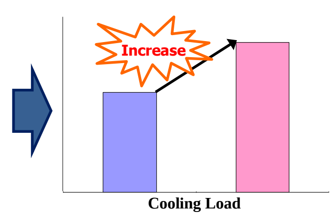
Building Technology Research Unit SungKyunKwan University, KOREA

Mechanical Ventilator with heat recovery : ERV

◆ **Intermediate Season**



ERV(Energy Recovery Ventilator)



Strength

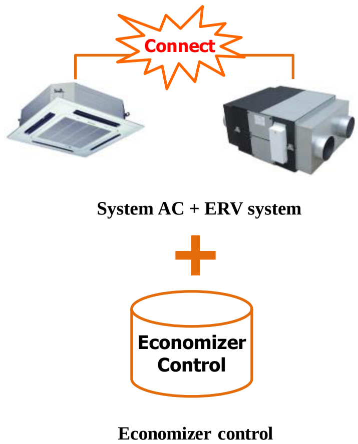
▪ERV has decrease cooling and heating load in **severe outdoor condition**.

Weakness

▪ ERV has a feature of heat recovery **regardless of the outdoor condition.**
▪ **ERV** and **system AC control** is **not connected.**
▪ In intermediate season, cooling load could be **increased** due to the outdoor air temperature could be increased **by heat recovery.**

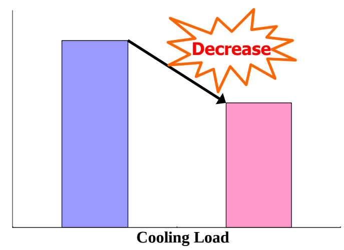
1

ERV with economizer cycle



- ERV is **connected** with cooling system.
- ERV has a function of **economizer cycle.**

- **Cooling load** could be **removed by outdoor air.**
- **Energy demand for cooling** will be **decreased.**



- **Economizer cycle** : the indoor temperature is controlled by outdoor air when outdoor condition is favorable.

2

Simulation

◆ Purpose

-The effect of the ERV with economizer cycle will be analyzed in terms of ***indoor environmental control performance*** and ***energy saving effect.***

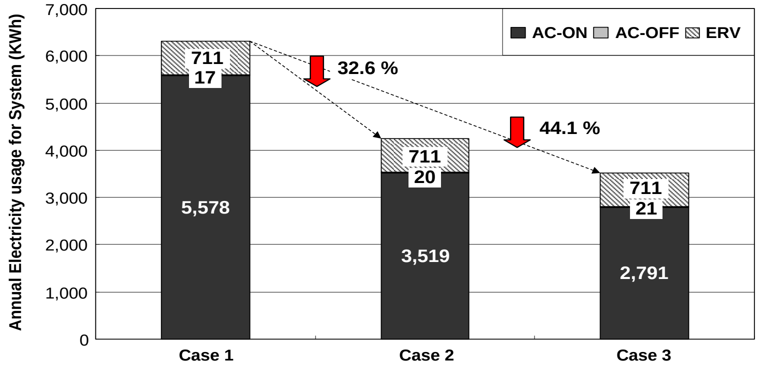
◆ Simulation Cases

Cases	Operation mode	
Case 1	AC + mechanical ventilator	
Case 2	AC + ERV (Normal control)	
Case 3	**AC+ERV (Economizer cycle control)**	 **+ Economizer control**

4

Simulation Result (Energy consumption)

◆ Annual electric requirement



AC + mechanical ventilator | AC + ERV (Normal control) | **AC+ERV (Economizer cycle control)**

- The reduction in annual total electricity consumptions of the system by about **32.6%** and **44.1%** respectively in Case 2 and 3 compared to that in Case 1.

5

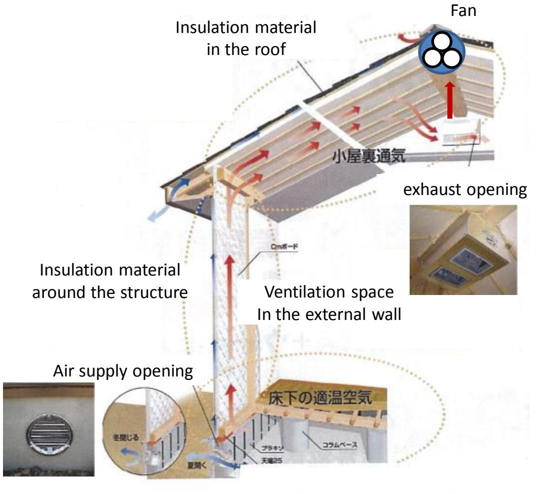
Double-skin System of Room-side Air Gap Applied to Detached House (Part 1): Simulation Analysis for Reduction of Cooling Load in the Forced Ventilated Wall

Department of Architecture, Faculty of Engineering,
The University of Tokyo
Kato Lab.

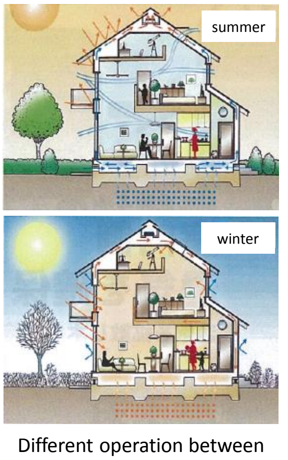
Kan Lin

1. Backgrounds and Objectives of the Study
   1.1 Overview of Buoyancy Ventilated Wall House

Insulation material with gap



Overview of the ventilation system



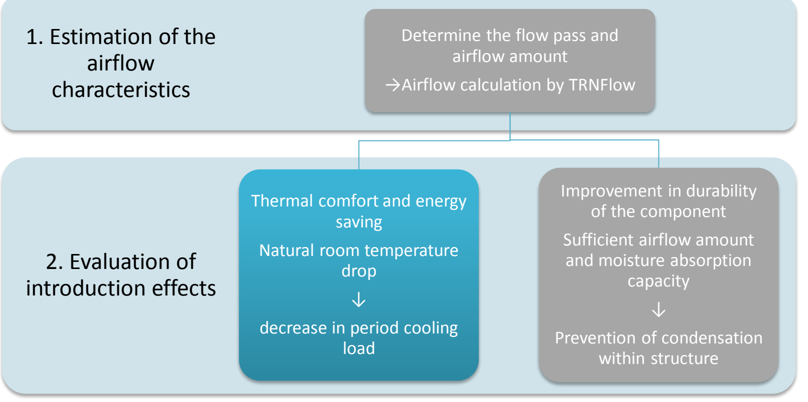
Different operation between summer and winter

1. Backgrounds and Objectives of the Study

1.2 Objectives and flow of the research

Objectives : to understand the basic properties of the double-skin system, temperature drop, and reduction in cooling load during the summer period by performing a ventilation network simulation.

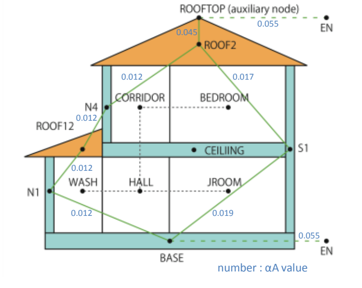
Flow of the research :

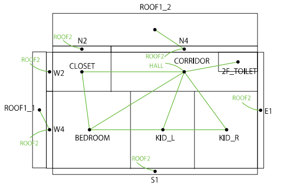


In this study, we evaluated the amount of airflow and the drop of natural room temperature by simulation.

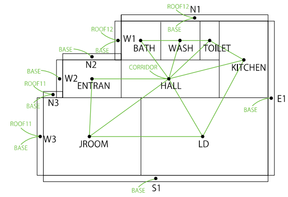
2. Overview of the calculation

air links in the model





2F



1F

In TRANFlow, airflow is calculated on the basis of the following equation.

$$\dot{m}=\alpha A\sqrt{\Delta p \cdot 2\rho}\quad [\mathrm{kg/s}]$$

$\dot{m}$: massflow [kg/s] α : coefficient of discharge [-] A: area of the opening $[m^2]$

Δp: pressure difference [Pa] ρ : air density $[kg/m^3]$

Simulation Cases

	Flow rate of the attic fan (m³/h)	Multiplier (-)
Case 0	0 (off)	-
Case 1	150	1/2
Case 2	300	1
Case 3	600	2

3. Result

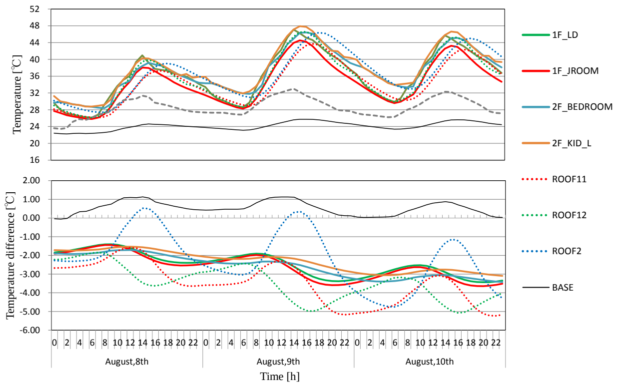


Figure 1: Temperature decrease during representative days (Case 2, 300 m^3/h)

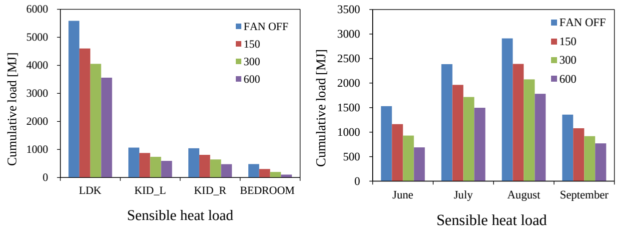


Figure 2: Total cooling load in each room/month

5

Wednesday 25 September 2013

13:45-15:15: Parallel Session 1B: Long oral presentation session- Field measurements and surveys addressing IAQ

Chairpersons: Manfred Plagmann, Samuel Caillou

- **National survey on ventilation system and occupants? Health in Japan** Kenichi Hasegawa, Japan
- **Energy efficiency and IAQ aspects of the school buildings in Greece** Niki Gaitani, Greece
- **Health issues in relation to building dampness in European Social Housing** Stavroula Karatasou, Greece
- **Sanitary aspects of domestic ventilation systems: an in situ study** Joris Van Herreweghe, Belgium

34th AIVC Conference
Field measurements and surveys addressing IAQ

NATIONAL SURVEY ON VENTILATION SYSTEM AND OCCUPANTS' HEALTH IN JAPAN

K. Hasegawa
(Akita Prefectural University)
H. Yoshino
(Emeritus Prof. of Tohoku University)

INTRODUCTION (1/2)

- It is important to maintain adequate air change rate in indoor for keeping occupants healthy in dwellings.
- In Japan, so called "sick house problem"
  - The indoor concentration of chemical substance had been higher than the guideline.
- After this affair, revision of the Building Standard Law was approved on July, 2002.
- Since 2003, the installation of mechanical ventilation has been needed in any dwellings.

INTRODUCTION (2/2)

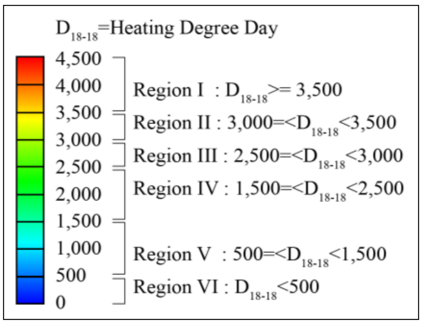
- A questionnaire in entire Japan were conducted
  - to clarify the actual conditions such as installation and operation of a ventilation system
  - to study effective ways of keeping indoor air clear with a ventilation system in dwellings.
- In this paper
  - the features of the home environment and occupants' health
  - the association between an indoor ventilation and environmental factors affecting occupants' health through a statistical analysis

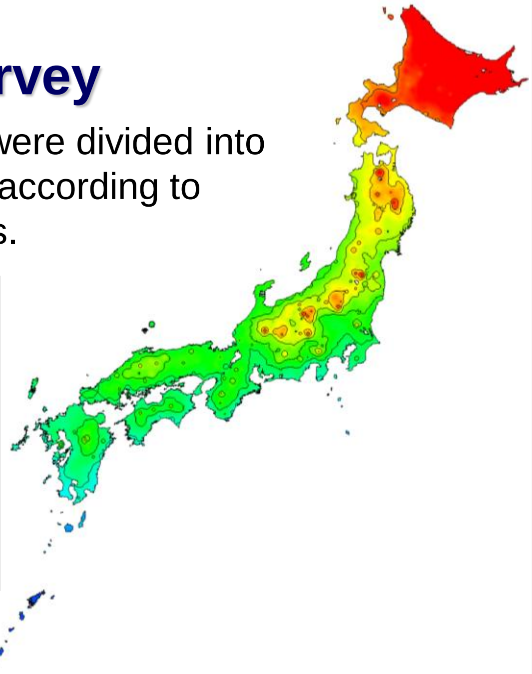
METHOD (1/4) - Outline of survey

- Questionnaires were distributed using internet survey web site on February 2012.
- The investigated houses were
  - detached houses and apartment houses
    - completed after 2003 and
    - installed a mechanical ventilation system.

METHOD (2/4)
- Outline of survey

- Investigated areas were divided into six kinds of regions according to heating degree days.





METHOD (3/4)
- Outline of survey

- The investigated areas (Region I, II, III, IV, V+VI), the number of questionnaires sent and respondents.
- The total number of respondents was 5,265 and the return rate was 67.4%.

Region	Distributed Questionnaires	No. of Respondents	Response[%]
Region I	787	526	67.4
Region II	641	417	
Region III	1,279	990	
Region IV	4,816	3,235	
Region V, VI	289	97	
Total	7,812	5,265	

METHOD (4/4)
- Outline of survey

- The contents of questions
  - the indoor environment, a ventilation system, self-reported health problems and health related QOL.
- The SF8 was used as a simple tool with which to evaluate the health related QOL.
- The health related QOL by the SF8
  - was assessed from the viewpoints of physical function, body pain, general health perception, mental health and so on
  - were summarized as Physical Component Score (PCS) by a combination of scale answers to eight specific questions

RESULTS
- Building characteristics (1/3)

Ventilation system in rooms

- A ventilation system of a mechanical exhaust and supply with and without a heat recovery was installed in about 30% of all dwellings.
- Type of a mechanical exhaust was used more than a mechanical exhaust and supply.

Items \ Region	Region I [n(%)] (N=526)	Region II [n(%)] (N=417)	Region III [n(%)] (N=990)	Region IV [n(%)] (N=3,235)	Region V, VI [n(%)] (N=97)
Ventilation system in rooms					
Mechanical exhaust and supply	75 (14.3)	82 (19.7)	192 (19.4)	669 (20.7)	24 (24.7)
Mechanical ventilation with heat recovery	56 (10.6)	62 (14.9)	111 (11.2)	286 (8.8)	6 (6.2)
Mechanical exhaust using fans on walls	264 (50.2)	216 (51.8)	415 (41.9)	1,286 (39.8)	45 (46.4)
Mechanical exhaust using ductwork system	131 (24.9)	57 (13.7)	272 (27.5)	994 (30.7)	22 (22.7)

RESULTS
- Building characteristics (2/3)

Pattern of operating the ventilation system

- Around 40% of dwellings operated a mechanical ventilation system all the time, while around 50% operated it intermittently.
- There were dwellings which didn't operate a mechanical ventilation system.

Items \ Region	Region I [n(%)] (N=526)	Region II [n(%)] (N=417)	Region III [n(%)] (N=990)	Region IV [n(%)] (N=3,235)	Region V, VI [n(%)] (N=97)
Pattern of operating the ventilation system during winter					
Using all the time	222 (42.2)	180 (43.2)	356 (36.0)	980 (30.3)	36 (37.1)
Intermittently	239 (45.4)	198 (47.5)	514 (51.9)	1,780 (55.0)	50 (51.5)
Not using	38 (7.2)	31 (7.4)	91 (9.2)	339 (4.2)	8 (8.2)
Others	27 (5.1)	8 (1.9)	29 (2.9)	136 (4.2)	3 (3.1)

RESULTS
- Building characteristics (3/3)

Reasons for not operating a mechanical ventilation system

- felt cold when operating a ventilation system
- for economizing on electric power.
- A few occupants thought that outdoor air pollutants such as pollen entered into rooms.

Items \ Region	Region I [n(%)] (N=276)	Region II [n(%)] (N=228)	Region III [n(%)] (N=601)	Region IV [n(%)] (N=2,113)	Region V, VI [n(%)] (N=58)
Reason for not operating the ventilation system					
Heat loss with operating it	76 (27.5)	64 (28.1)	153 (25.5)	512 (24.2)	9 (15.5)
Feeling cold with operating it	129 (46.7)	99 (36.9)	222 (36.9)	800 (37.9)	17 (29.3)
Entering pollen or dust from outdoor air	13 (4.7)	16 (7.0)	63 (10.5)	217 (10.3)	2 (3.4)
Economizing on electric power	77 (27.9)	75 (32.9)	209 (34.8)	839 (39.7)	25 (43.1)
Feeling noise when operating it	35 (12.7)	39 (17.1)	91 (15.1)	374 (17.7)	10 (17.2)
Not necessary to use it	87 (31.5)	79 (34.6)	215 (35.8)	781 (37.0)	27 (46.6)

RESULTS
- IAQ and health conditions (1/4)

Observed vapour condensation

- Vapour condensation on the glass surface in a living room was "Not observed" around 50% of all dwellings
- Around 10% of them observed vapour condensation with drop of water flowing.

Items \ Region	Region I [n(%)] (N=526)	Region II [n(%)] (N=417)	Region III [n(%)] (N=990)	Region IV [n(%)] (N=3,235)	Region V, VI [n(%)] (N=97)
Vapor condensation on the glass surface in a living room during winter					
Observed, clouded	36 (6.8)	37 (8.9)	77 (7.8)	342 (10.6)	10 (10.3)
Observed, drop of water attaching	131 (24.9)	113 (27.1)	287 (29.0)	936 (28.9)	24 (24.7)
Observed, drop of water flowing	54 (10.3)	53 (12.7)	149 (15.1)	434 (13.4)	8 (8.2)
Not observed	305 (58.0)	214 (51.3)	477 (48.2)	1,523 (47.1)	55 (56.7)

RESULTS
- IAQ and health conditions (2/4)

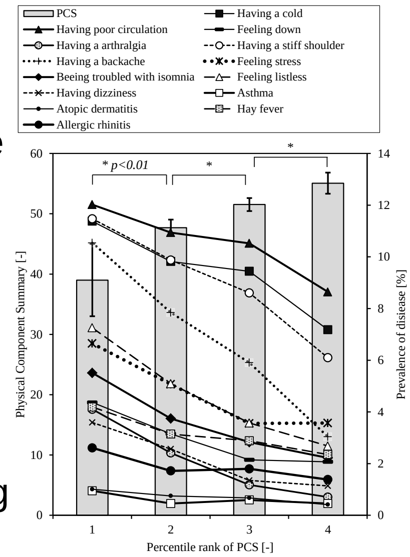
Observed mould growth

- Mould was visible on the surface of building envelopes in living room and bed room in around 15% of all dwellings.
- About 40% of dwellings observed mould growth on the surface in rooms.

Items \ Region	Region I [n(%)] (N=526)	Region II [n(%)] (N=417)	Region III [n(%)] (N=990)	Region IV [n(%)] (N=3,235)	Region V, VI [n(%)] (N=97)
Visible mould during winter					
Observed, in a living room and/or bed room	63 (12.0)	82 (19.7)	141 (14.2)	364 (11.3)	14 (14.4)
Observed, in a bathroom	112 (21.3)	151 (36.2)	328 (33.1)	1,018 (31.5)	37 (38.1)
Observed, in a kitchen	20 (3.8)	24 (5.8)	52 (5.3)	141 (4.4)	7 (7.2)
Observerd, other rooms	43 (8.2)	50 (12.0)	100 (10.1)	278 (8.6)	14 (14.4)
Not observed	360 (68.4)	218 (52.3)	584 (59.0)	1,985 (61.4)	51 (52.6)

RESULTS
- IAQ and health conditions (3/4)

- Prevalence of disease and its association with health related QOL
- All data of PCS score were distributed among 25% percentile rank.
  – Rank 1: lower than 25% percentile rank
  – Rank 4: higher than 75% percentile rank
- The averaged PCS score was significantly increasing when Rank was high.



RESULTS
- IAQ and health conditions (3/4)

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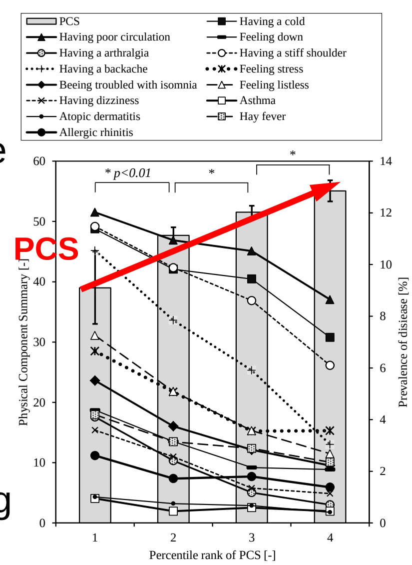
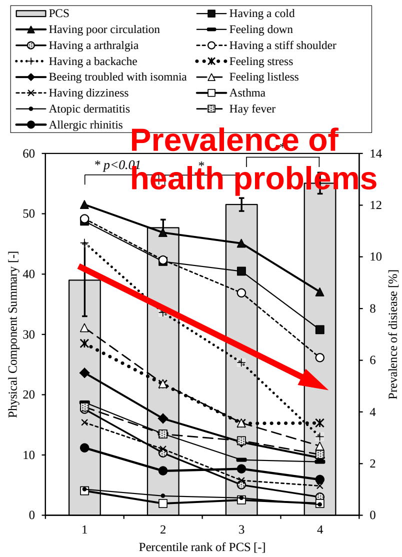


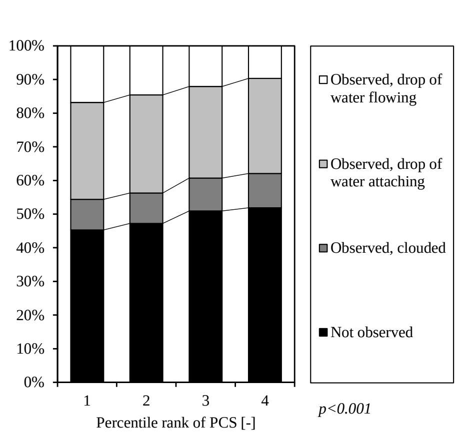
RESULTS
- IAQ and health conditions (4/4)

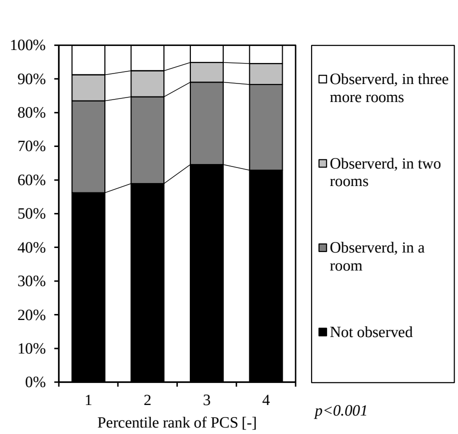
- Prevalence of self-reported health problems was decreasing with increasing ‘Percentile rank of PCS’.
- Health related QOL could represent the inclusive health condition on the basis of occupants’ self-reported answers.



RESULTS
- Health and indoor environment

- Proportion of respondents regarding indoor environmental quality in each ‘Percentile rank of PCS’

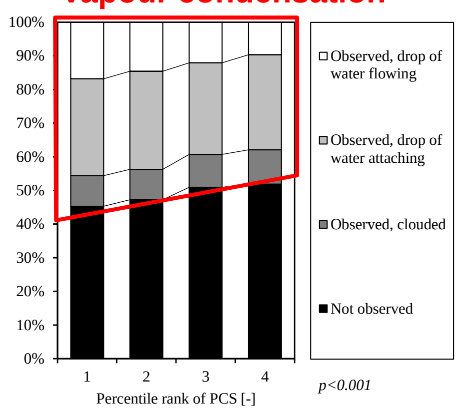




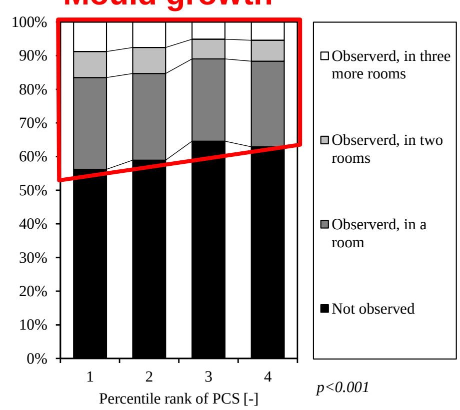
RESULTS
- Health and indoor environment

- Vapour condensation on the glass surface and mould growth in rooms significantly decreased when ‘Percentile rank of PCS’ was rising.

Vapour condensation



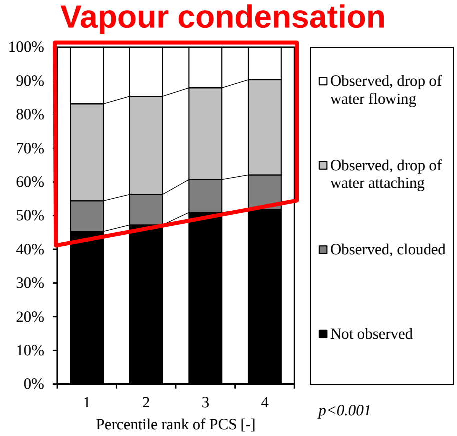
Mould growth



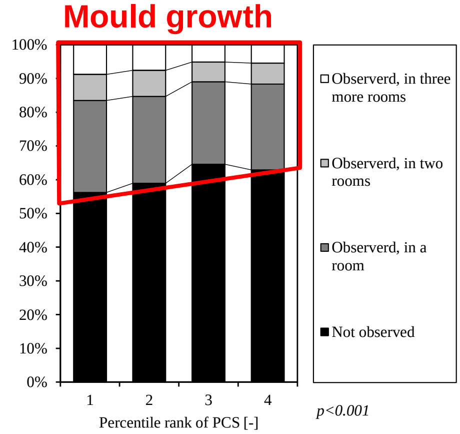
RESULTS
- Health and indoor environment

- These results indicated occupants’ health conditions was significantly associated with indoor dampness.

Vapour condensation



Mould growth



RESULTS - Ventilation system and Indoor environmental factors related health (1/5)

- Clarify the associations between ventilation system and indoor dampness related to occupants' health
- Adjusted ORs were calculated using a multivariable regression models using several variable factors related to ventilation system.
- Dependent variable
  - – Vapour condensation on the glass surface
  - – Mould growth in rooms
  - – Perception of mouldy odor
- Explanatory variable: Ventilation type, operating and cleaning ventilation system and so on.

RESULTS - Ventilation system and Indoor environmental factors related health (2/5)

- Association between vapour condensation, visible mould, perception of mouldy odour, and factors related indoor ventilation

Variable factor	Vapour condensation		Mould in rooms		Perception of mouldy odour	
	visible/not visible (N=5,062)	Adjusted OR (95% CI)	visible/not visible (N=5,062)	Adjusted OR (95% CI)	perceptible/not perceptible (N=5,062)	Adjusted OR (95% CI)
Type of ventilation system						
Mechanical exhaust	2,253 / 1,344	1.00 (Ref.)	468 / 3,129	1.00 (Ref.)	27 / 476	1.00 (Ref.)
Mechanical ventilation with heat recovery	290 / 213	0.82 (0.67-1.00)	80 / 453	0.70 (0.51-0.96)*	41 / 921	1.07 (0.70-1.63)
Mechanical exhaust and supply	640 / 322	0.99 (0.85-1.16)	128 / 834	0.86 (0.69-1.07)	179 / 3,418	0.72 (0.51-1.03)
Pattern of operating a ventilation system						
Using all the time	880 / 894	1.00 (Ref.)	153 / 1,621	1.00 (Ref.)	55 / 1,719	1.00 (Ref.)
Intermittently	1,937 / 844	2.10 (1.84-2.38)***	406 / 2,375	1.74 (1.43-2.14)***	162 / 2,619	1.82 (1.32-2.50)***
Not using	366 / 141	2.21 (1.76-2.78)***	87 / 420	2.01 (1.49-2.71)***	30 / 477	1.85 (1.15-2.97)*
Cleaning of a ventilation system regularly						
Yes	1,752 / 1,212	1.00 (Ref.)	326 / 2,638	1.00 (Ref.)	136 / 2,828	1.00 (Ref.)
No	1,431 / 667	1.21 (1.08-1.38)**	320 / 1,778	1.23 (1.03-1.46)*	111 / 1,987	0.96 (0.74-1.26)
Feel thermally comfortable in the morning						
Very cold	437 / 115	1.00 (Ref.)	137 / 415	1.00 (Ref.)	60 / 492	1.00 (Ref.)
cold	1,096 / 441	0.65 (0.52-0.83)***	221 / 1,316	0.52 (0.41-0.67)***	90 / 1,447	0.50 (0.35-0.71)***
slightly cold	1,227 / 781	0.44 (0.35-0.56)***	211 / 1,797	0.38 (0.29-0.48)***	78 / 1,930	0.33 (0.23-0.47)***
neutral	407 / 507	0.25 (0.19-0.32)***	67 / 847	0.24 (0.17-0.33)***	17 / 897	0.16 (0.09-0.27)***
slightly hot, others	16 / 35	0.16 (0.08-0.30)***	10 / 41	0.73 (0.35-1.53)	2 /49	0.34 (0.08-1.45)

Note: ***p<0.001, ** p<0.01, * p<0.05, + p<0.1 ; Adjusted for Area(Region I - VI). Ref.=referent.

RESULTS - Ventilation system and Indoor environmental factors related health (3/5)

- OR for mechanical ventilation with heat recovery was statistically significant for not visible mould in rooms.
- This result indicates that this type was better than the other types of ventilation system for prevention of mould growth in rooms.

Variable factor	Vapour condensation		Mould in rooms	
	visible/not visible (N=5,062)	Adjusted OR (95% CI)	visible/not visible (N=5,062)	Adjusted OR (95% CI)
Type of ventilation system				
Mechanical exhaust	2,253 / 1,344	1.00 (Ref.)	468 / 3,129	1.00 (Ref.)
Mechanical ventilation with heat recovery	290 / 213	0.82 (0.67-1.00)	80 / 453	0.70 (0.51-0.96)*
Mechanical exhaust and supply	640 / 322	0.99 (0.85-1.16)	128 / 834	0.86 (0.69-1.07)
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Using all the time	880 / 894	1.00 (Ref.)	153 / 1,621	1.00 (Ref.)
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Not using	366 / 141	2.21 (1.76-2.78)***	87 / 420	2.01 (1.49-2.71)***
Cleaning of a ventilation system regularly				

RESULTS - Ventilation system and Indoor environmental factors related health (4/5)

- ORs for operating a ventilation system intermittently and not using it were statistically significant for vapour condensation and mould.
- The risks of dampness in buildings were increasing when the operating time of a ventilation system was decreasing.

Variable factor	Vapour condensation		Mould in rooms	
	visible/not visible (N=5,062)	Adjusted OR (95% CI)	visible/not visible (N=5,062)	Adjusted OR (95% CI)
Type of ventilation system				
Mechanical exhaust	2,253 / 1,344	1.00 (Ref.)	468 / 3,129	1.00 (Ref.)
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Cleaning of a ventilation system regularly				

RESULTS - Ventilation system and Indoor environmental factors related health (5/5)

- ORs for not cleaning of a ventilation system was statistically significant for vapour condensation and mould growth.

Variable factor	Vapour condensation		Mould in rooms	
	visible/not visible (N=5,062)	Adjusted OR (95% CI)	visible/not visible (N=5,062)	Adjusted OR (95% CI)
Type of ventilation system				
Mechanical exhaust	2,253 / 1,344	1.00 (Ref.)	468 / 3,129	1.00 (Ref.)
Mechanical ventilation with heat recovery	290 / 213	0.82 (0.67-1.00)	80 / 453	0.70 (0.51-0.96)*
Mechanical exhaust and supply	640 / 322	0.99 (0.85-1.16)	128 / 834	0.86 (0.69-1.07)
Pattern of operating a ventilation system				
Using all the time	880 / 894	1.00 (Ref.)	153 / 1,621	1.00 (Ref.)
Intermittently	1,937 / 844	2.10 (1.84-2.38)***	406 / 2,375	1.74 (1.43-2.14)***
Not using	366 / 141	2.21 (1.76-2.78)***	87 / 420	2.01 (1.49-2.71)***
Cleaning of a ventilation system regularly				
Yes	1,752 / 1,212	1.00 (Ref.)	326 / 2,638	1.00 (Ref.)
No	1,431 / 667	1.21 (1.08-1.38)**	320 / 1,778	1.23 (1.03-1.46)*
Feel thermally comfortable in the morning				
Very cold	437 / 115	1.00 (Ref.)	137 / 415	1.00 (Ref.)

CONCLUSIONS (1/2)

- In order to clarify the actual conditions of installed ventilation system in dwellings, a questionnaire survey were conducted to the approximately 5,000 dwellings in Japan.

- Vapour condensation on the glass surface and visible mould growth in rooms significantly decreased when health related QOL was rising.

  ➡ These results indicated indoor dampness was associated with occupants' health conditions.

CONCLUSIONS (2/2)

- Through a multivariable regression analysis,
  - ➡ the mechanical ventilation with heat recovery was operating more effectively due to prevent moluld growth in rooms than the other types.
  - ➡ the risks of vapour condensation and mould growth increased with decreasing the operating time of a ventilation system.

Energy Efficiency & IAQ Aspects of the School Buildings in Greece

Niki Gaitani

National & Kapodistrian University of Athens, Greece

Objective

Energy efficiency & Indoor Air Quality
key issues of Energy Strategy & Environmental Policy in Europe

- Energy classification
- Environmental evaluation

Schools have standard energy requests & high levels of environmental comforts have to be guaranteed

State of the Art

Source: http://www.luzinterruptus.com/?p=1357

- 1930: Orientation of schools
- 1970: Natural Lighting & Ventilation
- 1980: Insulation
- 1982: Guidelines (incl shading, vegetation)
- 2002: EPBD (2002/91/EC)
- 2004: Bioclimatic approach, rating schemes
- 2008: Law 3661 on "Measures to reduce energy consumption in buildings and other provisions"
- 2010: EPBD recast (Directive 2010/31/EU)

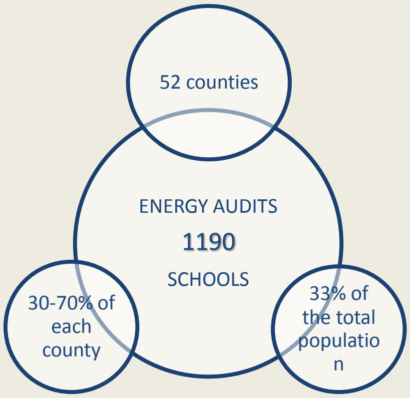
New buildings occupied & owned by public authorities have to be nearly zero energy buildings after 31 December 2018

Methodology

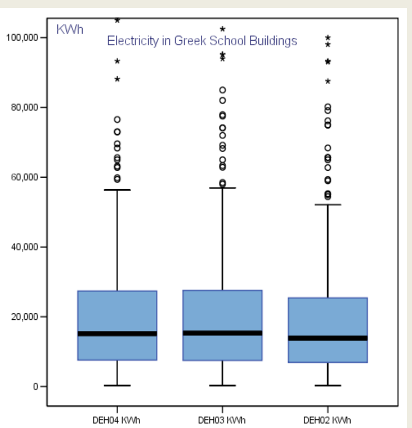
1. Energy Survey through Energy Audits
2. Statistical Analysis of the Data Base
3. Rating Energy Performance (K_means Clustering) Energy Classification
4. Definition of Typical School through PCA
5. Identification of best practices (thermal simulations with TRNSYS)
6. Environmental quality measurements IAQ

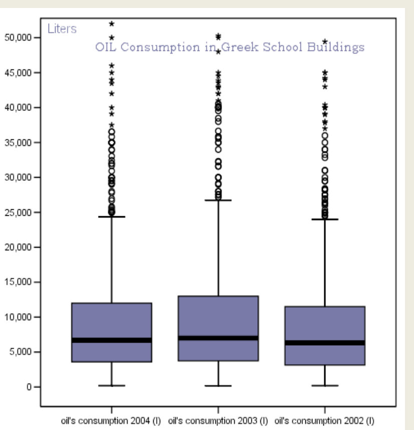
Survey Schools

- Energy Consumption for Heating (OIL, L) for 3 years
- Energy Consumption for Electricity (ΔEH, kWh) for 3 years
- Construction year of the building
- Area of the building and heating surface
- Number of users
- Operation Schedule
- Installed power of the boiler



Energy Consumption



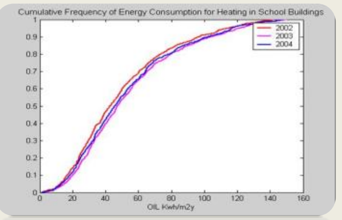


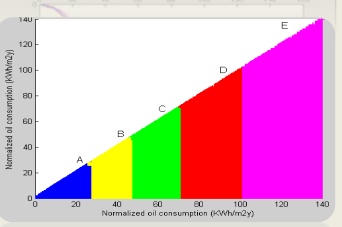
Median energy consumption electricity_ 13.925-15.252 kWh

Median energy consumption space heating (oil)_6300-7000 L

Classification

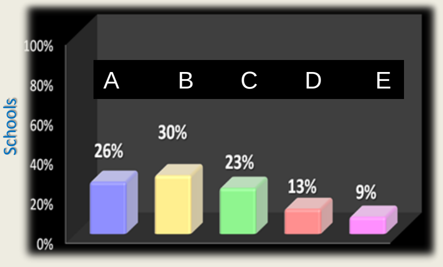
		$OILN_{04}$ kWh/m^2y	$OILN_{03}$ kWh/m^2y	$OILN_{02}$ kWh/m^2y
N	Valid	944	918	901
	Missing	247	273	290
Mean		63.8	65.8	61.0
Median		47.9	49.5	45.7
Std. Deviation		61.9	61.5	59.9
Percentiles	25	29.9	31.2	27.7
	50	47.9	49.5	45.7
	75	77.3	79.6	73.7





The energy performance of the school buildings, was rated using K-means algorithm and the audited school buildings were classified into five energy classes A–E

Benchmarks



A Class
Q_{25} =17kWh/m² Q_{50} =23kWh/m²

B Class
Q_{25} =37kWh/m² Q_{50} =42kWh/m²

C Class
Q_{25} =57kWh/m² Q_{50} =62 kWh/m

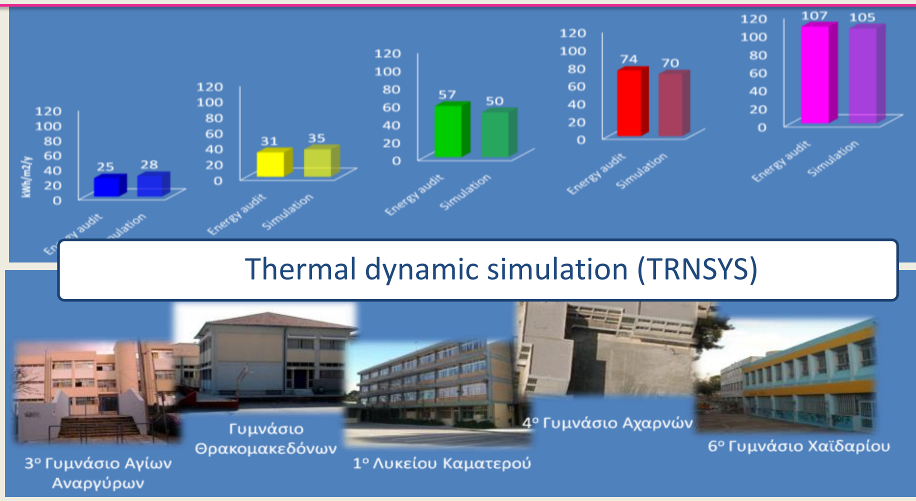
D Class
Q_{25} =81kWh/m² Q_{50} =87 kWh/m

E Class
Q_{25} =114kWh/m² Q_{50} =123 kWh/m²

A methodology based on the use of the principal components analysis (PCA) has been developed

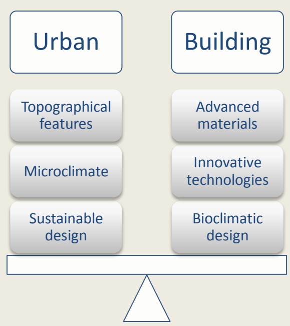
The typical characteristics of school buildings belonging to an energy class have been identified

Modeling Schools



Energy saving potential

Heat Recovery	• 15%
Double glazing Low e	• 19%
Demand control ventilation	• 23%
External insulation	• 32%
Air Tightness	• 44%



Growing experience in designing shows clearly that an integrated approach is essential

Environmental Quality

Measurements of air quality were conducted within 10 school buildings in the Greater Athens area

Hourly measurements of ambient indoor & outdoor temperature and relative humidity have been performed, while indoor air velocity and infiltration have been also monitored

Furthermore, CO_2, CO, TVOCs were measured in 83 examined classrooms

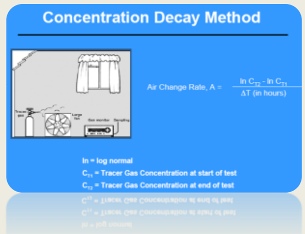
IAQ

	Min	Average	Max	Number of classrooms & percentage that exceed the acceptable limit	Min	Average	Max	Number of classrooms & percentage that exceed the acceptable limit	Min	Average	Max	Number of classrooms & percentage that exceed the acceptable limit	Number of classrooms & percentage that exceed at least one limit, in total
1	0,28	0,67	1,05	0/8 (0%)	413	675	1298	4/8 (50%)	0,14	0,40	0,78	8/8 (100%)	8/8 (100%)
2	0,74	1,42	2,67	0/9 (0%)	867	1258	1628	9/9 (100%)	0,00	0,60	1,32	8/9 (89%)	9/9 (100%)
3	0,30	1,09	3,10	0/8 (0%)	424	813	1664	5/8 (63%)	0,23	1,34	3,62	8/8 (100%)	8/8 (100%)
4	0,52	0,92	1,45	0/12 (0%)	105	661	1133	6/12 (50%)	0,01	0,76	1,53	11/12 (92%)	11/12 (92%)
5	0,25	0,36	0,44	0/3 (0%)	367	602	1040	1/3 (33%)	0,24	0,93	2,15	3/3(100%)	3/3 (100%)
6	0,14	0,57	1,15	0/11 (0%)	396	598	846	5/11 (45%)	0,05	0,60	1,68	11/11 (100%)	11/11 (100%)
7	0,28	0,88	1,70	0/7 (0%)	446	833	1373	4/7 (57%)	0,02	0,74	2,55	4/7 (57%)	5/7 (71%)
8	0,19	0,32	0,61	0/10 (0%)	363	576	786	7/10 (70%)	0,02	0,08	0,21	9/10 (90%)	9/10 (90%)
9	1,27	1,70	2,25	0/8 (0%)	408	600	1246	3/8 (38%)	0,58	1,28	2,29	8/8 (100%)	8/8 (100%)
10	3,80	4,08	4,47	0/7 (0%)	772	1070	1873	7/7 (100%)	1,42	2,45	5,34	7/7 (100%)	7/7 (100%)
Sum				0/83 (0%)				51/83 (61%)				77/83 (93%)	79/83 (95%)

- All CO concentration values were measured below the international limits
- Very high levels of CO_2 were measured related to inadequate ventilation
- In 7 out of 10 schools, TVOCs were measured in the classrooms above the recommended limit values

Natural Ventilation

School number	Infiltration (ACH)	Infiltration & natural ventilation (ACH)
1	0.1	3.5
2	0.2	2.8
3	0.4	9.0
4	1.2	4.6
5	1.9	6.9
6	0.1	7.4
7	0.2	1.7
8	0.3	3.8
9	0.9	7.3
10	0.3	2.4
11	0.5	12.1
12	0.9	10.2
13	1.3	6.0
14	0.4	11.7
15	0.4	1.3
16	0.4	1.4
17	0.3	2.0
18	0.2	4.8



Infiltration in all schools varied between 0.1 to 0.9ACH with a mean value close to 0.4ACH

Combined air flow rates (natural ventilation & infiltration) varied between 1.3-12.1ACH with a mean value of 2.2ACH

Thermal Comfort

A/α	Minimum WBGT (°C)	Average WBGT (°C)	Maximum WBGT (°C)
1	19	21	22
2	14	15	16
3	21	22	22
4	18	20	21
5	19	21	23
6	19	21	23
7	16	18	19
8	19	21	23
9	22	22	23
10	14	16	18

The average value of the calculated WBGT index was ranged from 15˚C to 22˚C

The cooling power calculated values was varied in the range 4.6-7.4mcal*cm-2*sec-1 of irritating warm environment to tolerable cold environment

A/α	Minimum CP (mcal $cm^{-2}sec^{-1}$)	Average CP (mcal $cm^{-2}sec^{-1}$)	Maximum CP (mcal $cm^{-2}sec^{-1}$)
1	4.30	5.21	5.90
2	6.70	7.07	7.30
3	4.70	5.06	6.10
4	5.30	5.91	7.30
5	4.50	5.20	6.20
6	3.80	4.55	5.70
7	5.80	6.27	7.10
8	4.00	4.78	5.90
9	4.00	4.70	6.40
10	6.60	7.36	8.20

Concluding remarks

Greek schools:

•have great potential for energy conservation. The energy consumption may be reduced up to 50% with simple measures

•feature indoor air quality problems

The data obtained endorse a general energy evaluation for space heating for the Greek school buildings. The clustering in 5 classes could be used for energy saving techniques applied from the decision makers

Thank you for your attention!

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34th AIVC Conference
25-26 September 2013
Athens, Greece

HEALTH ISSUES IN RELATION TO BUILDING DAMPNESS IN EUROPEAN SOCIAL HOUSING

S. Karatasou, M. Laskari and M. Santamouris
Group Building Environmental Studies, NKUA

ICE-Wish Project Participating Countries

ICE WISH

Demonstrating through Intelligent Control (smart metering, wireless technology, cloud computing, and user-oriented display information), Energy and Water wastage reductions In European Social Housing

2011-2014

- Genk (VMSW) - **Belgium**
- Schumen (CAC) - Bulgaria
- Aarhus (RING) - **Denmark**
- St. Quentin-Fallavier (OPAC38) - **France**
- Nuremberg (JOSEPH-STIFTUNG) - **Germany**
- Larisa (OIKAN) - Greece
- Firenze (CasaQualita) - **Italy**
- Warsaw (Warsaw) - **Poland**
- Bilbao (BILBAO-VIVIENDAS) - **Spain**
- Bournemouth (BBC) - UK

Objectives

- The aim of this study is to
  - Examine the **frequency of indoor dampness** in social housing in different European countries
  - Examine **whether dampness** in these residential buildings **is related to health issues** such as asthma, or allergies.

Data and Methods

- The sampling frame
  - low income occupants living in social housing across 7 different European countries
  - A total of 215 households have responded and participated to the survey
- Survey Tool : Questionnaire
  - Symptoms related questions
  - Building's dampness condition related questions
  - The analysis is based on participants' responses

Data and Methods

- Symptoms related questions:
  - ‘asthma or other respiratory problems’
  - ‘stroke or other circulatory problem’
  - ‘rheumatism or other joint problem’,
  - ‘Eczema or other skin condition’
  - ‘allergies’,
  - ‘colour blindness’ and
  - ‘requires use of a wheel chair’

Data and Methods

- Building’s dampness condition related questions
  - condensation on the windows/walls/ceilings
  - damp patches on the walls/ceiling
  - mould on the walls/ceiling
  - mould on the furniture, carpets or clothes.

This question was repeated for the following room types:

- kitchen,
- bathroom,
- bedroom,
- living-room
- any other space.

Results

⇨ **Descriptive overview of the European Countries included in the study**

	Belgium	Denmark	France	Germany	Italy	Poland (EG)	Spain	Poland (CG)	Total estimate
Symptoms									
Asthma	20.0%	12.0%	41.7%	8.3%	.0%	6.7%	22.2%	26.7%	15.9%
Stroke	4.0%	24.0%	25.0%	8.3%	.0%	3.3%	3.7%	3.3%	7.7%
Rheumatism	16.0%	20.0%	58.3%	16.7%	.0%	3.3%	18.5%	.0%	13.3%
Skin	4.0%	24.0%	8.3%	12.5%	.0%	3.3%	7.4%	.0%	7.2%
Allergies	28.0%	20.0%	41.7%	41.7%	31.8%	30.0%	25.9%	30.0%	30.3%
Dampness Conditions									
Condensation	27.6%	33.3%	19.0%	48.3%	18.2%	.0%	29.6%	3.3%	22.3%
Damp patches	17.2%	17.9%	19.0%	16.7%	29.2%	13.3%	20.7%	3.3%	9.8%
Mould structure	6.9%	7.4%	.0%	13.8%	18.2%	.0%	14.8%	3.3%	7.9%
Mould Furniture	.0%	.0%	.0%	3.4%	.0%	.0%	7.4%	.0%	1.4%

Results

⇨ **Dampness frequency per room type**

Room Type	Dampness per room type (n=215) (%)
Kitchen	15.8
Bathroom	**18.2**
Living Room	13.9
Bedroom	**19.4**
Other Place	8.5

⇨ **Dampness conditions per room type**

	Condensation	Damp patches	Mould /Structure	Mould/Furniture
Kitchen	14.0	3.7	3.0	0.6
Bathroom	15.2	**5.5**	**4.9**	0.6
Living Room	12.2	4.9	3.0	0.6
Bedroom	**15.9**	5.5	3.0	**1.8**
Other space	7.3	3.0	2.4	**1.8**

Binary logistic regression Results

⇨ **Symptoms related to the building dampness conditions**

Symptom	OR (95% CI) Condensation	Damp patches	Mould growth
Asthma	1.657 (.638-4.303)	**3.437 (1.072-11.022)****	2.588 (.750-8.937)
Stroke	0.736 (.193-2.804)	1.661(.336-8.210)	.761(.092-6.268)
Rheumatisms	1.723 (.718-4.133)	.689 (.148-3.209)	.744 (.159-3.487)
Skin	3.036 (.999 9.221)	**4.752 (1.285-7.573)***	1.792 (.360-8.911)
Allergies	**2.108 (1.005-4.422)***	1.250 (.413-3.784)	1.376 (.449-4.219)

Binary logistic regression Results

⇨ **Each Symptom related to the building dampness conditions. Category I any of the dampness conditions, Category II both dampness conditions**

Symptom	OR (95% CI) Category I	Category II
Asthma	**2.671 (1.055-6.762)***	1.330 (0.339-5.221)
Skin	2.688 (0.856-8.440)	1.472(0.28-7.747)
Allergies	1.886 (0.913-3.897)	**2.689 (1.094-6.610)****

Conclusions

⇨ **In total 215 households were examined in the present study, within seven different European countries.**

⇨ Dampness was reported by **16%** of the population in this study, while condensation in structural parts of dwellings was reported by **22%** of the same population

⇨ The most prevalent symptoms among participants are **allergies** and **asthma**

⇨ Main results of this study indicate an **increased risk** of asthma and allergies (**ORs of around 2.7**).

⇨ The increased prevalence of **asthma** and other respiratory symptoms is predominately present in participants reporting **damp patches**, while **allergies** are more prevalent in participants reporting **all conditions of dampness**

Conclusions

Thank You

Sanitary aspects of domestic ventilation systems: an *in situ* study

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Laboratory of Microbiology and Health

Belgian Building Research Institute

Overview

- Introduction
- Results
- Conclusions & recommendations

Overview

- **Introduction**
  - **micro-organisms?**
  - goal and approach
- Results
- Conclusions & recommendations

Introduction

Micro-organisms

- Micro-organisms: Molds, Bacteria, Yeast, Algae and Lichens
- Presence not visible with the naked eye, only in case of massive growth
- Required conditions: comfy temperature (5-35°C; (oxygen), substrate, **sufficient moisture (limiting factor)**
- Spread easily through the air
- can cause health issues

Plan de l'exposé

- **Introduction**
  - micro-organisms?
  - **goal and approach**
- Results
- Conclusions & recommendations

Introduction
Goal and approach

Why: Analyse the influence of the ventilation system and its parts on the sanitary aspects of the supplied and indoor air

How: Sampling of the outdoor, indoor and supply air & analysis of the surfaces (filters, grids,..)

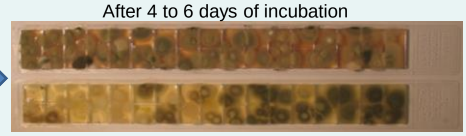
Exhaust Syst.: 5X
Balanced Syst.: 27X

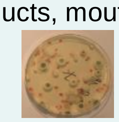
Houses without visible mold or dampness problems

Introduction

The approach

	Exhaust sytems (5)	Balanced systems (27)
Air sampling	After 4 to 6 days of incubation Quantitative: comparison of Outdoor, Supply, Indoor Qualitative: comparison of the identified genera identification	
Surface sampling	Adjustable supply grids	Filters, ducts, mouths …

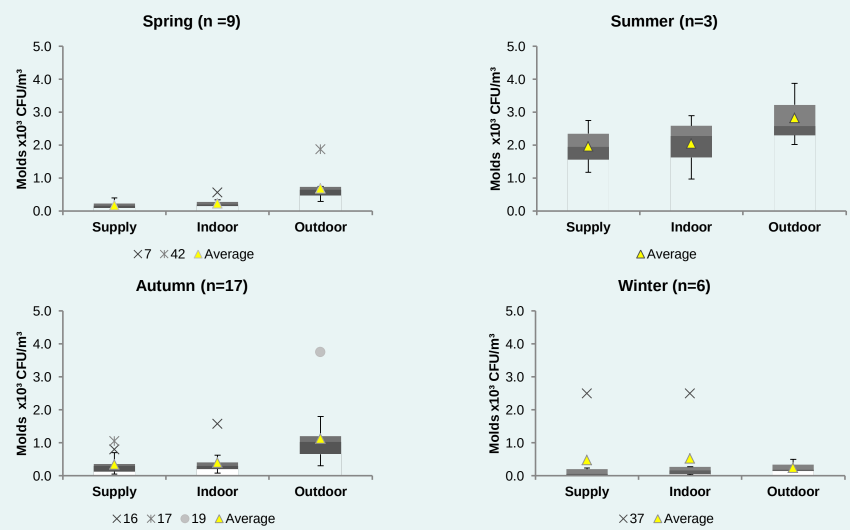



Overview

- Introduction
- **Results**
  - **Seasonal influences**
  - Exhaust systems
  - Balanced systems
- Conclusions & recommendations

Results

Seasonal influences: mold numbers



Results

Seasonal influences: conclusions

- mold load in the outdoor air is seasonal dependent (Bacterial load not-> data not shown)
- summer> autumn> spring> winter
- # supply and indoor air is related to # outdoor air (independent of the system type)
- # supply and indoor air < # outdoor air

Overview

- **Introduction**
- **Results**
  - Seasonal influences
  - **Exhaust systems**
  - Balanced systems
- **Conclusions & recommendations**

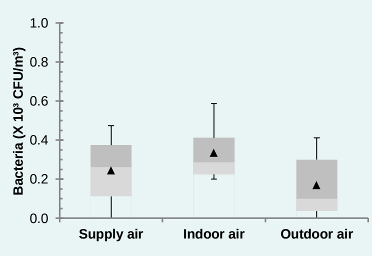
Results

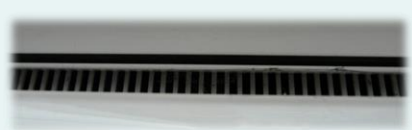
Exhaust systems: bacteria

- Indoor > Supply > Outdoor
- supply > outdoor

  => not due to a large amount of bacteria on the supply grid

  => aspiration of indoor air during sampling?





Adjustable supply grid

Results

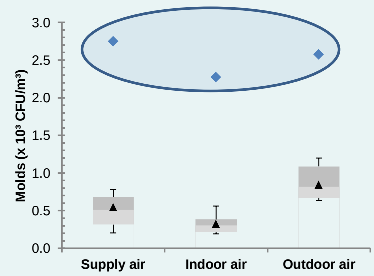
Exhaust systems: molds

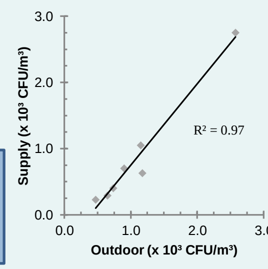
- outdoor > supply > indoor
- Direct relation between Outdoor and Supply

=> no change in the microbial composition of the supplied air

=> Quality of the supplied air is strongly seasonal dependent

1 house
→ 3 X sampled in three different seasons
Autumn and spring = normal values
Summer = extremely high values





Overview

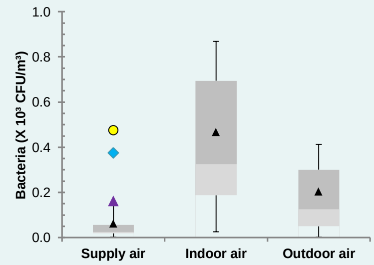
- Introduction
- **Results**
  - Seasonal influences
  - Exhaust systems
  - **Balanced systems**
- Conclusions & recommendations

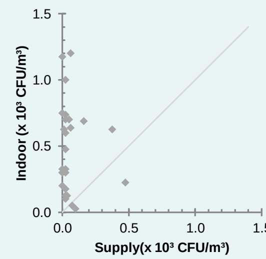
Results
Balanced systems: bacteria

- Indoor > Outdoor > Supply
- supply << outdoor

=> Filters cause a reduction in bacterial load
=> Most likely the results of a bulk effect and electrostatic interaction

○ : New Filters, no bulk effect
◆ : Old G3 sock filters, which might be leaky



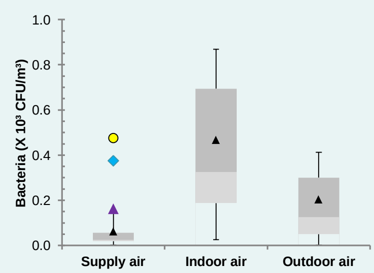


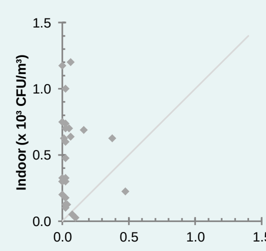
Results
Balanced systems: bacteria

- Indoor > Outdoor > Supply
- supply << outdoor
- Indoor >> outdoor although < supply

Indoor environment and human presence
(skin, hair and nostrils)

= important sources of bacteria





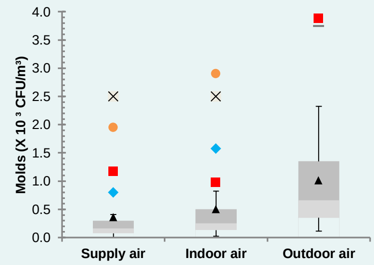
Results

Balanced systems: molds

- Outdoor > indoor > Supply
- supply < outdoor

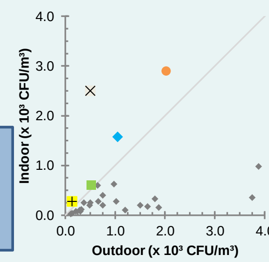
=> Filters cause a reduction (impact retention)

=> All exceptional values can be attributed to autumn and summer =>pressure on the system



■ : 70 % reduction, but still high mold levels

▬ : high mold load in the outdoor air, but no exceptional values for supply and indoor air (97% removal by the filter)

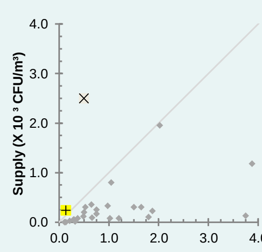


Results

Balanced systems: filter analysis and performance

- Main goal: protection of the system
  Optional: improvement of the air quality

- Majority: $\frac{supply}{outdoor} < 1$
  2X >1 : construction errors and under construction
  1X ≈ 1: leaking filters



Resultaten

Balanced systems: filter analysis and performance

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  Optional: improvement of the air quality

- Majority: $\frac{supply}{outdoor} < 1$
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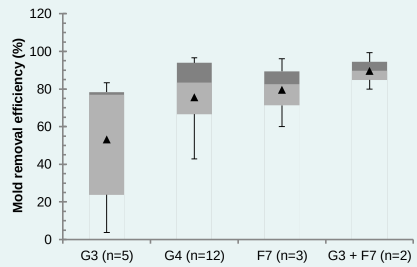
  1X ≈ 1: leaking filters

- Mesh size↓ → mold retention↑
  differences between the finest filters rather small



Resultaten

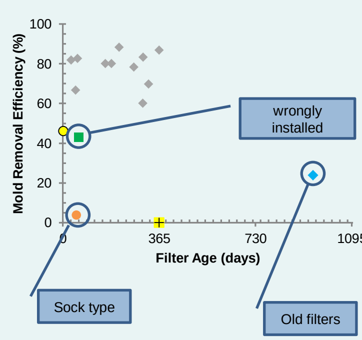
Systemen D: filter analyse en performantie

- Main goal: protection of the system
  Optional: improvement of the air quality

- Majority: $\frac{supply}{outdoor} < 1$
  2X >1 : construction errors and under construction
  1X ≈ 1: leaking filters

- Mesh size↓ → mold retention↑
  differences between the finest filters rather small

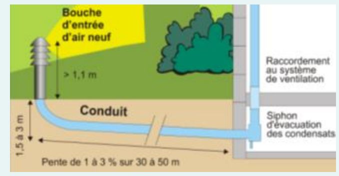
- Old filters always pose a risk,
  but new ones are not always reliable



Results

Balanced systems: Canadian Well

- Large amount of bacteria on the supply filter



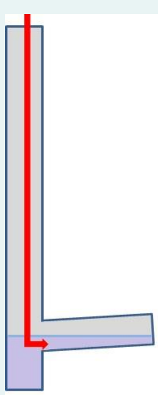
Bron: http://ericjarrot.free.fr/guide_puits_canadiens.pdf

- No influence observed on the number of bacteria in the supplied air BUT all samples were collected in winter

- Repeated in summertime (2 systems)
  => No influence on the bacterial level of the supply air
  => Condensation issues

Results

Balanced systems: Canadian well



Overview

- Introduction
- Results
- **Conclusions & recommendations**

Conclusions

- µB quality of outdoor air → µB quality of indoor air
- Indoor environment and human occupation have a large influence on the indoor bacterial level
- Exhaust : µb quality of the indoor air strongly dependent on outdoor air
- Balanced: possibility to improve the quality of the supplied air, especially for its mold load
  BUT:
  the efficiency is strongly dependent on the quality of the filters, the airtightness of the filters and its housing and their state

underscores the importance of a rational design, a proper installation and good maintenance

Recommendations
Design

- G4 is sufficient
- Good filter type, no sock filters

Priority: airtightness
- Prevent incorrect installation
- Prevent by-pass leakiness

higher efficiency desired?:

F7 fine dust filter can be combined with an inline coarse dust filter (G3 or G4) in front of the exchange unit

Recommendations
Installation

Avoid a vertical air intake
(accumulation of dirt on the pulsion site and filters at risk to become wet)

Respect a certain distance between the fresh air intake and exhaust points (chimney, aeration of wastewater,…)

Never launch the system in a building under construction

Ducts should be protected shortly after production and remain covered during storage, transport, installation and until occupation of the house

Recommendations

Maintenance

3 monthly based inspection and yearly cleaning of the controllable supply grids and extraction ducts

clean the filters every 2 to 3 months using a vacuum cleaner (HEPA14 filter)

Once a year, replace the filters, preferably before winter time

Clean the grill of the supply air intake and the supply and extraction mouths

Ducts: regular inspection and/or cleaning (rigid ducts) or replacement (flexible ducts) is recommended

Acknowledgements

Thank you to:

Agency for Innovation by Science and Technology in Flanders for the financial support

My colleagues

Thank you for your attention!

Wednesday 25 September 2013

13:45-15:15: Parallel Session 1C: Long oral presentation session- Airtightness: Collection and analysis of field data

Chairpersons: Andrzej Gorka, Paula Wahlgren

- **Airtightness quality management scheme in France: assessment after 5 years operation** Sandrine Charrier, France
- **Preliminary analysis of a French Buildings Airtightness Database** Adeline Bailly, France
- **A stochastic approach to predict the relationship between dwelling permeability and operational infiltration in English apartments** Benjamin Jones, UK

Energy conservation technologies for mitigation and adaptation in the built environment

The role of ventilation strategie and smart materials

34th AIVC Conference

3rd TightVent Conference

2nd Cool Roofs' Conference

1st VentiCool Conference

Airtightness quality management scheme in France

Assessment after 5 years operation

Sandrine Charrier

25-26 September 2013, Athens, Greece

Summary

- Context
- Committee process and its evolutions
- Control process
- Conclusion

Context

- **The French energy performance regulation allows 2 ways to justify the airtightness value of building envelope**
  - By a measure
  - By the application of a certified airtightness quality management (QM) approach
- **QM approach: precise description of who does what, when and how**
  - Throughout the whole project and construction
  - Each step must be traceable and traced
  - The efficiency must be proven by measuring the airtightness value of a sample of the production

Context

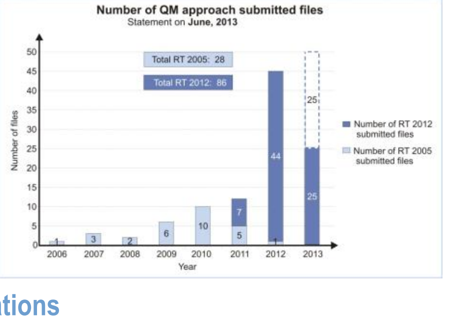
- **Airtightness QM approach certifications**
  - Delivered **from 2006 to 2012** for the 2005 version of the French EP regulation ("**RT 2005**")
  - Delivered **since 2012** for the 2012 version of the French EP regulation ("**RT 2012**")
  - Analyzed by a committee composed by national experts, called the **Annex VII committee**
- **The paper aims to:**
  - Present the quantitative and organizational evolutions after more than 5 years operation
  - Present the controls results of the certified constructors

Summary

Committee process and its evolutions

- **A successful approach in the RT 2005**
  - In the RT 2005, **a voluntary approach** in order to be better than regulatory buildings
    - → 28 requests from 2006 to 2012, 24 certifications

- **An important increase in the number of requests with the RT 2012**
  - In the RT 2012, the certified QM approach enables the constructor **to comply with the regulation**



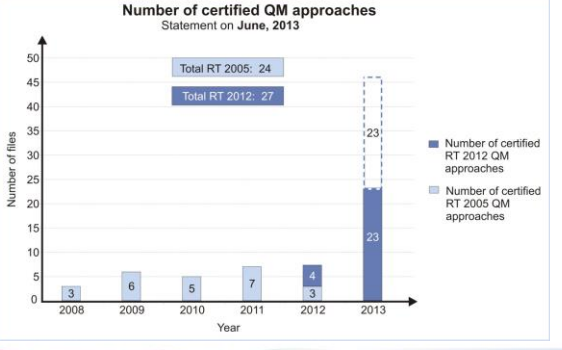
- **An evolution in the expectations**
  - RT 2012 QM approaches more precise than RT 2005 ones

Committee process and its evolutions

A consecutive evolution of the committee organization

- The **number of analyzed files** multiplied by **7** between 2011 and 2013
- **Time** between the first file submission date and the certification date **has not grown** since 2011 (around 10 months).

Consequence: the number of certified QM approaches increased in accordance with the requests evolution



Summary

- Context
- Committee process and its evolutions
- **Control process**
- Conclusion

Control process

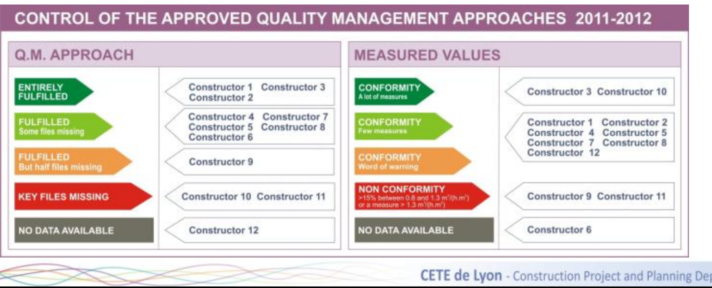
- **The French State set up 2 control processes in order to guarantee the certified approaches reliability**
  - Yearly file analysis
  - Control campaign by independent controllers

Control process

- **The yearly file analysis**
  - With this file analysis, the Annex VII committee checks whether:
    - the certified QM approaches are **actually implemented** and **fulfilled**
    - the **measured results** are in accordance with regulation
    - the **evolution of yearly measured results** tend to **lower values of airtightness**

Control process

- **The control campaign** [1]
  - Aimed at verifying the **actual implementation** of the certified approaches **on a sample of buildings**
  - Control done by independent state employees
  - Divided in 2 parts
    - **A qualitative control:** control of the fullfilment of files
    - **A quantitative control:** control of the effective airtightness level
  - **Results in a double label:**



Conclusion

- **Airtightness QM schemes: a successful process**

- **Control processes: both are complementary and maintained. A second control campaign will occur in 2013-2014**

- **Prospects**
  - As it occurred with measurers' qualification in 2010 [2], need to dedicate the airtightness QM approaches management to a **private entity**. Control of certifications would be maintained by state controllers.
  - Next step: **QM approaches for the airtightness of ventilation ducts**.

Acknowledgments

Thank you for your attention

Sandrine Charrier

Airtightness quality management scheme in France
Assessment after 5 years operation

25-26 September 2013, Athens, Greece

The authors are grateful to the French ministry for ecology, sustainable development, and energy (MEDDE), and in particular to the DGALN Department, for its support throughout this work.

The responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the Ministry.

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Charrier, S., Ponthieux, J.(2013). Airtigtness quality management scheme in France: Assessment after 5 years operation, 34th AIVC Conference and 3rd TightVent Conference, 25-26 September 2013, Athens, Greece

[1] Charrier, S., Huet, A., Biaunier, J.(2013). Control of airtightness quality management scheme in France: results, lessons and future developments. 34th AIVC Conference and 3rd TightVent Conference, 25-26 September 2013, Athens, Greece

[2] Leprince, V., Carrié, R., Olivier, M. (2011). The quality framework for air-tightness measurers in France : assessment after 3 years operation, 32nd AIVC Conference and 1st TightVent Conference, 12-13 October 2011, Brussels, Belgium.

Energy conservation technologies for mitigation and adaptation in the built environment

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Preliminary Analysis of a French Buildings Airtightness Database

Adeline Bailly

25-26 September 2013, Athens, Greece

French Ministry for Ecology, Sustainable development and Energy

CETE de Lyon, Construction Project and Planning Department

Summary

- Context
- Database parameters
- First airtightness performance analysis
  - Recent constructions airtightness
  - Residential buildings
  - Non-residential buildings
- Conclusion

Context

- **Improvements of air-leakage measurements in France:**
  - Labels (BBC-Effinergie label since 2007)
  - EP-Regulation RT 2012 (since January 1st 2013)

    → airtightness requirements for residential buildings

  - Effinergie+ label

    → airtightness requirements for residential buildings

    → compulsory measurement for some non-residential buildings

- **Impressive source of data "easily" available:**
  - Certified operators register

Database parameters

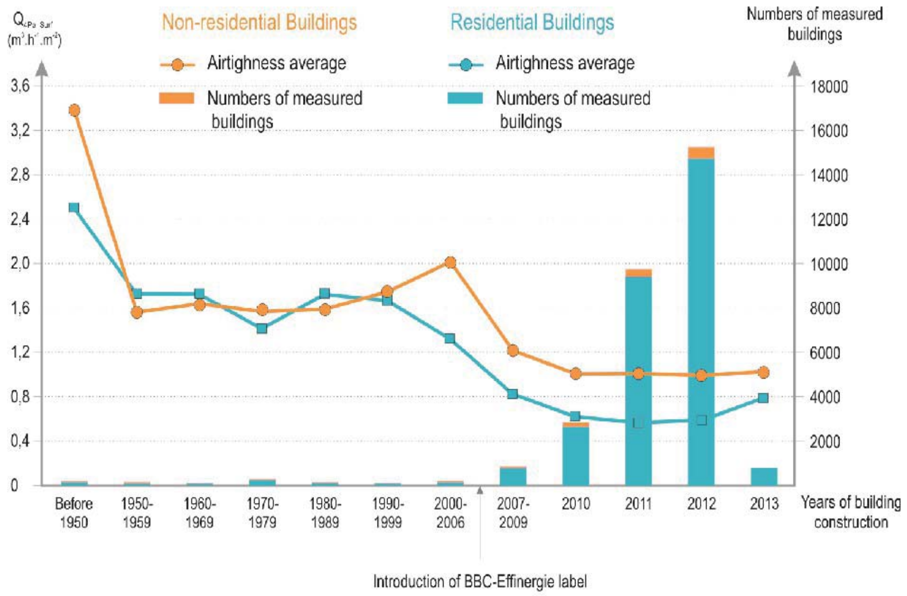
- **Buildings properties:**
  - Region and climate zone
  - Building use, building age
  - Certification & label
  - Main material, constructive mode, insulation type
  - Ventilation system, heating system
  - Area, volume

- **Measurement characteristics**
  - Measurement devices, method, local measured

- **Airtighness performance**
  - C, n, Q_{4Pa_surf}, n_{50}
  - W_{4Pa}, ELA_{4Pa}, NL

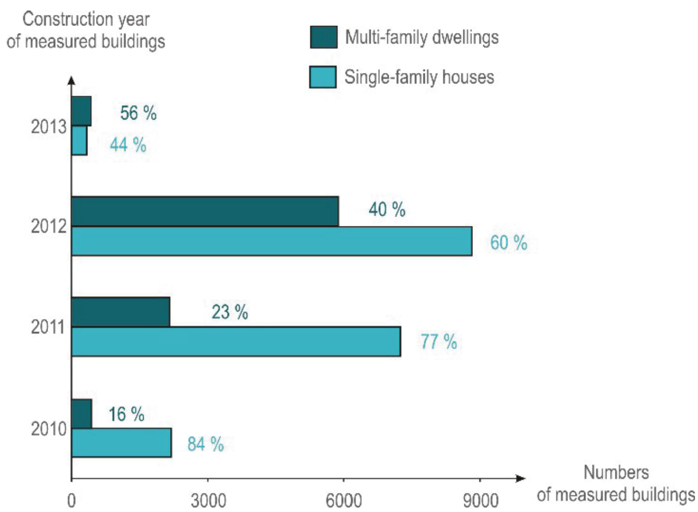
Recent constructions airtightness

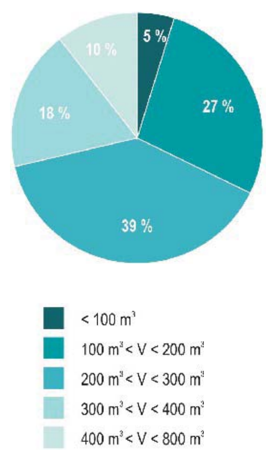
- **New buildings more concerned by airtightness measurements:**



Residential buildings

- **More multi-family dwellings measured in the last few years:**



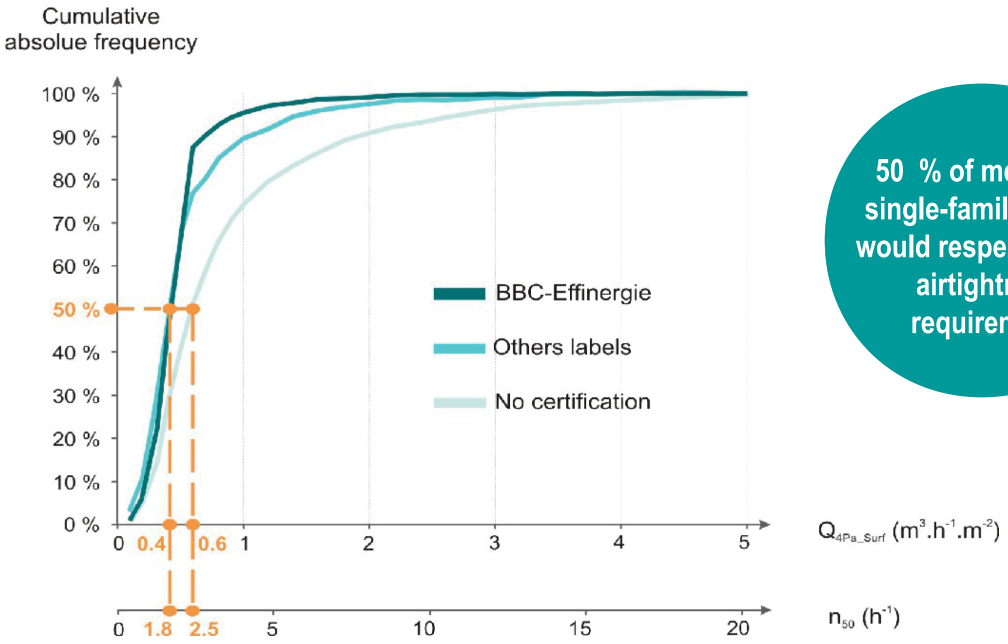


- **Main material :** Concrete , Brick and Wood

- **Important part of labels**

Residential buildings

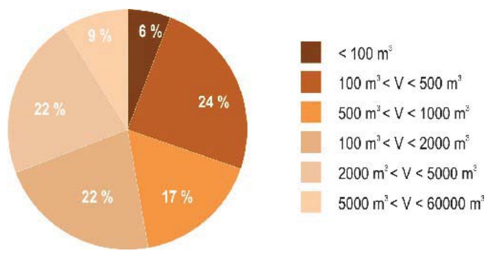
■ Label impact on single-family houses airtightness:



50 % of measured single-family houses would respect RT2012 airtightness requirements

Non-residential buildings

■ Non-residential buildings characteristics:



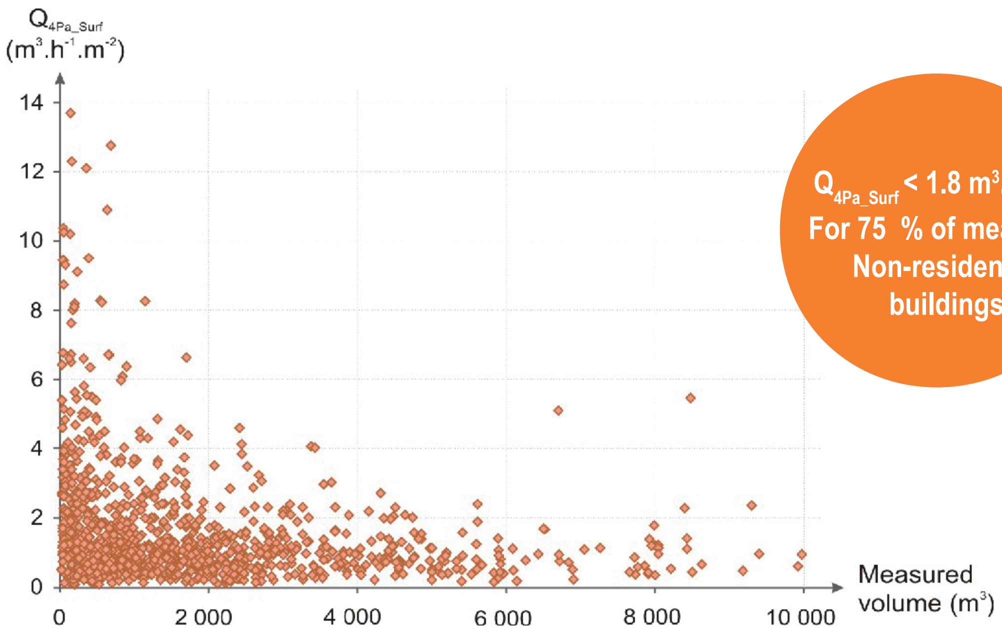
- Office buildings : 38 %
- Schools : 36 %
- Sanitary buildings : 10 %

- **Main material :** Concrete and Wood

Important part of buildings applying for a label: 44 %

Non-residential buildings

- Large volumes are not the worst



Q_{4Pa_Surf} < 1.8 $m^3.h^{-1}.m^{-2}$
For 75 % of measured
Non-residential
buildings

Conclusion

- An important data source
  - *2013: more than 31 000 data*
  - *100 000 data each year*
- Various parameters to study
- Many future studies to perform
  - *Cross analysis*
  - *Leaks distribution*

Thank you for your attention

Adeline Bailly

25-26 September 2013, Athens, Greece

The authors are very grateful to the French ministry for ecology, sustainable development, and energy (MEDDE), and in particular to the DGALN Department, for its support throughout this work.

The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the Ministry.

A stochastic approach to predicting the relationship between dwelling permeability and infiltration in English apartments

Benjamin Jones
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Context

1. UK has statutory commitment to reduce green house gas emissions to 80% below 1990 rates by 2050
2. Dwellings consume >25% of UK energy
3. Winter exfiltration heat loss is thought to be a significant contributor to heating energy consumption

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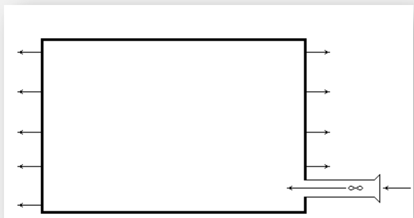
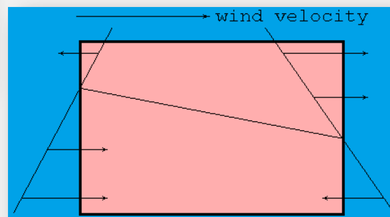
Problem 1: Estimating infiltration rate from air leakage rate



50Pa
Weather independent

~4Pa
Weather dependent



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Problem 1: Leakage Infiltration Ratio (LIR)

$$\left(\dot{V}_{50}/\dot{V}_{I} = \dot{M}_{50}/\dot{M}_{I} = \dot{N}_{50}/\dot{N}_{I}\right) \approx L$$

- 50: measured at a pressure differential of 50 Pascals
- I: under operational conditions during heating season
- Often, L =20 and then scaled

Problem 2:

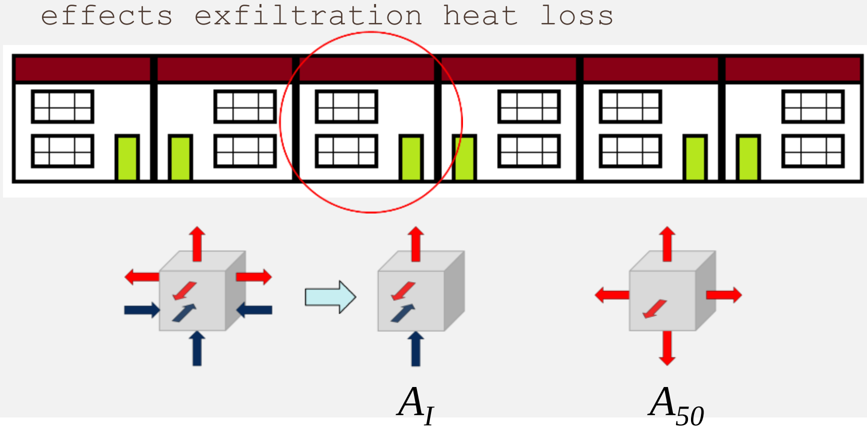
- No large-scale measurements of infiltration in UK houses

Problem 3:

- No evidence of the *significance* of exfiltration heat loss in UK dwellings
- Yet, policy is made based on the assumption that infiltration is a *significant problem*

Problem 4:

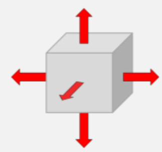
- Limited consideration of how dwelling type effects exfiltration heat loss



Party wall permeability: 50Pa

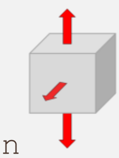
Two limiting assumptions when measuring the air leakage rate at 50Pa:

1. Party walls are permeable and airflow with adjacent dwellings does occur



$A_{50} > A_I$

2. Party walls are impermeable and airflow with adjacent dwellings does **not** occur



$A_{50} \approx A_I$

Predicted air flow for assumption 1 is less than that for assumption 2

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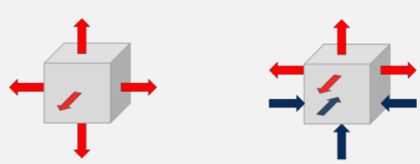
Party wall permeability



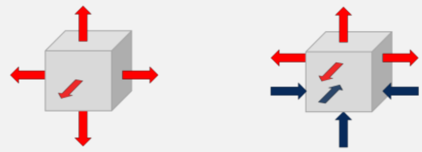
If A(1) is true [permeable party walls]:

- The LIR is L>>20.

If A(2) is true [impermeable party walls]:

- The LIR is L≈20

Research Questions



1. How can one predict distributions of infiltration rates for a housing stock?
2. What effects do the assumptions about party wall permeability have on the predictions?

Method: case-study selection

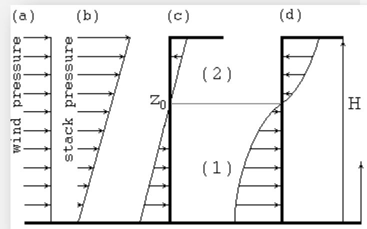
Using low-rise English Apartments:

1. Comprise 22% (4.9 million dwellings) of English housing stock, a subset of the UK stock
2. An apartment generally shares a significant proportion of its envelope area with adjacent apartments
3. Differences between two party wall permeability assumptions expected to be clearly observed

Method: a modelling approach

Following Persily *et al.* (2010) a stock

1. A model
2. Knowledge of the properties of dwellings
3. Suitable statistical approach



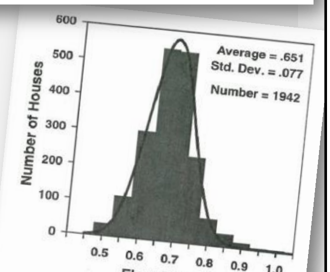


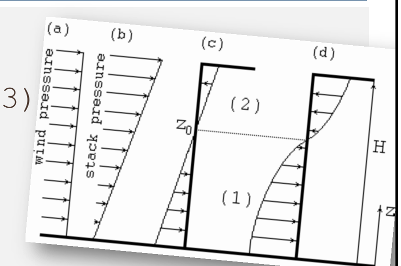
Figure 4 Distribution of leakage exponents.

Persily, A., Musser, A. and Emmerich, S.J. 2010. Modeled infiltration rate distributions for U.S. housing. *Indoor Air* 20(6): 473-485.

Model: DOMVENT3D

Following Jones *et al.* (2013)

1. A model of infiltration and exfiltration
2. Assumes uniformly porous facades
3. Linear pressure distribution
4. Integrates airflow in vertical plane
5. Single-zone dwelling



Jones, B.M., Lowe, R.J. *et al.* 2013. Modelling uniformly porous façades to predict dwelling infiltration rates. Building Services Engineering Research and Technology: Accepted for publication.

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Knowledge of dwellings

The English Housing Survey (DCLG)

1. Published by Department for Communities and Local Government every few years
2. Survey of 16,160 dwellings
3. Weighted inputs
4. Geometric, geographic, and environmental data

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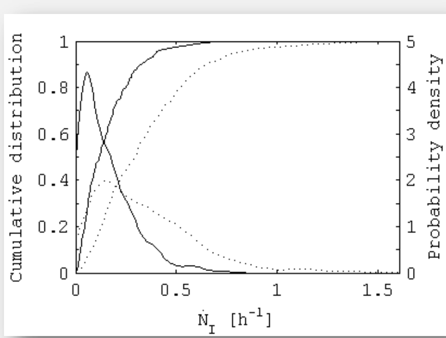
Knowledge of dwellings

Meta-data	Type	Source
Geographic	Weather file	CIBSE Test Reference Year
Geometric	Dwelling dimensions	English Housing Survey (EHS), Cambridge Housing Model (CHM)
	Dwelling orientation	U(0,360)
	Dwelling storey	EHS, U(min,max)
Physical	Dwelling permeability	Stephen (1998), and Pan (2010) with PCHIP
	Flow exponent	Sherman (1998)
	Wind pressure coefficients	Swami & Chandra (1987)
	Block aspect ratio	U(3,20)
Environmental	Terrain	EHS
	Sheltering	EHS, and Deru & Burns (2002)
	Internal air temperature	Palmer *et al.* (2011)

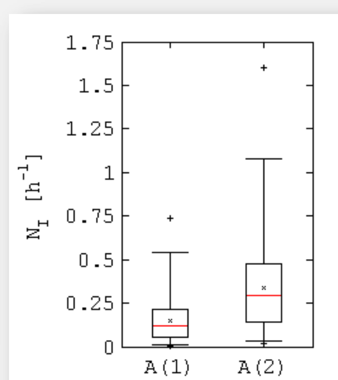
Stochastic Approach

- Monte-Carlo approach
- Latin hypercube sampling
- Sets of mini-cubes (each of 20 samples)
- Stopping criteria: change in σ<0.1%
- Run once for each part wall permeability assumption

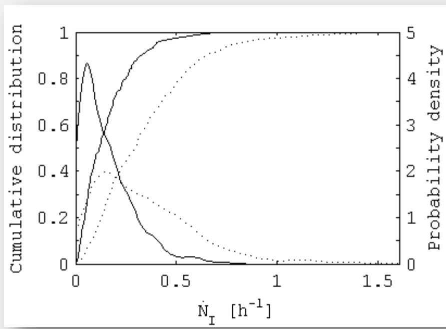
Results: infiltration rate

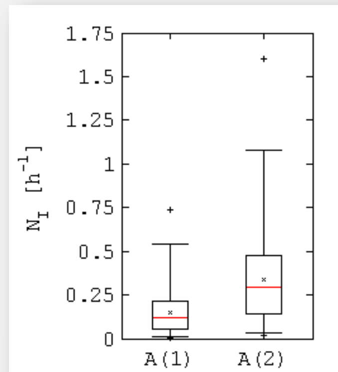


A(1): 360 samples ——
A(2): 860 samples ---



Results: infiltration rate

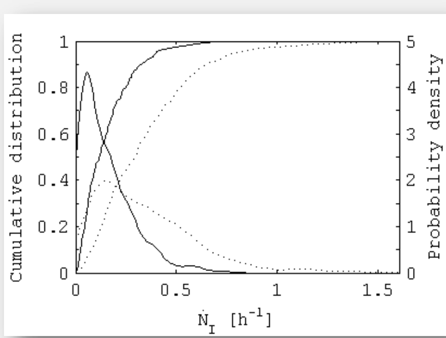


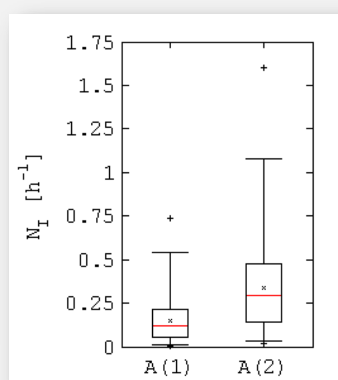


A(1): 97% <0.5 h^{-1} ——

A(2): 78% <0.5 h^{-1} ----

Results: infiltration rate

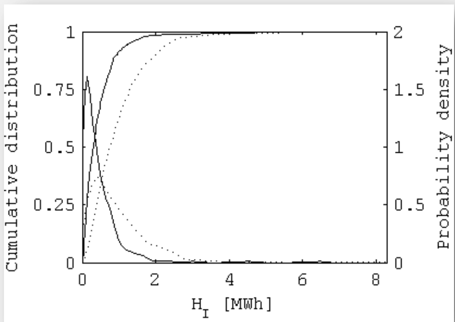


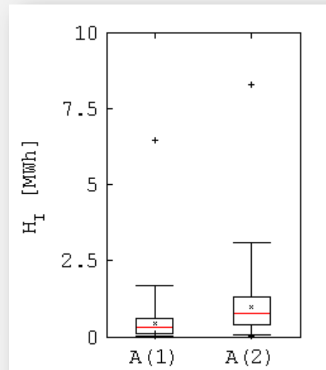


96% probability:

$0.01<N_I<1.08$ h^{-1}

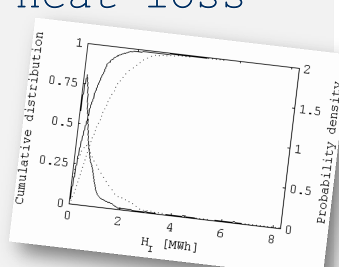
Results: exfiltration heat loss





96% probability:
$0.02<H_I<3.11$ MWh

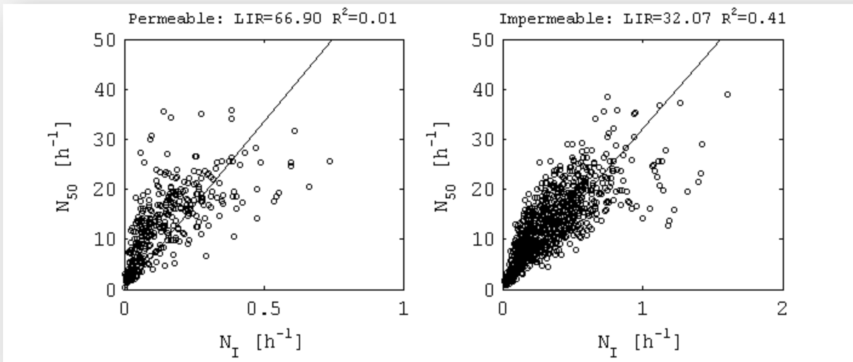
Results: exfiltration heat loss



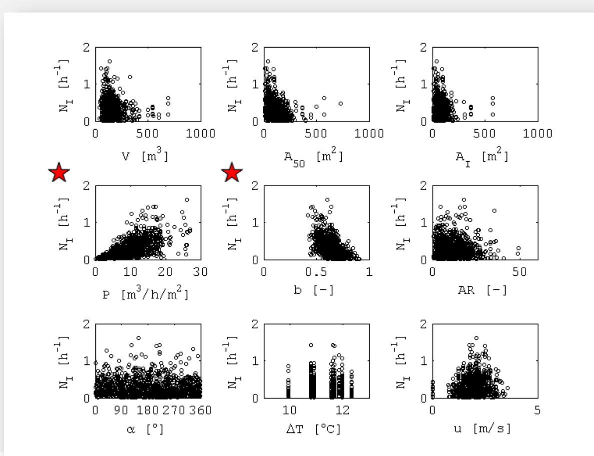
Median H_I are 300kWh and 748kWh for assumptions 1 and 2, equivalent to:

- 3 and 8 11W light bulbs on all year (non-stop), respectively
- 1 person occupying dwelling for 34% and 85% of the year, respectively

Results: LIR



Sensitivity analysis: visual



N_I: mean air changes per hour during heating season

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Sensitivity analysis: statistical

OUTPUTS	Mean infiltration rate, $\dot{N}_I$			Total heat loss, H_I		
INPUTS	τ	p	rank	τ	p	rank
Air permeability, $\dot{P}_{50}$ (m³/h/m²)	0.54	0.00	1	0.53	0.00	1
Airflow exponent	-0.35	0.00	2	-0.35	0.00	2
A_{50} (m²)	-0.22	0.00	3	-0.19	0.00	3
Mean wind speed at dwelling height (m/s)	0.08	0.00	4	0.09	0.00	4
Orientation (º)	-0.04	0.02	5	-0.05	0.01	5
Apartment volume (m³)	-0.03	0.16	6	0.04	0.03	7
Block aspect ratio	0.02	0.33	7	0.02	0.24	8
Mean temperature difference, $\overline{\Delta T}$ (ºC)	-0.01	0.66	8	-0.01	0.52	9
A_I (m²)	0.00	0.90	9	0.05	0.02	6

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Conclusions

1. Presents method of investigating winter exfiltration heat loss, probabilistically
2. Modelling approach can be applied to any stock of dwellings
3. Raises concern about the use of the LIR by building codes
4. Model CDFs and PDFs are useful tools with which to make informed policy decisions
5. Consideration of party wall permeability by building codes is important

Next

1. Short term (1): Apply to other dwelling types
2. Short term (2): develop meta-models using these predictions
3. Long term: An exhaustive field survey is required to give the model a reliable empirical basis
4. Request peer review
5. Make model publically available
6. Lobby government?

Thank-you

Benjamin Jones

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Wednesday 25 September 2013

13:45-15:15: Parallel Session 1D: Topical session- Cool Roofs: Recent developments and Rating Schemes

Chairpersons: Hashem Akbari, Afroditi Synnefa

- **The climate effects of increasing the albedo of roofs in a cold region** Hashem Akbari, Canada (Invited Speaker)
- **Interlaboratory comparison of cool roofing material measurement methods** Afroditi Synnefa, Greece
- **Development and analysis of inorganic coating for energy saving for buildings** Denia Kolokotsa, Greece
- **Study on the appropriate selection of urban heat island measure technologies to urban block properties** Hideki Takebayashi, Japan

The Effects of Increasing Roof Albedo in a Cold Climate

Hashem Akbari

Heat Island Group

Concordia University, Montreal, Canada

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34th AIVC Conference, Athens, Greece

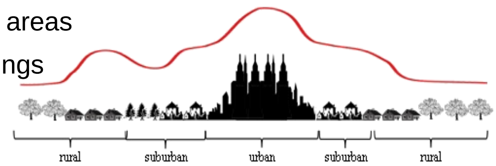
25 September 2013

Acknowledgement

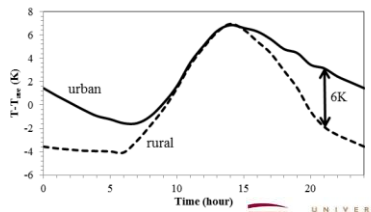
- This is a research progress report of doctoral student Ali Gholizadeh
- This research is supported by a grant from National Science and Engineering Research Council of Canada under discovery program

Urban heat island and mitigation strategies

- Urban heat Island
  - ✓ Higher temperature in urban areas
  - ✓ Higher intensity during evenings



- Mitigation strategies
  - ✓ Increase albedo
  - ✓ Increase vegetation
  - ✓ Use green roofs

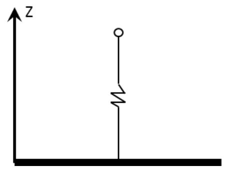


Urban climate modeling objectives

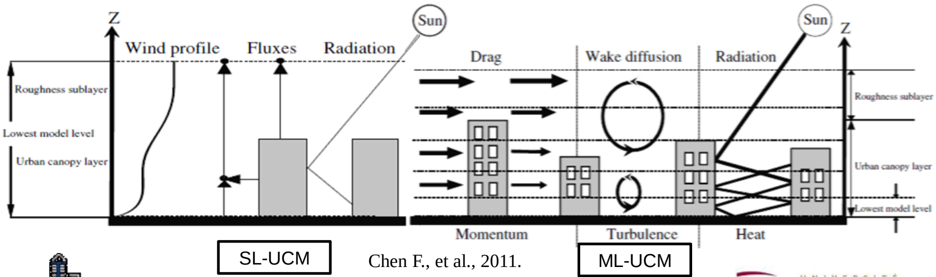
- Comparison of urban canopy models (UCM) coupled with mesoscale model
  - ✓ Multi-layer UCM (ML-UCM)
  - ✓ Single-layer UCM (SL-UCM)
  - ✓ Slab model
- Characterization of UHI
- Effect of increasing reflectivity of roofs

Urban canopy models

- Slab



- Single-layer and Multi-Layer

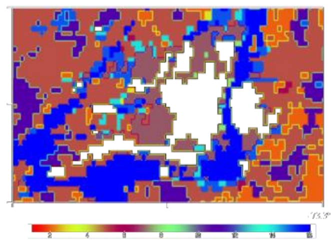


Chen F., et al., 2011.

Simulation domain

- Montreal (100×100 km^2 centered at ~45.5º N and ~73.6º W)
- July 12th LST
- Albedo of roofs changed from 0.2 to 0.8
- Grid size of 333×333 m^2
- Time steps of about 1 sec

Montreal (map.google.com) [top] and its LULC (USGS) [bottom]



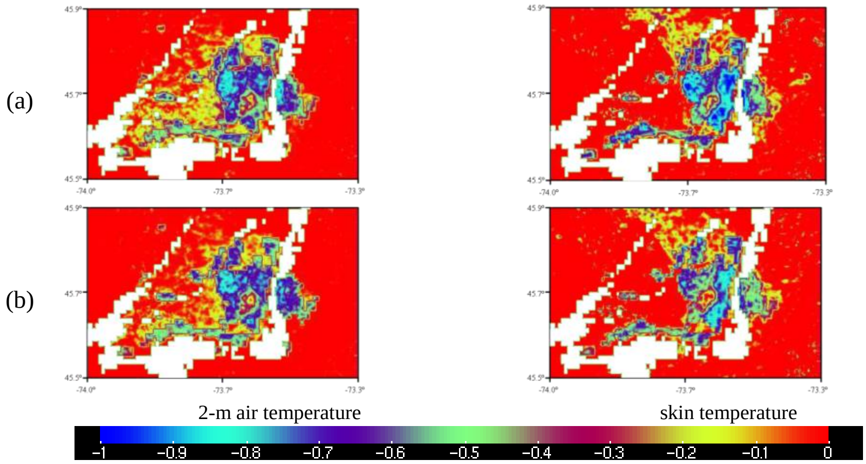
Simulation model and data

- Model: Weather Research and Forecasting (WRF) model version 3.4.1
- Weather data input (temperature, wind, RH, etc.): 3-hourly high resolution Northern America Regional Reanalysis (NARR) data
- Land cover land use: 24-categories USGS data
- Surface albedo: Advanced Very High Resolution Radiometer (AVHRR) data

Simulation model and data (cont.)

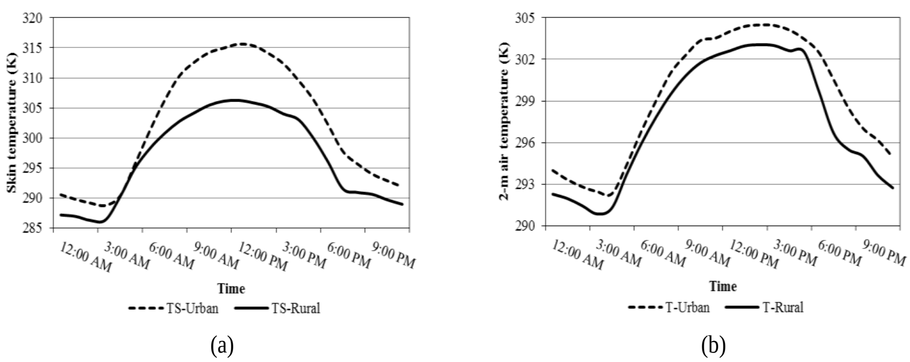
- **Microphysics model** (calculate the process of transforming water from one form to another form): Lin scheme
- **Land-surface model** (provides information of heat and moisture fluxes on land points): Noah-LSM
- **Planetary boundary layer model** (accounts for the exchange of vertical heat and momentum from the ground): MYJ scheme
- **Cumulus parameterization** (estimate the effect of cloud convection in a grid): Grell-Devenyi scheme
- **Radiation models** (determine different radiation processes)
  - **Longwave radiation**: New Rapid Radiative Model (RRTMG)
  - **Shortwave radiation**: Goddard scheme

Comparison of slab and SL-UCM with ML-UCM coupled to mesoscale model



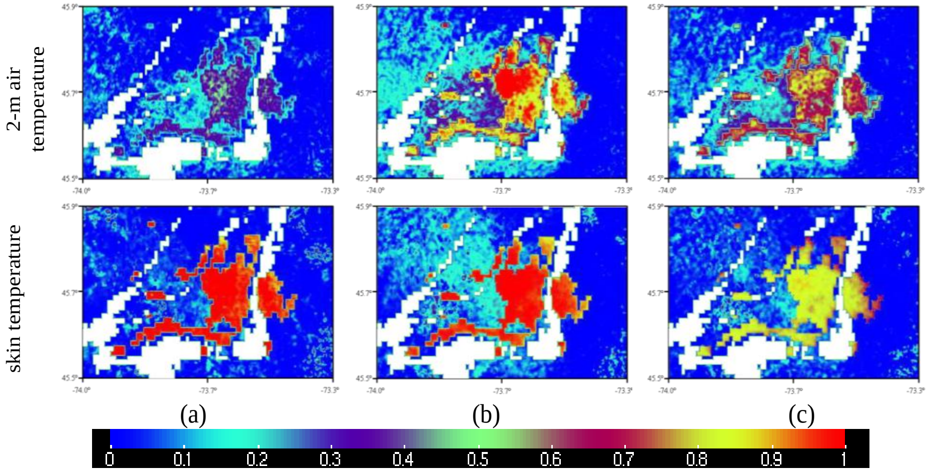
2-m air temperature and skin temperature difference between (a) Multi-layer UCM and Single-layer UCM, and (b) Multi-layer UCM and slab model of Greater Montreal in 12-July-2005

Characterization of UHI in Montreal



Temporal variation of (a) skin temperature and (b) 2-m air temperature (K) in urban and rural areas of Greater Montreal in 12-July-2005 using ML-UCM for CTRL case.

Effect of increasing roof albedo on urban temperature



2-m air temperature and skin temperature difference between CTRL and ALBEDO of Greater Montreal in 12-July-2005. (a) Multi-layer UCM, (b) Single-layer UCM, and (c) slab model.

Conclusions

- Since the temperature distribution of SL-UCM and slab model is different from ML-UCM, ML-UCM is the only appropriate UCM for climate simulation of a city
- Intensity of UHI of Montreal in a summer episode was about 4 K and 9 K considering 2-m air temperature and skin temperature
- Increasing the albedo of roofs (from 0.2 to 0.8) decreased the mean 2-m air temperature by 0.33 K

INTERLABORATORY COMPARISON OF COOL ROOFING MATERIAL MEASUREMENT METHODS

A. Synnefa, A. Pantazaras, M. Santamouris, E. Bozonnet, M. Doya, Michele Zinzi, A. Muscio, A. Libbra, C. Ferrari, V. Coccia, F. Rossi, D. Kolokotsa

ECRC EUROPEAN COOL ROOFS COUNCIL

GROUP BUILDINGS ENVIRONMENTAL STUDIES
NATIONAL & KAPODISTRIAN UNIVERSITY OF ATHENS

Contents

1. Introduction
2. Experimental details
3. Measurement methodology
4. Results
5. Conclusions

Introduction

Cool roofs:

- contribute to mitigating climate change,
- reduce the urban heat island effect
- increase the sustainability of buildings

Cool roofs technology has long been applied and promoted in the U.S. and other countries around the world like Japan, Australia, Brazil, India etc.

The European Cool Roofs Council

ECRC is developing a Product Rating Program:

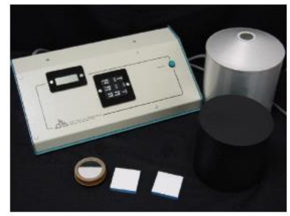
- a uniform and credible system for rating and reporting the radiative properties of roofing materials
- roofing product manufacturers will label various roof products with radiative property values (SR and e)
- Code bodies, architects, building owners, specifiers etc. can have credible radiative properties data
- The radiative properties that will be reported are the solar reflectance (SR) and the infrared emittance (e)

ECRC EUROPEAN COOL ROOFS COUNCIL

http://coolroofcouncil.eu/

Measurement of reflectance

Spectrophotometer with an integrating sphere

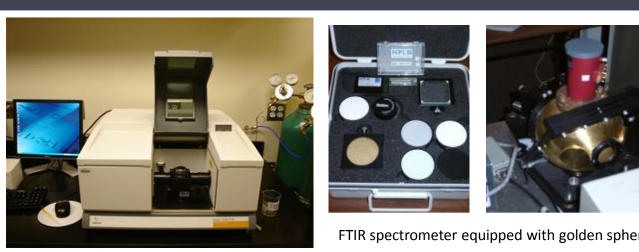


Solar Spectrum Reflectometer (ASTM C1549)

-ASHRAE 74 (1988),
-ASTM E903 (1996 and 2012),
-CIE 130 (1998),
-EN 410 (1998),
- EN 14500 (2008)
- ISO 9050 (1990).

Pyranometer (ASTM E1918, LBNL E1918A)

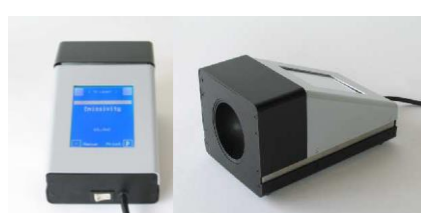
Measurement of emittance



FTIR spectrometer equipped with golden sphere

-ASTM E1585 (1993),
-EN 12898 (2001),

D&S Emissometer (ASTM C1371 (2010)



Inglas TIR-100 Emissometer (EN 15976 (2011))

ILC objectives

An interlaboratory comparison (ILC) was organised and conducted to provide the ECRC with information regarding its product rating programme under development, aiming to:

- compare different measurement methodologies (mainly ASTM and European (EN) standards,) for
- ✓ measuring and calculating (SR) and
- ✓ infrared emittance (e),
- provide information on their suitability to be used for cool roof products assessment.

Sample description

Product type	Sample description	Sample code	Characteristics
Coating	Waterborne elastomeric acrylic coating	S1	White, smooth
	Elastomeric waterproof coating	S2	NIR reflecting black, smooth
	Elastomeric waterproof coating	S3	Black, smooth
	Elastomeric waterproof coating	S4	NIR reflecting brown, smooth
	Aluminium-thermoplastic hydrocarbon based roof coating	S5	Aluminium, smooth
Asphalt membrane (modified bitumen)	Granulated bituminous membrane	S6	White, rough
	Granulated bituminous membrane	S7	Black, rough
	Granulated bituminous membrane	S8	Green, rough
Shingle	Multicoloured asphalt shingle	S9	Red, rough
Single ply membrane	FPO membrane	S10	White, smooth
Concrete tile	High profile multi-colour coated tile	S11	Multicoloured, profiled, Rough
	Curved profile tile, monocolour	S12	Profiled, smooth
	Flat monocolour tile	S13	smooth
Metal roof	Prepainted metal	S14	Silver, smooth
	Prepainted metal	S15	Dark brown, slight textured finish
	Prepainted metal	S16	Off white, Smooth
	Bare pretreated metal	S17	Silver, Smooth

The 17 samples represent the range of commercially available roofing materials covering the full range of reflectance and emittance values.

✓All product samples have been prepared following specific guidelines

Labs and instrumentation

	Spectrophotometer	Reflectometer	ASTM C1371 Emissometer	EN 15976 Emissometer
Lab 1		x	x	
Lab 2		x	x	x
Lab 3	x		x	
Lab 4	x		x	
Lab 5		x	x	
Lab 6	x		x	
Lab 8	x		x	
Lab 9	x	x	x	
Lab 10	x		x	
Lab 11	x		x	
Lab 12				x

✓ spectrophotometers equipped with integrating spheres of 150mm diameter and one large sphere of 75cm diameter

Reflectivity measurement

Spectrophotometer with an integrating sphere

- Measurements conducted according to ASTM E903 (1996) or EN 14500 (2008).
- The solar reflectance was then calculated using all the following reference solar spectra:
  - ✓ASTM E891-87 (1992) or ASTM G159-98 (1998)
  - ✓ASTM G173-03 (2008)
  - ✓CIE 85-1989 (The reference solar spectrum given in EN 410 (2011) – Glass in building. Determination of luminous and solar characteristics of glazing)

Reflectometer

- Measurements conducted according to ASTM C1549-04 (2004)

- ➢ ***Variegated products :*** SR determined according to CRRC-1 Method #1: Standard Practice for Measuring Solar Reflectance of a Flat, Opaque, and Heterogeneous Surface Using a Portable Solar Reflectometer
- ➢ ***Tiles:*** SR was determined using either the CRRC-1 Method #1 or the Template method as described in the CRRC-1 Standard (2008).

Emissivity measurement

D&S Emissometer

- Measurements were conducted using equipment and procedures in accordance with ASTM C1371 (2010).

Inglas TIR 100 Emissometer

- Measurements were conducted using equipment and procedures in accordance with EN 15976 (2011)

ILC results-QC of data

- **Homogeneity test of the samples** (ISO13528, 2005): initial characterisation of their radiative properties, all samples per product type measured by a single lab using one of the methods for determining SR and e.
- The samples that were found to present inhomogenities were replaced by new ones. The final homogeneity check showed that the set of samples to be measured was suitable for the ILC.
- **Detection and removal of outlier data** (ISO Guide 43, 1997) using the Grubb's test (significance level equal to 0.05) to determine whether the larger or smaller observation in a set of data is an outlier.

Solar reflectance evaluation

Spectrophotometer measurements:

Samples		N	Total Solar Reflectance (TSR) (ASTME903)								
			E891			G173			EN410		
			AVG	STDEV	CV	AVG	STDEV	CV	AVG	STDEV	CV
S1	white coating	6	86	1.11	0.01	85	0.67	0.01	83	0.99	0.01
S2	NIR refl. black coating	7	21	2.07	0.10	20	0.98	0.05	18	0.54	0.03
S3	black coating	7	4	0.38	0.09	4	0.36	0.08	4	0.41	0.10
S4	NIR refl. Brown coating	7	42	1.72	0.04	40	0.97	0.02	38	0.54	0.01
S5	Aluminium coating	7	76	2.16	0.03	76	1.97	0.03	76	1.94	0.03
S6	White Granulated bituminous membrane	7	31	1.29	0.04	31	1.04	0.03	31	1.24	0.04
S7	Black Gran. bituminous membrane	7	6	0.49	0.08	6	0.42	0.07	6	0.43	0.07
S8	Green Gran. bituminous membrane	7	11	1.11	0.10	10	0.80	0.08	10	0.54	0.05
S9	Multicoloured asphalt shingle	7	16	1.00	0.06	15	0.92	0.06	15	0.78	0.05
S10	White FPO membrane	6	86	1.33	0.02	86	0.83	0.01	85	0.56	0.01
S12*	Curved profile tile, monocolour	4	30	2.83	0.09	28	0.97	0.03	27	0.63	0.02
S13*	Flat monocolour tile	3	38	2.00	0.05	36	1.26	0.03	35	0.59	0.02
S14	Prepainted metal silver	6	51	1.63	0.03	51	0.73	0.01	50	0.72	0.01
S15	Dark brown Prepainted metal	7	13	0.49	0.04	13	0.41	0.03	13	0.42	0.03
S16	Off white Prepainted metal	6	53	1.03	0.02	53	0.58	0.01	52	0.64	0.01
S17	bare metal	7	57	3.10	0.05	57	3.22	0.06	57	3.07	0.05

AVG: average values
STDEV: standard deviation
C.V. :coefficient of variance (C.V.)
N :the number of labs that have measured the specific sample

- (STDEV)avg for E891, G173 and EN410 is 1.5%TSR, 1%TSR and 0.9%TSR respectively < ±3-4%TSR (ASTME903 uncertainty).
- Very good inter-laboratory agreement

Solar reflectance evaluation

Spectrophotometer measurements:

smaller pieces of the full uncut tiles measured by 4 labs.

Samples		N	Total Solar Reflectance (TSR) (ASTME903)								
			E891			G173			EN410		
			AVG	STDEV	CV	AVG	STDEV	CV	AVG	STDEV	CV
S1		6	86	1.11	0.01	85	0.67	0.01	83	0.99	0.01
S2		7	21	2.07	0.10	20	0.98	0.05	18	0.54	0.03
S3		7	4	0.38	0.09	4	0.36	0.08	4	0.41	0.10
S4		7	42	1.72	0.04	40	0.97	0.02	38	0.54	0.01
S5		7	76	2.16	0.03	76	1.97	0.03	76	1.94	0.03
S6	White Granulated bituminous membrane	7	31	1.29	0.04	31	1.04	0.03	31	1.24	0.04
S7	Black Gran. bituminous membrane	7	6	0.49	0.08	6	0.42	0.07	6	0.43	0.07
S8	Green Gran. bituminous membrane	7	11	1.11	0.10	10	0.80	0.08	10	0.54	0.05
S9	Multicoloured asphalt shingle	7	16	1.00	0.06	15	0.92	0.06	15	0.78	0.05
S10	White FPO membrane	6	86	1.33	0.02	86	0.83	0.01	85	0.56	0.01
S12*	Curved profile tile, monocolour	4	30	2.83	0.09	28	0.97	0.03	27	0.63	0.02
S13*	Flat monocolour tile	3	38	2.00	0.05	36	1.26	0.03	35	0.59	0.02
S14	Prepainted metal silver	6	51	1.63	0.03	51	0.73	0.01	50	0.72	0.01
S15	Dark brown Prepainted metal	7	13	0.49	0.04	13	0.41	0.03	13	0.42	0.03
S16	Off white Prepainted metal	6	53	1.03	0.02	53	0.58	0.01	52	0.64	0.01
S17	bare metal	7	57	3.10	0.05	57	3.22	0.06	57	3.07	0.05

- profiled and variegated tile samples cannot be measured with a spectrophotometer

Solar reflectance evaluation

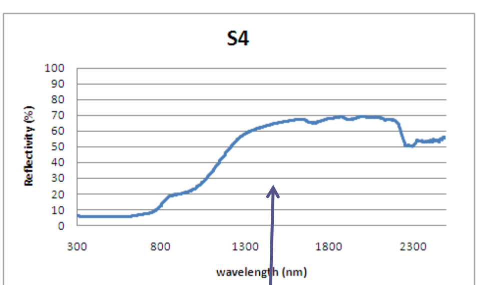
Spectrophotometer measurements:

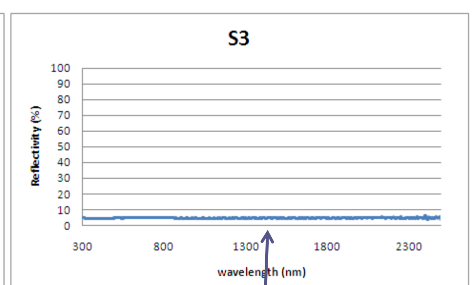
Samples		ΔSR E891 – G173	ΔSR E891 – EN410
S1	white coating	1	3
S2	NIR refl. black coating	1	3
S3	black coating	0	0
S4	NIR refl. Brown coating	2	4
S5	Aluminium coating	0	0
S6	White Granulated bituminous membrane	0	0
S7	Black Gran. bituminous membrane	0	0
S8	Green Gran. bituminous membrane	1	1
S9	Multicoloured asphalt shingle	1	1
S10	White FPO membrane	0	1
S12*	Curved profile tile, monocolour	2	3
S13*	Flat monocolour tile	2	3
S14	Prepainted metal silver	0	1
S15	Dark brown Prepainted metal	0	0
S16	Off white Prepainted metal	0	1
S17	bare metal	0	0

The highest differences were observed between the ASTM E891 and the EN 410 solar spectra

Solar reflectance evaluation

Spectrophotometer measurements:





Spectrally selective black coating

Non selective black coating

Solar reflectance evaluation

Spectrophotometer measurements:

Standard	Description	NIR (%)
ASTM E891-87 (1992)	Hazy sky AM1.5 beam-normal irradiance	58.1
ASTM G173-03 (2003)	Clear sky AM1.5 beam-normal irradiance	54.3
CIE 85(1989)	Global radiation, AM1	49.5

- The $NIRSR_{E891}$ (700-2500nm) is by 8.6%NIRSR higher than that of the CIE standard
- The choice of the solar spectrum for the calculation of SR affects the calculated SR value especially for spectrally selective materials.
- The observed differences are lower or equal to the total uncertainty of the ASTME903 which is equal to ±3-4%TSR

Solar reflectance evaluation

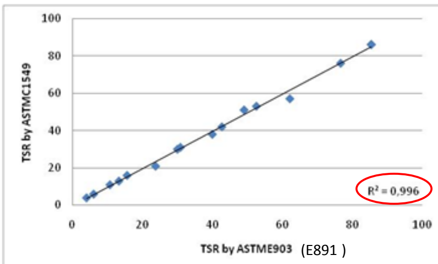
Reflectometer measurements

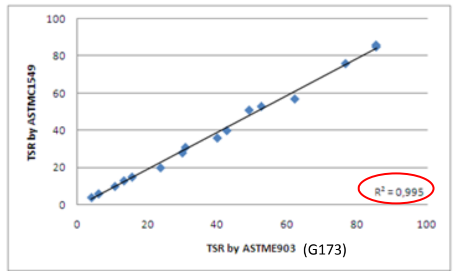
Samples	N	Total Solar Reflectance (ASTMC1549)			E903 - C1549
		AVG	STDEV	CV	
S1	4	85	1.94	0.02	1
S2	4	24	1.50	0.06	-3
S3	4	4	0.00	0.00	0
S4	3	43	0.98	0.02	-1
S5	4	77	1.04	0.01	-1
S6	4	31	1.31	0.04	0
S7	4	6	0.05	0.01	0
S8	4	11	0.48	0.04	0
S9	4	16	0.44	0.03	0
S10	4	85	0.53	0.01	NA
S11	4	19	1.24	0.06	1
S12	3	30	0.00	0.00	0
S13	3	40	0.00	0.00	-2
S14	4	49	0.35	0.01	2
S15	4	13	0.49	0.04	0
S16	4	53	0.49	0.01	0
S17	4	62	4.03	0.06	-5

- The STDEVavg of all the measurements is 0.87%TSR indicating a good inter-laboratory agreement when using this measurement method.
- The highest absolute differences between the two methods were observed for the NIR reflective black sample (S2) and the bare aluminium sample (S17) and were equal to 3 and 5%TSR respectively.
- The observed differences are comparable to the measurement methods' uncertainty which is estimated to be about 4%TSR.

Solar reflectance evaluation

Reflectometer – spectrophotometer measurements

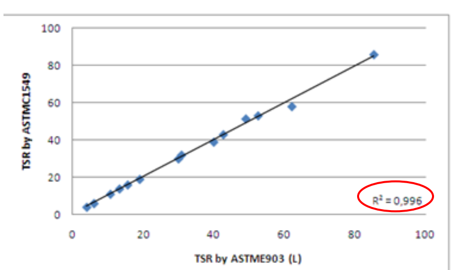


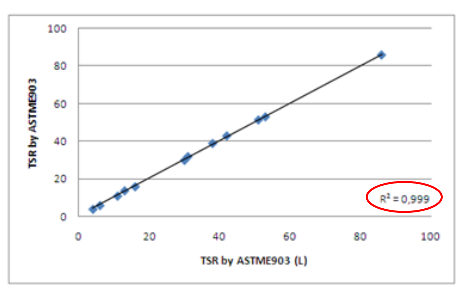


- Although there are differences as great as 5% in the absolute values achieved using the two different methods on the same samples, the overall trends are very similar.
- The results indicate a strong and positive correlation between the two test methods.

Solar reflectance evaluation

Large sphere spectrophotometer measurements





- Small –Large diameter sphere comparison: absolute differences 0-1.1%TSR.
- Reflectometr- Large diameter sphere comparison: absolute differences 0-4%TSR.
- A strong correlation between these test methods.

Infrared emittance evaluation

Samples									CV	Δe ASTMC1371 – EN15976
S1	white coating								0.01	-0.03
S2	NIR refl. black coating								0.01	-0.03
S3	black coating								0.02	-0.03
S4	NIR refl. Brown coatin								0.01	-0.01
S5	Aluminium coating								0.11	0.05
S6	White Granulated bituminous membrane	9	0.89	0.02	0.03	3	0.93	0.03	0.03	-0.04
S7	Black Gran. bituminous membrane	9	0.87	0.02	0.03	3	0.92	0.01	0.01	-0.05
S8	Green Gran. bituminous membrane	9	0.91	0.02	0.03	3	0.95	0.01	0.01	-0.04
S9	Multicoloured asphalt shingle	9	0.91	0.02	0.02	2	0.95	0.00	0.00	-0.04
S10	White FPO membrane	9	0.88	0.02	0.02	2	0.93	0.00	0.00	-0.05
S11	Profiled multicolored tile	4	0.90	0.03	0.03	1	0.97	NA	NA	-0.07
S12*	Curved profile tile, monocolour	5	0.92	0.03	0.03	1	1.00	NA	NA	-0.08
S13*	Flat monocolour tile	6	0.83	0.02	0.03	2	0.83	0.01	0.02	0
S14	Prepainted metal silver	9	0.71	0.04	0.06	3	0.67	0.02	0.02	0.04
S15	Dark brown Prepainted metal	9	0.86	0.01	0.01	3	0.90	0.02	0.02	-0.04
S16	Off white Prepainted metal	9	0.85	0.02	0.03	3	0.89	0.01	0.01	-0.04
S17	bare metal	8	0.06	0.01	0.24	3	0.05	0.02	0.33	0.01

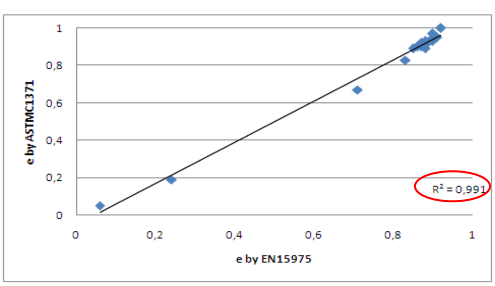
✓low conductivity samples and large: they cannot be applied on the D&S emissometer heat sink
✓Curved: the detector of the emissometer is not completely in contact with sample

AVG: average values
STDEV: standard deviation
C.V. :coefficient of variance (C.V.)
N :the number of labs that have measured the specific sample

- (STDEV): 0.01 - 0.04 and STDEVavg = ±0.02 <±0.04 (measurement method uncertainty)
- good consistency in the measured thermal emissivity between the participating laboratories.

Infrared emittance evaluation

Emissometer (ASTM-EN) measurements



- Absolute differences as high as 0.08 between the two methods, however overall trends are quite similar.
- A strong correlation between the two test methods for flat roof products.

Conclusions

- The differences in the TSR values from using different solar spectral irradiances (ASTM E891, ASTM G173 and EN 410) are in the range of 0-4%TSR and they are more important for spectrally selective materials.
- They contribute to the total uncertainty of the measurement method indicating that the use of single solar spectrum would provide comparable and “fair” results in the framework of a product rating programme.
- Profiled and variegated tile samples provided as full uncut tiles cannot be measured with a spectrophotometer.
- A strong correlation between the TSR determined by a spectrophotometer (ASTM E903) and a reflectometer (ASTM C1549) was found.
- A strong correlation was also found between the determination of TSR with a spectrophotometer with a large diameter integrating sphere and by both reflectometers (ASTM C1549) and spectrophotometers with a small diameter integrating sphere.
- The ASTM C1371 and EN 15976 standards give comparable results for infrared emittance of flat roof products.

DEVELOPMENT AND ANALYSIS OF INORGANICS COATINGS FOR BUILDINGS AND STRUCTURES

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Structure

- ✓ Introduction and Objectives
- ✓ Materials Used on Experiments
- ✓ Experimental procedure
- ✓ Measurement devices
- ✓ Samples with coatings applied in two layers
- ✓ Samples with coatings applied in one layer

Objectives of the research

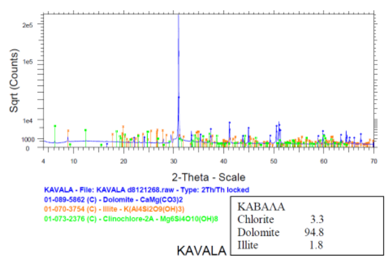
- ✓ There has been a growing interest in “natural,” “vernacular,” or “traditional” building materials and techniques.
- ✓ From an environmental point of view, these materials offer a low embodied energy and low embodied carbon alternative to conventional building materials such as concrete and steel.
- ✓ Other benefits of many natural materials include their ability to passively regulate humidity in a building, their reduced toxicity, increased thermal mass, and biodegradability at the end of life. Lime mortars and renders, in use since ancient times that were largely replaced by cement mixes by the second half of the 20th century are now reemerging as an important group of lower embodied energy binder materials.
- ✓ The study of lime renders’, mortars’ and natural paints’ thermo-physical properties are of a major importance.
- ✓ While the optical properties of common colorants and materials for the built environment are studied in the past, the natural materials and coatings’ optical characteristics and their potential role as a passive solar technique is still under study.
- ✓ The aim of the present work is to examine the performance of mineral-based inorganic coatings as a passive solar technique that contributes to buildings’ energy efficiency. This is achieved by investigating the optical properties and thermal behavior of these coatings in an attempt to lower the surface temperature of the built environment thus increasing energy efficiency.

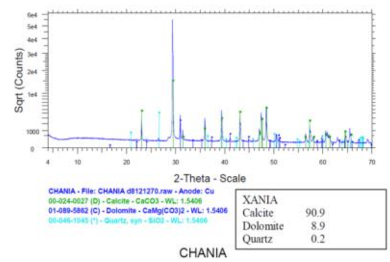
Materials Used on Experiments (binders)

- ✓ Natural Hydraulic Lime
  - calcining argillaceous or siliceous lime stones at temperatures of around 1200°C (1400°C for production of Portland cement)
  - NHL1: natural hydraulic lime
  - NHL2 : natural hydraulic lime NHL with pozzolanic additives
- ✓ White Portland Cement (WPC)
  - Similar to grey Portland cement in all respects except of its high degree of whiteness

Materials Used on Experiments (Aggregates)

- ✓ Aggregate powder: grading following the EN13196 with maximum particle size 250μm
  - Dolomite marble powder (DMP) originated from Kalala, Greece
  - Limestone powder (LMP) originated from Chania, Greece





Materials Used on Experiments (Aggregates)

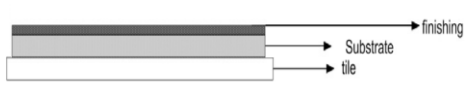
- ✓ Glass beads (GB)
  - Composition:
    - ○ SiO_2 (71-73%), Na_2O (13-15%), MgO (3-5%),CaO (8-10%), Al_2O_3 (0.5-2%) other (<2%)
  - Diameter: 180 – 850μm following the EN1424
  - Refractive index: 1.5- 1.55

Materials Used on Experiments

- ✓ Inorganic thermochromic pigment: $(Et_2NH_2)_2CuCl_4$
  - Low temperature : bright green
  - High Temperature : bright yellow
  - Change Temperature : 43°C
- ✓ Lime renders : mixing matured hydrated lime putty with aggregates of
  - ○ marble powder (MP render)
  - ○ Sand and natural earths (NP render)
- ✓ Cool White
  - Commercial cool paint
  - Solar reflectance : 89%, Infrared emittance : 0.89

Experimental procedure

- ✓ Samples with coatings applied in two layers :
  - The samples are constructed on top of a title with the following stratification



- ✓ Samples with coatings applied in one layer:
  - The substrate is constructed using 28% Portland Cement, 56% limestone and 16% water.

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Measurements performed

✓ Devices

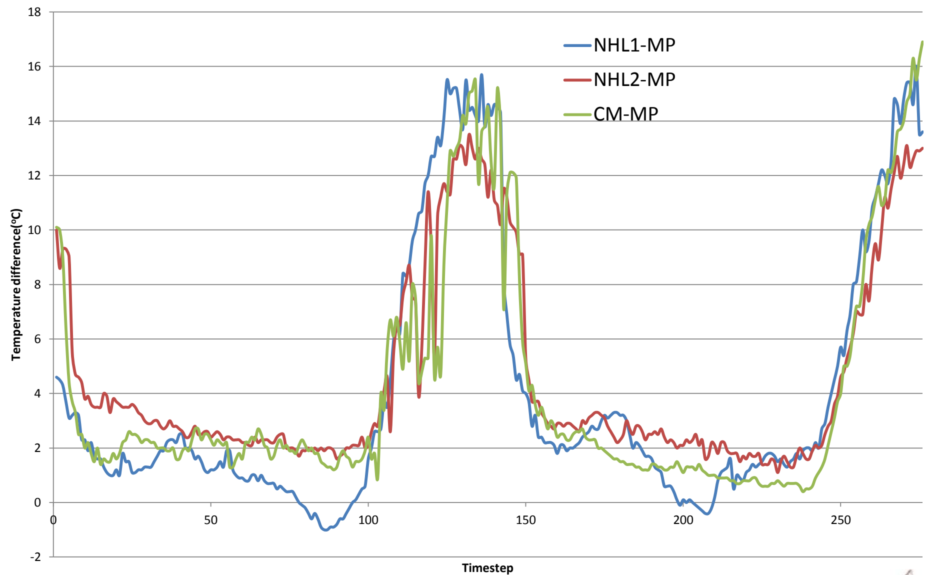
- Surface temperature : K-type surface temperature thermocouples
- Solar reflectance: Cary 5000 spectrophotometer with integrating sphere
- Infrared emittance: Devices and Services Emissometer Model AE1
- Thermal imaging : FLIR ThermaCam B2

Samples with coatings applied in two layers

Sample Code	Substrate	Finishing	Type
	Ratio per volume 1/5/2/1		
NHL1-MP	NHL1/LMP/L	MP	Render
NHL1-NP	NHL1/LMP/L	NP	
NHL2-MP	NHL2/LMP/L	MP	
NHL2-NP	NHL2/LMP/L	NP	
CM-MP	CM/LMP/L	MP	
CM-NP	CM/LMP/L	NP	
NHL1-CW	NHL1/LMP/L	CW	Paint
NHL2-CW	NHL2/LMP/L	CW	
CM-CW	CM/LMP/L	CW	
P-TC	P	TC	

NHL1	Natural Hydraulic Lime	MP	Hydrated lime putty with aggregates of marble powder
NHL2	Natural Hydraulic Lime NHL with pozzolanic additives	NP	Hydrated lime putty with aggregates of sands and natural earths
CM	Ordinary Portland Cement	LMP	Limestone powder
CW	Cool White	P	Plaster (gypsum)
L	Hydrated lime	TC	Thermochromic

Samples with coatings applied in two layers (temperature difference with ambient air)



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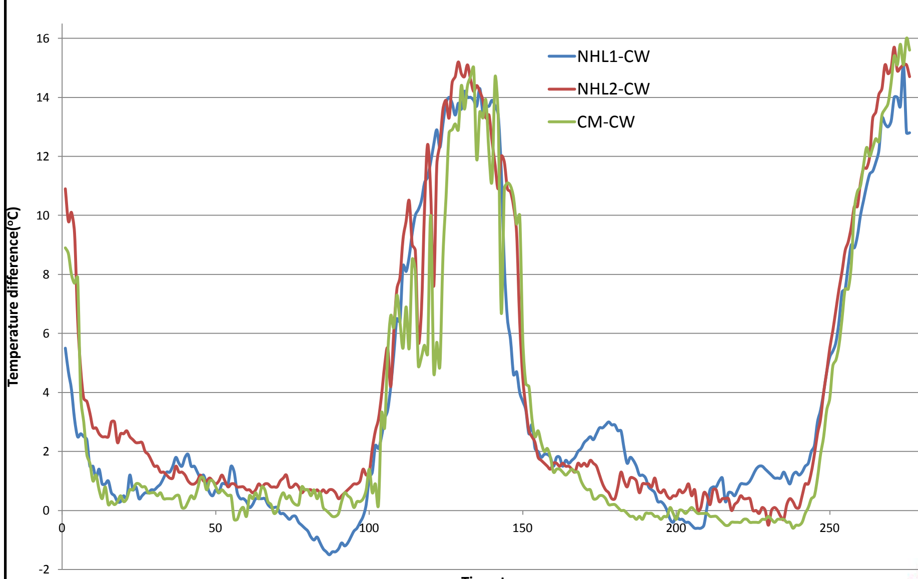
Samples with coatings applied in two layers (temperature difference with ambient air)



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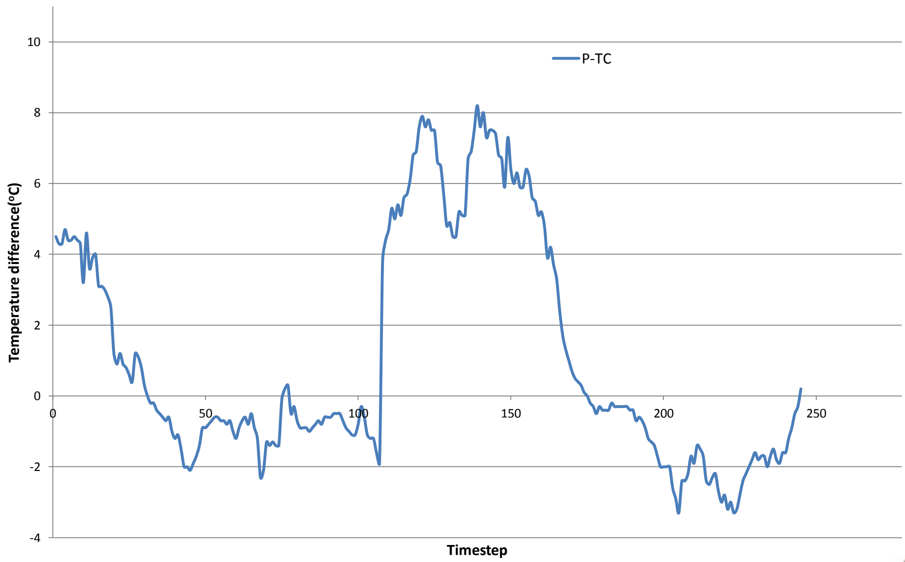
Samples with coatings applied in two layers (temperature difference with ambient air)



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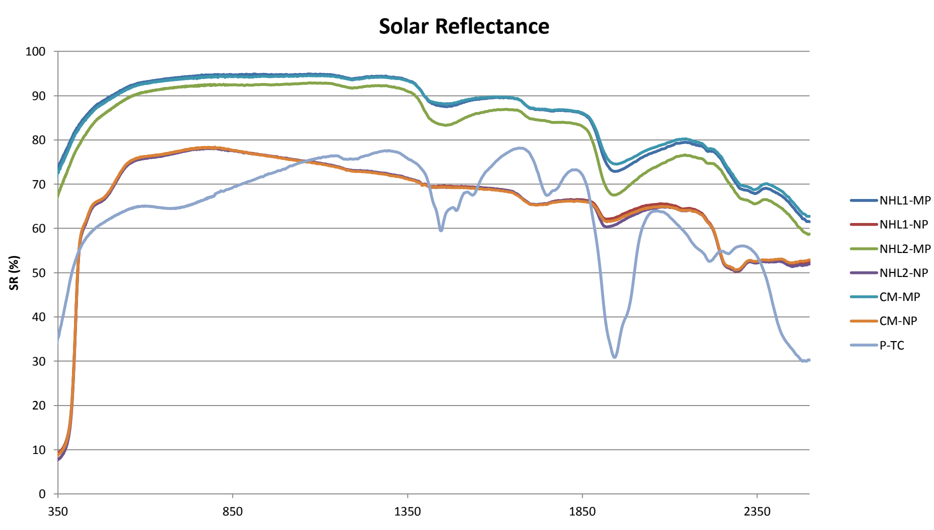
Samples with coatings applied in two layers (Solar Reflectance)



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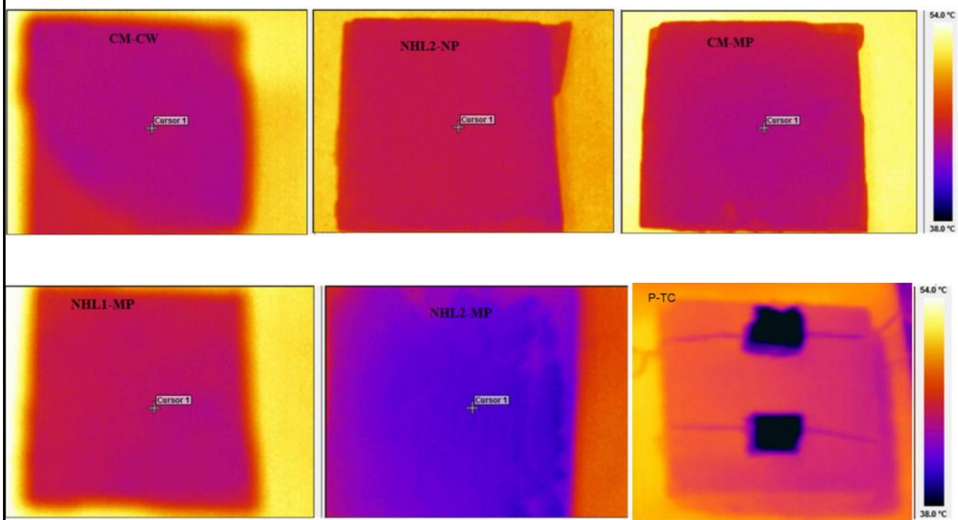
Samples with coatings applied in two layers (thermal imaging)



Samples with coatings applied in one layer

Sample Code	Finishing	Ratio per volume	Type
WCM-DMP	WCM/L/DMP	1/1/2	Render
WCM-LMP	WCM/L/LMP	1/1/2	
NHL2-DMP	NHL2/L/DMP	1/1/2	
NHL2 –LMP	NHL2/L/LMP	1/1/2	
NHL2 -LMP-GB	NHL2/L/LMP/GB	1/1/1.8/0.2	
NHL2 -DMP-GB	NHL2/L/DMP/GB	1/1/1.8/0.2	

WCM	white Portland cement
LMP	limestone powder
DMP	dolomite marble powder
GB	glass beads
L	hydrated lime

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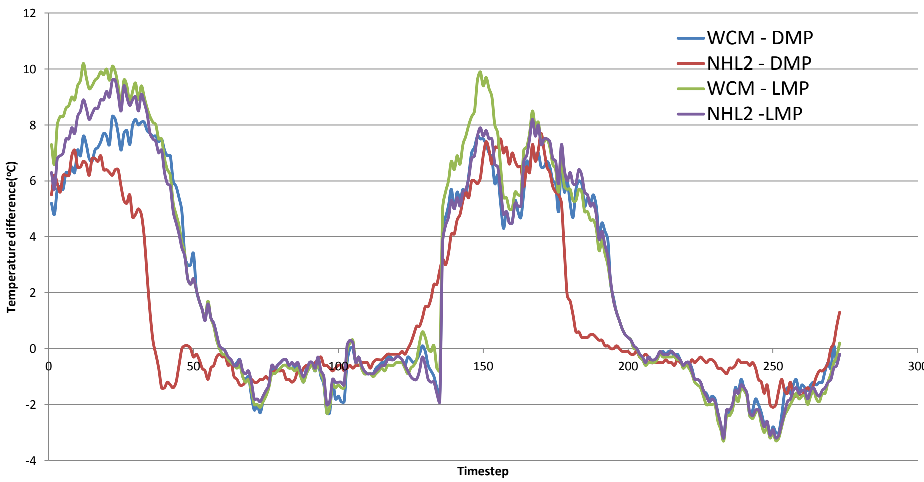
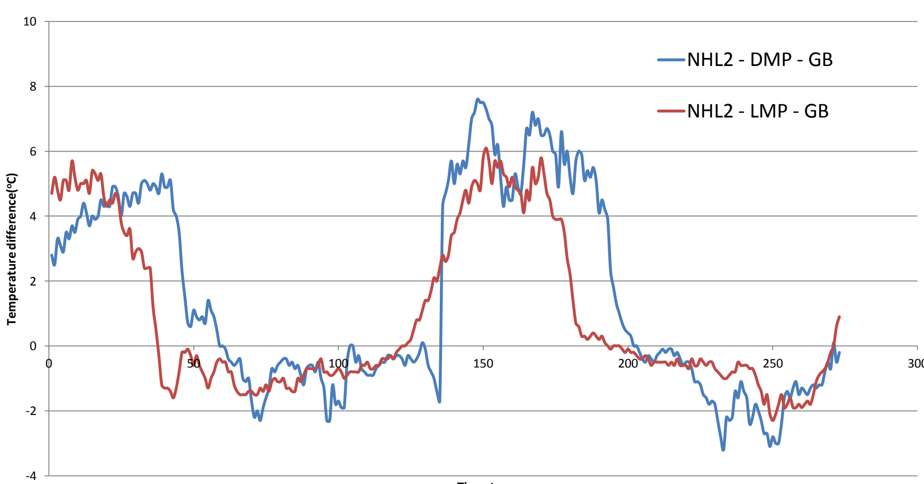
Samples with coatings applied in one layer (temperature difference with ambient air)



Samples with coatings applied in one layer (temperature difference with ambient air)



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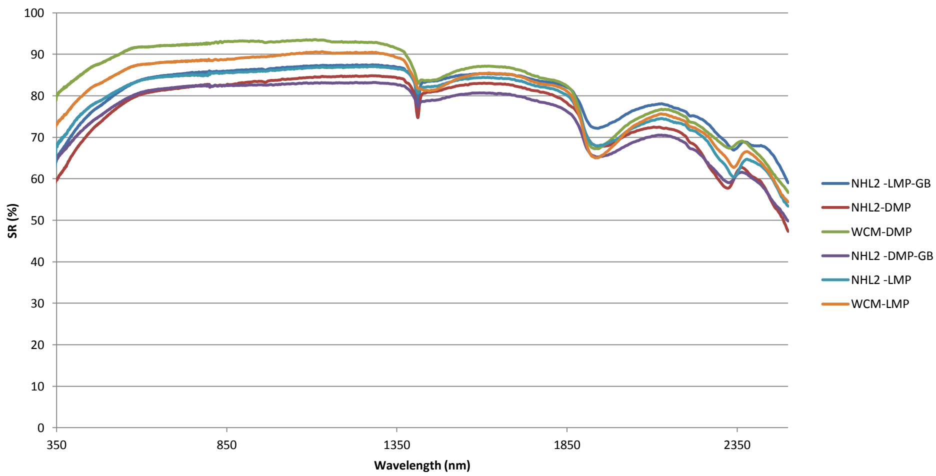
Samples with coatings applied in one layer (Solar Reflectance)



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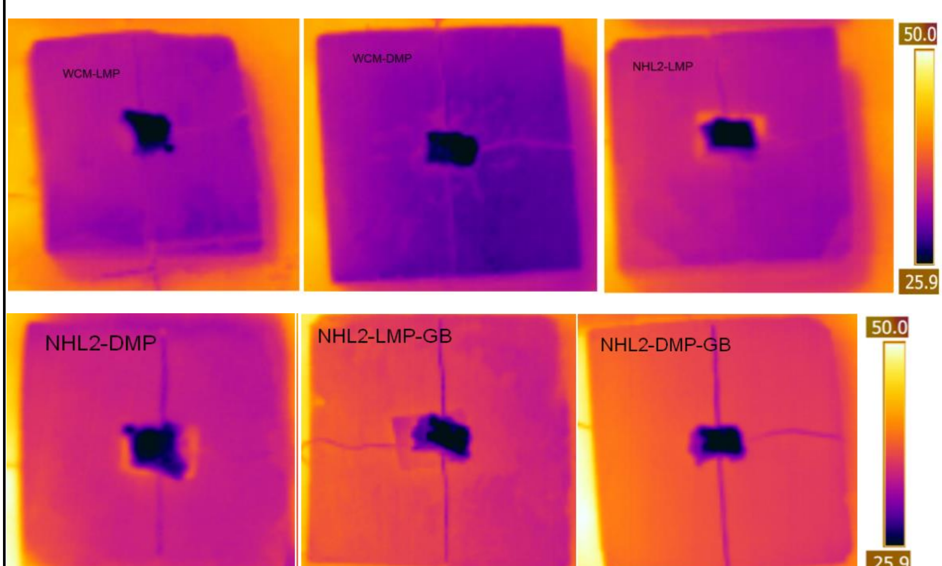
Samples with coatings applied in one layer (thermal imaging)



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Samples (Solar Reflectance – Infrared emittance)

Sample	SR(%)	SR_{IR}(%)	SR_{VIS}(%)	SR_{UV}(%)	E(%)
NHL1-NP	71	73	71	10	0.85
NHL1-MP	91	91	91	70	0.88
NHL2-NP	71	73	71	8	0.87
NHL2-MP	88	89	88	64	0.84
CM-NP	71	72	73	9	0.87
CM-MP	90	91	91	69	0.85
P -TH	66	69	63	34	0.87
WCM-DMP	89	90	90	78	0.83
WCM-LMP	86	86	85	71	0.81
NHL2-LMP	82	84	81	64	0.88
NHL2–DMP	79	81	77	57	0.88
NHL2-LMP-GB	83	85	81	62	0.88
NHL2-DMP-GB	80	81	78	63	0.85

Conclusions

- ✓ Most thermally effective
  - coatings applied in two layers
    - natural hydraulic lime with lime render of marble powder (13,5°C)
  - coatings applied in one layer
    - with dolomic marble powder and natural hydraulic lime with pozzolanic additions with glass beads (6,1°C)
- ✓ Addition of glass beads improved the overall performance of the sample (1.5°C)
- ✓ Inorganic thermochromic pigment
  - Very promising
  - Stability of long term exposure to solar radiation must be examined

Thank you for your attention

Study on the appropriate selection of urban heat island measure technologies to urban block properties

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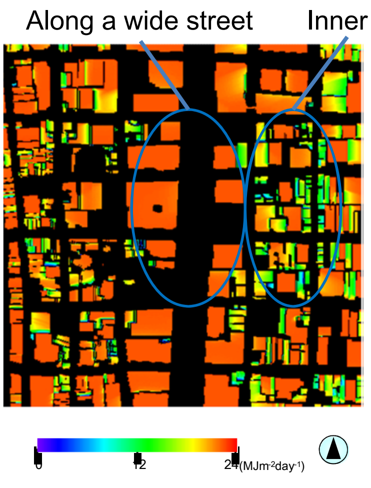
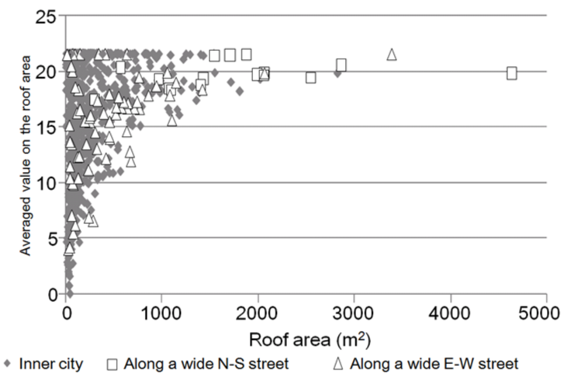
Previous study
Daily net solar radiation gain on the roof



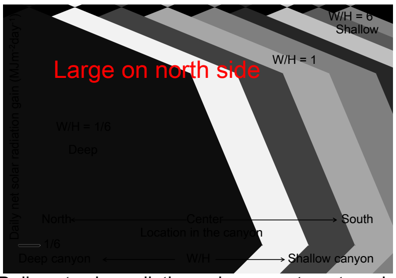
Daily net solar radiation gain on the roof



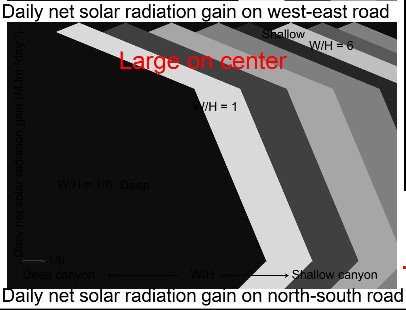
Roof area and daily net solar radiation gain on the roof

-> Large solar radiation gain on large roof area

Previous study
Daily net solar radiation gain on the road



Daily net solar radiation gain on west-east road



Daily net solar radiation gain on north-south road


Aspect ratio and daily net solar radiation gain on the road

-> Large solar radiation gain on large W/H

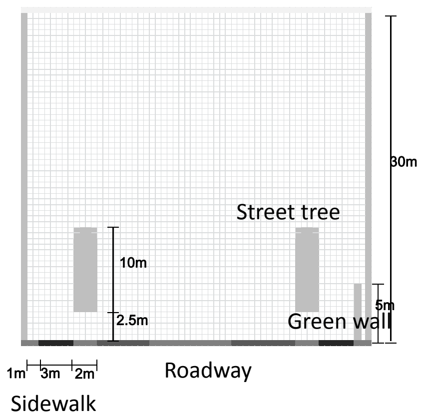
Background

From previous study results of daily net solar radiation gain, the higher priorities for the implementation of urban heat island measures are the roofs, the north sides of east-west roads, and the center of north-south roads.

Objective

- From the view point of introduction of appropriate technique for each place, it is analyzed the relationship between "<u>benefits</u>" by heat island measure technique and "<u>places</u>" it was introduced.
- Objective techniques are "<u>street tree</u>", "<u>green wall</u>", "<u>high reflectance paint</u>" and "<u>water-retentive pavement</u>", which are pointed out benefits are relatively large in previous study.
- Objective places are "<u>road</u>" and "<u>wall</u>" surface. Because the previous study results on the flat surface can be applied for roof surface.

Calculation method



Outline of street canyon model with street tree and green wall

Surface heat budget on each surface:

$$R_n = V + lE + A$$

Rn: net radiation [Wm^{-2}],
V: sensible heat flux [Wm^{-2}]
lE: latent heat flux [Wm^{-2}]
A: conduction heat flux [Wm^{-2}]

One-dimensional heat conduction equation:

$$C_p \gamma \frac{\partial T}{\partial t} = \lambda \frac{\partial^2 T}{\partial x^2}$$

$C_p\gamma$: heat capacity [$Jm^{-3}K^{-1}$)]
λ: thermal conductivity [$Wm^{-1}K^{-1}$]
T: the temperature of the wall, roof, or road [K]
t: time [s]
x: the distance to the wall, roof, or road [m]

Mesh interval for calculation is 0.5 m constant in both horizontal and vertical directions. Sky view factors from each surface and view factors between the surfaces are calculated by the Monte Carlo method. Mutual radiation between the surfaces is calculated using Gebhart's absorption factors.

Calculation condition

Road width: Narrow (20m), Middle (30m), Wide(50m)

roadway: 10m, 20m, 40m

building setback: 1m, sidewalk width: 3m, street tree width: 2m

Road orientation: East-west and North-south

Building height: 30m

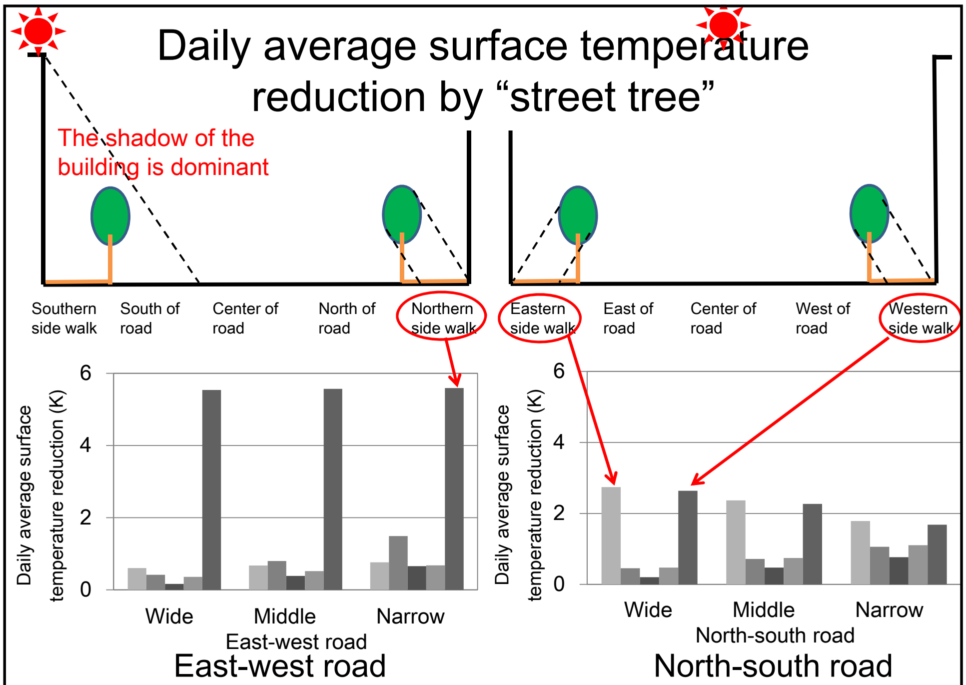
Weather condition: August 4, 2011 at Kobe (34°41.8′ N, 135°12.7′ E)

The convective heat transfer coefficient: constant value of 12.5 $Wm^{-2}K^{-1}$

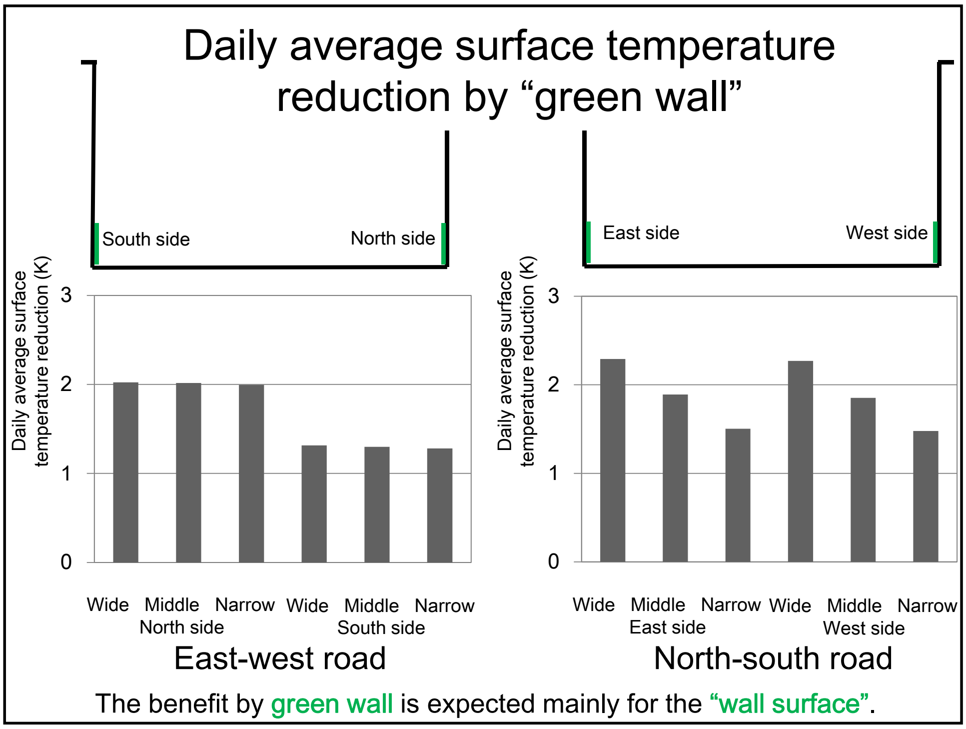
Initial surface and inner temperatures of each component: 27 deg. C

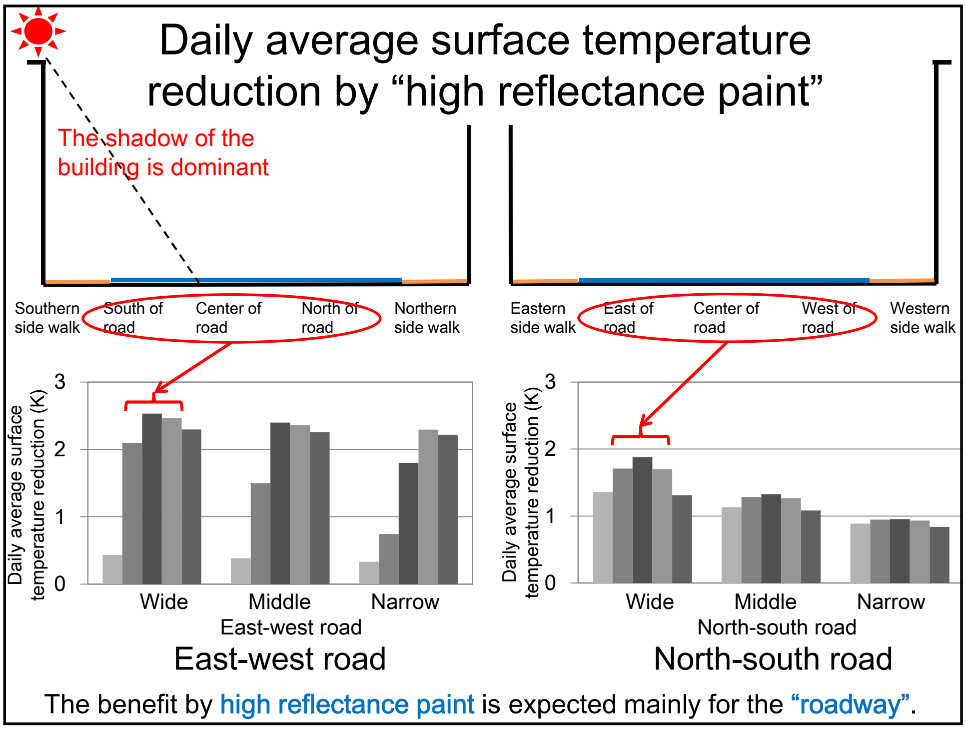
	Concrete	Asphalt	Soil
Solar reflectance	0.2	0.1	
Emissivity	0.95	1.0	
Thermal conductivity	1.64 $Wm^{-1}K^{-1}$	0.74 $Wm^{-1}K^{-1}$	0.62 $Wm^{-1}K^{-1}$
Heat capacity	1.93 $MJm^{-3}K^{-1}$	2.1 $MJm^{-3}K^{-1}$	1.58 $MJm^{-3}K^{-1}$
thickness	0.3mm	0.2mm	0.35m

Daily average surface temperature reduction by "street tree"

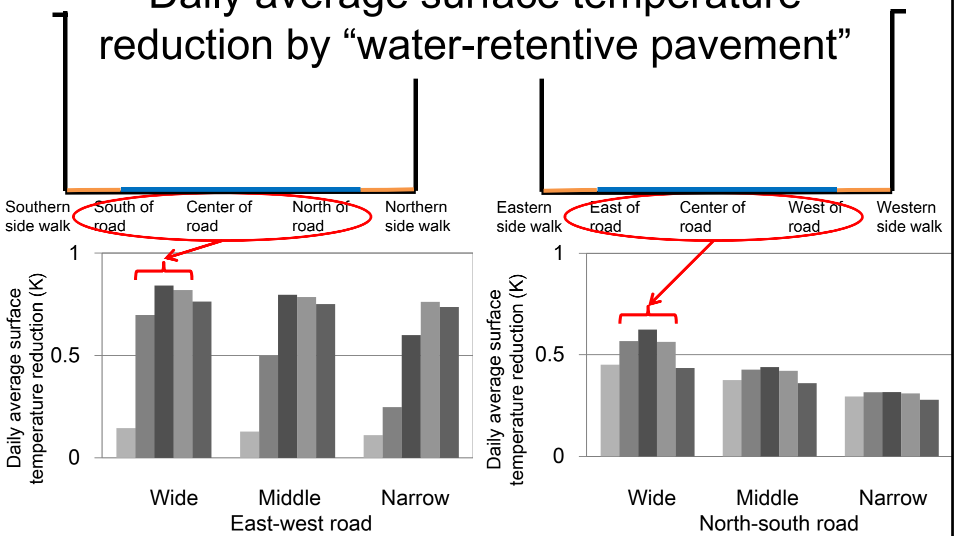


The benefit by street tree is expected mainly for the "sidewalk".


Daily average surface temperature reduction by “green wall”
South side
North side
East side
West side
Daily average surface temperature reduction (K)
3
2
1
0
Wide Middle Narrow Wide Middle Narrow
North side
South side
East side
West side
East-west road
North-south road
The benefit by green wall is expected mainly for the “wall surface”.


Daily average surface temperature reduction by “high reflectance paint”
The shadow of the building is dominant
Southern side walk
South of road
Center of road
North of road
Northern side walk
Eastern side walk
East of road
Center of road
West of road
Western side walk
Daily average surface temperature reduction (K)
3
2
1
0
Wide
Middle
Narrow
East-west road
North-south road
East-west road
North-south road
The benefit by high reflectance paint is expected mainly for the “roadway”.

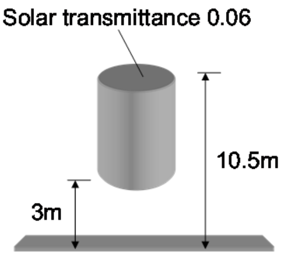
Daily average surface temperature reduction by "water-retentive pavement"



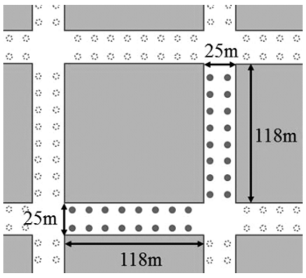
East-west road　　North-south road

The benefit by water-retentive pavement is expected mainly for the "roadway".
The difference between high reflectance paint and water-retentive pavement depends on solar reflectance, evaporative efficiency and weather condition.

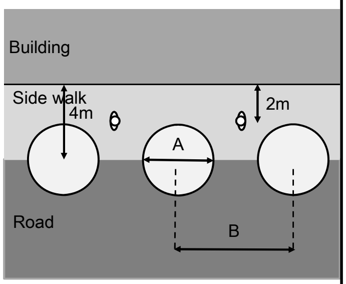
Calculation method of the solar radiation shielding by roadside tree



Street tree model



Objective urban block (building height is 18 m)

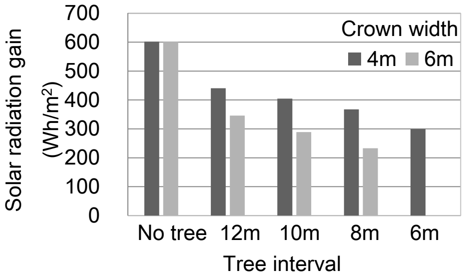


Location of street trees (A: crown width, B: tree interval)

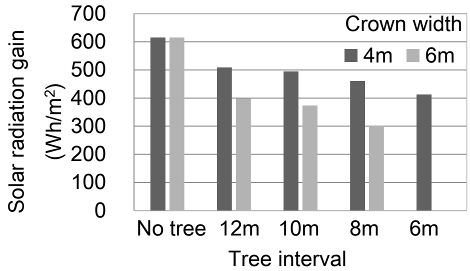
Parameter of street tree layout

Tree crown width (A)	Tree interval (B)
4 m	6, 8, 10, 12 m
6 m	8, 10, 12 m

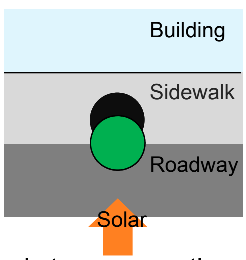
Solar radiation gain averaged along the street at 12:00 in several tree interval cases

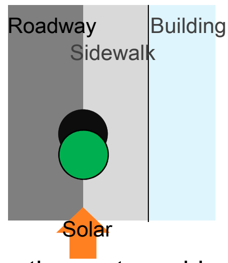


Northern sidewalk of East-west road



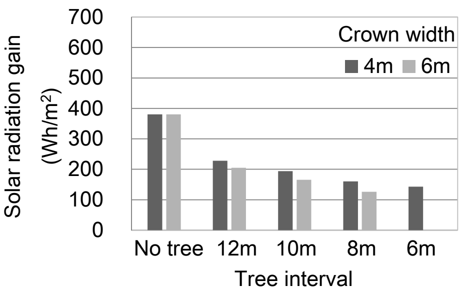
Eastern sidewalk of North-south road



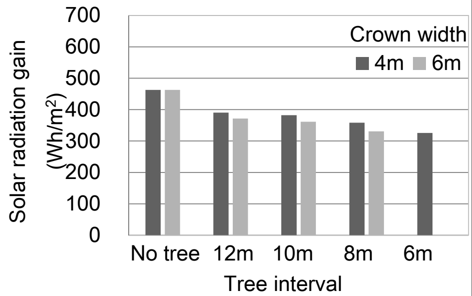


Shadow tends to occur on the northern sidewalk than the eastern sidewalk.

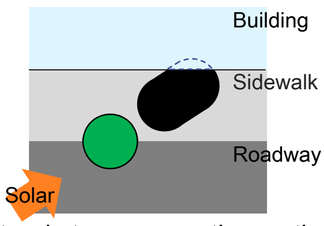
Solar radiation gain averaged along the street at 15:00 in several tree interval cases

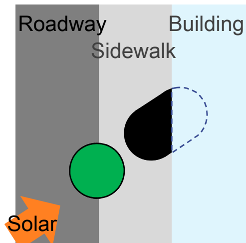


Northern sidewalk of East-west road



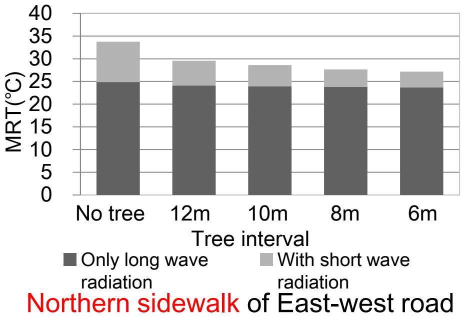
Eastern sidewalk of North-south road



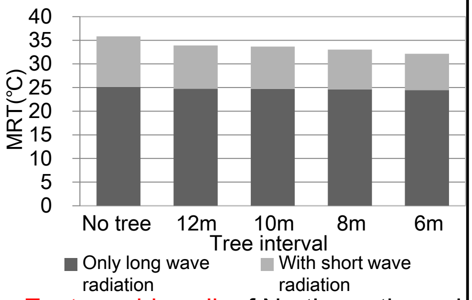


Shadow tends to occur on the northern sidewalk than the eastern sidewalk.

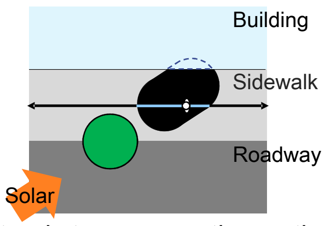
MRT averaged along the street at 15:00 in several tree interval cases (crown width is 4m)

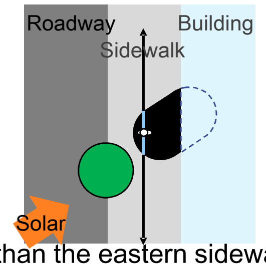


Northern sidewalk of East-west road



Eastern sidewalk of North-south road





Shadow tends to occur on the northern sidewalk than the eastern sidewalk.

Conclusions

- The benefit by street tree is expected mainly for the sidewalk.
- The benefit by high reflectance paint and water-retentive pavement is expected mainly for the roadway.
- The shadow by street tree is more significant to the thermal environment on the sidewalk. Shadow tends to occur on the northern sidewalk than the eastern (western) sidewalk.
- From the viewpoint of thermal environmental improvement, street tree is suitable for the sidewalk and high reflectance paint and water-retentive pavement is suitable for the roadway.

➡ **right technology in the right place**

Wednesday 25 September 2013

15:30-16:30: Parallel Session 2A: Long oral presentation session- Experience with ventilative and passive cooling

Chairpersons: Per Heiselberg, Lorenzo Pagliano

- **Passive cooling dissipation techniques for buildings and other structures: The state of the art** Denia Kolokotsa, Greece
- **Experimental analysis of different operational configurations for single sided natural ventilation as part of a low energy retrofit** Paul O'Sullivan, Ireland
- **Ventilative cooling of residential buildings: Strategies, measurement results and lessons-learned from three Active Houses in Austria, Germany and Denmark** Peter Foldbjerg, Denmark
- **Evaluation of ventilative cooling in a single family house** Karsten Duer, Denmark

Passive cooling dissipation techniques for buildings and other structures: The state of the art

M. Santamouris D. Kolokotsa

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Physics Department, Group Building Environmental Studies,
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Technical University of Crete
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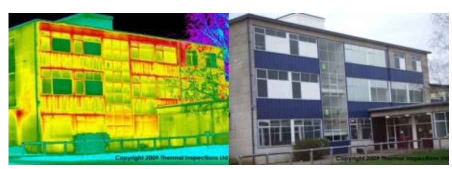
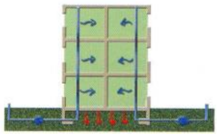
www.enveng.tuc.gr

The framework: Buildings and Cities

- ✓ **Building's scale**: Buildings present a very high energy consumption compared to the other economic sectors. Buildings are responsible for about 30-45 % of the global energy demand
- ✓ **Urban scale:** Heat island has a very serious impact on the energy consumption for cooling purposes. Heat island is the most documented phenomenon of climatic change and increases highly urban temperatures
- ✓ The energy needs for cooling have increased in a rather dramatic way.
- ✓ Discomfort for low income is also a major problem.



Passive Cooling Dissipation



- Heat dissipation techniques deal with the disposal of the excess heat of a building to a sink characterized by lower temperature, like the ambient air, the water, the ground and the sky.
- Three main processes of heat dissipation have been well studied and developed: a) **Ground cooling** based on the coupling of buildings with the ground; b) Convective or **ventilative cooling** based on the use of ambient air; c) **Evaporative cooling** using the water as a heat sink.
- More than 300 papers in the field.

Earth as a heat sink: earth to air heat exchangers

- The most common technique to couple buildings and other structures with the ground is the use of underground air tunnels, known as earth to air heat exchangers (EATHE).
- At the initial stage of the research many problems associated to the use of ground pipes were reported.
  - Accumulation of water inside the tubes
  - Problems of indoor air quality
  - Lack of efficient and dynamic control during the operation, etc.
- Today there is a significant number of successful applications of EATHE in either buildings or greenhouses.

Source Courtesy of the Aldo Leopold Foundation www.aldoleopold.org

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State of the art in ground cooling

- The state of the art was performed for:
  - Buildings: Almost 30 projects: nine offices, nine residential, five educational, two production and one commercial, multifunctional, athletic centre, hospital and care home projects.
  - Greenhouses: twenty different publications have been identified reporting application of EATHE systems in agricultural greenhouses.
  - Outdoor spaces: earth pipes to reduce the outdoor temperature. Fintikakis et al, 2011 showed that the maximum contribution of the earth to air heat exchangers was found to be close to 0.7 ◦C
  - Modeling strategies for coupling EATHE with buildings.

Reference	Country /Building	-Results
(Breesch et al. 2005)	Belgium Office	The maximum supply air **never exceeds 22 C.** Decrease the discomfort hours in the office by 20-30 % during the whole summer period.
(Pfafferott 2003)	Germany/Office	When the ambient temperature was above 36 C, the exit temperature was close to 24 C. The specific energy gains were close to 23.8 kWh/m2/year.
(Voss et al. 2007; Spieler et al. 2000; Wagner et al. 2000)	Germany Office	The specific energy gains were calculated close to 1,5 kWh/m2/year.
(Eicker 2010)	Germany/ Office	The maximum **heat dissipation per meter of tube was 8 W**, while the COP of the ETAHE for cooling was 18.
(Voss et al. 2007)	Germany /Office	The final primary energy use of the building was close to 73 kWh/m2/y
(Zimmermann 1995; Liddament 2000; Hollmuller 2002; Perino & Aschehoug 2009; Zimmermann & Remund 2001)	Switzerland /Commercial	Monitoring of the buildings has shown that the ETAHE system provides about **1/3 of total cooling demand.**
(Voss et al. 2007; Oetzel et al. 2002)	Germany Educational	The air circulated through the pipes decreased its temperature up to 7 K compared to the ambient temperature. The specific contribution of the earth to air heat exchangers varied between **10 to 16 kWh/m2/year.**
(Perino & Aschehoug 2009; Jeong & Haghighat 2003)	Norway Educational	**Monitoring has shown that the EATHE system covers all cooling needs of the building.**

Modeling strategies

- ✓ Analytical Steady State
- ✓ Analytical Transent State
- ✓ Neural Networks
- ✓ Coupling of EATHE with dynamic models such as TRNSYS.

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Water as a heat sink: Evaporative Cooling

- ✓ The state of the art review based on the categorization of evaporative cooling:
  - Direct evaporative coolers (DEC)
  - Indirect evaporative coolers (IEC)
  - Hybrid systems such as two stage DEC-IEC, three stage evaporative coolers, and combination of evaporative cooling with other technologies.

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DEC Applications and Results

- ✓ Direct evaporative cooling is the simplest and oldest form of air conditioning. It is performed using a fan to draw hot outside air into the building by passing it from an evaporative pad.

DEC Configurations

- ✓ **Water falls over films** (Giabaklou & Ballinger, 1996). Simulation results for, a semi-arid location in New South Wales Australia average relative humidity inside the building equal to 73.2% with average air velocity of 0.28m/s and average temperature of 24.18°C, which is close to the comfort range.
- ✓ The use **of micronisers** studied by (Robinson, et al, 2004). The micronisers spray small droplets of water into the air.
- ✓ **Porous ceramics** as evaporators (Riffat et al, 2004) and (He et al, 2010). The maximum cooling effect measured is almost 224 W/m2 with high porosity ceramic evaporator.
- ✓ An **evapo-reflective roof** to reduce passive cooling in buildings for hot arid climates has been proposed in (Ben Cheikh & Bouchair, 2004). The roof design consists of a concrete ceiling over which lies a bed of rocks in a water pool. Through simulations in Algeria it can **reduce the internal room air temperatures during the day up to 8 °C.**
- ✓ Coupled **DEC with a solar chimney** (Maerefat & Haghighi, 2010). The chimney effect forces the air to move through the cooling cavity with wetted cool surfaces. Numerical analysis together with experiments show that even when the solar intensity is low the indoor thermal conditions are within acceptable range.
- ✓ **Water evaporative walls** are proposed in (Naticchia, D'Orazio, Carbonari, & Persico, 2010) and (He & Hoyano, 2010). The reduction in the peak temperature **is 5 ◦C** after the spraying..

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IEC Configurations

- ✓ Indirect evaporative cooling techniques can be low energy solutions for medium and large buildings where passive cooling techniques cannot reach the required comfort conditions.
- ✓ Such systems require energy for the fan power for the air flow. On the one hand this fan power can be up to 20% less due to lower air velocities required and on the other hand the main reduction of the energy demand is attributed to the replacement of the conventional air conditioning system.

IEC Applications

- ✓ An indirect evaporative chilled was developed and tested in Shihezi City, China (Joudi & Mehdi, 2000) and (He & Hoyano, 2010). It saved more **than 40% electricity compared with ordinary air conditioning systems.**
- ✓ An IEC is tested in an experimental house, in Maracaibo, Venezuela by (Eduardo Krüger, González Cruz, & Givoni, 2010) . For the specific case study in Maracaibo**, the indoor temperature drop through the IEC is 0.9-1°C comparing with no cooling system.**
- ✓ Sub-wet bulb temperature IEC is examined by various researchers. The aim of such systems is to enable cooling below the wet bulb temperature of the ambient air. The concept is to reach the dew point of ambient air. The wet bulb cooling effectiveness for the examples studied is 1.26, 1.09 and 1.31 for the two-stage counter flow, parallel flow and combined parallel-regenerative cooler, respectively, and it is 1.16 for the single-stage counter flow regenerative cooler.
- ✓ The significance of the heat exchangers in the cooling efficiency of the IEC is analysed in (Zhan, et al, 2011; Zhan, Duan, et al., 2011). The counter-flow exchanger demonstrated better cooling effectiveness and 20% higher cooling capacity than the cross-flow system.

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Use of Air as a Heat Sink: Ventilative Cooling

- ✓ State of the art of night ventilation or nocturnal convective cooling.
- ✓ The cooling potential of night ventilation techniques depends on the air flow rate, the thermal capacity of the building and the appropriate coupling of the thermal mass and the air flow.
- ✓ The state of the art in the effectiveness of night ventilation is based either:
  - Ventilation experiments
  - Simulation based results

Night ventilation analysis via experiments

- ✓ Studies in real buildings or test cells, are reported in (Allard & Santamouris, 1998; Blondeau, Spérandio, & Allard, 1997; Geros et al., 2005; Geros, Santamouris, Tsangrasoulis, & Guarracino, 1999; Baruch Givoni, 1994; Kolokotroni, Tindale, & Irving, 1997; E Krüger, González Cruz, & Givoni, 2010; Kubota, Chyee, & Ahmad, 2009; Pfafferott, Herkel, & Jäschke, 2003; Santamouris & Assimakopoulos, 1997; Springer, Rainer, & Dakin, 2005; van der Maas & Roulet, 1991; Zimmerman & Andersson, 1998).
- ✓ Most of the studies conclude that the use of night ventilation in free floating buildings may decrease the **next day peak indoor temperature up to 3K.** In parallel, when applied in air conditioned buildings, a considerable reduction of the peak cooling may be expected.

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Night ventilation for offices

- ✓ The analysis of night ventilation for office buildings during summer period is performed by Blondeau et al (Blondeau et al., 1997) showing a reduction of diurnal variation from **1.5 to 2°C, resulting in a significant comfort improvement for the occupants**.
- ✓ The predicted effectiveness of night ventilation in four buildings in UK is studied in (Kolokotroni, Webb, & Hayes, 1998; Kolokotroni, 2001). A hybrid ventilation strategy, i.e., air conditioning during the day and natural ventilation during the night shows that energy savings of about **5% of the cooling energy could be obtained in typical buildings**
- ✓ Testing the night cooling in buildings with large internal loads, intensive night cooling enables the lowest internal mass temperatures and the lowest power loads throughout the whole working day. **The peak power load is reduced by 13%.**
- ✓ Gratia et al in (Gratia, Bruyère, & De Herde, 2004) studied the night ventilation potential for narrow offices in Belgium where **single-sided day ventilation can reduce cooling needs by about 30% and cross night ventilation can reduce the cooling demand by 38%.**

More applications of ventilative cooling

- ✓ Night ventilation coupled with double skin facades for industrial archaeology buildings is studied in (Ballestini, De Carli, Masiero, & Tombola, 2005) showing using simulation techniques that at least **12% of energy can be reduced on yearly basis**.
- ✓ Night ventilation and active cooling coupled operation strategy is studied for the large supermarkets in cold climates in China. Compared with the normal active cooling system, the coupled operation system can save energy at 2.99 kWh/(m^2 a) in cold climates in China while 3.24 kWh/(m^2 a) in Harbin (Wu, Zhao, & Wang, 2006).

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Ventilative Cooling and Urban Environment

- ✓ Impact and uncertainty of night ventilation due to poor outdoor environmental conditions and urban heat island phenomenon:
  - An urban office using night ventilation has 10% less cooling demand than a typical office while a suburban office where night ventilation is applied does not need extra mechanical cooling. During an extreme hot week, an optimised office in London would require 27% of the cooling needed by the reference office while in a rural location the value is 14% (Kolokotroni et al., 2006).
  - (Geros et al., 2005) analysed the cooling potential of night ventilation in the urban context. The research is focused on ten urban canyons in the area of Athens, Greece where various environmental parameters are measured. In non-air-conditioned buildings where the effect of night ventilation concerns the reduction of the indoor temperature the next day, the dominated inside the canyons conditions reduce the efficiency of the technique, (on average up to 4 °C for the studied canyons).

Conclusions

- ✓ Urban climate change and heat island effect is another important source enhancing the use of air conditioning and increasing peak electricity demand.
- ✓ Important research has been carried out that has resulted in the development of alternative to air conditioning systems, techniques and materials. The proposed technologies, known as passive cooling can provide comfort in non-air conditioned buildings and decrease considerably the cooling load of thermostatically controlled buildings. In parallel, passive cooling techniques and systems may be used to improve the outdoor urban environment and fight heat island.
- ✓ The proposed technologies have been tested in demonstration and real scale applications with excellent results. The efficiency of the proposed passive cooling systems is found to be high while their environmental quality is excellent.
- ✓ Expected energy savings may reach 70 % compared to a conventional air conditioned building while substantial improvements have been measured in outdoor spaces.

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Thank you for your attention

Santamouris, M., & Kolokotsa, D. (2013). Passive cooling dissipation techniques for buildings and other structures: The state of the art. Energy and Buildings, 57, 74-94.

EXPERIMENTAL ANALYSIS OF DIFFERENT OPERATIONAL CONFIGURATIONS FOR SINGLE SIDED NATURAL VENTILATION AS PART OF A LOW ENERGY RETROFIT

Paul D O'Sullivan & Maria Kolokotroni

34th AIVC Conference, Athens, Greece, 25th & 26th Sept 2013

Corresponding author: paul.osullivan@cit.ie

Background & Context

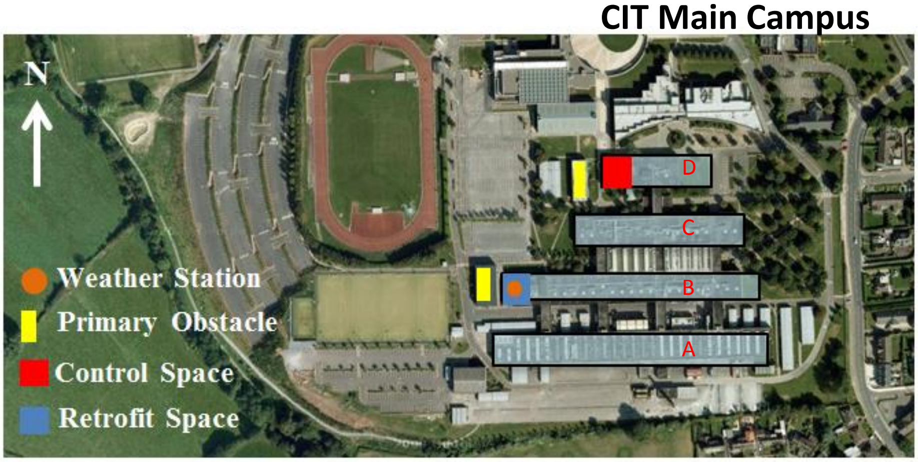
- CIT refurbished 3% of 29,000m^2 1974 building as pilot project
- Aimed at delivering nearly zero energy performance in retrofit
- Single sided ventilation chosen as cooling strategy
- Alternative ventilation opening solution in retrofit
- Undertaken a comparative analysis of existing and retrofit spaces

Objectives

- Measure time-averaged ventilation rate for the retrofit and control spaces under different conditions
- Compare time-averaged ventilation rate for different retrofit ventilation opening configurations
- Investigate the effect of wind & thermal forces during tests
- Investigate relative strength of zone vertical air temperature difference to envelope temperature diff.

Retrofit Space & Control Space - Location

CIT Main Campus



29,000m^2 existing 1974 building wings A - D

Long Term & Short Term Local Climate

Month	Cork Airport TMY3 95th Percentile			Summer 2013 95th Percentile**		
	G_h (Wh/m²)	T_a (°C)	WS (m/s)	G_h (Wh/m²)	T_a (°C)	WS (m/s)
May	742	17.2	10.0	730	16.0	6.3
June	815	19.5	9.3	826	20.6	5.0
July	**707**	**20.7**	**9.0**	**795**	**25.0**	**4.3**
August†	662	20.0	9.3	567	19.1	4.7
September*	574	19.4	9.0	-	-	-

† Data up to 15th August only for short term; *Data not yet available for short term; **Data taken from zero2020 weather station

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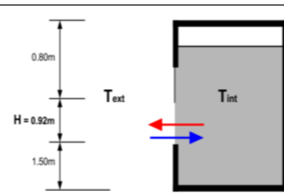
Control Space

External West Facing First Floor Zone

Zone Interior

Configuration	Vent Opening Type	Schematic Envelope Flow Model
CS/1.0/M 0.32m^2		

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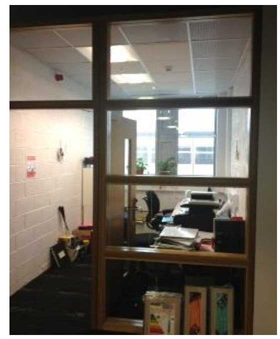
Retrofit Space

Retrofit Space External



RE Zone Interior

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Fenestration Module

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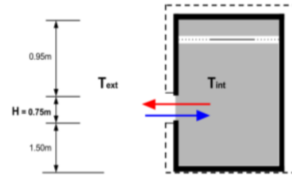
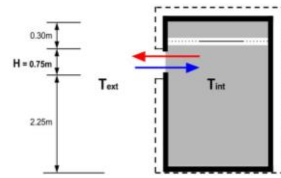
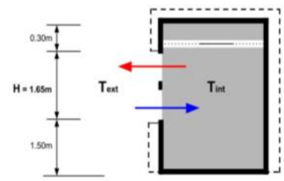
Retrofit Space Ventilative Cooling Configuration

Configuration	Vent Opening Type	Schematic Envelope Flow Model
RE/2.0/M $0.21m^2$		
RE/3.0/A $0.21m^2$		
RE/4.0/M/A $0.42m^2$		

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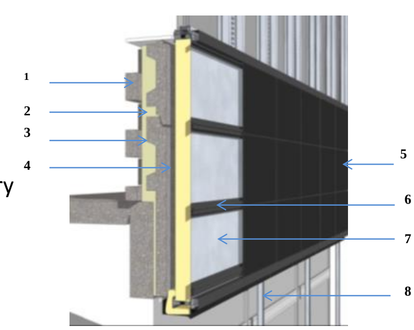
Properties of retrofit opaque wall

Location	ω/φ (W/mK) / h	f (W/mK)	U_{wall} (W/m^2K)	$U_{fenestr.}$ (W/m^2K)
Control Space	**5.49 / 1.017**	**0.608**	3.633	6.0
Retrofit Space	**5.92 / 0.963**	**0.004**	0.090	0.84

Opaque external wall retrofit details

Component 1-4 existing structure boundary

Component 5-8 new external envelope boundary



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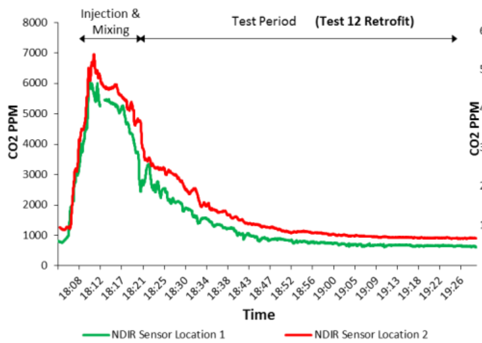
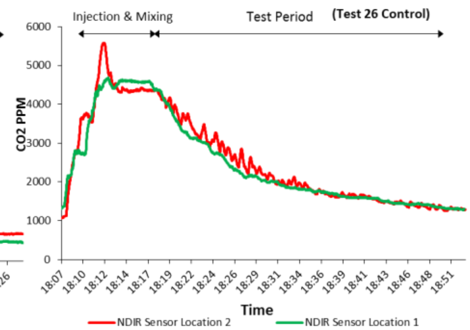
Tracer Gas Decay Method - Test Conditions





Config.	No of tests	Range of test durations	Average Conc. uniformity	Start PPM Range (Adj.)	End PPM Range (Adj.)	Average B.G. PPM (%)
CS/1.0/M	13	24 – 90 min	5.11 %	2776-5743	386-1286	10.3
RE/2.0/M	6	26 – 77 min	3.10 %	3129-4687	495-1583	12.3
RE/3.0/A	6	31 – 50 min	3.47 %	3105-3787	865-1424	13.4
RE/4.0/A/M	13	30 – 161 min	4.73 %	2546-4198	334-1179	13.0

Ventilation Rate Measurement Results

Control Space test results

Test Config.	Max ACH^{-1}	Min ACH^{-1}	Std. Dev.	Ave ACH^{-1}	Occ. < 3.0 ACH	Occ. < 1.5 ACH	WS Range (m/s)	No. of Windward/ Leeward tests	ΔT_{ie} Range (°C)
CS/1.0/M	4.7	1.2	1.2	2.8	7	4	1.41-5.20	9/4	4.2-8.9

Retrofit Space test results

Test Config.	Max ACH^{-1}	Min ACH^{-1}	Std. Dev.	Ave ACH^{-1}	Occ. < 3.0 ACH	Occ. < 1.5 ACH	WS Range (m/s)	No. of Windward/ Leeward tests	ΔT_{ie} Range (°C)
RE/2.0/M	3.6	1.3	0.9	2.1	1	2	1.36-5.24	4/2	0.5-5.5
RE/3.0/A	2.8	1.1	0.9	1.7	0	2	3.33-4.24	1/2	1.1-5.3
RE/4.0/A&M	3.7	0.5	0.9	2.5	5	3	1.52-4.47	7/6	0.4-7.1

Analysis of Dominant Forces

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

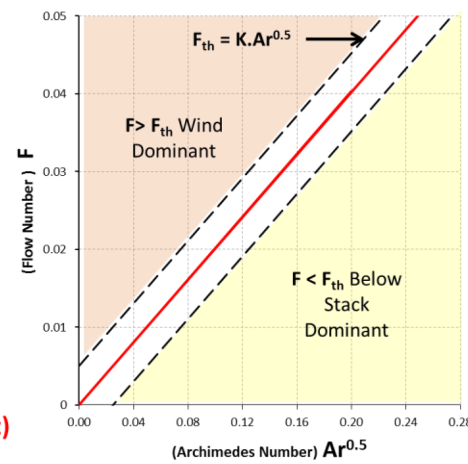
$$Ar^{0.5} = \frac{\Delta T g H}{T v_{wind}^2}$$

Dimensionless Flow number, F, described as:

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

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

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



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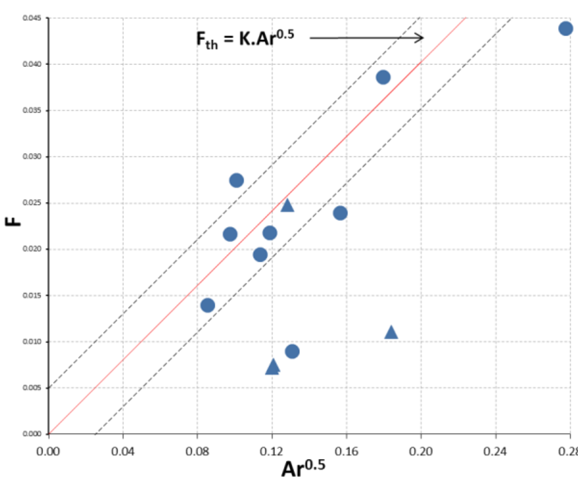
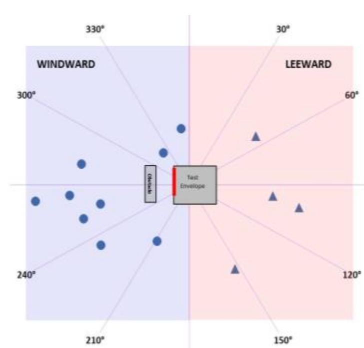
Warren Plot for CS Config





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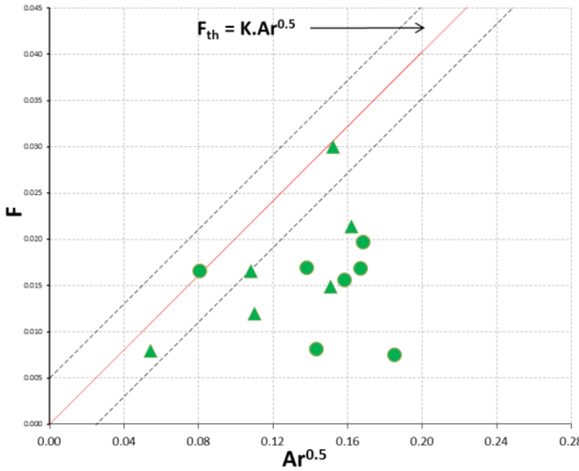
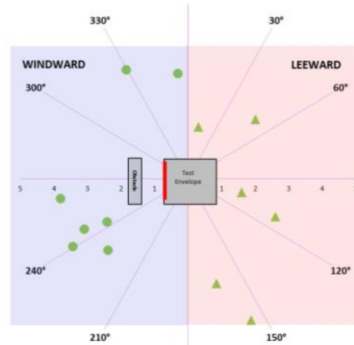
Warren Plot for RE Config





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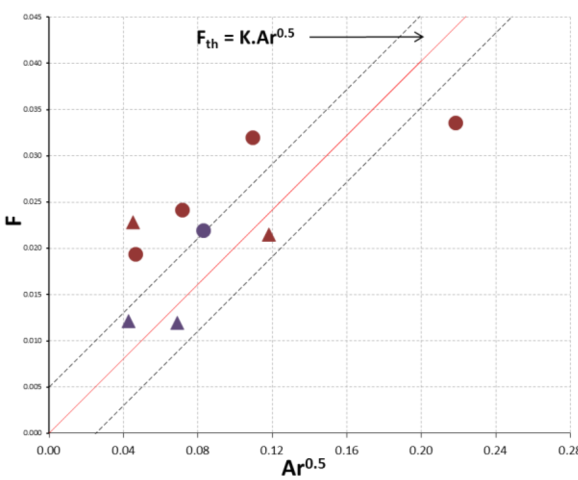
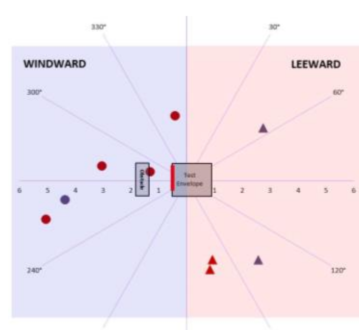
Warren Plot for RE2.0 & RE3.0 Config





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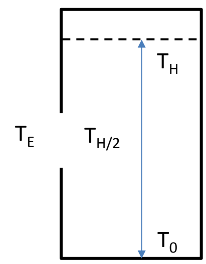
Analysis of Thermal Stratification

The stratification factor (*Str Fr*) $= \frac{Stratification\ Temp\ Difference}{Envelope\ Temp\ Difference} = \frac{\Delta T_s}{\Delta T_{ie}} = \frac{T_H - T_0}{T_{H/2} - T_E}$

StrFr Results for Test conditions close or equal to F_{th}

Config	Test	Str Fr	$\lvert F-F_{th} \rvert$	Km^{-1}	Kappa
CS/1.0	3	**0.227**	0.002	0.49	0.95
CS/1.0	4	**0.551**	0.002	0.94	0.76
CS/1.0	27	**0.565**	0.001	1.00	0.72
CS/1.0	2	**0.621**	0.003	1.81	0.64
RE/2.0	29	**0.700**	0.002	1.30	0.57
CS/1.0	14	**1.051**	0.003	3.20	0.38
RE/3.0	25	**1.111**	0.002	1.20	0.31
RE/3.0	16	**1.125**	0.004	0.60	0.13
RE/4.0	32	**1.438**	0.001	0.80	0.01
RE/4.0	24	**1.809**	0.000	1.20	0.01



Summary of StrFr Data

20th June – 19th July 2013 Values *Str.Fr ($\Delta T_s/\Delta T_{ie}$)* Data

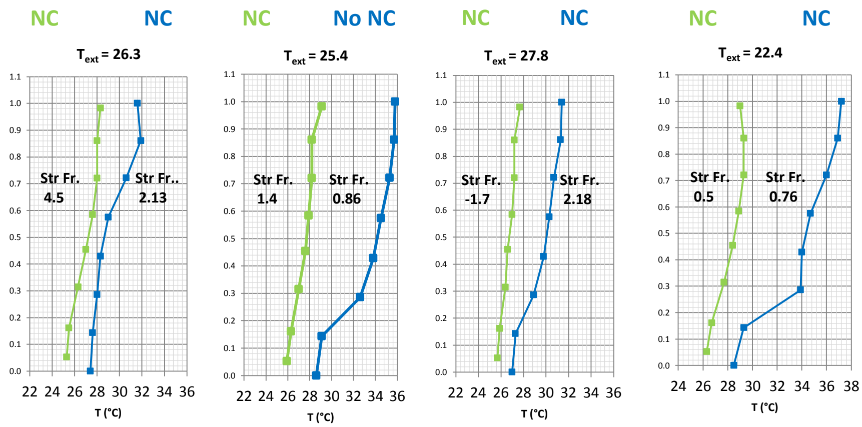
Space.	Occupied hours (09:00-18:00)				Unoccupied Hours (18:00-09:00)			
	50^{th}	75^{th}	95^{th}	**% occ hrs >1**	50^{th}	75^{th}	95^{th}	% occ hrs>1
Control	0.411	0.691	1.19	**9.0%**	0.192	0.333	0.622	0.0%
Retrofit	0.202	0.609	2.59	**14.5%**	0.157	0.290	0.611	2.2%

Analysis of overheating criteria retrofit and control space

Space.	hrs>25°C (%Σhrs)*	**hrs>28°C (%Σhrs)***
Control	34	**17**
Retrofit	33	**3.5**

**Based on 981 working hours May-September*

Vertical Temperature Distribution



12-Jul **15:30** 10-Jul **16:45** 13-Jul **16:50** 18-Jul **20:00**

RE vs. CS stratification

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Conclusion & Future Work

- Retrofit works modified the internal environment
- Time averaged ventilation rates generally lower in Retrofit
- Ventilation opening characteristics as important as thermophysical properties
- Influence of wind conditions on ventilation rates is complicated by local obstacles at the site nearby the CS and RE spaces
- Retrofit had higher relative stratification strength compared to the existing building
- Stratification profiles more linear in retrofit compared with control space

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Thank You

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Ventilative Cooling of Residential Buildings

Measurement Results from three Active Houses in Austria, Germany and Denmark

Peter Foldbjerg and Thorbjørn Asmussen
VELUX A/S, Department of Daylight, Energy and Indoor Climate
Peter.foldbjerg@velux.com

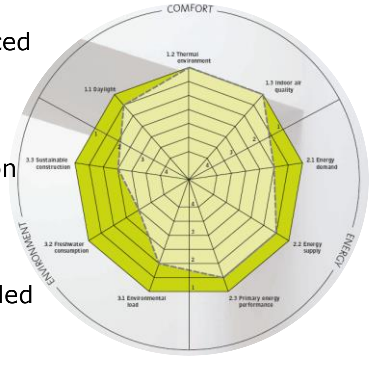
34th AIVC conference
25-26 September 2013, Athens, Greece

ModelHome 2020
Six experiments
Five countries

- *Completed in 2009:*
  Home for Life (HFL) in DK
  Completed in 2011:
  LichtAktiv Haus (LAH) in DE
  Sunlighthouse (SLH) in AT
- Measurements of IEQ and energy for one year
- The houses have been occupied by families for one year

Design targets

- Based on Active House principles: balanced focus on IEQ, energy performance and environmental impact
- Generous daylight conditions; windows on all facades and daylight from several directions in each room
- Ventilative cooling, automatically controlled natural ventilation and solar shading
- *Active House session Thursday 11:50*



Active House categories for thermal comfort

- Using method from EN 15251, adaptive approach (for naturally ventilated buildings) based on running mean temperature
- Scale: 1 to 4 (four levels, vs. three levels in EN 15251)

The maximum indoor operative temperatures are:
1. $T_{i,o} < 0.33 \times T_{rm} + 20.8°C$, for T_{rm} of 12°C or more
2. $T_{i,o} < 0.33 \times T_{rm} + 21.8°C$, for T_{rm} of 12°C or more
3. $T_{i,o} < 0.33 \times T_{rm} + 22.8°C$, for T_{rm} of 12°C or more
4. $T_{i,o} < 0.33 \times T_{rm} + 23.8°C$, for T_{rm} of 12°C or more (not in EN 15251)

"Too high" used in here applies to $T_{i,o} > 0.33 \times T_{rm} + 23.8°C$, for T_{rm} of 12°C or more

The minimum indoor operative temperatures are:
1. $T_{i,o} > 21°C$, for T_{rm} of 12°C or less
2. $T_{i,o} > 20°C$, for T_{rm} of 12°C or less
3. $T_{i,o} > 19°C$, for T_{rm} of 12°C or less
4. $T_{i,o} > 18°C$, for T_{rm} of 12°C or less (not in EN 15251)

"Too low" used here applies to $T_{i,o} < 18°C$, for T_{rm} of 12°C or less

Measurements

- Quantitative:
  Continuous hourly measurements in each room:
  - Temperatures, lux, humidity, CO_2-level
  - Energy production and consumption
  - Position of windows and solar shading, manual override of auto control

- Qualitative (Not part of this presentation):
  Families' experienced collected by anthropologists through visits and interviews with family members

Kristensen family in Home for Life

Dorfstetter family in Sunlighthouse

Oldendorf family in LichtAktiv Haus

5

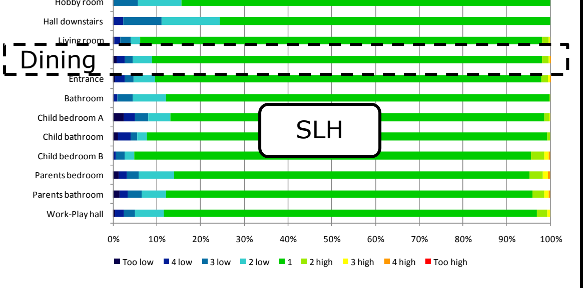
Thermal comfort; overview

VELUX®

- All main rooms achieve Active House level 1 regarding overheating (corresponds to EN 15251 category I)

- Focus on combined kitchen/dining: most challenging room due to large glazed area

- SLH: undercooling in all rooms



6

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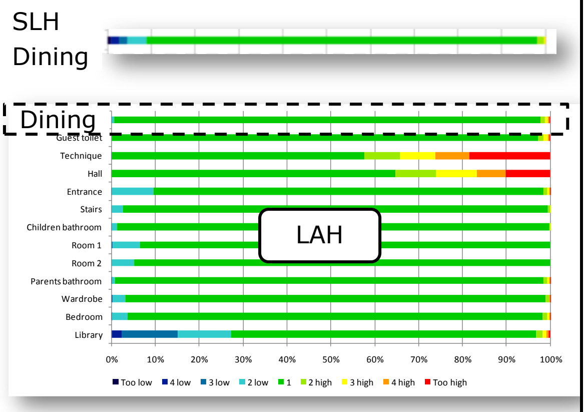
- SLH: undercooling in all rooms
- LAH: Overheating in hall and technique rooms, undercooling in top-floor “library”



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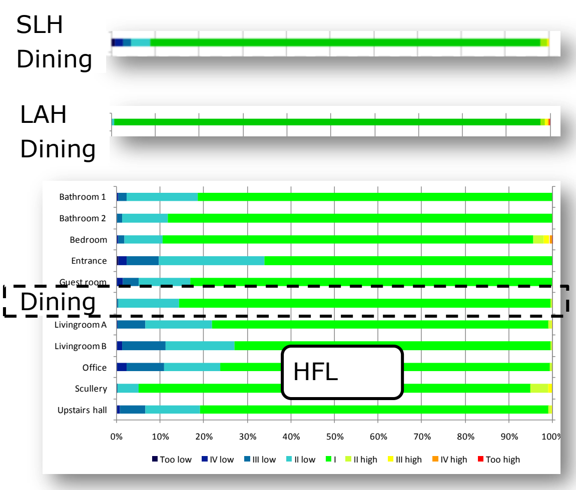
- HFL: undercooling in all rooms



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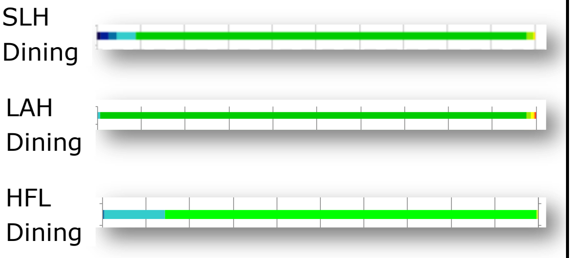
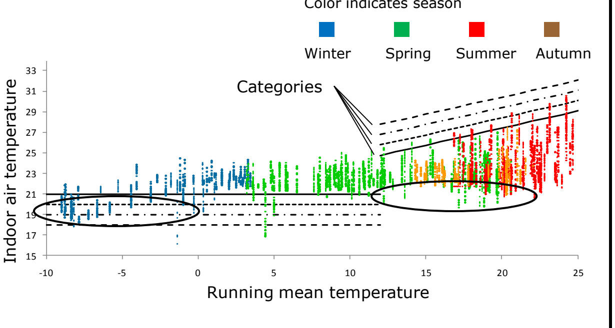


9

Measured temperatures: SLH, Austria

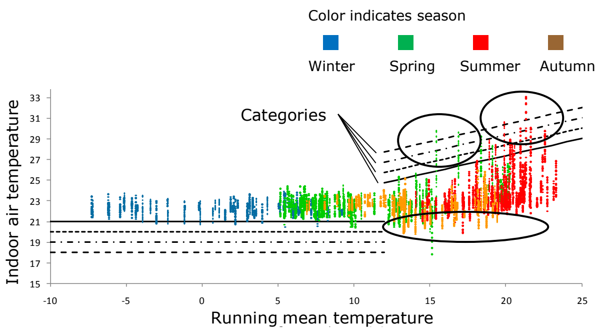
- Very little summer overheating in SLH
- Substantial undercooling, mainly during one cold winter week when the family had not yet moved in and when the heat pumped was not working properly
- Temperatures below 21°C are seen during summer due to use of night cooling



10

Measured temperatures: LAH, Germany

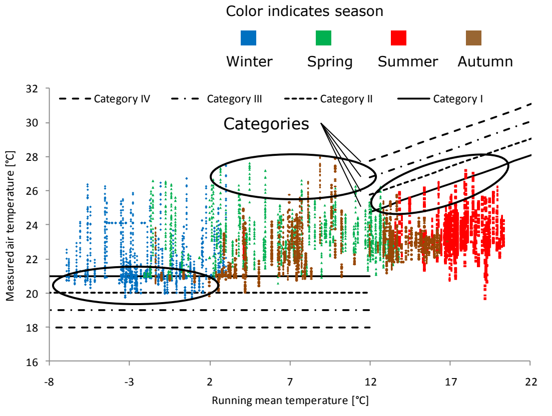
- Temperatures below 21°C occur during all seasons, but few episodes below 20°C
- Litle summer overheating
- A few spring episodes with high temperatures
- Temperatures below 21°C are seen during summer due to use of night cooling



11

Measured temperatures: HFL, Denmark

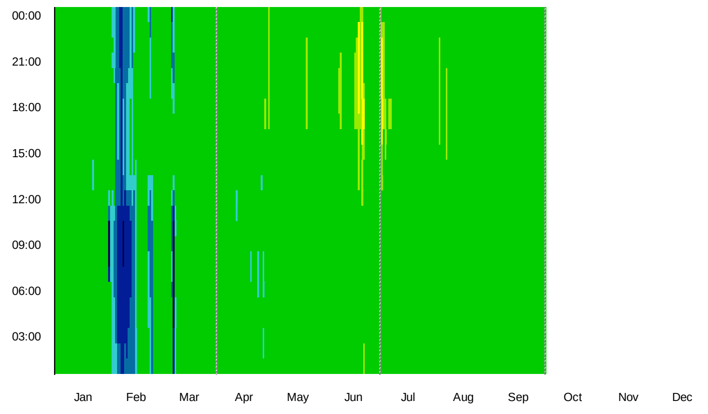
- Limited overheating in summer
- Some overheating in intermediate seasons
- Low temperatures during winter (mainly between 20°C and 21°C)



12

Temporal map, SLH Austria

VELUX



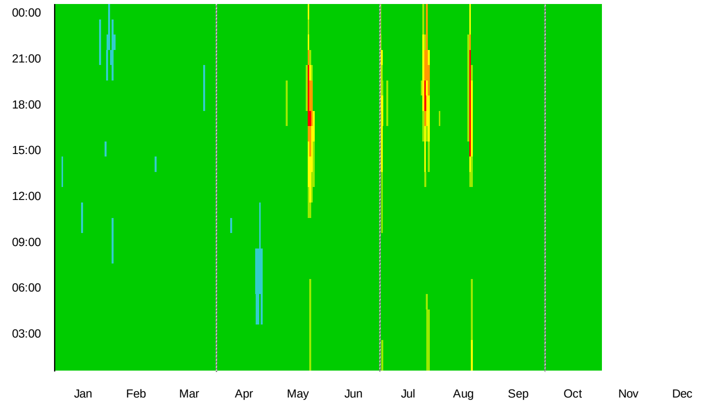
Color indicates Active House/ EN 15251 category

- Substantial wintertime undercooling is seen in one specific week before family moved in; heat pump not ready yet
- Some days reach cat. 2 or worse from 15:00 to 21:00, potentially due to solar gains

13

Temporal map, LAH, Germany

VELUX



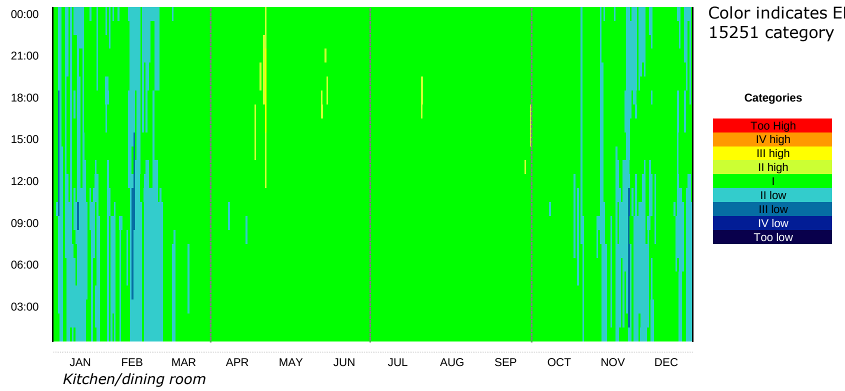
Color indicates Active House/ EN 15251 category

- No wintertime undercooling is seen
- Some days reach cat. 2 or worse from 12:00 to 21:00, potentially due to solar gains

14

Temporal map, HFL, Denmark

Color indicates EN 15251 category

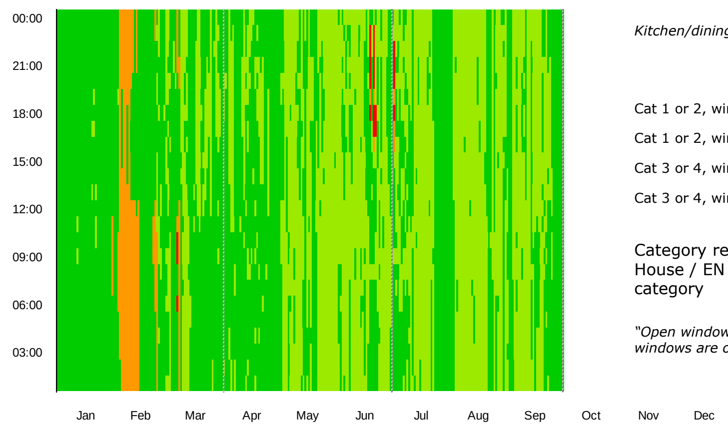


Kitchen/dining room

- Low temperature episodes in winter; length: 1 – 2 weeks
- Occupants reported an active choice of a 20°C heating setpoint
- Some days reach cat. 1 between 12:00 to 21:00, potentially due to solar gains

15

Temporal map; Use of windows; SLH, Austria



Kitchen/dining room

Cat 1 or 2, windows closed

Cat 1 or 2, windows open

Cat 3 or 4, windows closed

Cat 3 or 4, windows open

Category refers to Active House / EN 15251 category

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

- Windows closed during winter undercooling => not draft
- Windows used 24h May to September incl. night cooling
- Good thermal comfort occur when windows are open, except for 2 episodes

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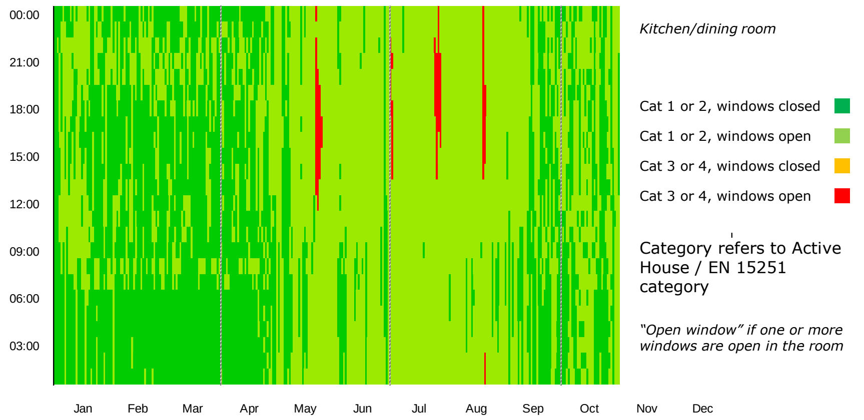
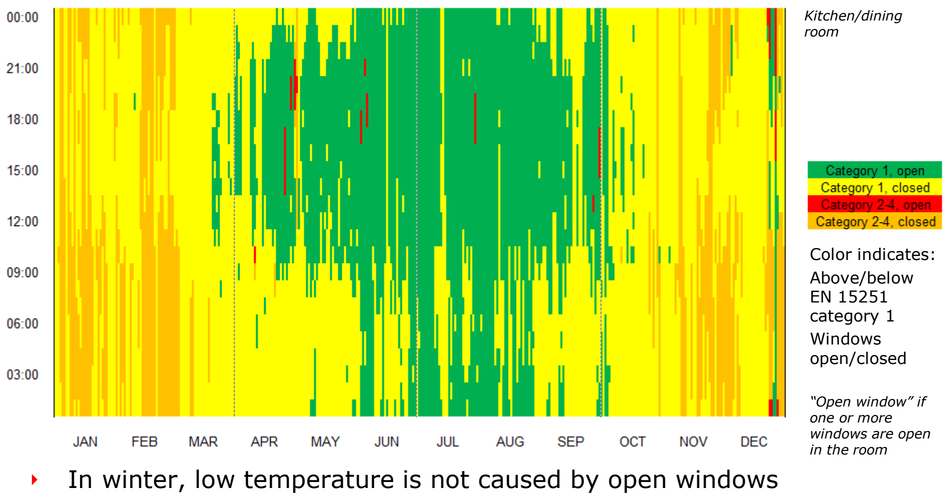
Temporal map; Use of windows; LAH, Germany



- Airings daily 6:00 to 8:00 and 20:00 to 22:00 all year
- Windows used 24h May to September incl. night cooling
- Daytime use of windows in transition periods
- Good thermal comfort occur when windows are open, except for 4 episodes

17

Temporal map; Use of windows; HFL; Denmark



- In winter, low temperature is not caused by open windows
- Good thermal comfort occur when windows are open, except for 4 episodes

18

Learnings and conclusions (1)

- The adaptive approach of Active House / EN 15251 used for evaluation
- The combined kitchen/dining room in contemporary architecture is the most challenging regarding overheating
- Some winter undercooling observed, with simple explanations:
  - HFL (DK): Temperatures between 20-21°C as occupant preference
  - SLH (AT): Heat pump malfunction before occupants moved in
  - LAH (DE): No noteworthy undercooling observed
- In residential buildings it is important that the heating system has adequate power, but measured temperatures in category 2 (or 3) can be an occupants preference and considered an acceptable trade-off with costs for heating

21

Learnings and conclusions (2)

- In the houses, the minimum measured temperature was constant in the summer, i.e. did not increase with increasing T_{rmt}
  - Indicates that occupants accept use of night cooling
- Some daytime overheating was observed in all the houses in the transition periods – probably caused by preference for solar gain utilisation instead of overheating prevention in these periods
- Practically no summer time overheating despite generous daylight conditions
- The use of window openings in the summer time generally occurred at the same time as category 1 thermal comfort, indicating that ventilative cooling contributed to good thermal comfort

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VELUX

Ventilative Cooling of Residential Buildings

Strategies, Measurement Results and Lessons-learned from three Active Houses in Austria, Germany and Denmark

Thanks for listening!

Peter.foldbjerg@velux.com

Evaluation of ventilative cooling in a single family house

AIVC conference, Athens 2013

Bruno Peuportier, Karsten Duer, Christoffer Plesner and Nicolas Dupin

1

Ventilative cooling in a single family house

CONTENT

- Purpose
- Background
- Methodology
- Results
- Conclusions

2

PURPOSE

Purpose

- To evaluate the ventilative cooling performance expressed as Air Change Rates and the resulting indoor air temperature in the zero energy Active House Maison Air et Lumière, located near Paris.

3

BACKGROUND

Background

- Low energy buildings are subject to important overheating risks
- Large potential of ventilative cooling.
- One barrier is the difficulty of evaluating air flows. Appropriate calculation methods and characterization of openings are needed, so ventilative cooling can be dealt with in design, regulation and certification tools.

4

METHODOLOGY

Methodology

ARMINES VELUX

- Laboratory testing of air flow characteristics of roof windows
- On-site measurements of
  - Air change rates
  - Indoor air temperatures
  - Climatic data
- Multi-zone thermal and airflow simulation of the building
- Comparisons between simulations and on site measurements.

LAB TEST

Methodology

ARMINES VELUX

Varying the flow rate -> varying pressure difference

$Q = S \cdot Cd\ (P2 - P1)^n$

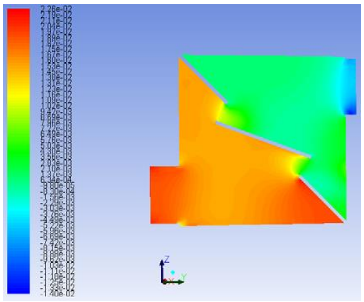
Section S = geometrical area

Identify Cd and n

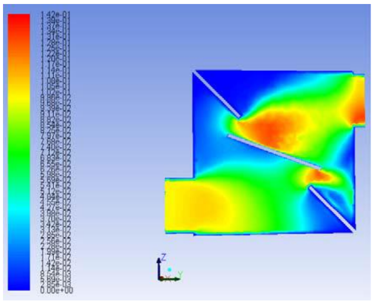
LAB TEST

Methodology

ARMINES VELUX



Static pressure



Air velocity

7

THE BUILDING

Methodology

ARMINES VELUX

Situated near Paris
135 m[2] Active House,
CO_2 neutral

8

THE BUILDING

Methodology

Ventilative cooling:

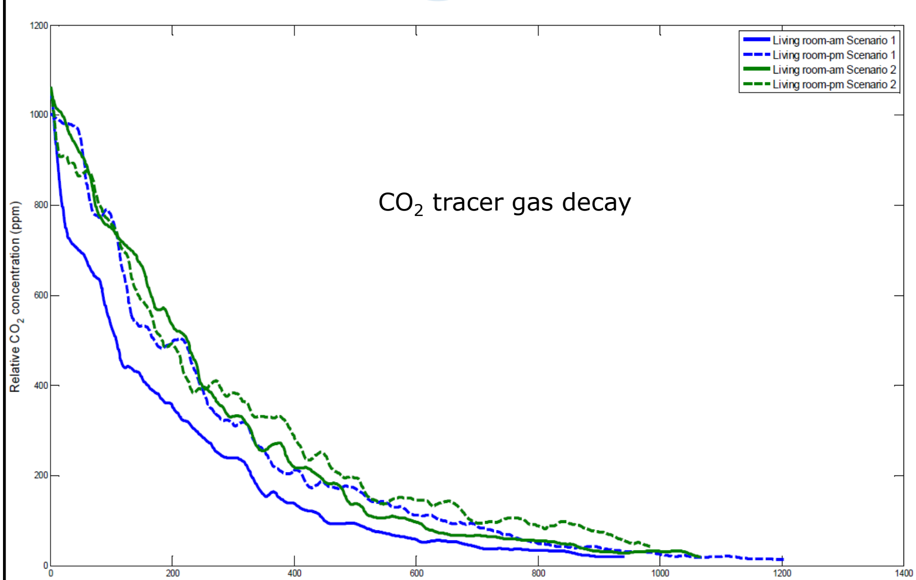
Supply air: vertical top flap windows and

Exhaust air: roof windows

Automatic control of windows, shadings etc

ON SITE MEASUREMENTS

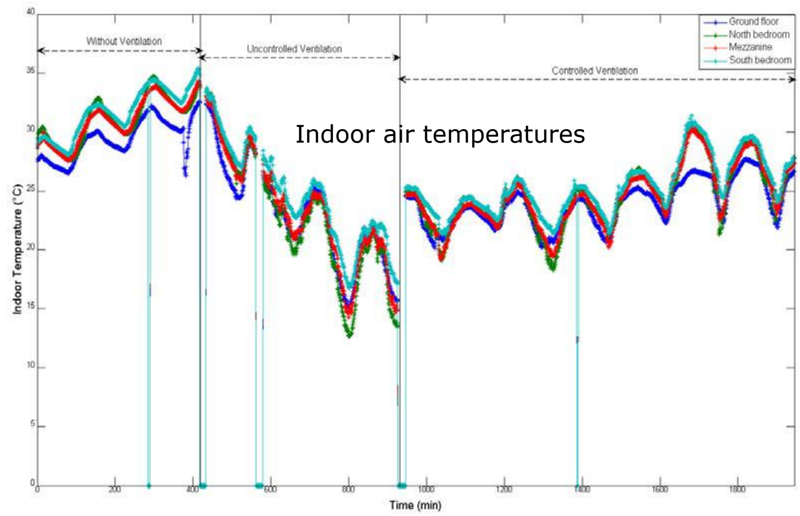
Methodology



ON SITE MEASUREMENTS

Methodology

ARMINES VELUX



SIMULATIONS

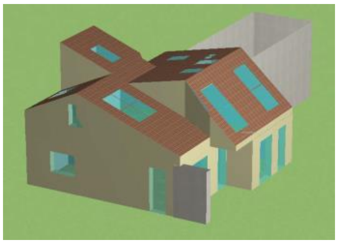
Methodology

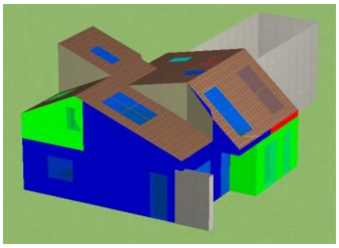
ARMINES VELUX

Multi-zone simulation of airflows using CONTAM

Multi-zone dynamic thermal simulation of indoor air temperatures using French tools PLEIADES + COMFIE

Using Cd and n evaluated during the lab test





12

ACH measured & simulated

Results

ARMINES VELUX

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

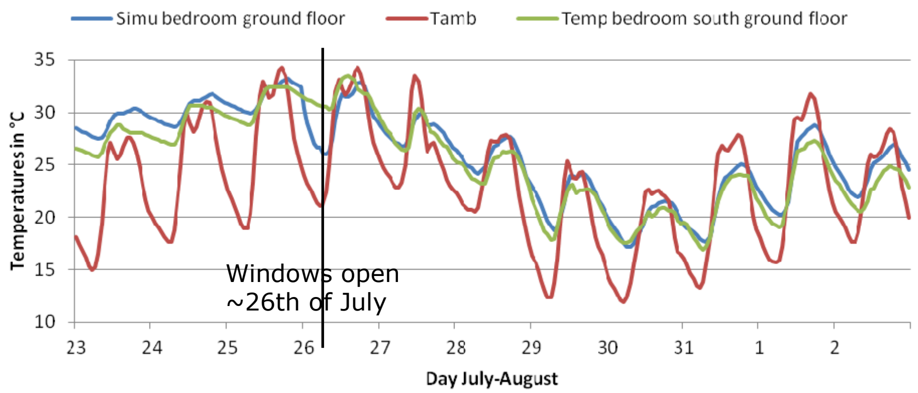
Good correspondence between measured and simulated air change rate – max 30% difference per case, 10% difference in average.

13

T_i measured & simulated

Results

ARMINES VELUX



Good correspondence between measured and simulated indoor air temperature (~1 K difference in average)

14

T_i simulated
Two cases

Results

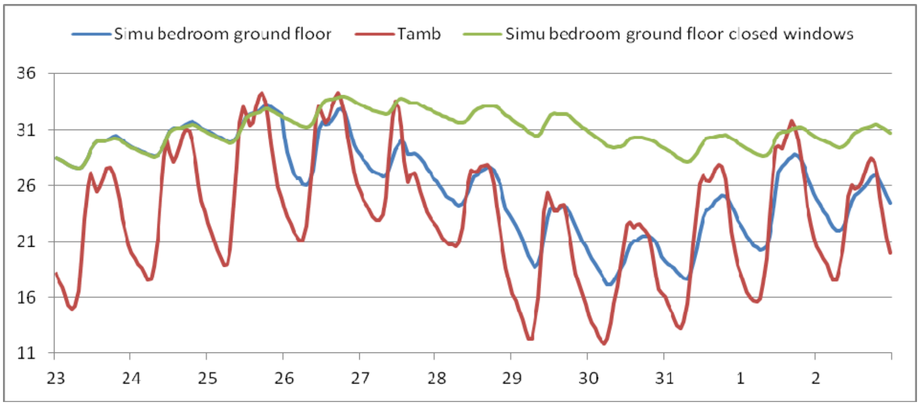


Figure 6 Simulated indoor air temperatures of the ground floor bedroom. Green: All windows closed. Blue: all windows opened from 26th of July. Red: Ambient temperature.

Conclusion

CONCLUSION

- (Surprisingly) good correspondence between air flow rates simulated in CONTAM and measured on site with CO_2 tracer gas decay. Average difference 10% and max difference per case is 30%

- (Surprisingly) good correspondence between indoor air temperatures simulated in dynamic simulation tool and measured on site. Average difference between measured and simulated temperature 1K.

Wednesday 25 September 2013

15:30-16:30: Parallel Session 2BC: Topical session- Quality of ventilation systems

Chairpersons: Arnold Janssens, François Durier

- **Securing the quality of ventilation systems in residential buildings: Existing approaches in various countries** Arnold Janssens, Belgium (Invited Speaker)
- **Overview of the UK residential ventilation market and initiatives to improve the quality of the installed systems** Alan Gilbert, UK (Invited Speaker)
- **Detailed analysis of regulatory compliance controls of 1287 dwellings ventilation systems** Jobert Romuald, France

SECURING THE QUALITY OF VENTILATION SYSTEMS IN RESIDENTIAL BUILDINGS: EXISTING APPROACHES IN VARIOUS COUNTRIES

34th AIVC Conference
3rd TightVent Conference
2nd Cool Roofs' Conference
1st venticool Conference

Paul Van den Bossche – Arnold Janssens

AIVC Conference 2013 Athens

Topical session Quality of ventilation systems

KU LEUVEN · VEA · wtcb.be · UNIVERSITEIT GENT

- International workshop
- Quality approaches
- Approaches for Belgium

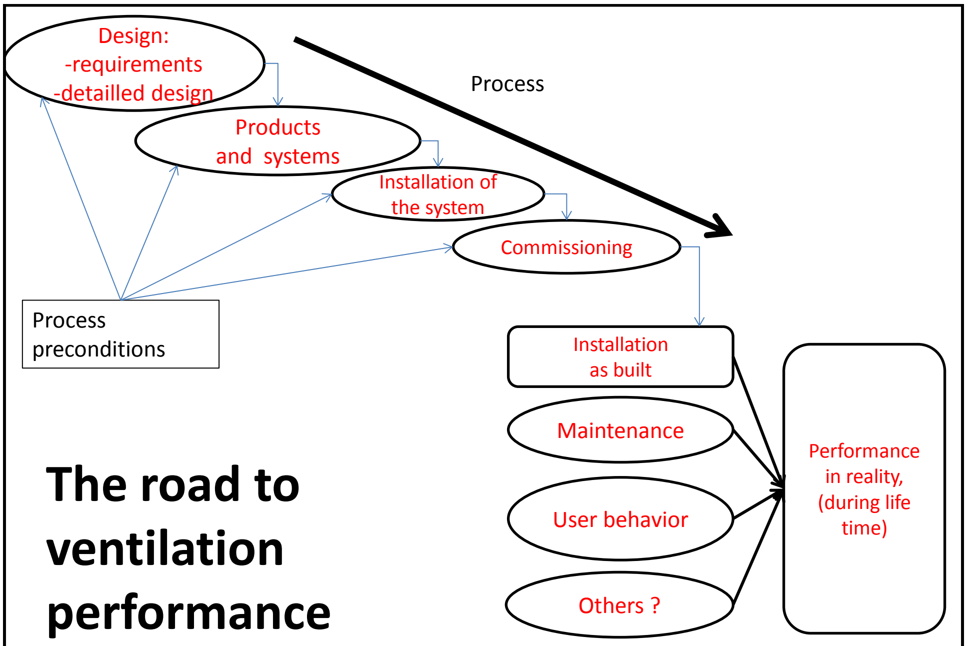
KU LEUVEN · VEA · wtcb.be · UNIVERSITEIT GENT

International workshop

Quality approaches

Approaches for Belgium

KU LEUVEN VEA wtcb.be UNIVERSITEIT GENT



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Precondition: Person competences

- For designers, installers, commissioners, inspectors, maintenance technics,…
- Examples:
  - HRAI contractor certification (Canada)
  - OVK inspectors (Sweden)
  - License designers (Poland)
  - Licence supervisors (Poland)
  - Competent person (UK)
- Evaluation:

+ Essential precondition

– Are acquired competences used in practice?

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Process approach: Design

- Check design at building permit request
- Examples:
  - Control at building permit (Finland, the Netherlands)
  - State Inspectorate (Romania)
- Evaluation:

+ Impact as from the start

– Legal criteria available?

– Competent authorities needed

– Detailled design not done is this stage

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Process approach: Components and systems

- Approaches:
  - Pure declaration of properties
  - Or with minumum levels to be achieved
- Examples
  - HVI certification (Canada and US)
  - Epbd product database (Belgium)
  - NF VMC, CSTBat (France)
  - TUV-RLT (Germany)
  - Eurovent-certification (Europe)
  - M1 cleanliness (Finland)
  - SAP (UK)
- Evaluation
  - (+) Clear information to designer/installer
  - (+) Uniform schemes across EU possible
  - (−) Quality is more than energy performance
  - (−) Not the main quality issue

Process Approach: Installation

- Compliance check at key stages
- Examples
  - By competent authorities (eg Canada)
  - In EPBD framework (Belgium)
- Evaluation
  - (−) Practical organisation
  - (−) No guarantee on end result

Overview International Quality approaches

Process approach: Whole company certification

- Whole process
  - Competence of persons
  - Organisation/management/complaints
  - Administration, document treatment
- Examples
  - Qualibat, Qualifelec (France)
  - Registration companies (Norway)
  - Specialist certification (Romania)
  - Cleaning companies (Germany)
- Evaluation

(–) Heavy process for small companies

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Overview International Quality approaches

As built approach: compliance check on site

- From compliance with mandatory requirements → quality checks
- Examples:
  - Permit to use(Estonia)
  - (Finland)
  - Acceptance before putting into use (Poland)
  - VPK (voluntary – the Netherlands)
  - OVK (Sweden)
- Evaluation

(+) Close to 'end user expectations'
(+) Direct feed-back to installer
(–) Not all requirements are easy to check
(–) Moment 'screen shot'
(–) Competence of evaluators

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Approach inspection and maintenance

- Examples
  - OVK, but not for small dwellings (Sweden)
  - Some housing companies (UK)
  - At putting for sale/rent (Belgium, Canada)
  - As part of energy audit (Estonia)
  - For passive stack by chimneys-sweeps (Poland)

Discussion points

- Availability of preconditions not sufficient to achieve quality in practice
- How far should legislation go to support quality?
  - Mandatory or voluntary?
  - Enforcement by authorities?
    - Checks, fines,…
- Certification as solution?
  - Self-declared schemes vs 3rd party certification
  - Product vs process certification
    - Problem: additional to all other EU certification schemes?

Drivers for better quality?

- Mandatory requirements with enforcement
  - Professional competences
  - Design, products, commissioning, inspection or maintenance
- Valorisation in energy performance assessment
  - As much as possible on as built situation (no 'paper quality')
- Financial incentives
- Public awareness
- Market functioning to improve quality?

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International workshop

Quality approaches

Approaches for Belgium

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Approaches in Belgium under discussion

Mandatory or voluntary?

- Voluntary
  - (+) possible to set high quality requirements
  - (–) no real impact if pure "voluntary"
- Mandatory
  - (+) whole market covered (obligation)
  - (–) unrealistic to set high quality requirements → market transition is needed!

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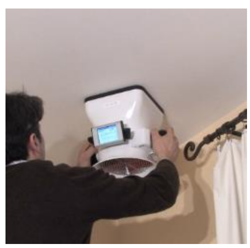
Declare performance on 2 levels

– Report on performance

- Eg "flow rate bedroom = 55 m³/h"



– Conformity check with requirements

- Eg "55 > requirement of 50 m³/h"

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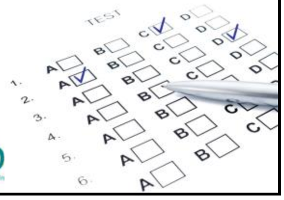
Declaration of conformity

- By certified ventilation reporter
  - Designer – contractor - supplier ….
  - Notified at third party (certification organisation)
  - Training – exam – test – project verification- …
  - Frequent random checks to evaluate the quality of the declarations
  - Eventual subdivided for partial declarations: design – carpenter – mechanical ventilation - …



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How to combine advantages of both approaches?

***Mandatory* Declaration of performances**

- Whole market covered (obligation)
- As built performances visible for all (customer,…)
- Robust organisation framework available for all, equal competition position
- But no compliance with requirements requested

***Voluntary* Guarantee of installation quality**

- Possible to set high quality requirements
- Different incentives possible

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Guarantee of installation quality? Possible (indirect) incentives

Legal framework - Mandatory

- Use of declared data in EPBD calculation
- Stepwise introduction of high quality requirements?
- …

Market self-regulation?

- Demand from customers?
- Prescription by architects/designers
- …

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Conclusion

- Concern about residential ventilation systems in almost every country
- Various approaches in operation with variable results
- Seek for balance between voluntary/mandatory

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Overview of the UK residential ventilation market and initiatives to improve the quality of the Installed systems

25-9-2013

Presented by

Alan Gilbert

BSRIA

ABOUT BSRIA – BUILDING SERVICES RESEARCH AND INFORMATION ASSOCIATION

What?

Who?

Where?

Who?	What?	Where?
Member based Association	Consultancy, test, instrumentation and research	Building services and construction industry

The built environment experts

BSRIA

ABOUT BSRIA – BUILDING SERVICES RESEARCH AND INFORMATION ASSOCIATION

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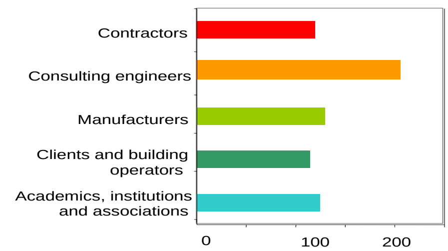
ABOUT BSRIA – BUILDING SERVICES RESEARCH AND INFORMATION ASSOCIATION

- £12.0 M turnover
- 170 staff
- 4,000 sq metres of laboratory space
- Offices in UK, China, North America, Germany, France and Spain; and Associates in Northern Ireland, Japan, Brazil and Australia
- Over 600 corporate members



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BUILDING REGULATION COMPLIANCE TESTING

Part E: Sound Insulation

Part F: Ventilation

Part L: Air Tightness

BSRIA Compliance

AIRTIGHTNESS – PART L1 – KEY STATISTICS

- 2011 – BSRIA tested approximately 8,500 domestic properties
- 2012 – BSRIA tested approximately 10,000 domestic properties
- 2013 – BSRIA will test approximately 20,000 domestic properties (approx' 35% total tested)



UK HOUSING SECTOR – KEY STATISTICS (12 MONTHS TO MARCH 2012)

-LAST FULL YEAR OF DATA

- 130,000 dwellings completed
- 27.4 million total number of dwellings in UK = 17.4 million privately owned, 4.7 million privately rented, 2.7 million rented from housing authorities and remainder rented from local authorities



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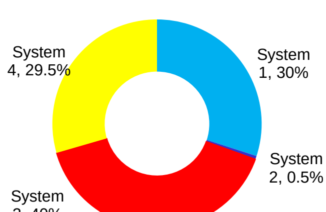
VENTILATION – UK REGULATIONS PART F – KEY STATISTICS

Type	Description	Background (trickle) ventilation	Comments
System 1	Background ventilators and intermittent extract fans including single room heat recovery ventilators	Yes	Size as per tables in Regulations based on floor area and number of bedrooms
System 2	Passive stack ventilation (PSV)	Yes	As above
System 3	Continuous mechanical extract (MEV): centralised and de-centralised	Yes and No	Size as per tables in Regulations or if air permeability >5m³/(m.²) none is required
System 4	Continuous mechanical supply and extract with heat recovery (MVHR): centralised and single room	No	



Estimated percentage mix of new build ventilation system types in 2012

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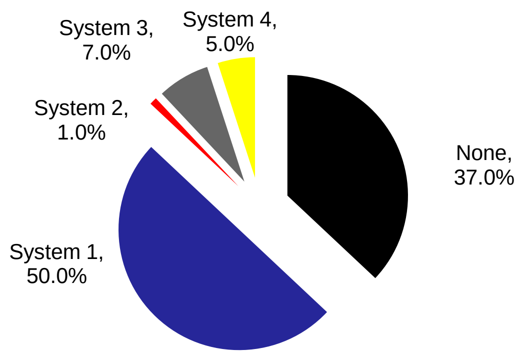
VENTILATION – ESTIMATED PERCENTAGE MIX OF VENTILATION SYSTEM TYPES IN TOTAL UK STOCK



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VENTILATION – UK REGULATIONS PART F – KEY STATISTICS

- In 2011 BSRIA tested less than **100** dwellings for airflow performance(completed systems and are post commissioning i.e. completed)
- In 2012 quantity increased to **500** dwellings
- In 2013 approximately **1000** dwellings will be tested for airflow performance

BSRIA

VENTILATION – PART F
– KEY STATISTIC (X40 RANDOM SAMPLE)

In 2011 **95%** of all dwellings when initially tested **FAILED** to meet the requirements contained in the Building Regulations. *In 2012 this high % improved but only a little !   2013 ?*



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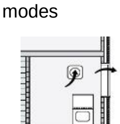
VENTILATION
– KEY FAILURE MODES (X40 RANDOM SAMPLE)

Value	Description
33 (82.5%)	Ductwork incorrectly fitted (kinked / bent / poor joints / excessive length)
10 (25%)	Undersized fans to meet the minimum ventilation requirement
6 (15%)	Insufficient fans or terminal outlets for dwelling type
3	No boost function
3	Incorrect installation data
2	Missing ductwork
1	Blocked ductwork

NOTE : Some dwellings had multiple failure modes



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VENTILATION – KEY FAILURE MODES

Poorly installed ductwork is without question one of the largest causes of systems not performing properly.

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VENTILATION – PART F – KEY STATISTIC (2013 SAMPLE)

- **In house study of 242 dwellings % level of failure similar to 2011 92% <u>initially</u> failed to meet the requirements in the Building Regulations**

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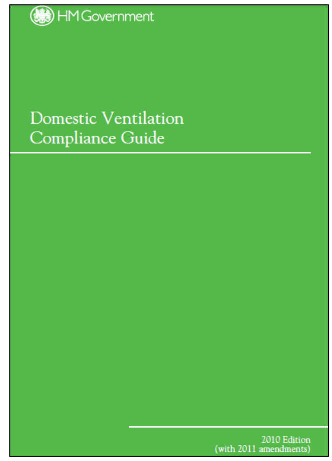
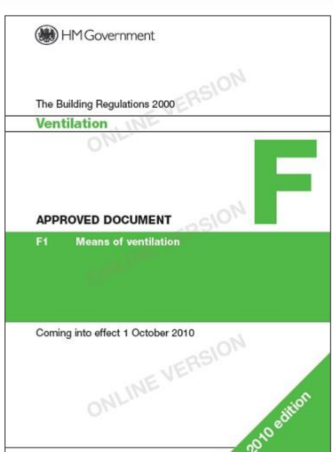
UK DOCUMENTS



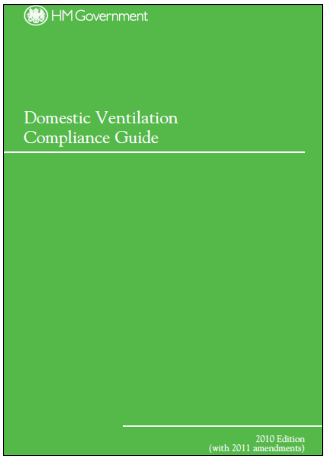
APPROVED DOCUMENT F



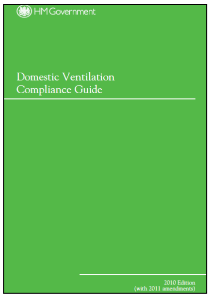
There shall be adequate means of ventilation provided for people in the building" and "Fixed systems for mechanical ventilation and any associated controls must be commissioned by testing and adjusted as necessary".

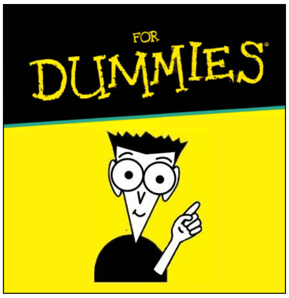
DOMESTIC VENTILATION COMPLIANCE GUIDE

Covers installation and commissioning and copies of completed forms should be left in dwelling + submitted to the Building Control Body as evidence that the work has been correctly undertaken.



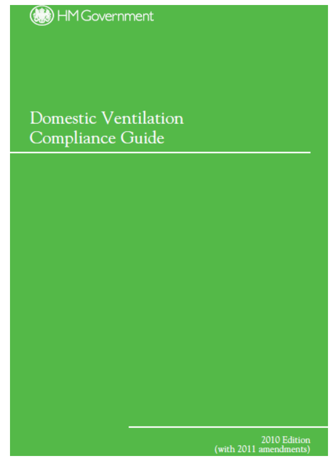
WHAT NEXT ?





WHY DO WE NEED MORE GUIDANCE ?

The Domestic Ventilation Compliance Guide Section 5.2 states “Measurement of air flows should be performed using equipment that has been calibrated at a UKAS accredited calibration centre”.



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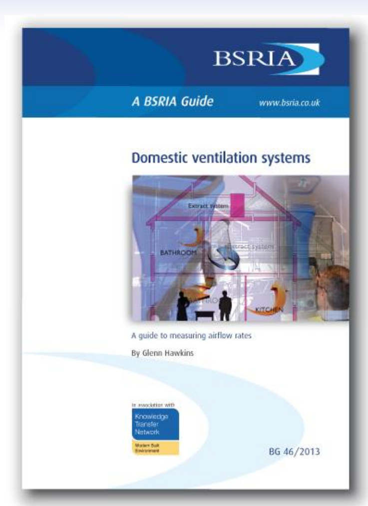

The aim of the guide is to improve the standard of domestic ventilation installations. In particular, it focuses on making sure that the methods used for measuring airflow rates are fit for purpose.

www.bsria.co.uk

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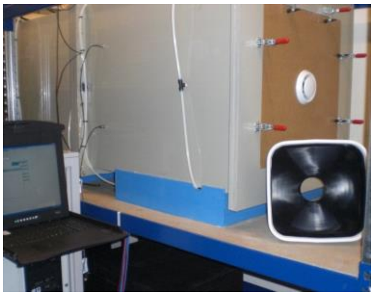
LABORATORY STUDY - STEP 1



Laboratory investigation into the market leading vane anemometer & hood assembly measurement accuracies

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LABORATORY STUDY - STEP 2

Laboratory investigation into various instruments and how they influenced the performance of typical fans in the marketplace

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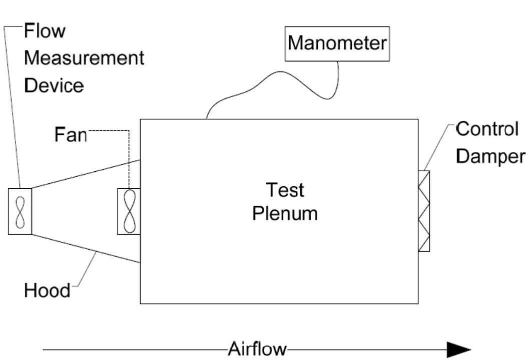
STEP 2 – TEST SET-UP

Figure 1 Test Rig Schematic



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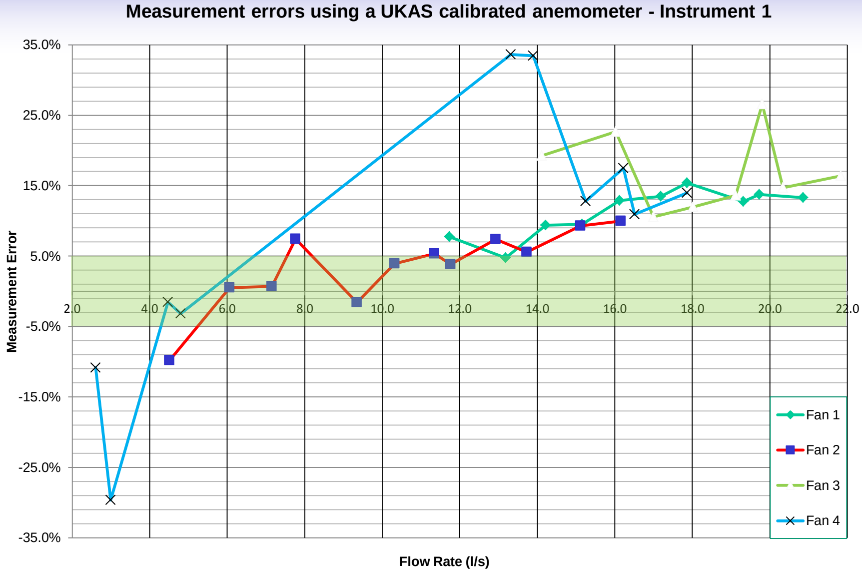
Measurement errors using a UKAS calibrated anemometer - Instrument 1



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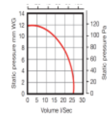
THE UNCONDITIONAL METHOD
- THE PREFERRED METHOD -

- Free from site-specific conditions such as fan type and model, airflow direction and instrumentation characteristics
- Uses a powered hood assembly to eliminate back pressure and turbulent flow effects
- Devices based on a zero-pressure method

THE CONDITIONAL METHOD

<u>Must take into account</u> specific site conditions such as fan performance characteristics, the resistance to airflow created by the measuring device, correction and conversion factors depending on the instrument used. This information is currently not available !!!!!

THE CONDITIONAL METHOD



VIDEO AT www.bsria.co.uk

True air volume

=

corrections for the anemometer + hood + fan system

=

Lots of unknowns especially in centralised fan systems with multiple grilles

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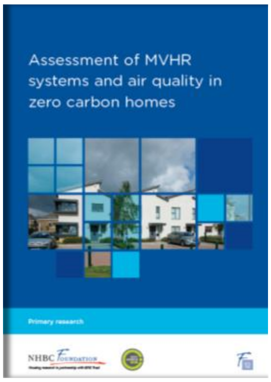
WHAT IS INDUSTRY DOING NOW ?

Good Homes Alliance

bpec

ecobuild the future



+
NHBC Guidance
(October 2013)

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VENTILATION – A FUTURE KEY STATISTIC ?

In 2014 **95%** of all dwellings when initially tested **PASSED** the requirements contained in the UK Building Regulations.

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Energy conservation technologies for mitigation and adaptation in the built environment

The role of ventilation strategie and smart materials

34th AIVC Conference

3rd TightVent Conference

2nd Cool Roofs' Conference

1st VentiCool Conference

AIVC INIVE

National and Kapodistrian University of Athens

Technical University of Crete

TightVent Europe

ECRC European Cool Roof Council

venticool

Analysis of regulatory compliance controls for 1287 dwellings ventilation systems

First step of " **VIA Qualité** " project

Romuald Jobert

25-26 September 2013, Athens, Greece

Liberté Égalité Fraternité
RÉPUBLIQUE FRANÇAISE

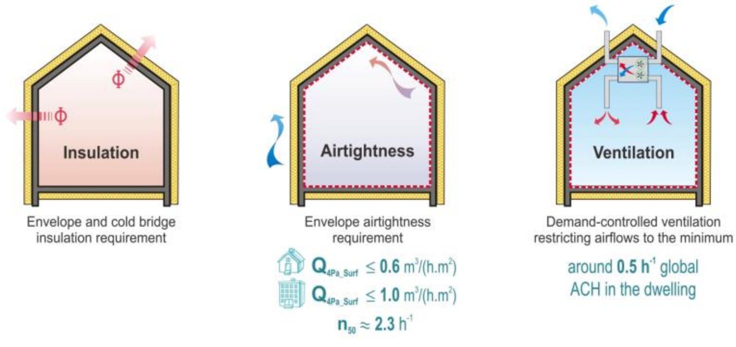
CETE de Lyon Centre d'Études Technique

Summary

- Background and context
- Overview of the French airing regulation
- "VIA Qualité" project issue
- Ventilation analysis of a large sample of dwellings
- Conclusion and perspective

Background and context

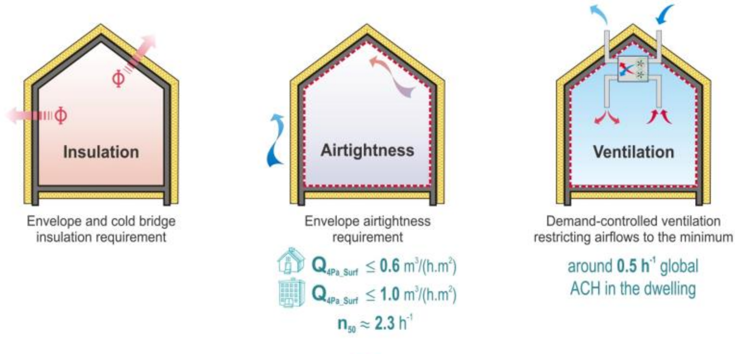
Since january 2013, the new French energy performance (EP) **regulation** (RT2012) **has required that all new dwellings must have an energy consumption level less than 50** kWh/(m^2.year)



What about risks for a generation of performing airtight dwellings to contribute to an unhealthy indoor air ?

Background and context

Since january 2013, the new French energy performance (EP) **regulation** (RT2012) **has required that all new dwellings must have an energy consumption level less than 50** kWh/(m^2.year)



in this design, on-site ventilation systems quality is essential !

Background and context

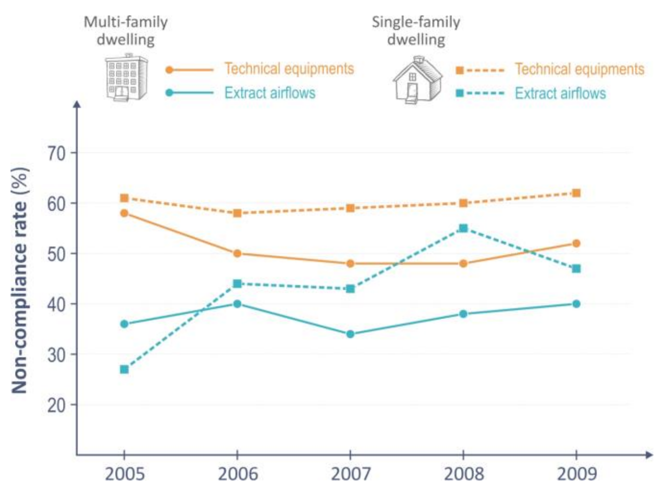
We have to admit that ventilation systems have frequent failures due to implementation and incorrect use problems

- **French construction technical regulation observatory** (ORTEC) **compiles the controls data on both sections**
- **The recent national statistics* are the following:**
  - **50%** of the controlled buildings do not meet the requirements in terms of ventilation technical equipment
  - **43%** of the controlled buildings do not comply with the regulatory airflow rates
    - 84% of non-complying exhaust flows are insufficient
    - 16% of non-complying exhaust flows are excessive

** French national statistics published by ORTEC in the last report of non-compliance rate for new buildings (CSTB-ORTEC, Synthesis report of ventilation topic, 2005-2009 period)*

Background and context

- **For single-family dwellings: the non-compliance average rate of technical equipment is higher than 60%**



Problematic

What are the solutions to increase ventilation quality once systems are installed and in-use ?

- **"VIA-Qualité" project proposes developing quality management approaches** (ISO 9001) **with the goal of improving both on-site ventilation and indoor air quality**

- **First step of this project: to analyze precisely types of dysfunctions**
  - ✓ Have an accurate picture of on-site ventilation quality
  - ✓ **Use control reports on airing regulation**

Control reports on airing regulation

- **These controls include two sections:**
  - "What can be seen and operated"
    Control of all ventilation technical equipment
  - "Exhaust and supply airflows measurements"
    Check of airflow or pressure difference (DCV)* at air outlets

- **Detailed control reports**
  - These reports include original detailed data with precise descriptions of dysfunction causes

- **A potentially important technical database !**

** Demand-controlled ventilation system*

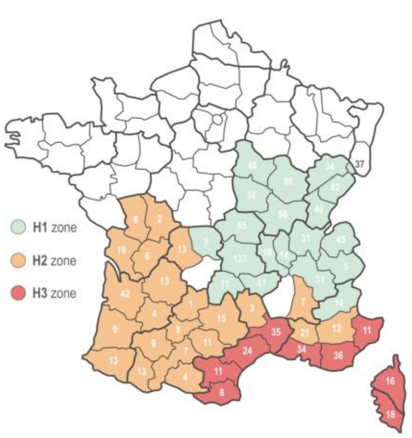
Overview of the analyzed sample

- 400 control reports, 1287 new dwellings

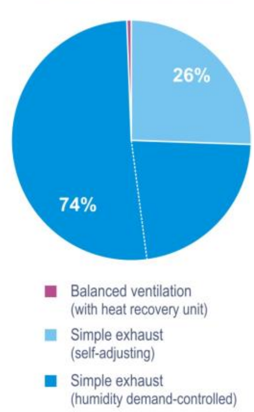
Overview of the analyzed sample

- 3 climatic zones
- 100% mechanical ventilation

Dwellings distribution in climatic zones
(according energy performance regulation)



Ventilation systems repartition
(representative for the new stock)



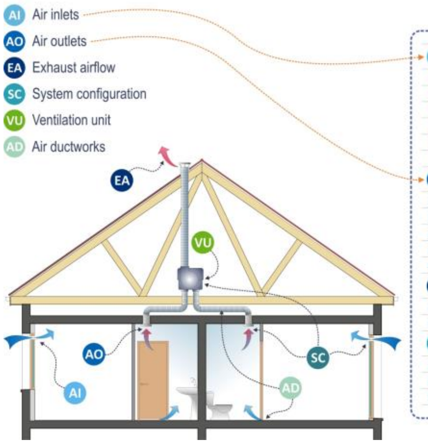
Global non-compliance rates

The statistic analysis of this sample reveals that 604 dwellings out of 1287 do not comply with the airing regulation

- Global non-compliance rates:
  - 47% of the total sample (at least one non-compliance remark)
  - 68% for single-family dwellings
  - 44% for multi-family dwellings
- These results confirm the national trend
- A large amount of anomalies

Distribution of ventilation dysfunctions

- List and classification of all the dysfunctions
  - 28 points of recurrent dysfunctions observed and classified among
  - 6 representative categories for the main mechanical ventilation systems



Extract from the dysfunctions list
(non independent categories regarding their causes)

AI Air inlets

AI1	absence of air inlets modules
AI2	air inlets implementation does not comply with prescribed rules and regulations
AI3	presence of inlet air in a humid or service room
AI4	no mortises in window frames or incorrect size
AI5	air inlet excess in the main rooms
AI6	obturation of air inlets in one or more rooms

AO Air outlets

AO1	Air outlets does not comply with regulation requirements
AO2	control for changing peak flow missing or inaccessible
AO3	dysfunction of air outlets equipped with presence detectors
AO4	absence of air outlets in one or more rooms
AO5	air outlets location does not comply with regulation and technical requirements

EA Exhaust airflows

EA1	air outlets does not comply with regulation requirements
EA2	control for changing peak flow missing or inaccessible

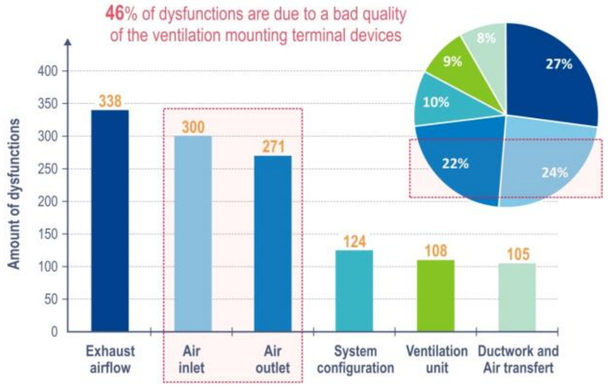
SC Exhaust airflows

SC1	system configuration does not comply with the technical note requirements
SC2	interversion of air inlet and air outlet
SC3	system configuration does not comply with calculations of thermal regulations

Analysis of dysfunctions compilation

The statistical analysis shows that the 604 non-complying dwellings count 1246 non-compliance or dysfunctions points

- Amount of dysfunctions items per category



Directly or indirectly, these dysfunctions contribute to a bad ventilation functioning, and also **affect indoor air quality**

Why these dysfunctions ?

Some tracks of answers…

- **Ventilation is not enough integrated at spaces design step**
  - inaccessible or too small technical shafts
- **Lack of attention at the mounting step**
  - actor’s dispersion inside multiple technical lots
  - ventilation rarely defined as a specific lot
  - no one responsible for the final result
- **Lack of continuity between program step, design, mounting, and also material and component furniture**
- **Control at commissioning is not systematic or incomplete**
  - Recent guides (CETIAT, 2012) describe precisely these receipt procedures

Conclusion and perspective

- Adapted industrial solutions are available but ventilation system dysfunctions are very frequently observed
  - That heavily limits the reliability of these installations
- A main issue for low and very low energy buildings
  - Guaranties on in-site ventilation installation quality become absolutely necessary (airtight envelopes…)

➢ The need of guaranties on in-site ventilation quality
  - The recent Effinergie+ label: ventilation airflows (advisable) and duct leakage measurements (compulsory) at commissioning

➢ Manage major projects leading to better practices at every stage of the construction
  - The implementation of quality **management approaches ?**

Acknowledgments

Thank you for your attention

Romuald Jobert
25-26 September 2013, Athens, Greece

The authors are very grateful to the French ministry for ecology, sustainable development, and energy (MEDDE), and in particular to the DGALN Department, for its support throughout this work.

The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the Ministry.

Wednesday 25 September 2013

15:30-16:30: Parallel Session 2D: Long oral presentation session- Analysis of cool roofs' characteristics and optical properties

Chairpersons: Despina Sergides, Stella Chadiarakou

- **Effect of ageing processes and atmospheric agents on solar reflectivity of clay roofing tiles** Chiara Ferrari, Italy
- **Field observation of cooling energy saving by the high reflectance paint** Chihiro Yamada, Japan
- **Composite material for renovation of roofs in existing buildings** Stella Chadiarakou, Greece
- **Cooling roofs through low temperature solar-heat transformations in hydrophilic porous materials** Dimitrios Karamanis, Greece

Effect of ageing processes on solar reflectivity of clay roof tiles

Chiara Ferrari[1,2],
Ali Gholizadeh Touchaei[2],
Antonio Libbra[1],
Mohamad Sleiman[3],
Alberto Muscio[1],
Cristina Siligardi[1],
Hashem Akbari[2]

[1]EELab - Department of Engineering «Enzo Ferrari» - University of Modena and Reggio Emilia Modena (Italy)
[2]Heat Island Group - Concordia University Montreal (Canada)
[3]Lawrence Berkeley National Laboratory Berkeley (Ca)

Athens, 25 september 2013

COLLABORATION

THIS RESEARCH WAS CARRIED OUT IN COLLABORATION WITH

HEAT ISLAND GROUP

Concordia University – Montreal – Canada

HEAT ISLAND GROUP

Lawrence Berkeley National Laboratory – Berkeley - California

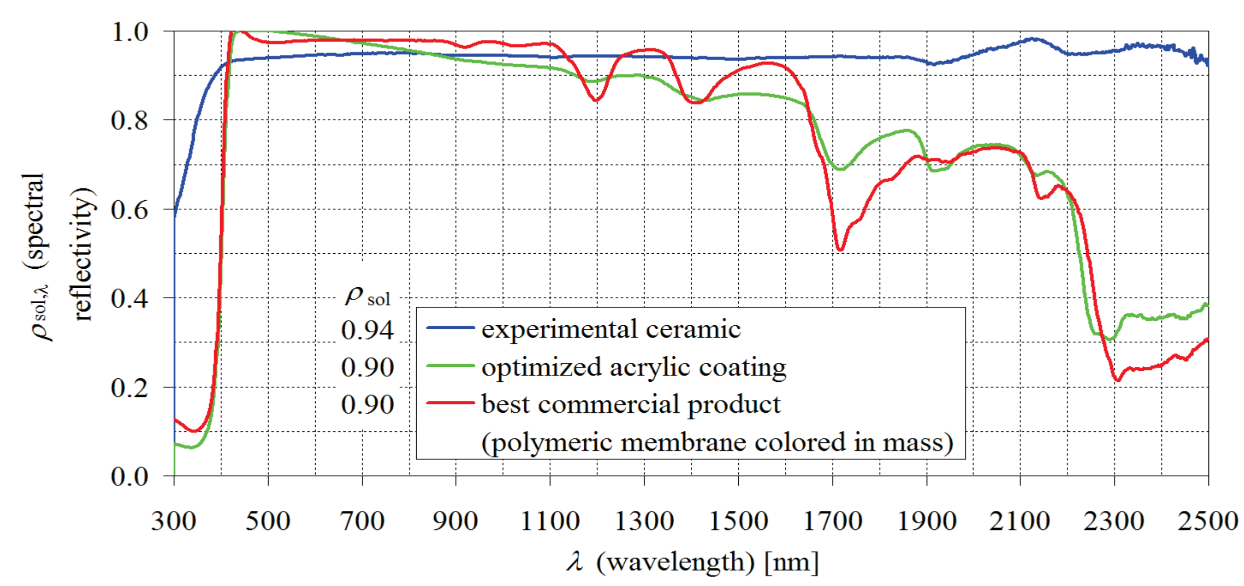
OUTLINE

- INTRODUCTION
  - Ceramic based cool roofs
- AIM OF THE WORK
- LITERATURE REVIEW
- SAMPLE COLLECTION
- METHODOLOGY
  - Aging
- RESULTS
- DISCUSSION
- CONCLUSIONS
- FURTHER PERSPECTIVES

Why Ceramics?

The cool roof market is currently dominated by organic based roofing membranes and coatings that can reach solar reflectance around 0.80÷0.90

Inorganic based coatings represent an interesting alternative to this solution

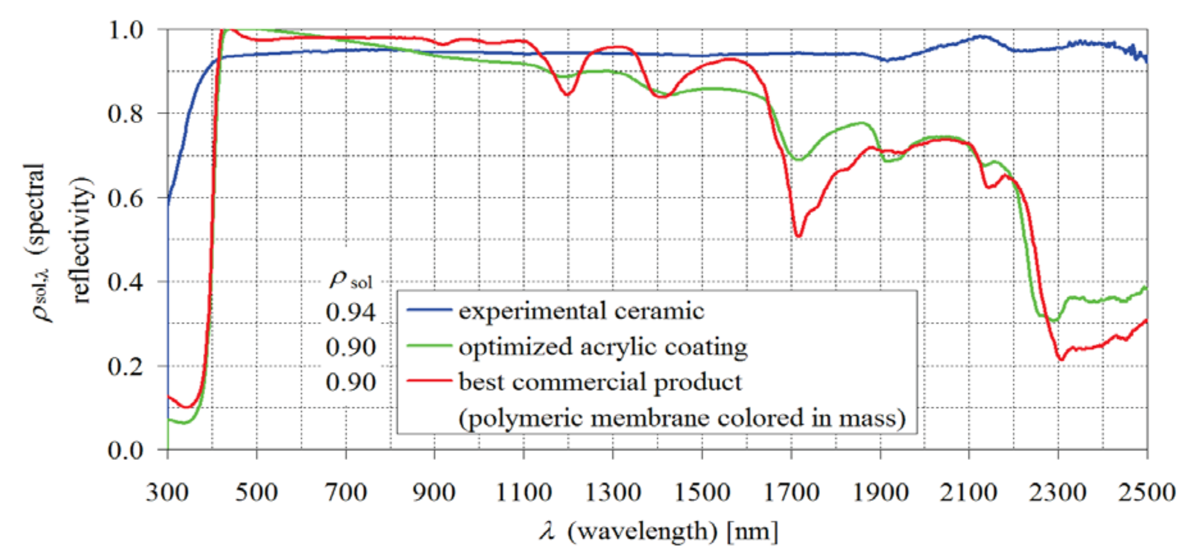


Libbra et al. Progress in Organic Coatings, Volume 72, Issues 1–2, September–October 2011, Pages 73-80

Why Ceramics?

- Interesting solar reflective behaviour (plateau for λ>1200 nm)
- Durability (chemical, physical and mechanical)
- High thermal emissivity
- Maintenance cost

- Weight
- Production cost



Libbra et al. Progress in Organic Coatings, Volume 72, Issues 1–2, September–October 2011, Pages 73-80

Typical values

Typical radiative properties of some fresh roofing materials

Material	Solar reflectance	Thermal Emittance
Gray-rock fiberglass asphalt shingle	0.10	0.90
Bare gray-cement concrete tile	0.15	0.90
Terracotta clay tile	0.40	0.90
Bare zincalume steel	0.75	0.05
Resin-coated zincalume steel	0.60	0.15
Zincalume steel w/25-µm white coating	0.70	0.85
Wood shake	0.50	0.90

(source: http://heatisland.lbl.gov)

Typical values

Typical radiative properties of some fresh roofing materials

Material	Solar reflectance	Thermal Emittance
Gray-rock fiberglass asphalt shingle	0.10	0.90
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Zincalume steel w/25-μm white coating	0.70	0.85
Wood shake	0.50	0.90

(source: http://heatisland.lbl.gov)

AIM of the WORK

Artificial vs natural ageing

Comparison of natural and artificial ageing processes simulating Arizona Climate and how ageing processes affect in different way cool clay roof tiles (uncoated cool pigmented roof tiles and tiles coated with polymeric cool coatings)

Effect of ageing and cleaning processes

How different cleaning process simulating rain and wind effect modify solar reflectance of clay roof tiles characterized by cool coatings

Artificial vs natural Ageing

Meng-Dawn Cheng, William Miller, Joshua New, Paul Berdahl, Understanding the long-term effects of environmental exposure on roof reflectance in California, Construction and Building Materials 26 (2012) 516–526

Sleiman, M., T. Kirchstetter, P. Berdahl, H. Gilbert, D. Francois, M. Spears, R. Levinson, H. Destaillats, H. Akbari, Proceedings of the 3rd International Passive and Low Energy Cooling for the Built Environment, Palenc 2010, 19-21 Sep 29 to Oct 1, 2010, Rhodes, Greece.

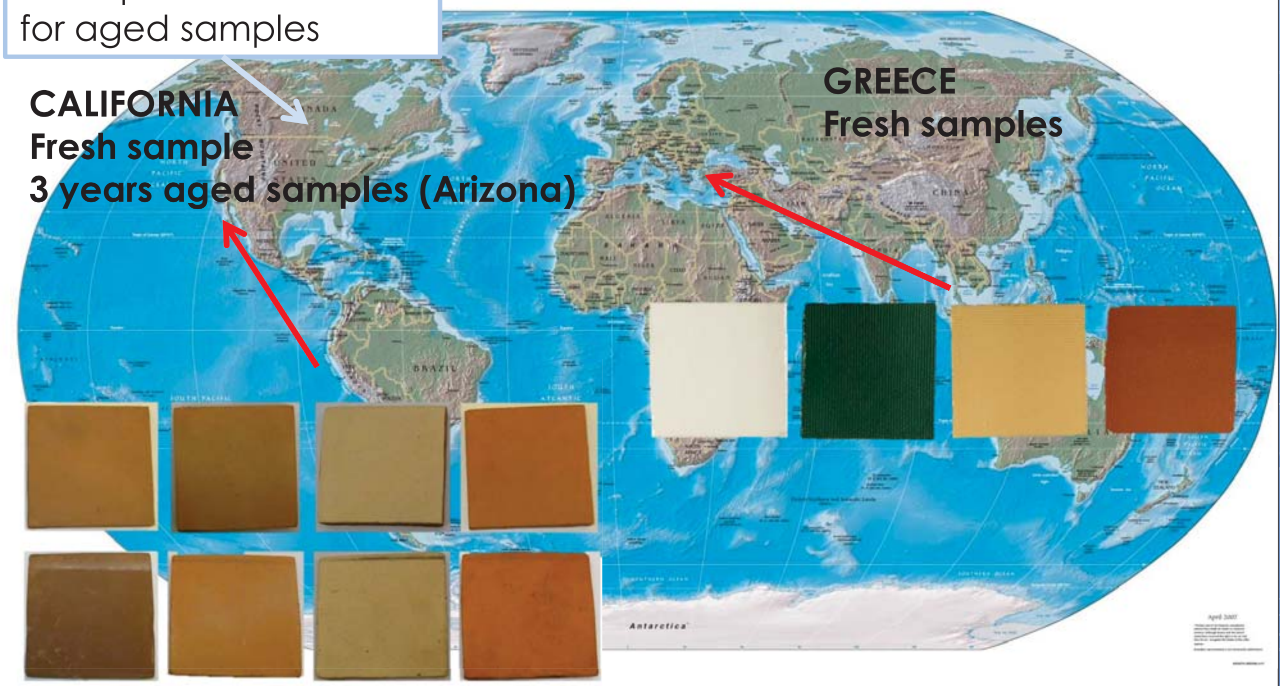
Effect of ageing and cleaning processes

R. Levinson, P. Berdhal, A. Berhe, H. Akbari, Effects of soiling and cleaning on the reflectance and solar heat gain of a light-colored roofing membrane, Atmospheric Environment 39 (2005) 7807-7824

S. Bretz, H.Akbari
Long-term performance of high-albedo roof coatings
Energy and Buildings 25 (1997) 159-167

H. Akbari, A. Berhe, R. Levinson, S. Graveline, K. Foley, A. H. Delgado R. M. Paroli
Aging and weathering of cool roofing memebranes,
LBNL Report – 55055 (2005)

As required from CRRC for aged samples



Clay roof tiles with inorganic based coating

Clay roof tiles with organic based coating

METHODOLOGY

Step 1
- Solar reflectance (ASTM E903 and ASTM C1549) of fresh and natural aged samples

Step 2
- Artificial Aging of fresh samples

Step 3
- Solar reflectance (ASTM E903 and ASTM C1549) of artificial aged samples

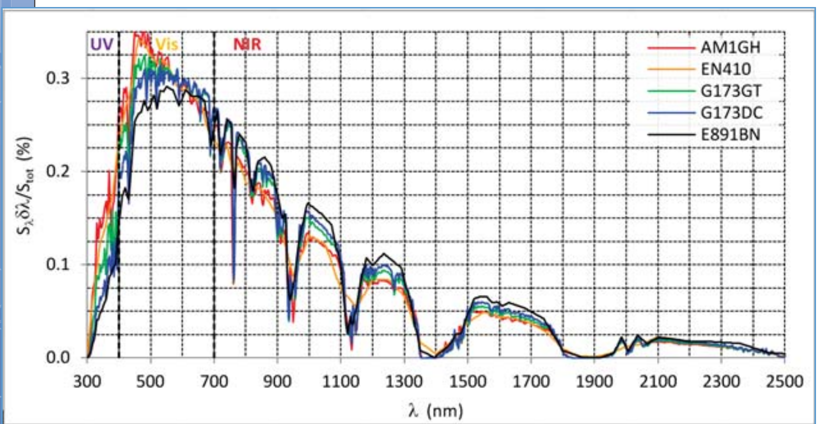
Step 4
- Cleaning step on natural and artificial aged samples

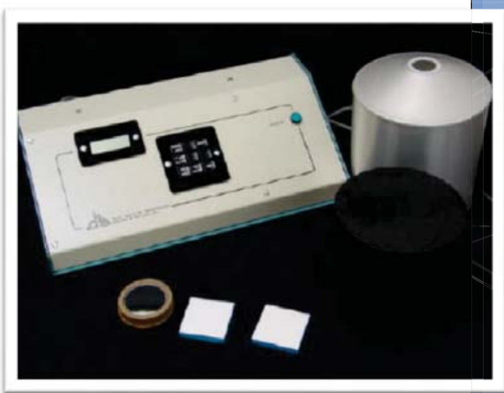
Step 5
- Solar reflectance (ASTM E903 and ASTM C1549) of samples after each cleaning step

Measurements

www.labsphere.com

Solar reflectance was measured via a spectrophotometer UV-Vis-NiR with a 150 mm integrating sphere operating in 280 – 2500 nm wavelength range according to ASTM E903 Standard Test Method and via Devices and Services Portable Solar Reflectometer (Version 6) according to ASTM C1549 Standard Test Method





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www.labsphere.com

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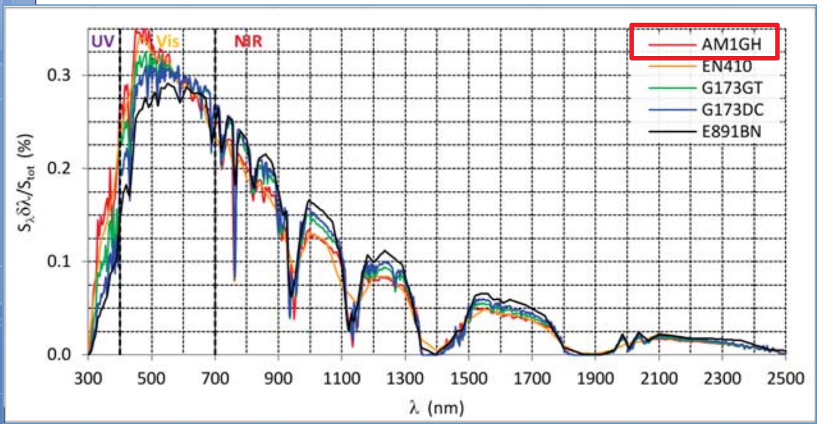


AGING

Decay of physical and chemical properties
Soiling
Microbiological growth

CRRC requires a 3 years ageing for each sample
3 different climate: OHIO, ARIZONA, FLORIDA

Natural ageing

Faithful reproduction of environmental conditions (also microbiological growth)

Long exposure time

Accelerate ageing

Soiling simulation through UV exposure and soiling mixture application under controlled contitions

Drastic reduction of exposure time

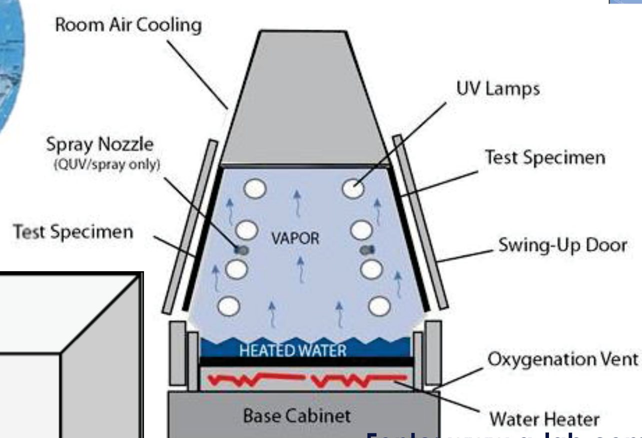
AGING

Natural Aging

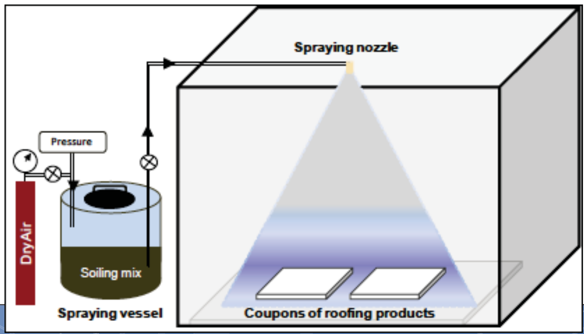
Test Farm

Artificial Accelerated Aging

Lab scale:
24h cycle in weatherometer (ASTM G154)
Soiling mixture deposition
24h cycle in weathermeter



Fonte: www.q-lab.com



Fonte: Heat Island Group - LBNL

AGING

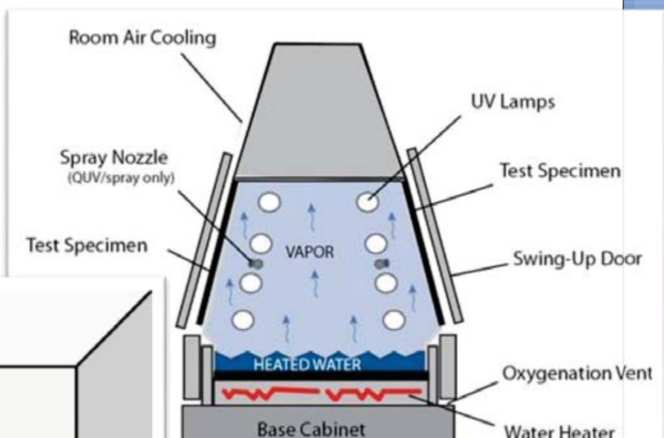
Natural Aging

Test Farm

Fonte: www.q-lab.com

Artificial Accelerated Aging

Lab scale:
24h cycle in weatherometer (ASTM G154)
Soiling mixture deposition
24h cycle in weathermeter



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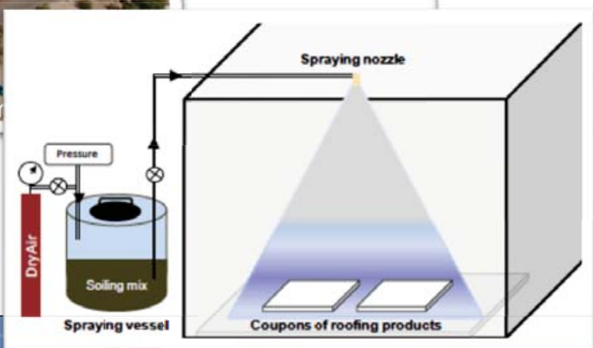


Fonte: Heat Island Group - LBNL

METHODOLOGY

Unweathered samples

Arizona soiling mixture

Average* soiling mixture

Accelerated ageing procedure

24 hour cycle in weatherometer with UV exposure (0.89 $W \cdot m^2$ T= 60 °C) and Water Condensation (T= 50 °C)

Soiling mixture deposition

24 hour cycle in weatherometer with UV exposure (0.89 $W \cdot m^2$ T= 60 °C) and Water Condensation (T= 50 °C)

70 wt% dust
20 wt% salts
0 wt% POM

* Ohio, Arizona and Florida pollution mixture according to CRRC test farms

METHODOLOGY

Unweathered samples

Arizona soiling mixture

Average* soiling mixture

Accelerated ageing procedure

24 hour cycle in weatherometer with UV exposure (0.89 $W \cdot m^2$ T= 60 °C) and Water Condensation (T= 50 °C)

Soiling mixture deposition

24 hour cycle in weatherometer with UV exposure (0.89 $W \cdot m^2$ T= 60 °C) and Water Condensation (T= 50 °C)

3 years condensed in 3 days

* Ohio, Arizona and Florida pollution mixture according to CRRC test farms

METHODOLOGY

Unweathered samples

Arizona soiling mixture

Average* soiling mixture

Cleaning steps:

Wind simulation – wiping

Air blowing with a cold flux (duration: 2 min on each coupon)

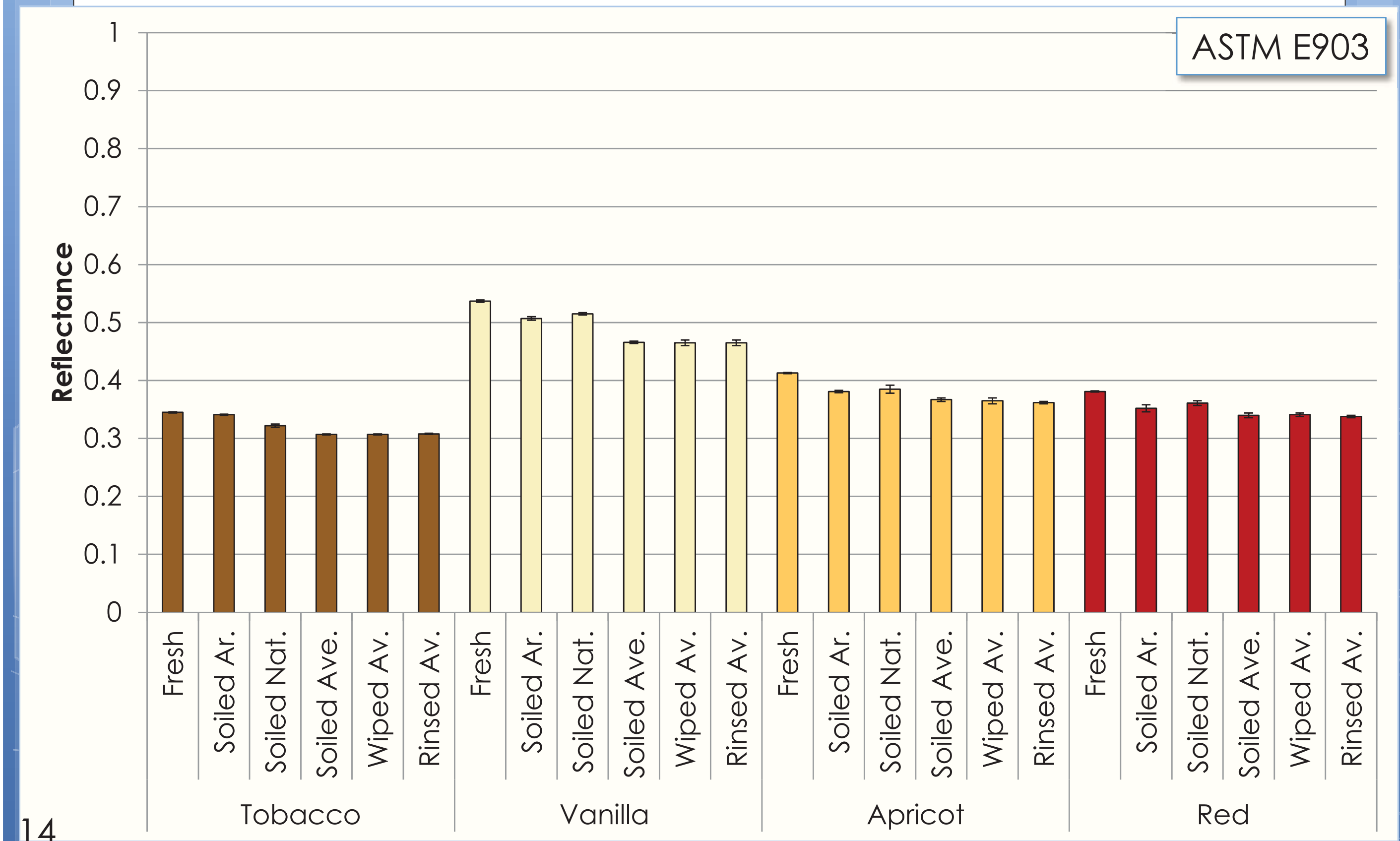
Rain simulation – rinsing

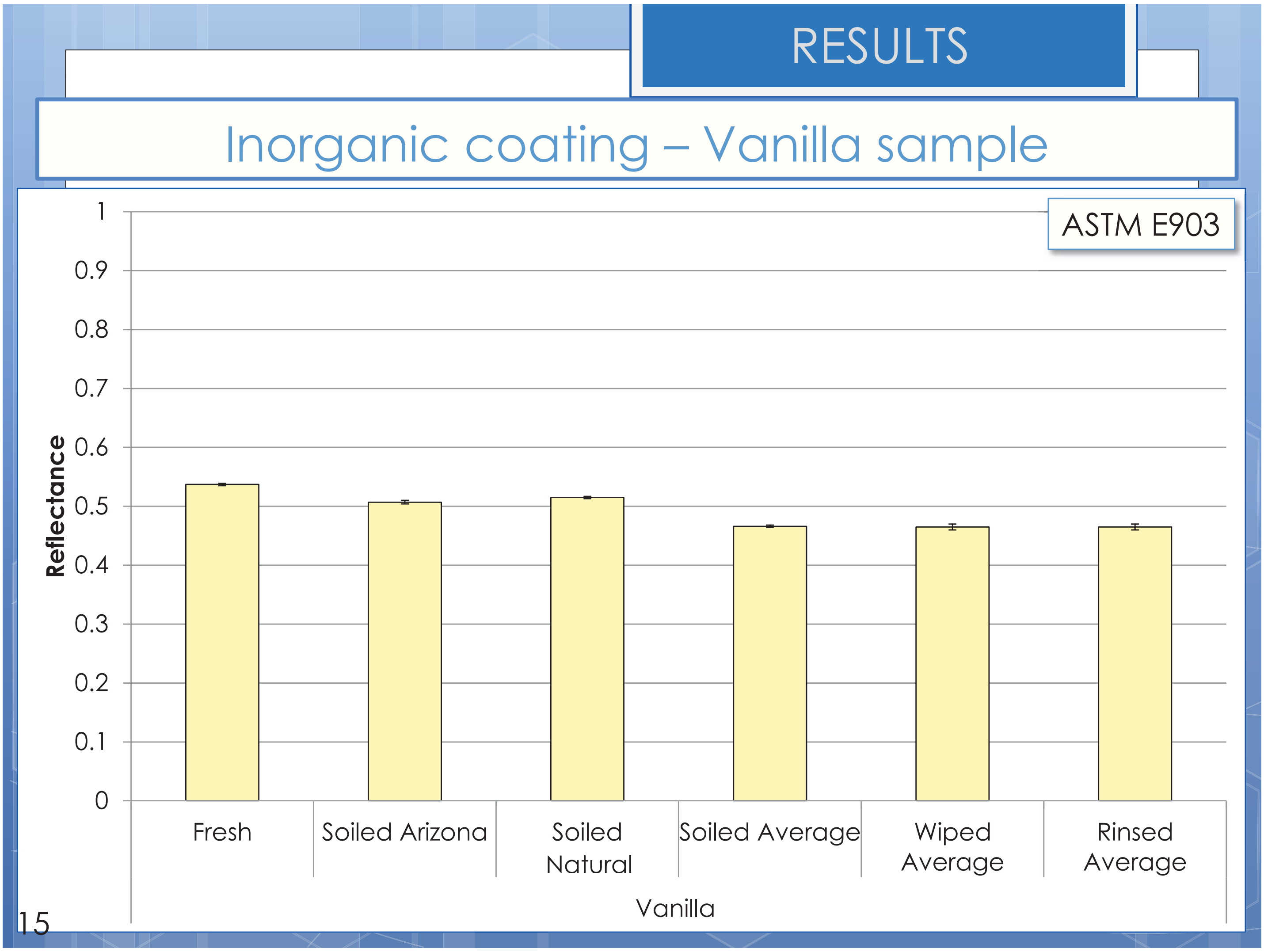
Rinsed under cold running water (duration: 2 min on each coupon)

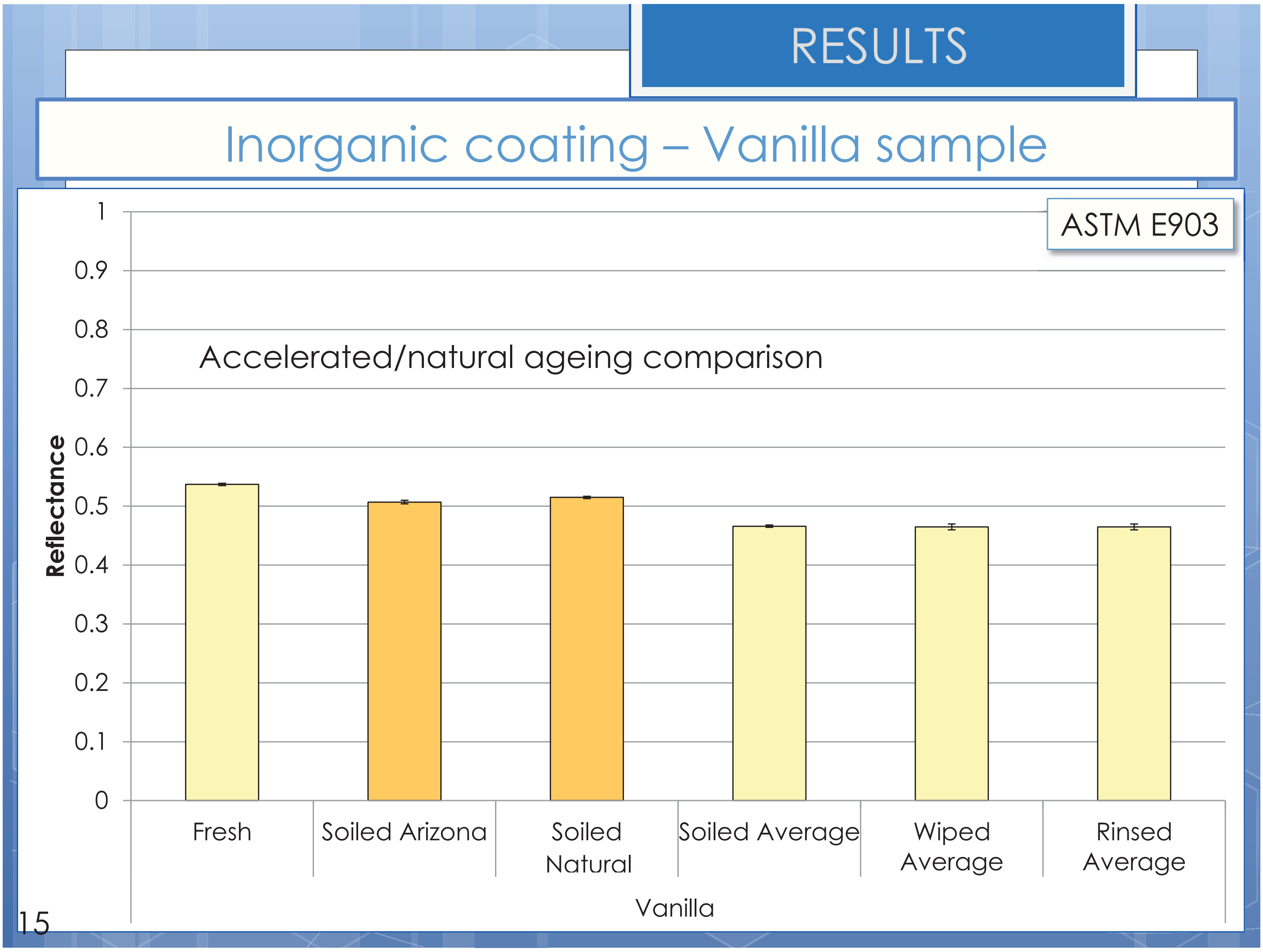
* Ohio, Arizona and Florida pollution mixture according to CRRC test farms

RESULTS

Inorganic coating – summary graph

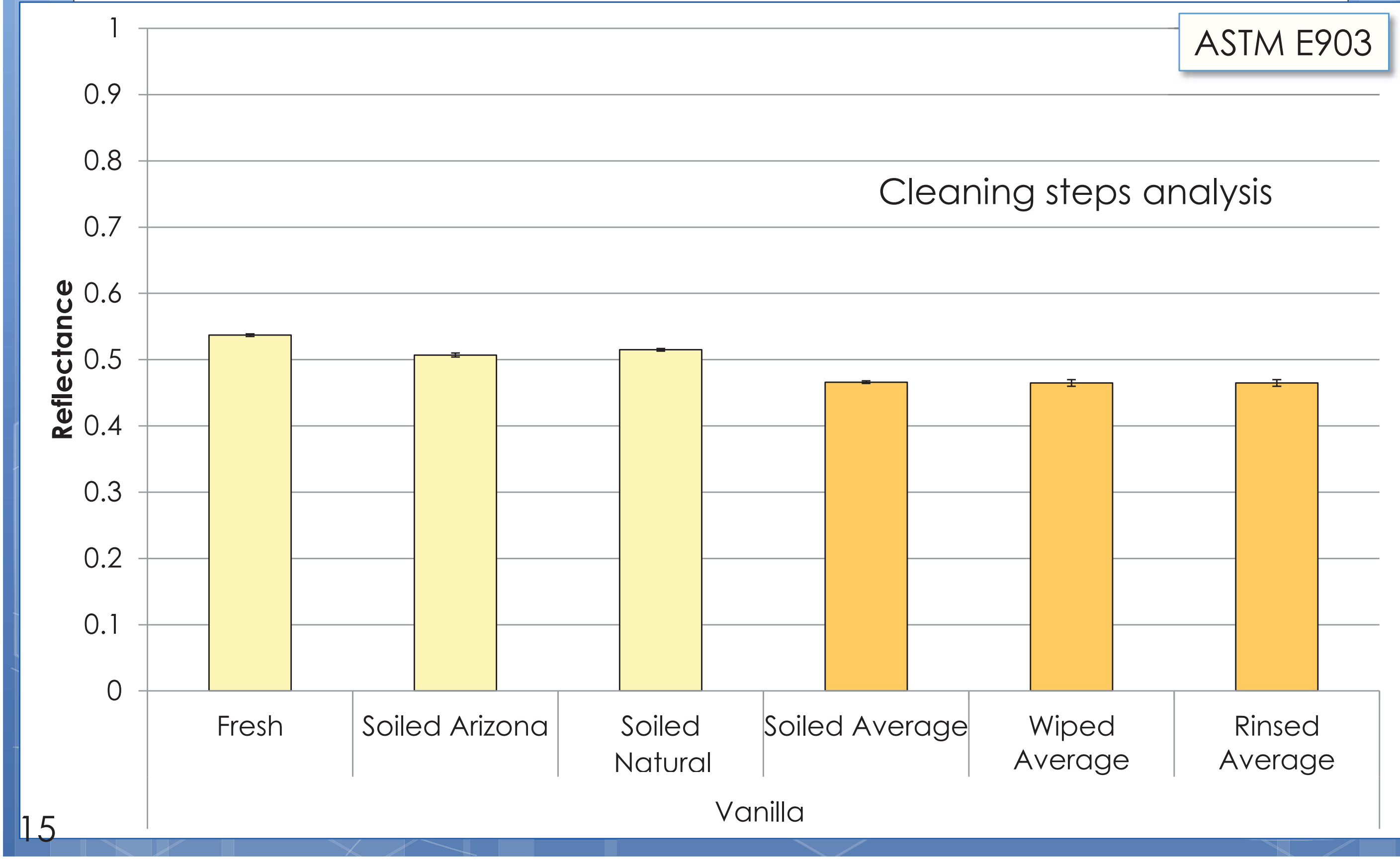



RESULTS
Inorganic coating – Vanilla sample
ASTM E903
Reflectance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Fresh
Soiled Arizona
Soiled Natural
Soiled Average
Wiped Average
Rinsed Average
Vanilla
15


RESULTS
Inorganic coating – Vanilla sample
ASTM E903
Accelerated/natural ageing comparison
Reflectance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Fresh
Soiled Arizona
Soiled Natural
Soiled Average
Wiped Average
Rinsed Average
Vanilla
15

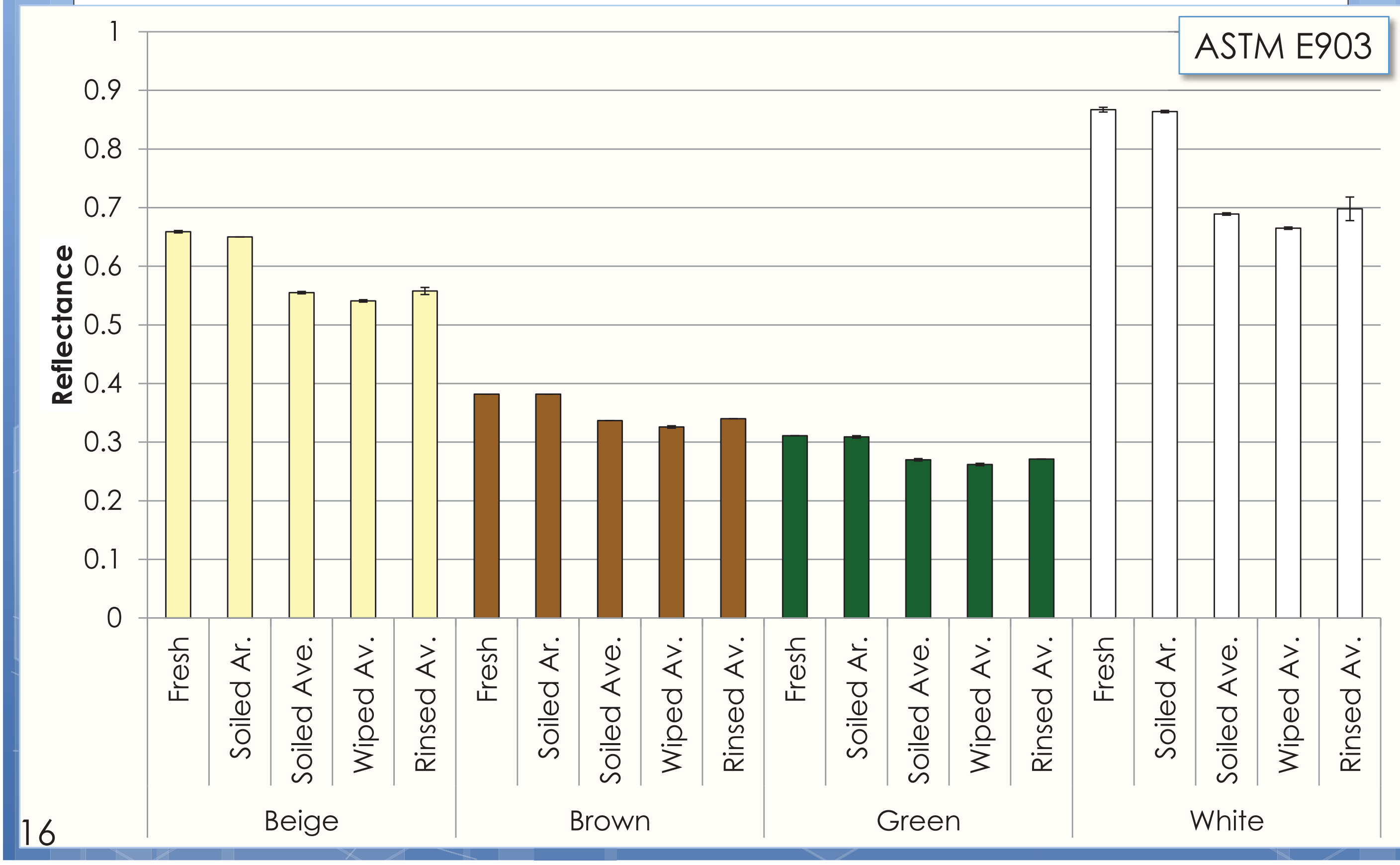
RESULTS

Inorganic coating – Vanilla sample



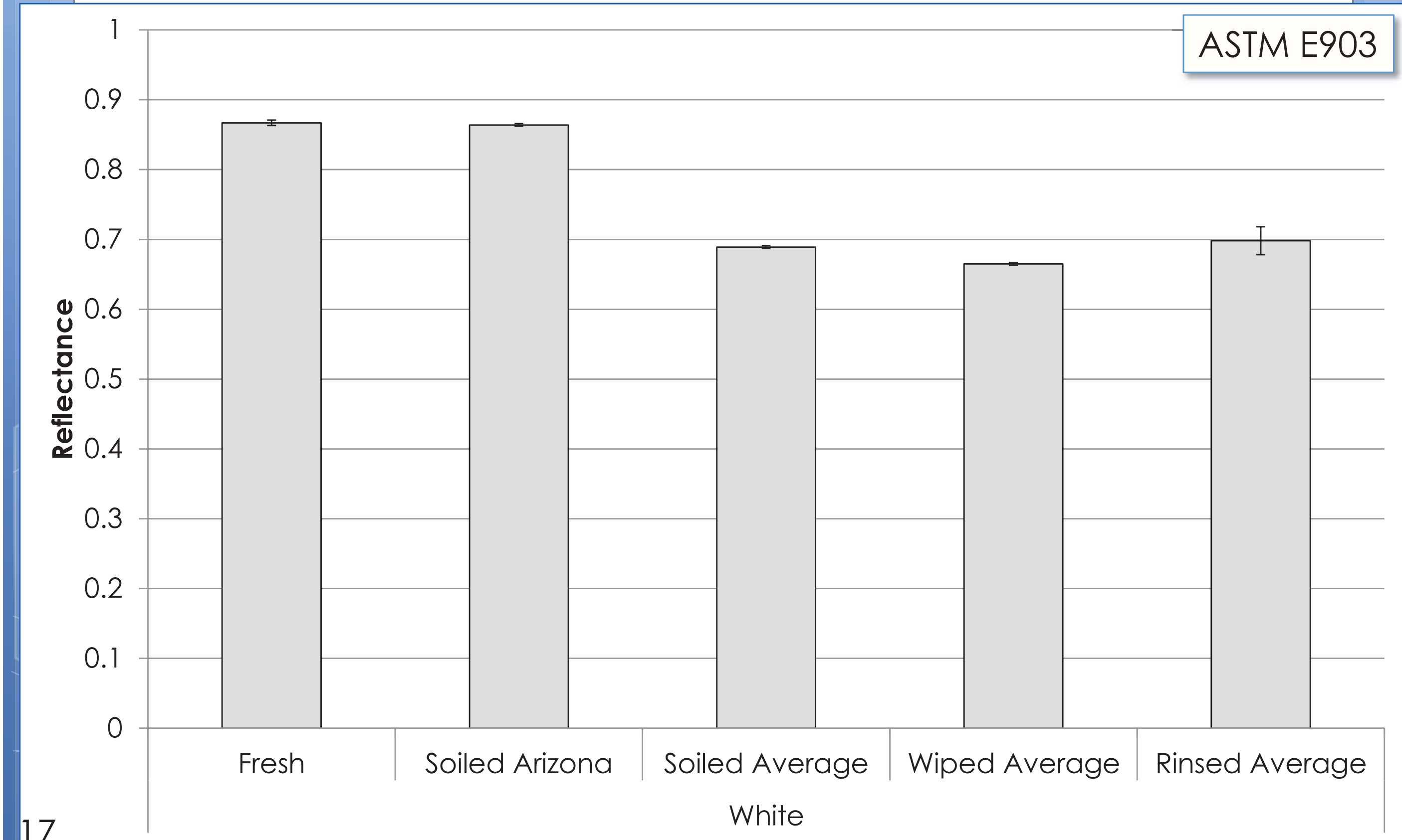
RESULTS

Organic coating – summary graph



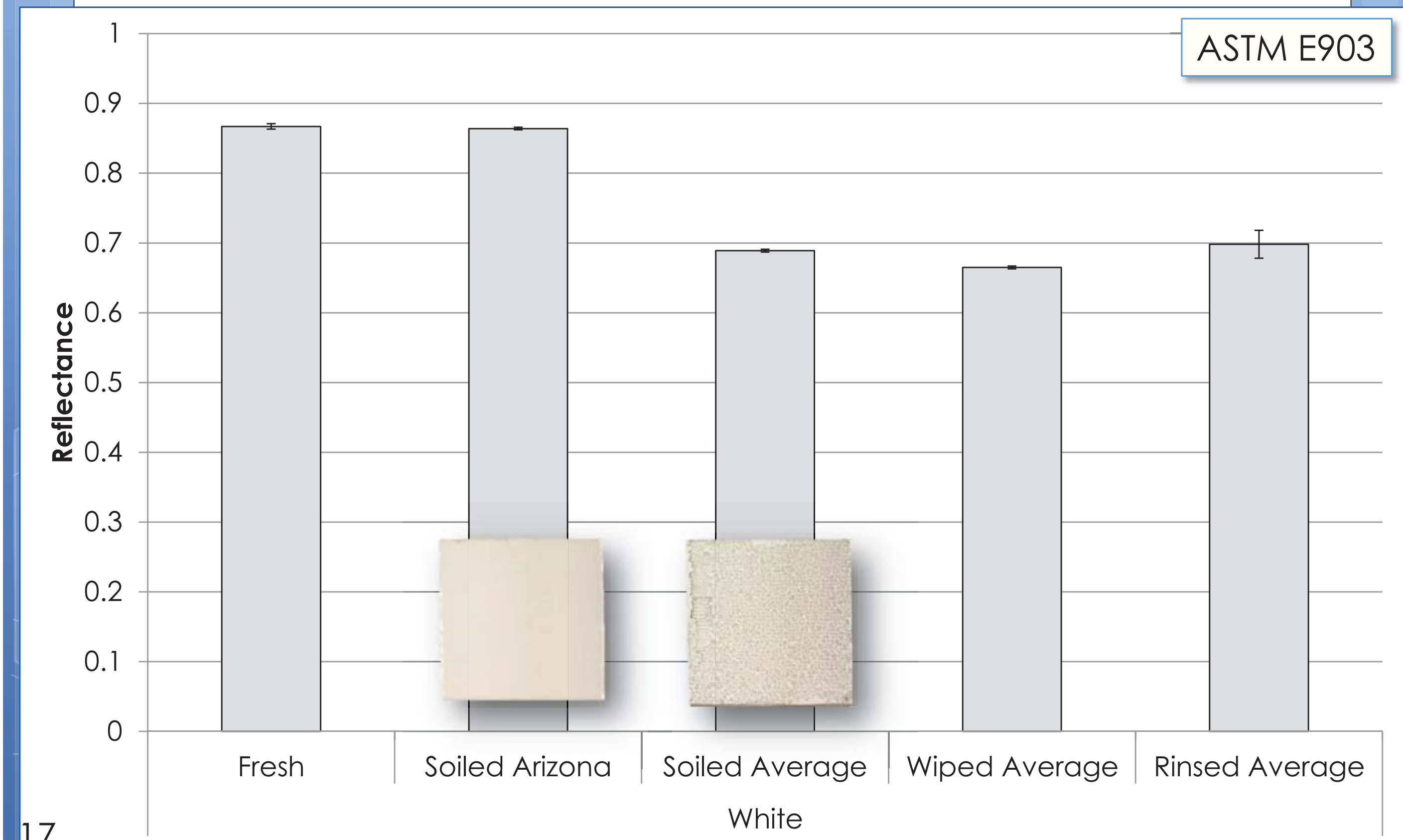
RESULTS

Organic coating – White sample



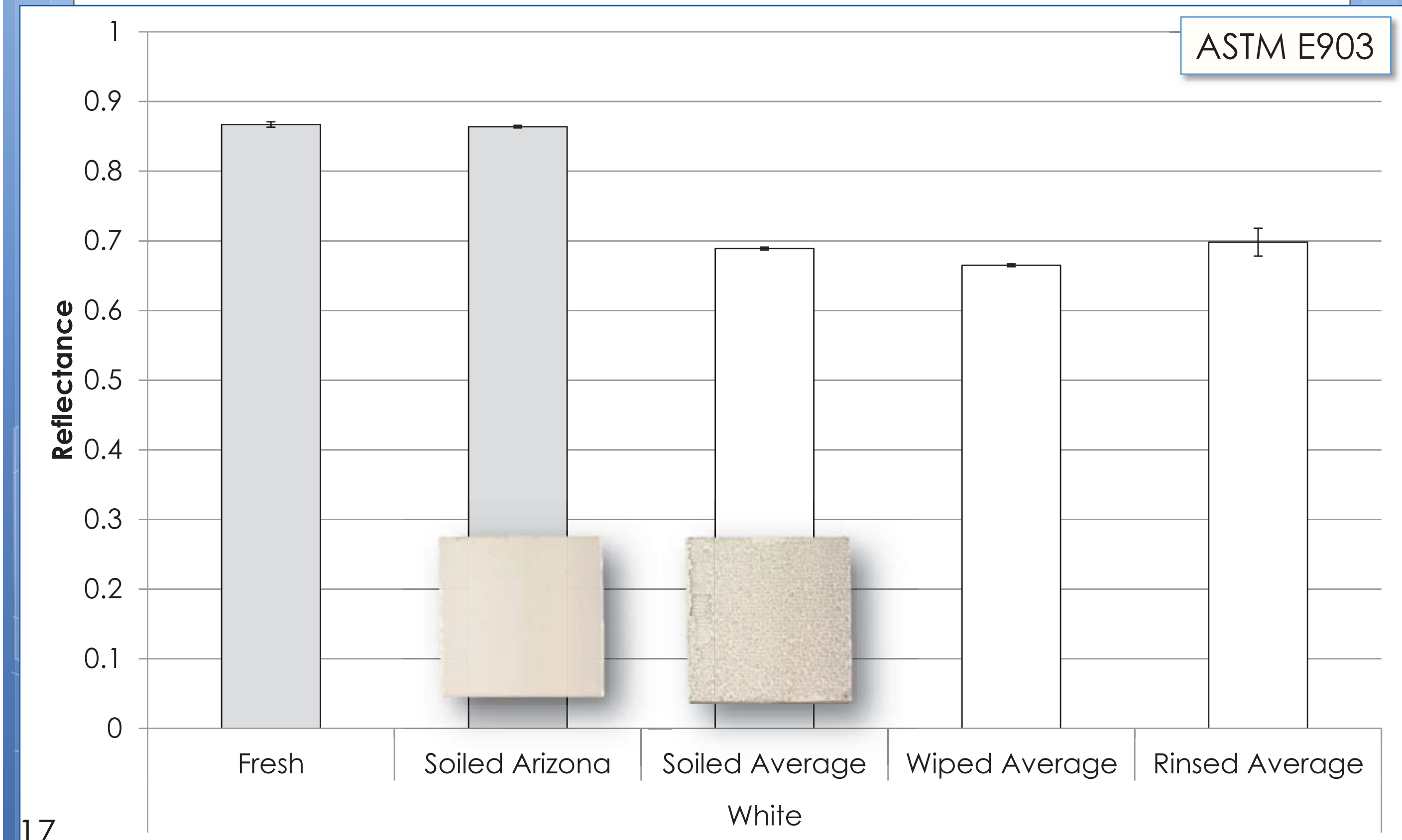
RESULTS

Organic coating – White sample



RESULTS

Organic coating – White sample



DISCUSSION

Summary table

ASTM E903

	Solar refl. R_0	Solar reflectance ratio R_n/R_0									
	Fresh	**Weatherometer**	**Soiled Ar.**	**Wiped Ar.**	**Rinsed Ar.**	**Soiled Nat.**	**Wiped Nat.**	**Rinsed Nat.**	**Soiled Av.**	**Wiped Av.**	**Rinsed Av.**
Tobacco	0.35	0.98	0.98	0.99	0.99	0.93	0.92	0.92	0.89	0.89	0.89
Vanilla	0.58	0.97	0.97	0.95	0.95	0.96	0.97	0.96	0.87	0.87	0.87
Apricot	0.41	0.90	0.90	0.92	0.93	0.93	0.94	0.96	0.89	0.88	0.88
Red	0.38	0.96	0.96	0.92	0.92	0.95	0.94	0.99	0.89	0.90	0.89
Beige	0.66	1	0.99	0.99	0.98	N/A	N/A	N/A	0.84	0.82	0.85
Brown	0.38	1	1	1	1	N/A	N/A	N/A	0.88	0.85	0.89
Green	0.31	1	0.99	0.99	0.99	N/A	N/A	N/A	0.87	0.84	0.87
White	0.87	1	1	1	1	N/A	N/A	N/A	0.80	0.77	0.80

DISCUSSION

Summary table

ASTM E903

	Solar refl. R_0	Solar reflectance ratio R_n/R_0									
	Fresh	Weatherometer	Soiled Ar.	Wiped Ar.	Rinsed Ar.	Soiled Nat.	Wiped Nat.	Rinsed Nat.	Soiled Av.	Wiped Av.	Rinsed Av.
Tobacco	0.35	0.98	0.98	0.99	0.99	0.93	0.92	0.92	0.89	0.89	0.89
Vanilla	0.58	0.97	0.97	0.95	0.95	0.96	0.97	0.96	0.87	0.87	0.87
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White	0.87	1	1	1	1	N/A	N/A	N/A	0.80	0.77	0.80

DISCUSSION

Summary table

ASTM E903

	Solar refl. R_0	Solar reflectance ratio R_n/R_0									
	Fresh	Weatherometer	Soiled Ar.	Wiped Ar.	Rinsed Ar.	Soiled Nat.	Wiped Nat.	Rinsed Nat.	Soiled Av.	Wiped Av.	Rinsed Av.
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Vanilla	0.58	0.97	0.97	0.95	0.95	0.96	0.97	0.96	0.87	0.87	0.87
Apricot	0.41	0.90	0.90	0.92	0.93	0.93	0.94	0.96	0.89	0.88	0.88
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Brown	0.38	1	1	1	1	N/A	N/A	N/A	0.88	0.85	0.89
Green	0.31	1	0.99	0.99	0.99	N/A	N/A	N/A	0.87	0.84	0.87
White	0.87	1	1	1	1	N/A	N/A	N/A	0.80	0.77	0.80

18

CONCLUSION

- Aim of the study (1): influence of **ageing** (natural and artificial) on solar reflectance
- Aim of the study (2): influence of simulated weathering agents (rain and wind) as **cleaning step**
- Considering the good thermal emittance of clay based products (ε=0.9) **just solar reflectance** was taken into account during this study
- Artificial ageing **simulates excellently** real ageing conditions
- Cleaning processes **does not seem to restore** solar reflectance of the samples
- Suitable reason of this lack in recovery of solar reflectance can be attributed to **the morphology of the samples** (surface roughness in particular) that prevent the cleaning processes)

FUTURE PERSPECTIVES

Step 1
- Solar reflectance (ASTM E903 and C1549) of fresh and natural aged samples

Step 2
- Artificial Aging of fresh samples

Step 3
- Solar reflectance (ASTM E903 and C1549) of artificial aged samples

Step 4
- Cleaning step on natural and artificial aged samples

Step 5
- Solar reflectance (ASTM E903 and C1549) of samples after each cleaning step

Step 6
- ***Microstructural, chemical and mineralogical characterization of all tested samples (Fresh, natural aged, artificial aged)***

Step 7
- ***Find new soiling mixture simulating european pollution conditions***
- ***Desing and create a GLAZED ceramic based cool color product (R>0.50)***

Effect of ageing processes on solar reflectivity of clay roof tiles

Energy conservation technologies for mitigation and adaptation in the built environment:
The role of ventilation strategies and smart materials

34th AIVC Conference
3rd TightVent Conference
2nd Cool Roofs' Conference
1st venticool Conference

Thank you
for your
kind attention!

Athens, 25 september 2013

FIELD OBSERVATION OF COOLING ENERGY SAVING BY THE HIGH REFLECTANCE PAINT

Chihiro Yamada
Department of Architecture
Graduate School of Engineering
Kobe University

Research background

Nowadays, high reflectance paint is becoming famous in Japan for the mitigation of urban heat island phenomenon and the reduction of cooling load.

Coating the high reflectance paint
on the roof of objective building

Research background and purpose

Akbari et al. analyzed the cooling energy saving in buildings actually used in USA. However, there are few studies in Japan. It is required by building owner or manager that the cooling energy saving by high reflectance paint in the building actually used.

In this study, we analyzed the cooling energy saving in a building actually used based on measured results before and after painting.

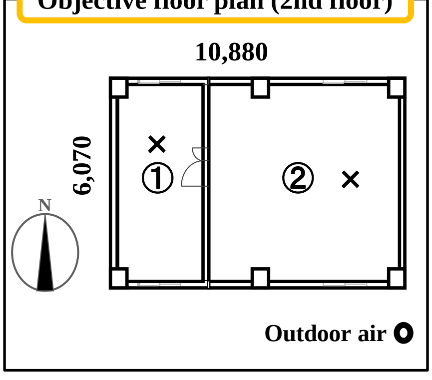
Outline of Objective Building and Measurement

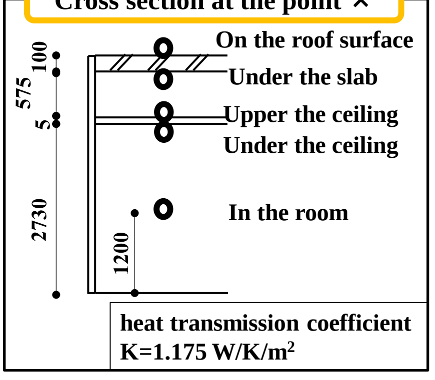
Objective building and measurement period

Two story research building with about 60 m^2 floor area in Kobe University

	Measurement period
Before painting	Jul. 7 to 31, 2011
After painting	Aug. 3 to Sep. 26, 2011
One year after painting	Jul. 12 to Sep. 26, 2012

Objective floor plan and cross section



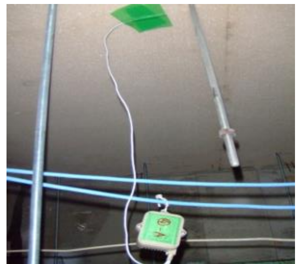


- In addition, power consumption of air conditioner in each room is measured
- The air conditioners in both rooms were continuously running for 24 hours.

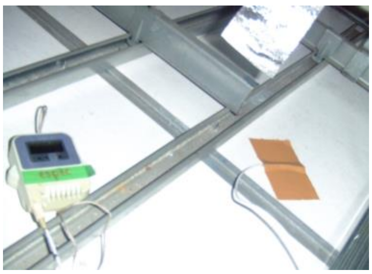
	The certificate cooling capacities of air conditioners
Room1	7.1kW
Room2	14.5kW

Pictures of measurement scenes

Temperature on the roof surface



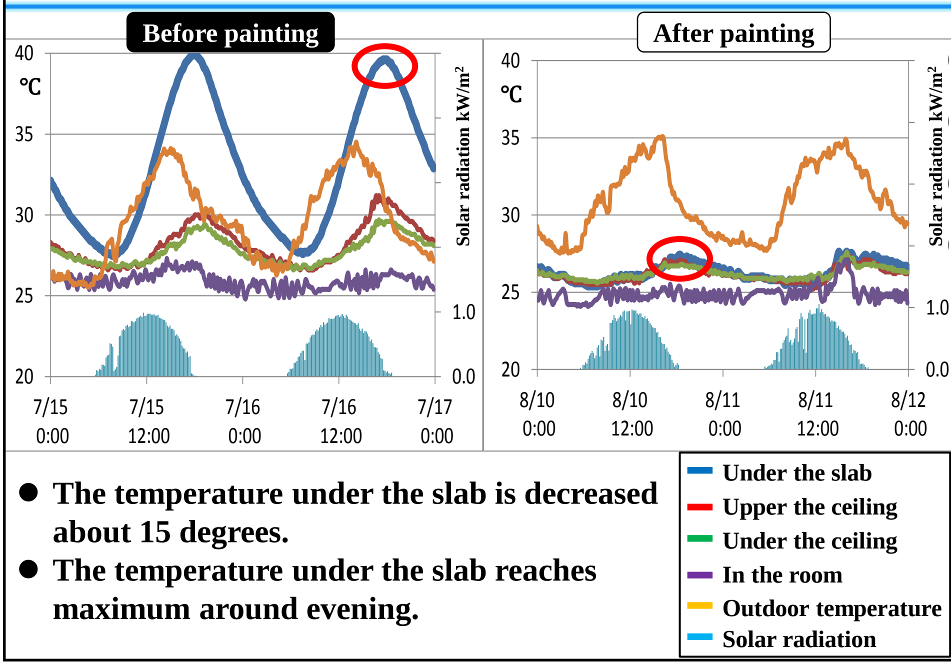
Temperature under the slab



Temperature upper the ceiling

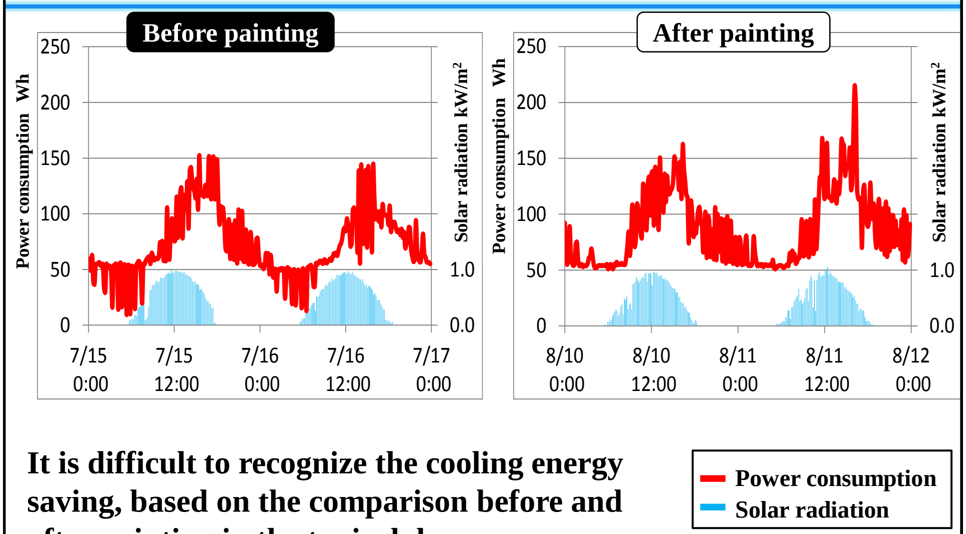
Temperature under the ceiling

Measurement result of temperature on cross section



- The temperature under the slab is decreased about 15 degrees.
- The temperature under the slab reaches maximum around evening.

Measurement result of cooling power consumption

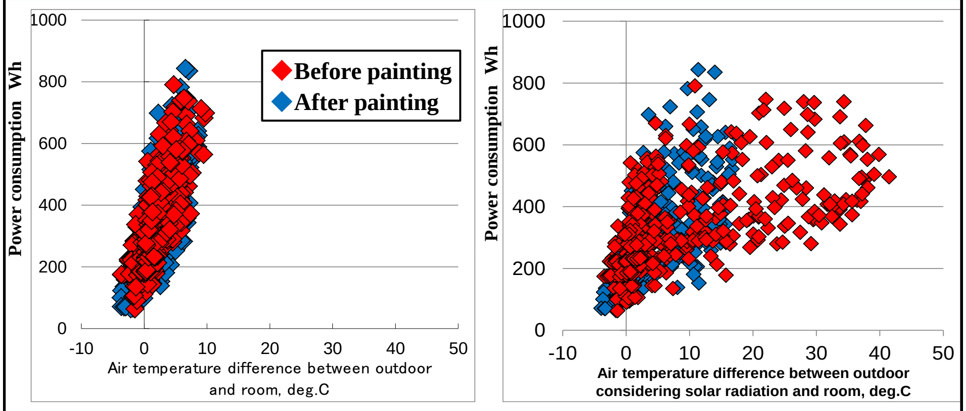


It is difficult to recognize the cooling energy saving, based on the comparison before and after painting in the typical day.

Urban Environment / Building Facilities Lab.

Analysis of Cooling Energy Saving by High Reflectance Paint

Every hour data



The difference before and after painting of the sol-air temperature which is influenced by solar radiation is large, however power consumption doesn't change so much.

Evaluation Method Of Cooling Energy Saving

It is difficult to recognize the relationship between temperature difference and power consumption by every hour data.

⇩

I'll analyze the relationship between daily averaged outdoor to room air temperature difference and daily integrated cooling power consumption

Evaluation Method Of Cooling Energy Saving

Factors influence cooling power consumption are

- ○internal heat generation
- ○set temperature of air conditioner
- ○weather condition(air temperature, solar radiation)

Because the object of this study is the evaluation of cooling energy saving in the building actually used, we didn't instruct the users how to use the room.

⇩

The measurement results are affected by above 3 factors

Analysis of cooling energy saving

Cooling power consumption influenced by internal heat generation, set temperature of air conditioner and weather condition is shown as follows.

$$E = AI + B\Delta T + C$$

A: coefficient related to solar absorptance, which is changed by painting

B: coefficient related to thermal conductance, which is not changed by painting

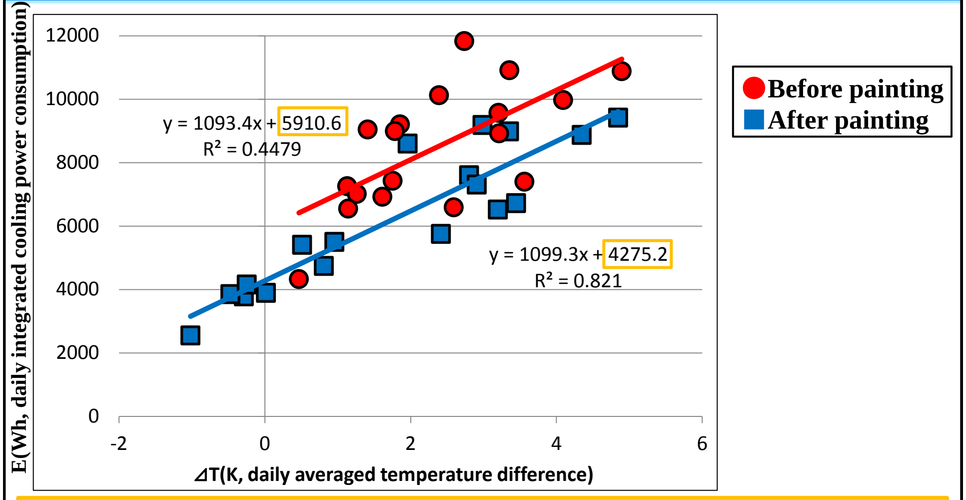
C: internal heat generation, which is not changed by painting

E: daily integrated cooling power consumption (Wh/day), which is measured

I: daily integrated solar radiation (Wh/day), which is measured

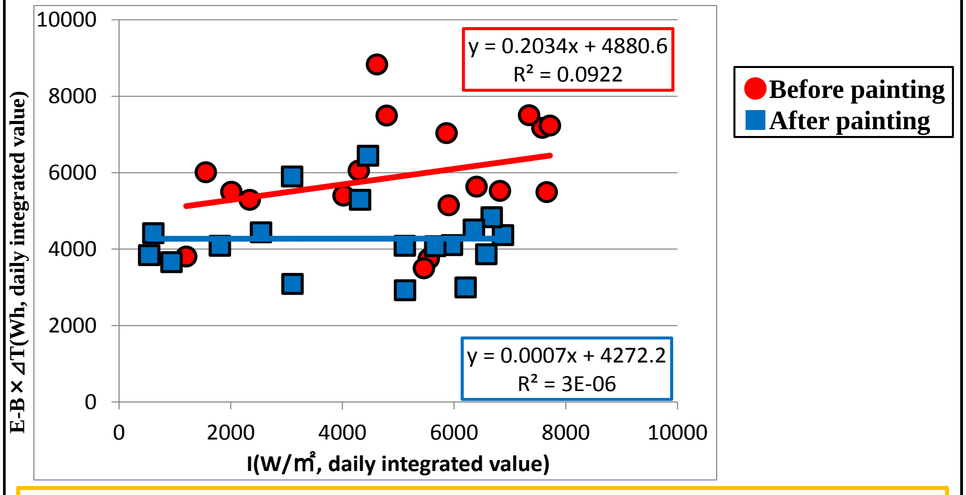
⊿T: daily averaged temperature difference of outdoor and room (K), which is measured

E=BΔT+(AI+C) applied to room ①



Since both slopes of regression equations of before and after painting are similar, the cooling energy saving is calculated as follows: 5910.6 - 4275.2 = 1635 Wh/day

E-BΔT=AI+C applied to room ①



Cooling power consumption doesn't change after painting even if the daily integrated solar radiation is large.
Since the internal heat generation was not controlled during measurement, the coefficient C is not similar before and after painting.

E-BΔT=AI+C applied to room ① and ②

		Regression equation	Energy saving
Room 1 (floor area: 22.5㎡)	Before painting*	$E=48.6\Delta T+262.7$ (R^2=0.45)	-
	After painting**	$E=50.3\Delta T+190.8$ (R^2=0.82)	72Wh/m²/day
	One year after painting***	$E=48.0\Delta T+171.6$ (R^2=0.82)	91Wh/m²/day
Room 2 (floor area: 43.5㎡)	Before painting*	$E=26.7\Delta T+151.3$ (R^2=0.54)	-
	After painting**	$E=27.6\Delta T+116.6$ (R^2=0.60)	35Wh/m²/day
	One year after painting***	$E=26.9\Delta T+142.8$ (R^2=0.77)	9Wh/m²/day

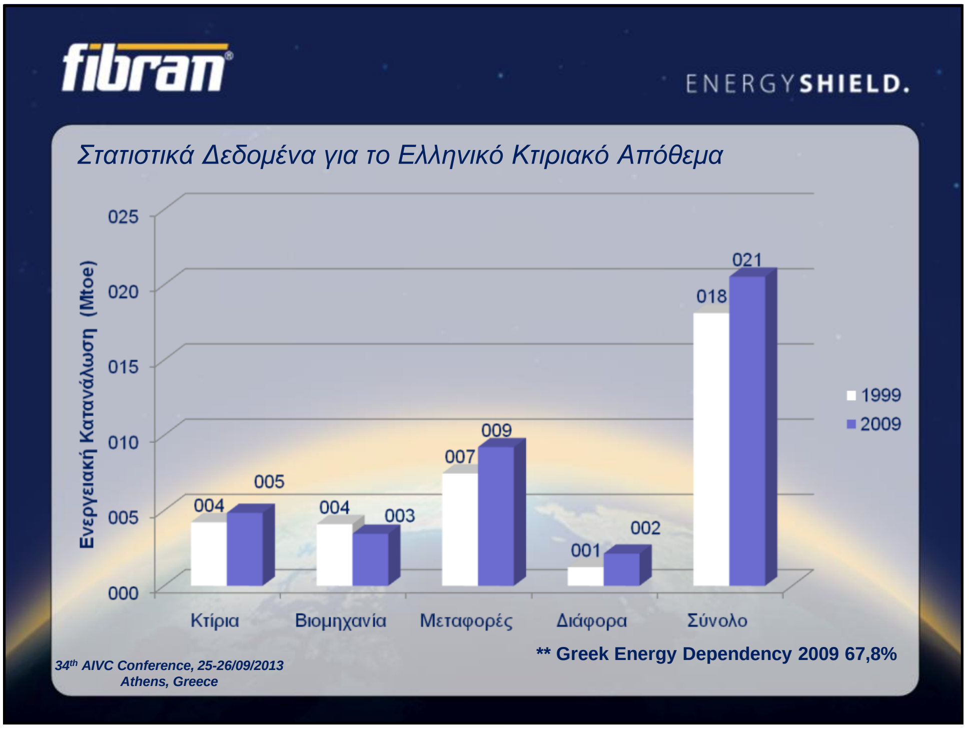
***before painting: from Jul. 12 to Jul. 31, 2011, **after painting: from Aug. 3 to Sep. 26, 2011, ***one year after painting: from Jul. 12 to Sep. 26, 2012**

- **Because slopes of regression equation (coefficient B) of before, after and one year after painting are relatively similar in each room, the influences by ΔT to cooling power consumption are similar in each room.**
- **Cooling energy saving in room 2 is smaller than that in room 1. The internal heat generation ratio to the total cooling load in room 2 is larger than that in room 1, because floor area in room 2 is approximately twice as large as room 1.**

Conclusion

- **Even if we use results measured in a building actually used, we could evaluate approximate energy savings, by analysis of the relationship between outdoor to room daily averaged temperature difference and cooling power consumption.**
- **Cooling power consumption saving by high reflectance paint is estimated around 1.6kWh/day (72Wh/m²/day). Similar result is confirmed one year after painting.**


fibran
ENERGYSHIELD.
Composite Materials for Renovation of Roofs in Existing Buildings
Stella Chadiarakou
Dr. Mechanical Engineer
FIBRAN S.A., GREECE
Agis Papadopoulos
PEDL, Department of Mechanical Engineering AUTH, GREECE
Mattheos Santamouris
Physics Department – Section of Applied Physics
UA, Greece
34th AIVC Conference, 25-26/09/2013
Athens, Greece


fibran
ENERGYSHIELD.
Στατιστικά Δεδομένα για το Ελληνικό Κτιριακό Απόθεμα
Ενεργειακή Κατανάλωση (Mtoe)
025
020
015
010
005
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005
004
003
007
009
001
002
018
021
Κτίρια
Βιομηχανία
Μεταφορές
Διάφορα
Σύνολο
1999
2009
** Greek Energy Dependency 2009 67,8%
34th AIVC Conference, 25-26/09/2013
Athens, Greece

Στατιστικά Δεδομένα για το Ελληνικό Κτιριακό Απόθεμα

- Περιφέρεια
  - <1980 1.274.113
  - >1980 627.293
- Αστικά Κέντρα
  - <1980 1.496.102
  - >1980 507.712

Περιφέρεια → 1.901.406

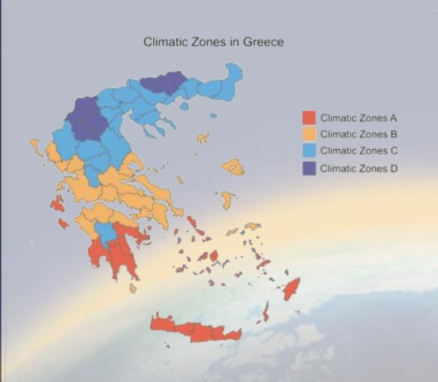
Αστικά Κέντρα → 2.003.814

1.901.406 + 2.003.814 = 3.905.220

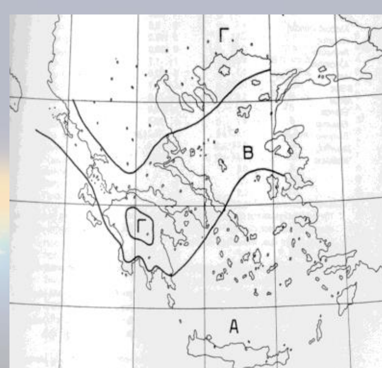
3.905.220: 71% <1980, 29% >1980

Κ.Εν.Α.Κ. – Κλιματικές Ζώνες

2010

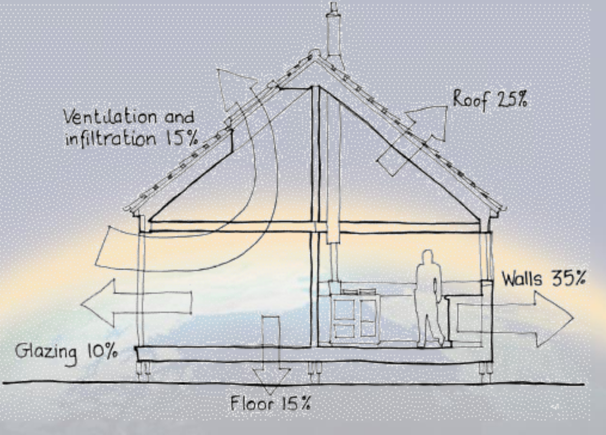


1979



34th AIVC Conference, 25-26/09/2013
Athens, Greece

Heat Losses from building envelope



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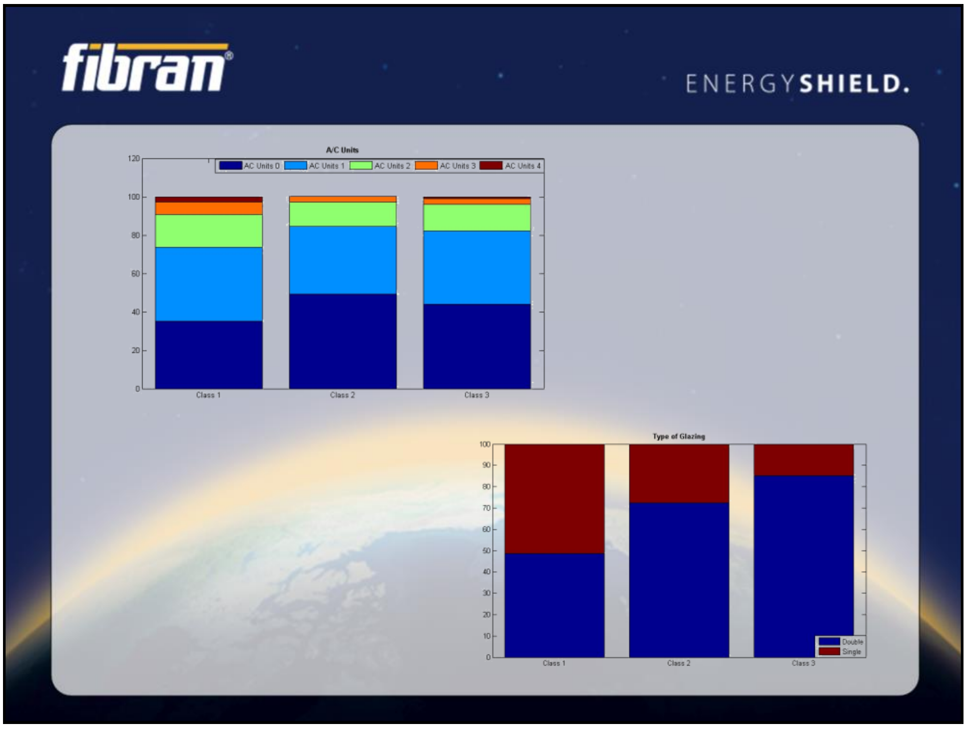
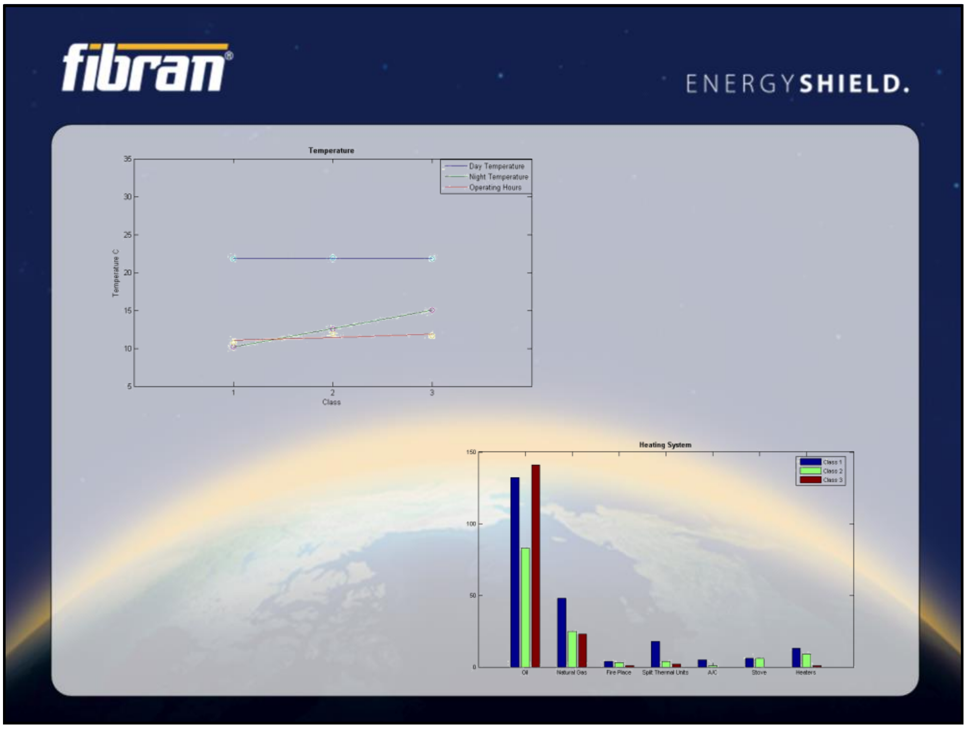
Athens, Greece

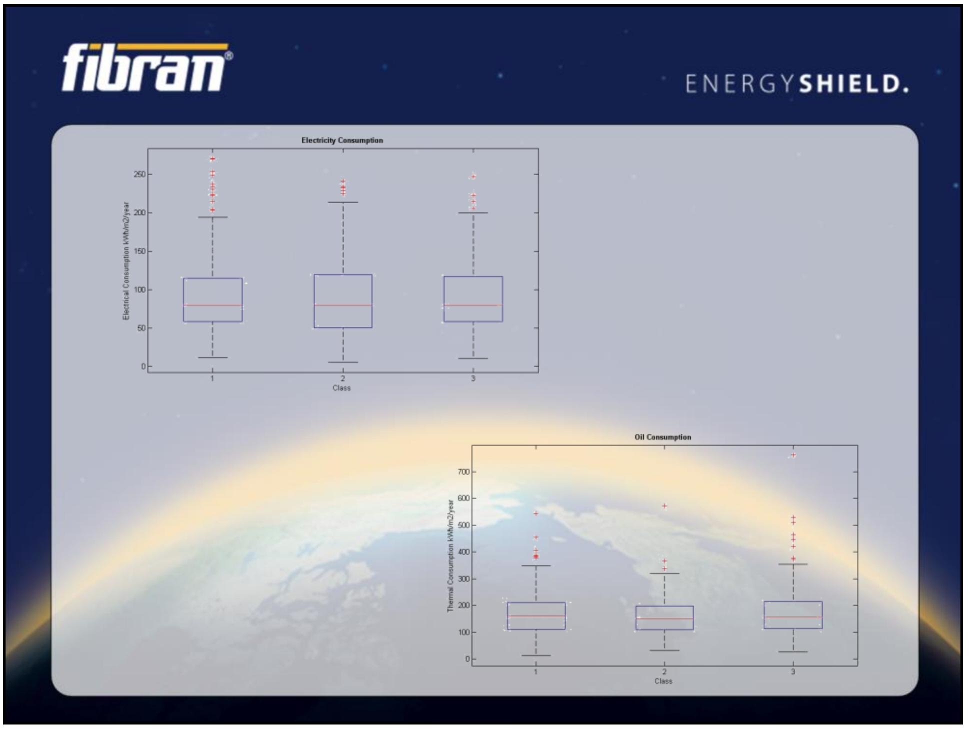
New Regulation (KENAK) – U limits

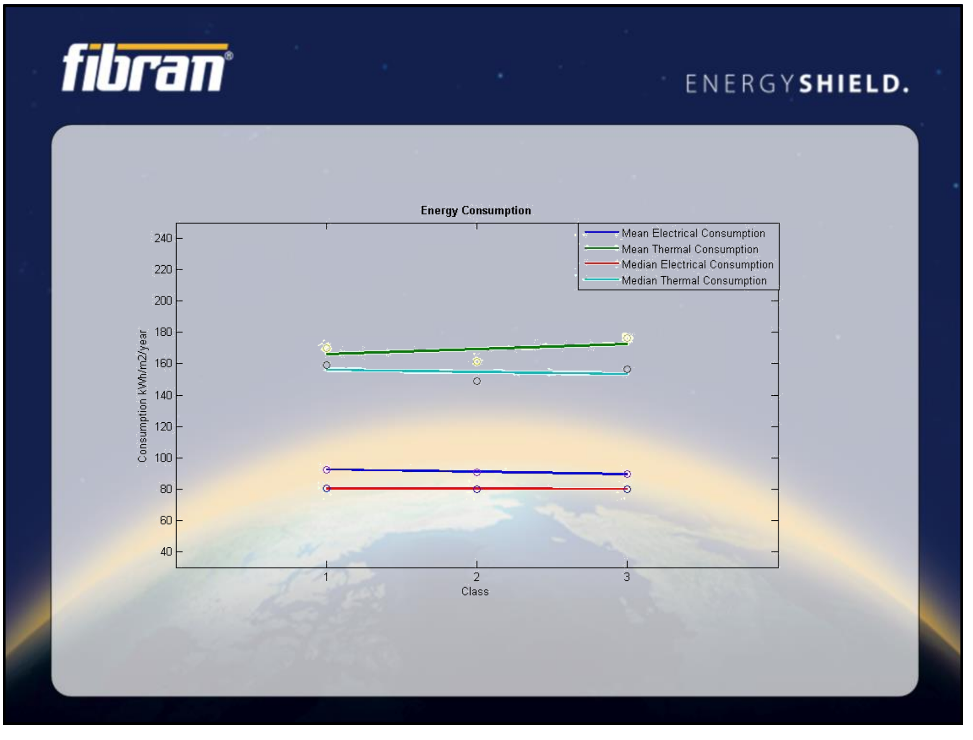
Building Element\Climatic Zone	A		B		C		D
Regulation	Old	New	Old	New	Old	New	New
Vertical Element (Wall)	0,7	0,6	0,7	0,5	0,7	0,45	0,4
Horizontal Element (Roof)	0,5	0,5	0,5	0,45	0,5	0,40	0,35
Windows		3,2		3,0		2,8	2,6
Km	1,9		1,9		1,9		

Climatic Zone	A	B	C	D
Minimum Thickness	cm	cm	cm	cm
Roof	6 /4	7 / 5	7 / 5	10 / 7
Wall	5 / 4	6 / 5	7 / 5	8 / 6
Concrete element	5 / 4	6 / 5	7 / 6	8/ 7


fibran
ENERGYSHIELD.
A/C Units
AC Units 0
AC Units 1
AC Units 2
AC Units 3
AC Units 4
Class 1
Class 2
Class 3
Type of Glazing
Double
Single
Class 1
Class 2
Class 3


fibran
ENERGYSHIELD.
Temperature
Day Temperature
Night Temperature
Operating Hours
Temperature C
Class
Heating System
Class 1
Class 2
Class 3
Oil
Natural Gas
Fire Place
Split Thermal Units
A/C
Stove
Heaters


fibran
ENERGYSHIELD.
Electricity Consumption
Electrical Consumption kWh/m2/year
Class
Oil Consumption
Thermal Consumption kWh/m2/year
Class


fibran
ENERGYSHIELD.
Energy Consumption
Mean Electrical Consumption
Mean Thermal Consumption
Median Electrical Consumption
Median Thermal Consumption
Consumption kWh/m2/year
Class

fibran ENERGYSHIELD.

Simulation Scenarios (1)

U value	Basic	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Walls Bricks	0,646	0,316	0,237	0,181	0,146	0,123	0,106
Walls Concrete	0,801	0,349	0,255	0,191	0,153	0,127	0,109
Walls Last Floor	0,569	0,297	0,226	0,174	0,142	0,119	0,103
Floors (ext)	0,546	0,307	0,222	0,172	0,14	0,118	0,102
Flat Roof	0,336	0,237	0,237	0,181	0,122	0,105	0,093

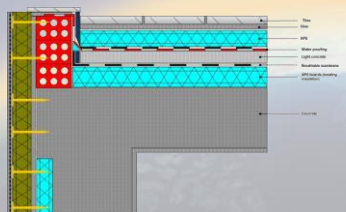
fibran ENERGYSHIELD.

Simulation Scenarios (2)

Scenarios	Thickness of Insulation			
	Wall	Concrete element	Roof	Floor
Basic	50mm	30mm	60mm	50mm
Scenario 1	60mm	60mm	100mm	50mm
Scenario 2	100mm	100mm	100mm	100mm
Scenario 3	150mm	150mm	150mm	150mm
Scenario 4	200mm	200mm	200mm	200mm
Scenario 5	250mm	250mm	250mm	250mm
Scenario 6	300mm	300mm	300mm	300mm

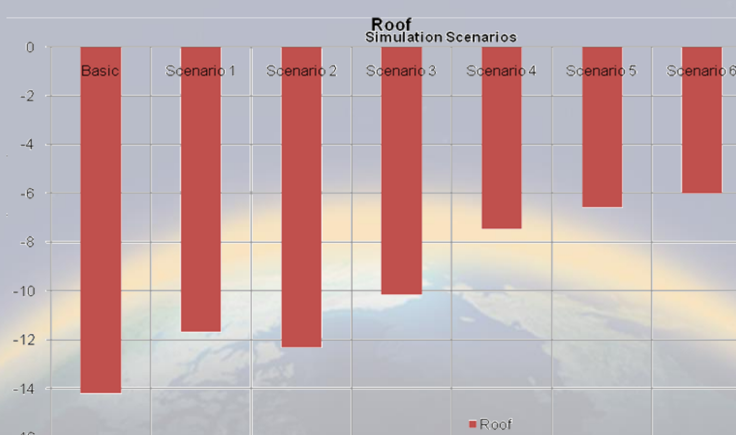
fibran ENERGYSHIELD.

Thermal insulation construction solution for the roofs



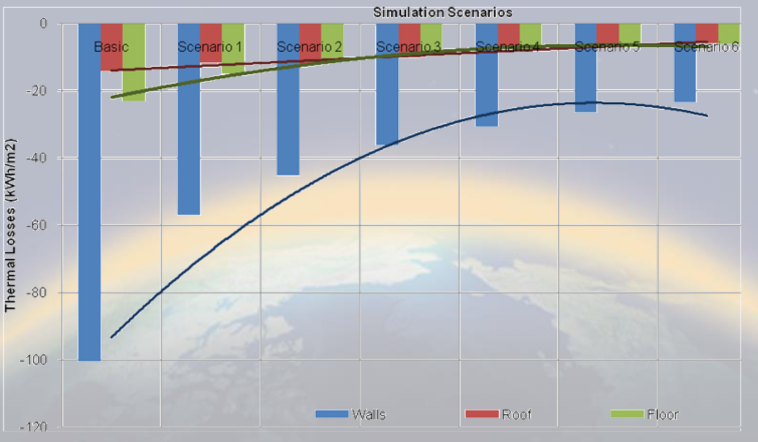
fibran ENERGYSHIELD.

Heat balance Results



fibran ENERGYSHIELD.

Thermal Losses Results for total building envelope



fibran ENERGYSHIELD.

Conclusion…. Future work

- Roofs contributes with 25% of the total energy losses from the building envelope
- Retrofitting insulation scenarios need to take into consideration construction limitation
- Applied composite thermal insulation light materials could provide with approximately 28% of thermal losses mitigation
- Future work is to provide with a ceramic tile that could be included in the cool material library

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Athens, Greece

Cooling Roofs Through Low Temperature Solar-Heat Transformations in Hydrophilic Porous Materials

D. Karamanis[1,*], E. Vardoulakis[1], E. Kyritsi[1], V. Kapsalis[1], G. Gorgolis[1], S. Krimpalis[1], G. Mihalakakou[1], N. Ökte[2]

[1] Department of Environmental & Natural Resources Management, University of Western Greece (currently part of the University of Patras), Seferi 2, 30100 Agrinio, Greece
[2] Department of Chemistry, Boğaziçi University 34342 Bebek, Istanbul, Turkey

*[*]Corresponding email: **dkaraman@cc.uoi.gr***

World urbanization-Population distribution the last century

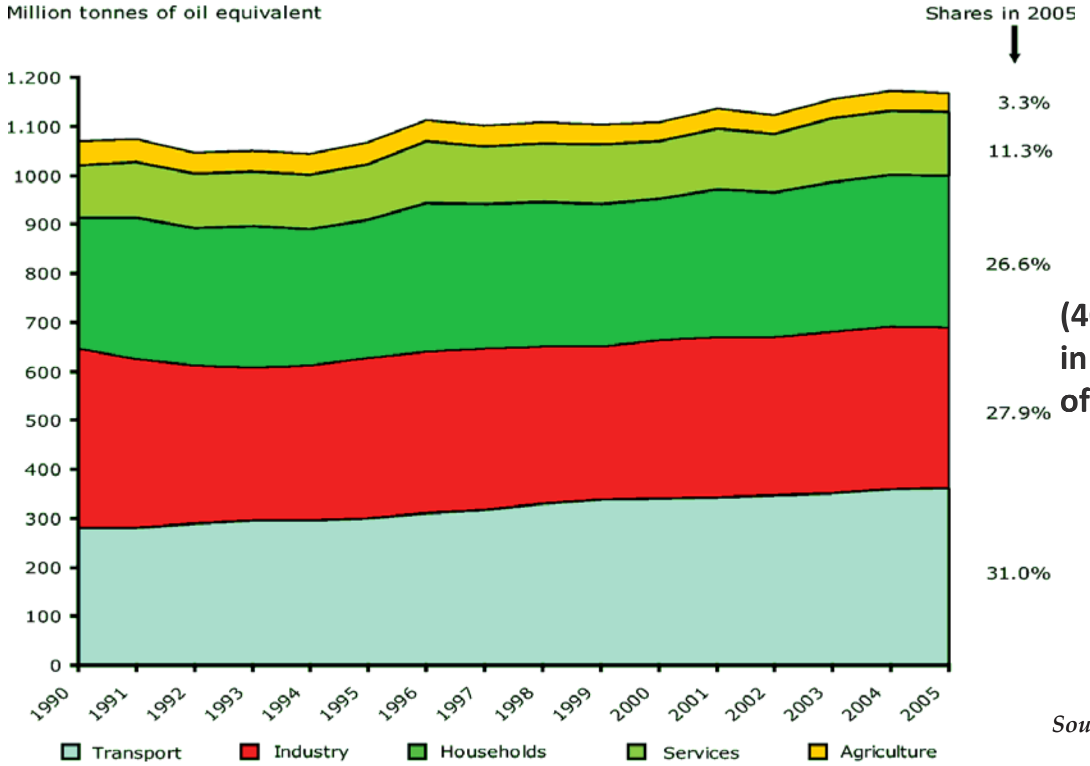
A. Population size and growth	Population (billions)				Average annual rate of change (percentage)		
	1950	1975	2005	2030	1950-1975	1975-2005	2005-2030
Total population World	2.52	4.07	6.45	8.13	1.92	1.54	0.92
More developed regions	0.81	1.05	1.21	1.24	1.01	0.48	0.11
Less developed regions	1.71	3.02	5.24	6.89	2.29	1.84	1.09
Urban population World	0.73	1.52	3.17	4.94	2.91	2.46	1.78
More developed regions	0.43	0.70	0.91	1.01	2.00	0.84	0.46
Less developed regions	0.31	0.81	2.27	3.93	3.91	3.42	2.20
Rural population World	1.79	2.55	3.28	3.19	1.43	0.84	-0.12
More developed regions	0.39	0.34	0.30	0.23	-0.46	-0.42	-1.15
Less developed regions	1.40	2.21	2.98	2.96	1.82	1.00	-0.03

Source: United Nations, New York, 2005

B. Urban indicators	Percentage urban				Rate of urbanization (percentage)		
	1950	1975	2005	2030	1950-1975	1975-2005	2005-2030
World	29.1	37.3	49.2	60.8	1.24	0.92	0.85
More developed regions	52.5	67.2	74.9	81.7	1.23	0.36	0.35
Less developed regions	17.9	26.9	43.2	57.1	2.04	1.58	1.12

Over 50% of world population in cities with 75% in developed countries

Energy Consumption Increase



(40% of total in buildings of EU and US)

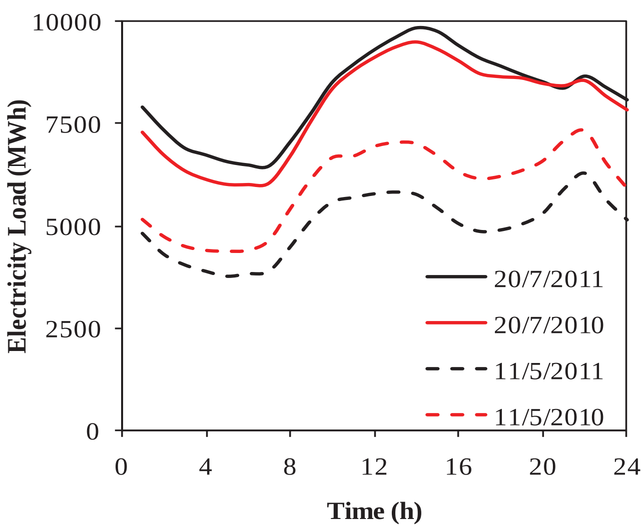
Source: *Eurostat, 2007.*

Energy & Buildings

Situation in Greece

Heating
(2/3 of total energy)
Covered from natural gas and oil

Cooling
(1/3 in summer)
Covered from electricity



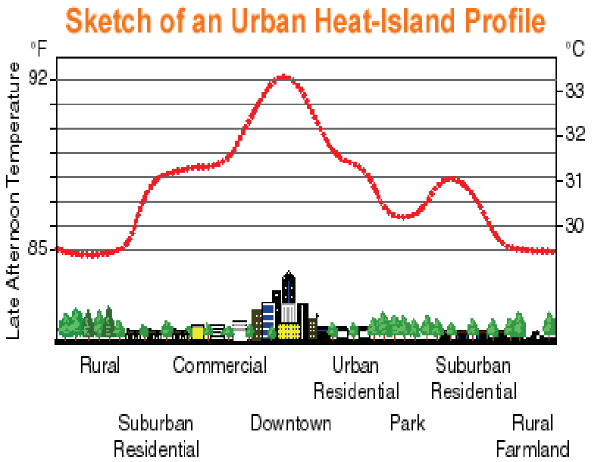
Hourly electricity load in Greece in typical days of July and May at 2010 and 2011 (ΔΕΣΜΗΕ)

The mean monthly electricity consumption in Greece increased by 23% in July of 2011 compared to the mean annual while the hourly load of a typical day in July was up to 70% higher than the load at May

A high amount of electricity is needed for a very short summertime period and is mainly produced from fossil fuels

Urban Heat Island Effect

- Urban areas can be up to 10 degrees warmer than their surrounding rural areas, like an “island” of heat surrounded by cooler rural areas .
- Large horizontal temperature gradient exist at the urban/rural boundary, could be as large as 4 °C/km
- First noticed ~170 years ago. Even with numerous studies since the 1960’s, it is still studied and observed even in small cities like Agrinio (poster session).



Graphic courtesy of LLBL Heat Island Group

UHI Direct and Indirect Effects

- Increases demand for cooling energy and electricity generation which leads to higher pollutants emissions
- Increases chemical weathering of building materials
- Increase discomfort and even mortality rates during the summer time

UHI Mitigation Measures

- Reduce thermal and pollutants emissions of human origin
- Increase the green spaces in the urban environment
- Minimize energy consumption in buildings with the use of passive cooling techniques
- Use “cool” materials of high emissivity and reflectivity as construction materials
- Cool roofs with green, reflective materials and water evaporation
- Combinations of the previous

“weathered” green roof at our University

“cool” white in Santorini

Sweating Buildings as Humans !

Nature | Research Highlights

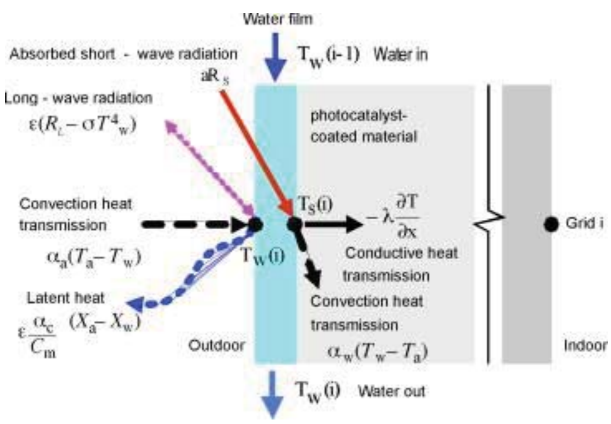
Hydrogel (from ETH ZURICH) makes buildings sweat

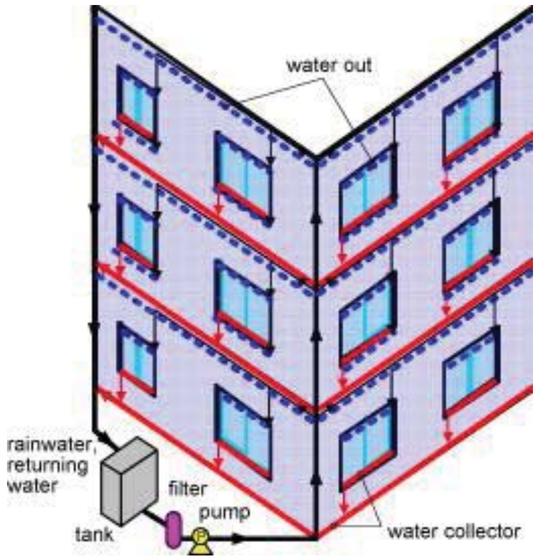
Nature
489,180 (13 September 2012),
Published online, 12 September 2012

Passive cooling with Photo-induced hydrophilicity

TiO_2 thin films covers and water

Under solar irradiation, water thin film of few um and cooling due to evaporation

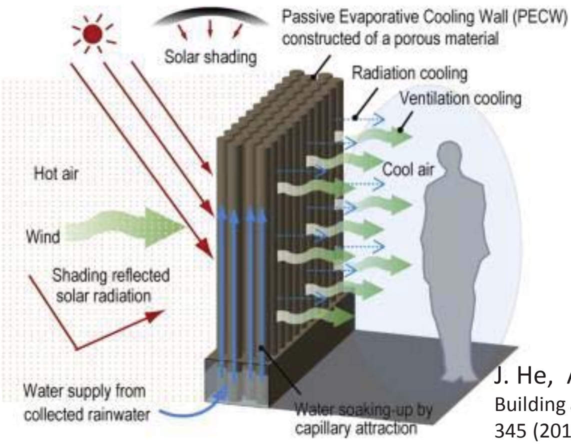




J. He, A. Hoyano
Energy and Buildings 40 (2008) 968

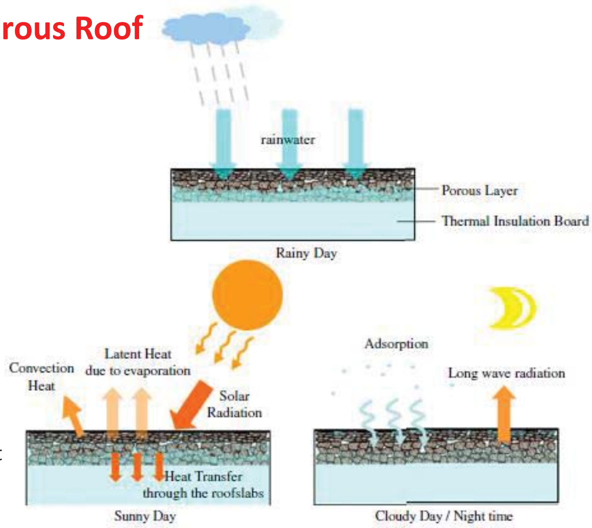
Evaporative Cooling and Porous Materials

Porous Wall



J. He, A. Hoyano
Building and Environment
345 (2010) 461

Porous Roof

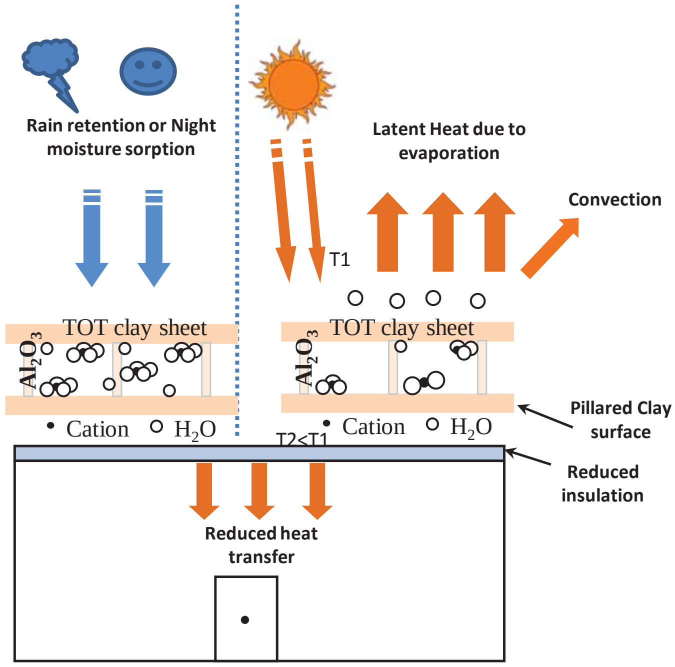


Principle

When evaporation takes place, the surface temperature of the porous material decreases, because of the latent (and adsorption) heat being released. Subsequently, heat flux coming through the roof slab, which raises temperatures inside the building, is also reduced.

Q. Meng, W. Hu
Energy and Buildings 37 (2005) 1
S. Wanphen, K.Nagano
Building and Environment 44 (2009) 338

Solar cooling with building integration of porous materials



Cycle: Night moisture adsorption–condensation- solar evaporation-desorption

Surface temperature of porous material is reduced due to the solar radiation absorption for providing the sensible and latent heat of water evaporation

Heat flux through roof or façade is reduced

Vardoulakis et al. Solar Energy Materials & Solar Cells 95 (2011) 2363.

Solar cooling with building integration of porous materials

Additive (Green roofs or roofs covered with gravel stones (our University)

The principle of building integrated evaporative cooling has been validated with the addition of **liquid water** in ***natural porous materials*** and irradiation from a metal halide lamp (500 W/m^2) (Wanphen et al., 2009), ***synthetic and aluminum pillared clays*** (Vardoulakis et al., 2011) or ***modified lignite fly ash*** (Karamanis et al., 2012) with metal halide lamp (100 W/m^2) and ***pHEMA polymer*** and sun simulation of class A, AM1.5 (Rotzetter et a., 2012). Recently, we showed that the principle can be applied by **moisture** sorption on the ***highly hydrophilic natural sepiolite*** (Karamanis et al., 2012).

With overnight uptake of water vapor on porous sepiolite in 70% relative humidity (to resemble the night outdoor condition), lower surface temperatures were observed under low simulated solar irradiation in comparison to concrete due to heat absorption for water evaporation and desorption with the accompanied mass reduction.

Solar Cooling and Porous Materials

The design of appropriate materials for roof covering with combined properties of high reflectance (especially in the visible range), moisture sorption and evaporation through infrared absorbance and self cleaning through ultraviolet absorbance could contribute significantly to the reduction of the heat flux entering the building from the roof

Required Properties of Porous Materials

- Highly Hydrophilic with High Heat of Adsorption
- High Moisture Sorption at night and Desorption during the day
- Thermal , Hydrothermal and Ageing Stability
- Non Toxic and Easy to Handle
- Low Cost
- Added ability for CO_2 storage or/and toxic pollutants degradation

Solar Cooling and Porous Materials

Water sorption properties of Porous Materials

Sorbents	Water sorption capacity, g/g	Rate of water sorption	Regeneration	Price	Toxicity	Long-term stability	Potential applications
Silica gel	0.40–0.45	Medium	High	Low	Low	High	Desiccation, heat pump, sorption refrigeration, thermal energy storage, fresh water production, gas dryer, ice-maker, corrosion protection, storage of food
Zeolites	0.20–0.45	High	High	Low	Low	High	Humidity sensor, desiccation, drying of ethanol, heat pump, sorption refrigeration, thermal energy storage, gas dryer, cold storage system, corrosion protection, ice making systems, hygienic animal bedding
Aluminophosphates	0.15–0.54	Medium	Medium	Medium	Low	Low	Humidity sensor, separation of water from liquid mixtures
Mesoporous materials	0.45–0.84	Medium	Low	Medium	Low	Low	Removal of VOCs in water
Clays	0.25–0.48	High	Low	Low	Low	Low	Humidity sensor, cosmetic, batteries, corrosion protection

E. Ng and S. Mintova, Microp. Mesop. Mat. 114 (2008) 1-26

Solar Cooling and Porous Materials Studies at our Group

✓ Materials - Natural resources, recycled wastes and modified composites

- Typical soil, bentonite, sepiolite and clinoptilolite
- Al-pillared bentonite (Sol. Ener. Mater. & Sol. Cells 2011)
- Ti-Sepiolite (multifunctional) (Ener. Conv. Manag. 2012)
- Fly and Bottom Ashes (modified) (Appl. Ener. 2012)

✓Characterization (nano-micro scale):

- Elemental Analysis, X-ray Diffraction, Microscopy
- Nitrogen Sorption Isotherms and Pore Size Distribution
- UV/VIS/NIR absorption spectroscopy
- Thermal Analysis, Conductivity and Reflectivity Measurements

✓ Water vapor adsorption and surface temperature reduction

- Water (Vapor) Sorption, Evaporation Rate and Temperature Variation with (without) low-high irradiation, Simulated conditions in wind tunnel, Near future outdoor tests in model structures (constructions ready)

Solar Cooling and Porous Materials

Water molecules confined within narrow pores, with pore widths of a few molecular diameters, can exhibit a wide range of physical behavior. The introduction of wall forces, and the competition between fluid–wall and fluid–fluid forces, can lead to shifts in transitions and a lowering of critical points (e.g. freezing, gas–liquid, liquid–liquid) that are familiar from bulk behavior

In mesoporous materials, the exothermic process of capillary condensation is observed (preceded by a molecular layering on the pore walls) with the appearance of a dense liquid-like state in mesoporous adsorbents for chemical potential lower than its bulk saturating value .

A similar phenomenon should occur on desorption, with the system persisting in the liquid state at chemical potentials (pressures) below the true equilibrium value.

Therefore, the temperature of the mesoporous material surface should be reduced after LOW-temperature solar-heat transformation (as observed on sun irradiated surfaces)

Mesoporous Materials and Solar Cooling

Materials of this work

Typical well ordered aluminosilicate and silicate mesoporous nanomaterials (MESO)
Composites of MESO-TiO_2 nano-oxides (prepared in situ)
Building Covers (soil used in green roofs, calcium carbonate as marble dust)

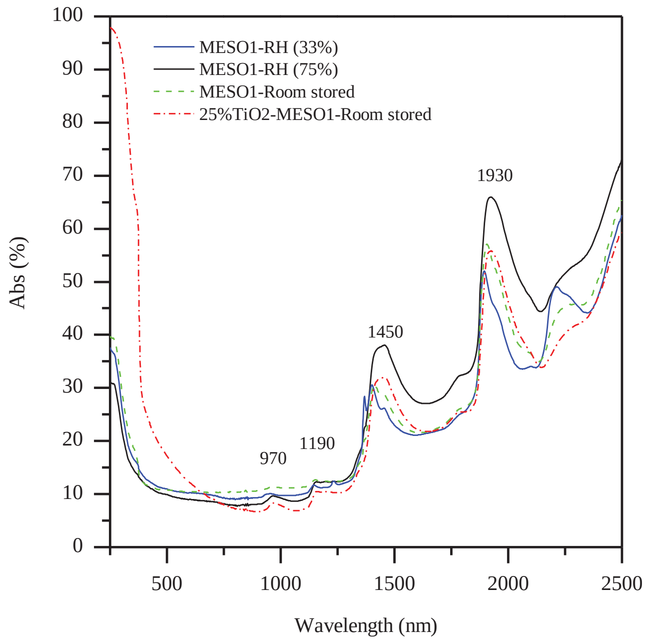
Characterization

X-ray diffraction (XRD), Nitrogen adsorption–desorption isotherms
Scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDX)
Thermogravimetry (TG) and differential thermogravimetry (DTG) measurements (moisture dependence)
Optical characterization with UV/VIS/NIR spectrophotometry (moisture dependence) (poster session)
Thermal conductivity measurements (poster session)
Water adsorption kinetics and isotherms

Wind tunnel characterization with simulated low solar radiation (xenon lamps)

Photodegradation of a model compound under UV irradiation

Mesoporous material characterization Absorbance Spectrophotometry



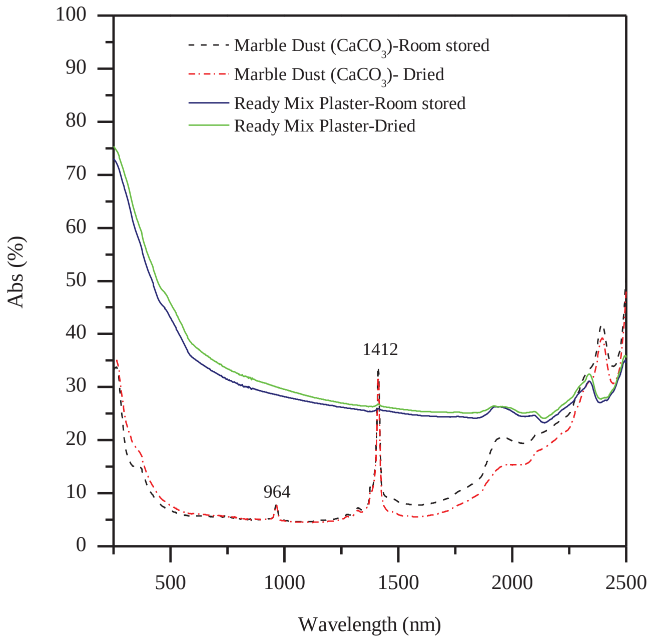
In the NIR region of the spectrum for the MESO sample saturated at 75% relative humidity (RH), four main maxima located at c. 970 nm, c. 1190 nm, c. 1450 nm and c. 1930 nm are clearly observed, indicating the water vapor condensation within the mesopores.

These maxima correspond to different OH stretching bands due to water.

In the MESO sample saturated at 33% of RH, the intensity of the maxima is much lower due to the reduction of the adsorbed water vapor.

Absorbance spectra of the MESO and 25%TiO_2-MESO materials as room stored and MESO after water vapor adsorption 33% and 75% of RH

Building covers material characterization Absorbance Spectrophotometry

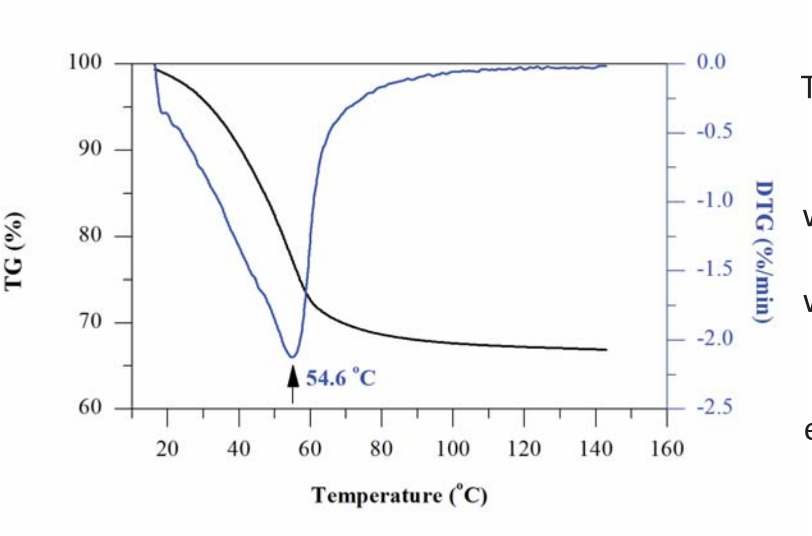


The marble dust shows the highest reflectance of all the studied materials, indicating its suitability as a "cool" reflective material. In addition, the intense 1412 nm peak in the $CaCO_3$ spectrum as well as others of lower intensity, are mainly due to water bound in the structure since are observed in both dried and room stored samples.

Absorbance spectra absorbance spectra of marble dust ($CaCO_3$) and Ready Mix Plaster as received (room stored) and after drying

Mesoporous material characterization

Thermogravimetry

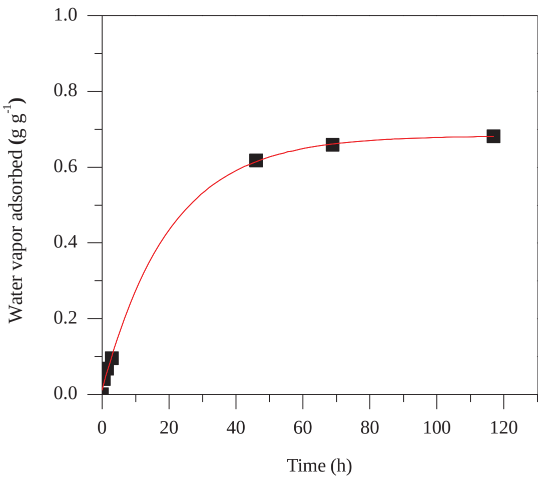


There is one major endothermic peak of temperature around 55 °C where the physisorbed and condensed water (at 75% of RH) is released from the mesoporous material. This "free water" bound due to condensation is being removed by the low temperature heating fluxes through evaporation and desorption from the pores.

The mesostructured samples are appropriate for such applications and almost all of the sorbed water is expected to be removed under the summer solar radiation.

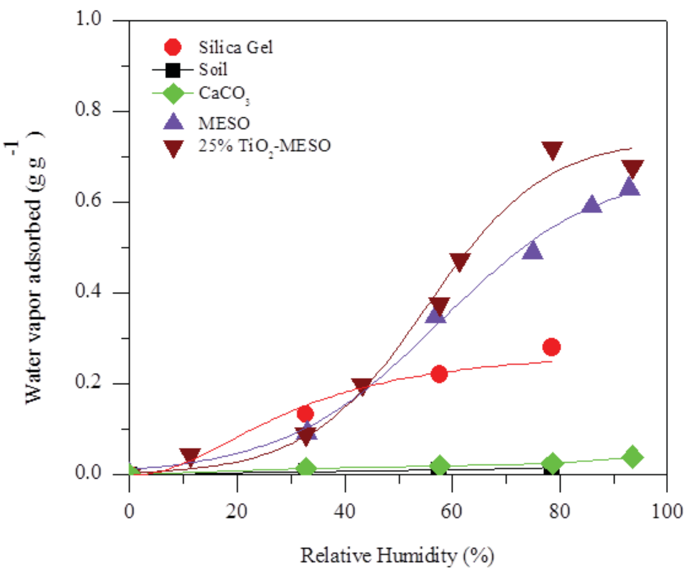
Efficiency of MESO for passive cooling of buildings

First-order kinetics of water vapor adsorption (93% RH and 25 °C)



Rate constants of the order of 20 hours (quite slow process and should be improved)

Water vapor adsorption at 25 °C



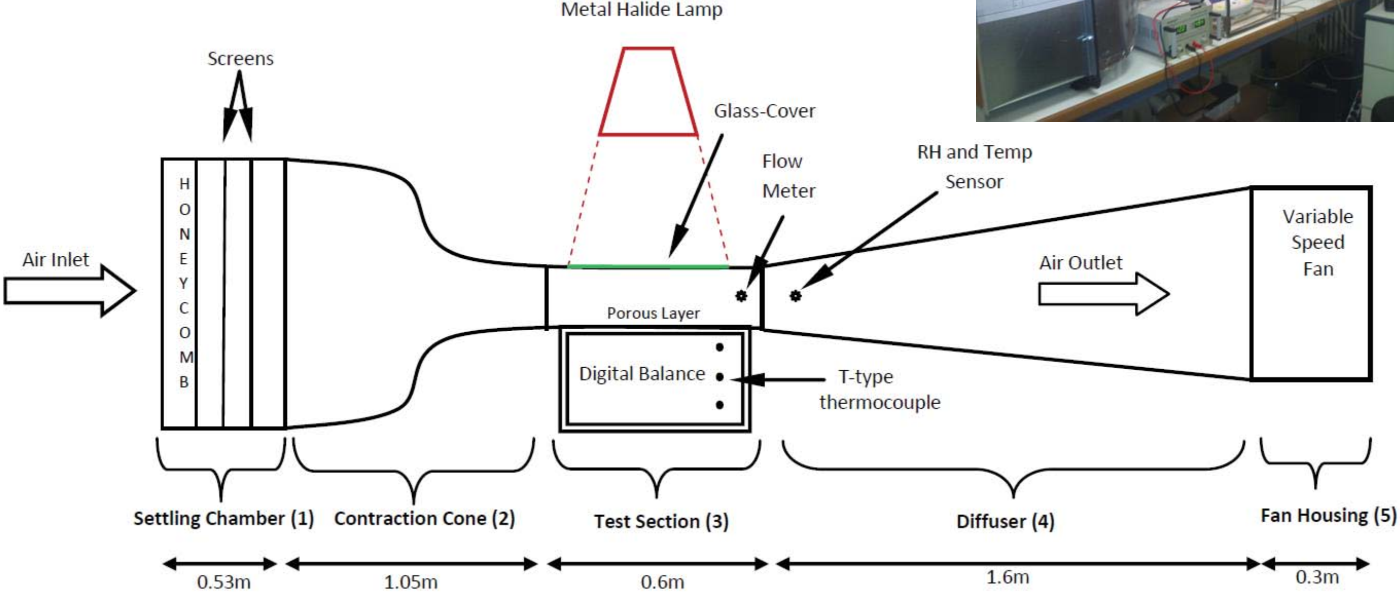
MESO Type V isotherm: hydrophobic character in the low-pressure region but with a capillary condensation step 0.55-0.6

Efficiency of MESO for passive cooling of buildings

"Wind Tunnel" of controllable atmospheric conditions

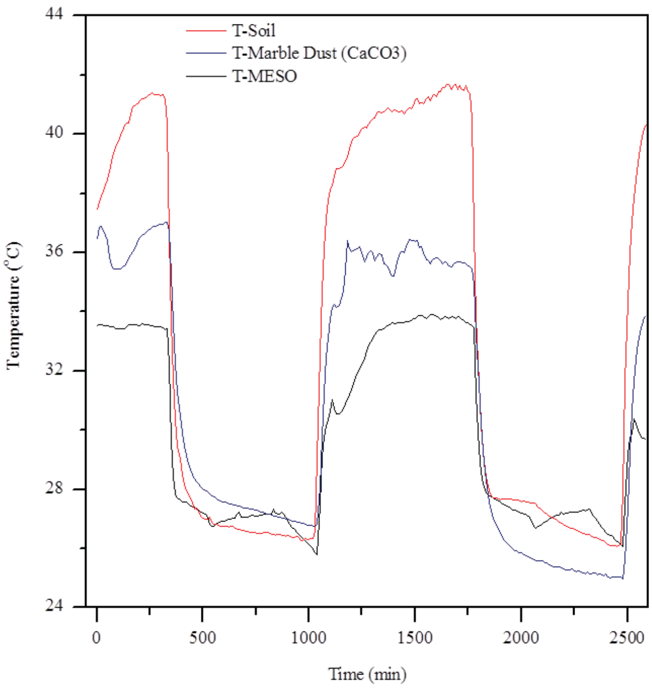
Adjustable wind speed at 1.5 m/s simulating urban summer wind speed

Two xenon lamps (160 W)



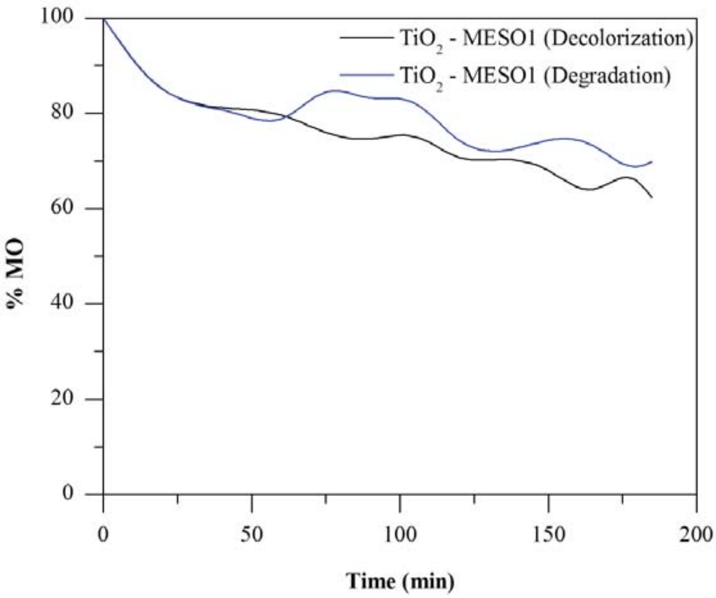
Efficiency of MESO for passive cooling of buildings

The difference of temperature increase under simulated solar irradiation (300 W/m^2) between the MESO sample and marble dust with comparable reflectance was almost 5 °C in the first irradiation hours and reduced to 2 °C at the end of irradiation. The MESO difference with the soil sample was even higher. By considering a latent heat of 2300 kJ kg^{-1} for water vaporization at the attained material temperatures, the observed MESO mass reduction of 1 g (13% of the initial mass) corresponds to 2.3 kJ of absorbed energy for water evaporation or half of the absorbed incoming radiation. Further theoretical analysis in progress.



Multifunctional Applications of MESO

Photodegradation and decolorization of methyl orange in the presence of the TiO2–MESO composites.



TiO_2 (7%)-MESO nanocomposite exhibits photocatalytic activity in addition to the high water vapor adsorption. Therefore, different parts of the solar spectrum for simultaneous multifunctional purposes (like UV-VIS for photodegradation and IR for providing the thermal energy for phase changes) can be utilized by supporting semiconducting oxides on the mesoporous materials

Conclusions

The substantial temperature reductions with the use of the MESO materials indicates their significant potential for further research.

By in-situ TiO_2 nanoengineering, photocatalytic action is observed.

The nano-composite could be used in photodegradation applications with the UV-Vis solar radiation in addition to its thermo-response through the water vapor absorption resonances and continuum in the Vis and IR part of the spectrum.

Acknowledgment

This work has been supported by the University of Western Greece, Latsis Foundation and GSRT programmes of Hrakleitos II, Greece-Turkey Bilateral Program and ARISTEIA I ("Operational Programme Education and Lifelong Learning co-funded by the European Social Fund (ESF) and National Resources). Thanks are due to the Horizontal Network of Laboratories of the University of Ioannina and Bogazici University for the help in materials' characterization.

Thank you for your attention!

Wednesday 25 September 2013

17:00-18:30: Parallel Session 3A: Short oral presentation session- Ventilation and cooling strategies

Chairpersons: Peter Holzer, Angela Simone

- **Parametric analysis of environmentally responsive strategies for building envelopes specific for hot hyperarid regions** Isaac Meier, Israel
- **A low-energy innovative system for space cooling** Giouli Mihalakakou, Greece
- **Double facades: comfort and ventilation at an extreme complex case study** Wim Zeiler, Netherlands
- **Double skin system of room side air gap applied to detached house (Part 2) Simulation analysis for reduction of cooling load by natural ventilation in the wall** Togo Yoshidomi, Japan
- **Building Envelope Design for climate change mitigation: a case-study of hotels in Greece** Ifigenia Farrou, UK
- **The effect of a novel roof pond to the indoor air temperature for passive cooling** Artemisia Spanaki, Greece
- **Passive ventilation in multi-storey Atrium buildings: A first-order design guide** Andrew Acred, UK

Parametric analysis of environmentally responsive strategies for building envelopes specific for hot hyperarid regions

Alex Cicelsky & Isaac A. Meir

Center for Creative Ecology
Kibbutz Lotan, Hevel Eilot, Israel

Desert Architecture & Urban Planning Unit, Dept. Man in the Desert
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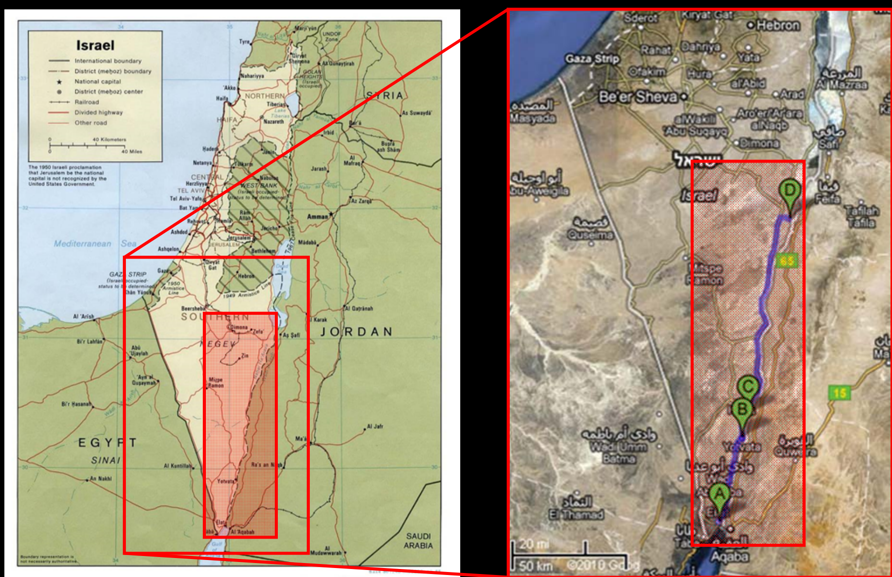

Arava Valley / Wadi 'Arabe - The Afro-Asian Rift between Israel anz Jordan. Israel Meteorological Service stations in the Arava: A. Eilat, B. Yotvata, C. Lotan, D. Hatzeva

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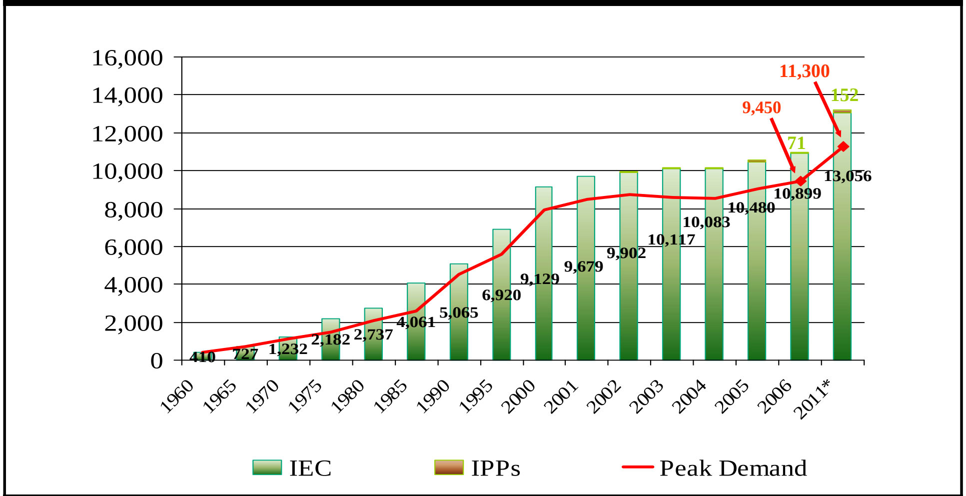
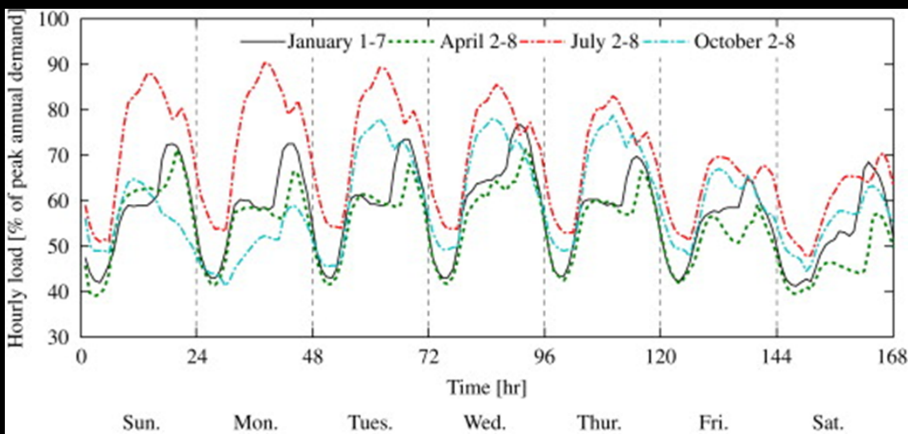
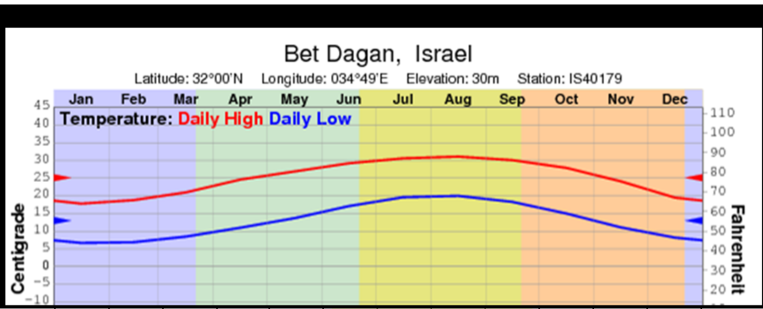


Israel Electric Corporation (IEC), Independent Power Producers (IPPs), December 2006



Typical weekly IEC load profiles for each season of the year 2006.

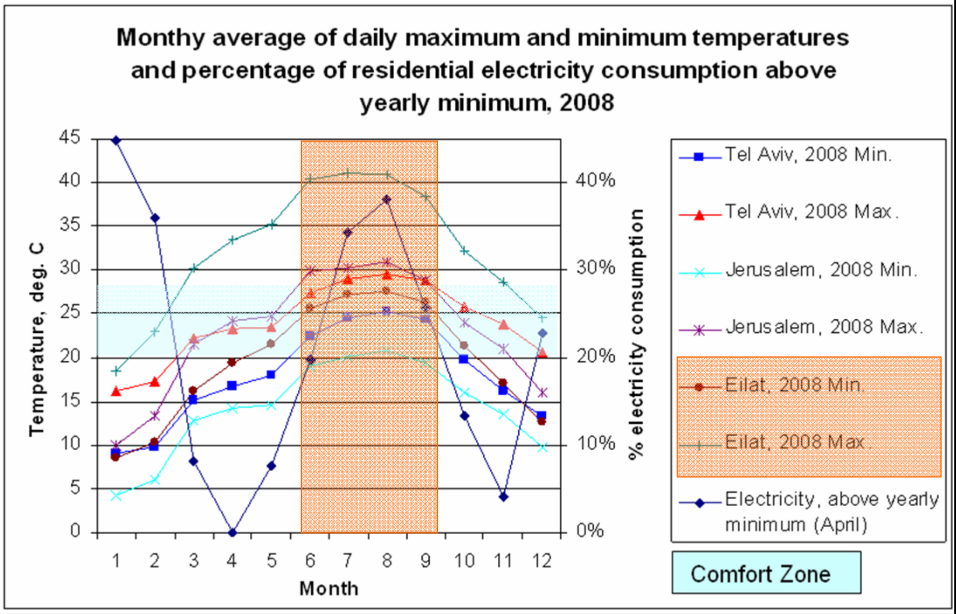
(IEC 2007; Solomon et al. in press)



2008 Residential Electricity Use													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
National (Million KWh)	1,745	1,505	1,051	964	1,043	1,202	1,469	1,558	1,298	1,112	1,006	1,249	15,202
Net heating/cooling load above base (April, Million KWh)	781	541	87	-	79	238	505	594	334	147	42	285	3,632
% Consumption above base	81%	56%	9%	0%	8%	25%	52%	62%	35%	15%	4%	30%	31%
% Yearly consumption attributed to heating													**15%**
% Yearly consumption attributed to cooling													**16%**

Residential electricity use, Israel, 2008 (IEC 2009)

Temperature data presentation http://www.climate-charts.com/Locations/i/IS40179.php



Daily Tmax/min vs % residential electricity consumption above yearly min (IEC 2009; CBS 2010)

Year	Total National %	Jeru-salem	Tel Aviv	Haifa	Rishon Lezion	Ashdod	Ramat Gan	Netanya	Ashkelon	Holon	Bat Yam	Bnei Brak	Petach Tikva	Beer Sheva	Rehovot	households, in thousands
2007	70.5															2073.6
2006	68.5	29.7	81.7	68.9	84.3	65.3	87.1	63.3	64.6	77.5	71.7	82.2	80.2	73.2	83.6	2026.8
2005	67.7															1989.2
2004	65.8	22.4	78.3	60.4	84.5	60.4	84.8	64.3	50.6	82.7	68.4	80.2	85	62.5	76.9	1950.1
2003	61.5															1901.3
2002	58.1															1872.6
2001	57.7															1799.4
2000	52.5															1752.3
1999	46.6															1717
1997	42.2															1504.9
change 1997-2007	167 %															138%

Percentages of households with A/C units 1997-2007, Israel

(CBS 1997-2010)

"...air conditioning for the cooling of buildings, inordinately affects the overall electric consumption of kibbutzim in the [Southern] Arava.

For each kibbutz in this study, average electricity consumption in August was found to be more than double that in March.

This dramatic seasonal increase occurs throughout a nearly 6-month [period when mechanical systems for] cooling [are employed], generally from mid-May to mid-October and peaks in July–August when daytime temperatures exceed 40°C".

Cohen, J., Pearlmutter, D. and Schwartz, M. (2009). "Lifestyle and energy consumption: a comparison of four collective communities in transition." Energy Efficiency 1570-646X

Prefab non-insulated poured concrete units (semidetached).

Prefab lightweight single family "caravilla" unit with unventilated clay tile roof (Rolan 2009) alongside dual family unit now with recently added shade on south side.

Prefab lightweight single family "caravilla" unit with flat roof (Rolan 2010) alongside recently constructed houses. Note sunlight on northern walls.

Ventilated white concrete tile roof, AAC block walls, double glazed windows with aluminum frames and external shutters. Note fully exposed S and short E wall with no large windows.

What building design, building system, construction materials and operational strategies need to be combined so that residential facilities in the Southern Arava will be energy efficient?

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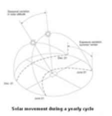
Climate Data:
- Air temperature
- Relative humidity
- Solar radiation intensity & direction
- Wind speed and direction



Thermal Simulation Model

Building description

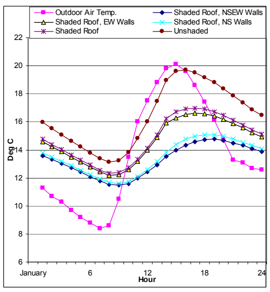
Geometry:
- Surface area and interior volume
- Orientation

Attributes of the materials of the envelope:
- Conductivity, density, specific heat, thickness, order of components, transparency, color, orientation

Shading

Operation
- Solar gain
- Ventilation
- HVAC appliances

~ Interior temperatures for each hour of the day, for each month of the year
~ Energy consumed in order to maintain set temperature



Simulation program input/output

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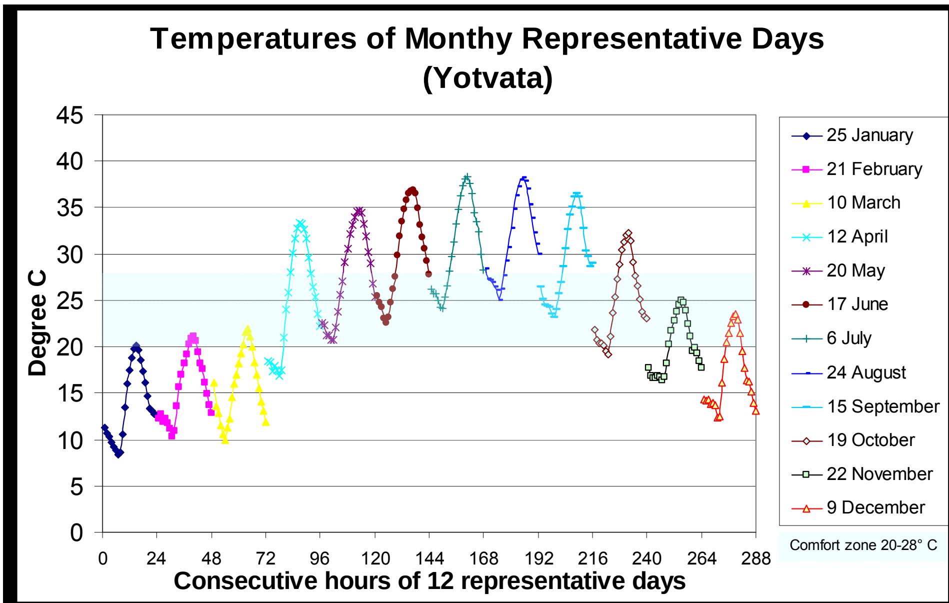
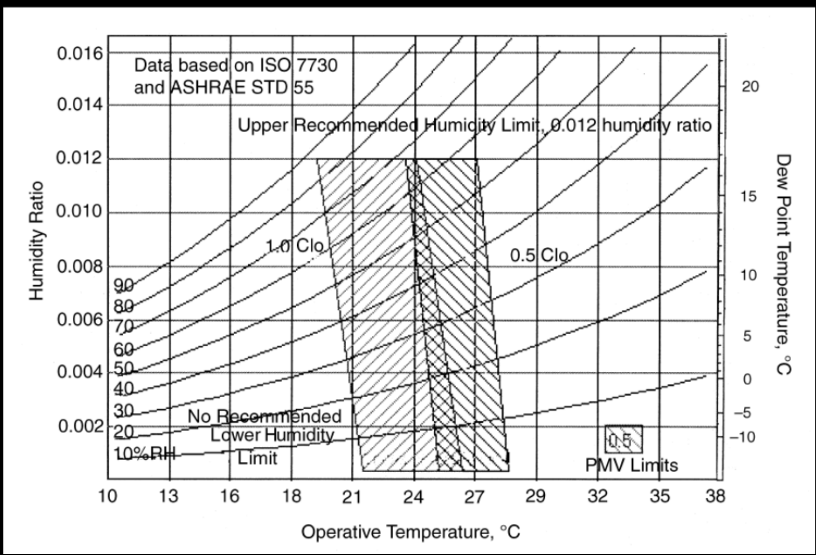
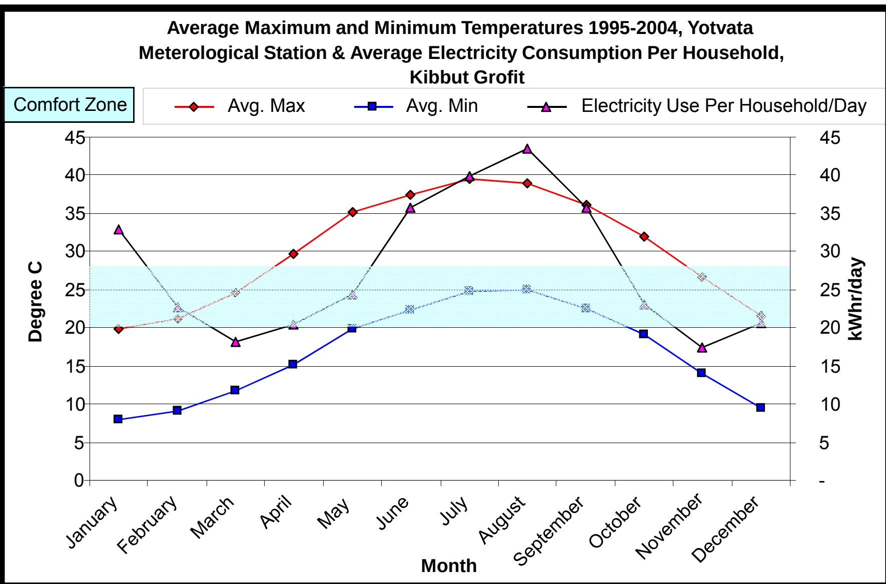


Temperature measurements of representative days for each month selected from the Yotvata Typical Meteorological Year (TMY). The consecutive hours in the graph are multiples of 24 times the numerical month of the year.



Thermal comfort and extended upper temperature limits



Average Maximum and Minimum Temperatures measured at Yotvata R&D, 1995-2004, interior temperature comfort zone 20-28°C, and average electricity consumption of household in Kibbutz Grofit 2008. (Lewi 2008; Daniels 2009).

Geometry	Square bldg 10/10m	Rectangular bldg 20/5m		
Orientation	N-S axis	E-W axis		
Construction	Lightweight [LW]: wood frame drywall construction envelope walls and roof (low thermal mass)	Medium weight [MW]: 22 cm thick AAC block envelope walls and roof (medium thermal mass)	Heavyweight [HW]: 20 cm thick cast concrete envelope walls and roof (high thermal mass)	
Wall shading	Unshaded/none	N, S walls shaded during all daylight hours	E, W walls shaded during all daylight hours	N, S, E, W walls shaded during all daylight hours
Roof shading	Flat, un-shaded roof	Shaded, well ventilated roof	Unventilated clay terracotta tile roof	Well ventilated clay terracotta tile roof
Insulation	Un-insulated [0] - No thermal insulation on walls/roof	Insulated [5] - 5cm layer of external thermal insulation (expanded polystyrene) on walls/roof	Insulated [10]- 10cm layer of external thermal insulation (expanded polystyrene) on walls/roof	Insulated [20] - 20cm layer of external thermal insulation (expanded polystyrene) on walls/roof
Window size	6 m² on N, S walls	6 m²on N, 12 m²on S walls		
Window treatment	Glazed openings not shaded by shutters	Glazed openings shaded by shutters	Seasonal operation of shutters – summer/closed in daytime; winter/opened in daytime.	
Window insulation	Low: single glazing	Medium: double glazing	High: triple glazing	
Ventilation – Air Changes per Hour (ACH)	10 ACH	20 ACH	30 ACH	50 ACH
Finish	Light color: reflective white finish of external walls/roof (absorption coefficient = 0.3)	Medium color: dark brown finish on external walls/roof (absorption coefficient = 0.65)	Dark color: dark brown finish on external walls/roof (absorption coefficient = 0.8)	

Methodology: Parameters

Climate Data:
Air temperature
Relative humidity
Solar radiation
intensity & direction
Wind speed and direction

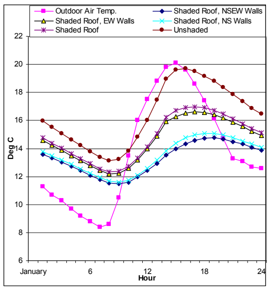
Building description
Geometry
Materials
Architectural Elements
Operation

6m²
12m²

6m²
12m²

QUICK II

~ Interior temperatures for each hour of the day, for each month of the year
~ Energy consumed in order to maintain set temperature



Methodology: QUICK II & data processing

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Climate Data

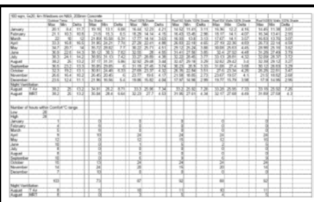
Parameter	Options used in simulation	
Window Size	South and North facing windows, total area on each face is 6 m2	
Window Type	Single glazing	
Geometry	Rectangular building, 20 X 5 m, long side facing south.	
Construction	Heavyweight: building envelope is 20 cm cast concrete.	
Insulation	Un-insulated	
Finish	Medium color (absorption coefficient = 0.65)	
Window treatment	No shutters [open]	
Roof	Flat roof	Shaded roof

Variables				
Ventilation	Unventilated		50 ACH night ventilation	
Wall and Window Shade	Un-shaded	North & south walls & windows	East & west walls & windows	All walls & windows

QUICK II

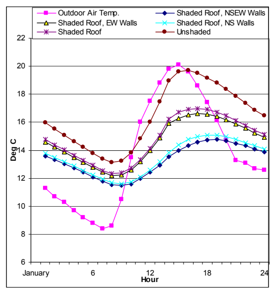
*.DAT File

Excel Spreadsheet



Data analysis & Calculation of hours of thermal comfort

Graphic representation of interior temperatures



Methodology: QUICK II & data processing

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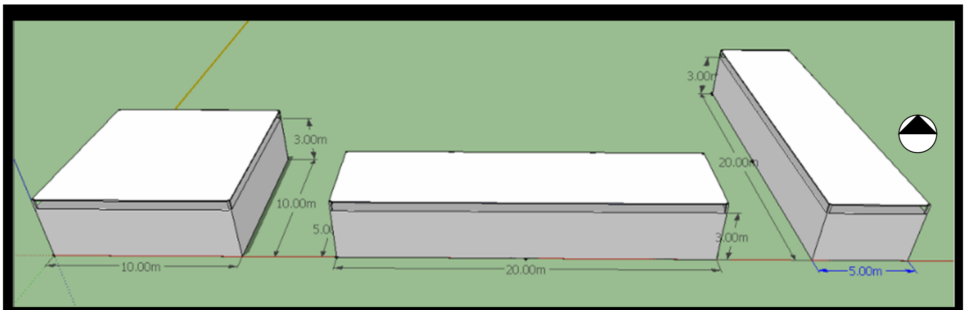
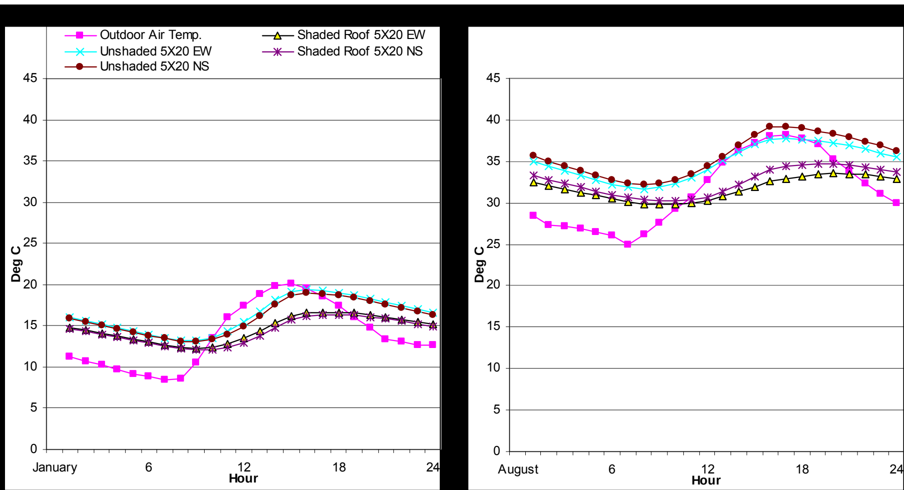


Geometry and orientation of 100 m² buildings for simulation (shown here with shade roofs). This view is an isometric perspective looking north.

Dimensions of simulated buildings.

Length	Width	Height	Ceiling/floor area	West/east wall area	North/south wall area	Total wall area	Difference in wall area
m	m	m	m²	m²	m²	m²	%
10	10	3	100	30	30	120	
20	5	3	100	15	60	150	+25%

Parameters: Geometry & orientation



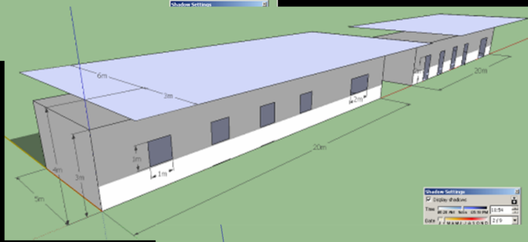
Orientation - axis comparison, 5x20m with long wall running EW or NS, concrete building with no insulation, 20 cm walls, no windows, with and without shaded ceilings

✓EW axis, rectangle

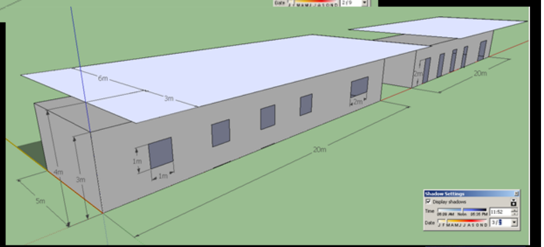
× ✓window orientation   × ✓ ceiling and wall shading   × un-insulated concrete

Parameters: Geometry & orientation

Sketch Up illustration of shade structure that allowed for winter solar gain, December 21 at solar noon.



The same building on February 9 & November 1 at solar noon.



The same building is completely shaded from March 3 until October 11 at solar noon.

Parameters: Shading

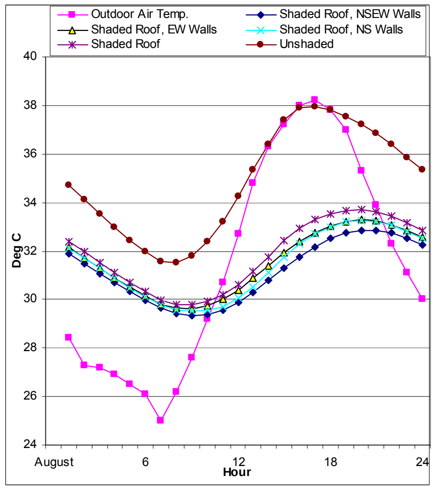
	Max°C	Min°C
External ambient temperature	20.1	8.4
Insulation thickness *Expanded polystyrene U=0.035W/m°C*		
50mm	17.95	16.30
100mm	18.09	16.62
200mm	19.72	17.64

Winter (January) maximum and minimum interior temperatures for a building with 20cm thick concrete walls and ceiling and 6m^2 of single glazed, south facing windows. The ceiling and walls of the building were un-shaded. Insulation ranged from 50 to 200 mm.

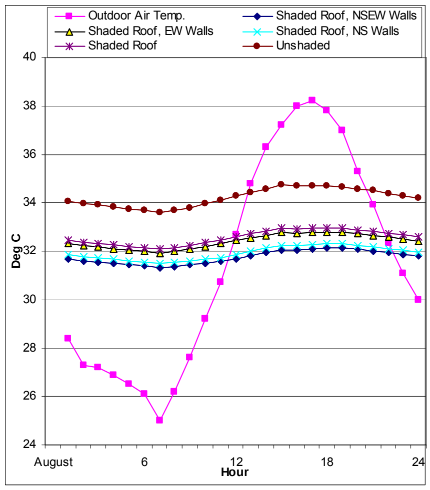
	Max°C	Min°C	Hours in comfort zone
External ambient temperature	20.1	8.4	
50mm	18.44	16.00	0
200mm	20.15	18.1	1

Same, with 12m^2 of single glazed, south facing windows.

Parameters: Insulation – Effect of insulation and area of glazing on reaching thermal comfort levels in winter in a heavyweight building



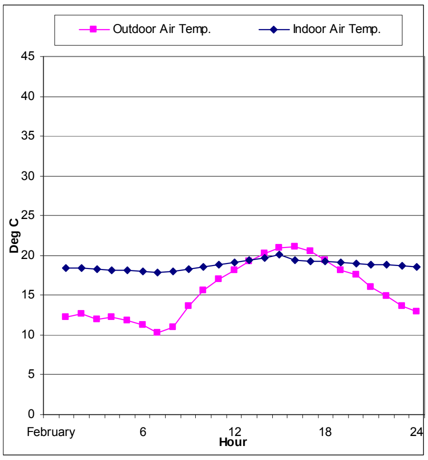
Un-insulated



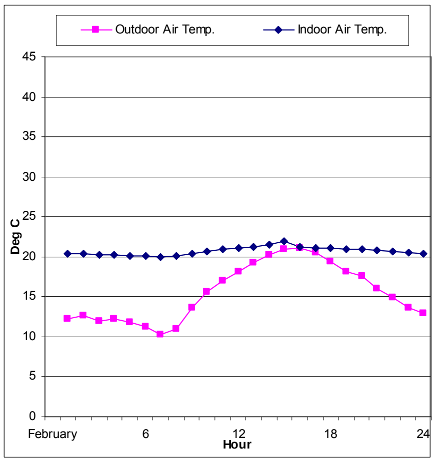
50mm polystyrene insulation

Effect of shading on buildings with increasing insulation on walls and ceiling in summer (August). Buildings had 6m2 south facing windows and 200mm concrete walls and ceiling

Parameters: Insulation – Effect of insulation on ceiling, east & west walls, north & south walls in summer



50mm polystyrene insulation



200mm polystyrene insulation

Effect of shading on buildings with increasing insulation on walls and ceiling in winter (January). Buildings had 12m2 south facing windows and 200mm concrete walls and ceiling

Parameters: Insulation – Effect of insulation and window area in winter

Legend: Below comfort zone | Within comfort zone | Above comfort zone

100 sqm, 5x20, 6m² N & 12m² S Windows, 50mm exterior XPS, 200mm concrete interior

	Shaded Ceiling, No Windows			Shaded Ceiling, N&S Windows			Shaded Ceiling, N&S Windows, Walls		
	Max	Min	Hrs	Max	Min	Hrs	Max	Min	Hrs
April	24.64	24.18	24	26.16	24.61	24	26.03	24.5	24
May	27.42	27	24	28.6	27.32	12	28.3	27.07	16
June	29.64	29.22	0	30.92	29.61	0	30.64	29.37	0
July	30.44	30.04	0	31.66	30.39	0	31.41	30.18	0
August	30.67	30.33	0	31.95	30.85	0	31.84	30.76	0
September	28.76	28.39	0	29.82	28.68	0	29.63	28.54	0

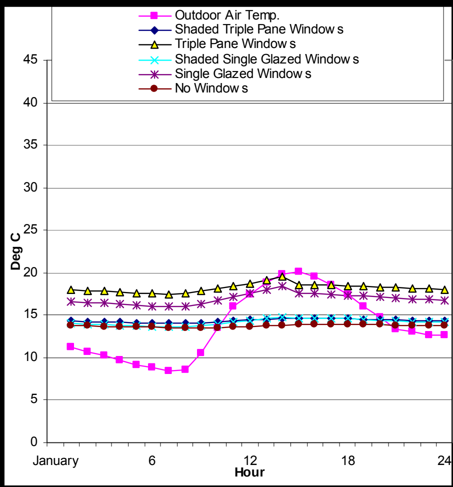
Parameters: Insulation – seasonal shading of windows

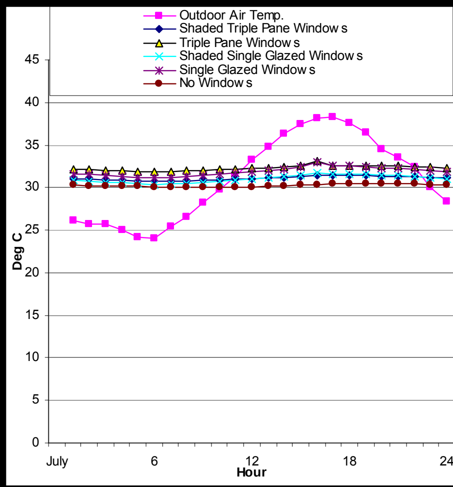
	U	R	D	λ	Price range[1]
	W/m²K	m²K/W	M	W/mK	$(US)/m²
single glazed	6	0.166667	0.004	0.024	80-150
double glazed	3	0.333333	0.004	0.012	90-300
triple glazed	1.5	0.666667	0.004	0.006	260-310

Determination of window conductivity with constant glass thickness factor

[1] Prices from local manufactures, importers (Marvin Windows) and online building centers (Home Depot USA http://www.homedepot.com/, Rehau UK http://www.rehau-trade-windows.co.uk/rehau-trade-windows.htm, Bauhaus Germany http://www.bauhaus.info, excluding taxes and installation.

Parameters: Window insulation





Comparison between single and triple glazed windows, shaded and un-shaded
Concrete building with 50mm XPS insulation

Parameters: Window insulation

100 sqm, 5x20, 6m² N & 12m² S Windows, Shaded Ceiling, 200mm exterior PS, 200mm concrete interior

Below comfort zone | Within comfort zone | Above comfort zone

	Single Glazed Windows				Shaded Single Glazed Windows			
	Max	Min	Delta	Hrs	Max	Min	Delta	Hrs
Jan	**20.15**	**18.1**	**2.05**	**1**	14.94	14.02	0.92	0
Feb	**21.9**	**19.98**	**1.92**	**23**	17.12	16.2	0.92	0
Mar	**19.91**	**18.59**	**1.32**	**0**	17.73	16.71	1.02	0
Apr	28.28	26.8	1.48	18	**27.05**	**25.74**	**1.31**	**24**
May	31.23	29.68	1.55	0	**29.26**	**28.21**	**1.05**	**0**
Jun	33.45	31.89	1.56	0	**31.65**	**30.56**	**1.09**	**0**
Jul	34.29	32.75	1.54	0	**32.42**	**31.36**	**1.06**	**0**
Aug	34.23	33.18	1.05	0	**32.92**	**32**	**0.92**	**0**
Sep	33.42	32.18	1.24	0	**30.53**	**29.61**	**0.92**	**0**
Oct	30.76	29	1.76	0	**27.11**	**26.1**	**1.01**	**24**
Nov	27.65	25.63	2.02	24	**22.33**	**21.49**	**0.84**	**24**
Dec	**23.6**	**21.64**	**1.96**	**24**	18.36	17.54	0.82	0
	Total			90				72
	Total combined comfort zone hours single glazed windows							**120**
	Triple Glazed Windows				**Shaded Triple Glazed Windows**			
	Max	Min	Delta	Hrs	Max	Min	Delta	Hrs
Jan	**22.03**	**20.33**	**1.7**	**24**	14.24	13.79	0.45	0
Feb	**23.76**	**22.18**	**1.58**	**24**	16.6	16.12	0.48	0
Mar	**20.69**	**19.81**	**0.88**	**18**	17.34	16.8	0.54	0
Apr	27.85	27.05	0.8	24	**25.96**	**25.34**	**0.62**	**24**
May	30.78	29.78	1	0	**27.93**	**27.45**	**0.48**	**24**
Jun	32.84	31.82	1.02	0	**30.26**	**29.75**	**0.51**	**0**
Jul	33.61	32.61	1	0	**31.06**	**30.59**	**0.47**	**0**
Aug	33.47	32.89	0.58	0	**31.57**	**31.17**	**0.4**	**0**
Sep	33.52	32.69	0.83	0	**29.18**	**28.81**	**0.37**	**0**
Oct	31.68	30.33	1.35	0	**26.19**	**25.66**	**0.53**	**24**
Nov	29.28	27.56	1.72	10	**21.34**	**20.92**	**0.42**	**24**
Dec	**25.32**	**23.63**	**1.69**	**24**	17.51	17.1	0.41	0
	Total			124				96
	Total combined comfort zone hours triple glazed windows							**186**

Evaluation of highly insulated envelope with low and high window insulation with seasonal shading operation; December-March Un-shaded, April-November Shaded (in bold).

Parameters: Window insulation

Hours of ambient temperatures within comfort zone 20-28°C are shaded blue

Hour	June Ext	June Int	June MRT	July Ext	July Int	July MRT	August Ext	August Int	August MRT	September Ext	September Int	September MRT
1	25.5	29.9	29.99	26.2	30.72	30.82	28.4	31.29	31.38	26.4	28.96	29.04
2	24.7	29.86	29.95	25.7	30.69	30.78	27.3	31.25	31.34	25.1	28.91	29
3	24.2	29.83	29.92	25.7	30.67	30.76	27.2	31.23	31.32	24.5	28.88	28.97
4	23.1	29.78	29.87	25	30.64	30.73	26.9	31.21	31.3	24.4	28.86	28.95
5	22.6	29.75	29.84	24.2	30.6	30.69	26.5	31.18	31.27	24.2	28.84	28.93
6	23.2	29.77	29.86	24.1	30.59	30.68	26.1	31.17	31.26	23.5	28.81	28.9
7	24.7	29.82	29.91	25.4	30.63	30.72	25	31.18	31.27	23.2	28.84	28.93
8	26.2	29.88	29.97	26.6	30.67	30.76	26.2	31.23	31.32	24	28.88	28.97
9	27.5	29.92	30.02	28.2	30.72	30.81	27.6	31.28	31.37	25.7	28.94	29.03
10	29.8	29.98	30.07	29.7	30.77	30.86	29.2	31.33	31.42	26.9	28.98	29.07
11	31.9	30.04	30.13	31.3	30.82	30.92	30.7	31.37	31.47	28.6	29.02	29.11
12	33.5	30.09	30.18	33.2	30.88	30.98	32.7	31.42	31.52	30.6	29.06	29.15
13	34.8	30.13	30.22	34.8	30.94	31.03	34.8	31.48	31.58	32.6	29.11	29.2
14	35.8	30.17	30.26	36.3	30.99	31.08	36.3	31.53	31.63	34.2	29.15	29.24
15	36.5	30.21	30.3	37.4	31.03	31.12	37.2	31.57	31.66	35.1	29.18	29.27
16	36.8	30.26	30.35	38.1	31.06	31.15	38	31.51	31.61	36.1	29.16	29.24
17	36.9	30.18	30.27	38.3	31.01	31.1	38.2	31.52	31.62	36.5	29.17	29.26
18	36.5	30.18	30.27	37.6	31	31.09	37.8	31.52	31.61	36.2	29.18	29.26
19	34.9	30.15	30.24	36.5	30.98	31.07	37	31.51	31.6	34.9	29.16	29.24
20	33.1	30.11	30.2	34.5	30.94	31.03	35.3	31.48	31.57	32.7	29.11	29.2
21	31.8	30.08	30.17	33.5	30.92	31.01	33.9	31.45	31.54	30.3	29.06	29.15
22	30.6	30.05	30.14	32.4	30.89	30.98	32.3	31.41	31.5	29.7	29.04	29.13
23	29.2	30.01	30.1	30	30.83	30.92	31.1	31.37	31.47	28.6	29.01	29.1
24	27.8	29.97	30.06	28.3	30.78	30.88	30	31.34	31.43	29	29.01	29.1

Evaluation of cooling potential by ventilation in summer months, June-September, building 200mm concrete with 200mm XPS, fully shaded, triple glazed windows. Temperatures °C.

Parameters: Ventilation

Legend: Hours of ventilation

Temperatures in comfort zone 20-28°C

August	Ext.	10 ACH Int.	10 ACH MRT	20 ACH Int.	20 ACH MRT	30 ACH Int.	30 ACH MRT	50 ACH Int.	50 ACH MRT
1	28.4	28.86	28.95	28.36	28.45	28.15	28.24	27.95	28.04
2	27.3	28.36	28.76	27.85	28.26	27.65	28.06	27.49	27.87
3	27.2	28.3	28.72	27.78	28.22	27.58	28.01	27.41	27.82
4	26.9	28.19	28.66	27.62	28.14	27.39	27.92	27.2	27.73
5	26.5	28.03	28.58	27.41	28.04	27.15	27.81	26.91	27.6
6	26.1	27.88	28.51	27.2	27.94	26.9	27.7	26.62	27.48
7	25	27.53	28.38	26.66	27.76	26.25	27.48	25.85	27.21
8	26.2	27.91	28.51	27.23	27.93	26.94	27.69	26.67	27.46
9	27.6	28.69	28.78	28.16	28.25	27.94	28.02	27.72	27.81
10	29.2	28.75	28.84	28.23	28.31	28.01	28.09	27.8	27.88
11	30.7	28.81	28.89	28.28	28.37	28.06	28.15	27.85	27.94
12	32.7	28.87	28.96	28.35	28.43	28.13	28.21	27.92	28
13	34.8	28.94	29.02	28.42	28.5	28.2	28.28	27.99	28.07
14	36.3	28.99	29.08	28.48	28.56	28.26	28.34	28.05	28.14
15	37.2	29.04	29.13	28.52	28.61	28.3	28.39	28.1	28.18
16	38	29	29.08	28.48	28.57	28.26	28.35	28.06	28.14
17	38.2	29.01	29.1	28.5	28.59	28.28	28.37	28.08	28.16
18	37.8	29.02	29.11	28.51	28.59	28.29	28.38	28.09	28.17
19	37	29.02	29.1	28.51	28.59	28.29	28.38	28.09	28.17
20	35.3	28.99	29.08	28.49	28.57	28.27	28.36	28.07	28.15
21	33.9	28.97	29.06	28.47	28.55	28.25	28.34	28.05	28.13
22	32.3	28.94	29.03	28.44	28.52	28.23	28.31	28.02	28.11
23	31.1	28.92	29	28.41	28.5	28.2	28.29	28	28.09
24	30	28.89	28.98	28.39	28.48	28.18	28.26	27.98	28.06

Representative summer (August) day outdoor, interior and mean radiant temperatures (°C) with ventilation rates of 10/20/30/50 ACH.

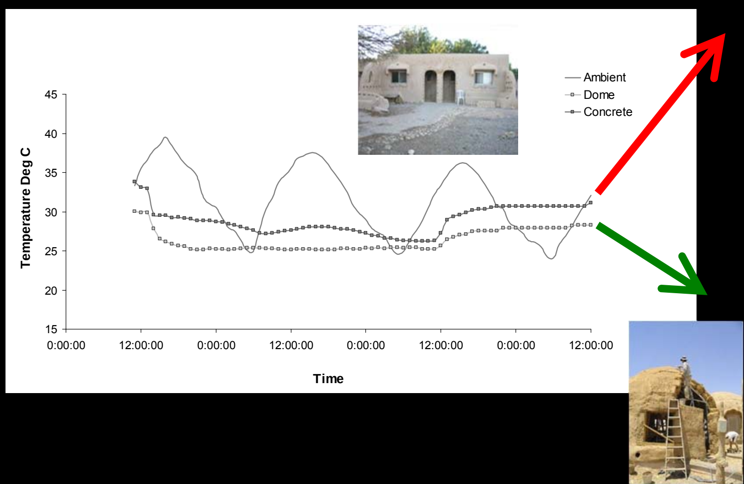
Parameters: Ventilation

	Lightweight	Medium weight	Heavyweight
Wall and ceiling	19mm gypsum wallboard	AAC blocks, 22 cm thick	200mm concrete
Insulation of wall and ceiling	50mm fiberglass batt	None 50 mm XPS	50 mm XPS 200 mm XPS
Roof	Clay tile unventilated / Well ventilated, no mass	Well ventilated, no mass	Well ventilated, no mass
Wall Shade	Shaded	Un-shaded Shaded	Shaded
No insulation Un-shaded walls		**84.67**	
No insulation Shaded walls		79.96	
50 mm fiberglass Well ventilated roof	51.66		
50 mm fiberglass Clay tile roof	62.69		
50 mm XPS		50.97	53.61
200 mm XPS			**27.81**

Simulated cooling loads (kWh) for buildings with same geometry, shading and windows as a function of different wall components. Set temperature 25°C, 24 hours a day, month of August.

Parameters: Construction

Air conditioned to 26°
Comparing original & improved



24.6 kwH

13.5 kwH

Energy consumption for AC vs. thermal comfort, straw bale vs. concrete – k.Lotan, Arava (J.Y. Golding, 2010)

Detail of building at Kibbutz Yotvata: The flat concrete surface at bottom left was recently painted white. The textured plaster in the hallway is still light in color whereas exterior plaster exposed to dust has darkened.

Parameters: Color of external surfaces

100 sqm, 5x20 on EW axis, 6m² N & 12m² S Windows, 200mm exterior XPS, 200mm concrete interior, triple glazed widows, all surfaces shaded (°C).
The Delta °C value is the difference between the max. (or min.) temp. when the exterior absorptivity was at 80% or 65% and the max. (or min.) temp. when the exterior absorptivity was at 30%.

	Absorptivity 80%			Absorptivity 30%			Delta °C				
	Max	Min		Max	Min		Max 80% - Max 30%	Min 80% - Min 30%		Max 65% - Max 30%	Min 65% - Min 30%
Jan	14.26	13.81		14.19	13.74		0.07	0.05		0.05	0.05
Feb	16.63	16.15		16.52	16.05		0.11	0.07		0.08	0.07
Mar	17.37	16.84		17.23	16.71		0.14	0.09		0.11	0.09
Apr	26	25.37		25.86	25.24		0.14	0.10		0.10	0.10
May	27.95	27.47		27.9	27.43		0.05	0.02		0.03	0.02
Jun	30.28	29.77		30.22	29.71		0.06	0.04		0.04	0.04
Jul	31.07	30.59		31.05	30.58		0.02	0.01		0.01	0.01
Aug	31.57	31.17		31.55	31.16		0.02	0.01		0.02	0.01
Sep	29.2	28.84		29.11	28.75		0.09	0.06		0.07	0.06
Oct	26.22	25.69		26.09	25.56		0.13	0.10		0.10	0.10
Nov	21.36	20.94		21.28	20.87		0.08	0.05		0.06	0.05
Dec	17.53	17.12		17.46	17.06		0.07	0.04		0.05	0.04

Comparisons of high performance building with dark, medium and light colored exteriors.

Parameters: Color of external surfaces

Geometry	Square 10x10m	**Rectangle 20 X 5m**		
Orientation	North - south axis	**East - west axis**		
Construction	Lightweight	Medium weight	**Heavyweight**	
Wall shade	None	North and South	East and West	**All**
Roof shading	None	**Well ventilated**	Unventilated clay tile roof	Well ventilated clay tile roof
Insulation	None	5 cm Styrofoam	10 cm Styrofoam	**20 cm Styrofoam**
Window size	$6m^2$ N & S walls	**$6m^2$ N & $12m^2$ S walls**		
Window treatment	Exposed	Shuttered	**Seasonal operation of shutters**	
Window insulation	Low (Single glazing)	**High (Triple glazing)**		
Ventilation	10 Air changes per hour (ACH)	20 ACH	30 ACH	50 ACH
Finish	**Light color**	Medium color	Dark color	

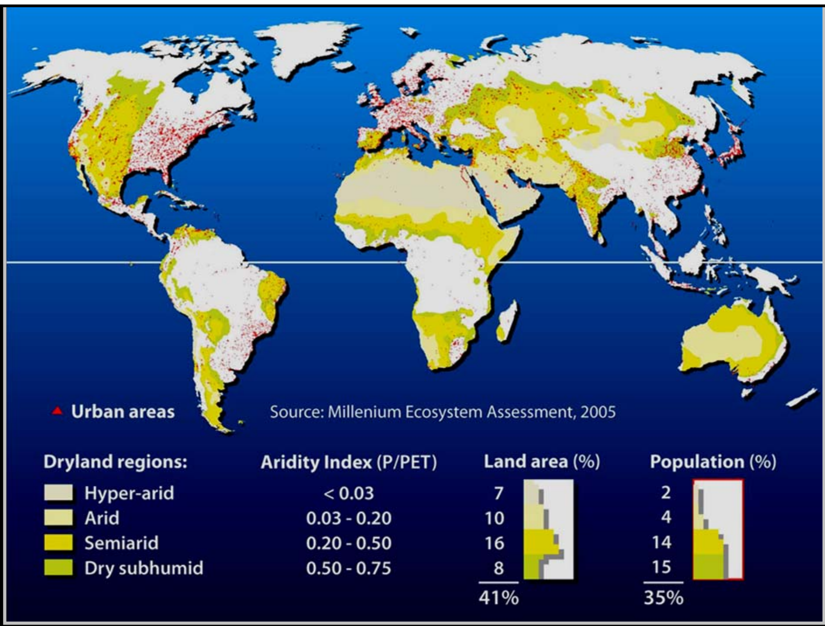
Discussion: Parametric analysis summary and conclusions

34th AIVC Conference

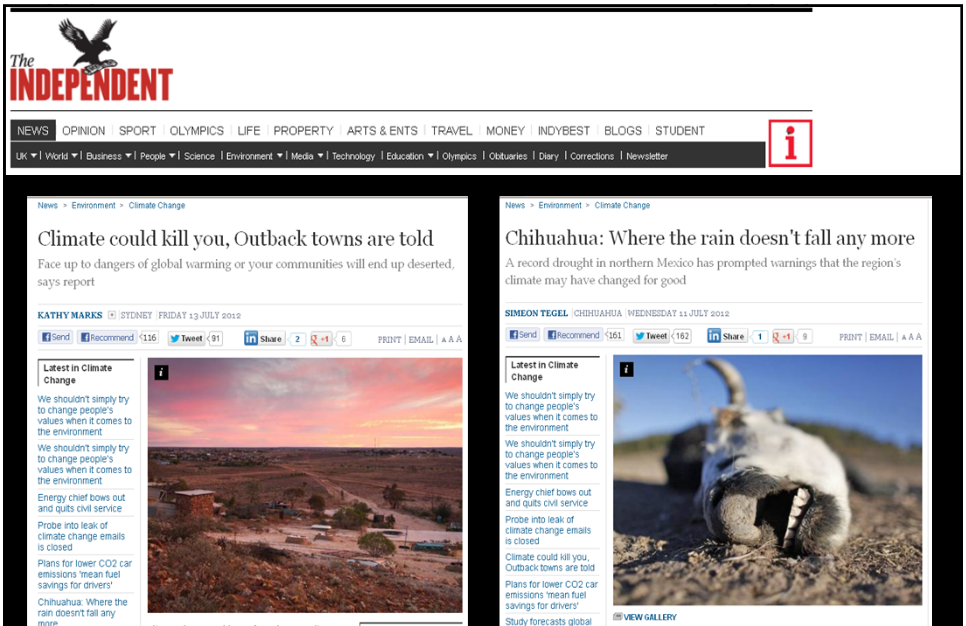
Norms	**Evaluation for lowering energy use for heating and cooling**
High mass with no or minimal (5cm) insulation	***Thicker insulation, high mass ceilings and walls*** - better functioning buildings, critical in maintaining heat gains from sunlight in the winter
Window quality and materials	***Lowering conductivity of windows increases heat retention of the interior***. Increasing MRT of windows in winter and lowering it in summer would be beneficial to thermal comfort.
Limited shading of walls	***Shading complete perimeter of building - beneficial in lowering interior temperatures in summer***. In winter shading design should allow solar gain to reach windows in December-March
Shading of ceiling	***Effective shading of ceilings coupled with complete ventilation*** between the roof material and a highly insulated ceiling.
Un-insulated AAC block construction	***AAC blocks NOT appropriate material*** for use as they have neither sufficient thermal mass or insulative characteristics. Because they need to be insulated, it is economically preferable to replace them with less expensive interior mass options.

Discussion: Parametric analysis summary and conclusions

34th AIVC Conference



Urban settlements and arid regions
Dry subhumid



Climate changes, whether we admit it or not. The Q is – how can we prepare ourselves for such changes


moshe klukowski

A low energy innovative system for space cooling

G. Mihalakakou and H. Bagiorgas

Department of Environmental & Natural Resources Management, University of Patras

OBJECTIVES

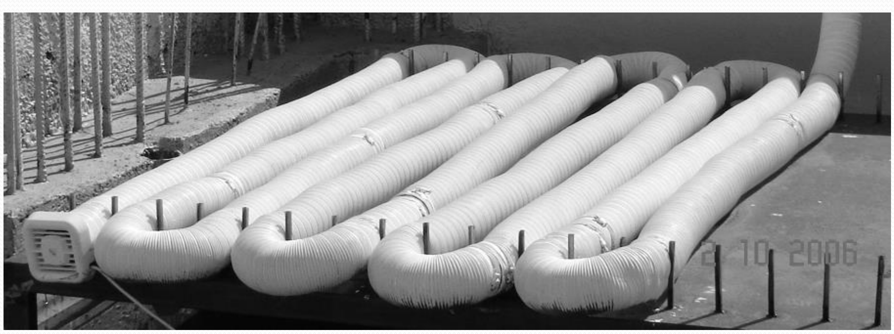
1. Present, describe and analyze the energy performance of a metallic nocturnal radiator placed on the roof of our Department in Agrinio, Greece
2. Compare the experimental data with the ones calculated using a mathematical model simulating the thermal performance of the system
3. Investigation of the cooling potential of the system connected to the University building
4. Use of the system for cooling a specific area of the building

The system is a metallic panel, and it consists of a folded and pressed long aluminium tube, with the circulating air flowing through it.

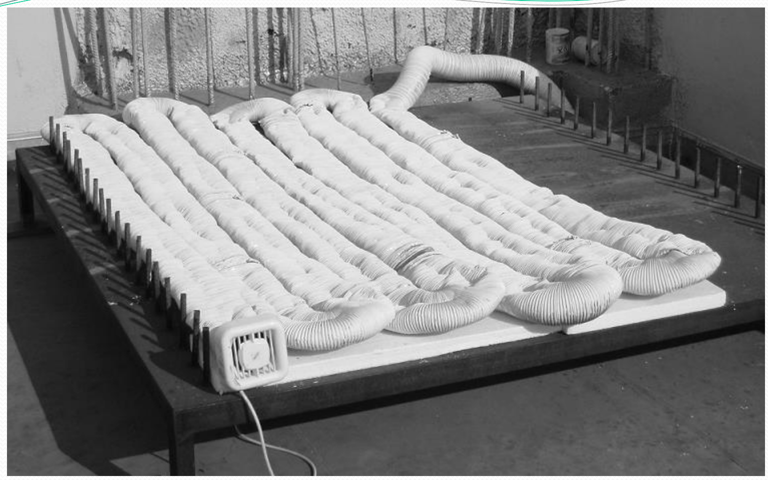
Radiator should have :

1. Low values of absorptivity in solar radiation in order to absorb the less possible solar radiation during the day and

2. High values of emissivity in the long-wave radiation to emit the heat during the night



Preparation of the metalic base with the folded aluminium tube.



The nocturnal radiator, taking a flat panel formation.

- The nocturnal radiator was used to provide space cooling for the building of the Department of the University.

- The results of this cooling effect were demonstrated by the comparison of the indoor air's temperature values of the thermal zone ***connected*** with the radiator with those of a similar zone ***without*** any cooling system, where remarkable differences were found.

Modeling of the nocturnal radiator

$$q_{win} = h_{win}(T_r - T_a)$$

$$h_{win} = 5.7 + 3.8v \quad if \quad v < 4ms^{-1}$$
$$h_{win} = 7.3v^{0.8} \quad if \quad v > 4ms^{-1}$$

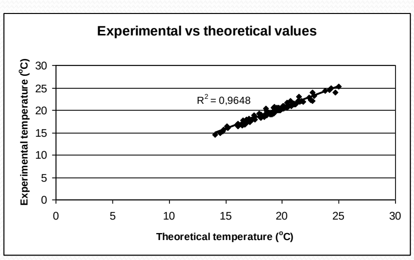
$$q_{amb} = h_e(T_r - T_{th}) \qquad h_e = h_{win} + h_{rad} \qquad h_{rad} = 0.000000227\tau\varepsilon T_a^2$$

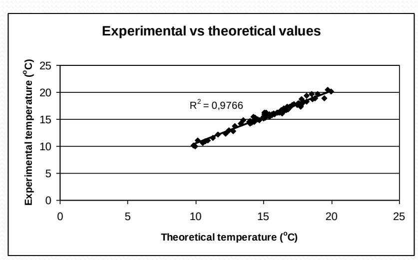
$$\theta_{th} = \theta_a - 0.000000057\varepsilon(1-\varepsilon_s)\frac{\theta_a^4}{h_e}$$

$$\varepsilon_c = c\varepsilon_{cs} \qquad \varepsilon_{cs} = 9.36 \cdot 10^{-6} T_a^2$$

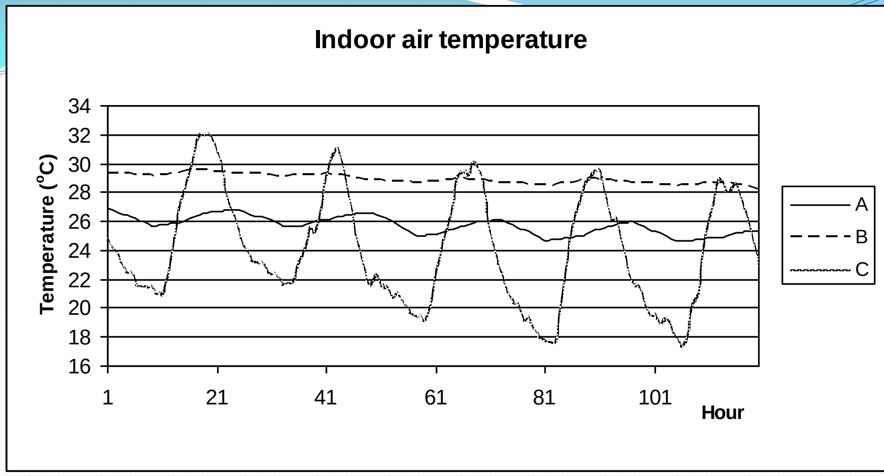
$$\theta_{out} = \theta_{th} + (\theta_{in} - \theta_{th})e^{-\frac{UA}{mc_p}} \qquad \theta_{out} = \theta_{th} + (\theta_{in} - \theta_{th})e^{-\frac{Uw}{1173zu}}$$

$$U = \frac{1}{R} \qquad U = \frac{1}{\frac{1}{h_e} + \frac{1}{h} + \frac{d}{k}} \qquad D_h = 2w[z/(w+z)]$$





Comparison of the experimental air temperature values at the radiator's outlet with the calculated ones for the whole experimental time period with the radiator painted with a paint: with emissivity 0.71 (left) and with emissivity 0.93 (right).



Temporal variation of the indoor air temperature values at both rooms, the room connected with the nocturnal radiator (A), and that not equipped with any cooling system (B) for 5 randomly selected days of the experimental time period (from the 15th of September at 10.00pm to the 20th of September at 06.00 am), and ambient temperature for the same period (C).

Conclusions

The nocturnal radiator was used to provide space cooling for the building of the Department of the University. The results of this cooling effect were demonstrated by the comparison of the indoor air's temperature values of the thermal zone connected with the radiator with those of a similar zone without any cooling system, where remarkable differences were found.

- ✓The temperature differences between the two rooms fluctuated between 2.5°C and 4°C with the highest values at the late nocturnal hours.
- ✓the radiator with the paint of 0.71 emissivity is less "effective" in the achievement of lower temperatures than the radiator with the paint of 0.93 emissivity.
- ✓there is a better agreement between theoretical and experimental temperatures for the radiator with the more emissive paint

DOUBLE FACADES: COMFORT AND VENTILATION AT AN EXTREME COMPLEX CASE STUDY

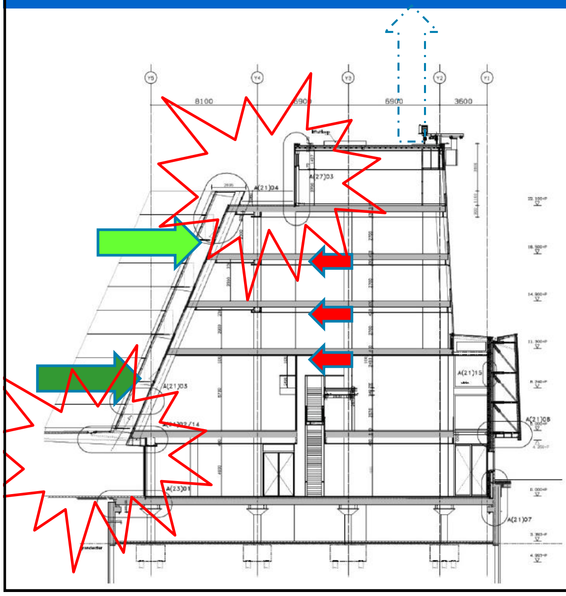
Wim Zeiler, Joep Richter and Gert Boxem

Technische Universiteit Eindhoven
University of Technology

Where innovation starts

Really special Building

Hybride ventilation: supply



Three different situations;

-Two through the cavity

-One mechanical

Technische Universiteit Eindhoven University of Technology

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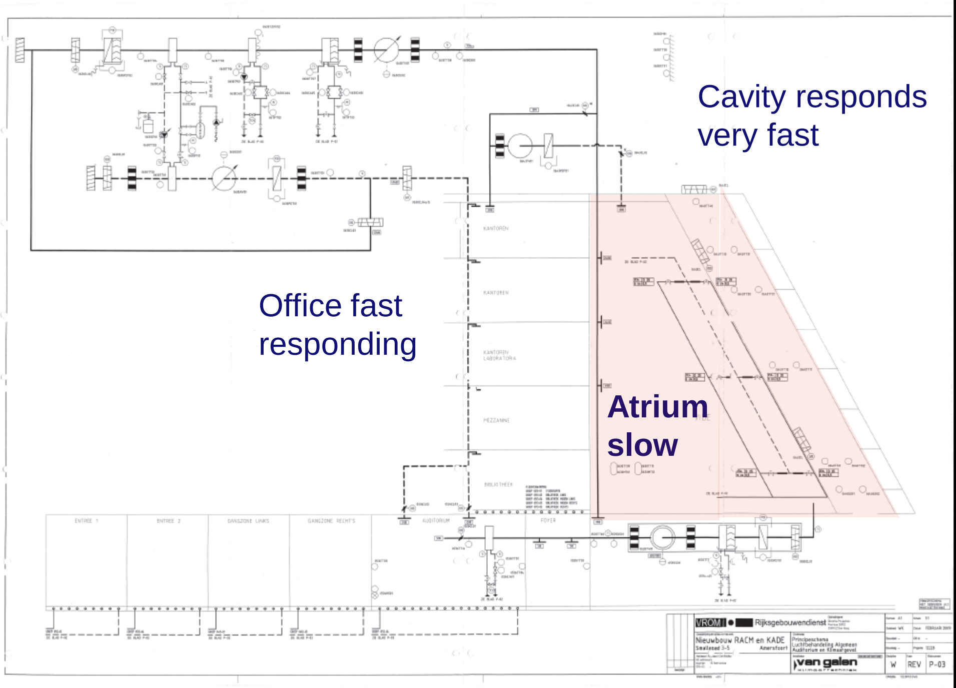
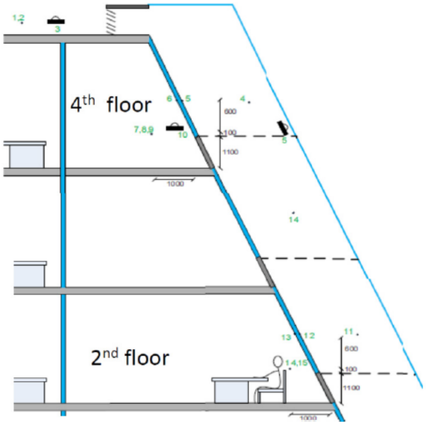
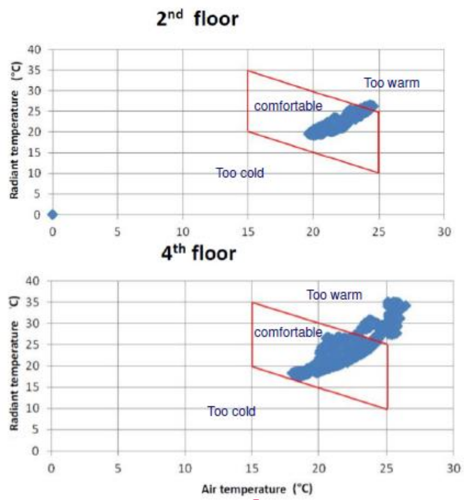


Resulting thermal comfort



The schematic measurements setting on the 2nd and 4th floor



Double-Skin System of Room-Side Air Gap Applied to Detached House (Part 2):

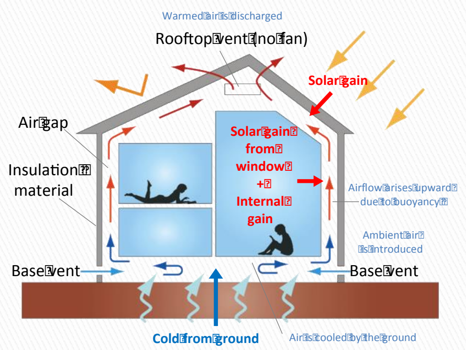
Simulation Analysis to Reduce Cooling Load Through Natural Ventilation in Wall

Togo Yoshidomi Graduate student, The University of Tokyo
Shinsuke Kato Professor, Institute of Industrial Science, The University of Tokyo
Kan Lin Graduate student, The University of Tokyo
Kyosuke Hiyama Associate Professor, Yamaguchi University

THE UNIVERSITY OF TOKYO

Overview

■ Overview of the system



Double-skin system of room-side air gap

■ Objective

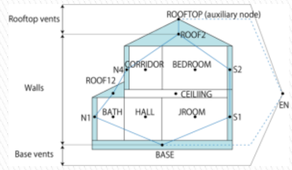
Using network simulation (TRNSYS, TRNFlow),

1. To carry out sensitivity analyses to the airflow rate in the gap.
2. To estimate the introduction effects: natural room temperature, cooling load.

1. Sensitivity Analysis on the Airflow Rate

■ Simulation cases: Opening area, External wind

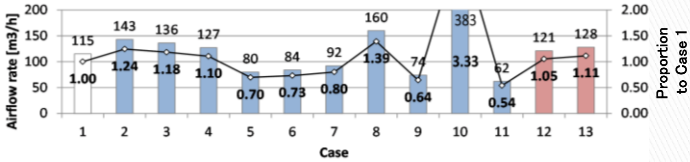
Case No.		1	2	3	4	5	6	7	8	9	10	11	12	13
Opening Area	Walls	–	×5	–	–	×0.5	–	–	–	–	×5	×0.5	–	–
	Rooftop Vents	–	–	×5	–	–	×0.5	–	×5	×0.5	×5	×0.5	–	–
	Base Vents	–	–	–	×5	–	–	×0.5	×5	×0.5	×5	×0.5	–	–
External Wind	Wind	–	–	–	–	–	–	–	–	–	–	–	Exist	Exist
	Surrounding Buildings	–	–	–	–	–	–	–	–	–	–	–	Exist	None



Simple model
(infiltration isn't considered)

■ Results

- Sensitivity to the airflow rate: walls > rooftop vents > base vents (Case 2-7), and the difference was smaller than in the case that all parts was changed (Case10, 11).
- The airflow rate increased due to the external wind (Case12, 13), and the increase was greater when there were no surrounding buildings (Case13).

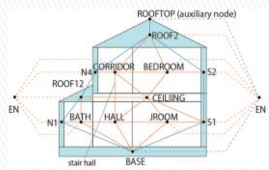


2. Estimation of introduction effects

■ Result: Natural room temperature drop

- Natural room temperature dropped around 1.7℃.

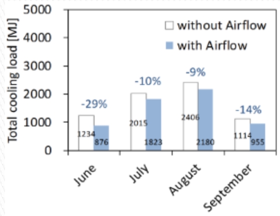
Zone	Average Temperature Difference
Average of 1F	-1.5
Average of 2F	-1.9
Roofs (1F and 2F)	-2.4
Under Floor Space	1.0



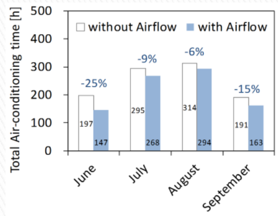
Detailed model
(infiltration considered)

■ Result: Cooling load reduction

- Cooling load was reduced by 15.5% in the period average, probably because the total air-conditioning time was shortened.



Total cooling load



Total air-conditioning time

Conclusion

- Sensitivity of the opening area in the air gap to the airflow rate is higher in the order: walls > rooftop vents > base vents. The airflow is increased by the external wind.
- Natural room temperature in the living room drops around 1.7℃. Cooling load is reduced by 15.5% in the summer period.
- Further work can be carried out to estimate the cooling effect of the ground surface by a detailed simulation of the geothermal heat.

Thank you for listening!

Building Envelope Design for climate change mitigation: a case-study of hotels in Greece

Ifigenia Farrou[1], Maria Kolokotroni[1], Mat Santamouris[2]

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Howell Building, Mechanical Engineering School of Engineering and Design

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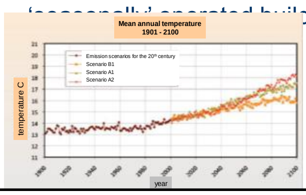
Physics Department Group Building Environmental Research

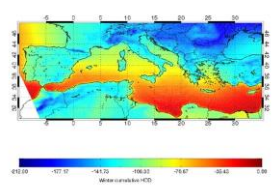
Aim

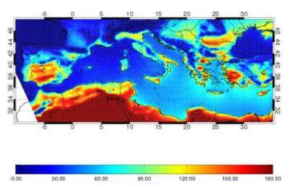
- **Assess the impact of the climate change on the energy demand of a hotel building using real climatic data and future climate change scenarios as developed by the Intergovernmental Panel on Climate Change (IPPC)**

Specific aims

- Investigate climate change mitigation strategies for a hotel building
- Assess the effectiveness of the optimum building envelope in the 3 climatic zones of Greece (A,B and C)
- Propose different strategies for a ‘all year’ operated and ‘seasonally’ operated buildin

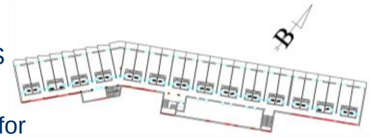






Methodology

- A hotel building was modelled using TRNSYS



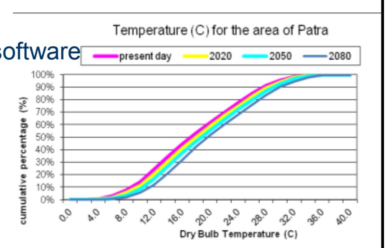
- The impact of climate change was assessed for

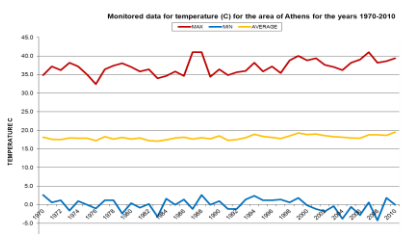
a. for the period **1970 – 2010 using real climatic data**
b. For years 2020, 2050 and 2080 using **generated future files** for Patra (climatic zone B), Thessaloniki (climatic zone C) and Iraklio –Crete (climatic zone A)

Generation of future files

3 steps:

- Weather files extracted from **METEONORM** software
- Converted in a **EPW** file
- '**Morphing**' method using a weather generator software





$x = x_o + \Delta x_m$ (shift)

$x = \alpha_m x_o$ (linear stretch)

$x = x_o + \Delta x_m + \alpha_m x\,(x_o - (x_o)_m)$

(a combination of shift and stretch)

Climate change mitigation strategies

Principle	Type of Principle	Option
switch off	Passive cooling	Reduce internal gains e.g. using **shading, using double low emission glazing**
switch off & absorb	Passive cooling	Increase the thermal response factor *(fr)* i.e. **adding insulation in walls & roof**
reflect	Passive cooling	Increase the reflectance of external surfaces in the summer period i.e. **using cool materials, using double low emission glazing**
blow away	Passive cooling	Intelligent **night ventilation and day time control**
convection	Hybrid cooling	Interact in the cooling set point and thermal comfort i.e. using **ceiling fans** in the rooms

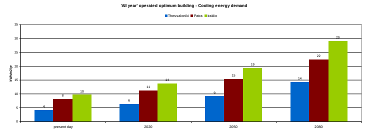
Results & Concluding Remarks

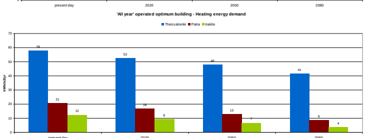
- Real monitored data for the period 1970 – 2010: Increase of cooling loads by 33% increase and decrease of heating loads by 22% in 2010 compared to 1970

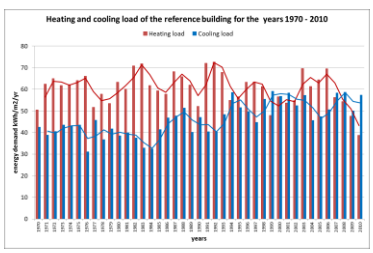
- Generated future files for climate zone B

✓Increase of cooling loads: 15% in 2020, 34% in 2050 and 63% in year 2080.

✓Decrease of heating loads: by 14% in 2020, 29% in 2050 and 46% in year 2080.







Results & Concluding Remarks

- **'All year' operated buildings:** high levels of insulation, double low e glazing, intelligently controlled night and day ventilation, ceiling fans and shading.

  - The building of year 2050 would need more shading and the building of year 2080 would need additional shading and cool materials.

- **'Seasonally' operated buildings:** Intelligently controlled night and day ventilation, cool materials, ceiling fans, shading and double low e glazing.

  - Only the building of year 2080 would need insulation

THANK YOU !

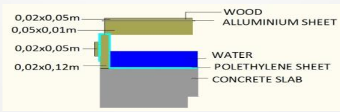
THE EFFECT OF A NOVEL ROOF POND TO THE INDOOR AIR TEMPERATURE FOR PASSIVE COOLING

Artemisia Spanaki[1], Dionysia Kolokotsa[2], Theocharis Tsoutsos[2], Ilias Zacharopoulos[1]

AIM:
The effect of a new passive cooling device to the indoor air is analyzed based both to experimental and simulating results.

TESTED DEVICE:
ventilated pond protected with an aluminium layer, placed on the roof of the examined building.

The indoor air temperature of the building has been recorded, before and after the placement of the roof cooling technique. The record indoor air temperature is analyzed, in regard to the ambient conditions. Furthermore, the record indoor air temperature before the application of roof cooling technique has been assessed in order to create the digital model of the building, using the TRNSYS software.



1 National Technical University of Athens, School of Architecture
2 Technical University of Crete, School of Environmental Engineering

THE EFFECT OF A NOVEL ROOF POND TO THE INDOOR AIR TEMPERATURE FOR PASSIVE COOLING

Artemisia Spanaki[1], Dionysia Kolokotsa[2], Theocharis Tsoutsos[2], Ilias Zacharopoulos[1]

EXPERIMENTAL SET-UP
The experimental records refer to the period between June and August on the Campus of Technical University of Crete in Chania – Greece. The climatic data on the site of the experiments was obtained from meteorological station of the Institute of Environmental Research, of the National Observatory of Athens.
The internal conditions are recorded by 2 loggers temperature - humidity T-Logg 100E brand Greisinger electronic.

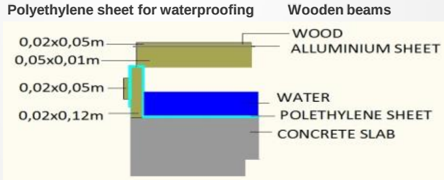
SETING UP THE TESTED DEVICE

Wooden frame

Polyethylene sheet for waterproofing

Wooden beams

Aluminum sheet above water level.



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THE EFFECT OF A NOVEL ROOF POND TO THE INDOOR AIR TEMPERATURE FOR PASSIVE COOLING

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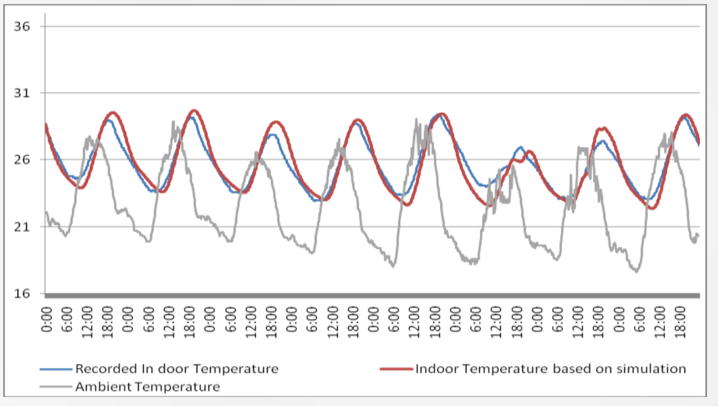
BUILDING SIMULATION

The indoor air temperature of the building before the addition of the investigated system on the roof has been recorded for a 22 days period. The climatic data of the 22 days period are used in order to simulate the building without any roof treatment.

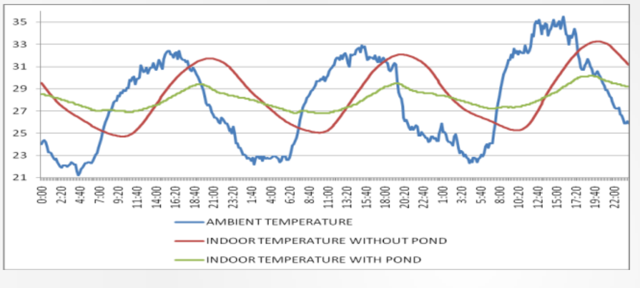


The calculated indoor air temperatures are compared to the experimental ones.
The maximum variation of experimental and simulating values are 12%.

THE EFFECT OF A NOVEL ROOF POND TO THE INDOOR AIR TEMPERATURE FOR PASSIVE COOLING

Artemisia Spanaki[1], Dionysia Kolokotsa[2], Theocharis Tsoutsos[2], Ilias Zacharopoulos[1]

THE EFFECT OF THE VENTILATED ROOF POND WITH ALUMINIUM LAYER TO THE INDOOR AIR TEMPERATURE



THE EFFECT OF THE VENTILATED ROOF POND WITH ALUMINIUM LAYER TO THE INDOOR AIR TEMPERATURE

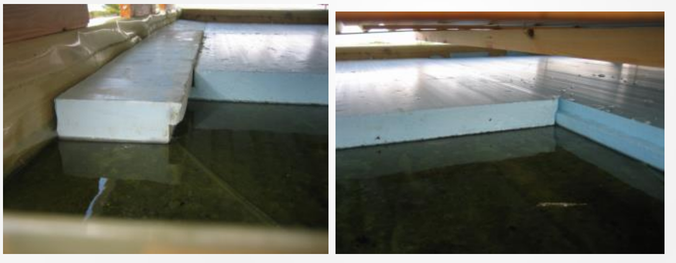
The fluctuation of the indoor air temperature for the building with the Ventilated pond with Aluminium layer varies from 1.6 and 3.1ºC for the whole period of experiments. The corresponding value for the building without any roof treatment varies from 4.8 to 8.2ºC.

- The proposed technique results a reduction of indoor air temperature to the 40% compared to the building with roof pond. The indoor air temperature fluctuation of the building with the ventilated pond with aluminium is the 25% of the ambient air temperature fluctuation.
- The mean maximum indoor air temperature in the building without any roof treatment reaches 31.7ºC, almost equal to the maximum ambient air temperature (32.4ºC). The corresponding mean maximum indoor air temperature in the building with the ventilated pond with the aluminium is decreased at 29.0ºC.
- The minimum indoor air temperature is 1.3ºC higher compared to the corresponding value for the building without any roof cooling technique, due to the increased heat capacity of water.

Artemisia Spanaki[1], Dionysia Kolokotsa[2], Theocharis Tsoutsos[2], Ilias Zacharopoulos[1]

CONCLUSIONS

The present investigation proposes a new passive roof cooling technique. The ventilated pond with aluminium layer can easily be constructed with common materials. According to the experiments, the system reduces the indoor air temperature fluctuation.
Further research can further investigate alternative durable and strong materials that can be used for the construction of the system. Furthermore, issues related to the thermal performance of the system in respect to climatic conditions should be also investigated.



Winter mode: the water is removed and replaced by insulating panels.

1 National Technical University of Athens, School of Architecture
2 Technical University of Crete, School of Environmental Engineering

Imperial College London

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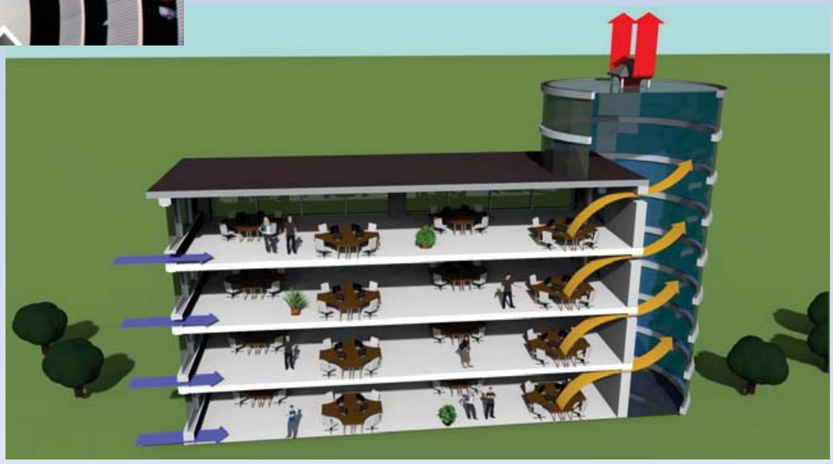
Natural Ventilation in Atrium Buildings - Preliminary Design

Andy Acred



Imperial College London

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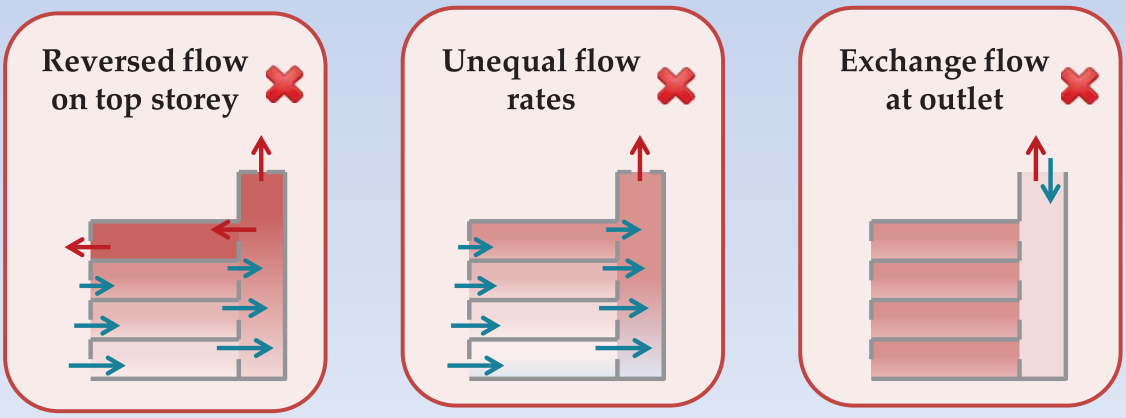
Multi-compartment buildings: the challenge

- Multiple interacting flows of heat and air
- Can lead to undesirable flow patterns and uncomfortable indoor environment
- An atrium does not always enhance flows!



Current design tools

- CFD modelling,
- Multizone software
- Energy modelling software

✓ Highly detailed
✗ Need expert knowledge
✗ Iterative / case specific

Our approach

- Simple mathematical models
- Balance 'core' variables
- Algebraic design calculations
- Design charts

✗ Highly simplified
✓ Experimentally verified
✓ Quick calculations
✓ Intuitive

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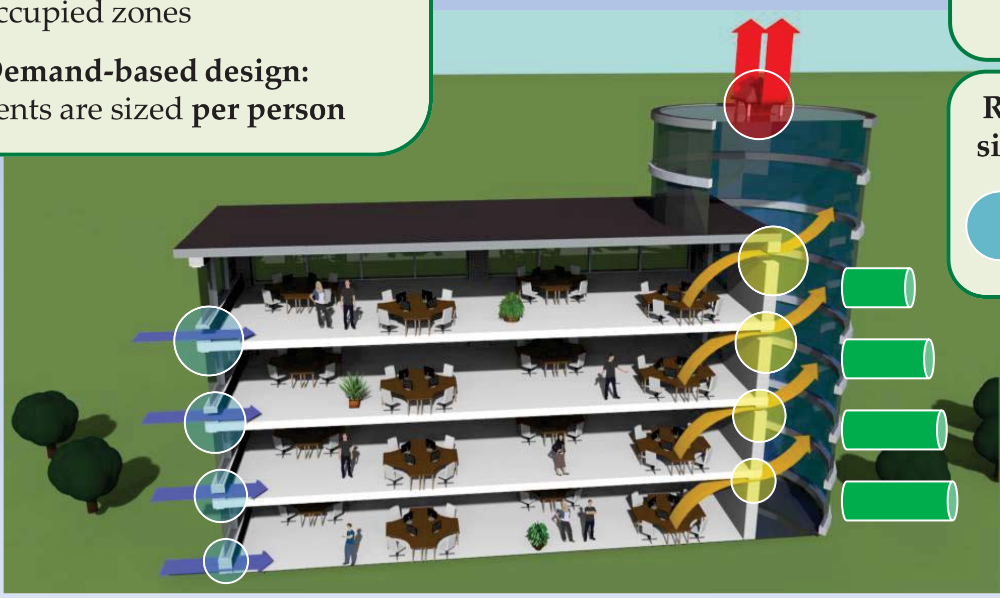
✓ Equal **ventilation rate per person** in all occupied zones

✓ Equal **temperatures** in all occupied zones

✓ **Demand-based design:** vents are sized **per person**

Atrium enhancement

Required vent size per person



A starting point for more detailed modelling

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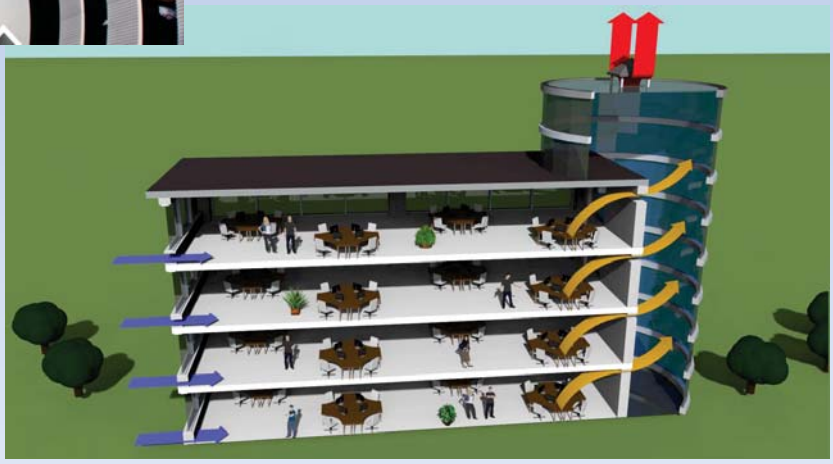
Natural Ventilation in Atrium Buildings - Preliminary design



Andy Acred

Wednesday 25 September 2013

17:00-18:30: Parallel Session 3B: Short oral presentation session- Ventilation system performance and indoor air quality

Chairpersons: Wouter Borsboom, Pavel Charvat

- **Investigation of the air flow field in front of the reinforced slot exhaust Hood** Ondrej Pech, Czech Republic
- **Energy saving and Indoor Air Quality in office buildings** Eleni Provata, Greece
- **Occupancy estimation based on CO2 concentration using Dynamic Neural Network Model** Hwataik Han, Republic of Korea
- **Analysis of Indoor Air Quality in Greek primary schools** Paraskevi Dorizas, Greece
- **Does Indoor Environmental Quality affect students' performance?** Paraskevi Dorizas, Greece
- **Indoor and outdoor distribution of airborne pollutants in naturally ventilated classrooms** Paraskevi Dorizas, Greece
- **Instationary operation of a ventilation system** Martin Schmidt, Germany
- **Energy saving opportunities by suitable HVAC management: the Procuratie case in Venice** Luigi Schibuola, Italy
- **High efficiency retrofit in historic buildings by demand-controlled ventilation** Luigi Schibuola, Italy
- **Uncertainties in different level assessments of domestic ventilation systems** Regina Bokel, Netherlands
- **Measurements and modelling of an earth- to- air heat exchanger for retail building ventilation** Andrzej Gorka, Poland

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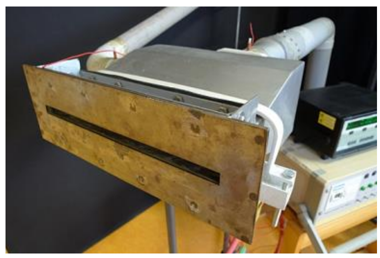
Faculty of Mechanical Engineering
Brno University of Technology, Czech Republic

INVESTIGATION OF THE AIR FLOW FIELD IN FRONT OF THE REINFORCED SLOT EXHAUST HOOD

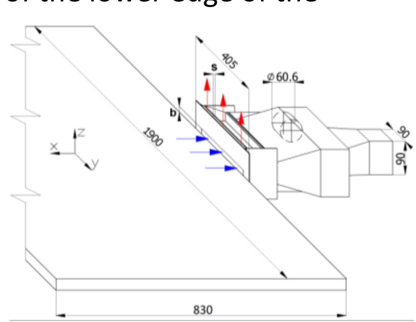


Ondřej Pech and Milan Pavelek
pech@fme.vutbr.cz, pavelek@fme.vutbr.cz

September 25, 2013

INTRODUCTION OF MEASUREMENT:

- The air flow field in front of the reinforced slot exhaust hood with the workbench at the level of the lower edge of the exhaust opening was observed.
- For velocity measurement six hot bulb thermo-anemometric sensors was used.
- Traditional exhausting mode *I*=0 and three reinforced exhausting modes(I=0.3, 0.6, 0.9) were measured.



- The velocity in the exhaust opening was set to w_{ex}= 8 m·s^{-1}.

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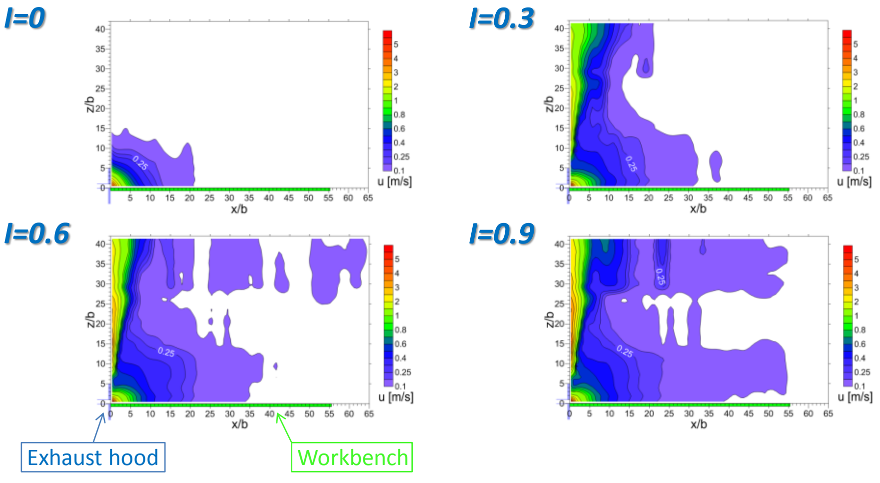
Brno University of Technology, Czech Republic

RESULTS AND CONCLUSION



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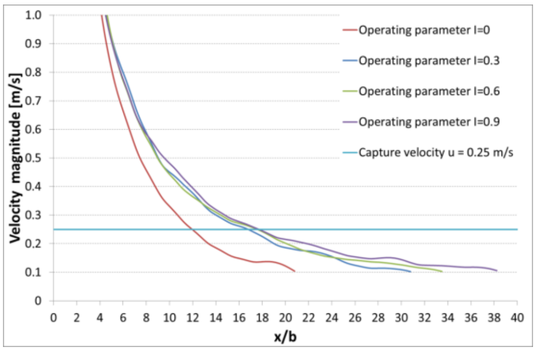
Energy Institute
Faculty of Mechanical Engineering
Brno University of Technology, Czech Republic

RESULTS AND CONCLUSION

- The results of the measurement show that in reinforced mode the effective suction area becomes longer in comparison to the traditional mode.



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Energy Institute
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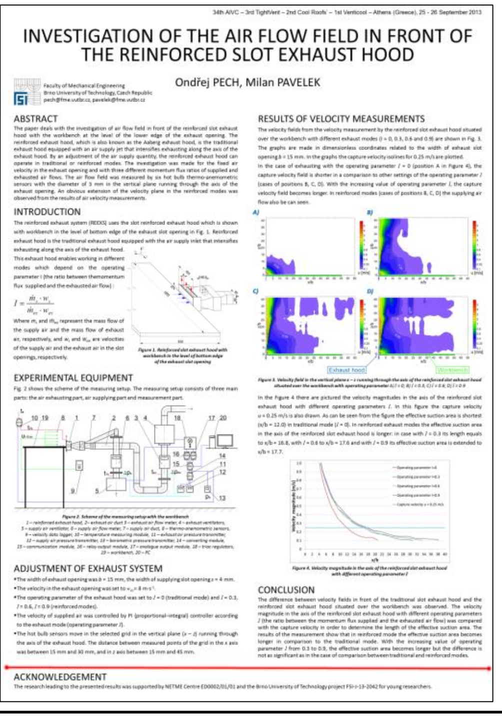
Brno University of Technology, Czech Republic

THANK YOU FOR YOUR ATTENTION.

Ondřej Pech and Milan Pavelek
pech@fme.vutbr.cz, pavelek@fme.vutbr.cz

The research leading to the presented results was supported by:
- **NETME Centre ED0002/01/01**
- **Brno University of Technology project FSI-J-13-2042 for young researchers**.



Energy saving and indoor air quality in office buildings

E. Provata, D. Kolokotsa
Technical University of Crete, Environmental Engineering Department, Chania, Greece

EMBER

Energy Management in the Built Environment Research Unit

Methodology

TRNsys → Simulation of building's thermal behaviour

COMIS → Simulation of air flow and pollutant transport

Calculate the energy demands and the CO_2 levels

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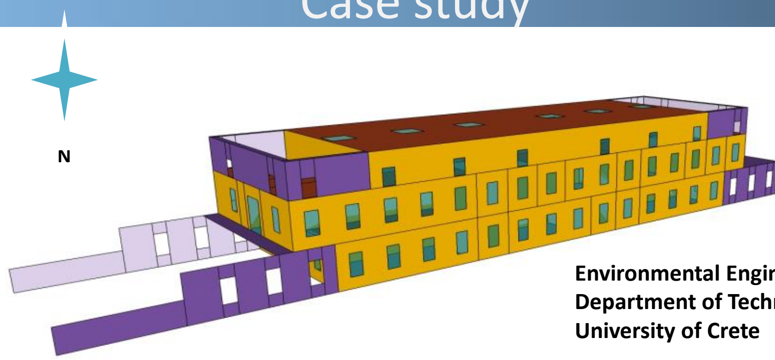
Case study



Environmental Engineering Department of Technical University of Crete

- **30 thermal zones**
- **Meteorological data**
- **Constructive characteristics**
- **Operating characteristics**
- **Occupant's characteristics**

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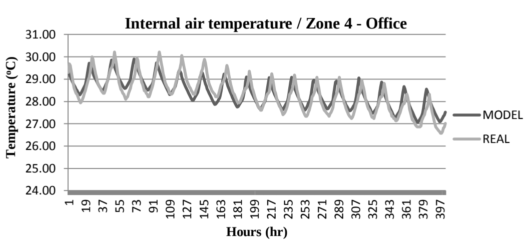
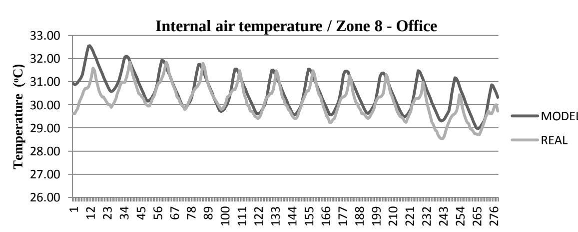
Energy Management in the Built Environment Research Unit

Validation

✓ **Comparing the internal air temperature**





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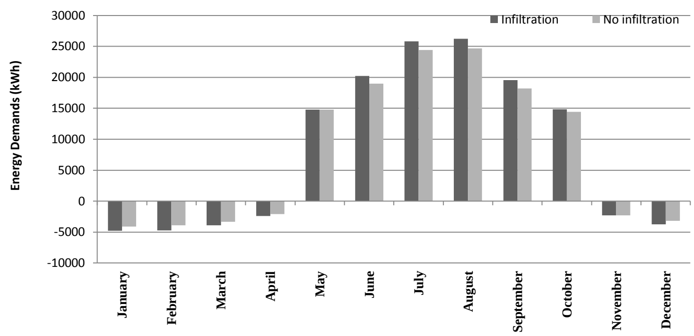
Energy demands



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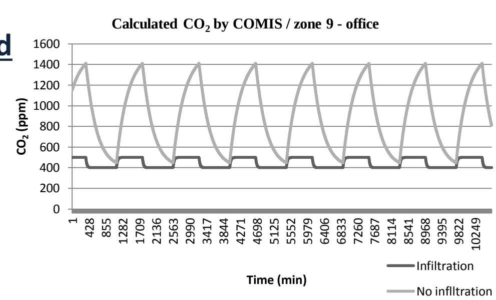
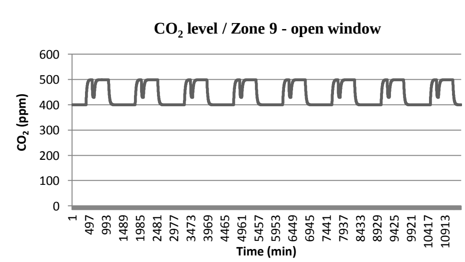
CO_2 levels at an office zone

✓ **3 scenarios were examined**

1. Full insulated building
2. Infiltration on
3. 1 hour natural ventilation





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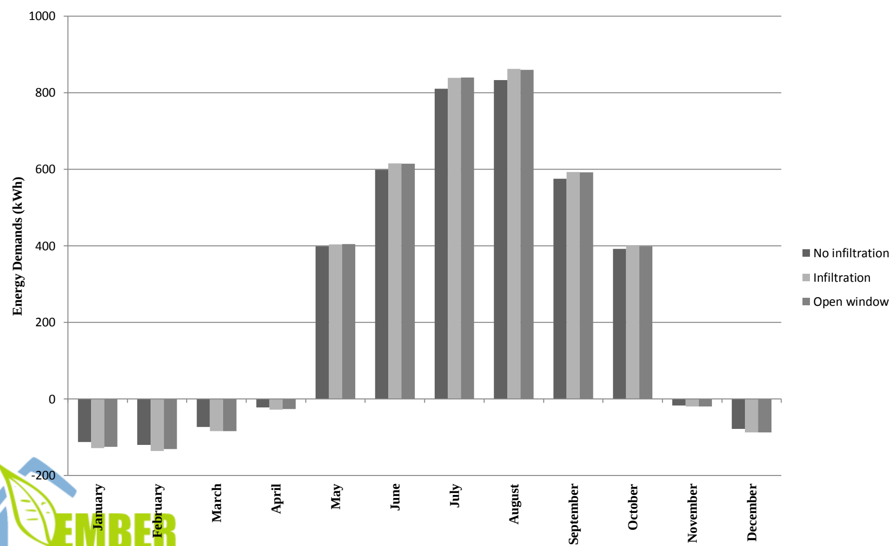
Energy demands of zone 9



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Conclusions

- ✓ Fully insulated buildings need less energy but create an unhealthy internal environment
- ✓ When the building is ventilated properly, it needs more energy
- ✓ We need to achieve a balance between energy demands and indoor air quality

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Energy Management in the Built Environment Research Unit

Thank you!

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Energy Management in the Built Environment
Research Unit

OCCUPANCY ESTIMATION BASED ON CO2 CONCENTRATION USING DYNAMIC NEURAL NETWORK MODEL

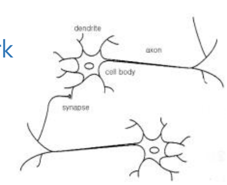
2013. 9. 25

Hwataik Han, Ph.D., P.E.
Kyung-Jin Jang, Changho Han, and Junyong Lee

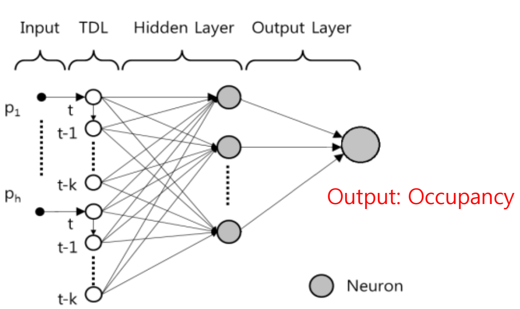
KOOKMIN UNIVERSITY

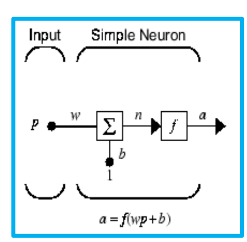
Dynamic Neural Network Model

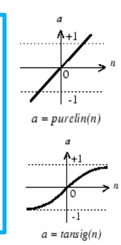
- Biological Neural Network



- Aritificial Neural Network





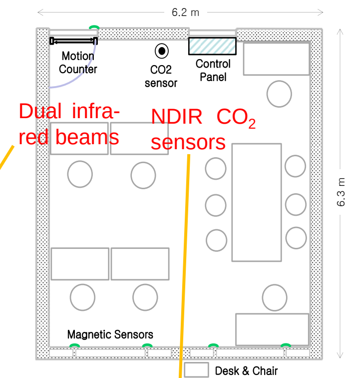


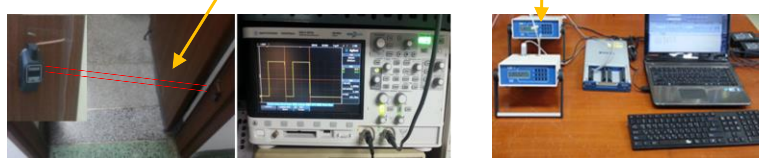
- Tangent hyperbolic function
  for transfer function of hidden layer
- Linear function
  for the transfer function of output layer

Experiments

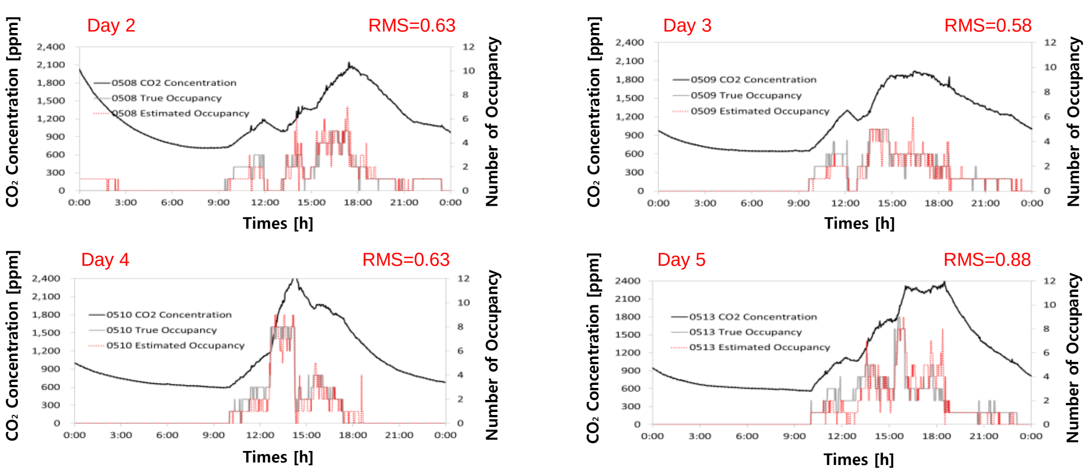
- Experiments conducted in May, 2013
- Office room for graduate students (6.2 m x 6.3 m) located on the second floor of a five-story college building
- Number of occupants ranged from 0 to 8 persons

- Dual beam infra-red motion counter, NDIR CO_2 sensors
- Measurement interval : 1 min
- Office - Model trained with the 1st day data
- Occupancy estimated for the rest of the days
- MatLab R2012a Neural Network Toolbox used

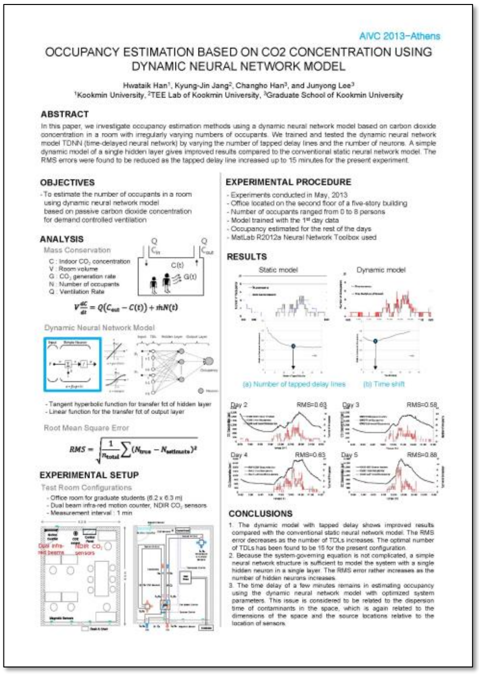




Results and Conclusions



1. A simple dynamic network model with a single hidden neuron in a single layer gives good results.
2. The optimal number of TDLs has been found to be 15 for the present configuration.
3. The dispersion time of contaminants should be considered.



AIVC 2013–Athens

OCCUPANCY ESTIMATION BASED ON CO2 CONCENTRATION USING DYNAMIC NEURAL NETWORK MODEL

Hwataik Han[1], Kyung-Jin Jang[2], Changho Han[3], and Junyong Lee[3]
[1]Kookmin University, [2]TEE Lab of Kookmin University, [3]Graduate School of Kookmin University

ABSTRACT

In this paper, we investigate occupancy estimation methods using a dynamic neural network model based on carbon dioxide concentration in a room with irregularly varying numbers of occupants. We trained and tested the dynamic neural network model TDNN (time-delayed neural network) by varying the number of tapped delay lines and the number of neurons. A simple dynamic model of a single hidden layer gives improved results compared to the conventional static neural network model. The RMS errors were found to be reduced as the tapped delay line increased up to 15 minutes for the present experiment.

OBJECTIVES

- To estimate the number of occupants in a room using dynamic neural network model based on passive carbon dioxide concentration for demand controlled ventilation

ANALYSIS

Mass Conservation

C : Indoor CO_2 concentration
V : Room volume
G : CO_2 generation rate
N : Number of occupants
Q : Ventilation Rate

$$V\frac{dC}{dt} = Q(C_{out} - C(t)) + \dot{m}N(t)$$

Dynamic Neural Network Model

- Tangent hyperbolic function for transfer fct of hidden layer
- Linear function for the transfer fct of output layer

Root Mean Square Error

$$RMS = \sqrt{\frac{1}{n_{total}}\sum(N_{true} - N_{estimate})^2}$$

EXPERIMENTAL SETUP

Test Room Configurations

- Office room for graduate students (6.2 x 6.3 m)
- Dual beam infra-red motion counter, NDIR CO_2 sensors
- Measurement interval : 1 min

EXPERIMENTAL PROCEDURE

- Experiments conducted in May, 2013
- Office located on the second floor of a five-story building
- Number of occupants ranged from 0 to 8 persons
- Model trained with the 1st day data
- Occupancy estimated for the rest of the days
- MatLab R2012a Neural Network Toolbox used

RESULTS

CONCLUSIONS

1. The dynamic model with tapped delay shows improved results compared with the conventional static neural network model. The RMS error decreases as the number of TDLs increases. The optimal number of TDLs has been found to be 15 for the present configuration.
2. Because the system-governing equation is not complicated, a simple neural network structure is sufficient to model the system with a single hidden neuron in a single layer. The RMS error rather increases as the number of hidden neurons increases.
3. The time delay of a few minutes remains in estimating occupancy using the dynamic neural network model with optimized system parameters. This issue is considered to be related to the dispersion time of contaminants in the space, which is again related to the dimensions of the space and the source locations relative to the location of sensors.

Thank you for your attention !

Hwataik Han, Ph.D., P.E.

Dean/College of Engineering
Professor/ Mechanical Engineering

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ANALYSIS OF INDOOR AIR QUALITY IN GREEK PRIMARY SCHOOLS

Paraskevi Vivian Dorizas*, Margarita-Niki Assimakopoulos, Constantinos Helmis, Mat Santamouris

Faculty of Physics,
Department of Environmental Physics & Meteorology,
University of Athens,
Greece
* pdoriza@phys.uoa.gr

Joint Conference
34th AIVC- 3rd TightVent- 2nd Cool Roofs' – 1st venticool
25-26 September 2013, Athens, Greece

Presentation contents

- Objectives
- Methodology
- Results & Discussion
- Conclusions

Objectives

- Create integrated concentration profile of air pollutants in school classrooms
- Evaluate air pollutant levels
- Compare indoor vs outdoor PM concentrations
- Investigate activities affecting PM concentrations

Methodology

- Measurement sites → Sample: 9 schools
- Measurement period: April & May 2013
- Measurements from 1 to 5 days per school

- Measuring instruments:

(VOCs, CO, CO_2)

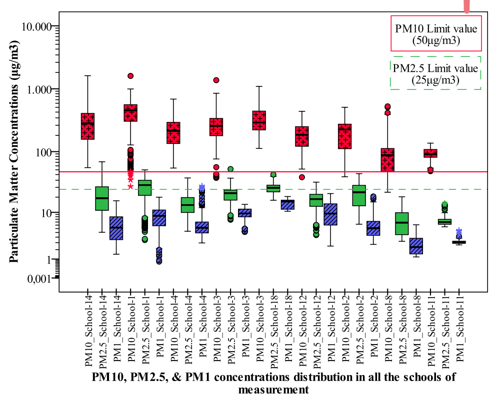
(PM_{10} outdoors)

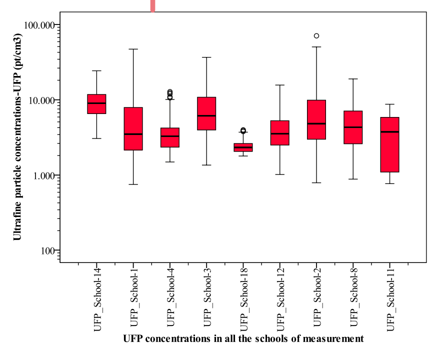
(PM_{10}, PM_5, $PM_{2.5}$, PM_1, $PM_{0.5}$)

(UFP)

Results & Discussion

Distribution of indoor PM (PM_{10}, $PM_{2.5}$, PM_1 & UFP) concentrations

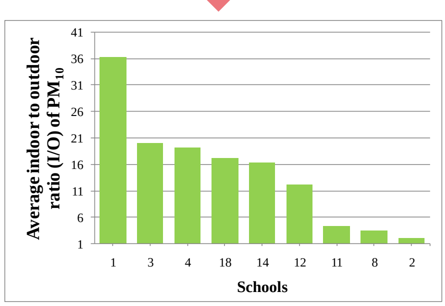


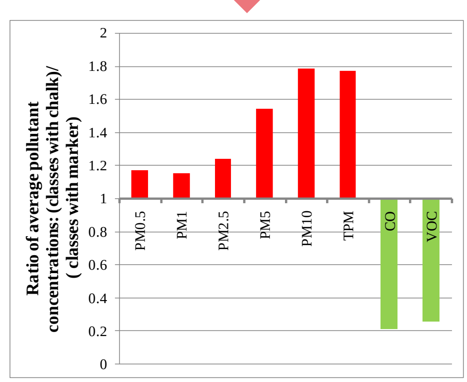


Results & Discussion

Indoor vs Outdoor PM_{10} concentrations

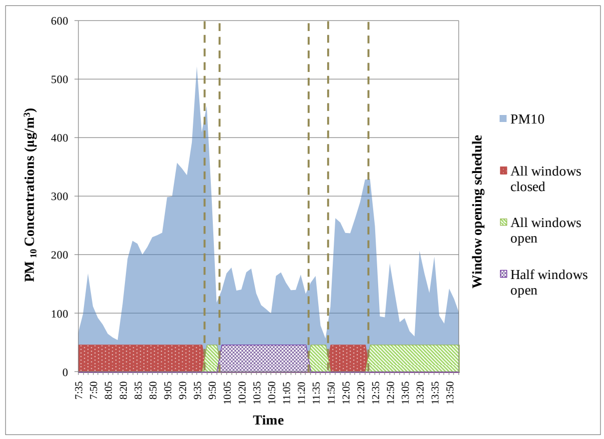
Use of chalk (blackboard) vs use of marker (whiteboard)





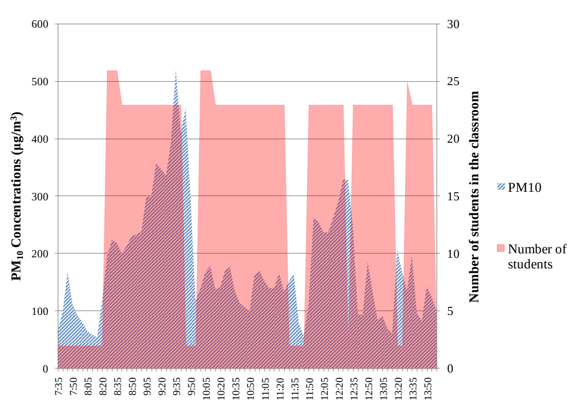
Results & Discussion

- PM$_{10}$ concentrations as a function of window opening



Results & Discussion

- PM$_{10}$ concentrations as a function of human presence



Conclusions

- Extremely high indoor PM_{10} concentrations
- $PM_{2.5}$ concentrations from all the schools were below the limit values
- UFP remained in rather low levels
- CO_2 in many cases exceeded the limit value indicating inadequate ventilation & overcrowded classrooms
- I/O PM_{10} ratios is much greater than 1
- Chalk use led to significant $PM_{2.5}$ & PM_{10} concentrations, while marker use led to increased VOCs and CO concentrations
- Window opening and the presence of students significantly affected the variation of the indoor PM_{10} concentrations

Thank you for your attention!

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This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Heracleitus II. Investing in knowledge society through the European Social Fund. We are greatly indebted to the school directors, pupils and parents, without whose consent this study would have not been possible.

DOES INDOOR ENVIRONMENTAL QUALITY AFFECT STUDENTS PERFORMANCE?

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Joint Conference
34th AIVC- 3rd TightVent- 2nd Cool Roofs' – 1st venticool
25-26 September 2013, Athens, Greece

Presentation contents

- Objectives
- Methodology
- Results & Discussion
- Conclusions

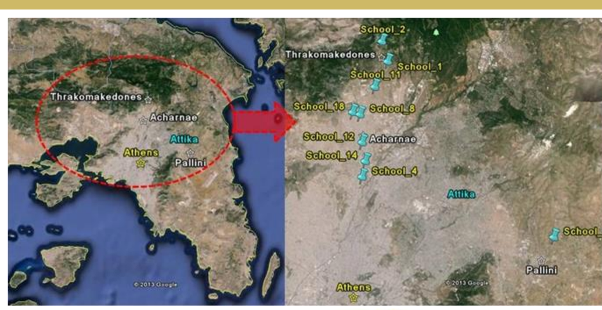
Objectives

- Investigate students' IEQ evaluation of their classrooms
- Evaluate students' possible Sick Building Syndrome symptoms (SBS)
- Assess students' performance in relation to pollutant levels and to their evaluation of the IEQ

Methodology

Sample:

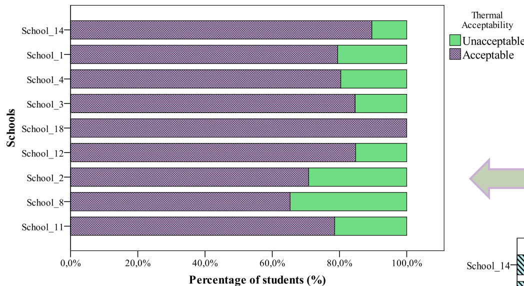
9 primary schools



- 1st part: CO, CO_2 & VOCs measurements

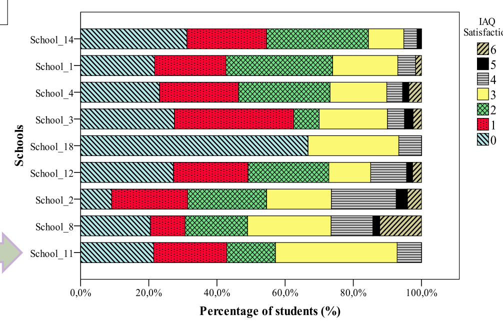
- 2nd part: IEQ Subjective Evaluation- Questionnaire survey *(IEQ perception & SBS symptoms)*
- 3rd part: Performance tests *(Numerical exercises &code of symbols)*
- Sample: 193 students participated, 655 questionnaires & 1310 tests collected in total

Results & Discussion

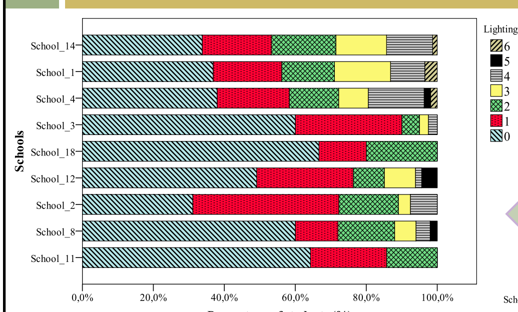


•Distribution of votes for the assessment of the thermal acceptability per school

Distribution of IAQ satisfaction votes per school (0: totally satisfied, 6: totally dissatisfied)

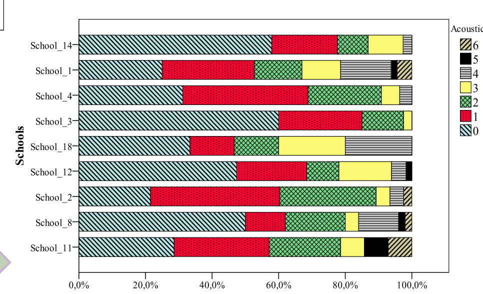


Results & Discussion



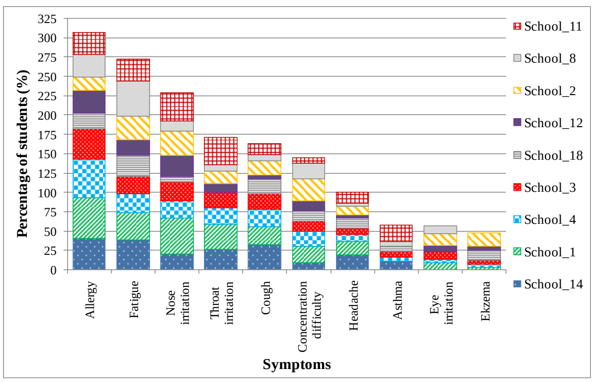
Distribution of votes referring to lighting satisfaction per school (0: very satisfied, 6: very dissatisfied)

Distribution of votes votes referring to acoustics satisfaction per school (0: totally satisfied, 6: totally dissatisfied)

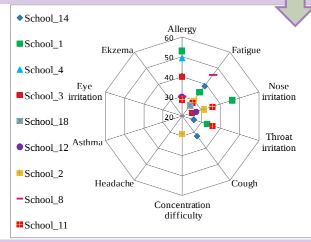


Results & Discussion

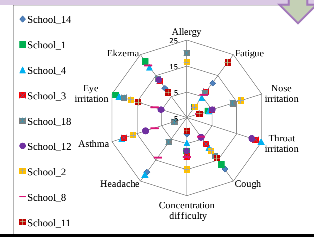
Distribution of students' sick building syndrome symptoms per school



for cases ≥ 25% of the total students/ school



for cases < 25% of the total students/ school



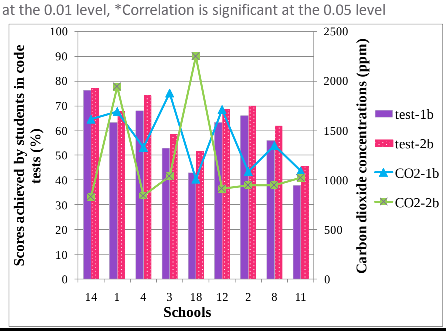
Results & Discussion

Pearson's Spearman's rho correlation coefficients between test scores and pollutant levels

Pearson correlation coefficient	CO	VOC	CO2	Spearman's correlation coefficient	CO	VOC	CO2
Test 1a	0.014	-0.008	-0.02	Test 1a	0.039	0.025	-0.104**
Test 1b	-0.196**	-0.093*	-0.082*	Test 1b	-0.055	-0.005	-0.063
Test 2a	-0.008	0.054	0.032	Test 2a	0.008	0.024	-0.049
Test 2b	-0.013**	-0.025	-0.110**	Test 2b	-0.120**	-0.058	-0.208**

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level

Averaged test scores per school and corresponding CO_2 concentrations. Greater scores achieved are linked to lower CO2 concentrations



Results & Discussion

Pearson's and Spearman's correlation coefficients between test scores and the subjective evaluation of the IEQ

Correlation coefficients	Tests	IAQ satisfaction	Air: Fresh-Stuffy	Odor	Lighting	Acoustics	Overall rating	Subjective PPD
Pearson	Test 1a	-0.016	-0.004	-0.036	-0.081*	-0.140**	-0.083*	0.114*
	Test 1b	-0.073	-0.131**	-0.072	0.089*	-0.116**	-0.121**	0.071
Spearman's	Test 1a	-0.058	-0.051	-0.068	-0.108**	-0.152**	-0.091*	0.122**
	Test 1b	-0.067	-0.112	-0.061	0.101**	-0.07	-0.096*	0.080*

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level

Conclusions

- Thermal comfort: Acceptable for the majority of the students in all the schools
- IAQ: Approx. 20% of the students were totally satisfied with the IAQ in most of the schools
- Lighting: Greater percentage of totally satisfied compared to the IAQ votes
- Acoustics: Strong differences in the distribution of votes from school to school
- The majority of students believed that the overall IEQ enhances their performance
- Allergy, fatigue, nose and throat irritation seemed to be the main SBS symptoms of students
- Significant negative correlations appeared between the test scores and CO& CO_2 concentrations
- Test scores also correlated to the evaluation of the IEQ by the students.

Thank you for your attention!

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Helmis Constantinos,
Santamouris Mat,
Sifnaios John,
Stathi Katerina

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INDOOR AND OUTDOOR DISTRIBUTION OF AIRBORNE POLLUTANTS IN NATURALLY VENTILATED CLASSROOMS

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Presentation Contents

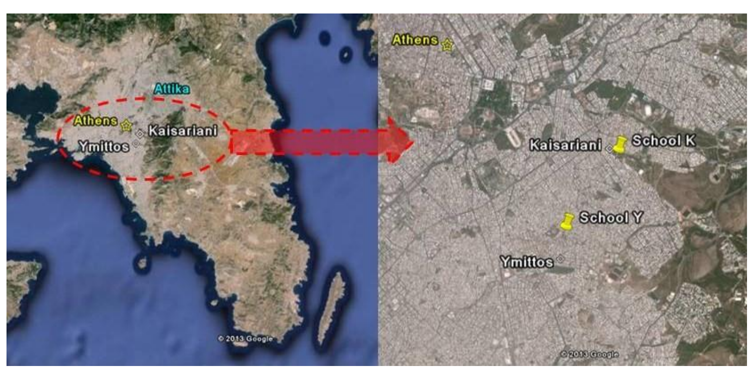
- Objectives
- Methodology
- Results & Discussion
- Conclusions

Objectives

- Compare the indoor to outdoor air pollutant concentrations
- Evaluate the indoor to outdoor (I/O) ratios of pollutants
- Examine vertical distributions of PM & airborne fungi

Methodology

Sample:
2 high schools



Measurements: From January to May 2011 once every 2 weeks per school

Measuring Instruments:

UFP

PM_{10}, $PM_{2.5}$, PM_1

CO_2

Airborne fungi

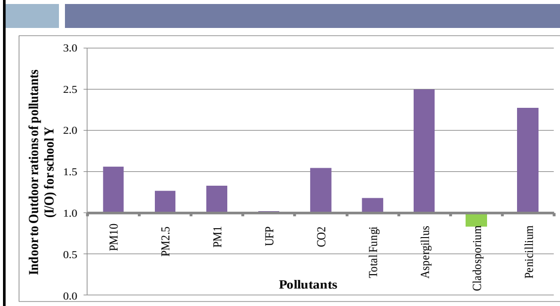
Results & Discussion

Correlation coefficients between the indoor & outdoor pollutants

	Ymhttos		Kaissariani	
Parameter	**Pearson**	**Spearman**	**Pearson**	**Spearman**
PM_{10}	0.705	0.667	0.628	0.595
$PM_{2.5}$	0.887**	0.857**	0.606	0.690
PM_1	0.909**	0.850**	0.451	0.571
UFP	0.425	0.595	0.866**	0.833*
CO_2	0.565	0.714*	0.337	0.383
Total fungi	0.240	0.405	-0.137	0.5
Aspergillus	-0.118	-0.117	-0.199	-0.067
Cladosporium	-0.114	0.06	0.263	0.396
Penicilium	0.157	0.406	-0.034	0.446

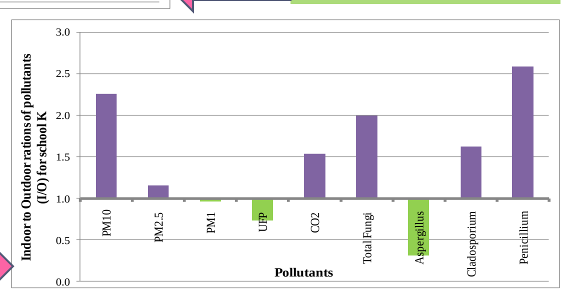
** Correlation is significant at the level 0.01, * Correlation is significant at the level 0.05

Results & Discussion



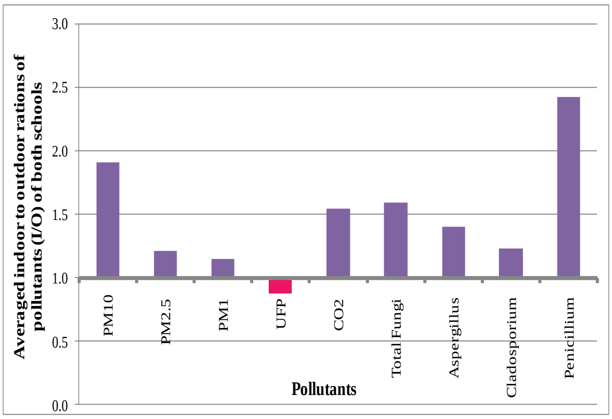
I/O ratios for school Y
I/O>1 for most cases
Cladosporium : I/O<1

I/O ratios for school K
I/O>1 for most cases
PM1: I/O~1
UFP: I/O<1
Aspergillus: I/O<1



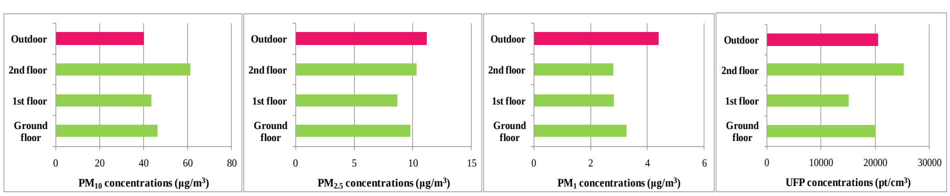
Results & Discussion

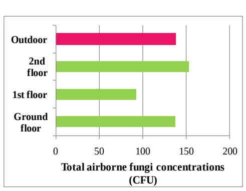
Averaged I/O concentration ratios for both schools



- I/O>1 for most cases
- Presence of indoor sources (increased presence of students, inadequate ventilation)
- UFP: I/O<1

Results & Discussion





Averaged vertical distribution profile of pollutants for both schools

- Ground floor concentrations similar to outdoor *(affected by vehicle emissions)*
- 1st floor concentrations lower than the ones of the 2nd *(loss from deflected traffic polluted air on the 1st floor from the surrounding trees that trap the particles)*
- 2nd floor concentrations greater than the ones of the 1st floor *(overwhelmed by regional sources influences)*

Conclusions

- Indoor PM concentrations correlated to the outdoor ones
- Indoor airborne fungi did not correlate to the outdoor
- Indoor concentrations greater than outdoor
- Vertical distribution profile similar for most pollutants
- Ground floor concentrations similar to outdoor
- 1st floor concentrations lower compared to ground floor
- 2nd floor concentrations greater than the 1st floor
- Regional sources & indoor activities affected the vertical distribution profile of pollutants

Thank you for your attention!

Dorizas Paraskevi Vivian*,
Assimakopoulos Margarita Niki,
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Instationary Operation of a Ventilation System

Martin Schmidt
AIVC Conference, 25.09.2013, Athens
EBC | Institute for Energy Efficient Buildings and Indoor Climate

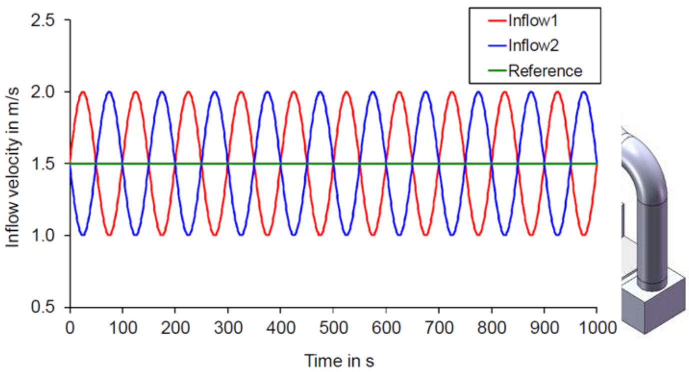
E.ON Energy Research Center

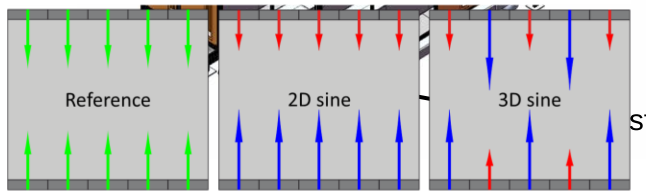
RWTH AACHEN UNIVERSITY

Ventilation setup

E.ON Energy Research Center

Slot Diffuser

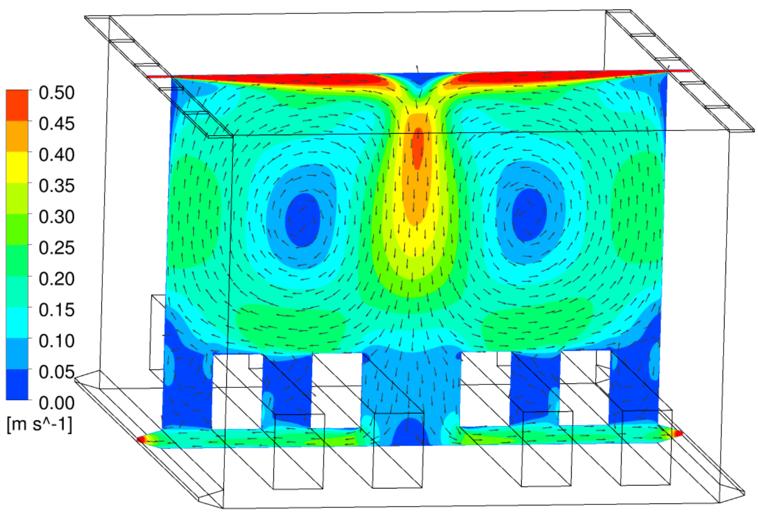




st air

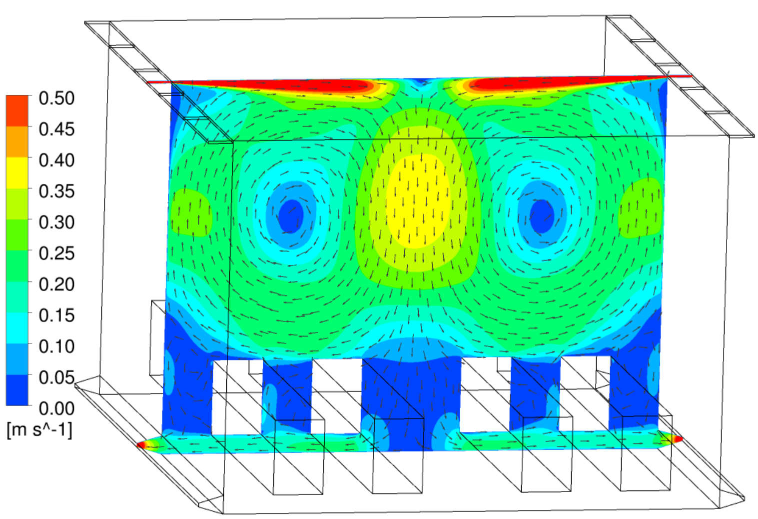
Results – Reference case

E.ON Energy Research Center



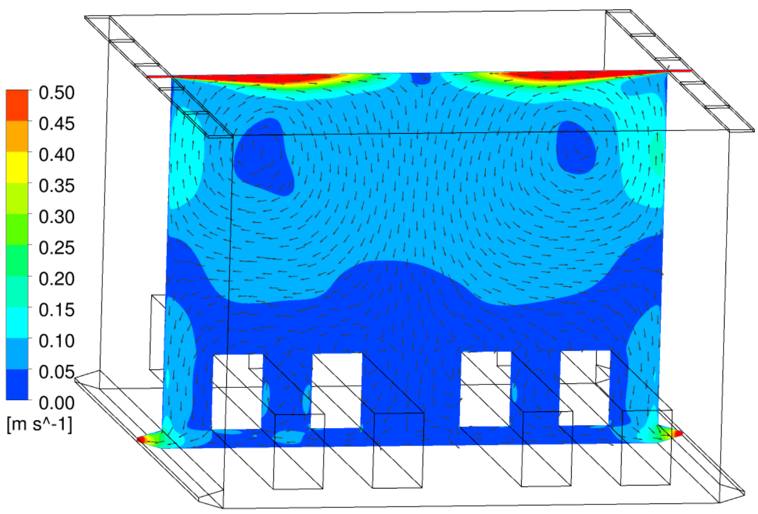
Results – 2D sine $T = 0.125 \cdot \tau_n$

E.ON Energy Research Center



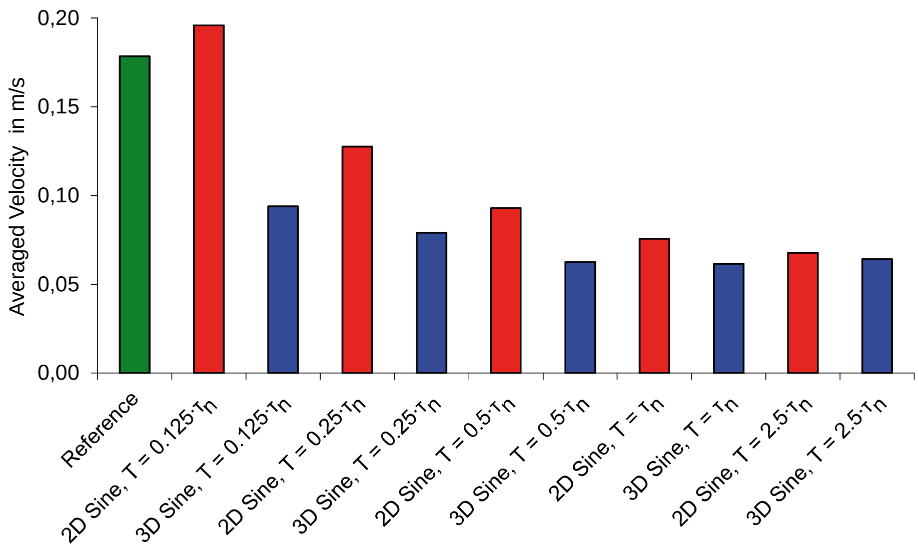
Results – 2D sine $T = \tau_n$

E.ON Energy Research Center



Results – Volume averaged velocity

E.ON Energy Research Center



Energy saving opportunities by suitable HVAC management: The Procuratie case in Venice

Luigi Schibuola - University IUAV of Venice

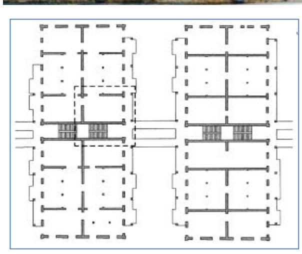
AIVC Congress – Athens 25 - 26 September 2013

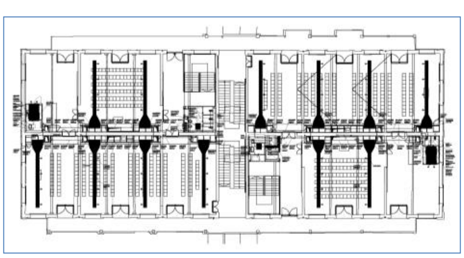
The building plant system

- Procuratie are old customs warehouses in the harbour area recently transformed in university facilities.

-From the original modular structure, classrooms of 1, 2 or 4 modules for 45, 90 or 180 seats have been obtained. Total design occupancy is 1760 persons for each building.

-Each module presents an air handling unit with Demand –Controlled Ventilation (DCV) with modulating valves controlled by CO_2 sensors.





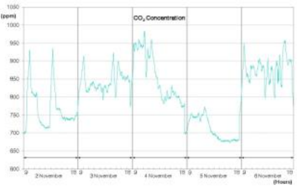
Experimental results

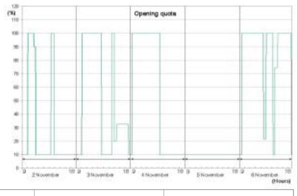
- A user friendly BMS permits a precise control of the internal parameters and their monitoring.

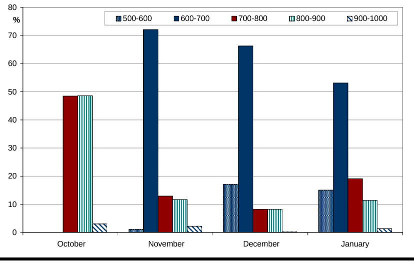
- The extreme variability of CO_2 concentration confirms a very variable presence and the difficult of a prediction in advance.

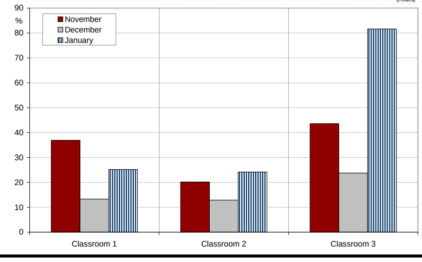
- Average opening quotas highlight the different ventilation requirement in different period.

- In total the average opening amount is 31%.









Optimization of the control parameters

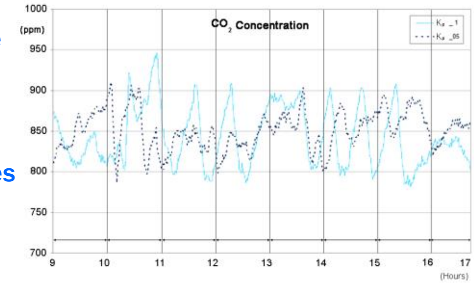
- The presence of modulating servomotors has permitted to use the opportunity offered by PID control implemented in the BMS.

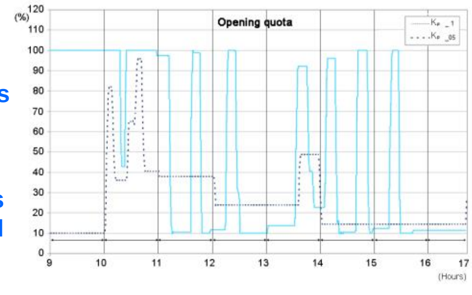
-But an optimization was necessary because initially the modulating valves operated in on-off control owing to a very little hysteresis (5 ppm).

-A tuning of the PID parameters was also obtained by using data from monitoring.

- In detail the original (gain) K_p =1 was changed to the best value 0.5 as indicated by tests.

-So we have less drastic interventions and oscillations of CO_2 %. The control more closely follows the demand.





Some conclusions

-School buildings are particularly suitable to take advantage from a variable ventilation rate by an automatic control based on CO_2 sensors.

-The high variability of the occupancy permits a strong reduction of the average ventilation flow rate if compared to the case of a constant ventilation flow rate.

- In this way DCV permits to achieve relevant energy and economy savings also in historic buildings subject to monumental restrictions.

- But a correct tuning of the parameters of the control systems is fundamental to optimize the working of the plant.

- In presence of a user friendly BMS, monitoring can permit an investigation of the real operating conditions in order to achieve this optimization.

High efficiency retrofit in historic buildings by demand-controlled ventilation

Luigi Schibuola - University IUAV of Venice

Crucifers complex

I
U
A
V

The main cloister of Tolentini

AIVC Congress – Athens 25 - 26 September 2013

Crucifers complex

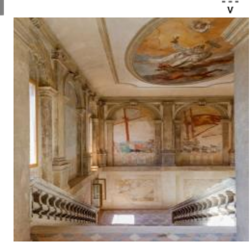
-The ancient Crucifers complex will be transformed into a residential facility for the university.

-The convent and hospital was founded in the 12th century by the order of Crucifers. It is subject to heavy monumental preservation restrictions.

- Foreseen 177 flats for students, 32 residential units for visiting professors and various services open also to the city community

- Internal plants are fan-coils or radiant panels. Demand–Controlled Ventilation (DCV) is present for the bar, restaurant and residential units.

-The heat and cold are produced by an electric heat pump and condensing boilers.



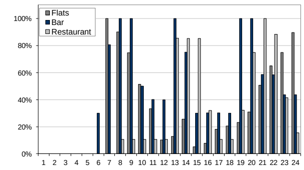
Crucifers: DCV performance analysis

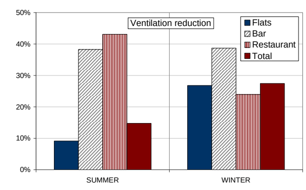
- As the work is in progress, the analysis was carried out by simulation.

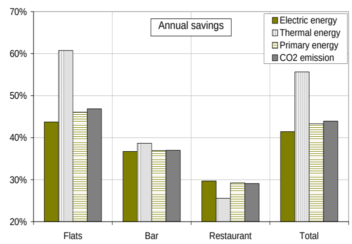
-Typical distributions of the hourly occupancy in the various periods have been obtained by investigation for similar facilities already present in Venice.

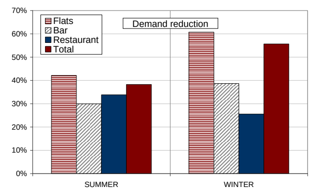
- The reduction of ventilation amount and energy demand were calculated in comparison with the case of constant ventilation air change during the working hours.

- The consequent annual energy savings are remarkable









3

Tolentini

- The former Convent of Tolentini built at the end of 1500.

-The second and third floors will be transformed into new reading rooms of the university library. In the first floor we have new plants for the Aula Magna.

-For the reading rooms, primary air and fan-coils hidden behind the new cladding and a raised floor.

- Aula Magna will be totally air-conditioned by two AHUs. For a AHU final ducts are under the platform of the speakers.

Views of the work in progress

First floor of the library

Aula Magna

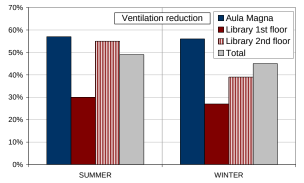
Tolentini

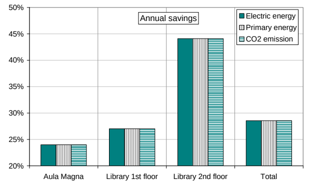
-DCV by CO_2 sensors installed in the return ducts. The control acts on modulating dampers.

-DCV is independent for the first and second floor of the library.

-For Aula Magna DCV acts on the dumpers for air intake and expulsion of the two installed AHU.

-Also in this case the analysis points out an excellent energy saving.





Conclusions

-DCV can give a fundamental contribution to the reduction of the energy requirement in historic buildings re-used for public functions.

-But, above all, its realization does not involve problems regarding restrictions about preservation exigencies.

Uncertainties in different level assessments of domestic ventilation systems

Regina Bokel, Zhiming Yang, Hans Cauberg

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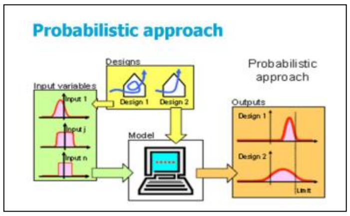


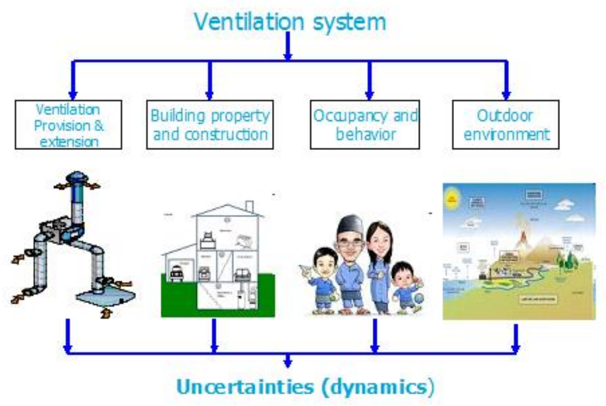
Assessment levels

- Project

- Global

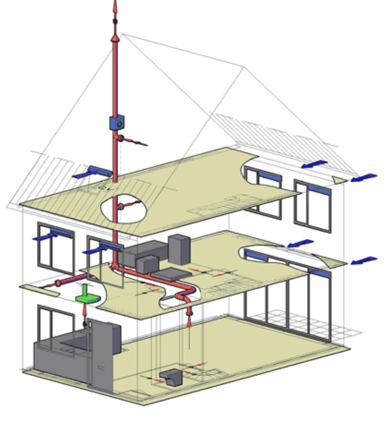
- Design

Subtitle

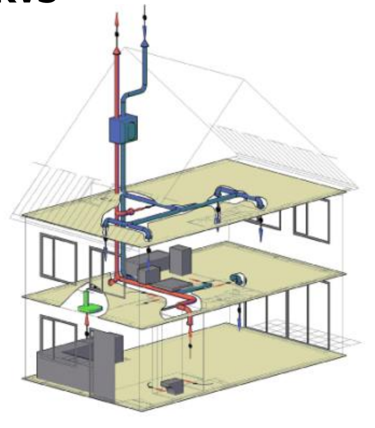


EXAMPLE:
MENSS = Mechanical Exhaust with Natural Supply System
BHRVS = Balanced Ventilation with Heat Recovery System

MENSS



BHRVS



- Poster:
  - Macedonia Foyer of the Divani Caravel Hotel
- Article:
  - page 505 of the conference proceedings

Wednesday 25 September 2013

17:00-18:30: Parallel Session 3C: Long & Short oral presentation session- Methods for characterizing airtightness – Durability

Chairpersons: Rémi Carrié, Derek Sinnott

- **Durability and measurement uncertainty of airtightness in extremely airtight dwellings** Arnold Janssens, Belgium
- **Airtightness of buildings - Calculation of combined standard uncertainty** Christophe Delmotte, Belgium
- **Impact on IAQ of building material emitted pollutants through building leaks: State of the art and sample testing methodology** Sarah Juricic, France
- **Application of blower door test measurements in the evaluation of workmanship influence in airtightness** Nuno Ramos, Portugal
- **Control of airtightness quality management scheme in France: results, lessons and future developments** Sandrine Charrier, France
- **Airtightness of very large volume buildings: Measuring method and first results** Florent Boithias, France
- **Comparison of different air tightness and air exchange rate measurements in a very small test building before and after sealing** Stanislavs Gendelis, Latvia

Durability and measurement uncertainty of airtightness in extremely airtight dwellings

W. Bracke
J. Laverge
N. Van Den Bossche
A. Janssens

Presenter: A. Janssens

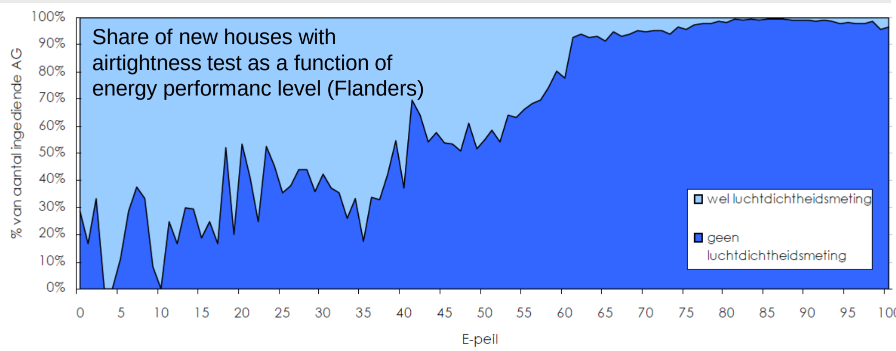
Athens • 25-26 September 2013

Outline

- Introduction
- Test repeatability and seasonal variations
- Durability of airtightness
- Conclusions

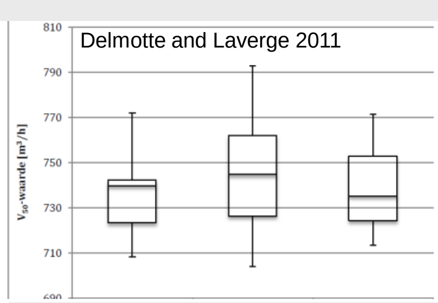
Introduction

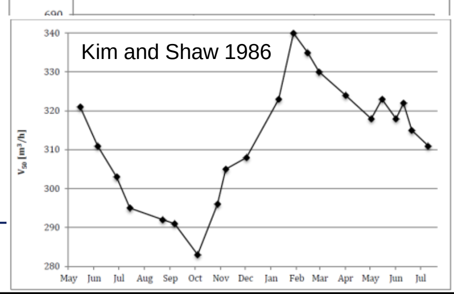
- Airtightness important to meet energy performance requirements
- Increasing number of new houses with airtightness test
- Result of test may have financial consequences (fines, subsidies)
- Reliability of test?
- Long-term performance of airtightness, specifically for airtight houses?



Introduction: what is known from literature?

- Repeatability
  - Measuring procedure EN13829, method A
  - St. deviation 1-2%
  - Max. variation 4-5%
- Seasonal variation
  - Reported variations < 45%
    - Mainly results from leaky houses
  - Swelling-shrinkage of wood
  - Freezing-thawing of water
- Durability
  - No conclusive results





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Outline

- Introduction
- Test repeatability and seasonal variations
- Durability of airtightness
- Conclusions

Test objects for analysis of airtightness test repeatability and seasonal variation of airtightness

- Semi-detached passive show house
- Masonry construction
- n_{50} = 0.55 h^{-1} °2009

- Detached passive show house
- Woodframe construction
- n_{50} = 0.21 h^{-1} °2009

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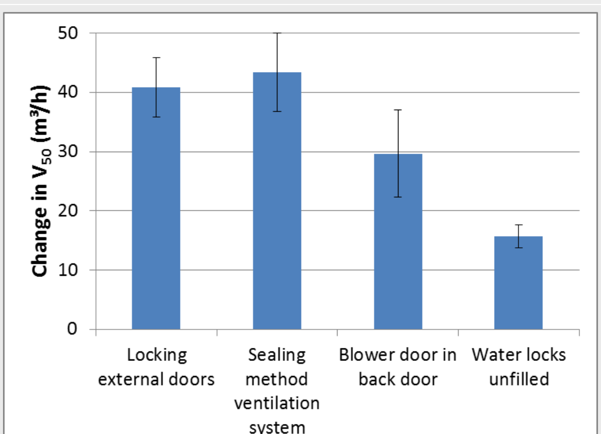
Influence of differences in preparation
-room for interpretation EN13829

- Position of blower door
- Locking of external doors
- Method of disconnecting and sealing ventilation system
- Filling water locks

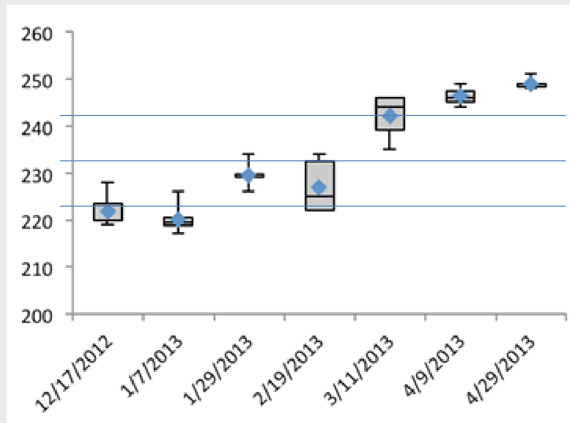
Influence of differences in preparation



- Apparently small differences in preparation
- Relatively large impact on measured leakage in passive houses
- ΔV_{50} of 50 m³/h represents 20 to 35% change in n_{50}

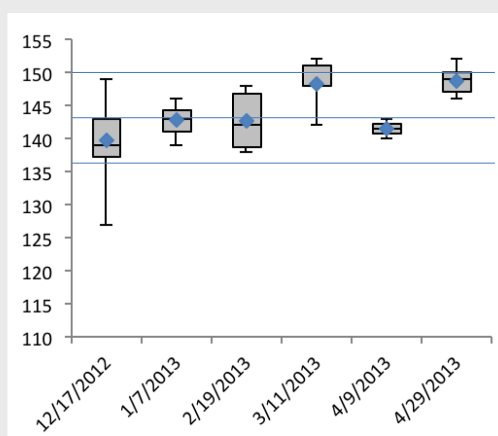
Repeatability and seasonal variation masonry house

- 7 test days in 5 months
- 48 tests in total
- Repeatability in line with literature
- Increasing leakage over time (+12%)



Repeatability and seasonal variation woodframe house

- 6 test days in 5 months
- 44 tests in total
- Repeatability in line with literature
- No seasonal variation



Outline

- Introduction
- Test repeatability and seasonal variations
- Durability of airtightness
- Conclusions

Test objects for analysis of durability

- 15 inhabited dwellings from passive house estates
  - +2 show houses
- Semi-detached and terraced masonry construction
- Age inbetween 3 and 27 months
- New test results compared to original certification tests
  - Identical test preparation?

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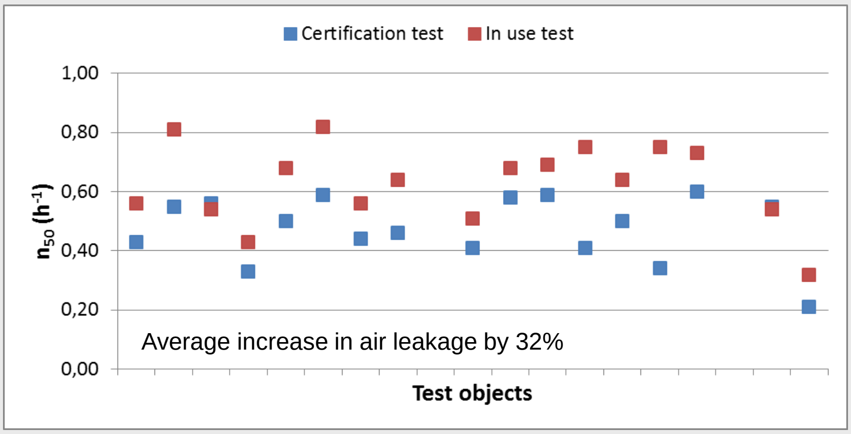
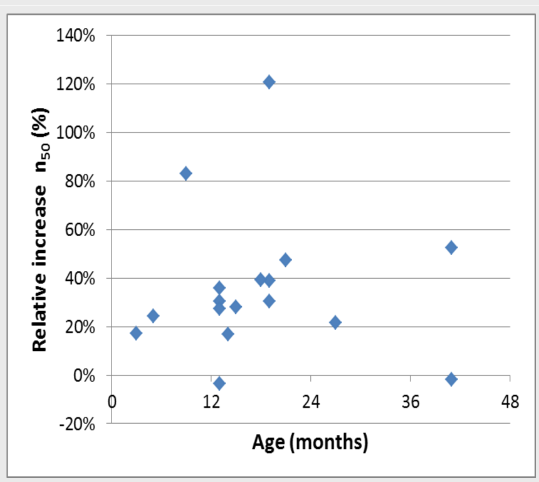
Durability of airtightness



Durability of airtightness: relative increase

- No significant relation with age
- Part of increase might be explained by differences in building preparation
  - Ventilation systems
  - Locking doors
- Observed leakage
  - Operable doors
  - Service penetration



Conclusions

- Study on air leakage in extremely airtight houses
- Relative repeatability intervals in line with literature
  - More specific building preparation guidelines needed for better reproducibility of ambitious leakage requirements
- No clear evidence of seasonal variation of air leakage
- Long-term performance of airtightness
  - 90% of houses showed larger leakage over time
  - Relative degradation of airtightness, but small in absolute values

Ευχαριστώ για την προσοχή σας!

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Airtightness of buildings

Calculation of combined standard uncertainty

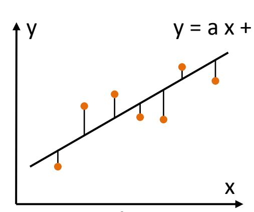
Christophe Delmotte, Ir
Laboratory Air Quality and Ventilation
BBRI – Belgian Building Research Institute

ISO 9972 – Global procedure

Can we estimate the uncertainty of the results?

- Temperatures
- Pressures
- Air flows

→



↓

Air leakage rate

- Reference values (e.g. volume) →

↓

Derived quantities

Combined standard uncertainty

Standard uncertainty of the result (y) of a measurement, when that result is obtained from the values of a number (N) of other quantities (x_i) through a functional relationship (f)

$$u_c^2(y) = \sum_{i=1}^{N} \left(\frac{\partial f}{\partial x_i}\right)^2 u^2(x_i) + 2\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} \left(\frac{\partial f}{\partial x_i}\right)\left(\frac{\partial f}{\partial x_j}\right) u(x_i)\,u(x_j)\,r(x_i, x_j)$$

Combined standard uncertainty

Can be calculated at each step of the procedure if we know:

- The standard uncertainty of the input
- The function

Standard uncertainty of the input

Type A evaluation of standard uncertainty

- Standard deviation of the mean when independent observations have been obtained under the same conditions of measurement

May be used for
the zero-flow pressure difference

Is it applicable for the pressure – airflow couples?

- Do we measure n times the same point?
- Do we measure 1 time n different points?

Standard uncertainty of the input

Type B evaluation of standard uncertainty

- For an estimate of an input quantity that has not been obtained from repeated observations
- Evaluated by scientific judgment based on
  - manufacturer's specifications
  - data provided in calibration and other certificates
  - previous measurement data…

May be used for temperature, volume…
and pressure – airflow couples

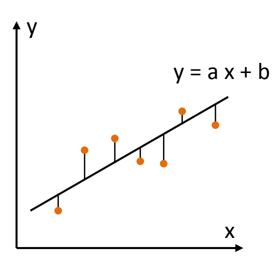
Functions used in ISO 9972

All functions are available in the standard

Except those for the linear regression

Function	Combined standard uncertainty
$T_{int} = \frac{T_{int,1} + T_{int,2}}{2}$	$u_c(T_{int}) = \sqrt{\frac{u^2(T_{int,1})}{4} + \frac{u^2(T_{int,2})}{4}}$
$T_e = \frac{T_{e,1} + T_{e,2}}{2}$	$u_c(T_e) = \sqrt{\frac{u^2(T_{e,1})}{4} + \frac{u^2(T_{e,2})}{4}}$
$\Delta p_i = \Delta p_{m,i} - \frac{\Delta p_{0,1} + \Delta p_{0,2}}{2}$	$u_c(\Delta p_i) = \sqrt{u^2(\Delta p_{m,i}) + \frac{u^2(\Delta p_{0,1})}{4} + \frac{u^2(\Delta p_{0,2})}{4}}$
$q_{m,i} = q_{r,i}\sqrt{\frac{T_{int}}{T_0}}$	$u_c(q_{m,i}) = \sqrt{\left(\sqrt{\frac{T_{int}}{T_0}}\, u(q_{r,i})\right)^2 + \left(\frac{q_{r,i}}{2\,T_{int}}\sqrt{\frac{T_{int}}{T_0}}\, u_c(T_{int})\right)^2}$

Ordinary method of least-squares



Consists of finding the line y = a x + b that minimalize the sum of the squares of the difference between the measurement points and the line

Ordinary method of least-squares

Applicable when

all the y values are equally uncertain

- $y_i = \ln(q_{env,i})$

and the uncertainties on x are negligible

- $x_i = \ln(\Delta p_i)$

ISO 9972 measurements
do not respect these conditions

Ordinary method of least-squares

The standard uncertainties
of the constant a and b are given by

$$u_c(a) = \sqrt{\frac{N\ s^2}{N\sum x_i^2 - (\sum x_i)^2}} \qquad u_c(b) = \sqrt{\frac{s^2\ \sum x_i^2}{N\sum x_i^2 - (\sum x_i)^2}}$$

- Based on the uncertainty of the input

$$s^2 = u_c^2(y)$$

- Or based on the scattering
of the y_i values around the regression line

$$s^2 = s^2(y) = \frac{\left(y_i - y_{i,est}\right)^2}{N-2} = \frac{(y_i - a\,x_i - b)^2}{N-2}$$

Weighted method of least-squares

When calculating the line y = a x + b
the points with less uncertainty
receive more weight

$$w_i = \frac{1}{u_c^2(y_i)}$$

- Applicable when
  all the y values are not equally uncertain
  and the uncertainties on x are negligible

Simplification of the weighted method

Supposing that all $q_{env,i}$ values
are equally uncertain

$$u_c(q_{env,i}) = C \qquad C = constant$$

$$y_i = \ln(q_{env,i})$$

$$then \ \ u_c(y_i) = \sqrt{\left(\frac{u_c(q_{env,i})}{q_{env,i}}\right)^2} = \frac{u_c(q_{env,i})}{q_{env,i}} = \frac{C}{q_{env,i}}$$

$$w_i = \frac{1}{u_c^2(y_i)} = \frac{q_{env,i}^2}{C^2} \longrightarrow w_i = q_{env,i}^2$$

Weighted method of least-squares

When calculating the line y = a x + b
the points with less uncertainty
receive more weight

$$w_i = \frac{1}{u_c^2(y_i) + a^2\, u_c^2(x_i)}$$

- Applicable when
  all the y values are not equally uncertain
  and the uncertainties on x are not negligible

Weighted method of least-squares

The standard uncertainties
of the constant a and b are given by

$$u_c(a) = \sqrt{\frac{\sum w_i}{w_i \sum w_i x_i^2 - (\sum w_i x_i)^2}} \qquad u_c(b) = \sqrt{\frac{w_i x_i^2}{w_i \sum w_i x_i^2 - (\sum w_i x_i)^2}}$$

Their estimated correlation coefficient is given by

$$r(a\,,b) = -\frac{\sum w_i x_i}{\sqrt{w_i \sum w_i x_i^2}}$$

Rest of the calculation

Combined standard uncertainty of the air leakage and the derived quantities

$$u_c(q_{50,p}) = \sqrt{\begin{aligned}&\left(e^b\, 50^a \left(\frac{T_0}{T_{int}}\right)^{1-a} \ln\left(50\frac{T_{int}}{T_0}\right) u_c(a)\right)^2 + \left(e^b \left(\frac{T_0}{T_{int}}\right)^{1-a} 50^a\, u_c(b)\right)^2 \\ &+ \left(\frac{e^b\,(a-1)}{T_{int}}\, 50^a \left(\frac{T_0}{T_{int}}\right)^{1-a} u_c(T_{int})\right)^2 \\ &+2\left(e^b \left(\frac{T_0}{T_{int}}\right)^{1-a} 50^a\right)^2 \ln\left(50\frac{T_{int}}{T_0}\right) u_c(a)\, u_c(b)\, r(a\,,b)\end{aligned}}$$

Yes, it is possible to estimate the uncertainty of the results

Use the weighted method of least-squares (y and x) in place of the ordinary one

There are other sources of uncertainty

- Wind variation
- Uneven pressure around the building
- Uneven size and type of openings…

The combined standard uncertainty must be considered as a part of the total uncertainty

Impact on IAQ of building material pollutants through building leaks

Author : Sarah JURICIC

Co-authors : Catherine HUNG and Florent BOITHIAS

CETE de Lyon

25/9/2013

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RÉPUBLIQUE FRANÇAISE

Ministère de l'Écologie, du Développement durable et de l'Énergie

CETE de Lyon

From January 1st 2014 on all 8 CETE, Certu, Cetmef and Sétra evolve into a public organization called CEREMA.

Key points

- Large scale renovation program in France
- Airtightness levels achieved low → **numerous leaks** in the envelope
  - A **threat** to IAQ ?

From the IAQ point of view, what is the importance of airtightness treatment in achieving successfully a retrofit operation ?

What is the impact on IAQ of a leaky retrofitted wall ?

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Three ways to look at it ...

- Transfer of pollution from **outdoors** to **indoors**
  - Pollutant penetration through leaky walls relalitevely well-documented.
  - Liu and Nazaroff (2003) and Olea et al (2007)
- Airflow induced by envelope leakages cause **ventilation disorders**
  - Some ventilation systems identified as unsuitable with poor airtightness (Brogat, 2003)
  - Not the focus of this paper, although complementary studies could be performed
- Retrofitted wall as a **source of pollutants** itself
  - Building materials known as pollutants sources
  - Complex interdependance between hygrothermal behaviour and airtightness levels required
  - Infiltration rate relevant regarding pollutants from concealed spaces (Hayashi et al, 2008)

Quantifying the impact of poor airtightness on IAQ **two** methodologies

- Sample testing in laboratory conditions
  - Controlled ambiant conditions
  - Wall sample submitted to depressurization inducing an airflow
  - Measurement of VOCs at different depressurization levels
- On site measurements campaign
  - Target : dwellings undergoing retrofit operations
  - Three measurements campaigns :
    - before, after and 6 months after retrofit
  - Measurement of VOCs at different depressurization levels

Discussion and perspectives

- Expected
  - quantification of the influence of leaky retrofitted walls on IAQ
  - Influence of the overal level of airtightness, assessing the need to require proper airtightness treatment during a retrofit
- These future tests take place in a larger project led by the CETE de Lyon
  - IAQ could be identified as concern as important as energy consumption in a retrofit operation
  - Results shall help identifying the keys to a successful renovation strategy

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FIN

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Ministère de l'Écologie, du Développement durable et de l'Énergie

Application of blower door measurements in the evaluation of workmanship influence in airtightness

Nuno M. M. Ramos, Vasco P. de Freitas, Pedro F. Pereira, António Curado and Alexandre Machado

(Presented by **Pedro F. Pereira**)

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

LFC

SCOPE

A large sample of identical dwellings was analyzed using the blower door test. This analysis was performed in a set of dwellings that were identical and also identically renovated allowing for the comparison of two different contractors involved in the retrofit. The blower door test was used as an indicator of workmanship quality.

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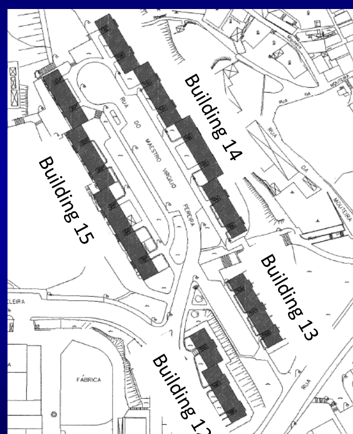
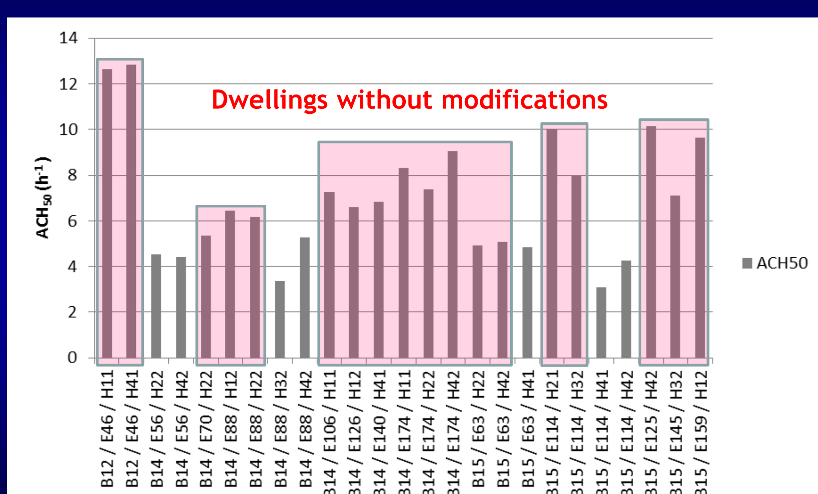
CASE STUDY



The neighborhood has 4 detached buildings with similar typologies. It has been retrofitted in 2009 and 2010, based on the same design project for all buildings. The contractor "C1" was responsible for the retrofitting of the buildings 12 and 15 and the contractor "C2" for the building 14.

RESULTS



RESULTS AND CONCLUSIONS

Type of dwellings		Specimens	q_{50} (A) mean ($m^3/h \cdot m^2$)	q_{50} (A) COV (%)	ACH_{50} mean h^{-1}	ACH_{50} COV (%)
All dwellings		25	25.75	35	6.94	38
All dwellings	T1	4	23.64	26	10.48	26
	T3	15	27.97	35	6.46	36
	T4 (A and B)	6	21.60	31	5.78	25
All dwellings without modifications	T1	4	23.64	26	10.48	26
	T3	9	34.33	21	7.93	21
	T4 (A and B)	5	22.53	31	6.08	22
Modified dwellings	T3	6	18.43	32	4.24	32
All dwellings without modifications by contractor	T1 - B12 (C1)	2	28.72	1	12.75	1
	T1 - B14 (C2)	2	18.56	14	8.22	14
	T3 - B14 (C2)	6	29.98	11	6.93	11
	T3 - B15 (C1)	3	43.05	3	9.94	3
	T4 (A and B) - B14 (C2)	1	20.79	-	5.34	-
	T4 (A and B) - B15 (C1)	4	22.97	35	6.26	24

- The work by two different contractors was compared based on blower door tests, allowing to find differences of up to 50% increased ACH50 mean values in identical typologies. Based on that it’s possible to say that contractor C2 is better than C1;
- A COV = 11 % was found for a sample of 6 identical dwellings retrofitted by the best contractor. A high COV could also be an indicator of poor workmanship, but in this case there was not enough data to support that;
- User action can have an important effect on building airtightness. In this case of social housing where heating is reduced to an absolute minimum, the users acted on air inlets in several apartments, reducing ACH50 mean values to almost 50% of the initial values. This action is not necessarily good as it may result in poor ventilation.

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LFC

Energy conservation technologies for mitigation and adaptation in the built environment

The role of ventilation strategie and smart materials

34th AIVC Conference

3rd TightVent Conference

2nd Cool Roofs' Conference

1st VentiCool Conference

Control of airtightness quality management scheme in France

Lessons and future developments

Sandrine Charrier

25-26 September 2013, Athens, Greece

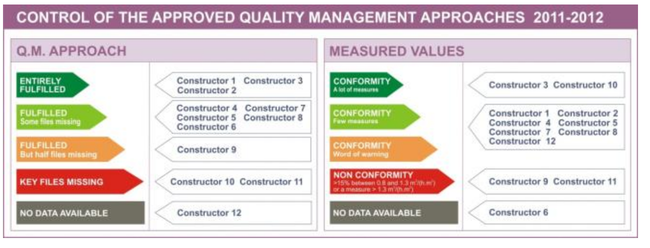
Context

- **The French energy performance regulation allows 2 ways to justify the airtightness value of building envelope**
  - By a measure
  - By the application of a certified quality management (QM) approach
- Since 2007, 51 QM approaches have been certified.

- **The French State has set up a control campaign in order to check the actual implementation of the certified approaches**
  - The first campaign occurred in 2011 2012
  - The paper aims to present the control campaign and its results.

Control campaign

- **The control campaign was divided into two parts:**
  - **A qualitative control:** For a sample of buildings, control of the fullfilment of some files
  - **A quantitative control:** For a sample of buildings, control of the effective airtightness level
  - Control done by independant state employees
- **Results: a synthesis with a double label**



Acknowledgments

Thank you for your attention

Sandrine Charrier

Control of airtightness quality management scheme in France
Lessons and future developments

25-26 September 2013, Athens, Greece

The authors are grateful to the French ministry for ecology, sustainable development, and energy (MEDDE), and in particular to the DGALN Department, for its support throughout this work.

The responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the Ministry.

AIRTIGHTNESS OF VERY LARGE VOLUME BUILDINGS

MEASURING METHOD AND FIRST RESULTS

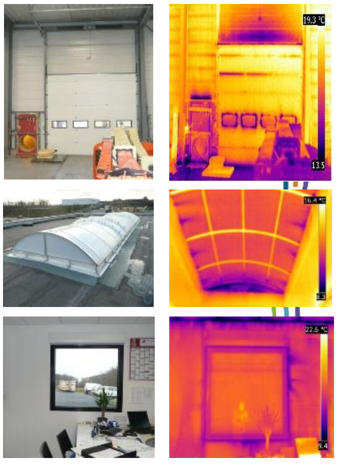
Florent BOITHIAS, Sylvain BERTHAULT, Sarah JURICIC

CETE de Lyon (future CEREMA)

Crédit photo : Arnaud Bouissou/MEDDE

Aim of the study

- Measure **large commercial buildings** to get:
  - airtightness levels
  - frenquently observed leakage points
- Data is then used to:
  - propose **legal requirements** to the Ministry of construction
  - provide **technical advice** to building professionals



Methodology

- To measure large commercial buildings, a specific tool called **MEGAFAN** is used
- Specifications:
  - Max. air flow rate: **300 000 m3/h**
  - Fan diameter: **2 m**
  - Connection to the building: flexible tube and false door

Results

- 8 commercial buildings: volume from **3 500** to **53 000** m^3
- Main building material: **steel**
- Most frequent **leaks**:
  - Pipe, stake and beam passages passages
  - rooflights
  - window and door jambs (especially emergency exits)
  - badly joint cladding pieces
- Buildings before 2010: n50 = **1.3** to **29.2**
- Buildings after 2010: n50 = **0.28** to **0.93**

LATVIJAS UNIVERSITĀTE
UNIVERSITY OF LATVIA

34th AIVC Conference

Comparison Of Different Air Tightness and Air Exchange Rate Measurements in Very Small Test Buildings

Staņislavs Gendelis, Andris Jakovičs, Andrejs Nitijevskis, Jānis Ratnieks

ERAF EIROPAS REĢIONĀLĀS ATTĪSTĪBAS FONDS
EIROPAS SAVIENĪBA
IEGULDĪJUMS TAVĀ NĀKOTNĒ

This research work is supported by ERAF project 2011/0003/2DP/2.1.1.1.0/10/APIA/VIAA/041

VTPMML

INTRODUCTION

- Five test buildings (wood, aerated concrete, ceramics, plywood, filled ceramics) with the same *U*-values for all boundary structures (window, door).
- Buildings are equipped with the same air-air heat pumps.
- The main aim is to compare the energy consumption.
- Air tightness and air exchange rate are measured.

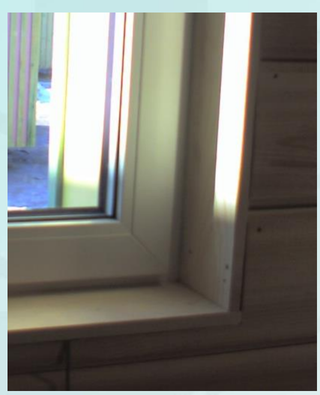
VTPMML

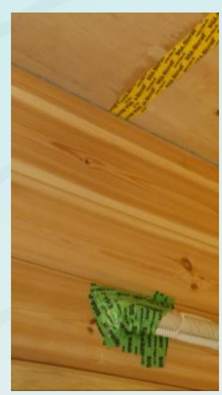
AIR TIGHTNESS – 1

Fan model (maximum flow)	Additional membrane	Air exchange rate n_{50} (1/h)	Air permeability q_{50} (m/h)
Model 3000 (max 14440 m^3/h)	No	**2.36**	**1.18**
Model 200 (max 1155 m^3/h)	No	**1.97**	**0.98**
Model 200 (max 1155 m^3/h)	Yes	**1.97**	**0.98**

VTPMML

AIR TIGHTNESS - 2





Log building at different construction stages	Air exchange rate n_{50} (1/h)	Air permeability q_{50} (m/h)
Stage 1. Unfinished interior	**4.26**	**2.13**
Stage 2. Finished interior, not sealed joints	**1.97**	**0.98**
Stage 3. All joints are sealed	**1.91**	**0.94**

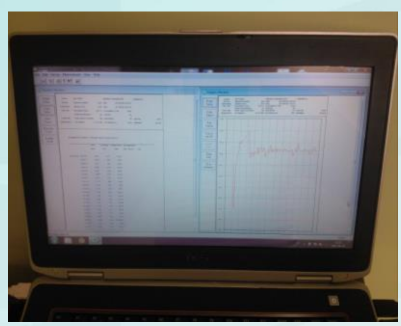
VTPMML

AIR TIGHTNESS - 3

Test building after sealing (construction description)	Air exchange rate *n* (1/h)		Air perme-ability *q* (m/h)	
	n_{50}	n_4	q_{50}	q_4
LOG (log house + internal insulation)	**1.91**	**0.36**	**0.94**	**0.18**
EXP (polystyrene filled ceramic blocks)	**0.67**	**0.09**	**0.34**	**0.05**
AER (aerated concrete + external insulation)	**1.12**	**0.18**	**0.56**	**0.09**
CER (ceramic blocks + external insulation)	**1.47**	**0.20**	**0.70**	**0.10**
PLY (plywood boards filled with mineral wool)	**0.93**	**0.13**	**0.46**	**0.06**

VTPMML

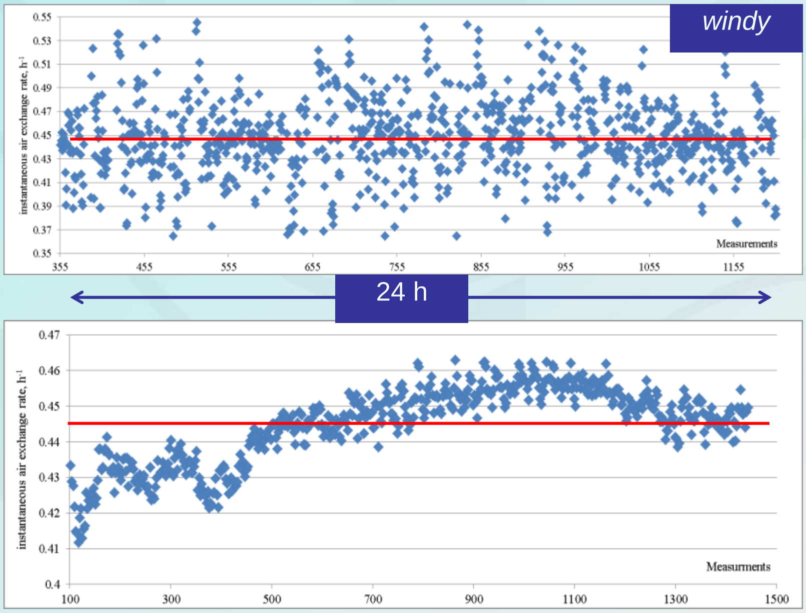
AIR EXCHANGE RATE - 1



Test building after sealing (construction description)	Ventilation		Air exchange *n* (1/h)
	system	opening	
LOG (log house +internal insulation)	On	Open	**0.45±0.03**
LOG (log house + internal insulation)	Off	Sealed	**0.03±0.01**
EXP (polystyrene filled ceramic blocks)	On	Open	**0.48±0.02**
AER (aerated concrete + external insulation)	On	Open	**0.50±0.03**
CER (ceramic blocks + external insulation)	On	Open	**0.43±0.04**
PLY (plywood boards filled with mineral wool)	On	Open	**0.44±0.01**

VTPMML

AIR EXCHANGE RATE - 2



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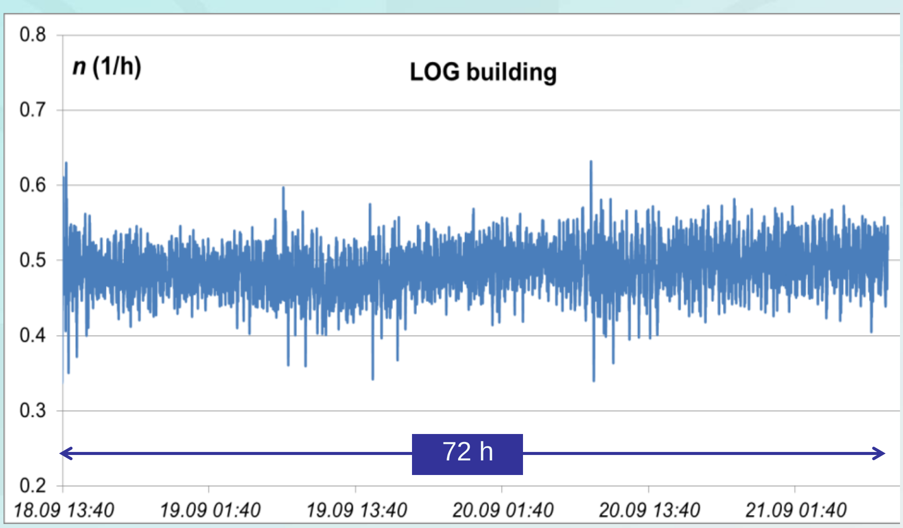
AIR EXCHANGE RATE - 3



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CONCLUSIONS

- Air filtration **cannot be completely excluded** (especially for wooden materials).
- Standard blower door fan used in small buildings may cause remarkable errors due to **poor accuracy at very small flows**.
- Tracer gas method demonstrated the **dominant role of mechanical ventilation** in overall air exchange process in very tight buildings.
- Comparing blower door tests and evaluated actual air exchange, it has been established that correlation between **those parameters can be fixed very approximately**.

VTPMML

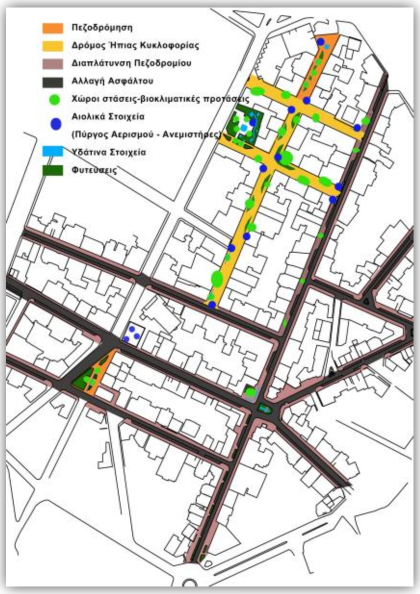
Wednesday 25 September 2013

17:00-18:30: Parallel Session 3D: Short oral presentation session- Applications of cool materials in the built environment

Chairpersons: Argyro Dimoudi, Triantafullia Nikolaou

- **Use of cool materials in outdoor places in order to mitigate the urban heat island in a medium size city in Greece** Argiro Dimoudi, Greece
- **A case study of sustainable urban planning with the use of a decision support system** Afroditi Synnefa, Greece
- **Using cool paving materials to improve microclimate of urban areas- Design realisation and results of the Flisvos project** Mat Santamouris, Greece
- **Experimental determination of comfort benefits from cool-roof application to an unconditioned building in India** Vishal Garg, India
- **Simulation of the cooling effect of roof added photovoltaics** Vasilios Kapsalis, Greece
- **Experimental analysis of small scale roof ponds, protected by a variety of materials in different positions in regard to water level** Artemisia Spanaki, Greece
- **Cool fluorocarbon coatings in industrial buildings: Optical properties and energy performance** Eleni Mastrapostoli, Greece
- **Urban gardens: As a solution to energy poverty and urban heat island** Vasiliki Tsilini, Greece
- **A holistic approach of the development and application of innovative composite cool-thermal insulating materials** Sofia – Natalia Boemi, Greece

- **Solar optical and thermal properties of mesoporous materials for cooling applications compared to typical building materials** Spyros Krimpalis, Greece
- **Heat island phenomenon and cool roofs mitigation strategies in a small city of elevated temperatures** Eftychios Vardoulakis, Greece
- **Assessing thermal risk in urban areas – An application for the urban agglomeration of Athens** Anastasios Polydoros, Greece
- **Evaluation of the application of cool materials in urban spaces: a case study in the center of Florina** Stamatis Zoras, Greece



USE OF COOL MATERIALS IN OUTDOOR PLACES IN ORDER TO MITIGATE THE URBAN HEAT ISLAND IN A MEDIUM SIZE CITY IN GREECE

A. Dimoudi[1]
S. Zoras[1]
A. Kantzioura[1]
X. Stogiannou[1]
P. Kosmopoulos[1]
C. Pallas[2]

1 Lab of Envir and Energy Efficient Design of Buildings &Settlements, Dep of Environment Engineering, Democritus University of Thrace, Greece

[2] Serres Municipality

Aim - Paper Outline

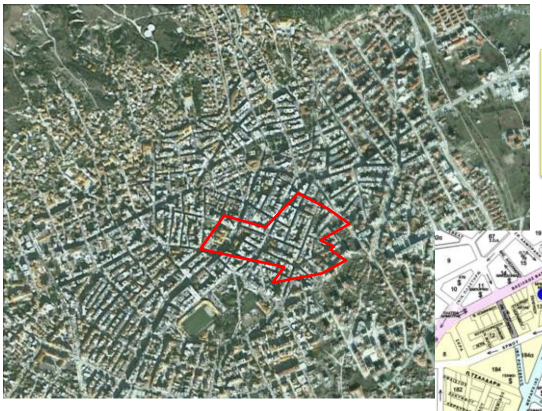
Aim :

The aim of the current study was:
• to investigate the thermal behaviour of conventional construction materials in outdoor spaces in an urban centre and
•to evaluate the effects of replacing them with cool materials .

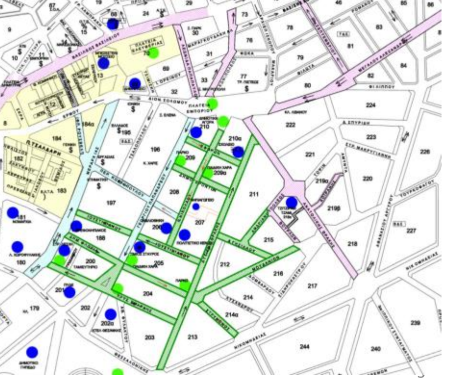
Paper outline :

The paper presents :
i) the measurements of surface temperatures of conventional materials in the roads, the pavements and the vertical surfaces and also
ii) the CFD modelling of the area with conventional materials and after the replacement with cool materials.

Site description

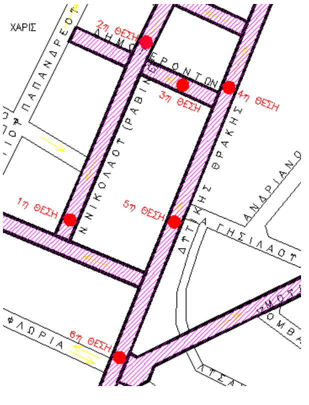


The investigation was conducted at Serres city in North Greece - 41°05′ North and 23°33′ East



The study area is located in the central parts of the city which contains a densely urban structure.

Monitoring details

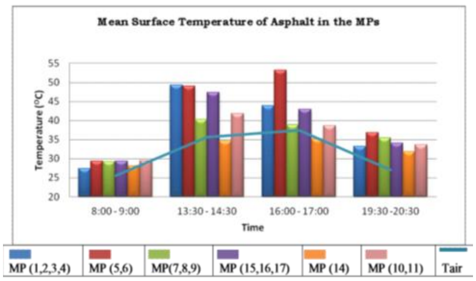


Monitoring details

- Air Temperature at 1.8 m height
- Surface temperature with an infrared thermometer
- 20 Measurement Points

- The experiments were performed on June and July 2011.
- The experimental procedures were carried out
  - at morning time 8:00am, when the absorbed solar radiation doesn't influence the materials temperature,
  - at 13:30pm and16:00pm and
  - at 19:30 when the materials emitted the absorbed temperature

Measurements analysis

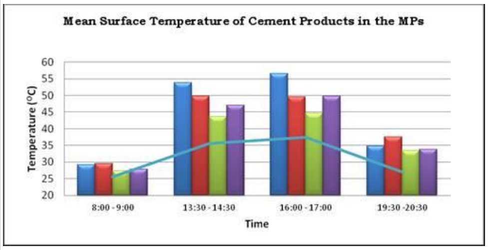


Asphalt

The T_{asph} exceeded 45ºC during afternoon and they can reach up to 50 and 56ºC.

The T_{asph} is higher than the T_{air}.

The difference between T_{asph} and T_{air} remains on high levels even during the afternoon, under shadowing conditions, and it is between 1,1ºC and 13,2ºC.



Cement products (concrete pavement tiles)

The mainly observed cement products are pavement tiles and ground cover pavers. Their colours are light gray, gray, yellow and red.

The temperatures during the morning and afternoon time are under shadow, while in the noon, the measurement points are exposed in solar radiation.

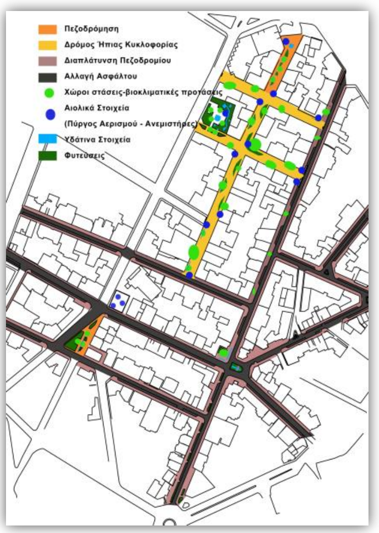
Surface temperatures are higher than air temperature.

The surface temperature of gray tiles is always higher than the other colour tiles and may reach temperatures similar to asphalt, up to 56ºC during afternoon hours.

The surface temperature in the different tiles remains higher than the air even in late afternoon, up to about 5 ºC.

USE OF COOL MATERIALS IN OUTDOOR PLACES IN ORDER TO MITIGATE THE URBAN HEAT ISLAND IN A MEDIUM SIZE CITY IN GREECE

Bioclimatic design solutions



Replacement of conventional floor materials with cool materials at pedestrian streets and pavements

Replacement of asphalt with cool photocatalytic asphalt at streets.

The cool materials will cover the 86% of open areas and the water permeable materials (special pressed soil, low height vegetation, water surfaces) the 7%.

Shading of external places with permanent shading elements designed, mainly at sitting places that are created at selected places, but also at open spaces (e.g. park).

Extensive vegetation is also used for shading that apart from other cooling benefit, it contributes to psychological realm and aesthetic improvement of the area.

Extensive use of vegetation with nati species – shrubs and t - along the streets that as a natural condition system through its evapotranspiration phenomena thus, reduc the air temperature in area.

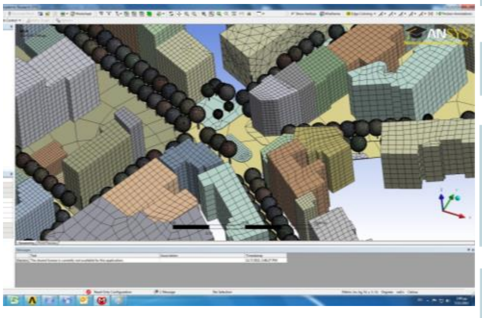
Enforcement of air ventilation in the outdoor spaces with outdoor fans located at selective places to increase air circulation through the streets and create comfort sitting places during hot days.

Several water installations, like fountain - jet, water-curtains, spray-systems in selected locations in the area for introduction of direct evaporation combined with the natural evapotranspiration of vegetation.

USE OF COOL MATERIALS IN OUTDOOR PLACES IN ORDER TO MITIGATE THE URBAN HEAT ISLAND IN A MEDIUM SIZE CITY IN GREECE

Simulation study of the area

The simulation of the thermal conditions in the study area was performed with the detailed 3-dimensional tool ANSYS CFX 13,



Fluid domain dimension of enclosed study area: 1,000m*800m*80m (height)

Dimension of a typical element in the mesh: 5.0 m

Dimension of the denser mesh close to solid surfaces: 0.1 to 0.5m

Boundary conditions were defined by monitored data (Tair, WS,WD, radiation, Tsurf) that were taken during the summer period 2011

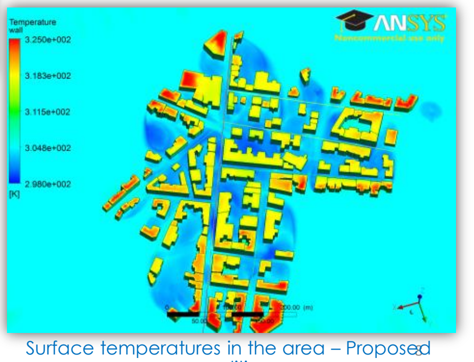
A time step (5 sec) and convergence criteria (10^{-4} RMS of residuals) have defined under steady state of transient calculation

USE OF COOL MATERIALS IN OUTDOOR PLACES IN ORDER TO MITIGATE THE URBAN HEAT ISLAND IN A MEDIUM SIZE CITY IN GREECE

Simulation results

Surface temperatures in the area – Existing condition

The **mean surface temperature** in the area during noon of the hottest day (July 19th) reached 40.3°C in the existing condition while materials replacement with cool materials together with other interventions, reduced the surface temperature to 33.8°C, thus, obtaining **a temperature reduction of 6.5°C.**



Surface temperatures in the area – Proposed condition

Conclusions

- Measurements in conventional materials (asphalt, pavement tiles) in a city centre reported surface temperatures up to 50 -56 °C during the summer period.

- Bioclimatic interventions combined with replacement of all conventional street and pavement materials with cool materials reduced surface temperature by 6.5 °C.

- This temperature reduction will have a big influence on the microclimate of the area, the thermal comfort of people in the outdoors spaces but also it will affect indoor conditions and houses' cooling loads.

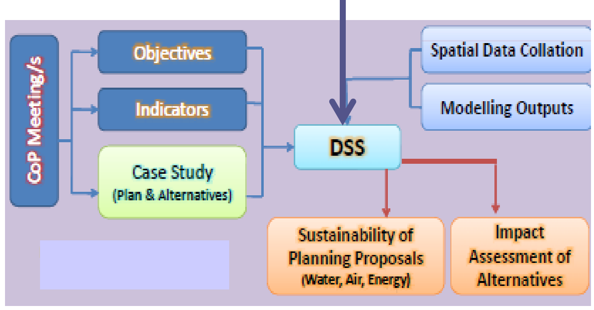
Thank you

A CASE STUDY OF SUSTAINABLE URBAN PLANNING WITH THE USE OF A DECISION SUPPORT SYSTEM

A. Synnefa, M. Stathopoulou, N. Adaktylou, D. Kolokotsa, K. Gobakis, N. Chrysoulakis, M. Santamouris and C. Cartalis

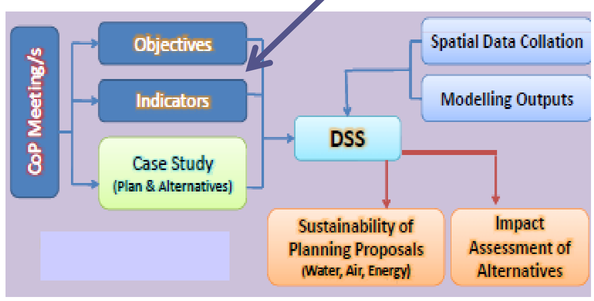
The Bridge approach

A Decision Support System (DSS) that evaluates planning alternatives based on environmental and socioeconomic impacts and thus assists urban planners in decision-making



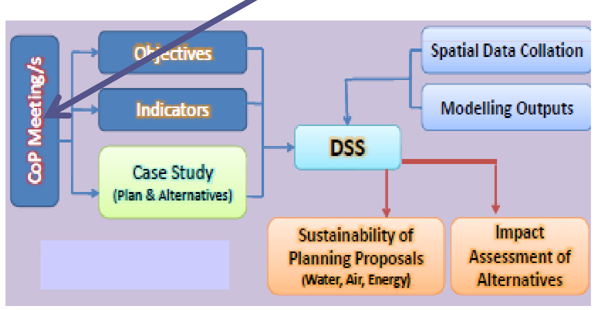
The Bridge approach

It integrates modeling tools for the multi-criteria analysis of energy, water and pollutant fluxes between a city and its environment in the evaluation of planning alternatives. This evaluation is based on assessing proposed planning interventions against previously defined sustainability objectives and associated environmental and socio-economic indicators



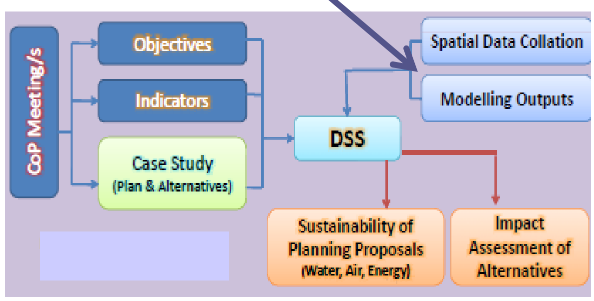
The Bridge approach

The concept of Communities of Practice (CoP), whereby stakeholders are involved from an early stage to establish key sustainability issues, and define objectives and indicators



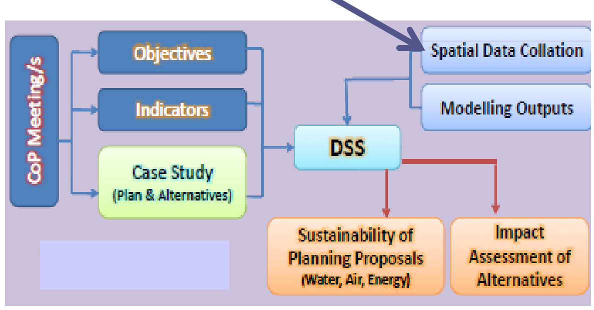
The Bridge approach

Environmental indicators were calculated by spatial models; socioeconomic indicators reflecting objective values (number of houses constructed, number of jobs created, etc.) were given as data attached to planning alternatives and subjective value judgments (such as landscape or urban quality) were defined by end-users



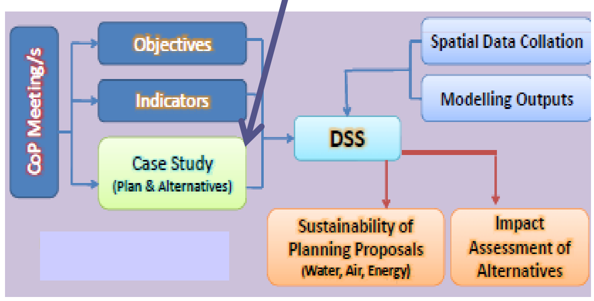
The Bridge approach

In order to evaluate the models used for the calculation of indicators in the case study cities, in situ observations were collected (micrometeorological measurements, site studies, airborne and satellite remote sensing observations).



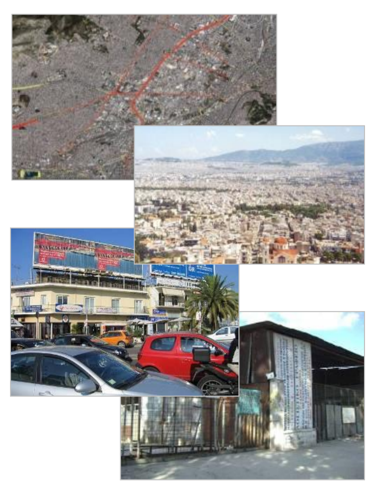
The Bridge approach

To develop and evaluate the DSS five case studies were chosen, each in a different city and country: Athens, Helsinki, London, Firenze and Gliwice



The Athens case study

- The municipality of Egaleo, a densely built urban area
- Five main road axes divide the area in 4quarters. One of the quarters is an industrial degraded area (brownfield) called Eleonas.
- Area: 650 ha
- Population is 74.046 (although it is estimated that at least 120000 people, mostly medium and low income, live and work in the area)
- Level of education of the inhabitants is low to medium and the rate of unemployment high.
- Egaleo is considered an environmentally degraded area facing problems with: air pollution, traffic and transport, thermal discomfort, lack of green/ free spaces, poor quality of building stock, energy



Athens CoP meetings

The main outcomes of the CoP meetings were the following:

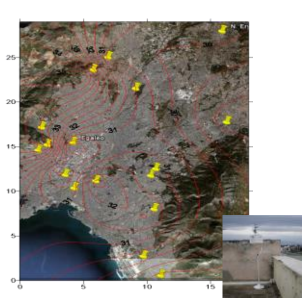
- enabling the Bridge partners and Athens planners to interact with each other and share experience on sustainable urban planning issues in Athens
- discussion of key issues of sustainable development in Athens and especially in Egaleo
- identification of planning priorities; Sustainability objectives and corresponding indicators with which to assess progress towards sustainable development
- selection, accordingly, of a planned intervention for the Athens case study and definition of underlying challenges, planning alternatives and collected indicators

Sustainability Objective (in order of priority)	Indicators
1. Reduce Thermal Discomfort	• Average outdoor temperature (air) and humidity; • Average surface temperature (roads, buildings, etc.); and • Wind speed.
2. Improve Air Quality and Reduce Emissions	• Concentration of pollutants (NOx, SOx, PM10, PM2.5); • CO2 concentration; • Source of emissions (% per building/sector type); • Number of days above established air quality thresholds; and • Effects of meteorological conditions (e.g. temperature) on concentrations.
3. Increase Green Space Areas	• Area (% or m2) of urban green space; • Number of trees planted; and • Types of trees planted.
4. Optimize Water Use	• Volume of water used (for irrigation).
5. Improve Energy Efficiency	• Energy consumption for lighting the avenue; and • % of energy from renewable sources (i.e. solar panels).
6. Optimize Quality of Materials Used	• Solar reflectance of materials used.

Sustainability Objective (in order of priority)	Socio-economic complement of the Environmental indicators
1. Mobility	• road traffic intensity, • quality of pedestrian sideways, • number of parking slots.
2. Public health and safety	• number and severity of road accidents and pedestrian injuries, • number of people suffering from short term effect of air pollution (upper respiratory infections such as bronchitis and pneumonia, allergic reactions) • number of people suffering from long term effects of air pollution (e.g. chronic respiratory disease, lung cancer, heart disease)
3. Social inclusion	• extent to which roads and sideways can be used by disabled or differently able people and groups (e.g. number of safe-street-crossing points, number of repose places along the street), • local community composition – compared to other areas: % of elderly people, foreigners, low-income families etc.
4. Economic criteria	• financial costs of the interventions, • estimated side-effects on local economy
5. Place identity	• aesthetic value of the area and changes due to planning intervention

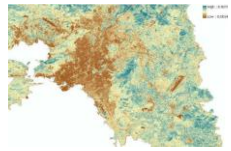
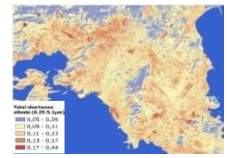
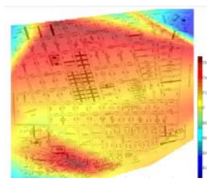
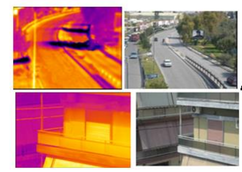
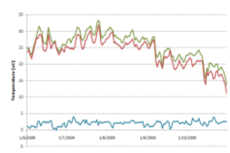
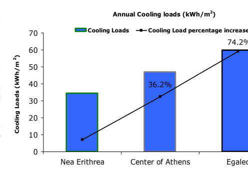
Experimental campaign and data collection

- The data collection was performed at city, local and building scale using different methodologies.
- It includes tower based meteo measurements, urban air quality measurements, heat island measurements, outdoor environmental assessment, building related observations, remote sensing and GIS data and statistical socioeconomic information collection.
- All the collected data are available in the Bridge database

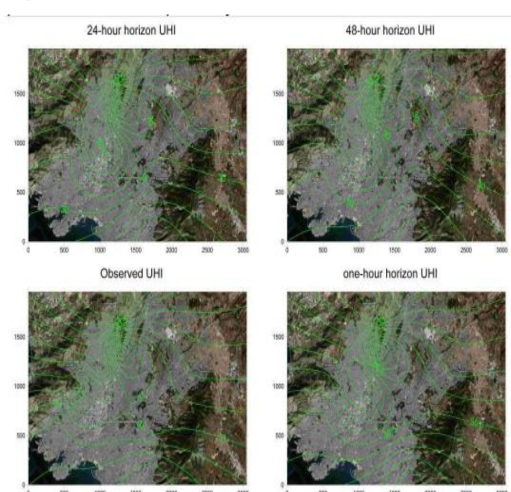


Experimental campaign and data collection

- Large solar availability, hot climatic conditions and low precipitation levels,
- Low albedo and vegetation index,
- Air quality problems for some pollutants (mainly PM10 and NO2),
- Strong UHI effect (mean UHI intensity of 2 -3 °C reaching on occasions 6 - 8 ° C,
- Increased surface and air temperatures and low wind speeds resulting in thermal discomfort for the people in the area (during summer)
- Poor environmental conditions inside buildings (thermal discomfort and lack of IAQ) and increased cooling loads due to the heat island effect

Development of an ANN model for UHI prediction

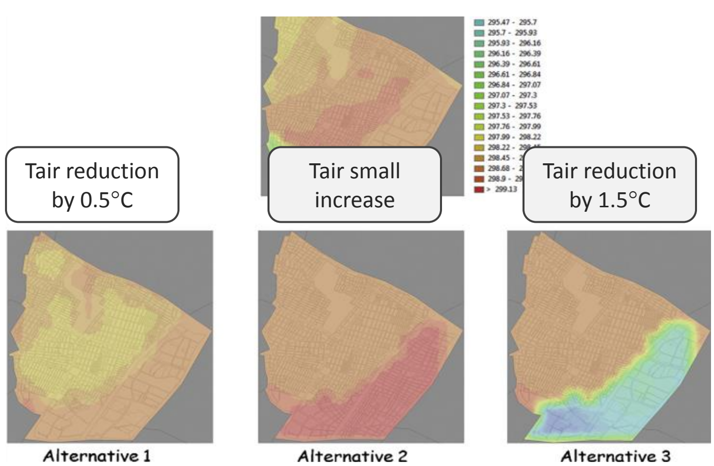


- An ANN (Artificial Neural Network) model able to predict the UHI in Athens, focusing on Egaleo area was developed
- The specific NN architecture and methodology is accurate for the 24 hours prediction horizon using a limited set of data.
- NN prediction methodology can be an important tool for peak energy load predictions during heat waves and hot summer days contributing to the demand and supply energy management.

The planning alternatives

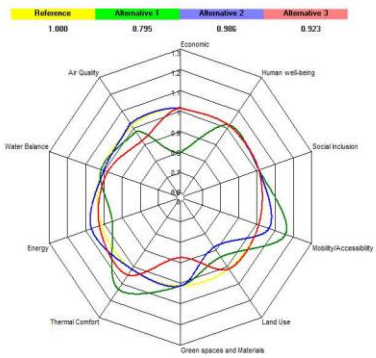
1. applying cool materials on all buildings and roads in the Egaleo municipality (A)
2. changing the land use of Eleonas area with the municipality from its current brownfield/industrial use to urban fabric, including housing and newroads (B)
3. changing Eleonas from brownfield/industrial to green space (C)

DSS evaluation



Mean air temperature (K) for the evening period (20:00–23:00 LST) for summertime for Athens base case (top) and planning alternatives (bottom), which are maps of differences

DSS evaluation



- The 2nd alternative performed better followed closely by the 3rd ,
- The 1st alternative obtained the highest score for the dimension “thermal comfort”.

- More information: www.bridge-fp7.eu/

Using cool paving materials to improve microclimate of urban areas – Design realization and results of the Flisvos project

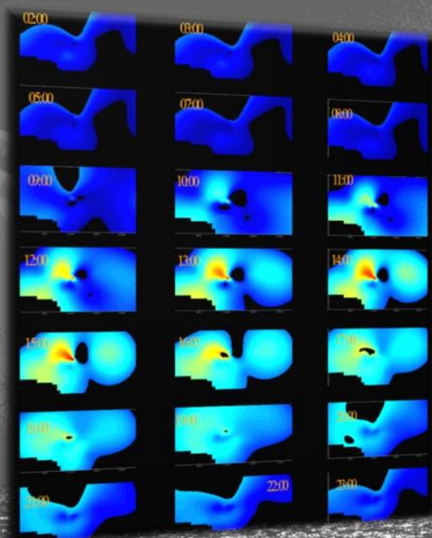
M. Santamouris , N. Gaitani , A. Spanou , M. Saliari , K. Giannopoulou , K. Vasilakopoulou
Univ. Athens

and

T. Kardomateas, Prefecture of Athens

Heat Island has an important energy and environmental Impact on buildings increasing the peak electricity demand as well as the absolute energy consumption for cooling.

It is characteristic that the cooling demand of an office building increases by 120 % because of the heat island.



Heat Island in Athens is strong and is developed in dense areas with important anthropogenic heat and with a positive heat balance because of the use of absorbing materials, lack of vegetation and low urban ventilation rates.

Heat Island Intensity may reach values close to 10 K

The phenomenon is mainly observed in the Central, Western and Southern areas of the city, increasing substantially urban temperatures and making outdoor thermal comfort conditions worse

The Flisvos urban park is a coastal area located in the southwestern part of Athens, in the Municipality of Paleo Faliro, and covers a total area close to 80,000 m2, On the one side of the park there is a major traffic axis and on the other side there is the sea, Saronic Golf.

Flisvos park is currently an area visited by thousands of people and is a major recreation attraction for Southern Athens.

Extensive use of cool colored paving materials was made, aiming to reduce ambient temperatures during summer and improve the environmental quality

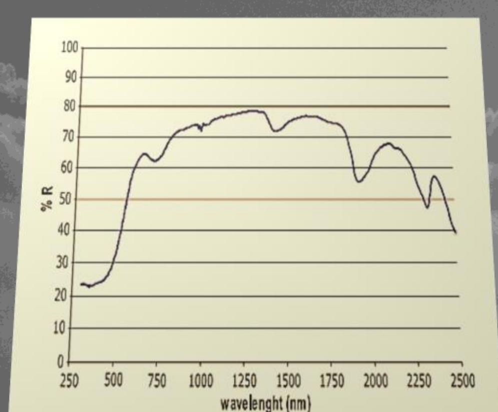
The paving materials were selected in order to satisfy the following criteria:

a) To present the higher possible non specular reflectivity to solar radiation. However, the use of white materials presenting a reflectivity SR >0.85, is highly undesirable as may cause high contrast levels and glare

b) To present the lowest possible decrease of the reflectivity because of the aging effects.

c) To present the highest possible emissivity factor, something common for most of the paving materials.

d) To present the highest possible durability and to be aesthetically pleasing.



Step 1. Monitoring of the initial situation

Step 2. Development of a computational model for the initial situation

Step 3. Monitoring of the final situation

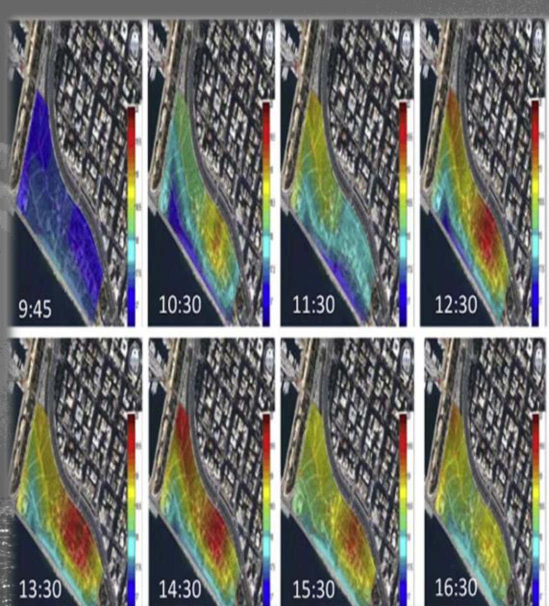
Step 4. Development of a computational model for the final situation

Step 5. Theoretical comparisons for a typical summer day

For the measurements, the mobile urban meteorological station of the University of Athens was used.

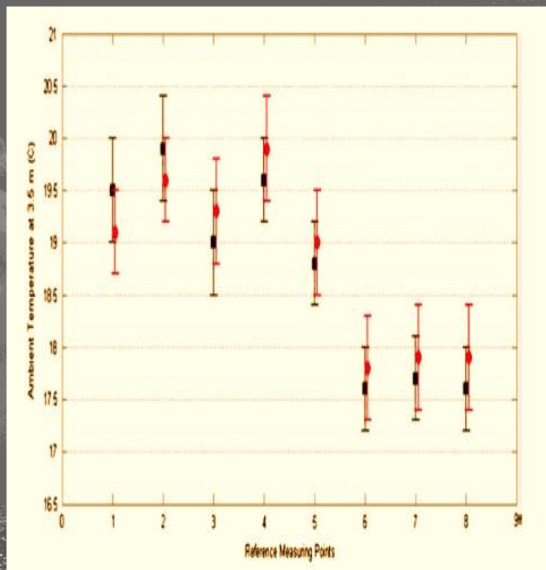
The mobile meteorological station consists of: (a) a vehicle and (b) a telescopic mast PT8 Combined Collar Mast Assembly with extended height of 15.3 m, retracted height 3.43 m and maximum head load 15 kg

Wind speed and direction anemometers and thermometers can be placed on the telescopic mast, at different heights. For the specific experiments, measurements of the ambient temperature and wind speed and direction were performed at a height of 3.5 m.

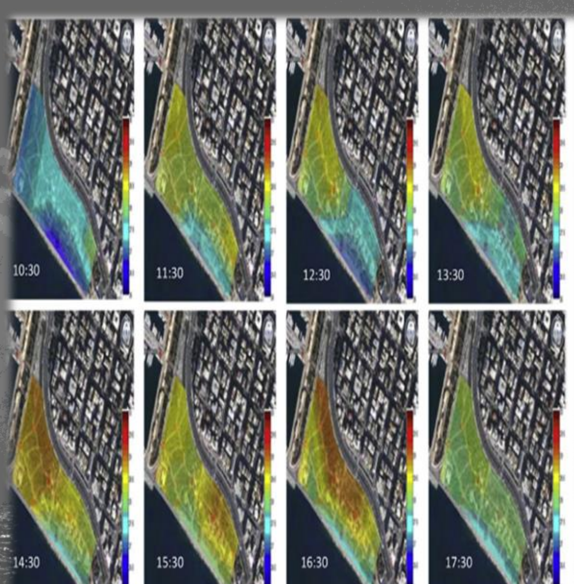


Ambient temperatures varied for both days between 16.5 C and 19.8 at a height of 3.5 m for the period between 9:00 and 17:00. Lower temperatures were always measured next to the sea front, while the maximum ones were recorded close to the existing constructions in the park and next to the highway.

The maximum spatial temperature gradient in the park was close to 2.2 K and was recorded in the early afternoon period

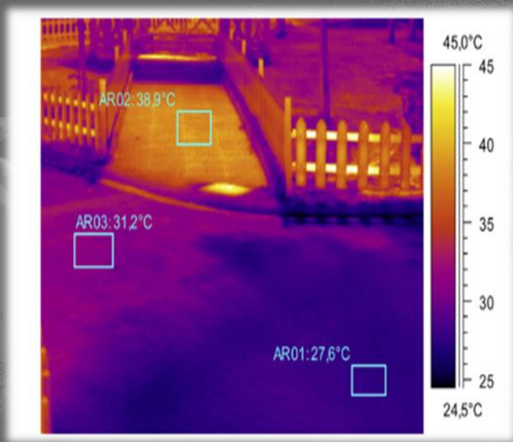


Specific simulations were carried out, in order to predict the thermal conditions in the considered space during the period when the measurements were performed. The maximum temperature difference between the two sets of data never exceeded 0.5 K. The spatial distribution of the temperature is also similar for both the measured and the theoretical data. The lowest temperatures were predicted to be present next to the sea front

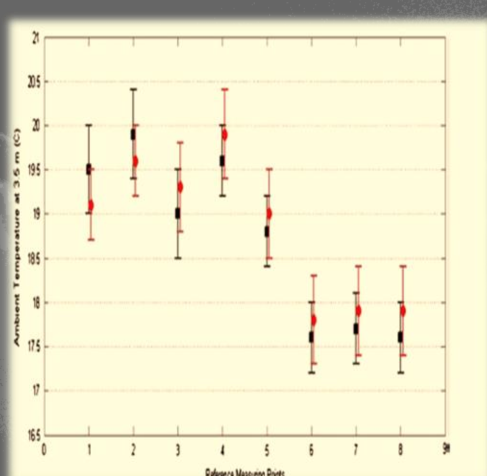


After the installation of the cool pavements in the park, detailed measurements were performed, using exactly the same experimental protocol as in the first monitoring campaign

The daily surface temperature of the non-shaded cool pavements varied between 31.3 C and 33.8 C during the first day and 37.6 C and 39.9 C during the second one

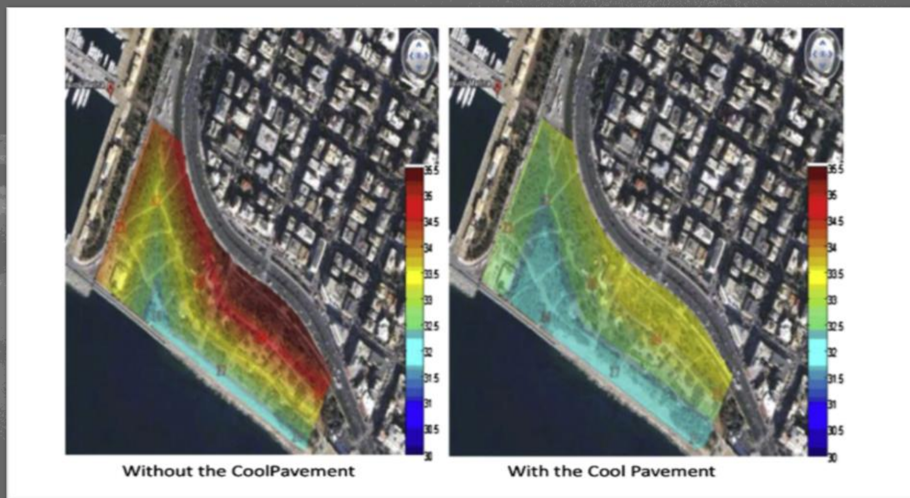


The maximum temperature difference between the cool and conventional pavements was 5.4 K and 7.6 K for the first and the second day respectively.

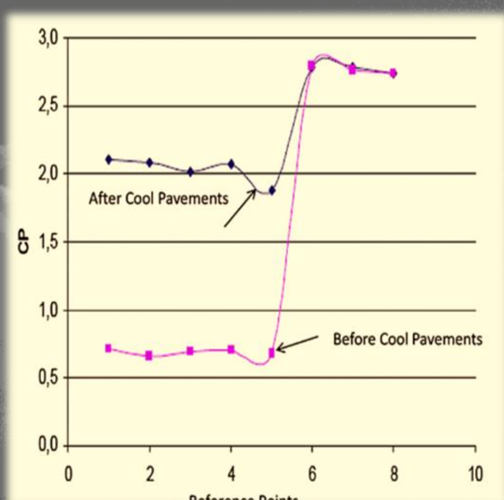


The same evaluation methodology as described previously was followed and CFD simulations were performed.

The achieved agreement between the two sets of data is found quite satisfactory and the difference never exceeded 0.4 K. The predicted spatial distribution of the ambient temperature is very close to the measured one.



As expected, for the part of the park close to the sea, temperatures are very similar and the impact of cool pavements is fully negligible. On the contrary, at the interior of the park the impact of cool pavements is important and contributes to a decrease of the maximum ambient temperature up to 1.9 K. This is very close to the results reported in similar projects were cool pavements have been considered to improve the environmental quality of open spaces



It was found that the extensive application of reflective pavements, under the specific climatic conditions, may reduce the peak daily ambient temperature during a typical summer day up to 1.9 K while surface temperatures were reduced up to 12 C.

In parallel, calculations of the thermal comfort conditions in the area have shown that cool pavements considerably improve comfort in outdoor urban spaces.

The specific results may change as a function of the climatic conditions prevailing in the area where cool pavements are applied.

In particular, under strong wind conditions, advection phenomena may dominate and the impact of local convection and radiation phenomena will be lowered.

Also, for lower levels of the ambient temperature and solar radiation the summer contribution of cool paving materials is expected to be reduced.

Finally, the use of cool paving materials is not expected to decrease the local ambient temperature during the winter period.

Experimental determination of comfort benefits from cool-roof application to an unconditioned building in India

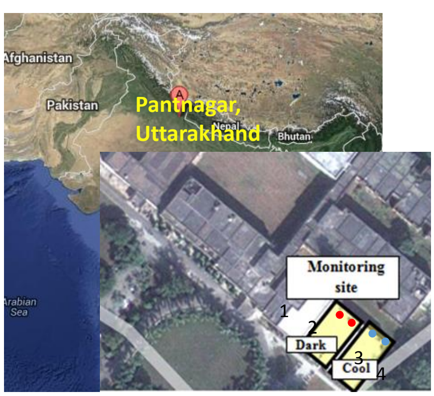
[1]Rathish Arumugam <rathish.iiit@gmail.com>, [1]**Vishal Garg,** [2]Jyotirmay mathur, [1]Niranjan Reddy, [1]Jalpa Gandhi, [3]Marc L. Fischer

1 Center for IT in Building Science, International Institute of Information Technology, Hyderabad, India

2 Center for Energy and Environment, Malviya National Institute of Technology, Jaipur, India

3 Sustainable Energy Systems Group, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, Berkeley, California, 94720, USA

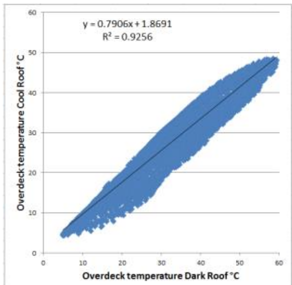
Project Location: Pantnagar



Location	Pantnagar
Lat/ Long	28.97°N, 79.41°E
Climatic Zone	Composite
Maximum Temp	42°C
Minimum Temp	2° C
Rainfall	145 cm

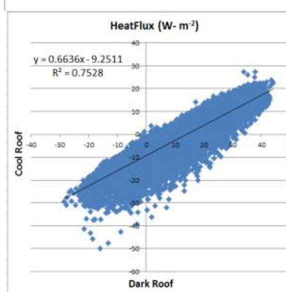
Building Information	
Operation Type	Educational Institution
Space Conditioning	Un-conditioned
No. of Floor	Two storeys
Roof Type	200mm Concrete roof
Floor to Floor height	3.65m

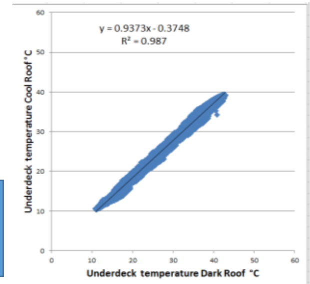
Scatter plots of temperatures and Heat flux



Scatter Plot for Over deck temperature

Scatter Plot for Heat flux

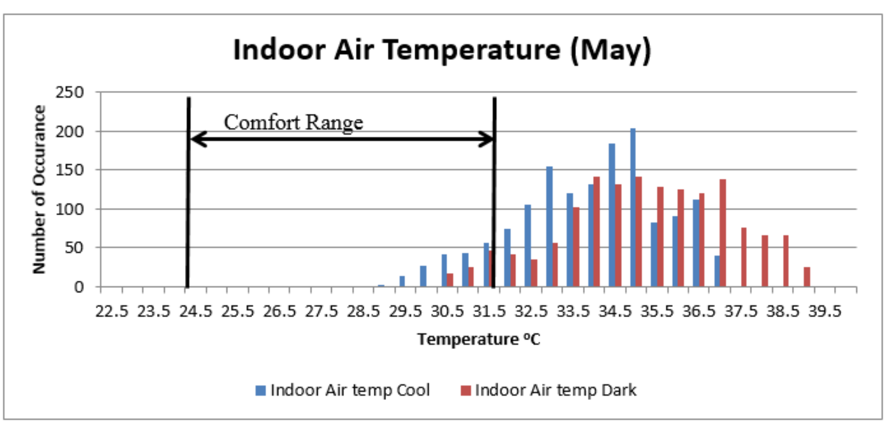




Scatter Plot for Under deck temperature

Indoor Adaptive Comfort

- Thermal comfort is expressed as a factor of outdoor effective temperature
- $T_n = 0.31 * T_{outside\ dry\ bulb} + 17.6^0C$
- $Comfort\ Band = T_n \pm 3.5^0C$



Results

- Average indoor air temperature reduction 1.07°C
- Peak indoor air temperature reduction 1.38°C
- Average Heat flux reduction 14.4 W m^{-2}
- Peak Heat flux reduction 18.3 Wm^{-2}
- Increased the number of adaptive comfort hours is 80 hours (about 8%)

SIMULATION OF THE COOLING EFFECT OF ROOF ADDED PHOTOVOLTAICS

Vasilis C Kapsalis*[1], Eftychios Vardoulakis and Dimitris Karamanis*[1]

1 Department of Environmental & Natural Resources Management, University of Patras, Seferi 2, 30100, Greece

**Corresponding authors: bkapsal@central.ntua.gr, dkaraman@cc.uoi.gr*

34th AIVC 2013 Conference

"Energy conservation technologies for mitigation and adaptation in built environment: The role of ventilation strategies and smart materials"

25-26 September 2013
Divani Caravel Hotel, Athens, Greece

Outlline

- INTRODUCTION

(Aim, Methodology, experiment setup)

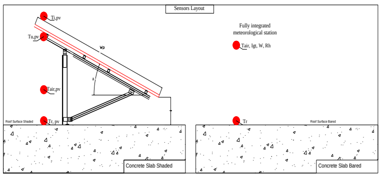
- RESULTS

- CONCLUSION

INTRONDUCTION

➢ Aim

- To examine the influence of BAPV in the building's cooling energy and peak load demand
- To gain a better insight of the building effective characteristics on thermal response.



➢ Experiment set up

- Measurements during August 2012
- Hobo data loggers, thermocouples
- Fully automated meteorological station is used.

➢ Methodology

- Dynamic simulation by TRNSYS is used. Built in components, custom design equations and in house weather data transformation imported.

RESULTS

According to our exploration some results are following:

- The roof added pv can passively reduce the daily rooftop cooling energy and peak load during the hot summer days in addition to electricity production
- The shading effect maximizes with the decrease of R and the increase of ρ
- The more insulated surfaces present larger attenuation in temperature variations
- The emissivity of the roof under pv is deduced.

CONCLUSION

- Dynamic simulation is a powerful tool to gain a better intuition of the building energy behaviour
- Sensitivity of the model observed in environmental factors
- Different conditions, material properties and longer time exploration is needed.

THANK YOU

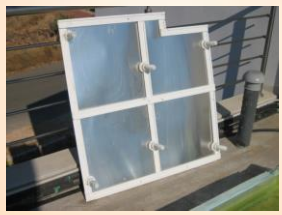
EXPERIMENTAL ANALYSIS OF SMALL SCALE ROOF PONDS, PROTECTED BY A VARIETY OF MATERIALS IN DIFFERENT POSITIONS IN REGARD TO WATER LEVEL

Artemisia Spanaki[1], Dionysia Kolokotsa[2], Theocharis Tsoutsos[2], Ilias Zacharopoulos[1]

AIM: experimentally investigation of ways to protect a water pond, in order to reduce bottom pond temperature.

TESTING DEVICES: Three identical bottomless ponds are together recorded. Water depth is kept constant in 0.10m, while each pond has an area of 1m².

TESTED MATERIALS FOR WATER PROTECTION: white textile, the textile used in ironing board, aluminum layer, aluminum foil and insulation panel. Some of the materials are keeping afloat on water level, while other are kept below or above water level.



material	White textile	Ironing Board	Aluminium layer	Aluminium foil
Emissivity	0.86	0.44	0.04	0.03

Table 1: Emissivity of tested materials for water protection.

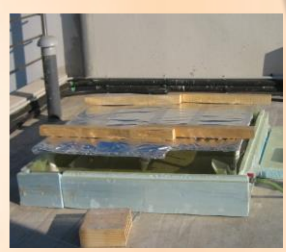
1 National Technical University of Athens, School of Architecture
2 Technical University of Crete, School of Environmental Engineering

EXPERIMENTAL ANALYSIS OF SMALL SCALE ROOF PONDS, PROTECTED BY A VARIETY OF MATERIALS IN DIFFERENT POSITIONS IN REGARD TO WATER LEVEL

Artemisia Spanaki[1], Dionysia Kolokotsa[2], Theocharis Tsoutsos[2], Ilias Zacharopoulos[1]

Base Case (white textile),

Ironing Board



Ventilated pond.

Aluminum foil on water level

Floating Insulating panel.

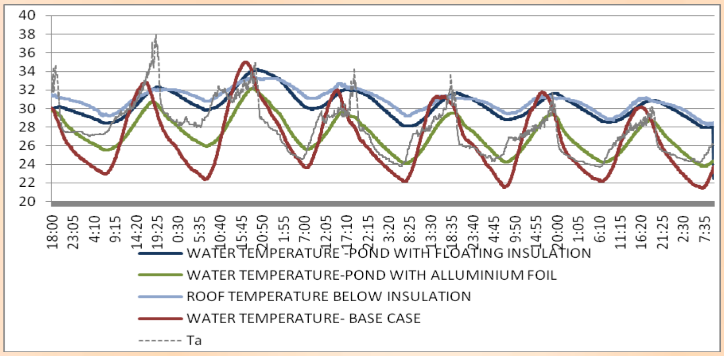
1 National Technical University of Athens, School of Architecture
2 Technical University of Crete, School of Environmental Engineering

Artemisia Spanaki[1], Dionysia Kolokotsa[2], Theocharis Tsoutsos[2], Ilias Zacharopoulos[1]

Comparing a roof pond with floating insulation to another one with floating aluminum foil.

Period: 23th –30th of July

Materials: Aluminum foil on water level, Floating insulation covered with aluminum foil, Roof temperature below insulation.



- The thermal performance of pond with aluminum foil floating on water level are higher compared to the corresponding values of the Base Case scenario.
- The daily maximum temperatures of the pond with aluminum floating on water level are lower compared to the Base Case scenario.
- The pond with the floating insulating has reduced temperature fluctuations, similar
- to the ones of the roof above insulation. The water below it does not contributes
- to the heat loss mechanism, so it is not worth to be further
- investigated.

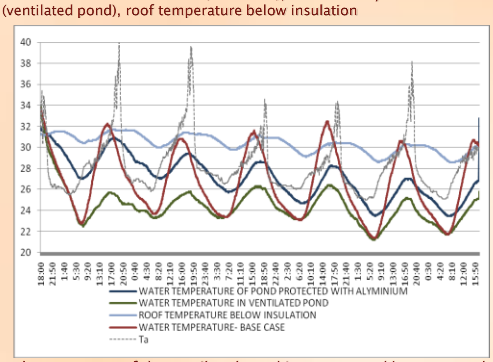
1 National Technical University of Athens, School of Architecture
2 Technical University of Crete, School of Environmental Engineering

EXPERIMENTAL ANALYSIS OF SMALL SCALE ROOF PONDS, PROTECTED BY A VARIETY OF MATERIALS IN DIFFERENT POSITIONS IN REGARD TO WATER LEVEL
Artemisia Spanaki[1], Dionysia Kolokotsa[2], Theocharis Tsoutsos[2], Ilias Zacharopoulos[1]

The effect of the position (below and above water layer) to the bottom pond temperature

Period: 13th –19th of July

Materials: white textile on water level (Base Case), aluminum layer on water level, aluminum layer above water level (ventilated pond), roof temperature below insulation



- Bottom pond temperature of the ventilated pond is represented by a curve almost parallel to the pond with a
- floating aluminum foil
- The daily minimum water temperature of the ventilated pond, is equal to the corresponding value of the
- Base case Scenario.
- Bottom pond temperature of the ventilated pond has low fluctuation.
- Placing an aluminum foil on water surface results daily decreased maximum water temperatures and increased minimum comparing to the corresponding values of the Base Case scenario.
- The ventilated pond results a remarkable bottom pond temperature reduction,
- compared to the other investigated ponds.

1 National Technical University of Athens, School of Architecture
2 Technical University of Crete, School of Environmental Engineering

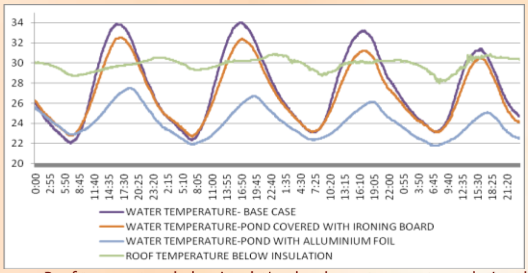
EXPERIMENTAL ANALYSIS OF SMALL SCALE ROOF PONDS, PROTECTED BY A VARIETY OF MATERIALS IN DIFFERENT POSITIONS IN REGARD TO WATER LEVEL

Artemisia Spanaki[1], Dionysia Kolokotsa[2], Theocharis Tsoutsos[2], Ilias Zacharopoulos[1]

The effect of the protection material properties to the bottom pond temperature

Period: 2^{nd} –5^{th} of July

Materials: white textile, ironing board, aluminum foil on water level



CONCLUSIONS

- **The use of reflective materials for water protection together with encouraging evaporative losses, can lead to bottom pond temperature reduction, compared to the Base case scenario (pond with floating white textile).**
- **The ventilated pond, protected with an aluminum layer gave lower daily maximum temperatures of water, while the minimum ones are practically equal to the corresponding values of the Base case scenario.**

- Roof temperature below insulation has lower temperatures during daytime compared to the bottom pond temperature of the base case scenario (Roof pond with white textile floating on water level).
- The mean daily maximum temperature of the bottom pond temperature in the Base case Scenario is 33.13ºC, thus 2.63ºC higher comparing to the corresponding mean maximum of the roof below insulation.
- The fluctuation of the temperatures of the roof below insulation is low. The mean daily minimum is 28.6ºC, while the corresponding temperature of water in the Base Case scenario is 6.0ºC lower.
- The total thermal performance of pond with aluminum foil seems to be better compared to the other tested devices, since the daily minimum and maximum bottom pond temperatures are lower. The mean daily maximum water temperature reaches, 26.35ºC, the mean daily minimum reaches

  22.23ºC, while the overall mean daily bottom pond temperature is 24,07ºC.
- The fluctuation for the roof above insulation panel and the corresponding
- Value of bottom pond temperatures are 7.61ºC and 5,27ºC respectively.

1 National Technical University of Athens, School of Architecture
2 Technical University of Crete, School of Environmental Engineering

Cool Fluorocarbon Coatings In Industrial Buildings: Optical Properties And Energy Performance

Elena Mastrapostoli,Theoni Karlessi, Alexandros Pantazaras, Kostas Gompakis, Dionysia Kolokotsa, Mattheos Santamouris

University of Athens,
Physics Department, Group Building Environmental Studies, Athens, Greece

Technical University of Crete
E-mail: dkolokotsa@enveng.tuc.gr
www.enveng.tuc.gr

Introduction and Objectives

- ✓ The aim of the present paper is to underline the contribution of an innovative cool fluorocarbon coating in the reduction of energy demand for cooling in an industrial building with increased heat gains under temperate climatic conditions.
- ✓ The material is tested using accelerated weathering procedures and its optical properties, i.e. solar reflectance and infrared emmitance are measured.
- ✓ The material is applied in an industrial building in Oss Netherlands.

Materials and Methods

- ✓ Tetrafluoroethylene (C_2F_4) monomer fluorocarbon coating in a water-borne (FC coating) formula on
  - cement tile (7x7cm)
  - aluminum substrate (10x10cm)
- ✓ with a thickness of approximately 110μm.

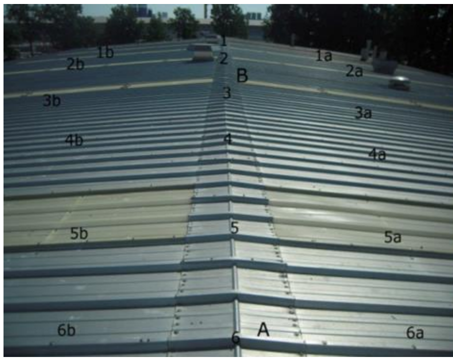
- ✓ This study includes for each sample:
- Spectral reflectance measurements over the spectrum 300-2500nm (UV-VIS-NIR)
- Calculation of the Solar Reflectance (%)
- Calculation of the Solar Reflectance Index (SRI)
- Measurement of the infrared emittance
- Calculation of maximum surface temperature
- Accelerated ageing of the samples in an Accelerated Ageing Xenon Test Chamber.

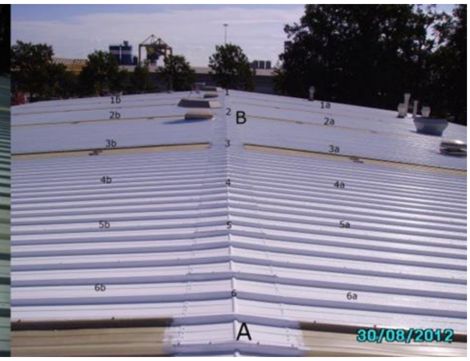
The samples before and after accelerated weathering

- ✓ Ageing Xenon Test Chamber (Q-SUN, Xe-3HS)

Sample	Description	Emmisivity	SRI	$T_{surface}$ °C
S4 before	FC coating	0.88	113	39.8
S4 after	FC coating	0.87	*110*	*41.0*

Application in industrial building in Oss Netherlands



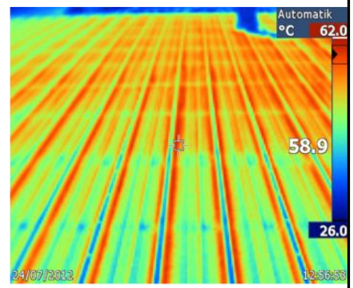


Application in industrial building in Oss Netherlands

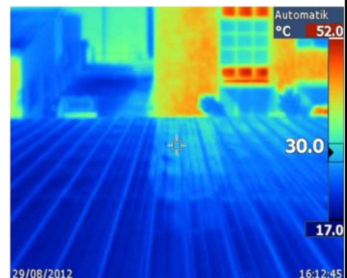
Joint Conference
34th AIVC- 3rd TightVent- 2nd Cool Roofs' - 1st venticool

Application in industrial building in Oss Netherlands

Before FC application



After FC application



Application in industrial building in Oss Netherlands

✓

Sensor 1

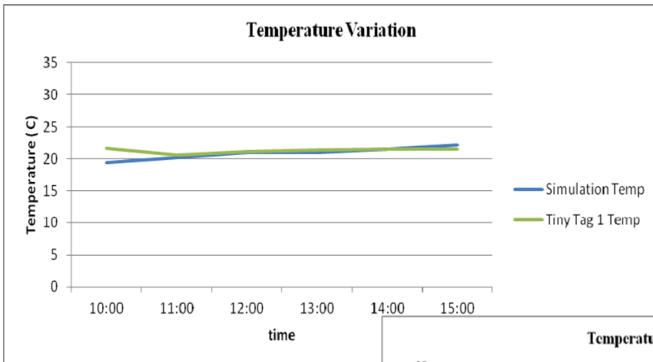
Sensor 2

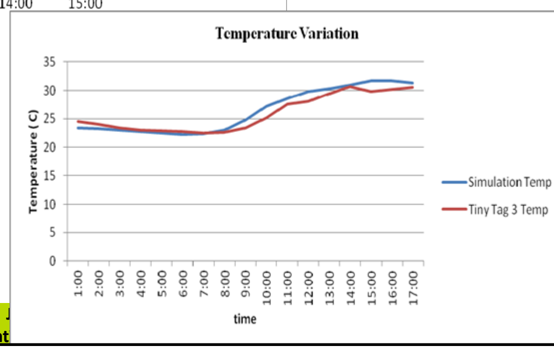
Sensor 3

Sensor 4

Sensor 5

Development of models for estimation of the heating and cooling demand





Conclusions

- ✓ In the present study the thermal and optical characteristics of a fluorocarbon cool material are measured. The cool material is applied in an industrial building with increased internal heat gains targeting to minimise the energy demand for cooling.
- ✓ The value of the roof albedo has changed from 0.3 to 0.67 after the application of the cool coating.
- ✓ There is an increase of 120% of the roof's albedo. Regarding the heating and cooling loads there was a decrease of 73% for cooling while there was a minor heating penalty of 5%.
- ✓ The overall study showed that cool materials can be a viable solution even for temperate climatic conditions and for industrial buildings where usually there is a significant burden in the cooling load due to machineries and production lines. This can make a significant difference in the use of air conditioning especially in mid seasons.

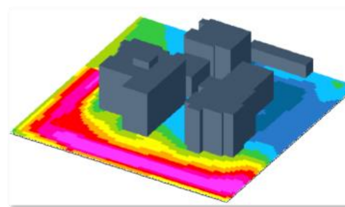
Thank you for your attention

Herewith we are acknowledging TecneXum GmbH, Essen, Germany, and Daikin Chemical Europe, Düsseldorf, Germany, for their support and to enable us to perform these studies and to publish the results

URBAN GARDENS: AS A SOLUTION TO ENERGY POVERTY AND URBAN HEAT ISLAND

Vasiliki Tsilini[1], Sotiris Papantoniou[1], Denia Kolokotsa[1], Efpraxia Maria[1]

Technical University of Crete
Department of Environmental Engineering



[1] Laboratory of Energy Management in the built environment
School of Environmental Engineering
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University Campus, 731 00, Chania, Greece

The aim of this work is to reduce the temperature in order to deal with:

- Urban heat island effect
- Energy poverty

HOW TO ACHIEVE THAT?

- Bioclimatic design
- Add vegetation
- Urban gardens

STUDY AREA

•Principal residences
•6 Buildings
•Green areas

METHODOLOGY

1st **scenario**: absence of vegetation

2nd **scenario**: current state

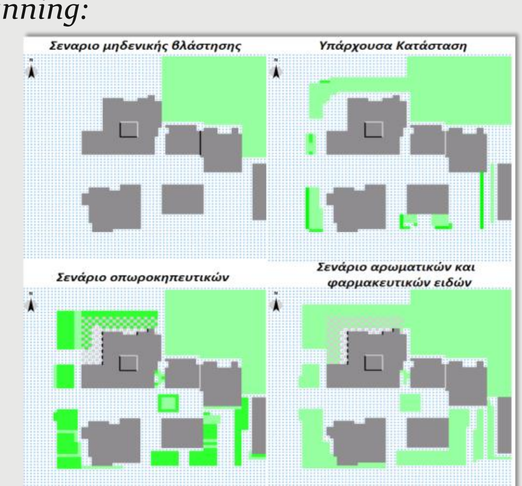
Use of biodiversity: traditional species, native plants

3rd **scenario**: cultivation of fruit and vegetables
(vineyards, tomatoes, cucumbers, onions, lettuce, red beet)

4th **scenario**: cultivation and aromatic and medicinal species
(basel, thymus, salvia, hyssopus, oregano)

USE OF THE MODELLING SOFTWARE ENVI-met

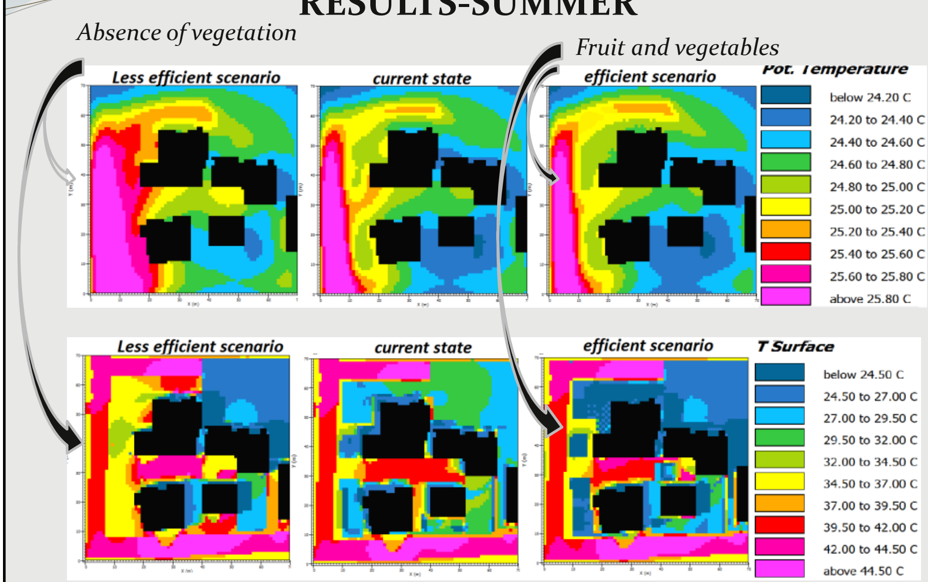
Urban planning:



USE OF THE MODELLING SOFTWARE ENVI-met

Scenarios	Summer	Spring	Autumn
Start Simulation at Day	21.07.2012	21.03.2012	21.10.2012
Start Simulation at time	00:00:00	00:00:00	00:00:00
Total Simulation Time in Hours	24.00	24.00	24.00
Save model State each min	60	60	60
Wind Speed in 10 m ab. Ground (m/s)	1.78	1.75	1.53
Wind Direction (0:N, 90:E, 180:S, 270:W)	0	270	180
Roughness Length z0 at Reference Point	0.1	0.1	0.1
Initial TemperatureAtmosphere (K)	293	293	293
Specific Humidity in 2500m (g Water/kg air)	7	7	7
Relative Humidity in 2 m(%)	50	60	65

RESULTS-SUMMER



CONCLUSIONS

•The importance of the sun position (greatest temperature fluctuations at 12pm and 3pm.

•The importance of the materials' nature.

•The importance of the plants' height.

Generally,

Add with biodiversity ⟹ Reduce the temperature

•Affects the urban heat island effect
•Contributes reducing energy needs

FUTURE WORK

•Incorporating the concept of the urban gardens in the legislative framework
•Take field measurements in order to confirm the results of the Envi-met software
•Use of resistant plants at winter
•Combination urban gardens with green roofs

Thank you for your attention!

Co-Funded by:

A holistic approach of the development and application of innovative composite cool thermal insulating materials

Dr. Sofia – Natalia Boemi
Aristotle University of Thessaloniki, Greece
nboemi@gmail.com

Development of innovative insulating cold materials for the energy upgrading of existing and new buildings

Duration: 09.11.2012 – 08.11.2014

Co-Funded by: GGET

The aim of the project :

is the design, development, production, evaluation, certification and introduction to the market of innovative, composite cool - thermal insulating materials based on the **new generation of extruded polystyrene (XPS) with improved vapour permeability** (lower water vapour diffusion resistance factor μ) as well as with **use of special plasters as a final coating with specific features of low emissivity coefficient ε**.

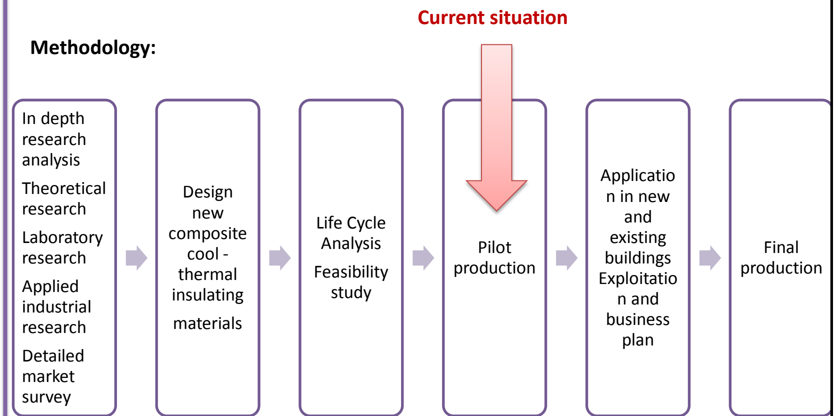
Scientific and technical goals

The development of a new product that:

1. Can be simply and quick installed in new-built constructions, having low demands in planarity and parallelism of the underlying constructive layers.
2. Can be **easily transported and storage on worksite**, with convenience for the preparation and manufacturing of special plaster coatings (where applicable), cut and fixation.
3. The LCA combined with the experimental measurements that has been conducted will eventually lead to the adaptation of the eco-label sign.
4. Present capabilities of **fire resistance, durability to impregnation and low resistance to water vapor diffusion**. The thermal reflective plaster coatings will assure the maximization of the useful impacts of thermal insulation.

Development of innovative insulating cold materials for the energy upgrading of existing and new buildings

Methodology:



<u>The new products</u>

- Will be environmental friendly and will adapt an eco-label sign.
- It will be included to the catalogue of cool materials
- The XPS will meet the requirements of European regulations, EN 13164
- It will comply with the requirement of ETAG 004
- It will receive CE certification,

Solar optical and thermal properties of micro- and meso-porous materials for cooling applications compared to typical building materials

UNIVERSITY OF PATRAS

DEPARTMENT OF ENVIRONMENTAL & NATURAL RESOURCES MANAGEMENT

S.Krimpalis and D.Karamanis

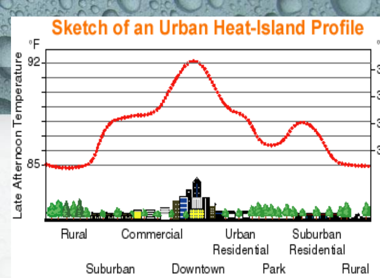
ENVIRONMENTAL PHYSICS, ENERGY AND CLIMATIC CHANGE GROUP

ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ
UNIVERSITY OF PATRAS

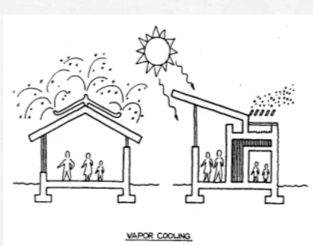
34th AIVC Conference

Urban Heat Island (UHI)

- maximum temperature difference between the urban and rural environments
- urban areas of more than 5 °C warmer than their surrounding rural areas have been observed in Agrinio



Graphic courtesy of LLBL Heat Island Group



Principle of evaporation cooling of buildings using porous materials: stored water or night sorbed moisture are evaporated during the hot day → reduced porous surface temperature → reduction of air temperature → reduced heat flow inside the building

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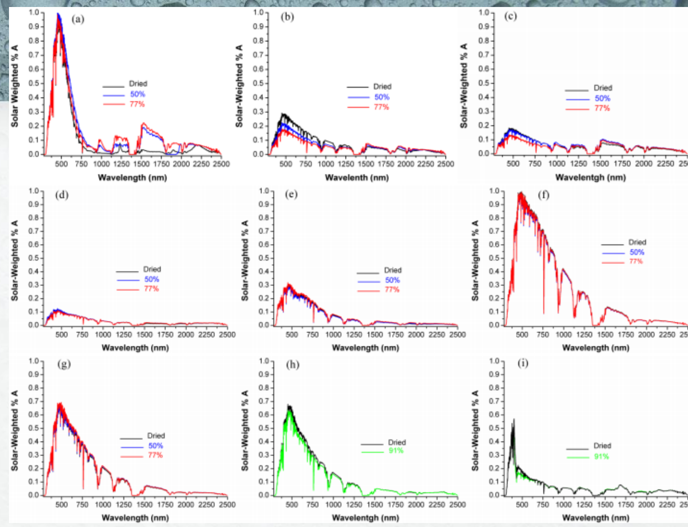
Solar-weighted absorbance spectra of a) MESO-1, b) MESO-2, c) MICRO, d) CaCO3, e) Cement White, f) Cement Black, g) Plaster, h) Marble and i) Reflective Paint, for different relative humidity.



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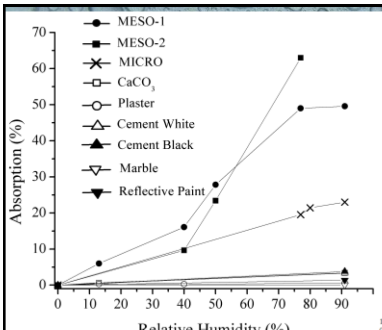
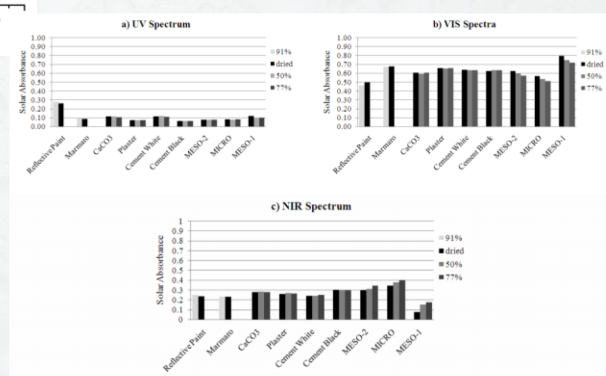


Water vapor sorption isotherm of the tested materials at 25 °C



Variation of normalized solar absorbance in correlation with relative humidity, separately for each solar sub-bund (UV/VIS/NIR).

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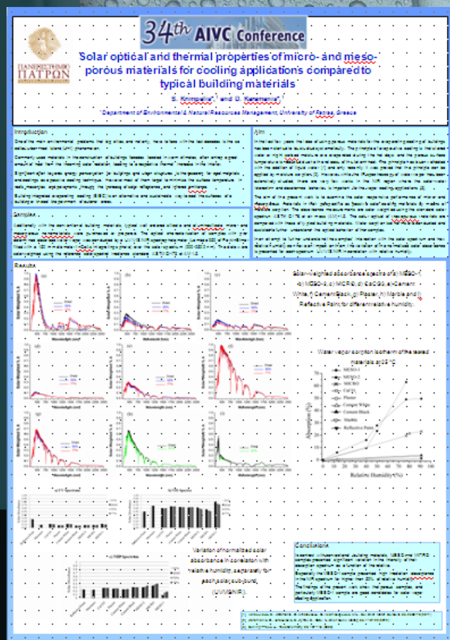

Thank you for your attention

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Heat Island Phenomenon and Cool Roofs Mitigation Strategies in a Small City of Elevated Temperatures

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Email: evardoul@cc.uoi.gr

Speaker: Vardoulakis Eftychios

Physicist, Msc, Phd Candidate

Project: Study of innovative energy materials and building passive cooling techniques to mitigate heat island effect

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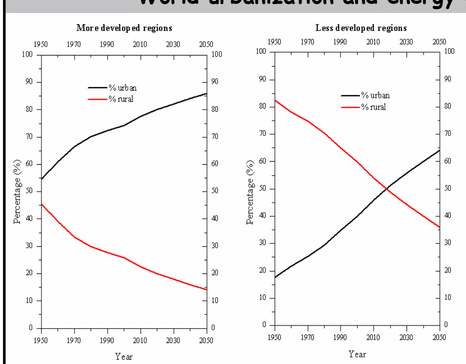
Energy conservation technologies for mitigation and adaptation in the built environment the role of ventilation strategies and smart materials

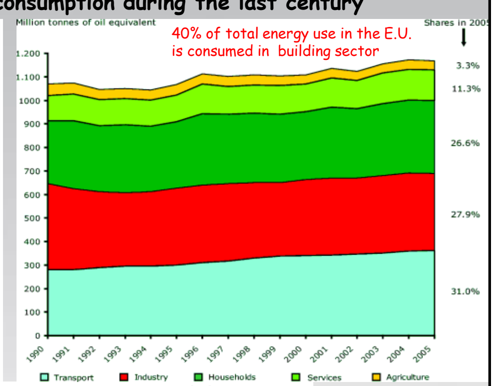
25-26 September 2013
Athens, Greece

Save Energy

World urbanization and energy consumption during the last century



Source: United Nations, New York, 2011



Source: Eurostat, 2007.

B. Urban indicators	Percentage urban 1950	1975	2005	2030	Rate of urbanization (percentage) 1950-1975	1975-2005	2005-2030
World	29.1	37.3	49.2	60.8	1.24	0.92	0.85
More developed regions	52.5	67.2	74.9	81.7	1.23	0.36	0.35
Less developed regions	17.9	26.9	43.2	57.1	2.04	1.58	1.12

Over 50% of earth's population lives in cities
Almost 75% in more developed regions

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Urban Heat Island Effect

High energy consumption in cities and buildings lead to higher temperatures in the city spar. → Published research in many European cities (Barcelona, Paris, Rome, Goteborg, London) show temperature differences even of 8 °C between rural and urban areas (mean hourly values)

In Greece extended research during the last 20 years focused mainly on big sized cities →

↓

Lack of research in small-sized cities

City	Mean Heat Island Intensity(°C)	Maximum Heat Island Intensity (°C)	Reference
Athens	10.0 °C in the city centre during summer 8.0 °C in the city centre during winter	Up to 15.0 °C during summer and up to 13.0 °C during winter	Santamouris et al., 2001; Livada et al., 2002; Gobakis et al. 2011;
Athens	Close to 5.0 °C during summer	-	Giannopoulou et al., 2010
Volos	2.0 °C during both seasons (summer and winter)	3.4 °C during summer and 3.1 °C during winter	Papanastasiou and Kittas ,2011
Chania	2.6 °C during the summer	8.0 °C during summer	Kolokotsa et al., 2009
Thessaloniki	2.0 to 4.0 °C during the summer	-	Giannaros et al., 2012

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Agrinio Heat Island Effect (population 93,000 inhabitants)

Characteristics

- ✓Heat island intensity reached occasionally even 6˚C (August 2010)
- ✓Mean Heat island intensity of 3.82 ˚C (August 2010)
- ✓Heat island effect appearance frequency is higher during nights

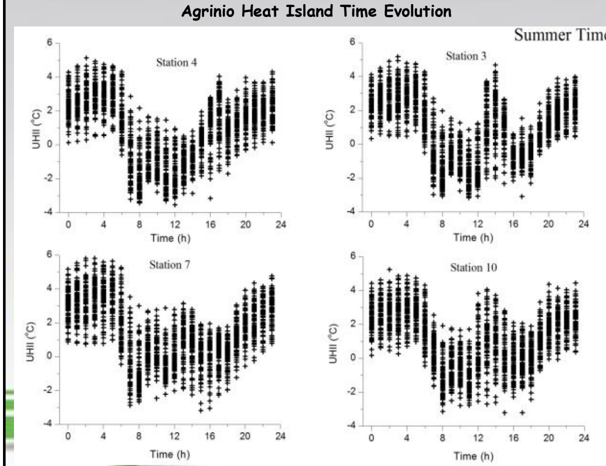
→ **We have to act now**

↓

Mitigation measures but why in Buildings???

- •They live too long and influence strongly urban energy balance
- •In general building sector can achieve much more with less energy consumption
- •We can achieve less energy consumption without serious cost in money, aesthetic and comfort

Agrinio Heat Island Time Evolution



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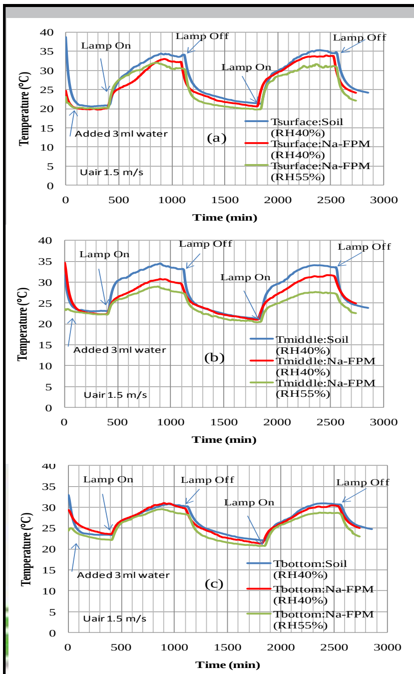
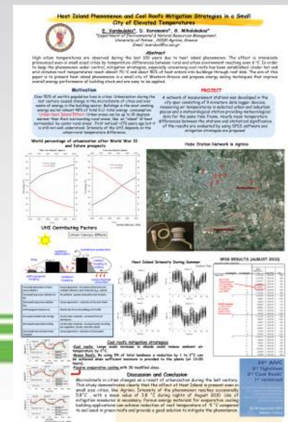


Source: Vardoulakis et al.,2011

Cool roofs mitigation strategies

- **Cool roofs:** Large scale increase in albedo could reduce ambient air temperature by 2°C.
- **Green Roofs:** By using 5% of total landmass a reduction by 1 to 2°C can be achieved when sufficient moisture is provided to the plants (at 13:00 hours).
- **Passive evaporative cooling** with 3D modified clays. Experimental results show 5 °C roof temperature reduction compared to green roof soil applications.



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Assessing thermal risk in urban areas – an application for the urban agglomeration of Athens

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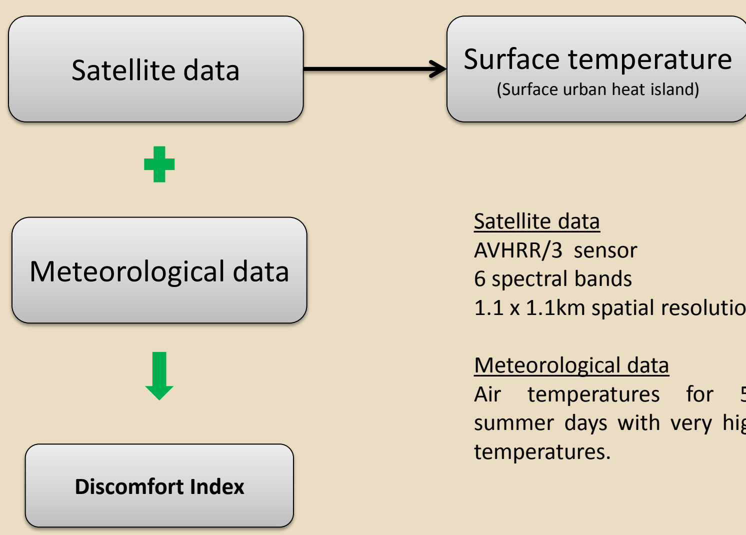
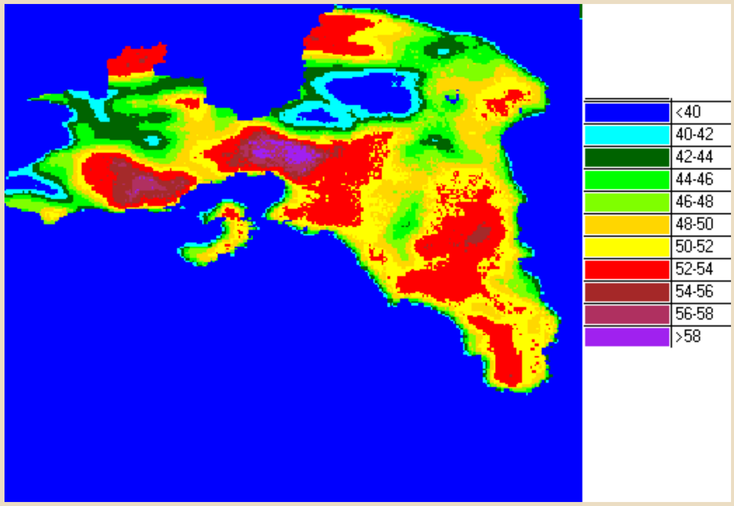


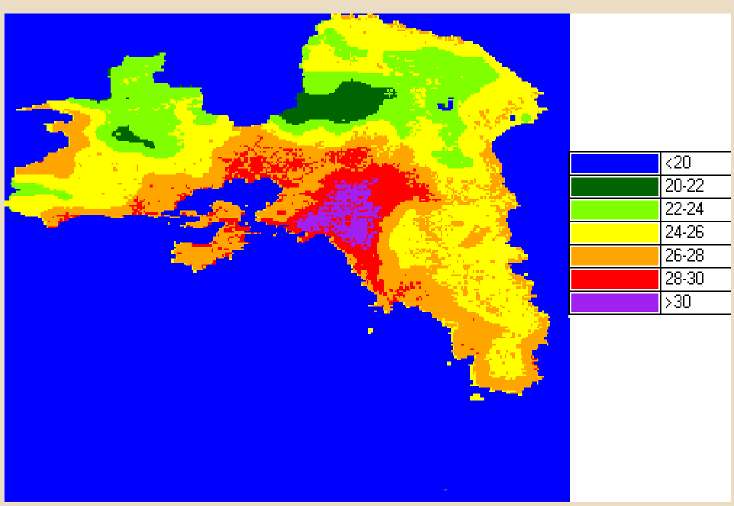
Satellite data
AVHRR/3 sensor
6 spectral bands
1.1 x 1.1km spatial resolution

Meteorological data
Air temperatures for 50 summer days with very high temperatures.

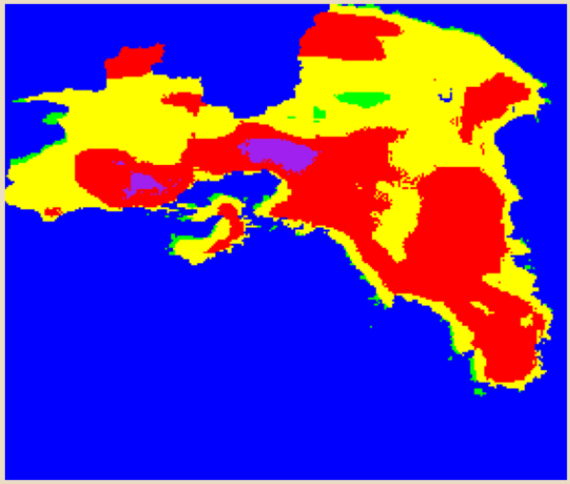
Daytime mean surface temperatures (°C)



Nighttime mean surface temperatures (°C)

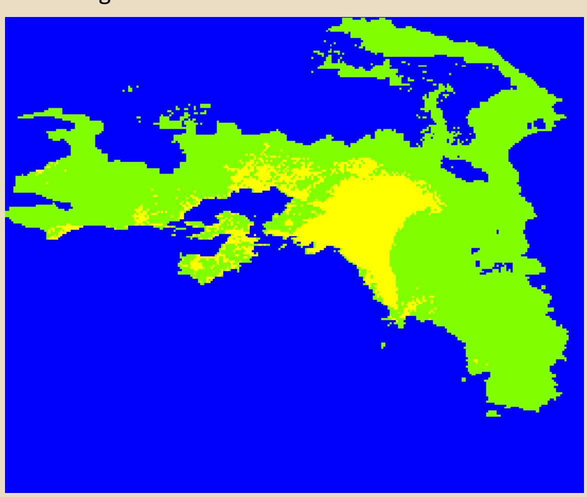


Daytime mean discomfort index values



- No discomfort
- Under 50% of the population feels discomfort
- Over 50% of the population feels discomfort
- Most of the population suffers discomfort
- Everyone feels severe stress
- State of medical emergency

Nighttime mean discomfort index values



- No discomfort
- Under 50% of the population feels discomfort
- Over 50% of the population feels discomfort
- Most of the population suffers discomfort
- Everyone feels severe stress
- State of medical emergency

Thank you

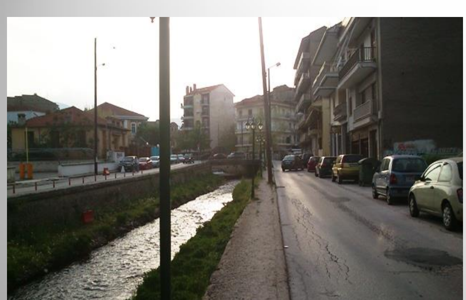
EVALUATION OF THE APPLICATION OF COOL MATERIALS IN URBAN SPACES: A CASE STUDY IN THE CENTER OF FLORINA

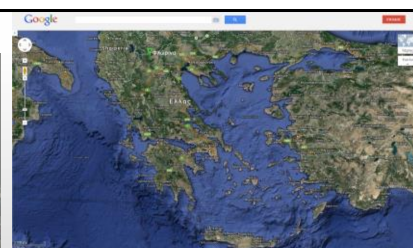
Stamatis Zoras , Panos Kosmopoulos, Argyro Dimoudi, Antonis Tsermentselis

Lab of Energy and Environmental Design in Buildings and Settlements
Democritus University of Thrace

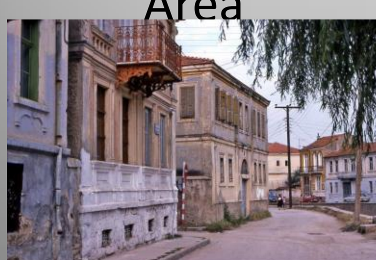
BIOCLIMATIC STUDY PROCEDURE

Description of the Simulated Area
Proof of Bioclimatic Concept
Model Verification
Material Description before and after Rehabilitation
CFD Results at present and after Bioclimatic Reformation
Microclimatic improvement





Florina Riverside Area

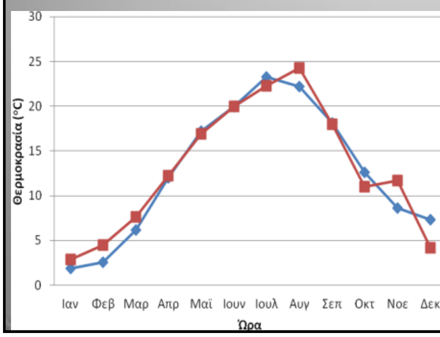


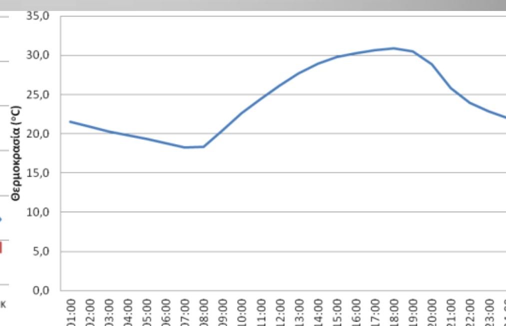
MODEL VERIFICATION

	Experimental / Simulated		
Material	Tair (°C) 1.8 m	WS(m//sec) 1.8 m	Tsurf (°C)
Pavement Flagstone	27.16 / 27.85	0.70 / 0.75	27.80 / 28.3
Concrete Brick	27.40 / 27.97	0.61 / 0.66	34.50 / 34.80
Asphalt	36.23 / 36.85	0.68 / 0.63	32.0 / 32.5

BIOCLIMATIC CONCEPT & MEASUREMENTS

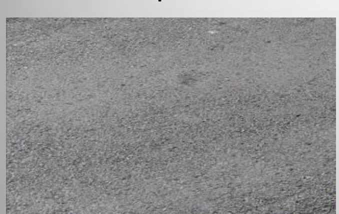
The meteorological data from the 26th of August, being the warmest day, was selected as input in CFD simulations



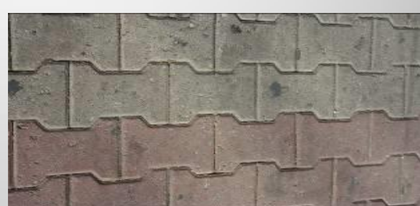


PRESENT CONVENTIONAL MATERIAL

Asphalt



Concrete Brick

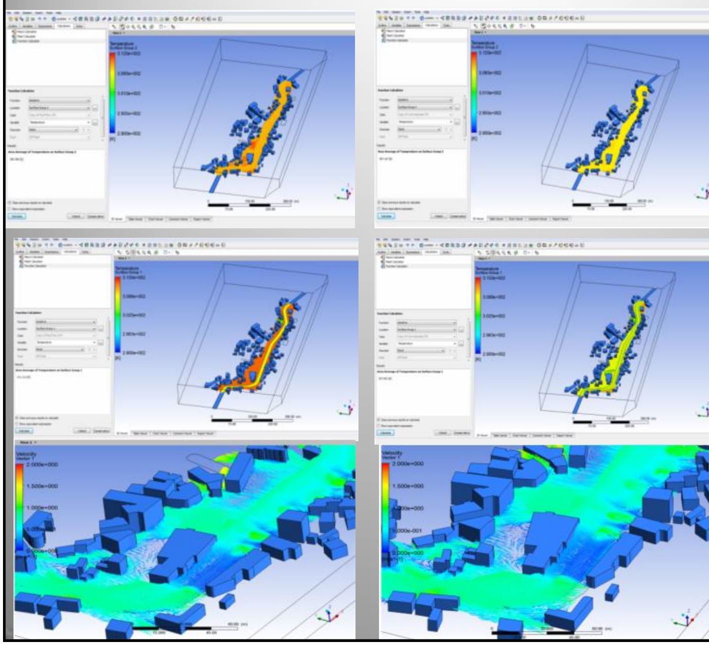


PROPOSED COOL MATERIAL

Stone Brick

Granite Slab

BIOCLIMATIC IMPROVEMENT



The calculated total air temperature before and after case was 35,57 ºC and 34.18ºC respectively. So, the air temperature improvement if bioclimatic measures are taken would be 1.39ºC.

The mean surface temperature during noon of the 26th of August for all surfaces reached 38.21 °C in contrast with the proposed bioclimatic configuration that reached 34.69ºC. The total predicted temperature difference was 3.52ºC.

Generally, human comfort would not be affected at all open locations due to insignificant differences in velocities before and after rehabilitation.

CONCLUSIONS

- Each targeted parameter would improve if the proposed rehabilitation would take place in future.
- Relatively low air temperature improvement may lead to significant thermal comfort improvement. This is because thermal comfort is rather independent from air temperature but mostly correlated to radiant temperature.
- Relatively high thermal comfort improvement is “easier” to be succeeded if surface thermal exchange is manipulated by any of the abovementioned ways.
- It is not so easy to reduce environmental temperature just by the replacement of surface materials because surface temperature reduction pass into air basically by convection.
- The wind field of velocities was approximately the same for the case before and after rehabilitation and therefore, it would not influence significantly the human thermal comfort conditions.
- Reflection coefficients of cooled materials were higher than the conventional materials but emission coefficients were approximately the same. Therefore, it is rather obvious the significance of roofs, green areas and trees within the open urban complex in relation to the improvement of air temperature.
- The exact influence of a bioclimatic intervention to microclimatic parameters must be studied in relation to urban complexity and climatic zone characteristics.