webinar
2020.03.26

Ventilative Cooling – Design and examples


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Ventilative Cooling – Design and examples

AGENDA

- 15:00 **Introduction to Annex 62** | Hilde Breesch, KU Leuven, Belgium
- 15:10 **Ventilative cooling design** | Guilherme Carrilho da Graça, University of Lisbon, Portugal
- 15:25 *Questions and Answers*
- 15:30 **Ventilative cooling potential & operational strategies** | Annamaria Belleri, EURAC, Italy
- 15:45 *Questions and Answers*
- 15:50 **Example ventilative cooling: CML Kindergarten (Portugal)** | Guilherme Carrilho da Graça, University of Lisbon, Portugal
- 16:00 **Example ventilative cooling: University Seminar Room** | Maria Kolokotroni, Brunel University London, UK
- 16:10 **Lessons learnt from ventilative cooling cases** | Paul O' Sullivan, Cork Institute of Technology, Ireland
- 16:20 *Questions and Answers*
- 16:30 End of the webinar

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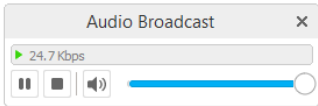

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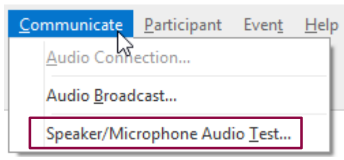

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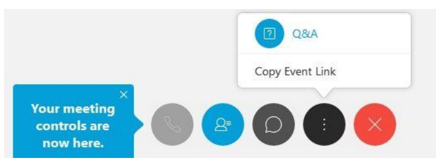
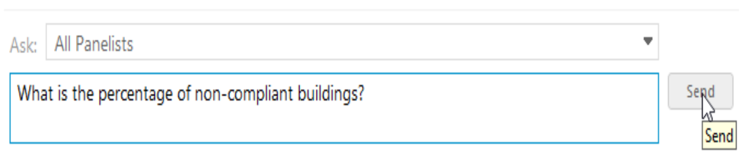


Select All Panelists | Type your question | Click on Send



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EBC

IEA EBC Annex 62

Ventilative Cooling

Hilde Breesch, KU Leuven

Per Heiselberg, Aalborg University

https://venticool.eu/annex-62-home/

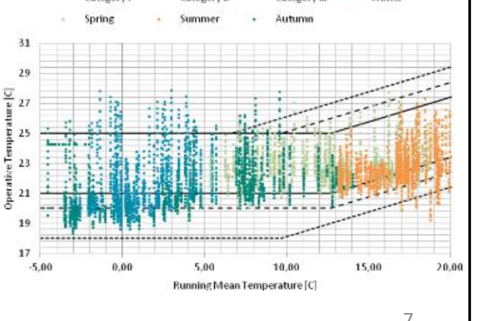
Background

Development towards nearly-zero energy buildings -> increased need for cooling all year

Elevated temperature levels = one of most reported problem in post-occupancy studies, in residences in “heating season”

large focus on reducing heating need in buildings

Need to address cooling need & develop energy-efficient cooling solutions



Ventilative cooling

Attractive & energy efficient passive solution to cool buildings & avoid overheating.

- Ventilation already present in most buildings through mechanical and/or natural systems
- Ventilative cooling: remove excess heat gains & increase air velocities -> widen thermal comfort range.
- cooling need not only in the summer period -> increased possibilities free cooling potential of low temperature outdoor air

Annex Objectives

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

Annex Leadership

Participating countries

– Australia, Austria, Belgium, China, Denmark, Finland, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Switzerland, UK, USA

Operating Agent:

– Denmark, represented by Per Heiselberg, Aalborg University

Subtask A:

– Leader: Switzerland, represented by Fourentzos Flourentzou, ESTIA
– Co-leader: Italy, represented by Annamaria Belleri, EURAC

Subtask B:

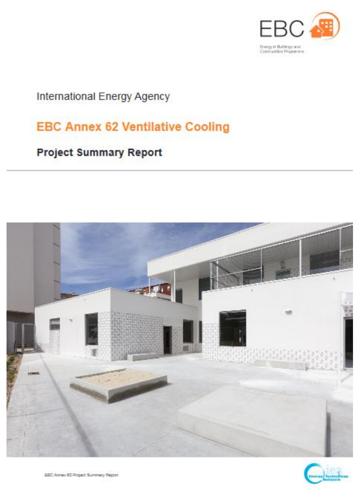
– Leader: Austria, represented by Peter Holzer, IBRI
– Co-leader: Denmark, represented by Theofanis Psomas, AAU

Subtask C:

– Leader: China, represented by Guoqiang Zhang, Hunan University
– Co-leader: Ireland, represented by Paul O'Sullivan, CIT

Deliverables

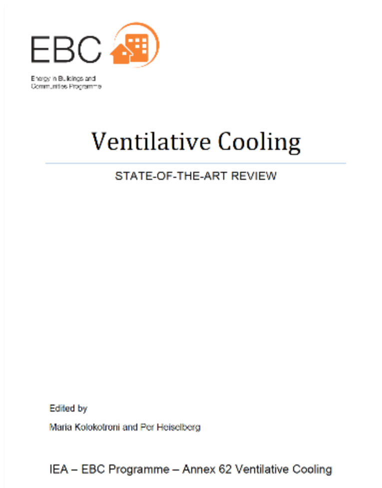
- Project Summary Report
  – Editors
    - Per Heiselberg, Denmark
  – Published June 2019



https://www.iea-ebc.org/projects/project?AnnexID=62

Deliverables

- State-of-the-art Report
  - Editors
    - Maria Kolokotroni, UK
    - Per Heiselberg, Denmark
  - Published in 2015



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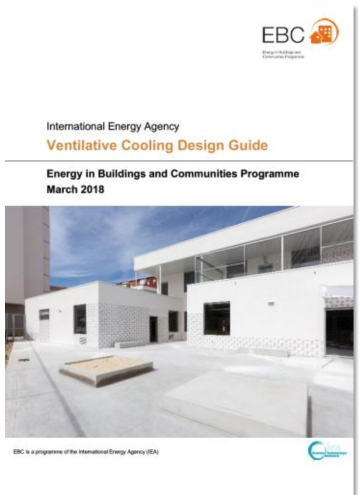
Deliverables

- Design Guide
  - Editors
    - Per Heiselberg, Denmark
  - Published March 2018



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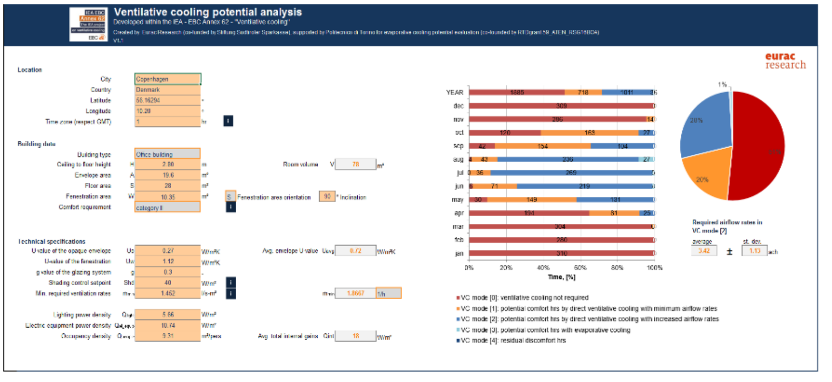
New Ventilative Cooling Tool

- Characteristics
  - Estimates climate potential dependent on building type & use
  - Suggests potential strategies & estimate necessary air flow rates



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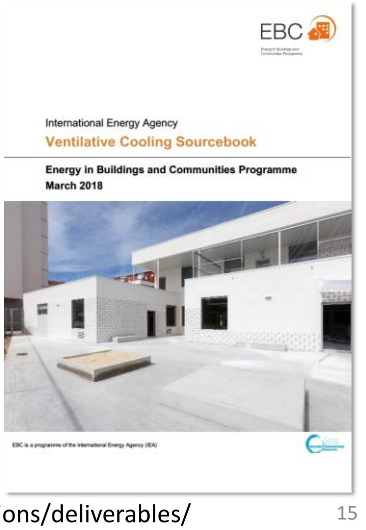
Deliverables

- Source Book
  - Editors
    - Peter Holzer, Austria
    - Theofanis Psomas, Denmark
  - Published March 2018



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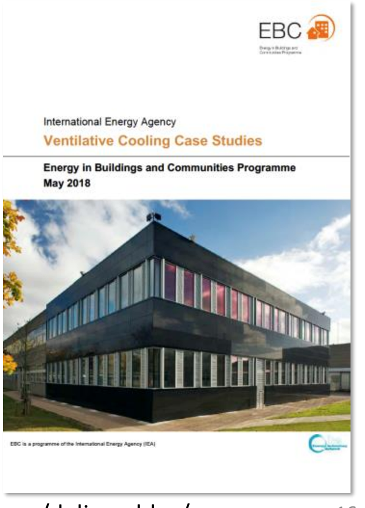
Deliverables

- Book of Case Studies
  - Editors
    - Paul O'Sullivan, Ireland
    - GuoQiang Zhang, China
  - Published April 2018



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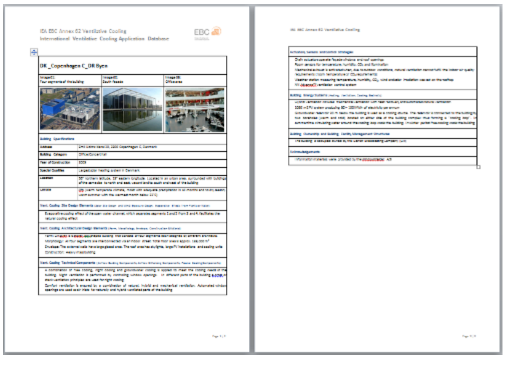
Buildings & Systems Database

- 91 built examples from Europe



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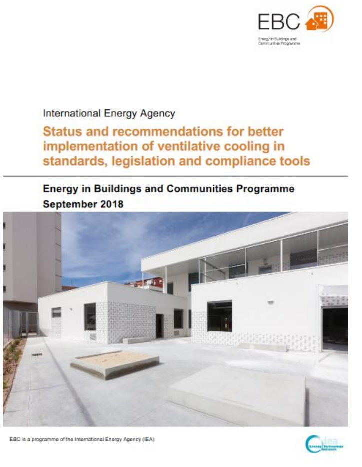
Deliverables

- Standards Recommendations
  - Editors
    - Karsten Duer, Christoffer Plesner, Denmark
  - Published September 2018



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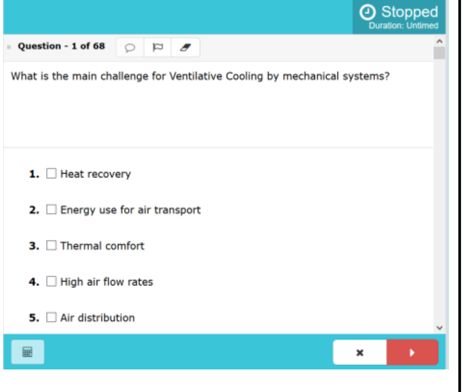
Deliverables

- Online tutorial
  - Published in 2018



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Ventilative cooling design

Prof. Guilherme Carrilho da Graça

DEGGE, Faculty of Sciences of the University of Lisbon, Portugal

MSc (MIT), PhD (UCSD), researcher in building energy efficiency, natural ventilation design, thermal and airflow simulation. Consultant, since 2002, in high performance building design. Worked in Europe, US, South America and Africa.

Ventilative cooling (VC):

- VC is the application of the cooling capacity of the outdoor air flow by ventilation to reduce or eliminate the energy demand for mechanical cooling in buildings.
- Ventilative Cooling utilizes the cooling potential of cool outdoor air.
- The airflow driving force can be either natural, mechanical or a combination of the two.
- The most common technique is the use of increased daytime ventilation airflow rates and/or nighttime ventilation.

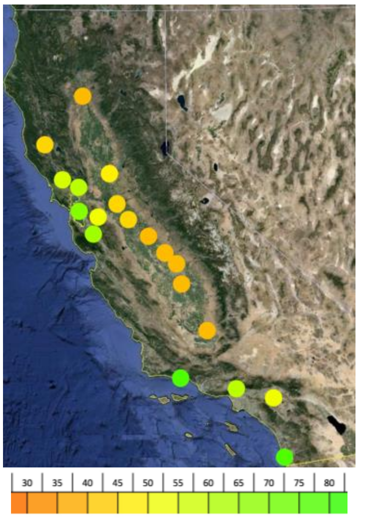
Introduction

Most modern office buildings use mechanical cooling in moments when an optimized ventilative cooling (VC) system could work.

Mechanical ventilation: 5-15W/m^2… + mechanical cooling… **HVAC energy consumption: 50%-60%** of total building energy consumption.

The best VC systems are able to replace mechanical cooling systems in the milder months of the year.

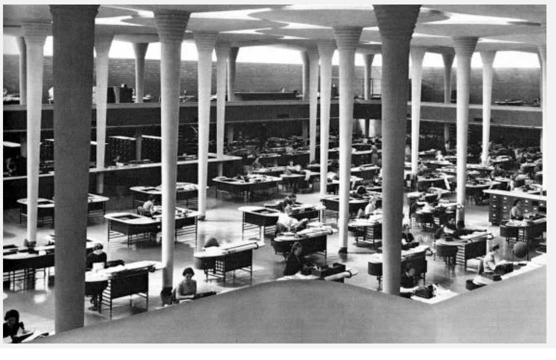
A successful **VC cooling system could halve office building energy consumption**.



Why is air conditioning a dominant feature in modern office buildings, even when natural ventilation (VC) has worked for centuries?

Early twentieth century offices were either narrow floor plan or large spaces with high ceiling.

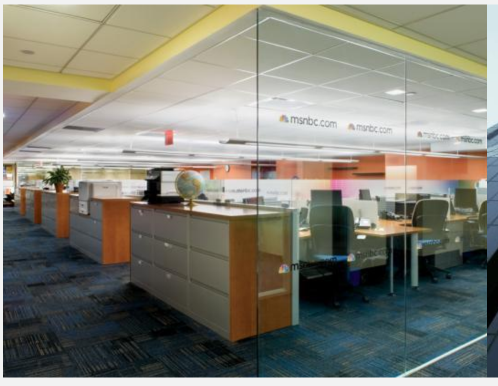
These configurations were good for VC either due to proximity of to window or the existence of an upper air layer to accumulate and exhaust indoor pollutants.

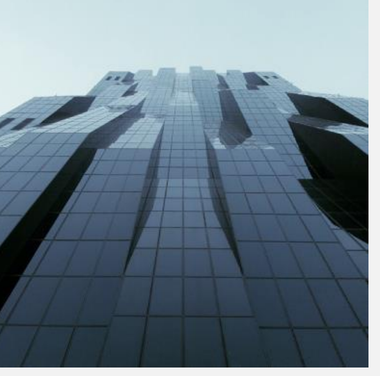


Why is air conditioning a dominant feature in modern office buildings, even when natural ventilation (VC) has worked for centuries?

The modern office is a harsh environment for VC.

NV cannot ensure thermal comfort in deep floor plans with high internal gains that, in many cases, are aggravated by a fully glazed solar collector like facade.





Natural light and spectacular architecture compromise VC systems…

In contemporary designs the desire to bring in natural light combined with the pressure for spectacular architecture leads to large glazed areas without proper shading that result in large solar gains that a VC system cannot effectively remove.

What can VC do and how are people doing it?

For non-domestic buildings VC can provide fresh air and limited cooling (sufficient in cold and mild weather periods) in spaces with limited depth or large height.

Performance data from buildings with VC indicates that minimum fresh air is usually achieved in spaces with limited depth (up to 6m or 15m) or wider rooms with large ceiling height (>5m) and high level exhaust.

The cooling capacity of most NV systems is limited to 20-30W/m^2 in cold or mild weather. When its warm outside….VC cooling power may go down to 0W/m^2.

The **typical size of the openings used is ((A_{in}+A_{out})/A_{room}):**

- **1-2%** for systems operating up to 18-20ºC outdoor.
- **3-5%** for systems operating up to 25ºC outdoor.
- **Up to 10%** for NV systems that try to provide warm weather cooling.

Ciências ULisboa

Does stack always improve wind-driven VC?

Two different flow driving forces that combine to drive all natural VC systems.

Stack is weaker but more reliable, because it is self adjusting: sensible heat internal loads drive the ventilation flow in a proportional way.

Wind is stronger but suffers from constant fluctuations in intensity and direction on a yearly, daily and minute scale.

In a given instant, the typical urban atmospheric boundary layer turbulence intensity is 10-20%, leading to wind pressure fluctuations of up to 40% (even more considering changes in wind direction).

Since every location will have moments of nearly zero wind pressure every wind driven **natural VC systems need to be designed for a worst case scenario of operating only with buoyancy forces.**

Ciências ULisboa
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International Energy Agency

Ventilative Cooling Design Guide

Energy in Buildings and Communities Programme
March 2018

Editor

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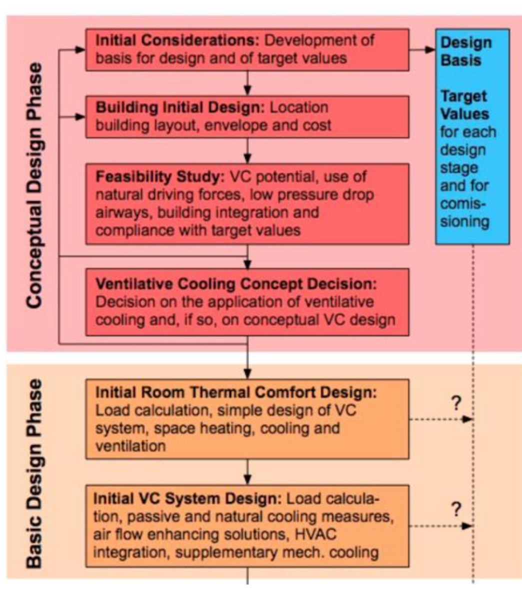


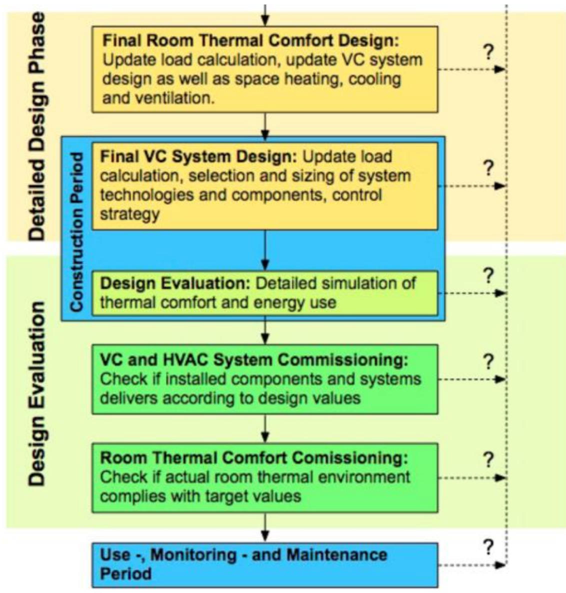


Figure 8. Design procedure for ventilation and ventilative cooling.

Table 8. Evaluation of the need for mechanical assistance in driving the air flow.

Ventilative cooling: Need for fan assistance?						
Outdoor environment		**N**		**M**		**Y**
Cold	Winter (heat recovery needed)			■	■	■
	Summer	■	■			
Moderate		■				
Hot and dry	Winter	■	■			
	Summer (low temp. difference)			■	■	
Hot and humid	Winter	■	■	■		
	Summer (mechanical cooling needed)			■	■	■
Dense urban area with low wind speeds (low natural driving force)				■	■	■
Dense urban area with high night temperatures (heat island)				■	■	■
High pollution level in the area (air filtration needed)				■	■	■
Noisy surroundings (high noise insulation needed)			■	■	■	
Building heat load level		**N**		**M**		**Y**
Low heat loads < 20 W/m² during occupation	Cold (> 10°C from comfort zone) (heat recovery needed)			■	■	■
	Temperate (2-10°C from comfort zone)	■	■	■		
	Hot and dry (-2°C .... +2°C from comfort zone)		■	■	■	
	Hot and humid				■	■
Medium heat loads 20 -30 W/m² during occupation	Cold (> 10°C from comfort zone) (heat recovery needed)		■	■	■	
	Temperate (2-10°C from comfort zone)	■	■			
	Hot and dry (-2°C .... +2°C from comfort zone)			■	■	■
	Hot and humid					■
High heat loads > 30 W/m² during occuation	Cold (> 10°C from comfort zone) (heat recovery needed)	■	■	■		
	Temperate (2-10°C from comfort zone)	■	■			
	Hot and dry (-2°C .... +2°C from comfort zone)				■	■
	Hot and humid					■
Thermal comfort		**N**		**M**		**Y**
High requirements for 95% of occupancy hours						■
Normal requirements for 90% of occupancy hours			■	■	■	
Normal requirements for 80% of occupancy hours		■	■	■		
Requirements adaptive to outdoor conditions		■	■			
Integration with other natural cooling solutions		**N**		**M**		**Y**
Chilled slab by ground water exchange		■	■			
Earth to air heat exchanger			■	■	■	
Evaporative cooling		■	■			

Table 9. Evaluation of the need of supplementary natural or mechanical cooling solutions.

Ventilative cooling System: Need for supplementary cooling?						
Outdoor environment		N		M		Y
Cold (> 10°C from comfort zone)						
Temperate (2-10°C from comfort zone)						
Hot and dry (-2°C …. +2°C from comfort zone)						
Hot and humid						
Dense urban area with low wind speeds (low natural driving force)						
Dense urban area with high night temperatures (heat island)						
High pollution level in the area						
Noisy surroundings						
Building heat load level:		N		M		Y
Low heat loads < 20 W/m² during occupation	Cold (> 10°C from comfort zone) (heat recovery needed)					
	Temperate (2-10°C from comfort zone)					
	Hot and dry (-2°C …. +2°C from comfort zone)					
	Hot and humid					
Medium heat loads 20 -30 W/m² during occupation	Cold (> 10°C from comfort zone) (heat recovery needed)					
	Temperate (2-10°C from comfort zone)					
	Hot and dry (-2°C …. +2°C from comfort zone)					
	Hot and humid					
High heat loads > 30 W/m² during occuation	Cold (> 10°C from comfort zone) (heat recovery needed)					
	Temperate (2-10°C from comfort zone)					
	Hot and dry (-2°C …. +2°C from comfort zone)					
	Hot and humid					
Thermal comfort:		N		M		Y
High requirements for 95% of occupancy hours						
Normal requirements for 95% of occupancy hours						
Normal requirements for 80% of occupancy hours						
Requirements adaptive to outdoor conditions						
Building and system:		N		M		Y
Low level of exposed building thermal mass						
Moderate level of exposed building thermal mass						
High level of exposed building thermal mass						
High space- and use-flexibility						

Ventilative cooling design

Thanks!

eurac research

Ventilative cooling potential & operational strategies

Annamaria Belleri
Eurac Research

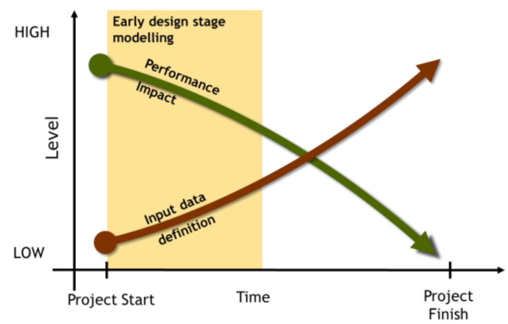
Outline

- Ventilative cooling potential tool
- How to use the tool within the design process
- Outlook and further tool developments ongoing

Why do we care?

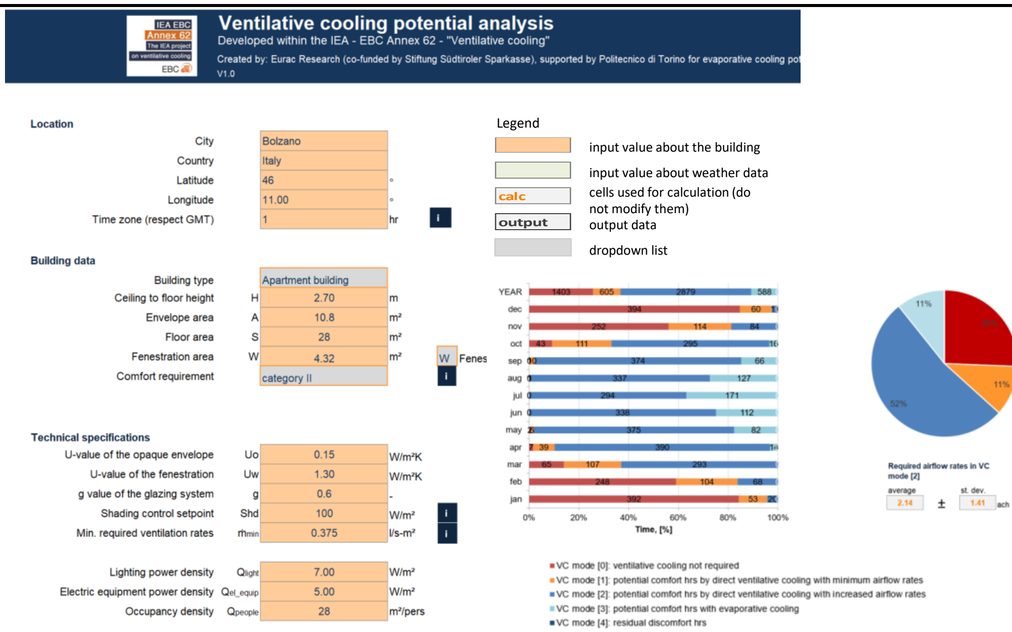
Being able to assess ventilative cooling potential **during the conceptual design phase**, when decisions about ventilative cooling application are made

Provide design airflow rates for ventilative cooling



Introduction

- Ventilative cooling is dependent on the **availability of suitable external conditions** to provide cooling
- As buildings with different use patterns, envelope characteristics and internal loads level (i.e. due to occupants, equipment and lighting) react differently to the external climate condition, the **ventilative cooling potential analysis cannot abstract from building characteristics and use**

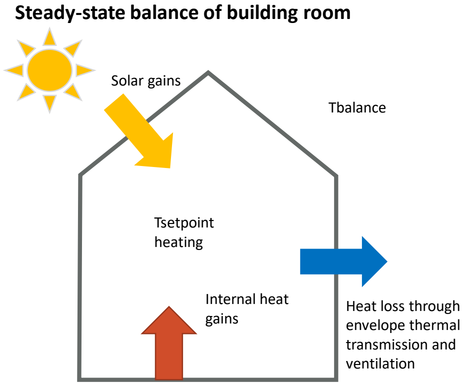


http://venticool.eu/wp-content/uploads/2017/05/V1.0_Ventilative-cooling-potential-analysis-tool.xlsm

Ventilative cooling potential evaluation

Background

Steady-state balance of building room



The **heating balance point temperature** is the outdoor temperature at which heat gains are equal to heat losses.

When outdoor temperature falls below heating balance point temperature, heating must be provided to maintain indoor air temperatures at a defined internal heating set point temperature.

This relies on the assumption that the accumulation term of the energy balance is negligible. It is a reasonable assumption if either the thermal mass of the zone is negligibly small, or the indoor temperature is regulated to be relatively constant.

For each hour of the annual climatic record (user-input) of the given location, the algorithm splits the total number of hours when the building is occupied into the following groups:

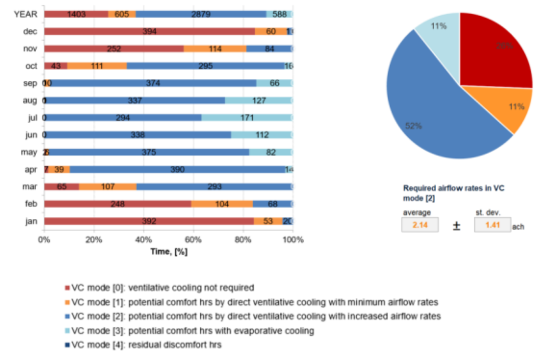
Ventilative cooling not required: when the outdoor temperature is below the heating balance point temperature no ventilative cooling can be used since heating is needed;

Potential thermal comfort by health-based ventilation: when the outdoor temperature exceeds the balance point temperature, yet falls below the lower temperature limit of the comfort zone, direct ventilation with airflow rate maintained at the minimum required for indoor air quality can provide comfort;

Potential thermal comfort by ventilative cooling: when the outdoor temperature is within the range of comfort zone temperatures, direct ventilation with increased airflow rate can provide thermal comfort

Potential thermal comfort by evaporative cooling: when the outdoor humidity is low enough to cool the air through water evaporation.

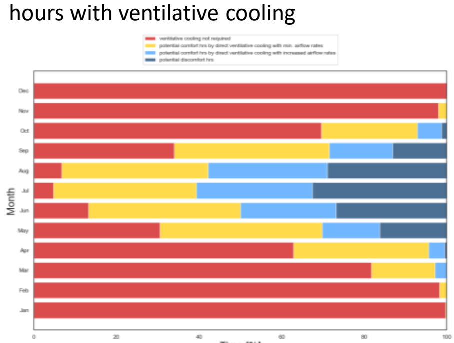
Remaining potential thermal discomfort hours: when the outdoor temperature exceeds the upper temperature limit of the comfort zone and furthermore this limit is also overtaken from the expected DEC outlet temperature.



Annamaria Belleri, Marta Avantaggiato, Theofanis Psomas & Per Heiselberg (2018) Evaluation tool of climate potential for ventilative cooling, International Journal of Ventilation, 17:3, 196-208, DOI: 10.1080/14733315.2017.1388627

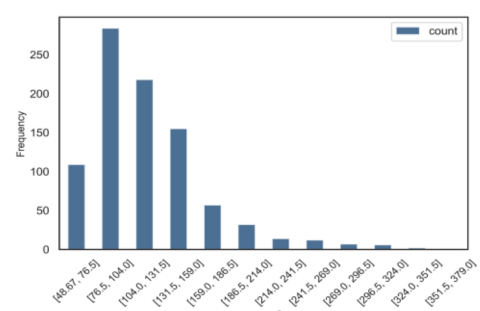
How to use the tool within the design process

1 Estimate the number of potential comfort hours with ventilative cooling



Light blue bars represent the percentage of time when ventilative cooling can potentially provide comfort.

2 Identify the design airflow rate



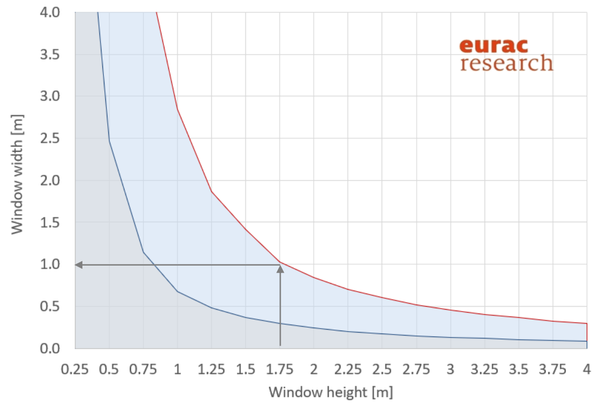
Frequency of the required airflow rates to keep building temperature within the comfort range.

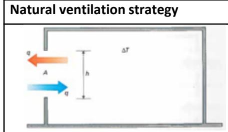
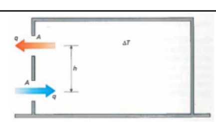
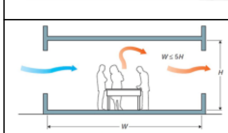
How to use the tool within the design process

3 Size window openings to provide the design airflow rate at pre-defined conditions

Window design

Max required airflow rate for ventilative cooling	ṁmax	360	m³/hr	
Required airflow rate for IAQ	ṁmin	103	m³/hr	
Room height	H	2.7	m	
Room depth	D	6	m	2H < D < 5H
Ventilation strategy		Single-sided: buoyancy only		
Select window opening type		side hung		
Window maximum opening angle	α	45	°	
Window opening discharge coefficient	cd	0.6		
Indoor temperature	Ti	25	°C	
Indoor-outdoor temperature difference	ΔT	3	K	
Wind speed	vref	0	m/s	
Insect screen?		N	Y/N	
Stack height - vertical distance between 2 openings	h	1	m	
Wind pressure coefficient - window 1	Cp1	0.2		
Wind pressure coefficient - window 2	Cp2	0.1		



Natural ventilation strategy		Equation	
	Single-sided ventilation – buoyancy driven	$A_{geo} = \frac{3q}{c_d\sqrt{\frac{g(T_i - T_e)H}{T_i}}}$	q = total air flow rate through the opening [m³/s]; A_{geo} = geometrical opening area [m²]; c_d = discharge coefficient for the opening. For windows typically 0,6-0,7 [-]; H = opening height [m]; g = gravitational acceleration [m/s²]; T_e = external temperature [K]; T_i = internal temperature [K]
	Single-sided ventilation – buoyancy and wind driven	$A_{geo} = \frac{2q}{c_d\sqrt{0.001 v_{ref}^2 + 0.035 * H * (T_i - T_e) + 0.01}}$	v_{ref} = wind speed at a reference height (building height) [m/s]; H = opening height [m]; T_e = external temperature [K]; T_i = internal temperature [K]
	Stack ventilation	$A_{geo} = \frac{q\sqrt{2}}{c_d\sqrt{\frac{2gh(T_i - T_e)}{T_e}}}$	q = total air flow rate through the opening [m³/s]; c_D = discharge coefficient h = height difference between midpoint height of the two openings [-]; T_e = external temperature [K]; T_i = internal temperature [K]
	Cross ventilation	$A_{geo} = \frac{q}{c_d\sqrt{\frac{\lvert c_{p1}\rho_u v_{ref}^2 - 2P_i \rvert}{\rho_u}}}$	A = effective opening area of the two windows ($A_1 = A_2$) [m²]; c_d = discharge coefficient [-]; C_{p1} = wind pressure coefficient of opening 1 [-]; C_{p2} = wind pressure coefficient of opening 2 [-]; ρ_u = outdoor air density [kg/m³]; v_{ref} = wind speed in the reference height (normally building height) [m/s]; P_i = internal pressure [Pa].

Source: IEA Annex 62 - ventilative cooling design guide

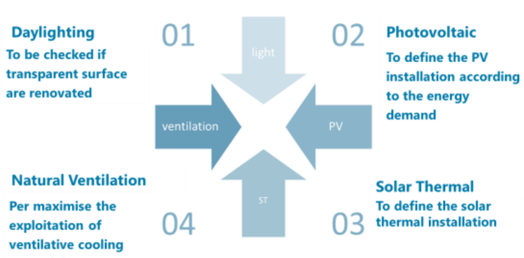
Outlook and further tool developments ongoing

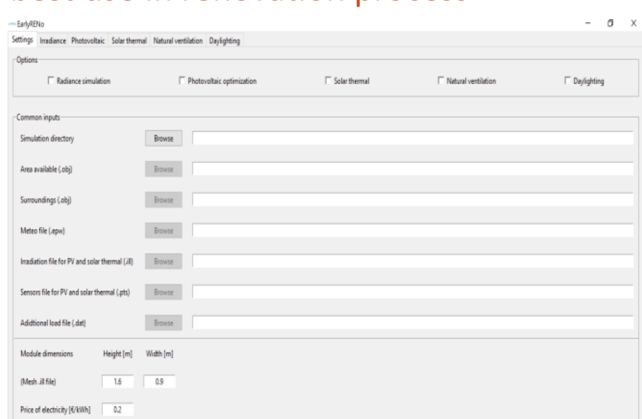
After release of version 1.0 (excel-based) as outcome of IEA EBC Annex 62, we have been working on:

- Integrating new window design features
- Ensuring compliance with new standard EN 16798-1: 2019 requirements
- User interface (simplified input data, data visualizations..)
- Python version including solar gains calculation through Radiance
- Investigating the use of a lumped capacitance model to consider building thermal mass
- Adapting the calculation methodology to EN ISO 52016-1 on building energy performance calculation and potential integration in the new standard on ventilative cooling systems (CEN/TC 156/WG21)

Early RENo tool

Early design methodology for RES best use in renovation process





https://4rineu.eu/2019/03/25/early-reno-graphical-user-interface/

4RinEU

Conclusion

- The tool is particularly suitable for **concept design phases**, as it requires only basic information about the building features and use
- The tool also provides building designers with useful information about the level of **ventilation rates needed to offset given internal heat gains rate**
- The tool is under continuous improvement and its methodology is being adapted to existing standard on energy performance calculation

Thank you for your attention

Annamaria Belleri

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www.eurac.edu

Follow us!

NOI TechPark Bolzano. Credits: NOI Spa

Implementing VC technologies in kindergartens

IEA EBC Annex 62 The IEA project on ventilative cooling

Guilherme Carrilho da Graça
Eng. Physics (IST), MSc (MIT), PhD (UCSD)

Assistant Professor in Building Energy Systems
University of Lisbon

Kindergarten design developed by Natural Works

Location	Lisbon, Portugal
Building Type	Kindergarten
Retrofit (Y/N)	N
Surroundings (Urban / Rural)	Urban
Ventilative Cooling Strategy	SS and DV
Year of Completion	2013
Floor Area (m^2)	680
Shape Coefficient (%)	32
Openable Area to Floor Area Ratio (%)	8
Window to Wall Ratio (%)	18
Sensible Internal Load (W/m^2)	53
STA KPI	-
Climate Zone (KG)	Csa
No. of Days with T_e max > 25	120
Cooling Season Humidity	Low
Heating Degree days (Kd)	215

2 Building Information

IEA EBC Annex 62 The IEA project on ventilative cooling

Parameter	Level of Influence
Initial Costs	●
Maintenance Costs	•
Energy costs	•
Solar Loads	●
Internal Loads	●
External Noise	•
Internal Noise Propagation	•
Air Pollution	•
Rain Ingress	●
Insect prevention	●
Burglary prevention	●
Privacy	●

4 Ventilative Cooling

IEA EBC
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The IEA project
on ventilative cooling

5 Control Strategies

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The IEA project
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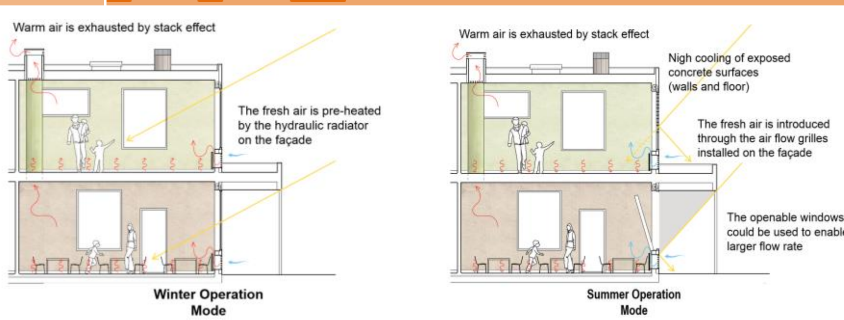

Season		Grille 0%= closed, 100% = open	Chimney 0º= closed, 90º = open	Window 0%= closed, 100% = open
Winter/Autumn	Day Night	30% 0%	30º 0º	30% 0%
Spring	Day Night	50% 50%	45º 45º	50% 0%
Summer	Day Night	100% 100%	90º 90º	100% 100%

6 Design Simulation

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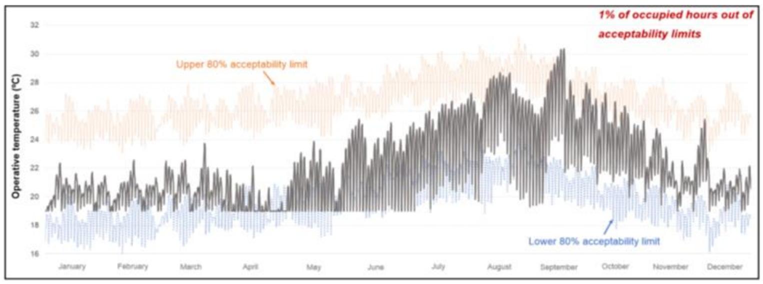
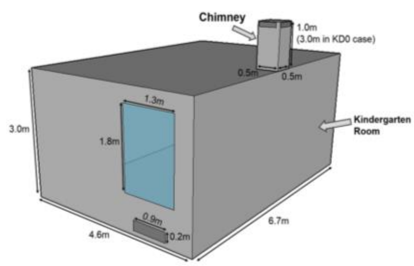
on ventilative cooling





Parameter	Value
T_e , Summer External Temp	30
T_z , Summer Operative Temp	26ºC
Overheating criteria	Adaptive comfort model (80% acceptability limit) for 99% hr_{occ}
Min IAQ air supply rate	7l/s/occupant
Cooling air supply rate	-
Noise Level Rating	-

7 Performance Evaluation

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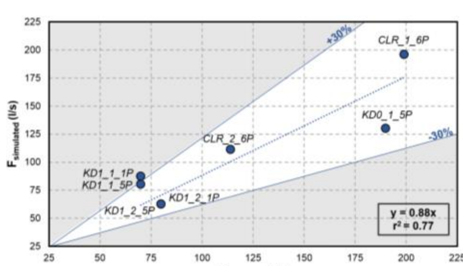
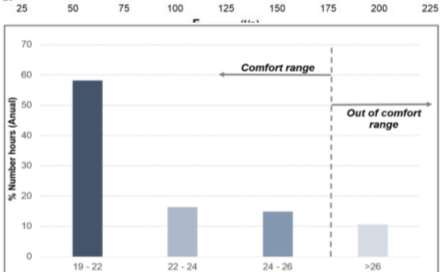
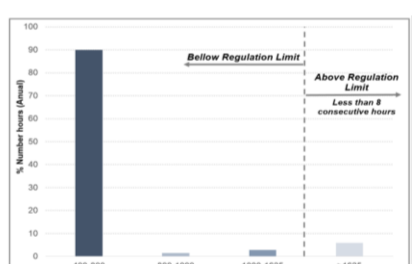
The IEA project
on ventilative cooling



Parameter	Typical year (TMY)
Total Hours > 25°C	12%
Occ Hours > 25°C	16%
Total Hours > 26°C	7%
Occ Hours > 26°C	10%





8

Ventilative cooling: Need for fan assistance?						
Outdoor environment		**N**		**M**		**Y**
Hot and dry	Winter	O				
	Summer (low temp. difference)			O[1]		
Dense urban area with low wind speeds (low natural driving force)					O	
Noisy surroundings (high noise insulation needed)				O[2]		
Building heat load level:		**N**		**M**		**Y**
High internal loads > 30 W/m² during occuation	Cold (> 10ºC from comfort zone) (heat recovery needed)	O[3]				
	Temperate (2-10ºC from comfort zone)	O[3]				
	Hot and dry (-2ºC …. +2ºC from comfort zone)				O[1]	
Thermal comfort:		**N**		**M**		**Y**
Normal requirements for 90% of occupancy hours					O[3]	
Building and system:		**N**		**M**		**Y**
High level of exposed building thermal mass		O[4]				

Notes on ratings used above:

1. Although the Lisbon climate is warm in the summer the kindergartens are closed in August. For this reason, we chose "Maybe".
2. This project included eleven kindergartens in different locations in the Lisbon urban area. In two cases, there were noisy surroundings. Cost constraints for all the buildings did not allow for the use of advanced acoustic insulation solutions.
3. The Portuguese building code mentions an indoor temperature range of 19-27°C with no proposed % of time outside this range. EN15251 proposes a requirement of no more than 5% of occupied hours outside this range. The project used these two criteria.
4. The buildings have exposed concrete internal and external walls (with exterior insulation) and exposed concrete floors

9

A simple quantitative interpretation of the table "need for fan assistance" can be done by attributing a value to each line (No=1, Maybe=3, Yes=5). In this case, the average value is 2.4: the project may need fan assistance. In fact, it was decided in the project to use chimneys to obtain the required assistance effect.

Ventilative cooling System: Need for supplementary cooling?						
Outdoor environment		**N**		**M**		**Y**
Temperate (2-10ºC from comfort zone)				O		
Dense urban area with low wind speeds (low natural driving force)				O		
Dense urban area with high night temperatures (heat island)			O			
Noisy surroundings				O		
Building heat load level:		**N**		**M**		**Y**
High internal loads > 30 W/m² during occuation	Temperate (2-10ºC from comfort zone)			O		
Thermal comfort:		**N**		**M**		**Y**
Normal requirements for 90% of occupancy hours				O		
Building and system:		**N**		**M**		**Y**
High level of exposed building thermal mass		O				
High space- and use-flexibility			O			

A simple quantitative interpretation of the table "need for supplementary cooling" can be done in the same way as the table before to identify the need for fan assistance. In this case, the average value is 2.1. This value is between "No" and "Maybe". The project uses night cooling and a ventilative cooling system that is assisted by chimneys. A monitoring campaign during the spring and early summer of 2016 showed that adequate thermal comfort can be achieved with 5-10% overheating hours. This is consistent with the results of the quantitative analysis of this table.

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Performance Evaluation

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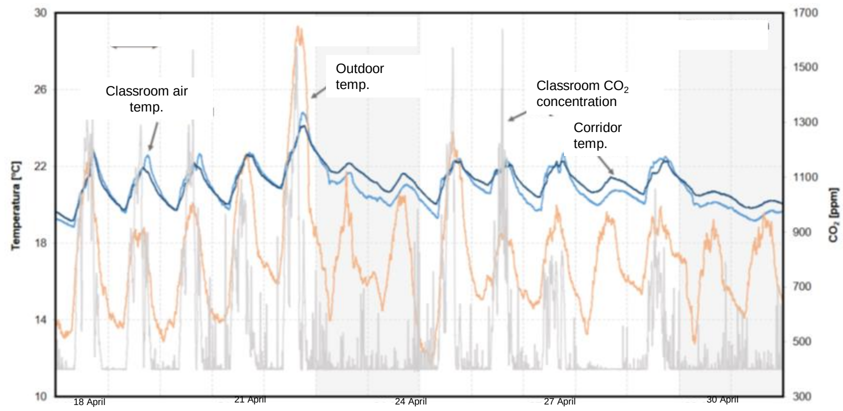

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Performance Evaluation

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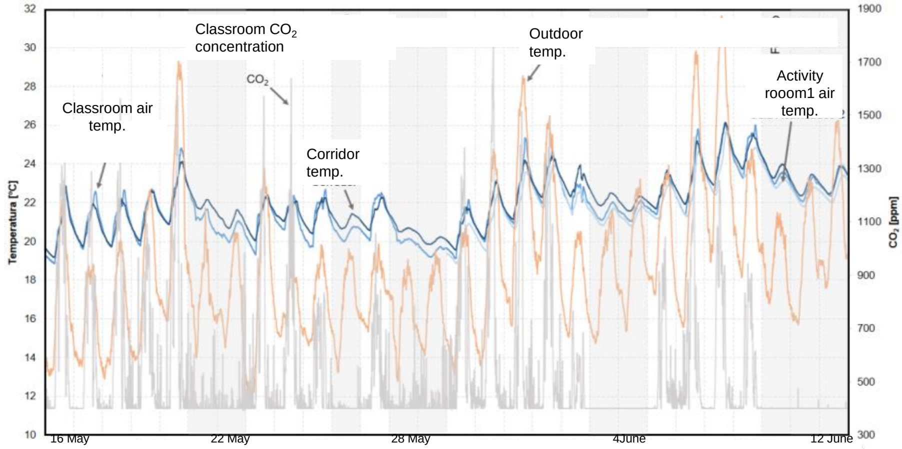
on ventilative cooling



12 Performance Evaluation

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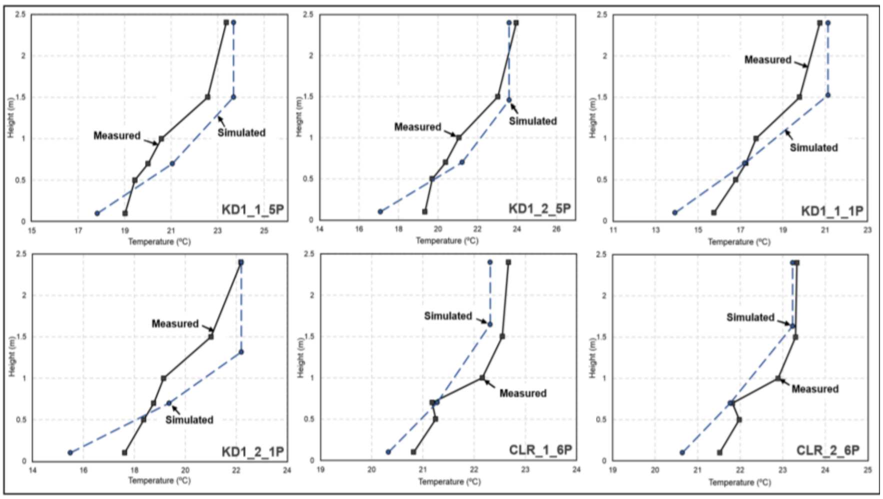
on ventilative cooling



Implementing VC technologies in kindergartens

IEA EBC
Annex 62
The IEA project
on ventilative cooling

Guilherme Carrilho da Graça Eng. Physics (IST), MSc (MIT), PhD (UCSD)

Assistant Professor in Building Energy Systems University of Lisbon

Kindergarten design developed by Natural Works

Thanks!!!!

Check the guide:

International Energy Agency

Ventilative Cooling Design Guide

Energy in Buildings and Communities Programme
March 2018

Example Ventilative Cooling University Seminar Room in the UK

Professor Maria Kolokotroni

Brunel University London

Department of Mechanical and Aerospace Engineering

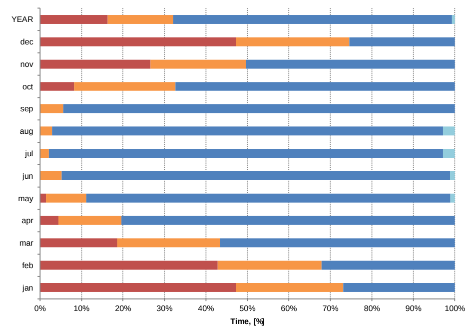
Leader: Resource Efficient Future Cities Group

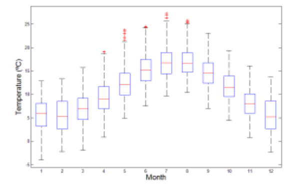
Research Institute of Energy Futures

Location and building description

Property	Unit	Value
Occupant density	m^2/p	4
Hours of occupancy	h/week	60
Sensible Internal Load	(W/m^2)	54
Window U-value	W/m^2K	1.82
Window g-value	(-)	0.43
Wall U-value	W/m^2K	0.56
Roof U-value	W/m^2K	NA
Floor U-value	W/m^2K	2.11
Q-value (from Japan)	(W/ m^2)/K	
Thermal Mass (ISO 13790)	-	Medium
Window to Wall Ratio	%	50
Air-tightness (@50 Pa)	1/h	<10 m^3/hm^2
Shape Coefficient (1/m)	%	50%

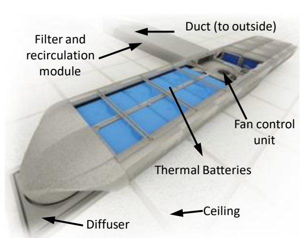
Climate and ventilative cooling



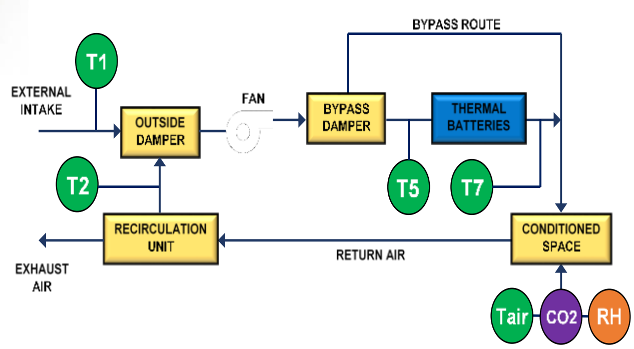


- VC mode [0]: ventilative cooling not required
- VC mode [1]: potential comfort hrs by direct ventilative cooling with minimum airflow rates
- VC mode [2]: potential comfort hrs by direct ventilative cooling with increased airflow rates
- VC mode [3]: potential comfort hrs with evaporative cooling
- VC mode [4]: residual discomfort hrs

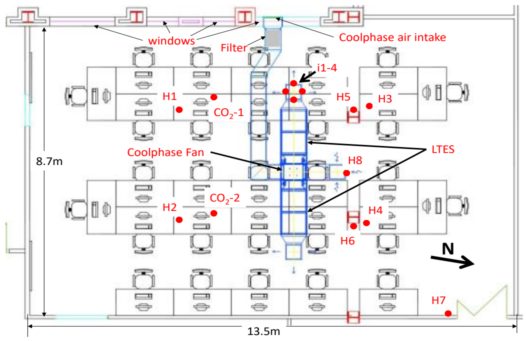
The system

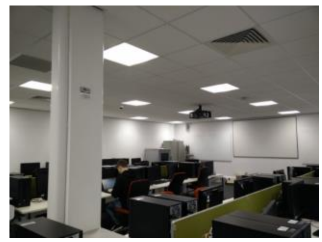


Cool-Phase® by Monodraught Ltd

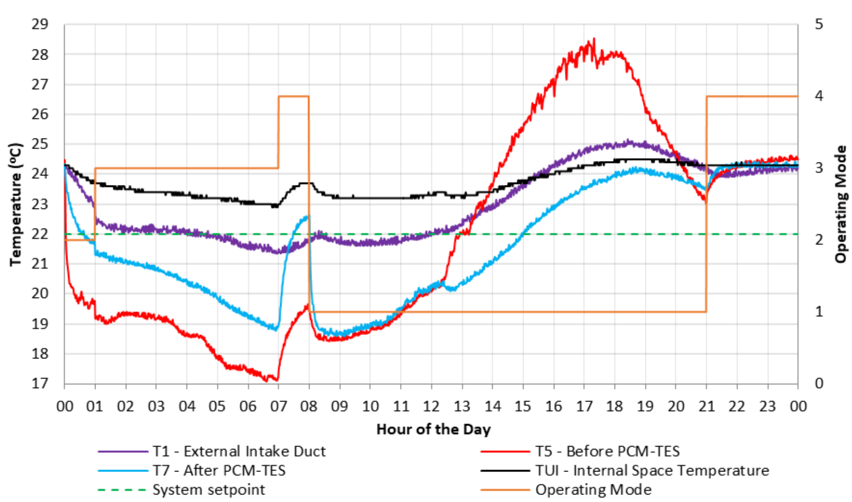


Seminar room

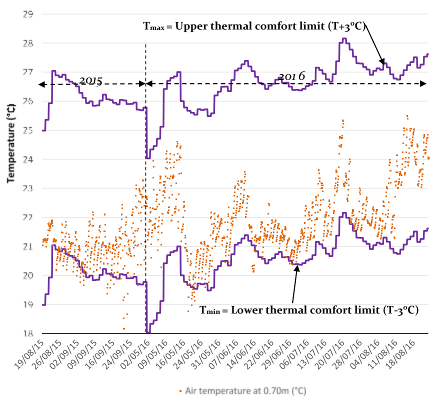


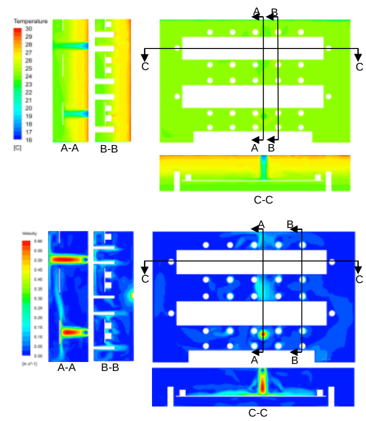


Operation



Thermal Comfort analysis





IQ

CO_2 concentration in the seminar room from 8:00 to 21:00.			
	2014	2015	> 1500 ppm for more than 20 min
Month	Avg. CO_2	Avg. CO_2	
Jan	601	563	0
Feb	719	671	1
Mar	695	645	0
Apr	559	549	0
May	469	443	0
Jun	412	420	0
Jul	409	420	0
Aug	423	418	0
Sep	493	541	0
Oct	599	689	0
Nov	701	752	0
Dec	551	586	0
Avg.	553	558	-

Summary of the talk

- This case-study presented a Ventilative cooling system that can be suitable for newly built and retrofit applications.
- It uses a mechanical ventilation system with PCM thermal storage that utilises night cool air for solidifying the PCM.
- The system's capacity and controls were able to provide indoor air quality and thermal comfort in the space under the external weather condition of West England.
- Detailed monitoring of the space and CFD analysis indicates that the system can provide acceptable thermal comfort throughout at occupant level.

Thank you

Ventilative Cooling – Design & Examples
AIVC & Venticool Webinar 26th March 2020

Design and Performance of Ventilative Cooling: Lessons Learned From a Review of Well Documented International Case Studies

Paul D O'Sullivan
MeSSO Research (https://messo.cit.ie)
Cork Institute of Technology, Ireland

agenda

- Annex 62 & Subtask C
- Climate
- Overview of Case Study Buildings
- Design Influences
- VC Strategies
- Control Strategies
- Performance
- Lessons Learned
- Brochure & Dissemination

Well Documented Case Studies of VC
Annex 62 – Sub Task C

To fulfil the scope of the Annex and to make energy-efficient use of ventilative cooling (air-based systems) the preferred solution the Annex focuses on the following specific objectives:

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

- Activity C.1.

Analysis and evaluation of performance of ventilative cooling solutions and of used design methods and tools using similar criteria and methods

- Activity C.2.

Lessons learned and development of recommendations for design and operation of ventilative cooling as well as identification of barriers for application and functioning.

What Climates Are Covered In The Case Studies?

Climate of Case Studies

Variation in climate regions for all case study buildings.

(Please refer to the Koppen-Geiger climate classification system for details on KG abbreviations in column 1)

K-G	General Description	Qty	Locations
Cfb	Temperate with warm summers and no dry season	5	Cork, IE; Ernstbrunn, AT; Waregemand Ghent, BE; Verrieres-le-Buisson, FR; Bristol, UK
Cfa	Temperate, hot summers and no dry season	3	Changsha, CN; Hayama, JP
Dfb	Cold with warm summers and no dry season	3	Stavern, NO; Trondheim, NO; Innsbruck, AT
Dfc	Cold with no dry season and cold summer	1	Larvik, NO
Csa	Temperate with dry, hot summers	2	Sicily, IT; Lisbon PT

Who, Where, What, When?

Contributions

Country	Building Name	Building Type	Year	Floor Area m^2	Strategy
IE	zero2020	Office	$2012^{(R)}$	223	Natural
NO	Brunla Primary school	Education	$2011^{(R)}$	2500	Hybrid
NO	Solstad barnehage	Kindergarten	$2011^{(N)}$	788	Hybrid
AT	UNI Innsbruck	Education	$2014^{(R)}$	12,530	Hybrid
AT	wk Simonsfeld	Office	$2014^{(N)}$	967	Hybrid
BE	Renson	Office	$2003^{(N)}$	2107	Natural
BE	KU Leuven Ghent	Education	$2012^{(N)}$	278	Hybrid
JP	Nexus Hayama	Mixed Use	$2011^{(N)}$	12,836	Natural
JP	GFO Building Osaka	Office	$2013^{(N)}$	394,000	Hybrid
PT	CML Kindergarden	Education	$2013^{(N)}$	680	Natural
UK	Bristol University	Education	$2013^{(R)}$	117	Mechanical

Country	Building Name	Building Type	Year	Floor Area m^2	Strategy
CN	Wanguo MOMA	Residential	$2007^{(N)}$	1109	Mechanical
FR	Maison Air et Lumiere	House	$2011^{(N)}$	173	Natural
IT	Mascalucia ZEB	House	$2013^{(N)}$	144	Hybrid
NO	Living Lab	Residential	$2014^{(N)}$	100	Hybrid

What were the design influences for Ventilative Cooling ?

Design Influences

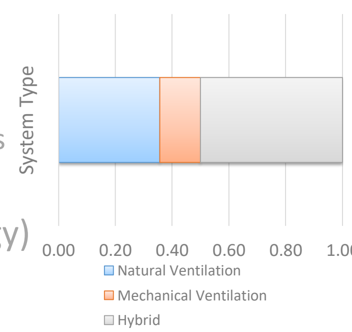
Country		Building	Lower Initial costs	Lower Maintenance Costs	Lower Energy Costs	Reducing Solar Loads	Reducing Internal Loads	Reducing External Noise	High Internal noise propagation	Elevated Air Pollution	Avoiding Rain Ingress	Insect Prevention	Burglary Prevention	Reduced Privacy	Air Leakage
IE	R	zero2020	H	M	H	H	L	L	L	L	M	L	H	M	M
NO	R	Brunla Primary school	H	H	H	L	M	L	L	H	M	L	L	L	H
NO	R	Solstad barnehage	L	L	H	L	L	L	M	H	L	L	L	L	H
AT	U	UNI Innsbruck	H	H	H	M	L	M	L	L	M	L	L	L	H
AT	R	wk Simonsfeld	H	H	H	M	L	L	L	L	L	L	L	L	M
BE	R	Renson	L	M	L	H	H	H	L	L	L	L	L	L	L
BE	U	KU Leuven Ghent	H	L	H	H	H	L	L	L	M	L	L	L	H
JP	R	Nexus Hayama	M	M	H	H	L	L	L	L	M	H	H	M	M
JP	U	GFO Building	H	M	L	L	L	L	L	L	L	L	L	L	L
PT	U	CML Kindergarden	H	L	L	M	M	L	L	L	M	M	M	M	L
UK	R	Bristol University	H	H	H	L	H	L	M	L	M	M	H	L	L
CN	U	Wanguo MOMA	H	M	H	H	L	L	L	L	M	L	M	L	H
FR	U	Maison Air et Lumiere	M	M	L	H	M	L	L	H	L	L	M	L	M
IT	R	Mascalucia ZEB	H	M	H	H	L	L	L	L	L	L	M	L	M
NO	U	Living Lab	L	L	H	H	M	L	M	L	H	L	L	L	H

How did We Do VC?

Ventilative cooling Concepts	Natural driven	Mech. Supply Driven	Mech. exhaust driven	Natural night ventilation	Mech. night ventilation	Air conditioning	Indirect Evap. Cooling	Earth to Air Heat Exch.	Phase Chang eMaterials
zero2020 (IE)	X			X					
Brunla Primary school (NO)	X			X					
Solstad barnehage (NO)	X		X	X	X				
UNI Innsbruck (AT)	X		X	X					
wk Simonsfeld (AT)	X		X						
Renson (BE)	X			X					
KU Leuven Ghent (BE)	X		X				X		
Nexus Hayama (JP)	X					X			
GFO Building (JP)	X	X	X			X			
CML Kindergarden (PT)	X			X					
Bristol University (UK)					X	X			X
Wanguo MOMA (CN)		X	X		X	X			
Maison Air et Lumiere (FR)	X								
Mascalucia ZEB (IT)	X			X				X	
Living Lab (NO)	X								

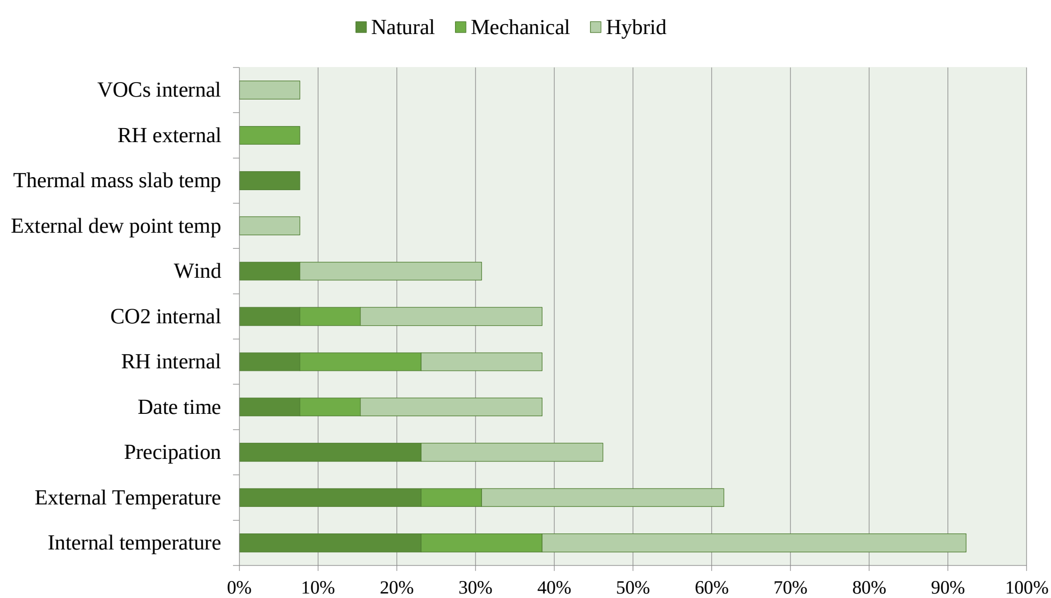
Summary points

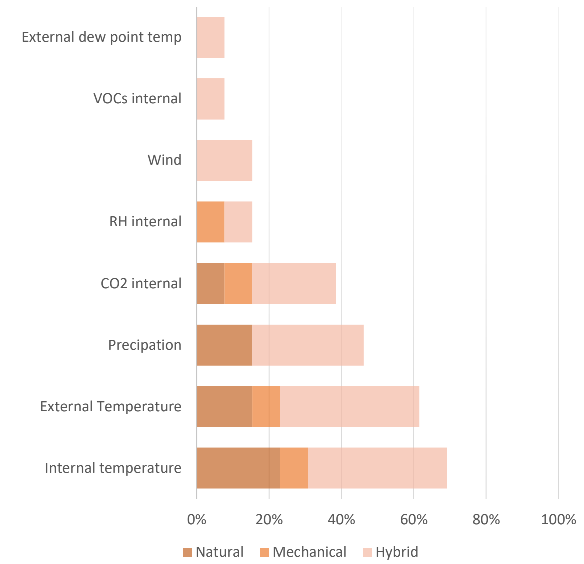
- 86%, of the VC case studies use natural ventilation
  - Generally, sensible internal loads for NV ≤ 30 Wm^{-2}. (Average is 25 Wm^{-2}.)
- 50% of buildings using Hybrid VC (most prevalent strategy)
  - Internal loads in Hybrid spaces were:
    ≥ 40 Wm^{-2} in Norway and Belgium
    ≤ 10 Wm^{-2} in Austria & Italy
- No. of Days with a maximum daily external temperature ≥ 25°C ranged from 10 to 120 days across all cases



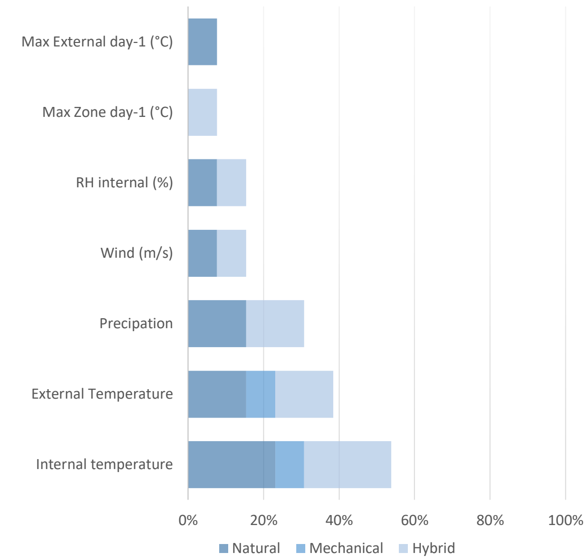
How Do We Control VC?

Control Strategies Overall





Occupied Hours



Night time ventilation

Summary points

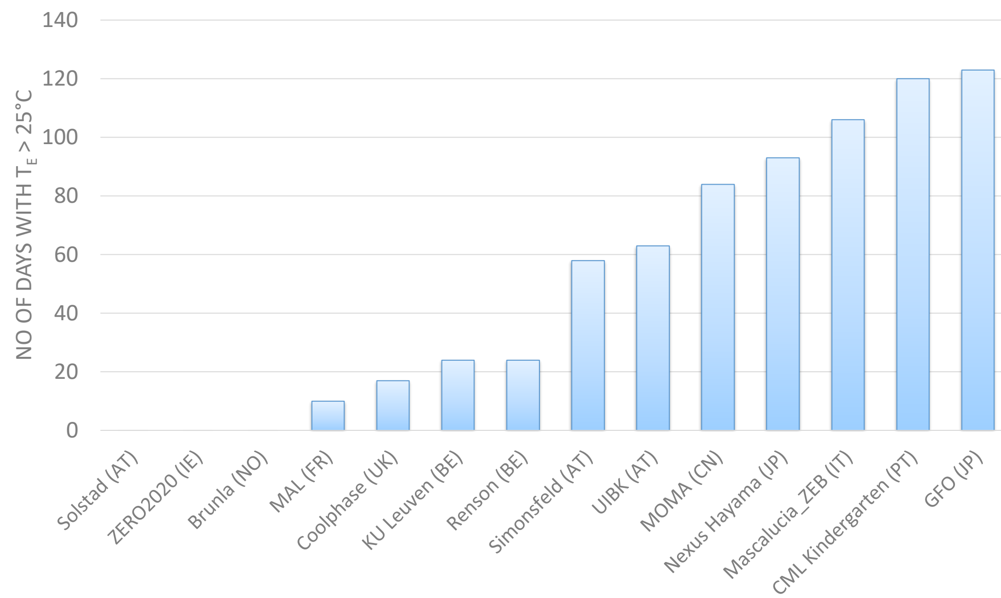
- **Temperature** and **RH** were the **main parameters** used (CO_2 for IAQ).
- Internal temperature used by all cases studies with set-point control
- Mean internal air temperature set-point was around 22°C. (20-24°C)
- Over 60% of case studies use **external temp** as a **low temp limit**
- Mean external low temperature limit set-point 14°C. (10-18°C)

Summary points

- All NV case studies had occupant interaction with the VC system
- Only 60% of hybrid systems had this interaction.
- 69% of the case studies had a night ventilation strategy
- Wind speed had to be ≤ 10m/s with no rain for night ventilation systems

How Have these Buildings Performed?

Climate Indicator



Overheating

Preliminary results of VC performance evaluation

Country	Building	Summer Design Values		overheating criteria	% Occ hrs above threshold		Occ hrs
		T_e	$T_{i,o}$		28°C	25°C	
IE	zero2020	26.0	25.0	T_i < 28°C for 99% occ hrs	0.7	5.5	2600
NO.1	Brunla School	25.0	26.0	T_i > 26°C	0.0	0.0	2600
NO.2	Solstad	25.0	24.0	T_i > 26°C	0.0	0.0	2860
AT.1	UNI Innsbruck	34.0	27.0	T_i < 26°C for 95% occ hrs	1.1	16.2	2600
AT.2	wkSimonsfeld	34.5	24.0	T_i > 26°C zone / T > 29°C gallery	0.0	5.0	3250
JP	Nexus Hayama	26.0	26.0	T_i < 28°C for 99% occ hrs (check)	1.0	40.0	8736
PT	Kindergarden	30.0	26.0	80% acceptability for 99% hr occ	2.6	16.0	3640

What Lessons did We Learn?

Design and Construction

- **Detailed building simulation is important when simulating ventilative cooling strategies.** Most case studies analysed highlighted the need for reliable building simulations in the design phase of a ventilative cooling system. This was considered most important when designing for hybrid ventilation strategies where multiple mechanical systems need harmonization.
- Some studies also said that **simulating the window opening in detail was important**.
- **Customisation may be an important factor when designing a ventilative cooling system**. In order to ventilate certain buildings it may be necessary to design custom components. Some case studies highlighted the need to have custom design systems that were specific to country regulations and the use of a building or space.

Design and Construction

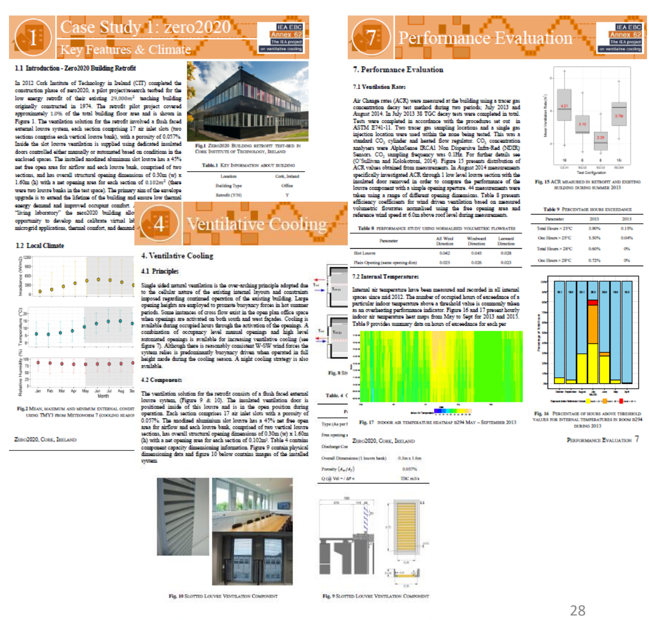
- Some consideration should also be given to the **clients expectations** around specific issues like **rain ingress and insect prevention**.
- **Ventilative cooling systems were considered cost-effective and energy efficient in design** by most case studies, but **particularly with naturally ventilated systems**. It was indicated that designing with the integration of manual operation and control was important, particularly in a domestic setting.

Operation

- **Engaging with the building owners or operators as soon as possible is integral to guaranteeing building performance for IAQ, comfort or energy savings**. For some case studies this specifically meant educating or working with the facilities operator or manager for the building, for others it meant educating the building occupiers themselves.
- It was suggested by some that this **engagement should be as early as the design stage**.

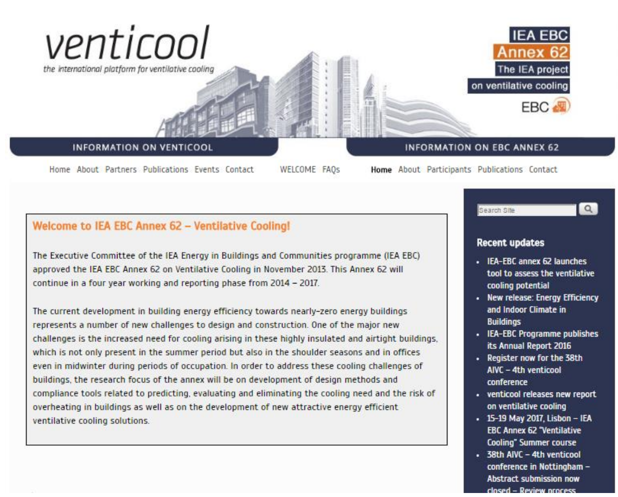
Operation

- **VC in operation is generally a good option.** Case studies comment on the reduction of overheating and improvement of comfort conditions in the buildings that used outside air. However **correct maintenance and calibration of the systems is integral to maintaining performance.**
- Some case studies highlighted the need to **exploit the outside air more with lower external air temperature control limits** during typical and night-time operation.
- Others suggested that **exploiting the thermal mass of a building was key.** However it was noted that care must be taken with considering these low temperatures as some case studies, particularly in cold climates observed more incidences of overcooling than overheating.



Dissemination

- All brochures are now available at the IEA-EBC Annex 62 website
- A summary document also available
  - Overview with key data distilled into important findings
  - Key lessons learned
  - Recommendations



http://venticool.eu/annex-62-publications/deliverables/

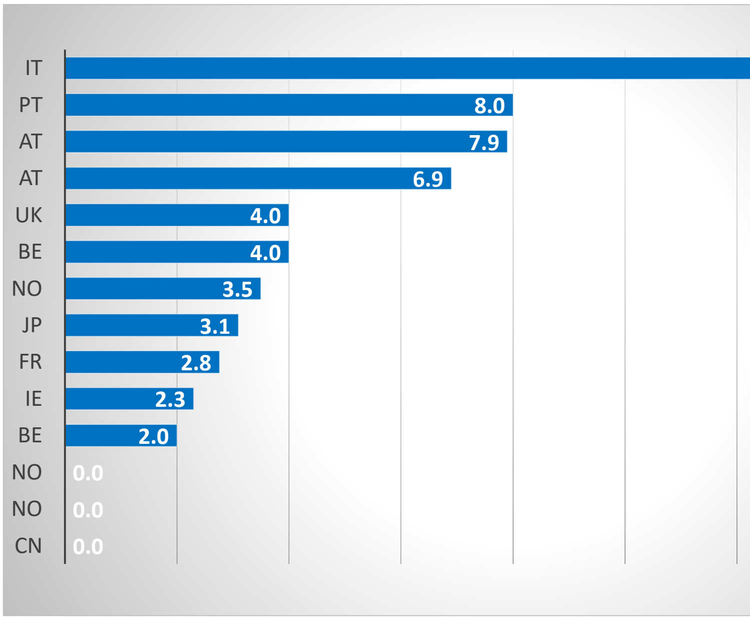
Dissemination

Thank You!

(I hope you and your family are keeping safe and healthy during this SARS-CoV-2 crisis. Good Ventilation of homes and work spaces is a key recommendation from the WHO.)

What about the Percentage Opening Area to Floor Area Ratio? A Key VC Metric?

Design Metrics – POF Ratio



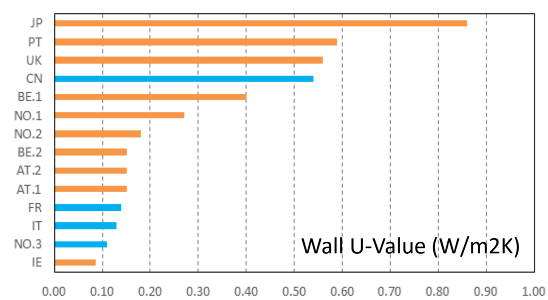
$$\frac{A_o}{A_f}\ x\ 100$$

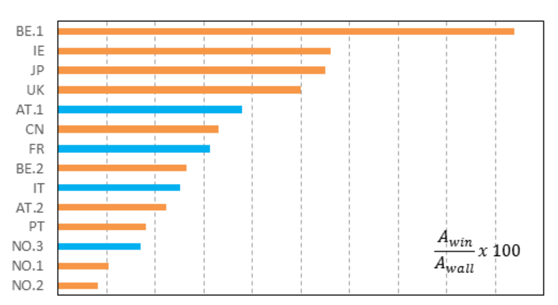
EBC

What Were the Building Characteristics?

Building Characteristics

EBC

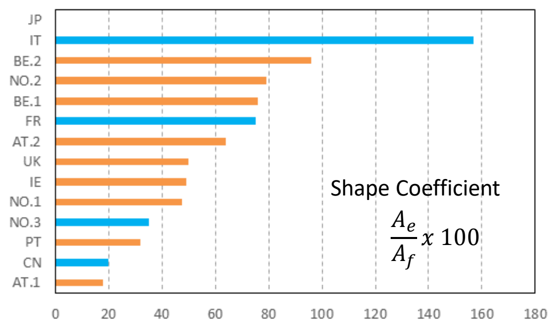




- Mean elemental U-value is 0.41 W/m^2K
- standard deviation is 0.34 W/m^2K
- Six case studies heavy /very heavy thermal mass (ISO13790)
- Average infiltration at 1.13 h^{-1}, (0.51 to 1.85 h^{-1})
- Average window/wall area ratio is 34%.
- Four case studies area ratios greater than 50%

- Some very good and very poor thermal performance
- Large variation in building shapes
- Norwegian case studies lowest window/wall ratios
- Belgium Offices from 2003 almost exclusively glass

Building Characteristics



- Minimum shape coefficient of 0.18
- Maximum shape coefficient of 0.96
- Italian home has very high shape coefficient

Control Strategies - Summary

How are We Simulating VC?

Design Simulation

Scope Development	Concept Design	Detailed Design	Performance Analysis
IE CIBSE Guide A	CIBSE Admittance	IES Apache /Macro	TRNSYS / PHPP / R
NO NS 3700	SIMIEN	Windmaster/SIMIEN	IDA Ice
NO NS 3700	SIMIEN	Windmaster / SIMIEN	IDA Ice
PHPP	Dynbil	TRNSYS	TRNSYS
TAS 9.2	TAS 9.2	TAS 9.2	PHPP
-	CAPSOL	-	-
RT2005 F	VELUX Daylight Vis.	Bsim (DK)	RT2012
PHPP	PHPP	EnergyPlus + GenOpt	PHPP
CASBEE	BEST/CFD/STREAM	CFD / STREAM	-
EnergyPlus	EnergyPlus	EnergyPlus	EnergyPlus
CIBSE Guide A	EFA / CIBSE TM 52	IES Apache	IES Apache
-	SIMIEN	-	IDA Ice

UK & IE – IES and CIBSE
NO – IDA ICE

IT, AT & IE – PHPP
PT - EnergyPlus