IEA EBC Annex 62

Ventilative Cooling

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Aalborg University

EBC
Energy in Buildings and Communities Programme

Background

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

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Why have we experienced an overheating problem?

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

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Ventilative Cooling in Offices

- Always a cooling need during occupied hours
- Cooling is not a new technology, but the need for cooling is increasing and more efficient systems have to be developed to fulfill future energy requirements
- Application of the free cooling potential of outdoor air is widely used in mechanical ventilation systems, while the use in natural and hybrid ventilation system is still limited in many countries

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Offices in Cold Climate

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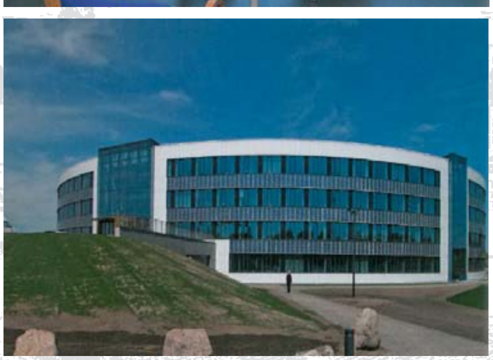
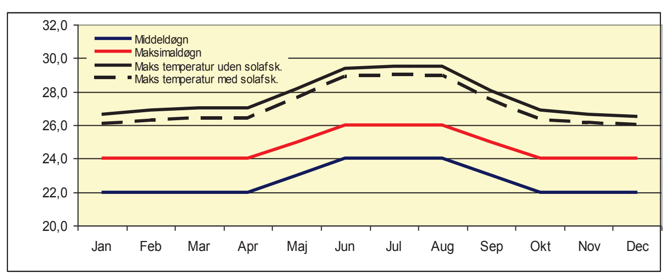
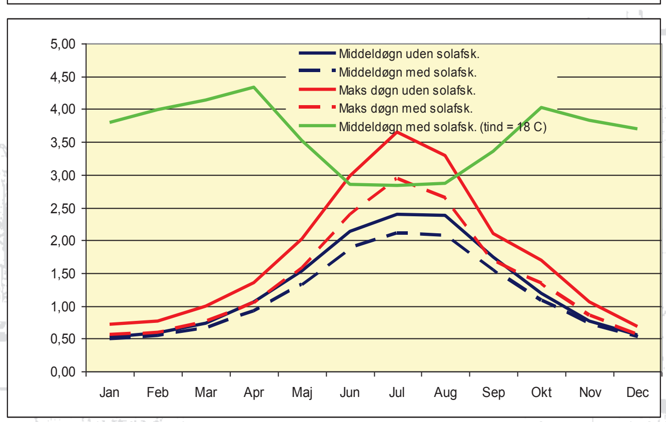
Challenges in a Cold Climate







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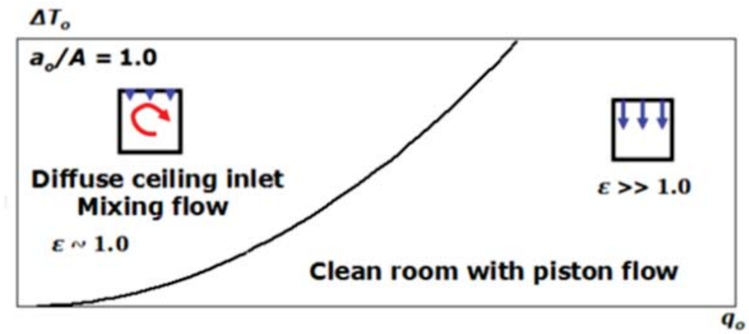
Diffuse ceiling air distribution patterns



Buoyancy control

Momentum control

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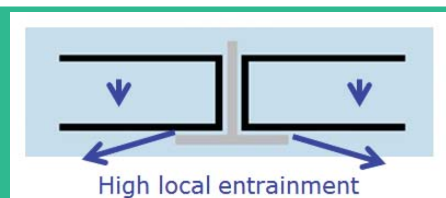
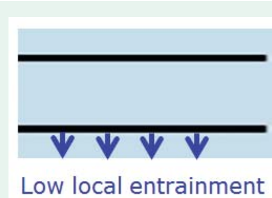
Opening types

Rockfon ceiling	
Ecophon ceiling	
Fully diffuse ceiling	

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Six Different Air Distribution Systems

-Tested in the same geometry and with the same load

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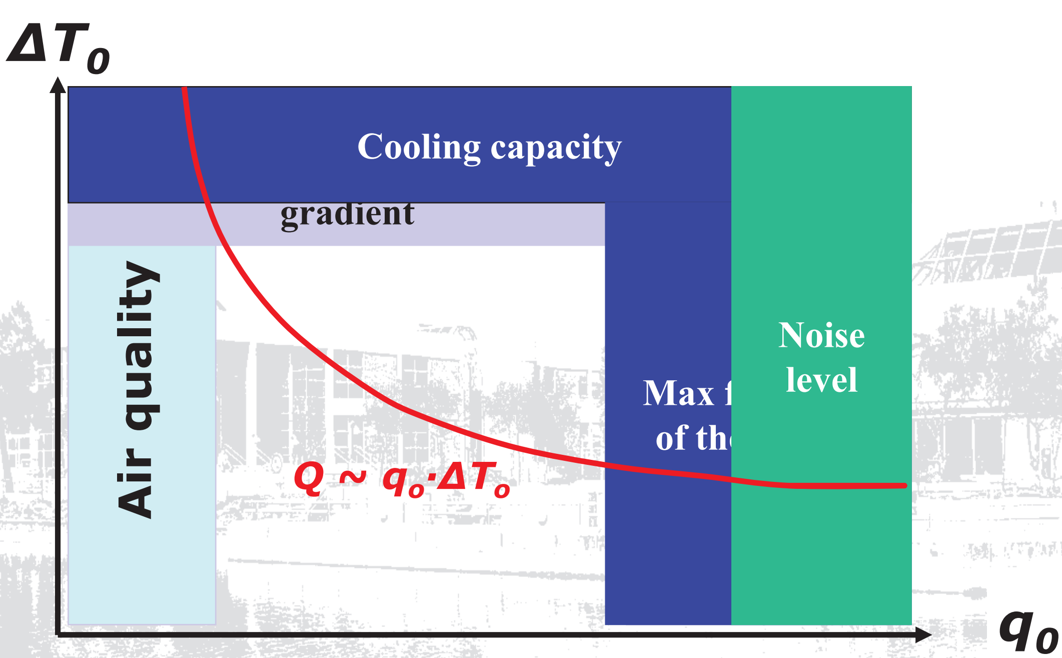
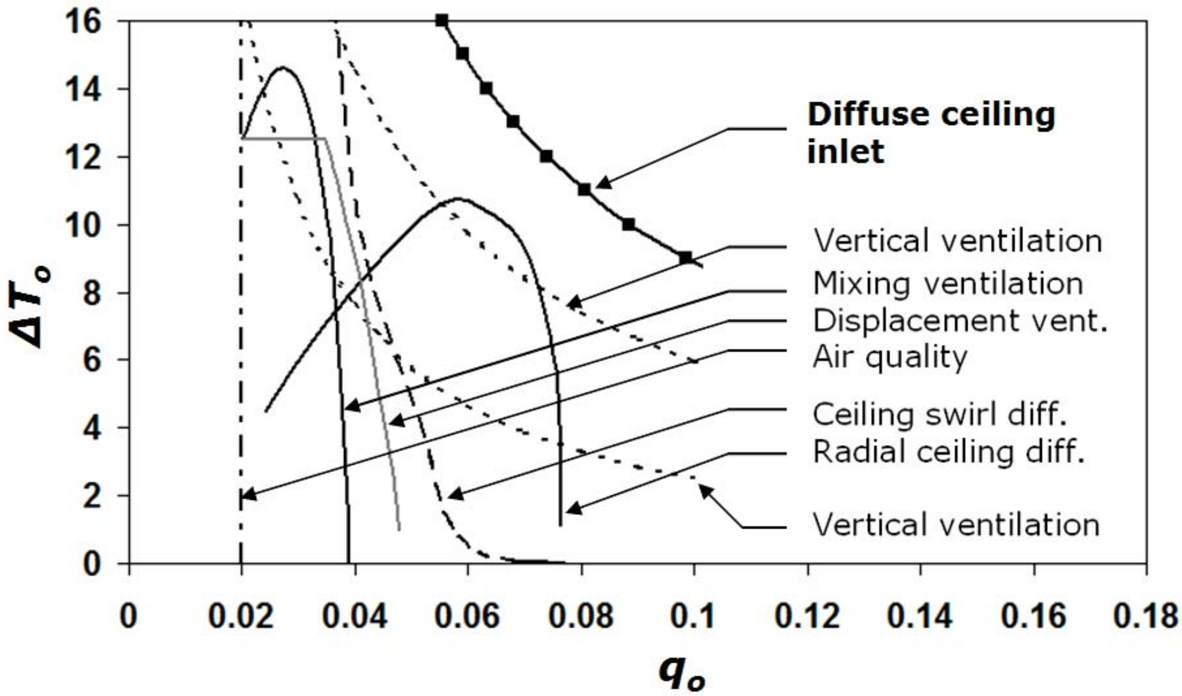
The q_o-ΔT_o Design Chart



qo - ΔTo Design Chart



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Definition of Ventilative Cooling

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

Ventilative cooling is a solution

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

Status of Application

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

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Annex Objectives

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

Annex 62 Ventilative Cooling

Annex Outcome

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

Annex 62 Ventilative Cooling

Annex Organization

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

EBC
Energy in Buildings and Communities Programme

Annex Leadership

- Participating countries
  - Austria, Belgium, China, Denmark, Finland, Ireland, Italy, Japan, Netherlands, Norway, Switzerland, UK, USA

- Operating Agent:
  - Denmark, represented by Per Heiselberg, Aalborg University
- Subtask A:
  - Leader: Switzerland, represented by Fourentzos Flourentzou, ESTIA
  - Co-leader: Italy, represented by Annamaria Belleri, EURAC
- Subtask B:
  - Leader: Austria, represented by Peter Holzer, IBRI
  - Co-leader: Italy, represented by Lorenzo Pagliano, POLIMI
- Subtask C:
  - Leader: China, represented by Guoqiang Zhang, Hunan University
  - Co-leader:

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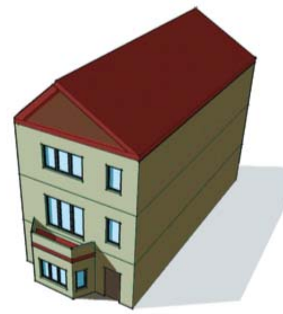
IEA EBC Annex 62 Seminar
Ventilative Cooling: Using the cooling potential of ventilation to reduce energy use in buildings
17th September 2014, Brunel University, Uxbridge

Monitoring summer indoor overheating risk and ventilative cooling behaviour in London homes

Dr Anna Mavrogianni, IEDE, The Bartlett, UCL



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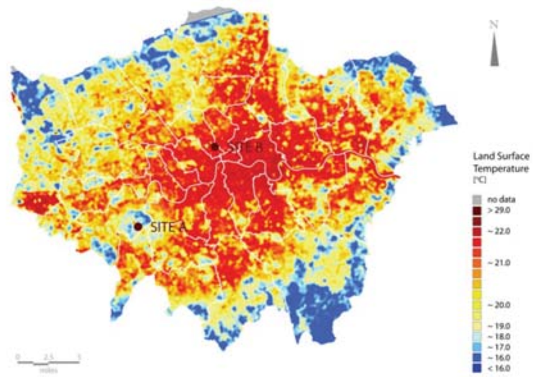
Overview

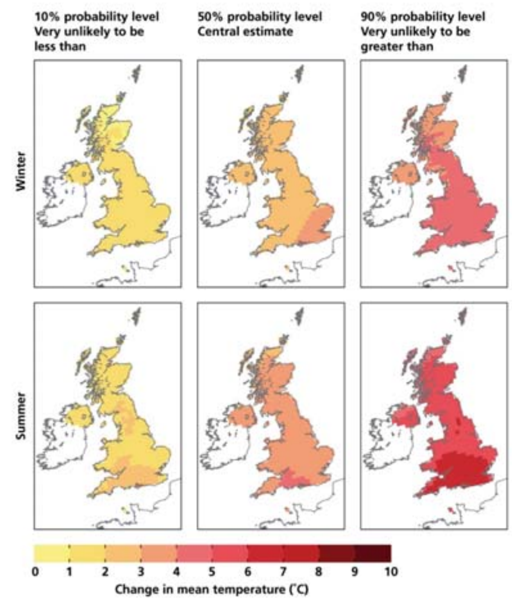
1	Background
2	The **LUCID** project: Overview
	Monitoring summer indoor overheating
	Exploring summer ventilation behaviour
3	The **AWESOME** project: Overview
	Modelling the impact of ventilation on indoor overheating
	Modelling the impact of ventilation on indoor air quality
4	Conclusions and future research

1 Background

Our **climate is changing** due to humanmade greenhouse gas emissions.

Overheating in cities will be exacerbated due to the **urban heat island** effect.





2080s, Medium Emissions scenario Source: UKCP09

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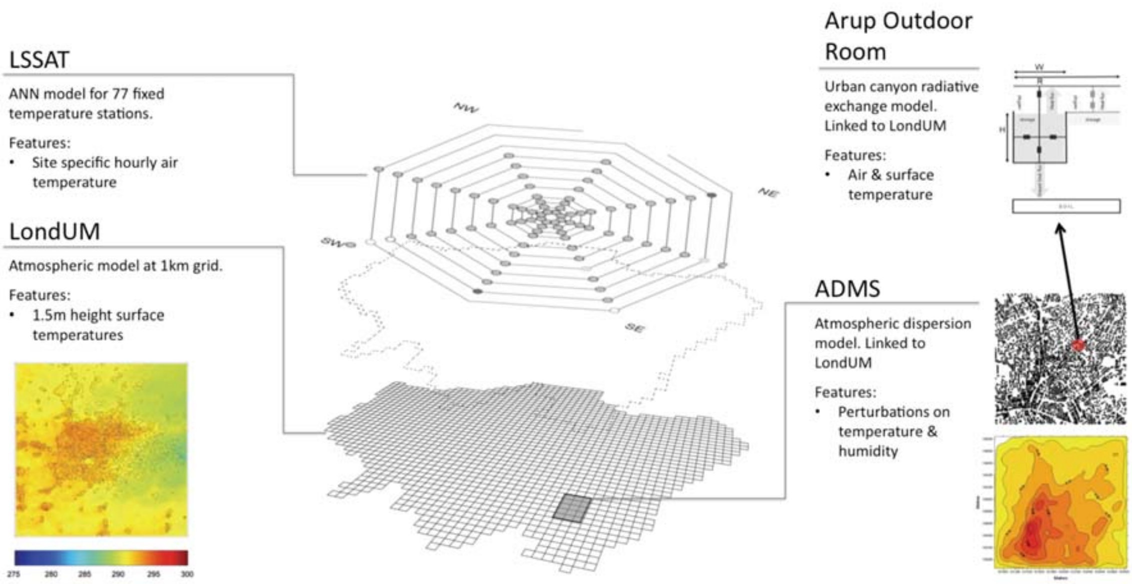
1 Background

Indoor overheating in homes

- Growing body of **evidence**
- Increased **research interest**

2 LUCID: Overview

Modelling the **local urban climate** and its impacts



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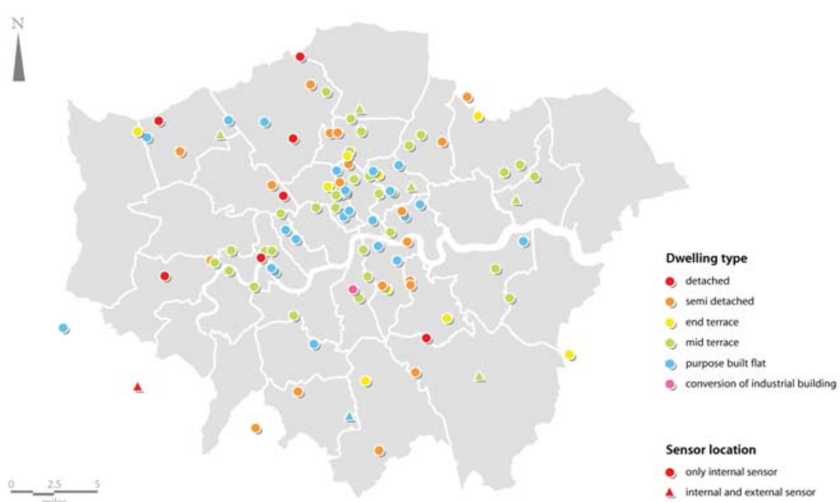
2 LUCID: Monitoring summer indoor overheating

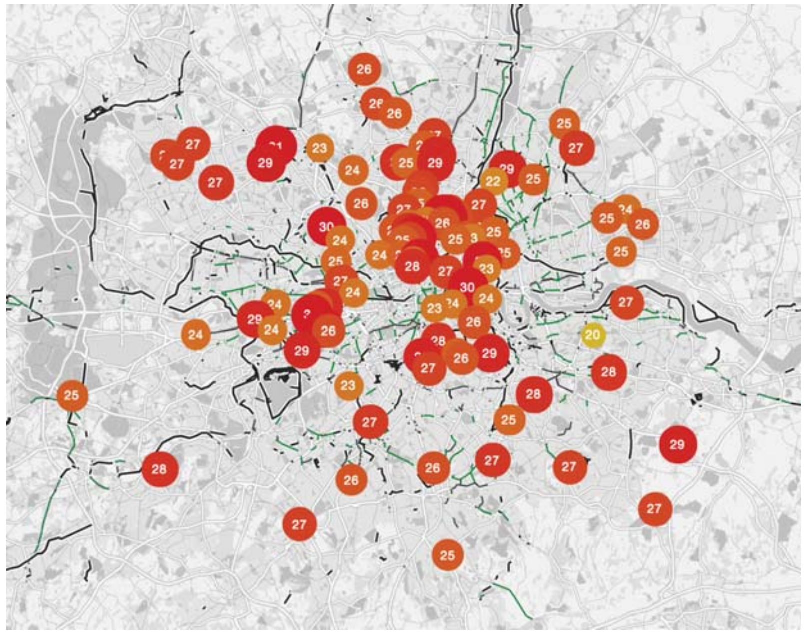
- **101 London dwellings** of varying morphology
- Convenience sample (UCL staff and students)
- Dry bulb **temperature** and relative **humidity** measured during summer 2009 (HOBO U12-012)
- 36 dwellings monitored during **hot spell** (29th June – 3rd July)
- **EPC survey**
- **Energy use and ventilation behaviour questionnaire** (80% response rate)



2 LUCID: Monitoring summer indoor overheating

Full sample
(June-August):

- The analysis of the monitoring data indicated that London homes and, in particular, bedrooms are already at risk of indoor overheating during hot spells under the current climate.
- There is no strong correlation between temperature and distance from the centre.



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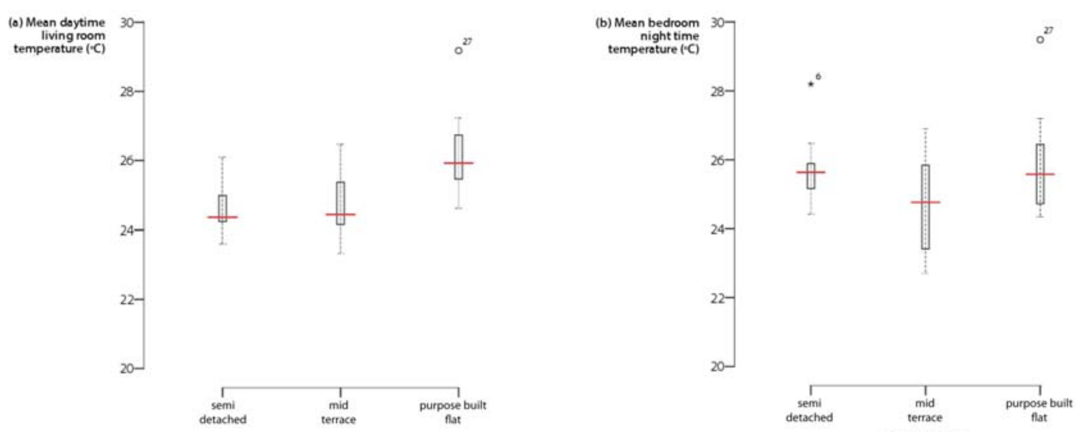
2 LUCID: Monitoring summer indoor overheating

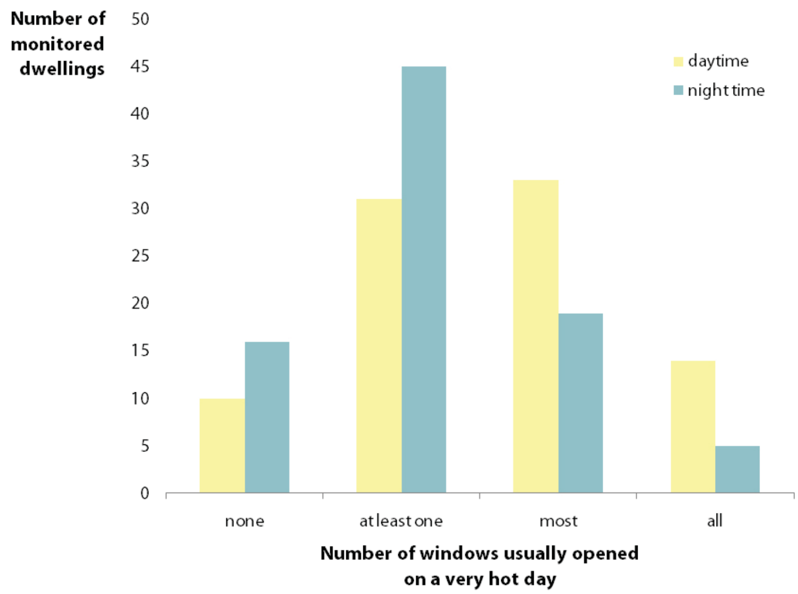


Sub-sample (hot spell):

- Significant levels of night time overheating were recorded in the main bedrooms.
- Sleep impairment due to temperature rising above the 24 °C threshold might have been caused in 86% (31 out of 36) of the bedrooms.

2 LUCID: Exploring summer ventilation behaviour

Full sample
(June-August):
- Around 70% of respondents open only one or no windows at night (mainly due to security reasons).
- Bedroom air temperatures were slightly higher in dwellings where the occupants tended to leave most or all windows open at night.



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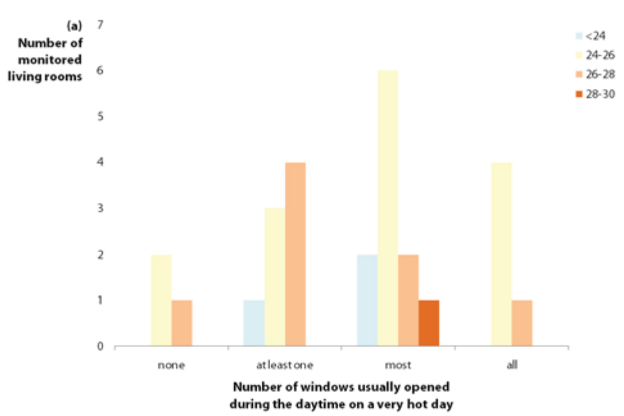
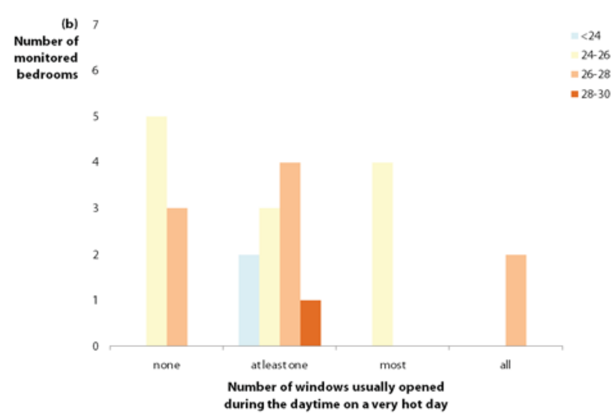
2 LUCID: Exploring summer ventilation behaviour



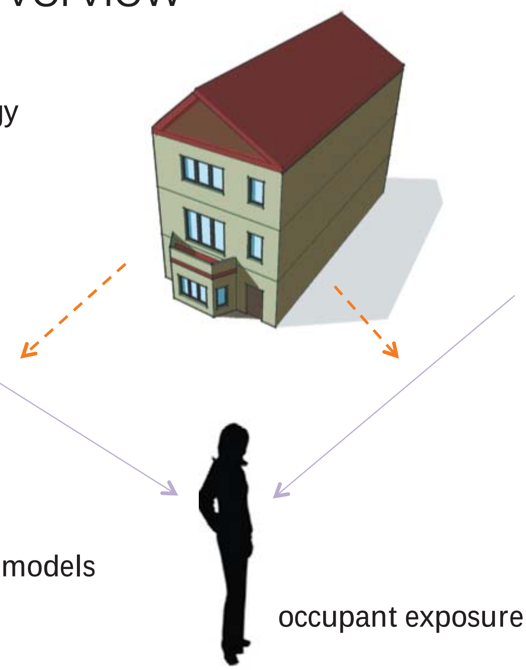


Sub-sample (hot spell):
- Daytime 'rapid' ventilation appears to increase the variability of living room temperatures.
- The effect of night time ventilation cannot be assessed with confidence due to the small sample of houses that left their windows open during the night (mainly due to security reasons).

3 AWESOME: Overview

1. Air pollution and meteorology
- measurements
- spatio-temporal models

NO_x $PM_{2.5}$ O_3



Effect modification
2. Models of building performance (temperature, indoor pollutants)

Temperature

- mortality
- morbidity

occupant exposure

Analyses

3. Time-space epidemiological models

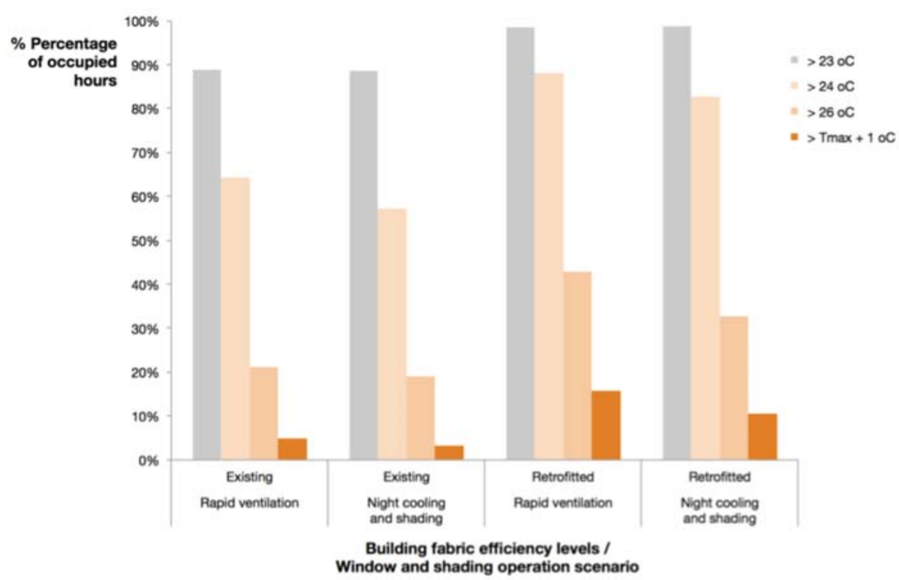
4. Decision analysis

5. Health impact models

3 AWESOME: Modelling summer indoor overheating

Modelling of a 1960s mid-floor purpose-built flat (bedroom, Medium emissions, 50th percentile, 2050s):

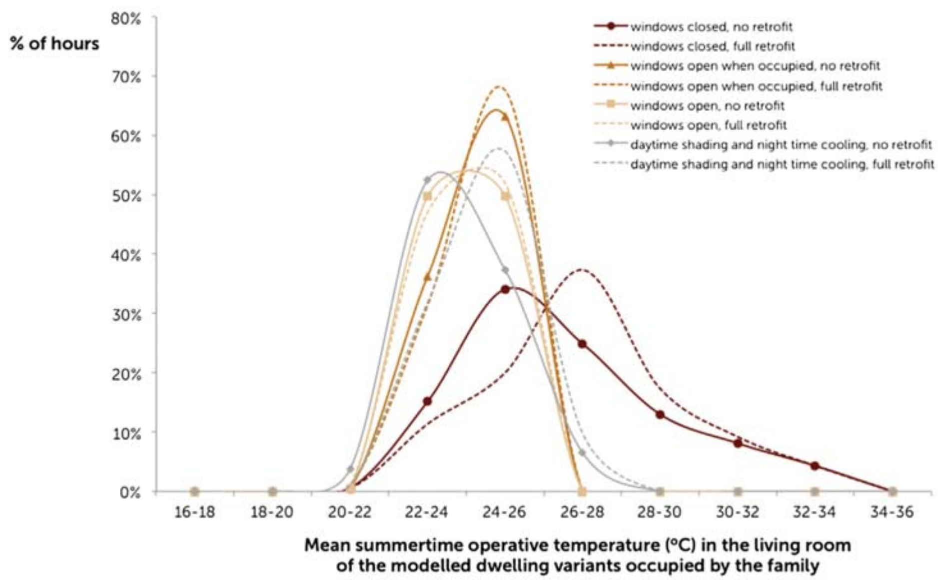
- **Energy efficient retrofit** may increase summer overheating.
- Small temperature reductions in the bedroom as a result of **night cooling** and **internal shading**.



3 AWESOME: Modelling summer indoor overheating

Modelling of London dwelling archetypes (living rooms, current climate):

- Overheating rankings vary as a function of **occupancy patterns, window opening and shading use**.
- Daytime **internal shading** and **night cooling** can modify overheating risk but only to a certain extent.



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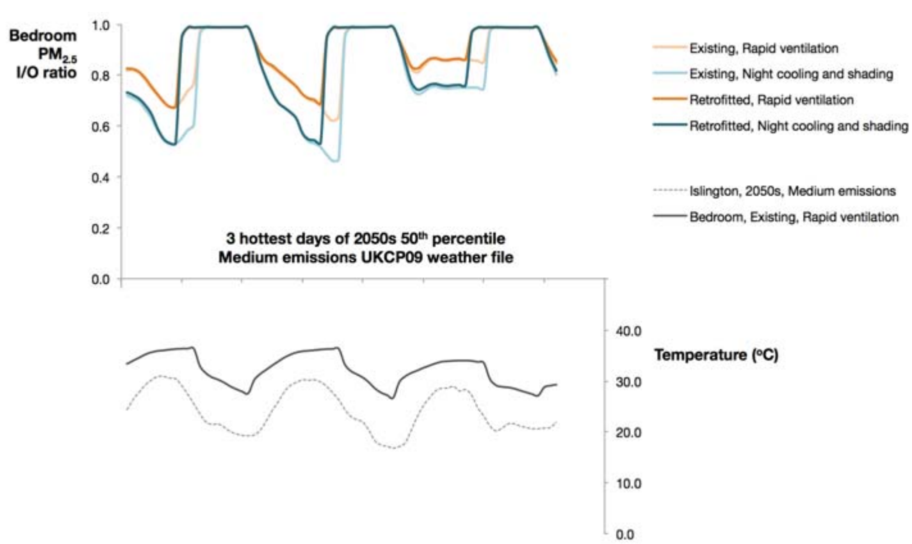
3 AWESOME: Modelling summer indoor air quality

Modelling of a 1960s mid-floor purpose-built flat (bedroom, Medium emissions, 50th percentile, 2050s):

- There are trade-offs between **thermal comfort** and **indoor air quality**:
- Bedroom internal temperatures rise above the window opening threshold, which causes PM2.5 I/O ratios to approach 1.0 due to the ingress of outdoor air.



4 Conclusions

- London homes **already experience** hours with **temperatures above the recommended thresholds**, even during relatively mild summers.
- In the future, such risks are likely to be exacerbated due to **climate change** and certain **retrofit** measures (increased airtightness, internal wall insulation).
- No strong correlations between distance from the centre and overheating risk were observed, which may be an indication that **building characteristics** and **occupant behaviour** may be more important for overheating than the location within the **urban heat island**.
- **Natural ventilation** alone may not suffice to keep indoor thermal conditions within acceptable limits and its cooling potential may be further limited due to **noise**, **security** and **outdoor air pollution** concerns.
- Rankings of dwellings based on their propensity to overheat vary as a function of **occupancy patterns**, **window opening** and **shading use** behaviour.

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4 Ongoing and suggested future research

- Carrying out a large-scale summer thermal monitoring study of statistically representative UK dwellings, potentially including **thermal diaries** and **occupancy sensors**, including information on **window size** and **local wind speeds**.
- Including a detailed comparison of the **static vs. adaptive** thermal comfort approach.
- Further exploring the complex interrelationships between the **indoor thermal environment** and **airborne contaminant transport** in heat vulnerable urban homes.
- Linking markers of exposure to indoor excess temperatures and pollutants with **health markers** (morbidity and mortality data) to assess the **modifying effect of the indoor environment**.

Publications

Journal papers

- Mavrogianni A., Davies M., Wilkinson P., Pathan A. *London housing and climate change: Impact on comfort and health*. Open House International. 2010; 35(2): 49-59.
- Mavrogianni A., Wilkinson P., Davies M., Biddulph P., Oikonomou E. *Building characteristics as determinants of propensity to high indoor summer temperatures in London dwellings*. Building and Environment. 2012; 55: 117-30.
- Taylor J., Davies M., Mavrogianni A., Chalabi Z., Biddulph P., Oikonomou E., Das P., Jones B. *The relative importance of input weather data for indoor overheating risk assessment in London dwellings*. Building and Environment. 2014; 76: 81-91.
- Mavrogianni A., Davies M., Taylor J., Chalabi Z., Biddulph P., Oikonomou E., Das P., Jones B. *The impact of occupancy patterns, occupant-controlled ventilation and shading on indoor overheating risk in domestic environments*. Building and Environment. 2014; 78: 183-198.
- Taylor J., Shrubsole C., Davies M., Vardoulakis S., Das P., Mavrogianni A., Oikonomou E. *The modifying effect of the building envelope on population exposure to PM2.5 from outdoor sources*. Indoor Air. 2014; Available online.
- Mavrogianni A., Taylor J., Thoua C., Davies M., Kolm-Murray J. *Urban social housing resilience to excess summer heat and pollution*. Building Research and Information. 2014; Under review.
- Taylor J., Mavrogianni A., Davies M., Das P., Shrubsole C. *Understanding and mitigating overheating and indoor pollution risks using coupled temperature and indoor air quality models*. Building Services Engineering Research and Technology. 2014; Under review.

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Publications

Conference papers

- Mavrogianni A., Davies M., Taylor J., Raslan R., Oikonomou E., Biddulph P., Das P., Jones B., Shrubsole C. *Assessing heat-related thermal discomfort and indoor pollutant exposure risk in purpose-built flats in an urban area*. In: International Conference on Solar Energy Applications to Buildings, Conference internationale Energie Solaire et BATiment (CISBAT) - International Conference on Clean Technology for Smart Cities and Buildings: From Nano to Urban Scale; 4-6 September 2013; Lausanne, Switzerland
- Mavrogianni A., Davies M., Taylor J., Raslan R., Oikonomou E., Biddulph P., Das P., Jones B., Shrubsole C. *The unintended consequences of energy efficient retrofit on indoor air pollution and overheating risk in a typical Edwardian mid-terraced house*. In: FutureBuild - International Conference; 4-6 September 2013; University of Bath, Bath, UK.
- Mavrogianni A., Taylor J., Thoua C., Davies M., Kolm-Murray J. *A coupled summer thermal comfort and indoor air quality model of urban high-rise housing*. In: 8th Windsor Conference: Counting the Cost of Comfort in a Changing World; 10-13 April 2014. Cumberland Lodge, Windsor, UK.
- Taylor J., Biddulph P., Mavrogianni A., Altamirano-Medina H., Shrubsole C., Das P., Davies M. *A novel post-processing contaminant transport and decay model for EnergyPlus*. In: International Building Performance Simulation Association - England (IBPSA-England) Conference - Building Simulation and Optimisation 2014 (BSO14); 23-24 June 2014; UCL, London, UK.
- Taylor J., Davies M., Wilkinson P., Mavrogianni A., Milner J., Shrubsole C., Das P., Chalabi Z. *Modelling the modifying effect of homes on population exposure to pollution*. In: International Society for Environmental Epidemiology (ISEE) 26th Conference; 24-28 August 2014; Seattle, Washington, USA.

Thank you!

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Any questions?

venticool: The international platform for ventilative cooling

Ventilative Cooling workshop: Using the cooling potential of ventilation to reduce energy use in buildings, UK, September 17, 2014

- The platform
- Main goal and scope
- Main targets
- Partners
- Dissemination & Communication

The platform WHY?

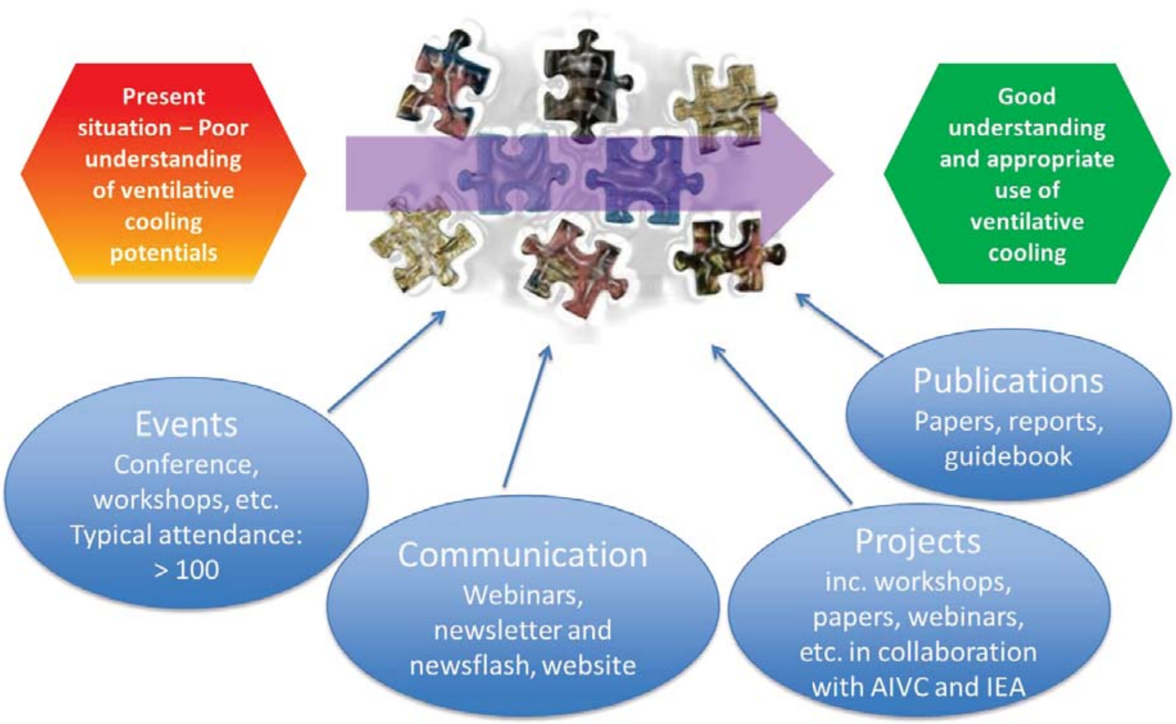
Present situation – Poor understanding of ventilative cooling potentials

The platform WHY?

Present situation – Poor understanding of ventilative cooling potentials

Good understanding and appropriate use of ventilative cooling

The platform WHY?



The platform WHY?

Reasons behind.

– Ventilative cooling has a **great yet largely unrealised potential** in terms of energy conservation in buildings while providing adequate indoor air quality and comfort

– Need to **increase communication, networking and awareness raising** to mobilise the untapped energy savings potential

The platform

- **Inaugurated in September 2012** to answer the growing need for international collaboration on ventilative cooling
- **Facilitated the programme development of IEA Annex 62** with the organization of key meeting points at workshop and conferences.
- **Key partner** of **Annex 62** and the European project **QUALICHeCK**
- venticool is firmly anchored at international level and gradually becomes **THE international meeting point** for ventilative cooling activities.

Main goal and scope

- **The scope** of venticool covers natural, mechanical and mixed-mode ventilation
- **The goals**:
  - Increase communication, networking, knowledge and awareness at key targets to mobilise the significant energy saving potential using ventilative cooling

Main targets

- **Policy makers and standards writers**
- **Stakeholders organizations** (at European and national level)
- **Training centres** (front-runners and associations/networks)
- **Designers, engineers, builders, HVAC installers** (front-runners and associations/networks)
- **Research and technical centres**

Partners

The platform is financially and technically supported by:

AGORIA naventa

ES-SO European Solar-Shading Organization — Energy Savings & Comfort

VELUX®

WindowMaster® Natural Ventilation

Wienerberger Building Material Solutions

INIVE

Dissemination & communication

- Conferences
- Workshops
- Webinars
- Website
- Venticool newsletter
- Publications
- Social Media
- Wikipedia

Dissemination & communication (Next steps)

- **Conferences:**
  - **35th AIVC- 2nd venticool conference, 24-25 September 2014, Poznan**
  - **36th AIVC conference, Madrid Spain, 2015**
- **Workshops**
  - **“Ventilative Cooling: Using the cooling potential of ventilation to reduce energy use in buildings” Brunel University, Kingston Lane, Uxbridge, UK, 17 September 2014**
  - **“QUALICHeCK workshop on sustainable summer comfort technologies”, Athens, Spring 2016**
- **Webinars**
  - **1st Annex 62 webinar, 2014**
  - **2nd Annex 62 webinar, 2015**
  - **3rd Annex 62 webinar, 2016**
  - **4th Annex 62 webinar, 2017**

Dissemination & communication (Next steps)

- Publications
  - Co-writers of CEN/TC 156 standards
  - Position and input for 2nd EPBD recast
  - REHVA special issue in the framework of Annex 62
  - REHVA guidebook
  - Proceedings of "ventilative cooling" tracks of AIVC conferences
- Articles on ventilative cooling for a special issue of the International Journal of Ventilation (IJV)
- Website
- Venticool newsletter
  - Next issue in December
- Social media
  - LinkedIn & BUILD UP community
- Wikipedia
  - Venticool & Ventilative cooling

The platform WHY?

Joining venticool

1. As **Partner**
2. As an **individual** in **venticool club** a discussion forum on ventilative cooling.

If you are interested to join us please contact us at: info@venticool.eu

Thank you for your attention!

Analytical and Experimental Modelling of Energy Storage in Phase Change Materials for Natural Cooling of Buildings

Dr Zsolt Bakó-Biró

Monodraught® Cool-phase®

Summary

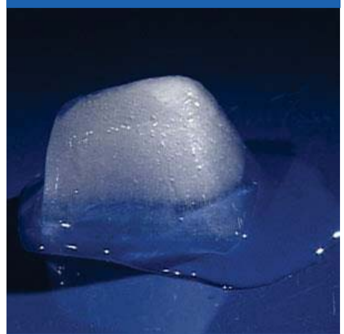
- Introduction
- Product overview
- Model development and Test procedures
- Implementation
- Case Study

Energy Potential of Phase Change

WATER

Sensible heat - 4.2 J/g/°C

MELTING / FREEZING



Latent heat - 334 J/g

ICE

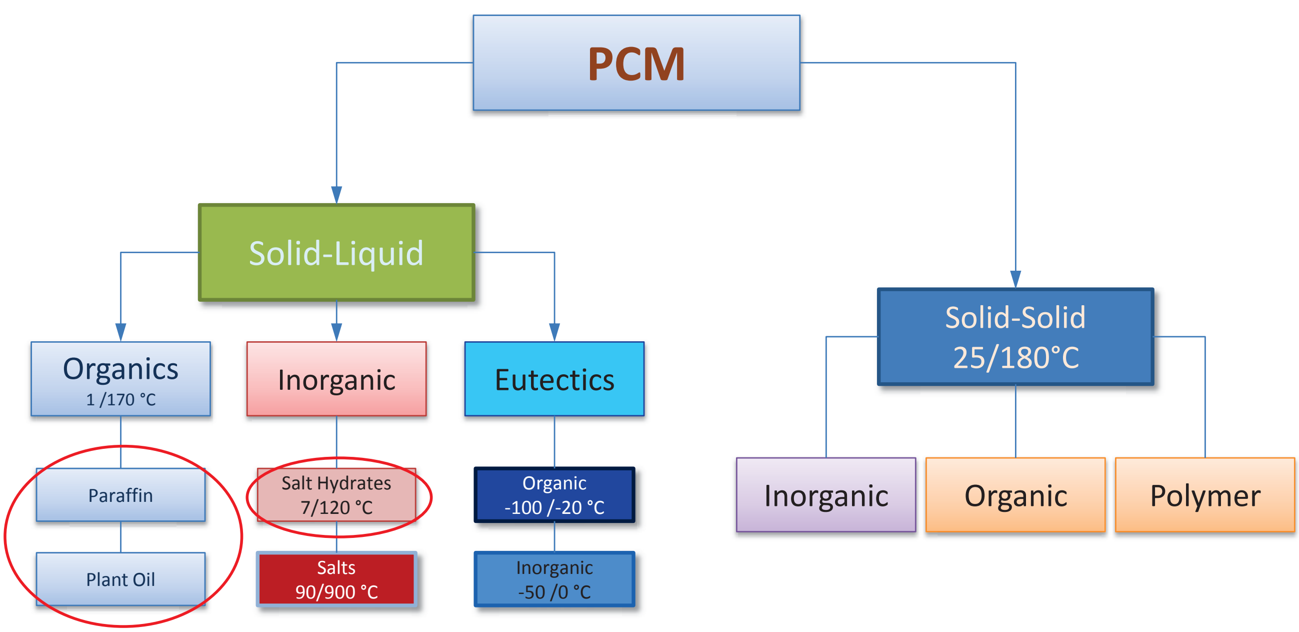
Sensible heat - 2.1 J/g/°C

125g of ice will cool down 1L of water by 10°C

$$Q_{water} = 4.2\ J/g°C \times 1000g \times 10\ °C = 42000\ J$$

$$Q_{Latent} = 334\ J/g \times 125g = 41750\ J$$

PCM Classification



Monodraught® Coolphase® CIBSE Building Performance Awards 2012 Winner Ashden Award winner 2013

PCM Properties

ORGANICS:

Advantages:
- Stable
- Encapsulation
- Energy dense

Disadvantages:
- Expensive
- Flammable
- Thermal conductivity

SALT HYDRATES:

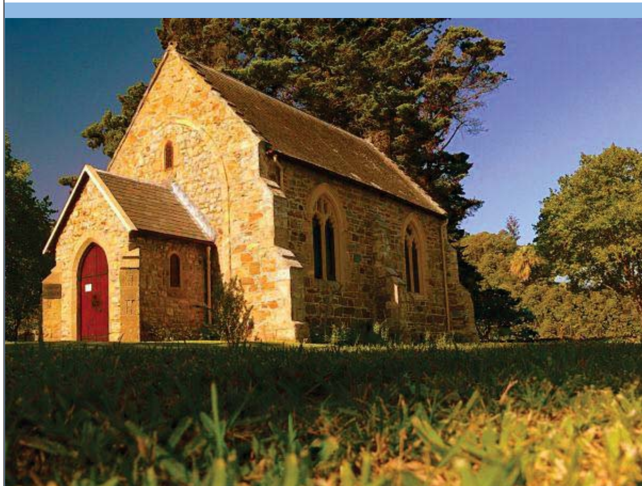
Advantages:
- Cost
- Sustainable

Disadvantages:
- Corrosive (plastic & metals)
- Thermal conductivity
- Segregation

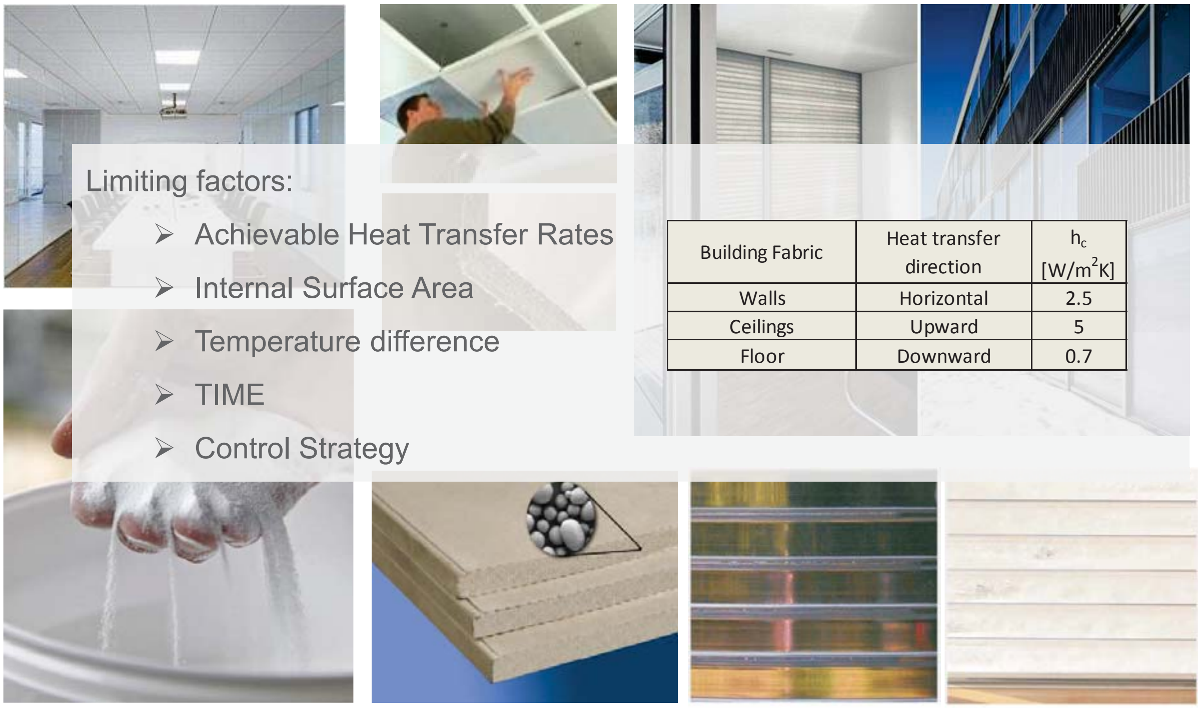
Intelligent thermal mass

- Easy to retrofit, intelligent thermal mass
- Dissipates heat built up

Melt / Freeze 1Kg of PCM	≈	Heat / Cool 200Kg of Concrete by 1°C



Passive thermal mass products



Limiting factors:

- Achievable Heat Transfer Rates
- Internal Surface Area
- Temperature difference
- TIME
- Control Strategy

Building Fabric	Heat transfer direction	h_c [W/m^{2}K]
Walls	Horizontal	2.5
Ceilings	Upward	5
Floor	Downward	0.7

GLASSXcrystal in its liquid state

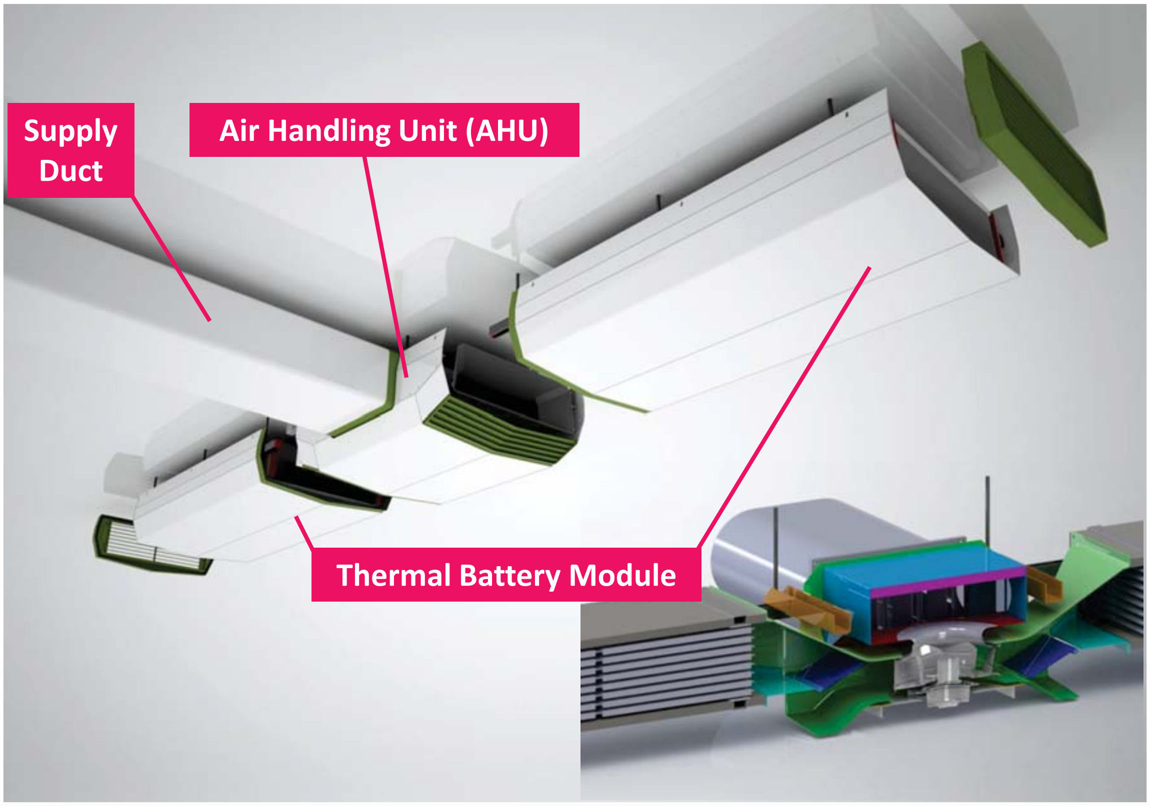
GLASSXcrystal in its crystal state

Cool-phase

Product Summary

Monodraught® Cool-phase® CIBSE BUILDING PERFORMANCE AWARDS 2012 WINNER Ashden Award winner 2013

Ventilation and Storage Concept



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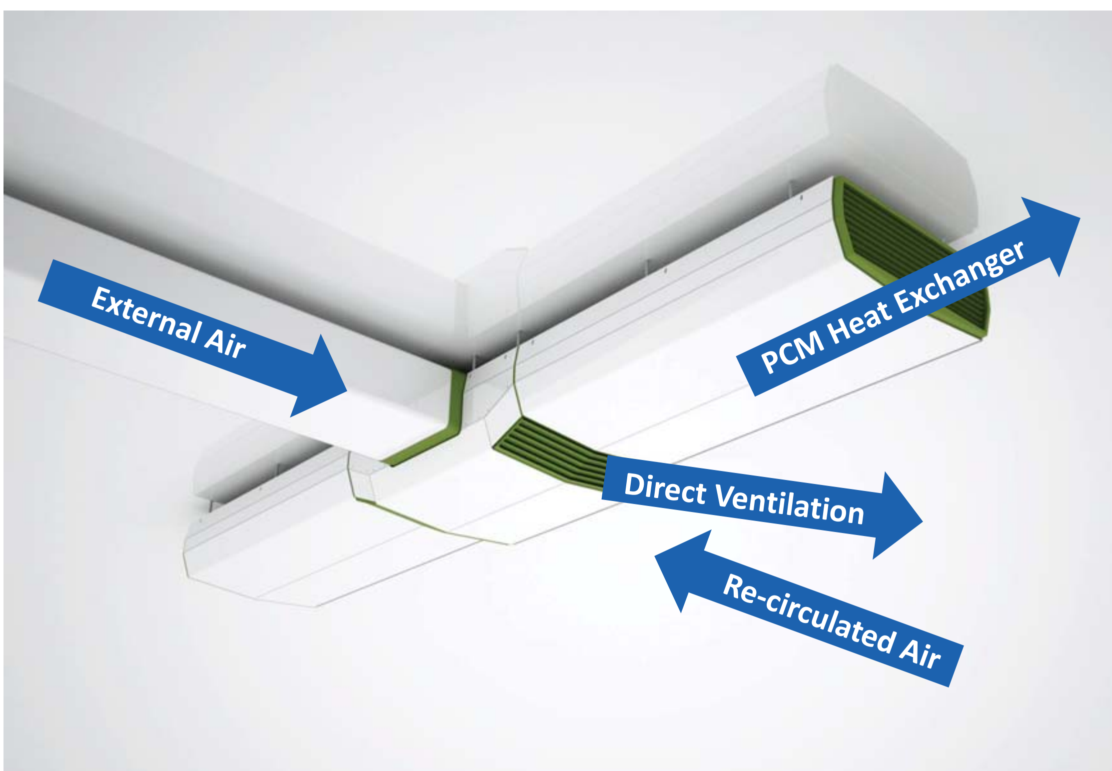
How it works - CP Delta (2011-2012)



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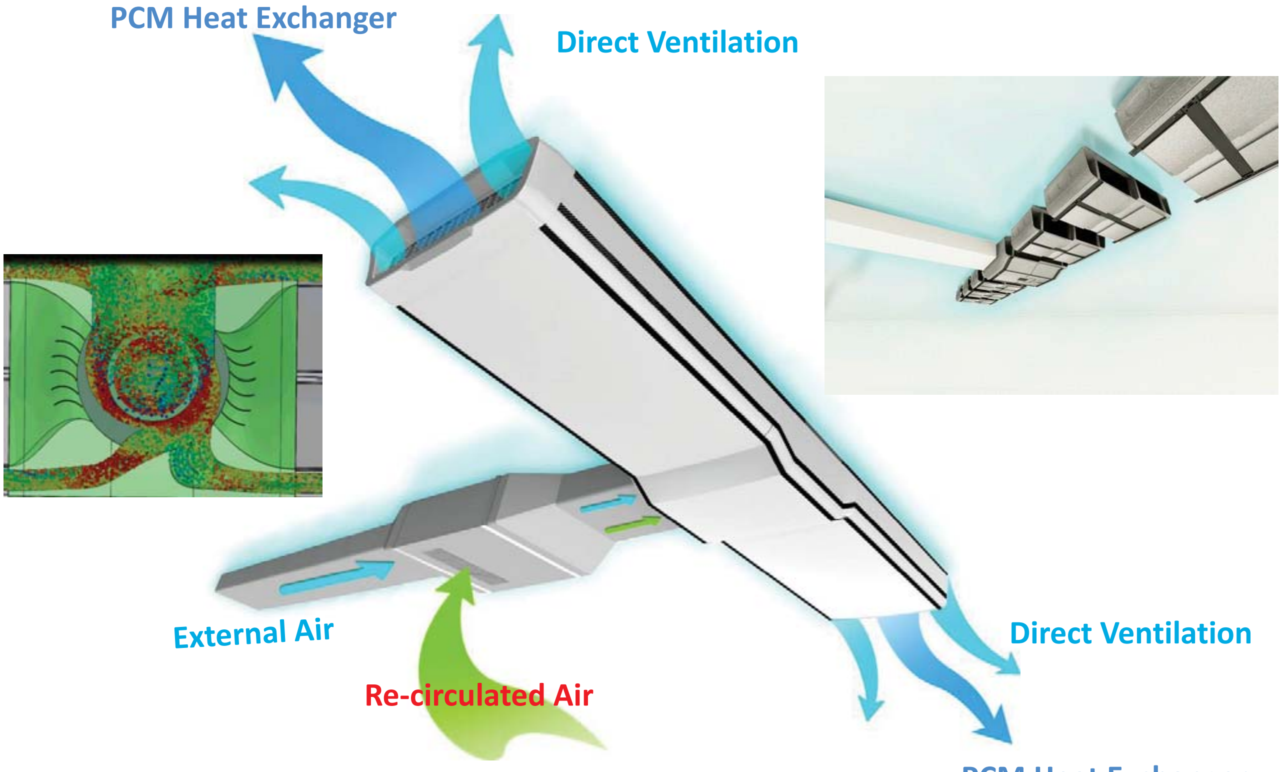
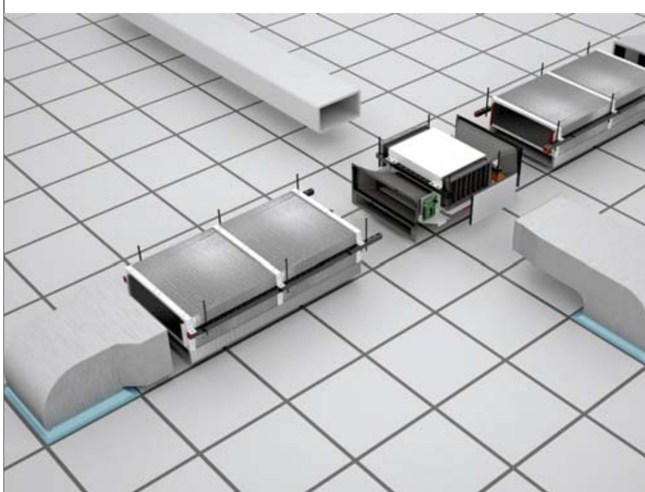
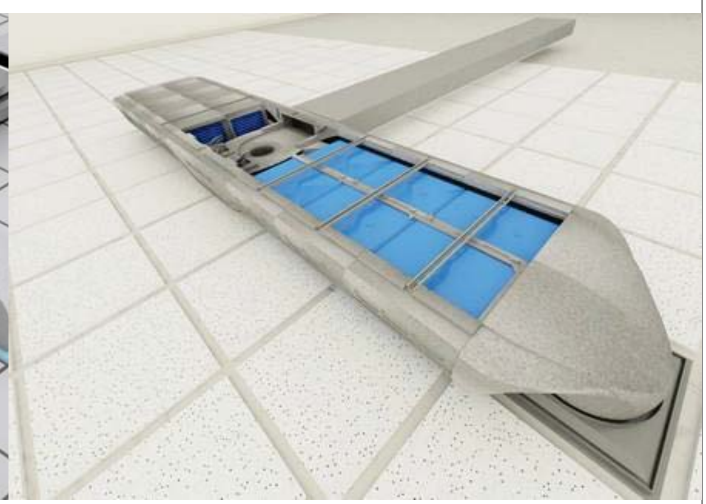
How it works - CP Nova (Current)

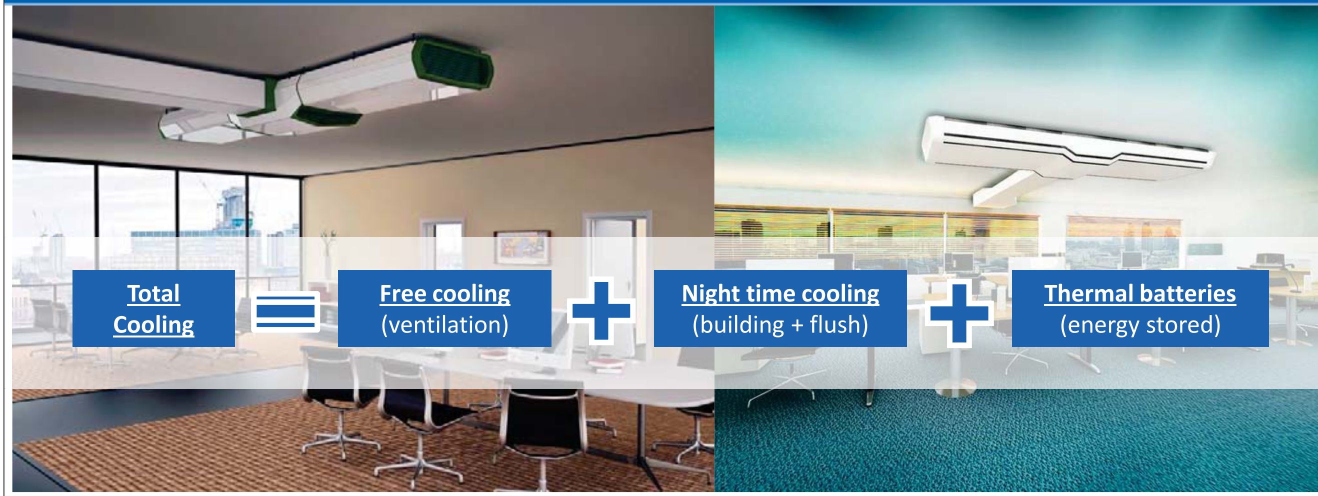


Ceiling Void Installation





Performance criteria



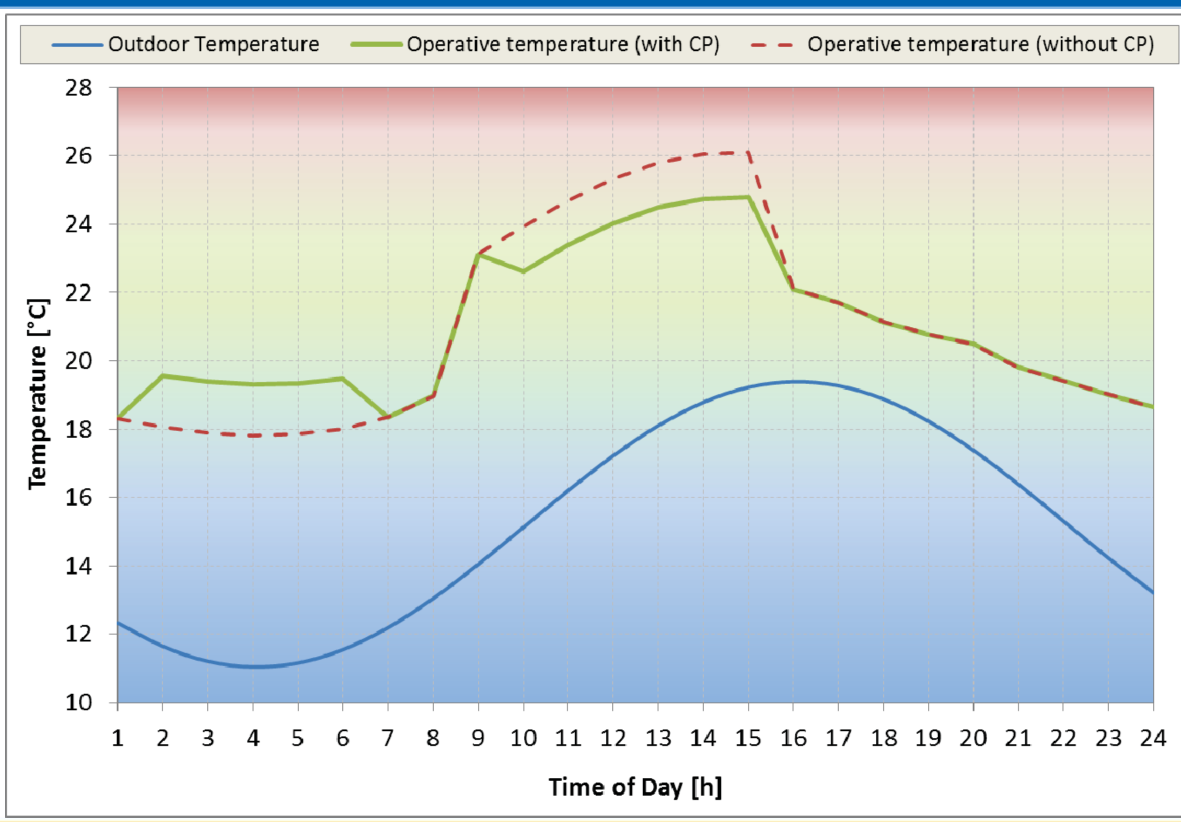
Delta Unit (2011-2012):

- Normal ventilation rate – **100 to 250** l/s
- Maximum ventilation rate - **350** l/s
- Typical energy usage – **30W to 120W**
- Thermal energy storage - **8 KWh**

Nova Unit (Current):

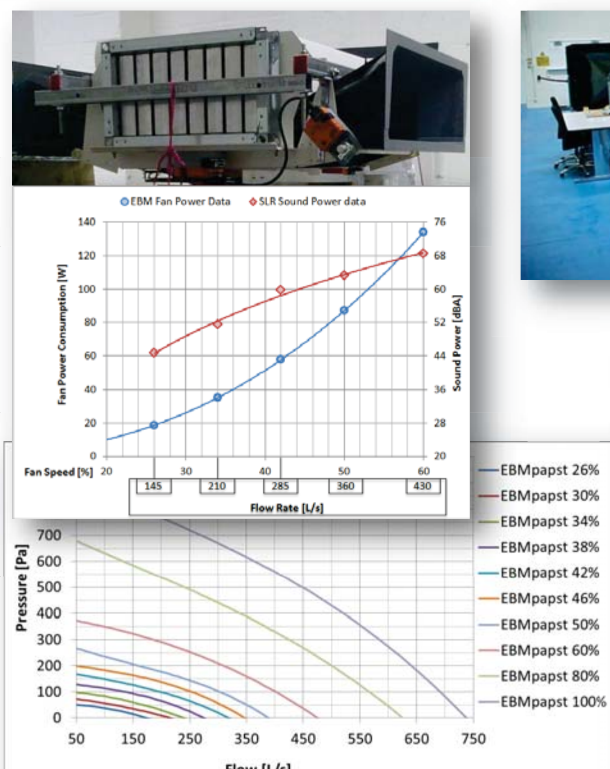
- Normal ventilation rate – **100 to 260** l/s
- Maximum ventilation rate - **320** l/s
- Typical energy usage – **7W to 80W**
- Thermal energy storage – 6, **8, 10 KWh**

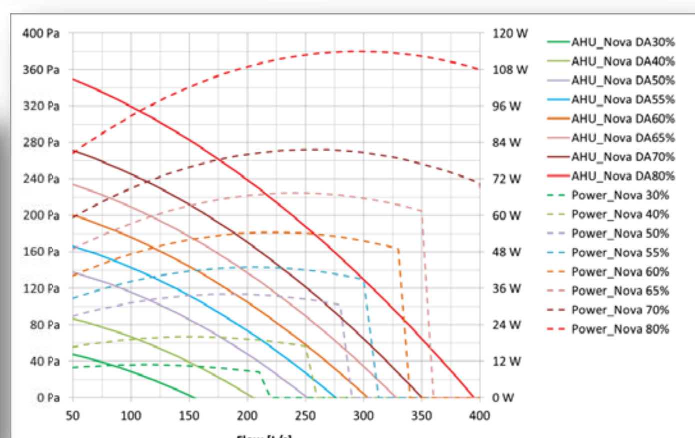
CP Operation Schedule (CIBSE Admittance Model)



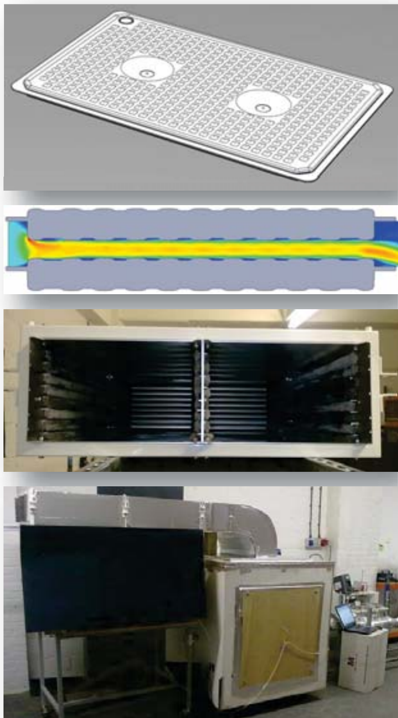
Testing & Modelling

EBMpapst – AHU Independent tests



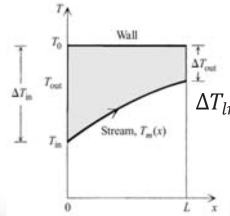


Heat Transfer Modelling

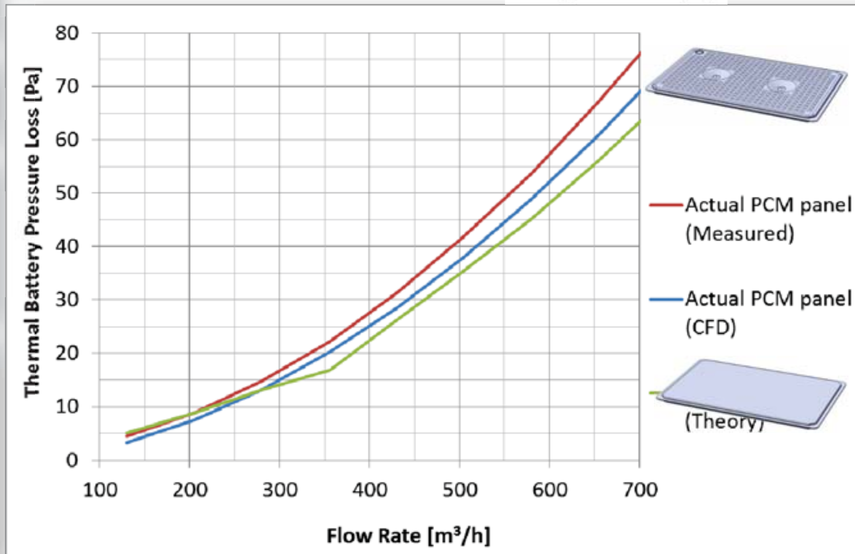


$$Q_h = h \cdot A_w \cdot \Delta T_{lm}$$

$$Q_h = \dot{m} \cdot c_p \cdot (T_{out} - T_{in})$$

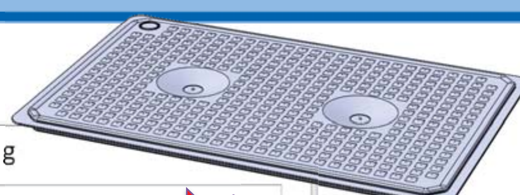


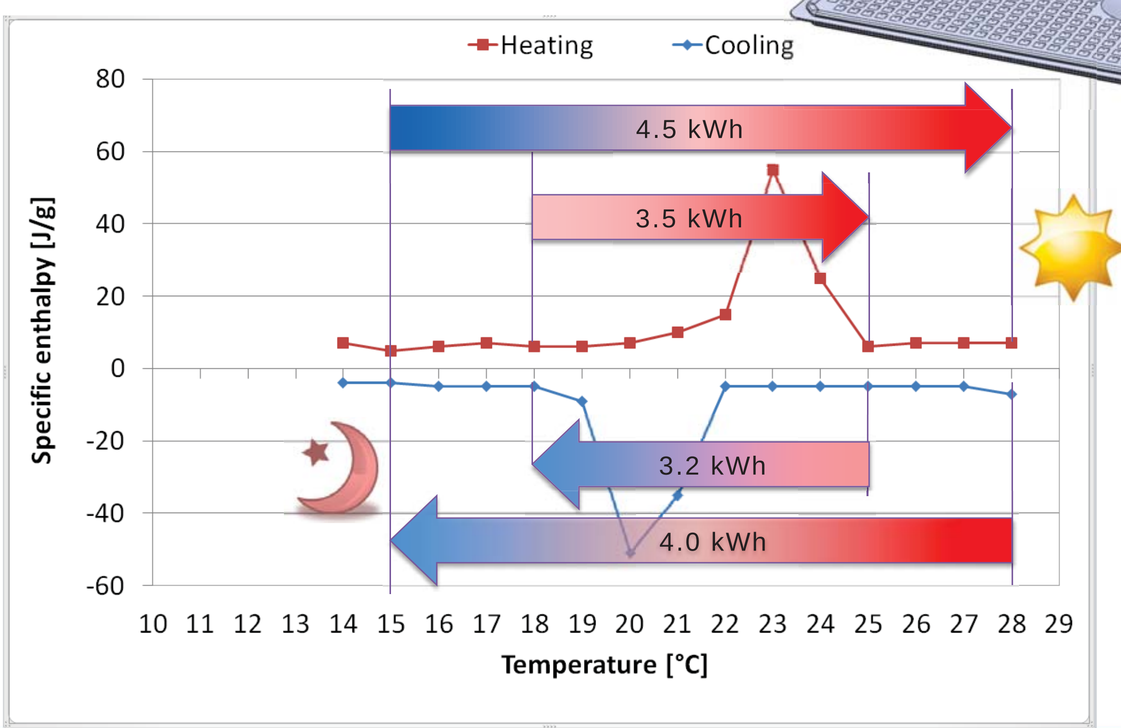
$$\Delta T_{lm} = \frac{\Delta T_{in} - \Delta T_o}{\ln \frac{\Delta T_{in}}{\Delta T_o}}$$



PCM Panel

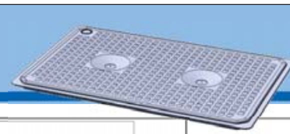
➢ PCM characteristics (SP22A17)

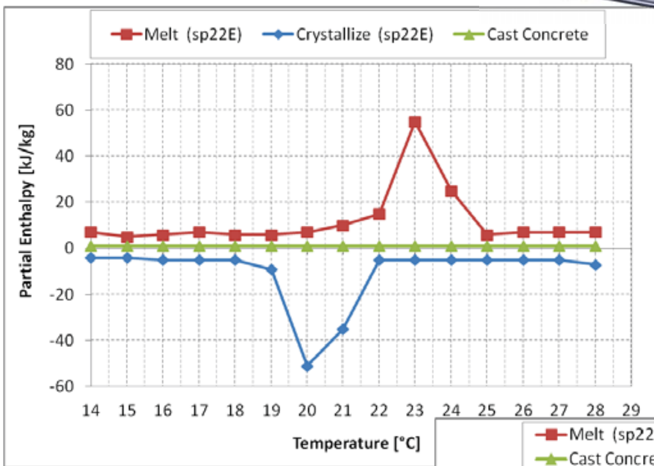


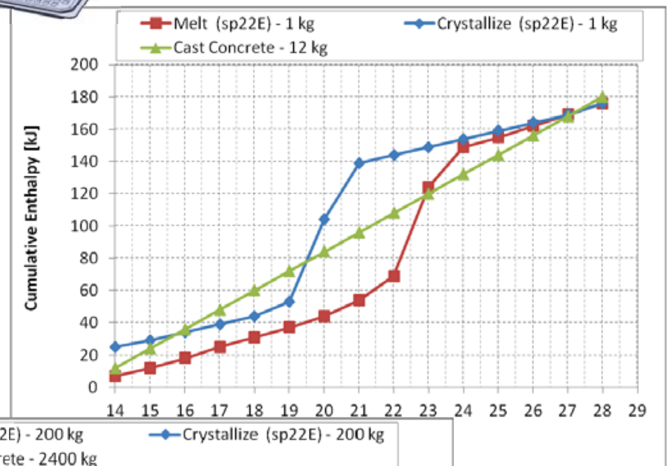


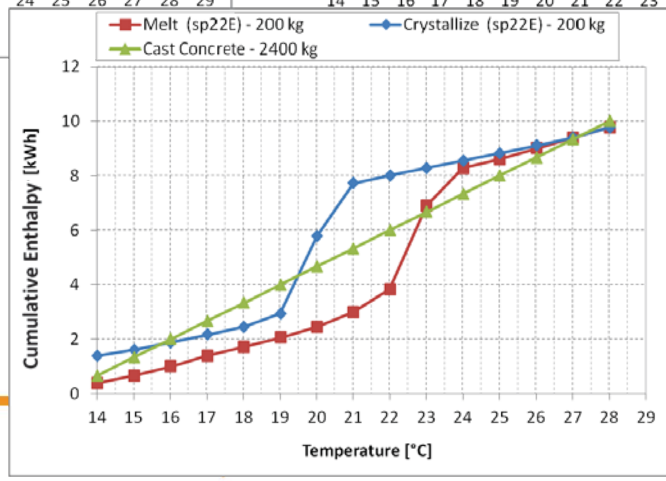
Monodraught® Coolphase®

PCM characteristics



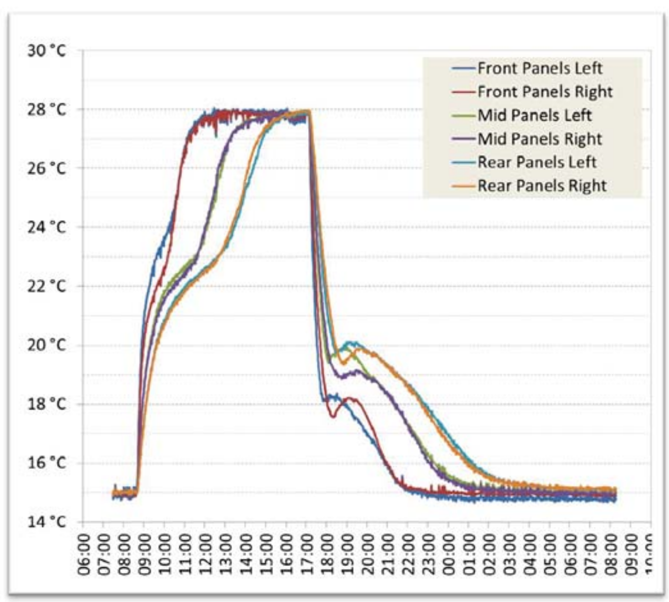






TB Performance Testing – Full Scale

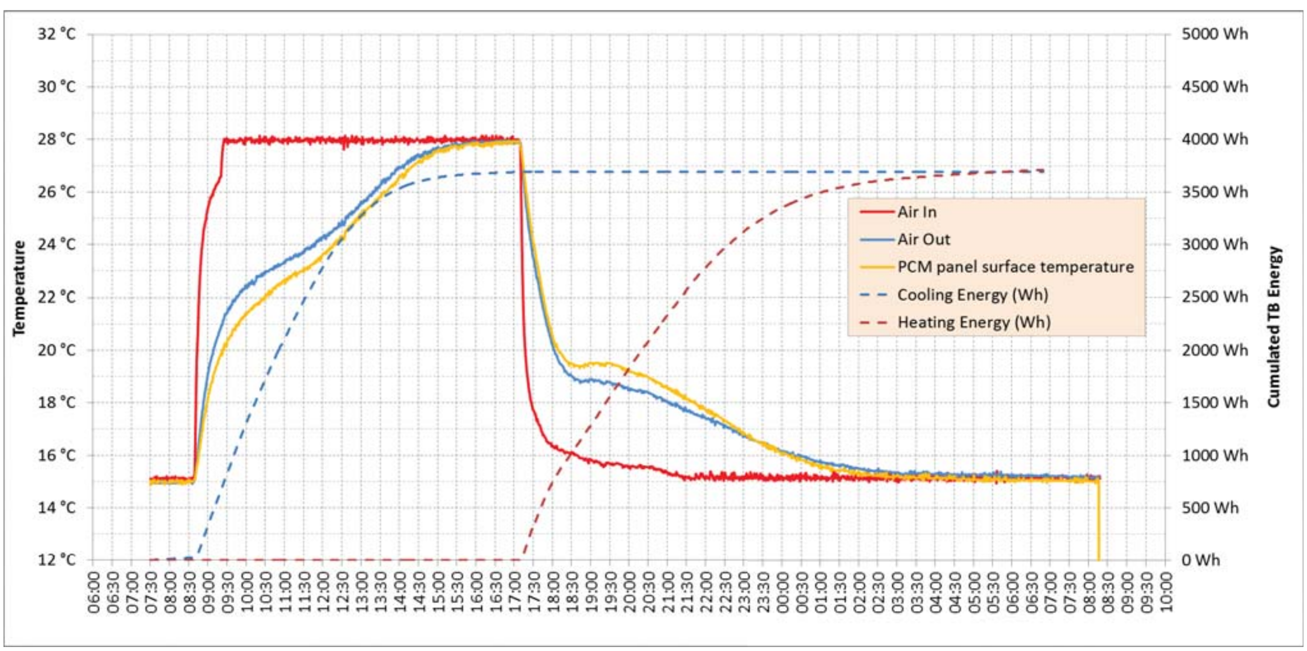
- TB cooled to 15°C at night and exposed to constant temperature of 28°C



TB Performance Testing – Full Scale

- Measurement Setup
  - Controlled airflow and supply air temperature (15°C-28°C)
  - Temperature sensors upstream and downstream of the TB
  - Surface temperature measured on 6 panels (front & back edges)

TB Performance Testing – Full Scale



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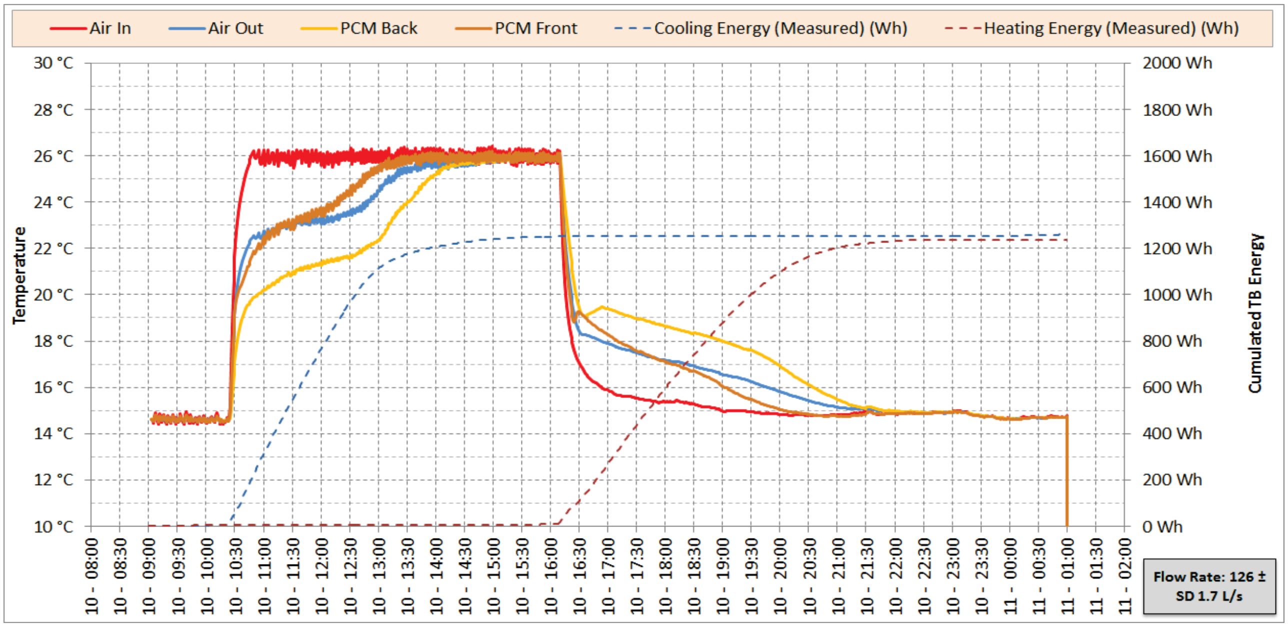
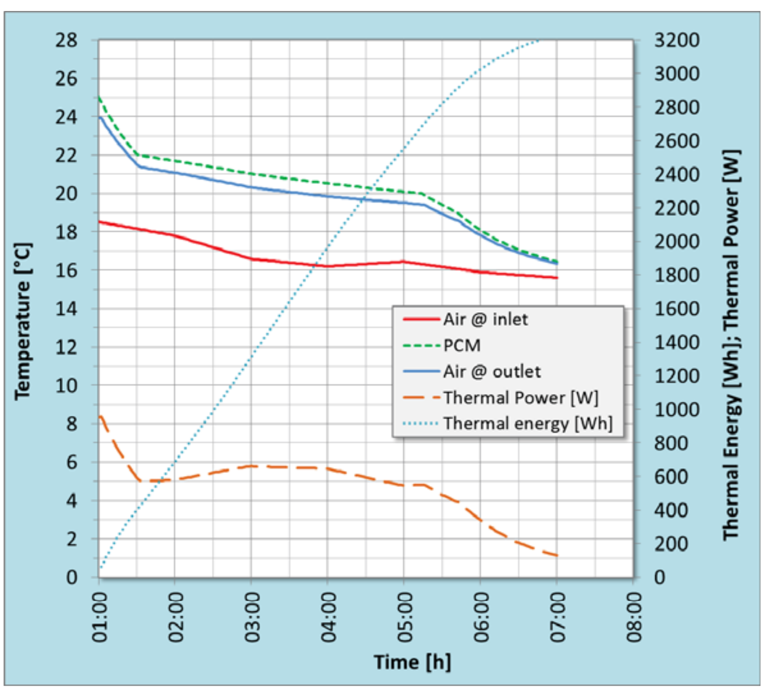
TB Performance Testing – Full Scale

- Delivered performance of 1 battery module (15°C - 26°C temperature range)



TB Charging model (Excel tool)

- TB night charging (01:00 – 06:00; 5h) (warm night London):



- AHU: Charging Mode
- Fan speed: 50% (288 L/s)
- Flow rate: 144 L/s /TB

- PCM temperature: 25°C → 18°C
- Thermal Energy: 3015 Wh

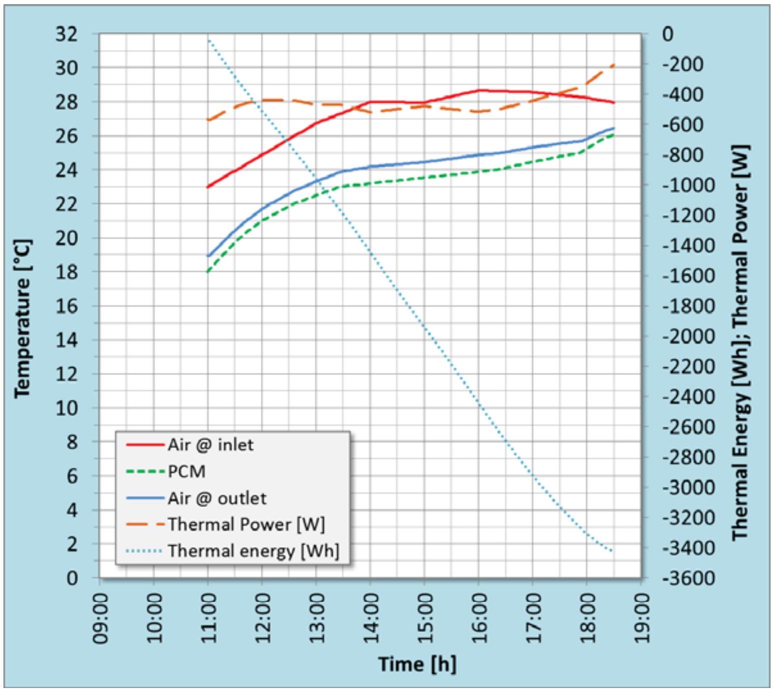
- Thermal Power:
  - Start: **952 W**
  - End: 340 W
  - Average: 603 W over 5h

- Power Consumption:

  5h x 87.3W = 436.5 Wh

TB Discharge Model (Excel Tool)

- TB discharge (11:00 – 17:30; 6.5h) (hot day London)



- AHU: Cooling Mode
- Fan speed: 42% (230 L/s)
- Flow rate: 115 L/s /TB

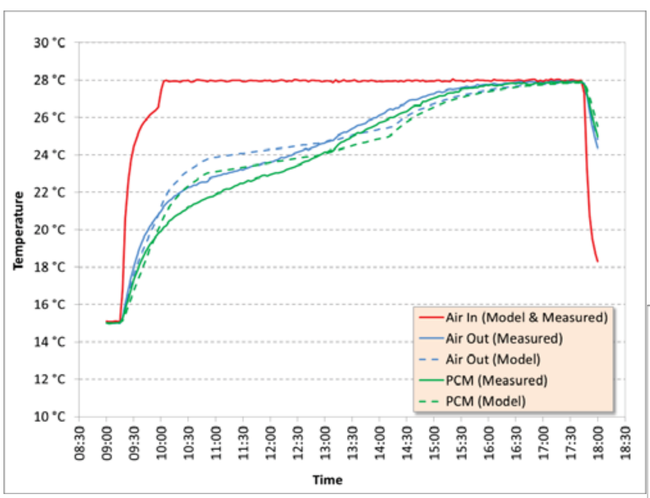
- PCM temperature: 18°C → 25°C
- Thermal Energy: -3127 Wh

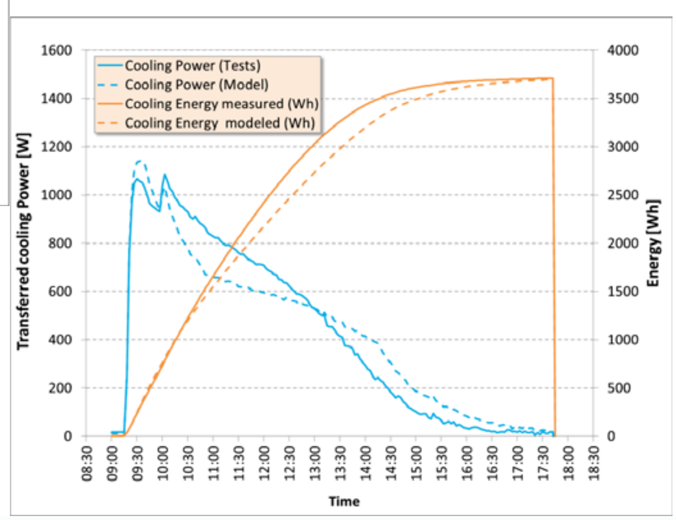
- Thermal Power:
  - Start: **-563 W**
  - End: -392 W
  - Average: -481 W over 6.5h

- Power Consumption:
  6.5h x 57.9W = 376.4 Wh

- EER=(2x3127)/813=7.7

TB Performance Testing vs Model





IES Implementation

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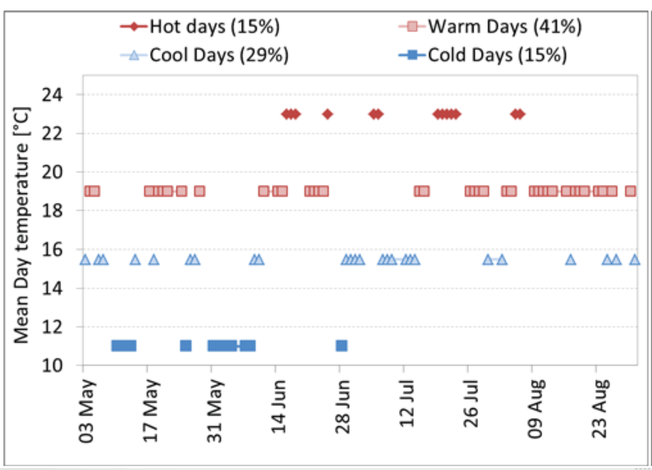
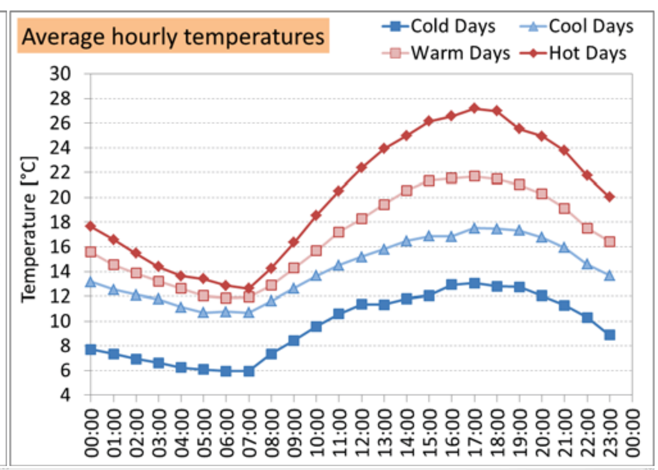
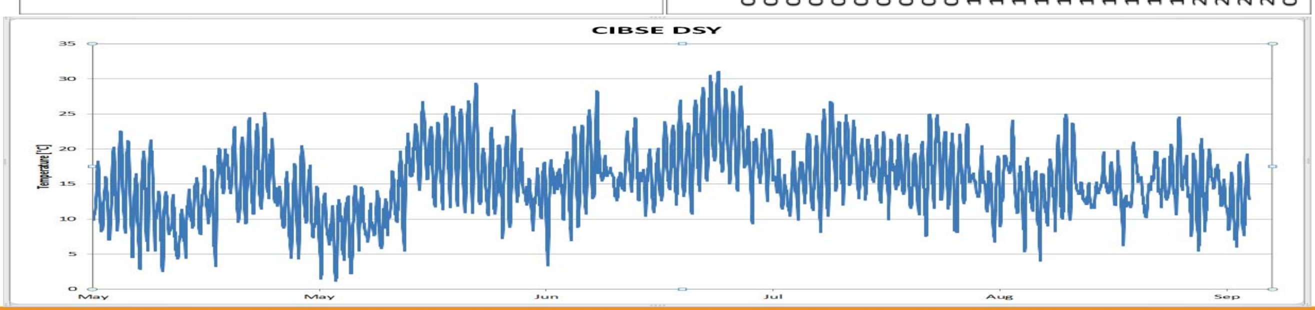
Temperature profile and frequency

- Weather analysis (Excel tool)

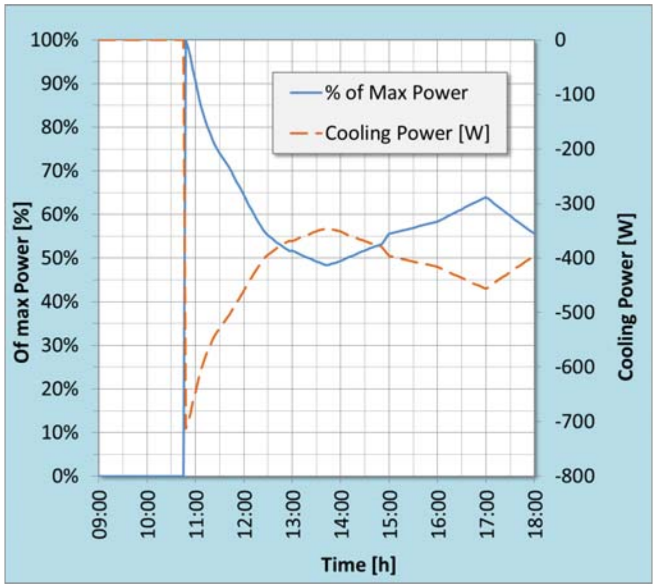






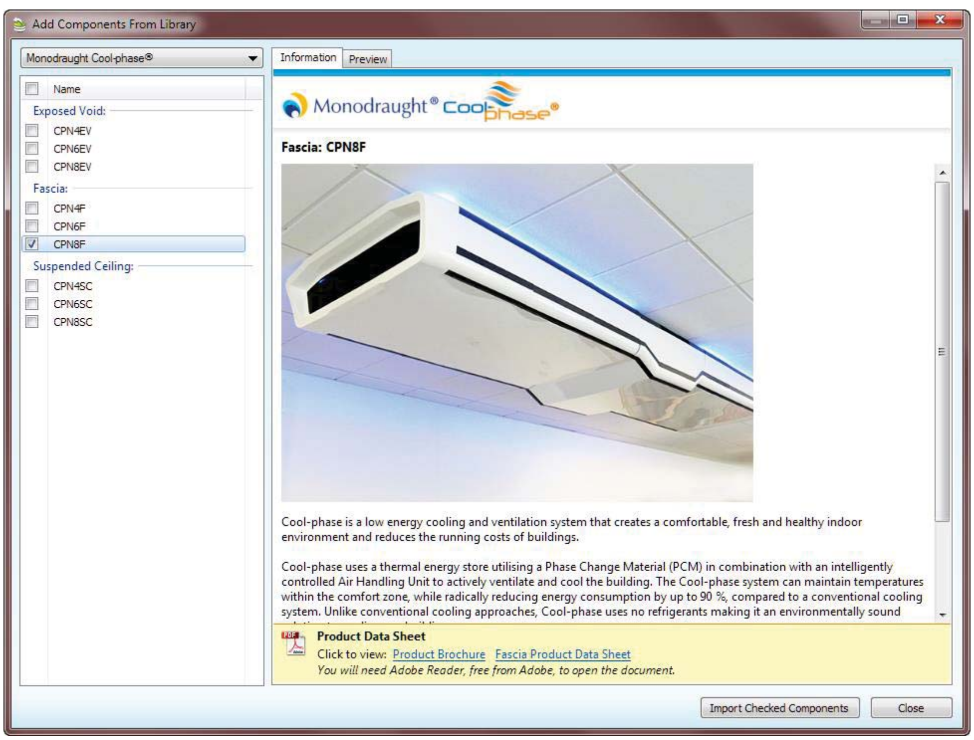
TB Discharge Profile (IES)

Fresh Air mode

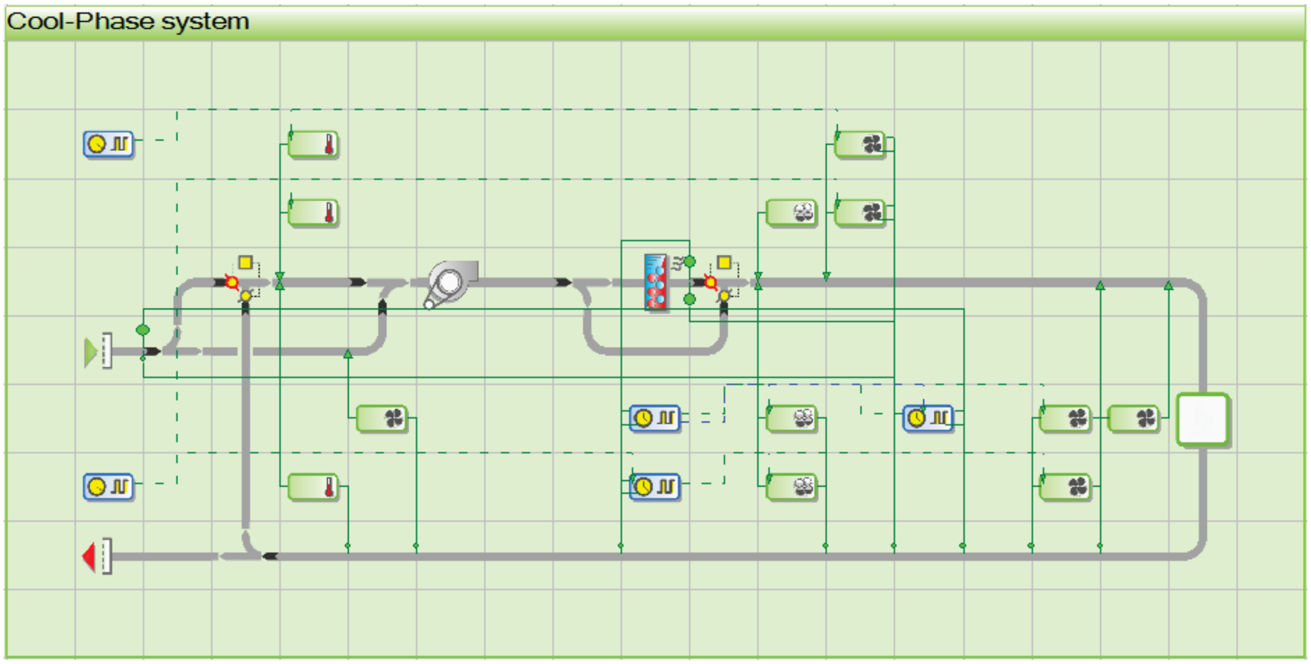


- Thermal Power:
  - **Start: -713 W (IES input)**
  - **Thermal Profile 0-100%**

IES Component Tool



IES Integration – as ApacheHVAC



Case Study

Notre Dame School Building (London)

Case study – Notre Dame School Building (London)

About the Case Study:

Two COOL-PHASE systems were installed in an IT classroom in April 2011. The classroom (approx. 70 m^2) has high internal heat gains with 30 PCs and an overhead projector, while partly shaded windows on two sides (NW & SE) create solar gains.

Two control rooms were chosen in order to provide a comparison to the performance of the COOL-PHASE systems; the first was another IT classroom with 30 PCs and an overhead projector, resulting in similar internal heat gains. Due to external gains from SW facing windows, there was higher external heat loading than the classroom where COOL-PHASE was installed. This classroom had a Split Air Conditioning (AC) system already installed to provide cooling.

The second control room was a Geography classroom with much lower internal and external heat loading. This classroom had a single PC and overhead projector. The room was chosen as it was located next to the room with the COOL-PHASE systems and would provide a baseline to compare performance to.

- All rooms prior to the install used manually operated windows to provide natural ventilation.
- Data logging equipment was installed in each of these classrooms.
- Temperature and CO_2 levels were monitored every minute. The data loggers were installed in February 2011 during the Spring term so that the two environments could be compared before the COOL-PHASE® low energy cooling and ventilation systems were installed.
- To verify the data logger readings, the temperature was recorded with a hand held digital meter in 8 locations around the room.
- The resulting temperature gradient was measured and used to identify any local hot or cold spots within the room.

Case study – Notre Dame School Building (London)

Before and After

Temperatures and CO_2 levels were monitored during the Spring term prior to the install to enable the two IT classrooms to be compared.

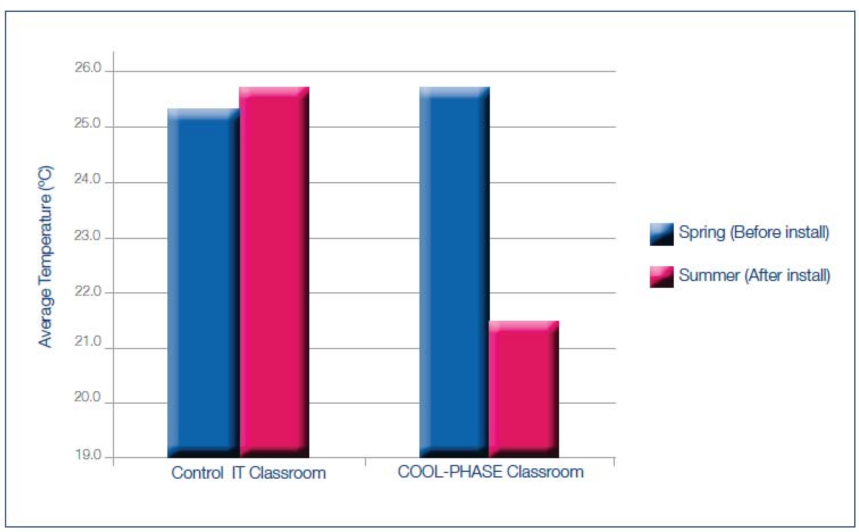
The average temperature in both environments during the Spring term are very similar. This shows both rooms have very similar internal heat loading.

The results show that the average temperatures increased in the control room slightly between the Spring and Summer term as can be expected due to warmer weather.

However the room with the COOL-PHASE system has not replicated these trends and instead has seen a significant reduction in the average temperatures before and after the install.

The external heat loading in the control IT classroom is higher than the room where COOL-PHASE is installed and this would become a more significant factor in the Summer term, however the AC system should be able to overcome the total heat loading.

Despite the differences between the rooms, it is clear that the COOL-PHASE system has had a significant impact on average temperatures.



Comparison of the temperature before and after the install

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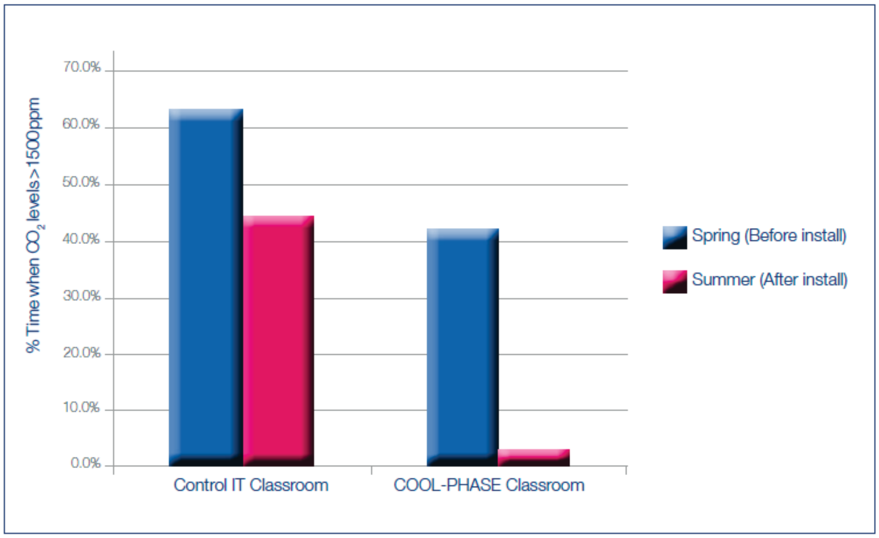
Case study – Notre Dame School Building (London)



Comparison of the CO_2 levels before and after the install

A similar pattern can be seen for the CO_2 levels. The results show that the control IT classroom had worse ventilation than the classroom where COOL-PHASE was installed.

This can be expected as the control classroom only had windows on one side; whereas the room where the COOL-PHASE systems were installed has windows on two opposite sides of the room allowing cross ventilation.

An improvement in air quality between the Spring and Summer term can be explained by the windows being opened more frequently.

However the results before and after the install of the COOL-PHASE system shows a very significant reduction in the number of hours where the CO_2 levels exceed 1500 ppm.

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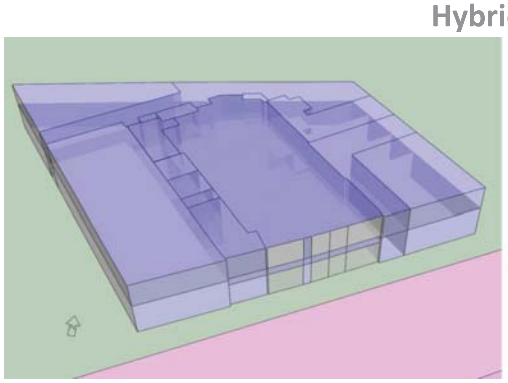
Cool-phase

Hybrid operation with VRF



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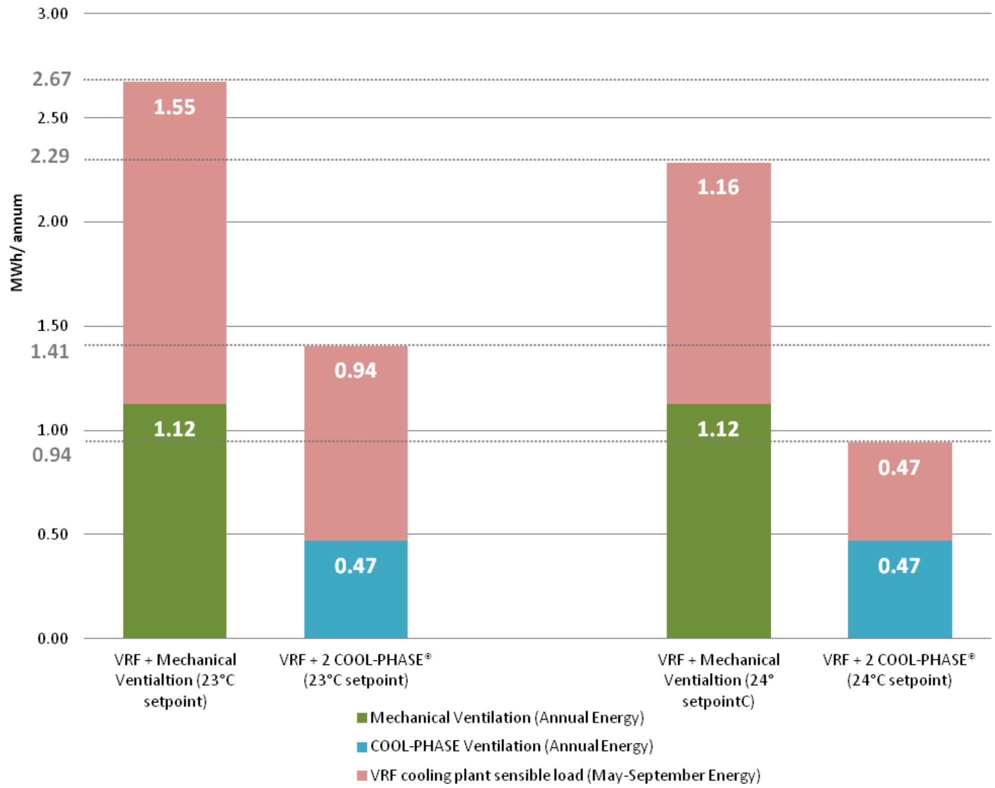
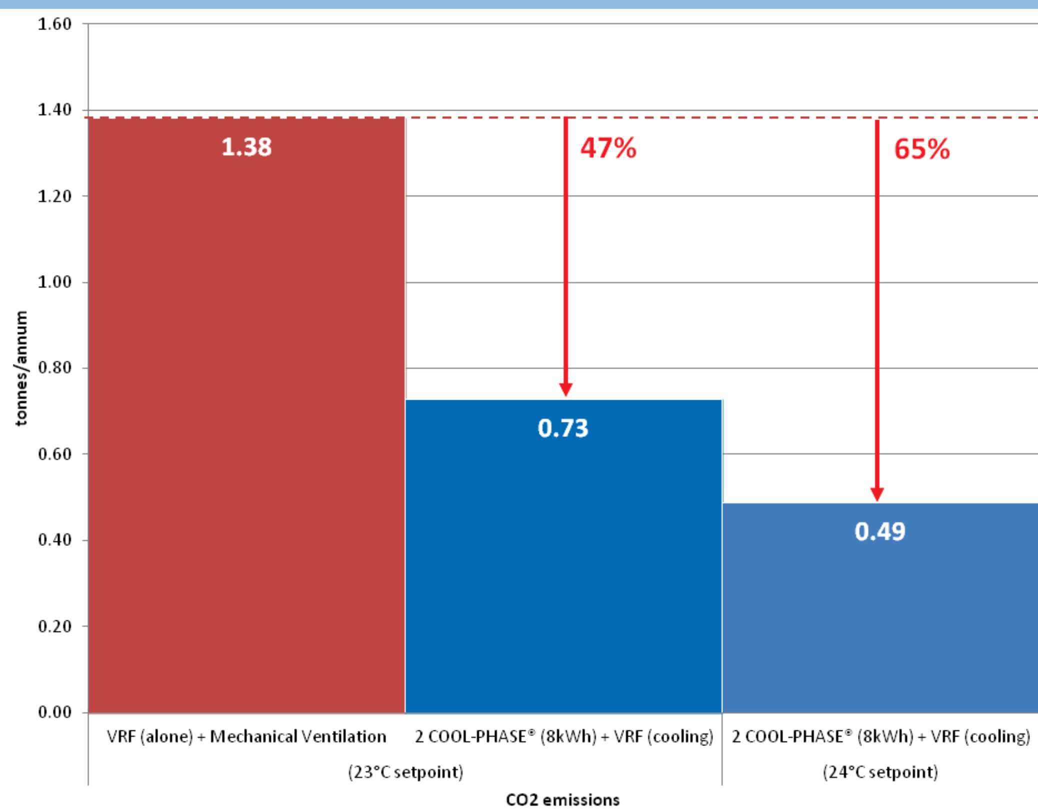
Hybrid operation with VRF



Hybrid operation with VRF



Monodraught®

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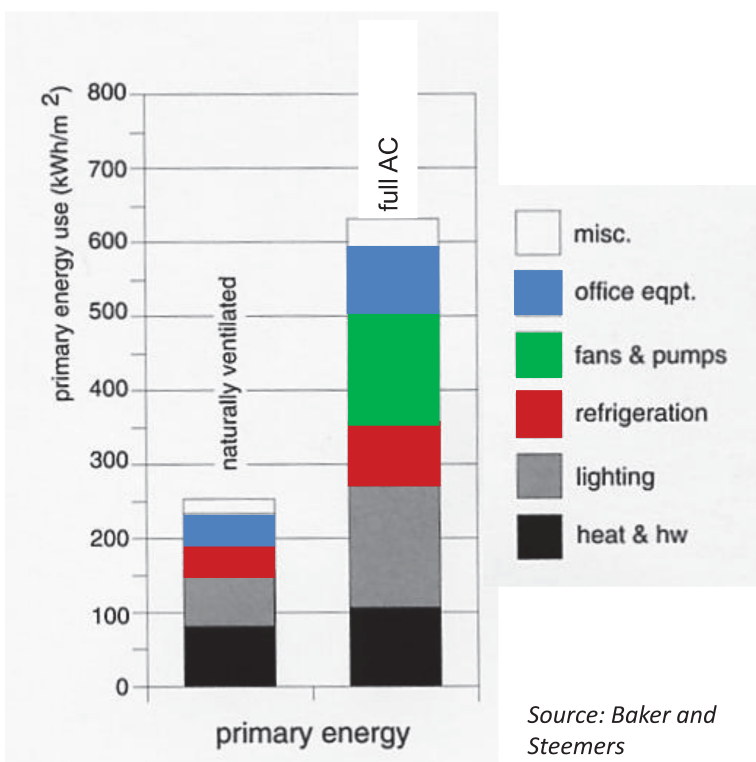
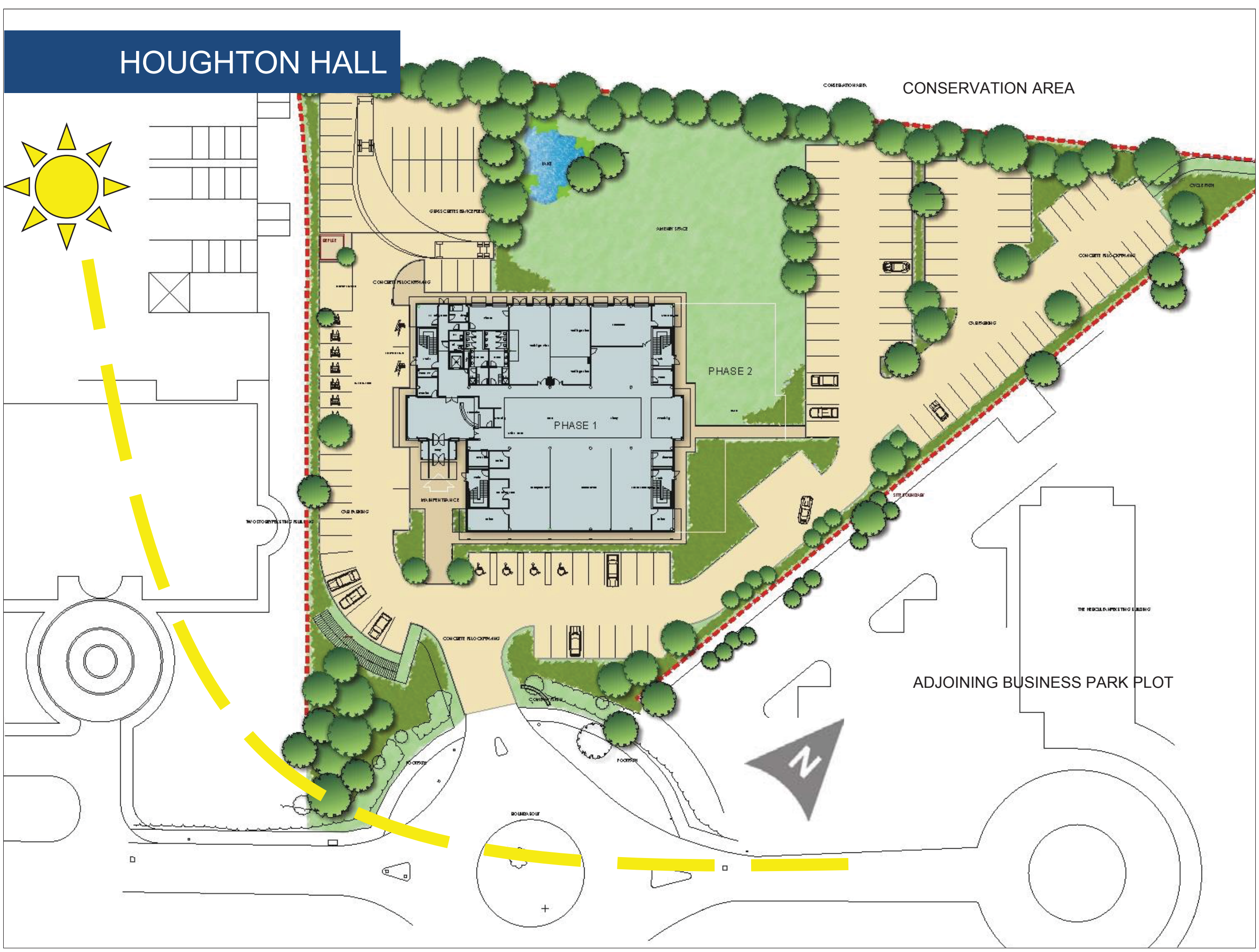
Energy Use In Buildings

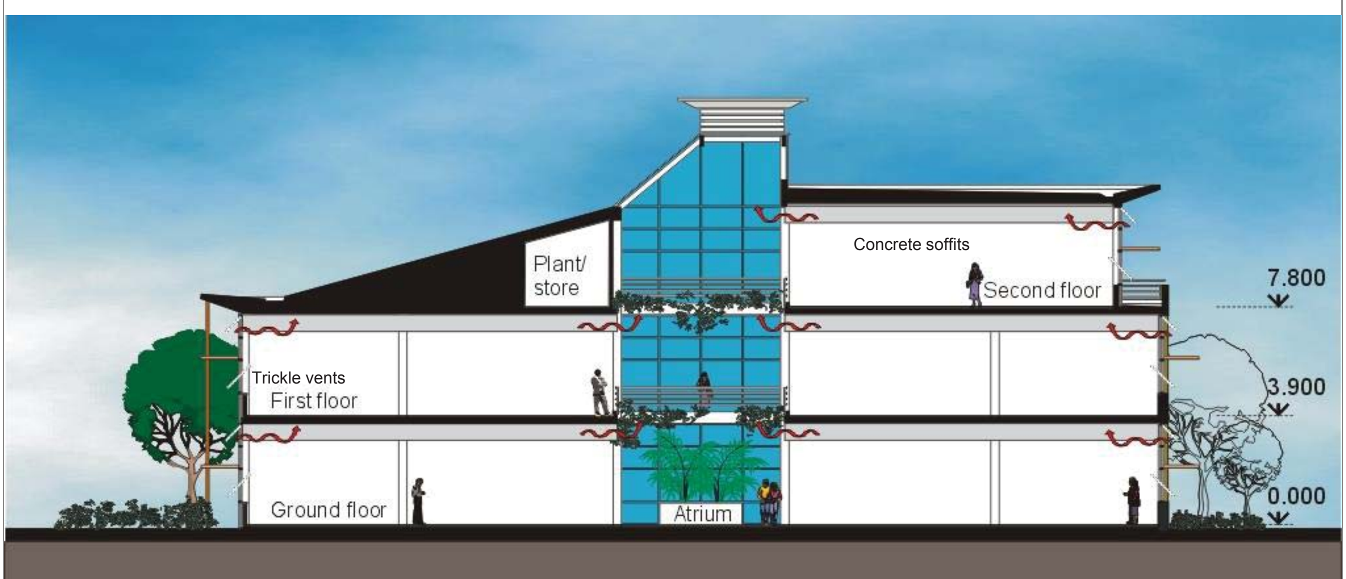


Source: Baker and Steemers


HOUGHTON HALL
Aldwyck

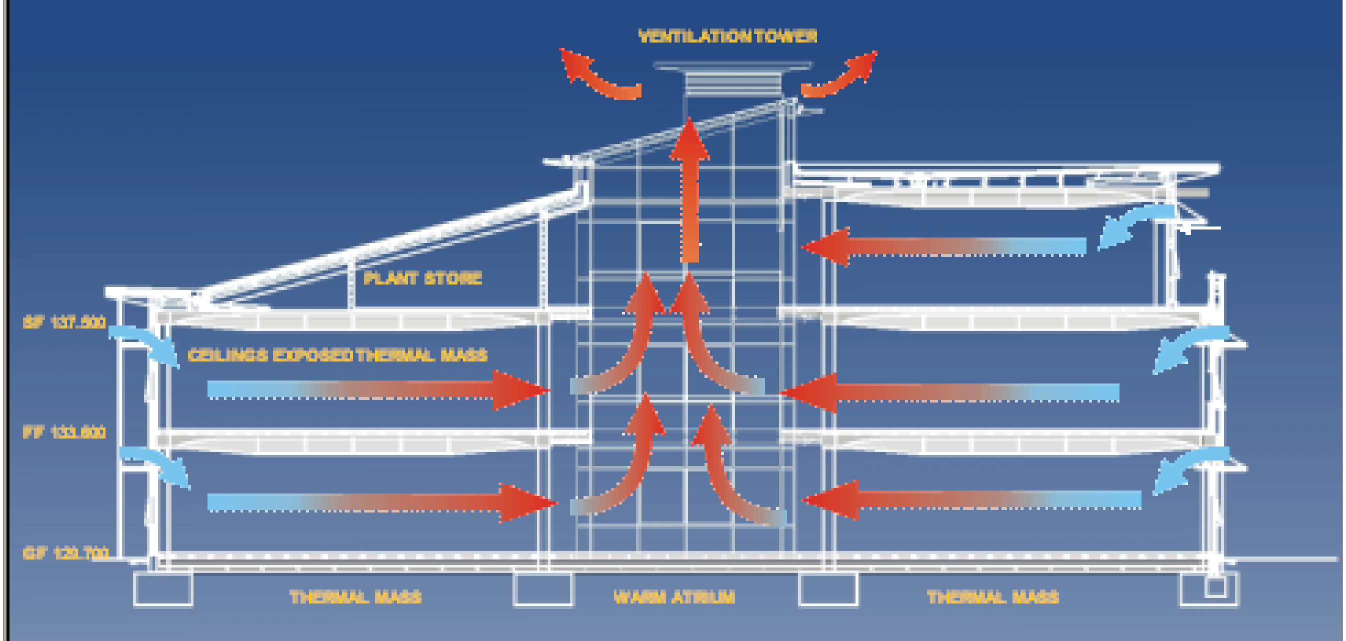

HOUGHTON HALL
CONSERVATION AREA
PHASE 1
PHASE 2
ADJOINING BUSINESS PARK PLOT
N

HOUGHTON HALL



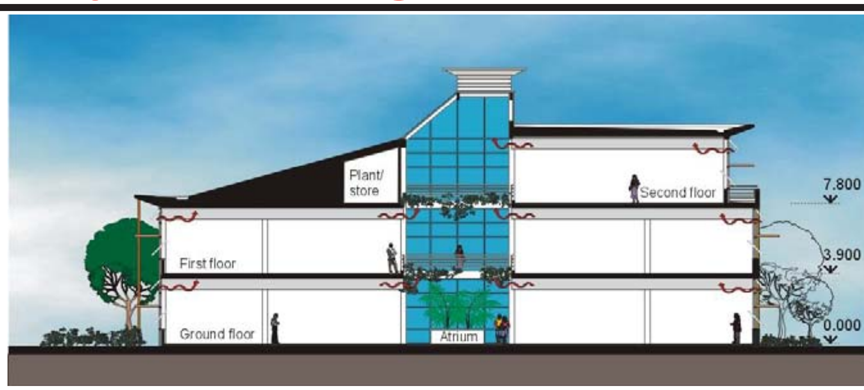
©Breathing Buildings

Building designed for outflow through stacks

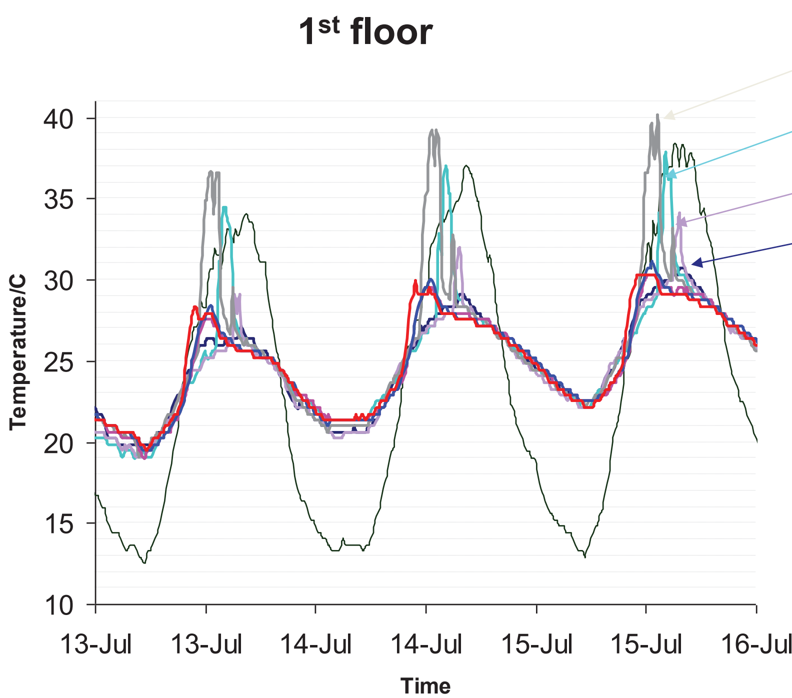


Complex Spaces – Houghton Hall

Breathing Buildings



Temperature Measurements

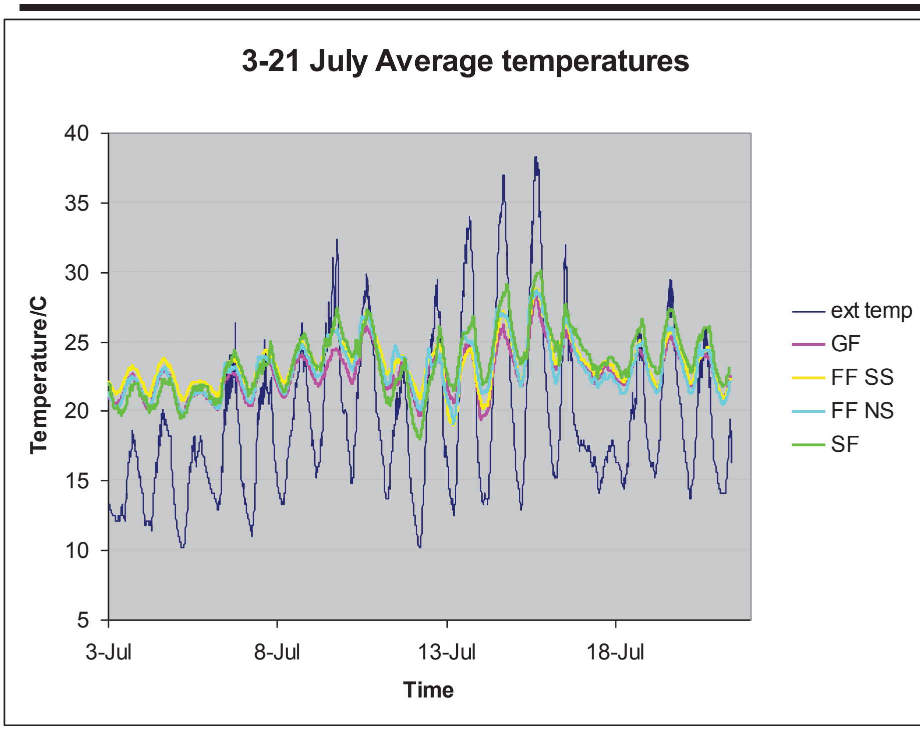


- North side of the atrium
- East end of the atrium
- South side of the atrium
- West end of the atrium (dark blue line, very small peak)
- Within main floor

Atrium peak temperatures follow exposure to sun

Region near/within atrium hotter than desk area under exposed concrete → benefit of thermal mass

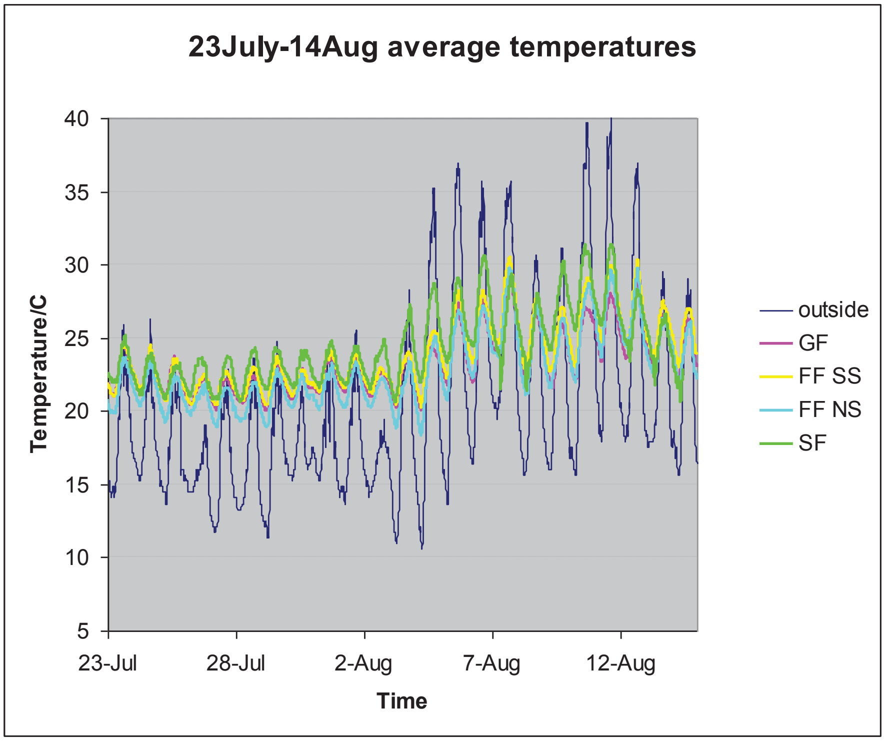
Temperature Measurements



Main floor temperatures less than outside and buffered by thermal mass…

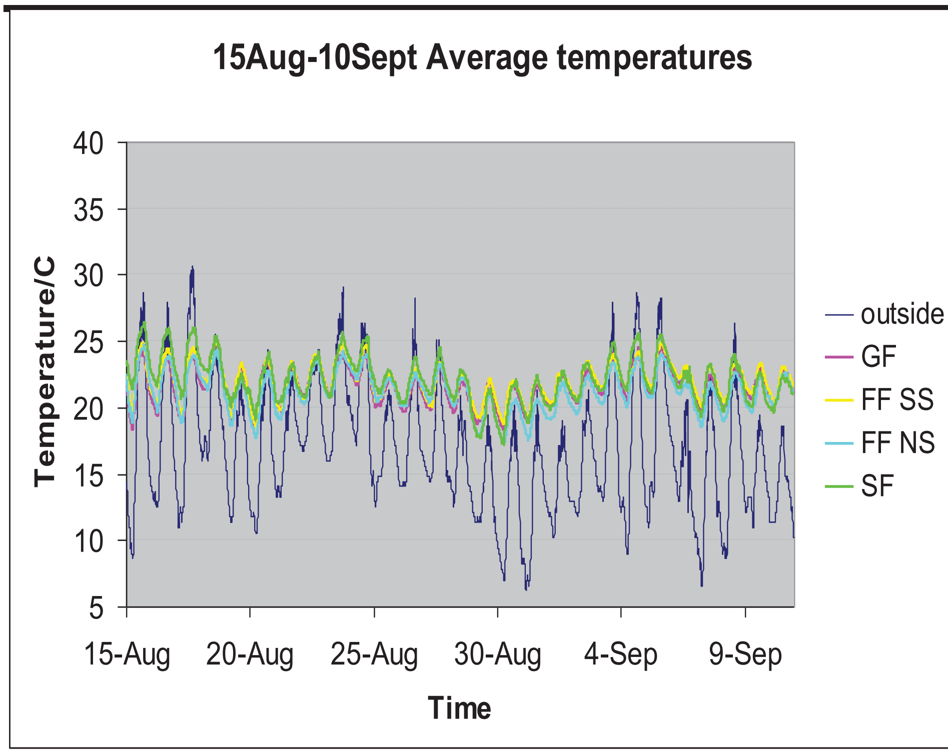
but still rather warm mid-July

Temperature Measurements



Warm inside again in early August

Temperature Measurements



Cooler after mid-August

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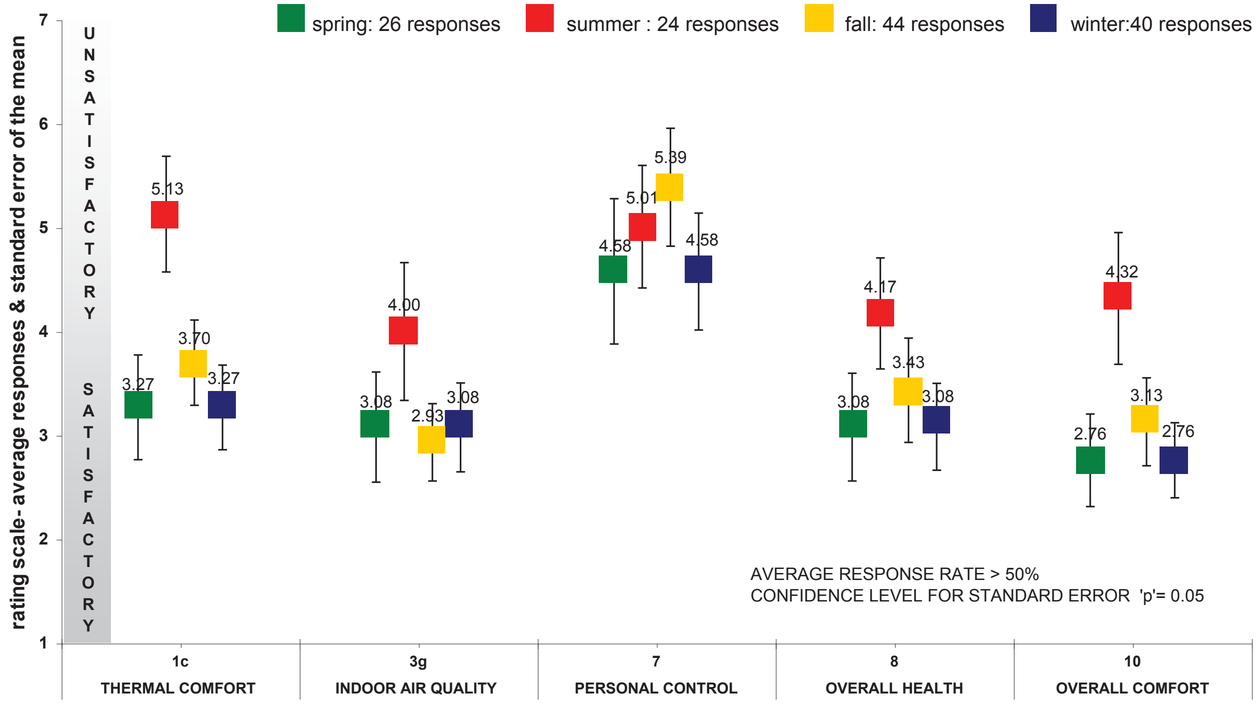
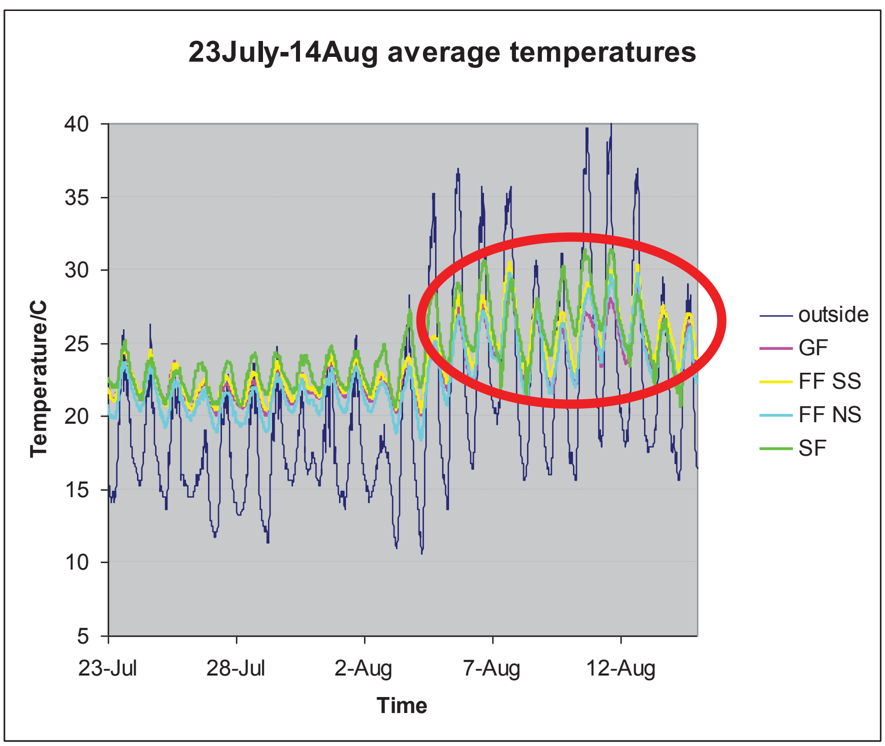
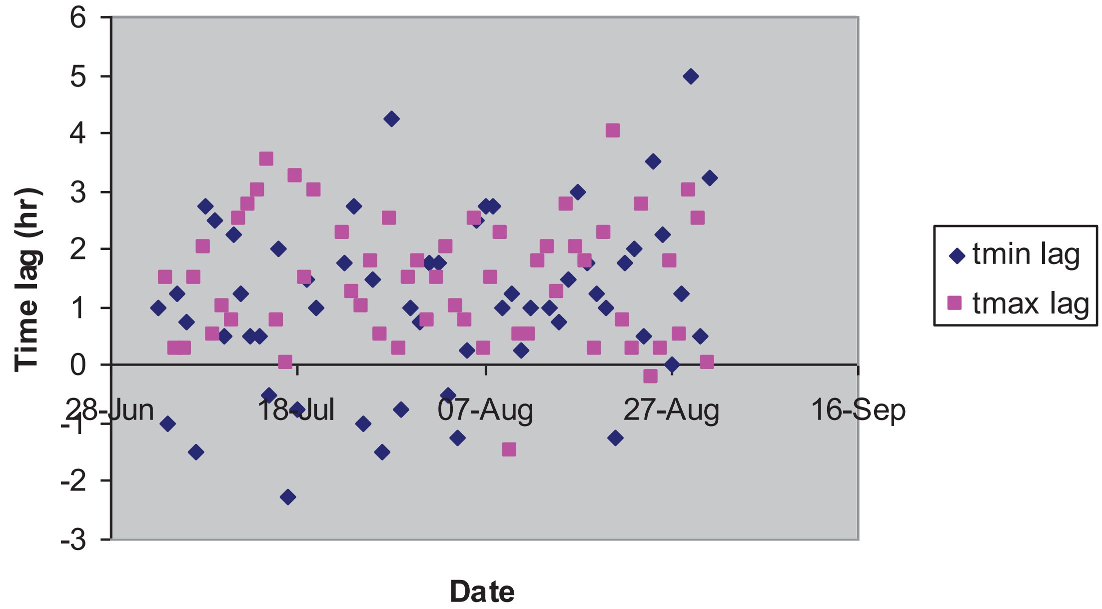
Survey Results



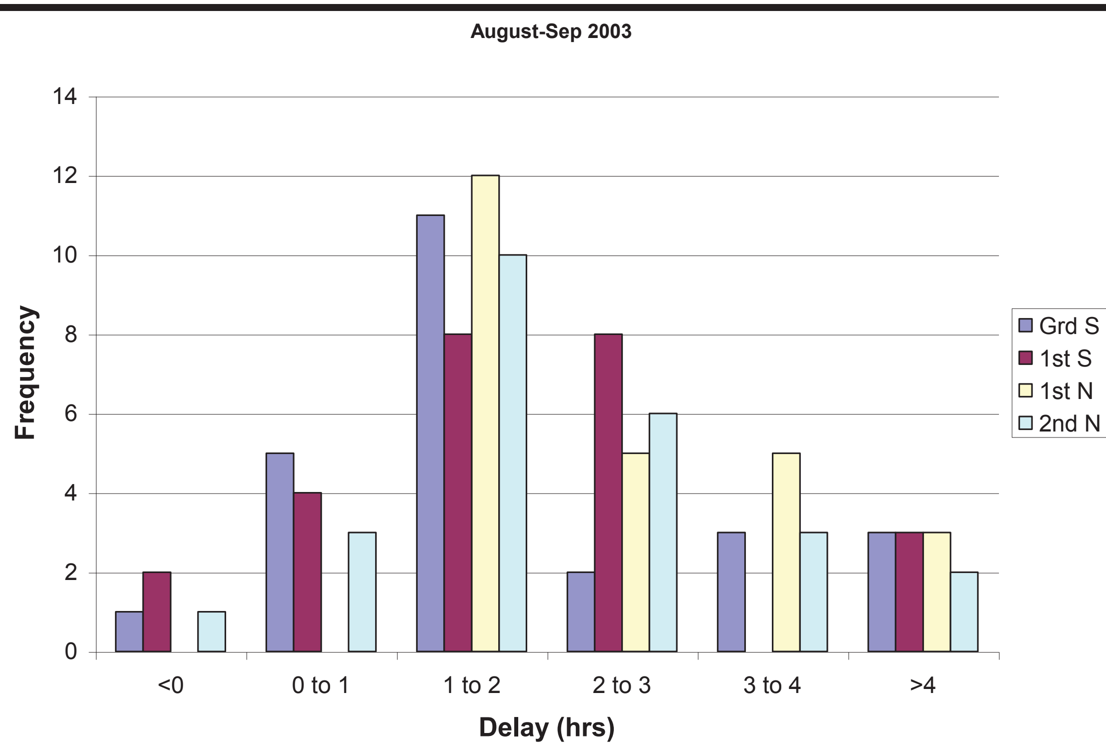
Can we improve performance?



Time Lags

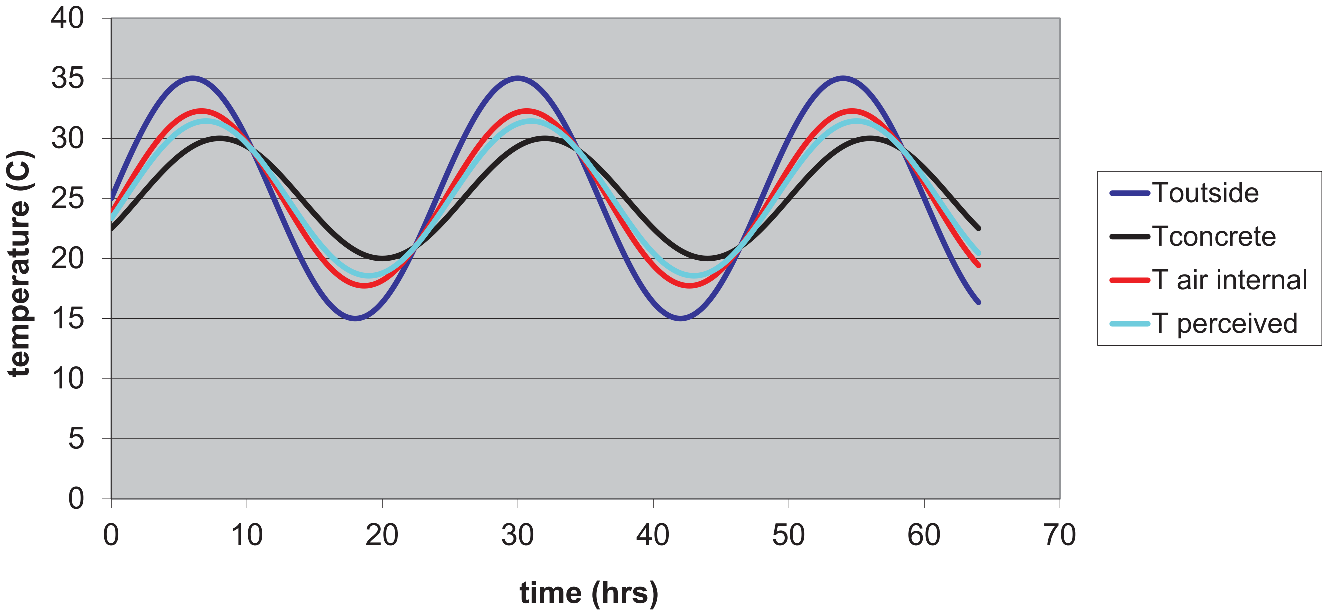


Range of time lag for building to reach max or min temp

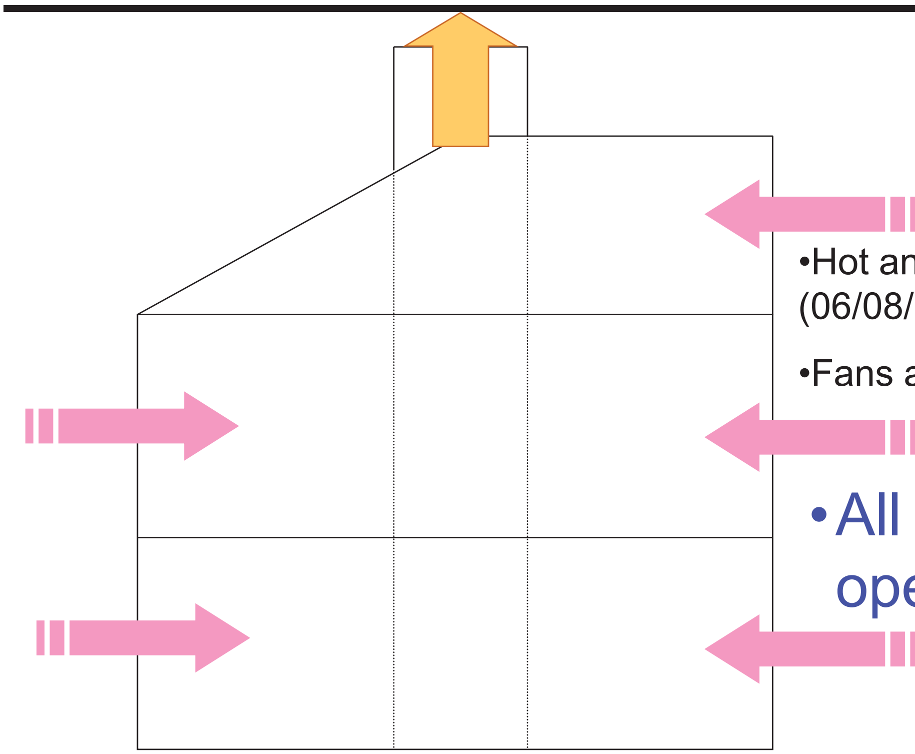


Buffer for max temp 1-3 hours

Maximising Effectiveness of Thermal Mass

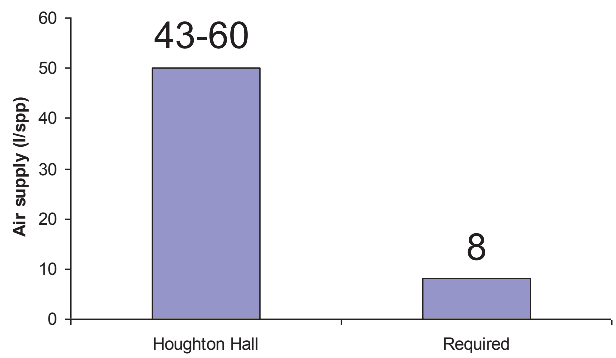


Air Flow Results



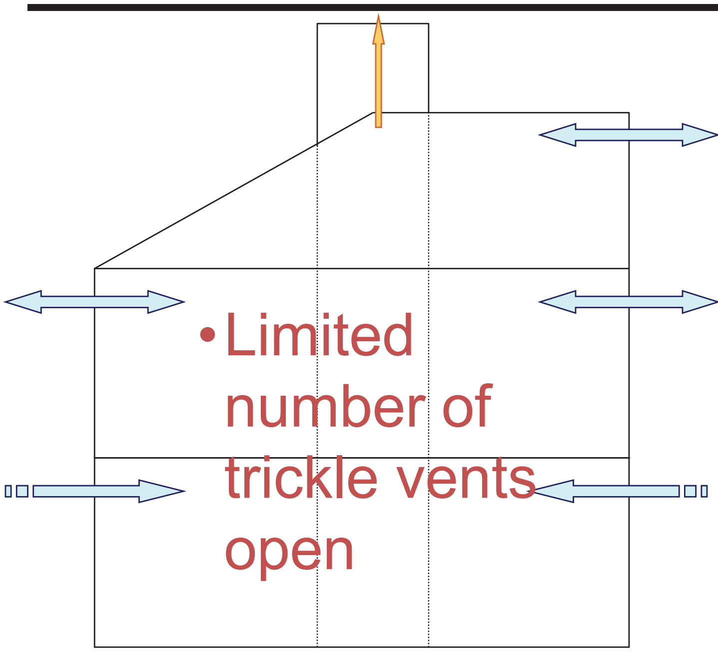
- Hot and still day (06/08/03)
- Fans are operating all day
- All windows open

Air Quality

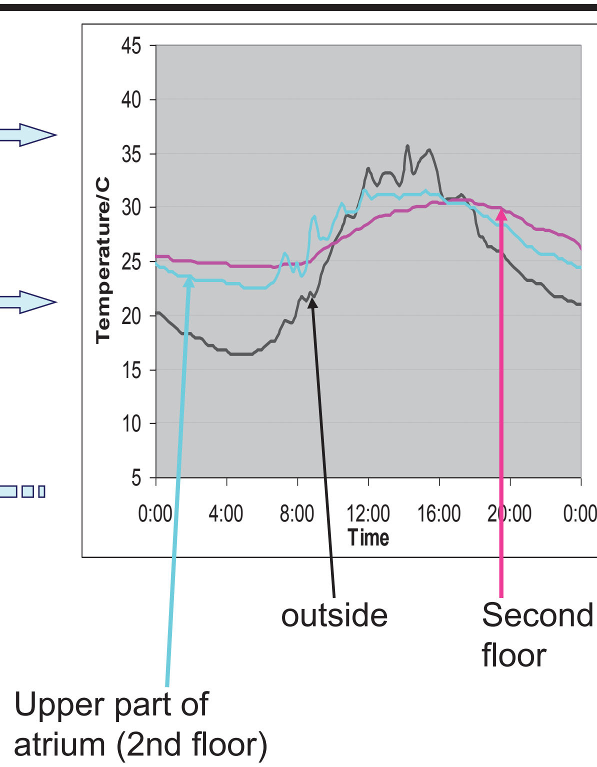


Measurements show fresh air supply well in excess of minimum required

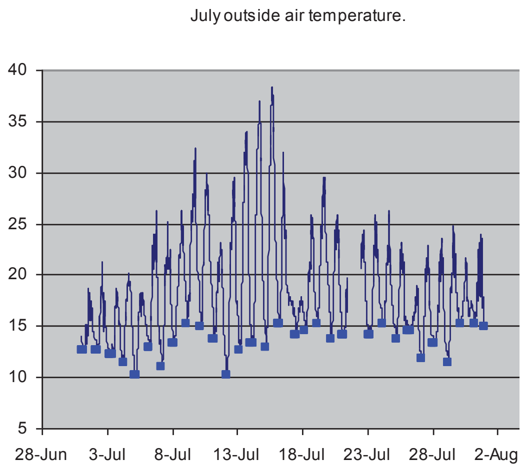
Night Time Operation

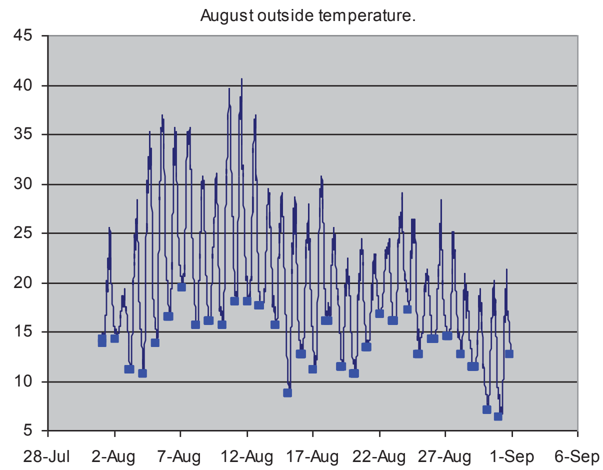


- Limited number of trickle vents open



Opportunity for Improvement

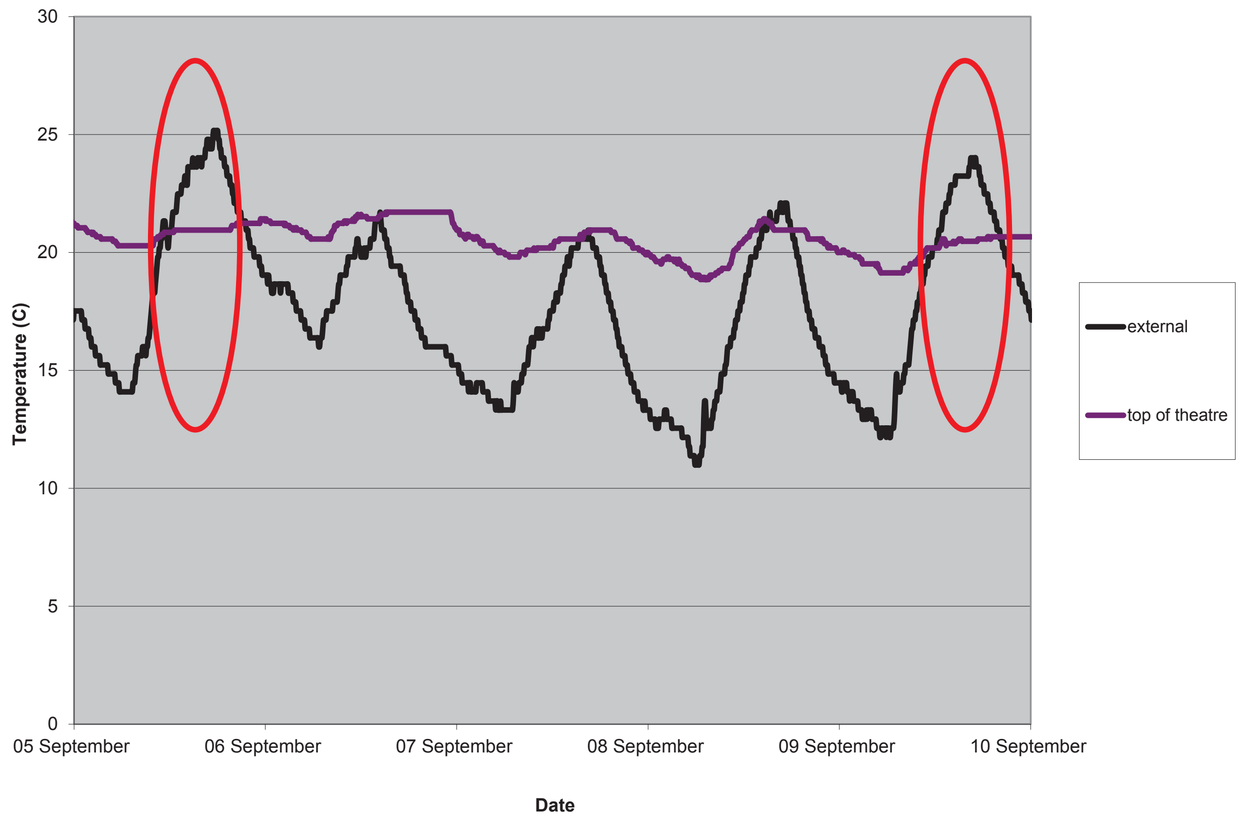




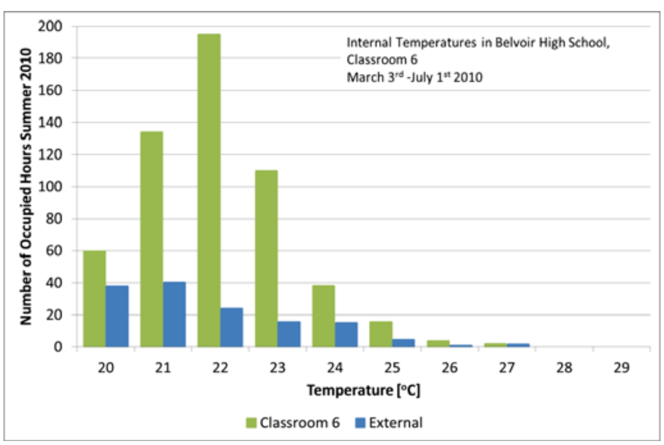
1. Opportunity to use cool air from outside during night **even more effectively** to reduce building temperature
2. Reduce window openings during summer day to **maximise benefit of thermal mass**

Contact Theatre, after renovation

Contact Theatre, Studio



Belvoir High School



BB101 Standards

120 hours for which T_{room}>28°C

$(T_{room})_{max}$ = **32°C**

$(T_{room} - T_{external})_{max}$ = **5°C**

Belvoir High School

0 hours for which T_{room}>28°C

$(T_{room})_{max}$ = **27.5°C**

$(T_{room} - T_{external})_{max}$ = **2.3°C**

Internal Comfort

Priority School Building Programme

Making sense of the new Priority School Output Specification from the Education Funding Agency. How is the output specification different from previous guidelines, how do the standard school designs meet the output specification and how Breathing Buildings can help you model the ventilation system energy use in IES.

Hybrid Designs

Summary

- Natural ventilation low energy
- Exposed thermal mass
- Fan driven ventilation not “free cooling”

Cutting edge natural ventilation of high-rise buildings in Japan

Hisashi Kotani

Dept. of Architectural Eng., Osaka University

Natural ventilation in Japan

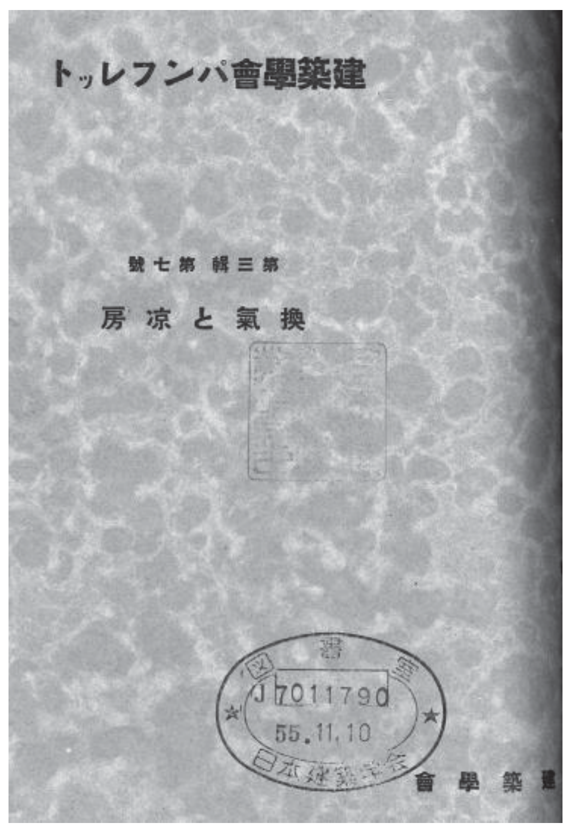
- Natural ventilation and cross-ventilation have been noticed as an important issue in Japan for long time because of its hot and humid climate in summer time.
- Researches on natural ventilation and cross-ventilation has been conducted in the early days in Japan.
- Architectural Institute of Japan (AIJ) was founded in 1886.

Natural ventilation in Japan

- **The first volume of AIJ Transactions, 1936,**
  - **2 papers for ventilation and cross-ventilation,**
  - **1 for acoustics**
  - **4 for daylight in the field of building environment**
- **Volume 5 of AIJ Transactions in the next year, 1937**
  - **3 papers for ventilation and cross-ventilation,**
  - **2 for moisture,**
  - **1 for thermal comfort**
  - **3 for acoustics**
  - **'ventilation path' and 'cross-ventilation' were titled in the papers in Volume 5.**

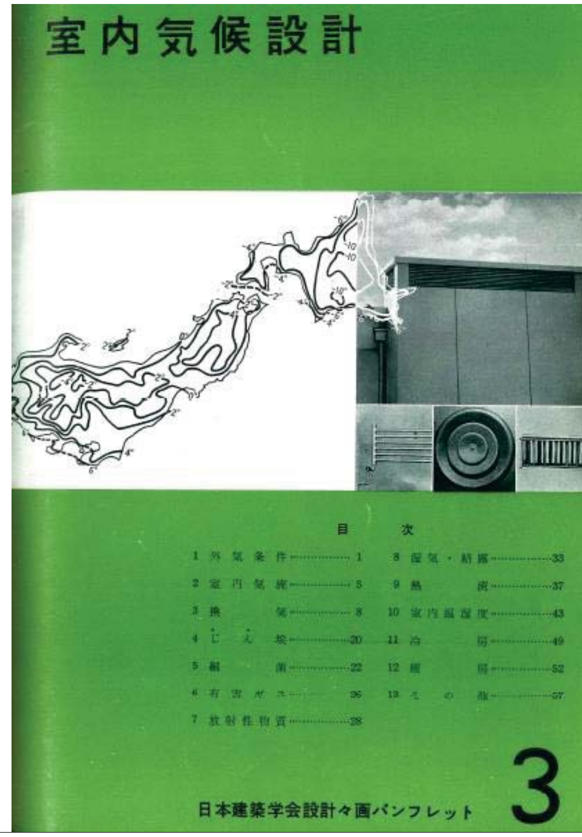
Natural and Cross ventilation research in Japan

- AIJ Pamphlet Vol.3, No.7 (1930)
  "Ventilation and cooling"
  exactly the same concept with "ventilative cooling" !!
- Main discussions are standard of ventilation rate and calculation theory.

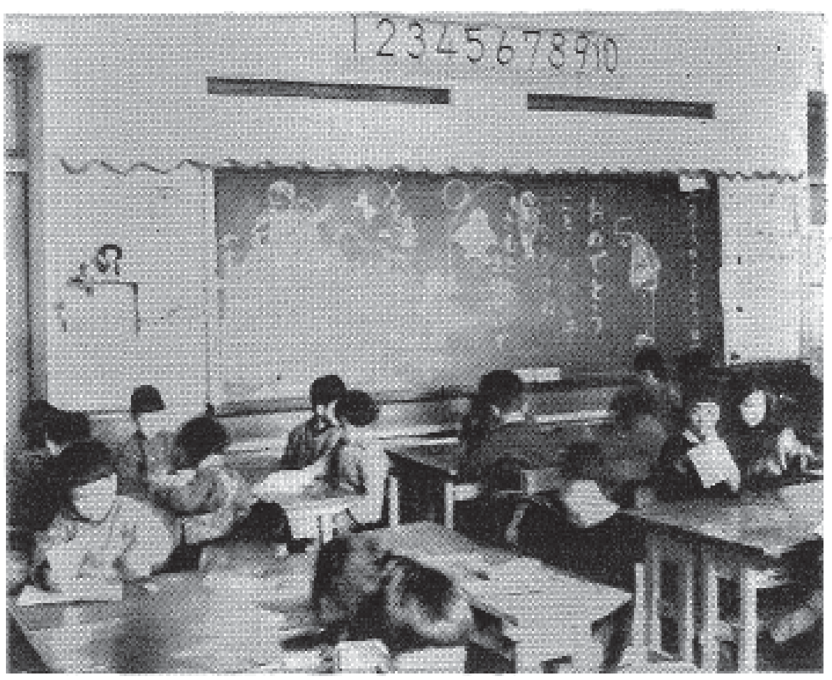


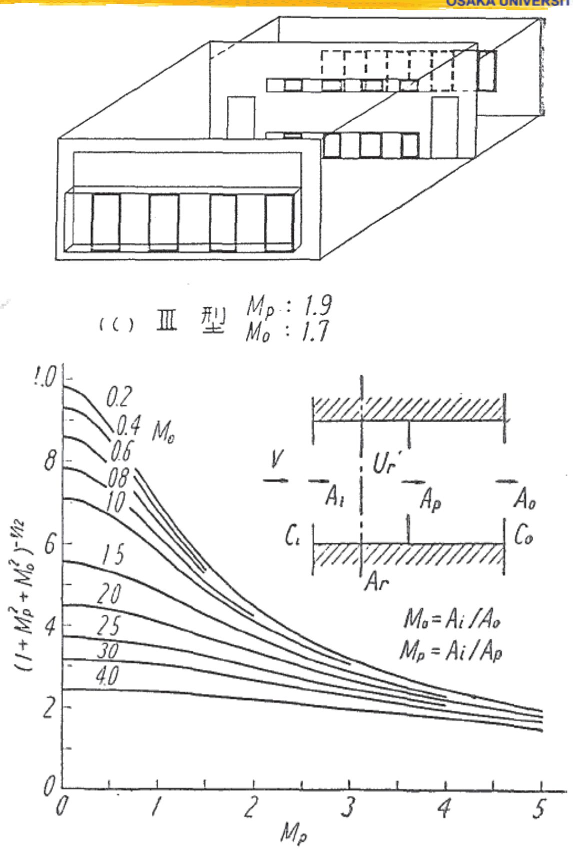
Natural and Cross ventilation research in Japan

- AIJ Design Planning Pamphlet Vol.3 （1957） “Indoor climate design”
- Cross-ventilation designs were discussed.



Natural and Cross ventilation research in Japan





Natural research in Japan

- ⌘Some results by Japanese researchers in the early days are useful even at the present days but almost all papers were written in Japanese unfortunately.

Brand-new book

- ⌘Published by Natural ventilation design WG, AIJ (Architectural Institute of Japan), 2013
- ⌘Focuses on non-residential buildings, company offices, public offices, school buildings…
- ⌘Now preparing to translate to English

Contents

Case studies sheets

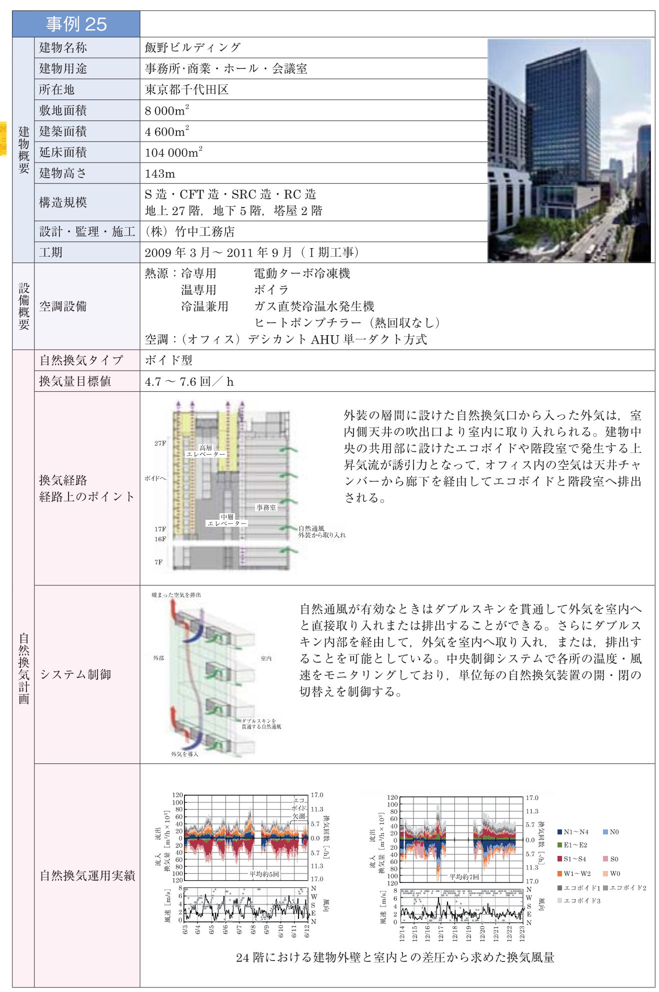
- Building outline
- Building service outline
- Natural ventilation design

  natural ventilation type

  main point of ventilation route

  system control method

  performance evaluation



事例 25		
建物概要	建物名称	飯野ビルディング
	建物用途	事務所·商業・ホール・会議室
	所在地	東京都千代田区
	敷地面積	8 000m²
	建築面積	4 600m²
	延床面積	104 000m²
	建物高さ	143m
	構造規模	S 造・CFT 造・SRC 造・RC 造 地上 27 階，地下 5 階，塔屋 2 階
	設計・監理・施工	（株）竹中工務店
	工期	2009 年 3 月～ 2011 年 9 月（Ⅰ期工事）
設備概要	空調設備	熱源：冷専用　電動ターボ冷凍機 温専用　ボイラ 冷温兼用　ガス直焚冷温水発生機 ヒートポンプチラー（熱回収なし） 空調：（オフィス）デシカント AHU 単一ダクト方式
自然換気計画	自然換気タイプ	ボイド型
	換気量目標値	4.7 ～ 7.6 回／ h
	換気経路 経路上のポイント	外装の層間に設けた自然換気口から入った外気は，室内側天井の吹出口より室内に取り入れられる。建物中央の共用部に設けたエコボイドや階段室で発生する上昇気流が誘引力となって，オフィス内の空気は天井チャンバーから廊下を経由してエコボイドと階段室へ排出される。
	システム制御	自然通風が有効なときはダブルスキンを貫通して外気を室内へと直接取り入れまたは排出することができる。さらにダブルスキン内部を経由して，外気を室内へ取り入れ，または，排出することを可能としている。中央制御システムで各所の温度・風速をモニタリングしており，単位毎の自然換気装置の開・閉の切替えを制御する。
	自然換気運用実績	24 階における建物外壁と室内との差圧から求めた換気風量

Case studies

事例 25		
建物概要	建物名称	飯野ビルディング
	建物用途	事務所·商業・ホール・会議室
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	敷地面積	8 000m^2
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	構造規模	S 造・CFT 造・SRC 造・RC 造 地上 27 階，地下 5 階，塔屋 2 階
	設計・監理・施工	（株）竹中工務店
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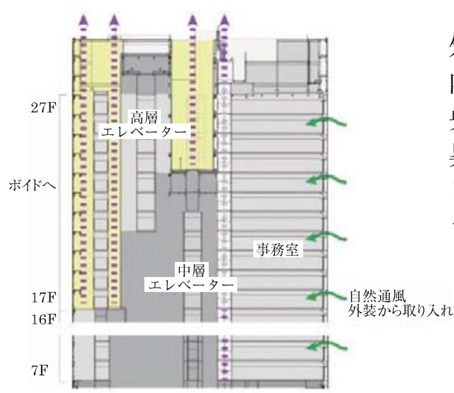
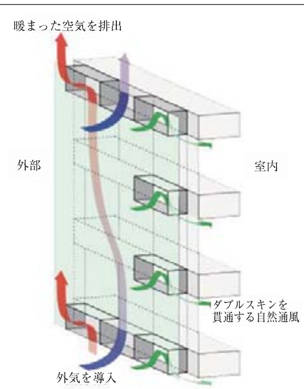
自然換気計画	自然換気タイプ	ボイド型
	換気量目標値	4.7 ～ 7.6 回／ h
	換気経路 経路上のポイント	 外装の層間に設けた自然換気口から入った外気は，室内側天井の吹出口より室内に取り入れられる。建物中央の共用部に設けたエコボイドや階段室で発生する上昇気流が誘引力となって，オフィス内の空気は天井チャンバーから廊下を経由してエコボイドと階段室へ排出される。
	システム制御	 自然通風が有効なときはダブルスキンを貫通して外気を室内へと直接取り入れまたは排出することができる。さらにダブルスキン内部を経由して，外気を室内へ取り入れ，または，排出することを可能としている。中央制御システムで各所の温度・風速をモニタリングしており，単位毎の自然換気装置の開・閉の切替えを制御する。

Two cases

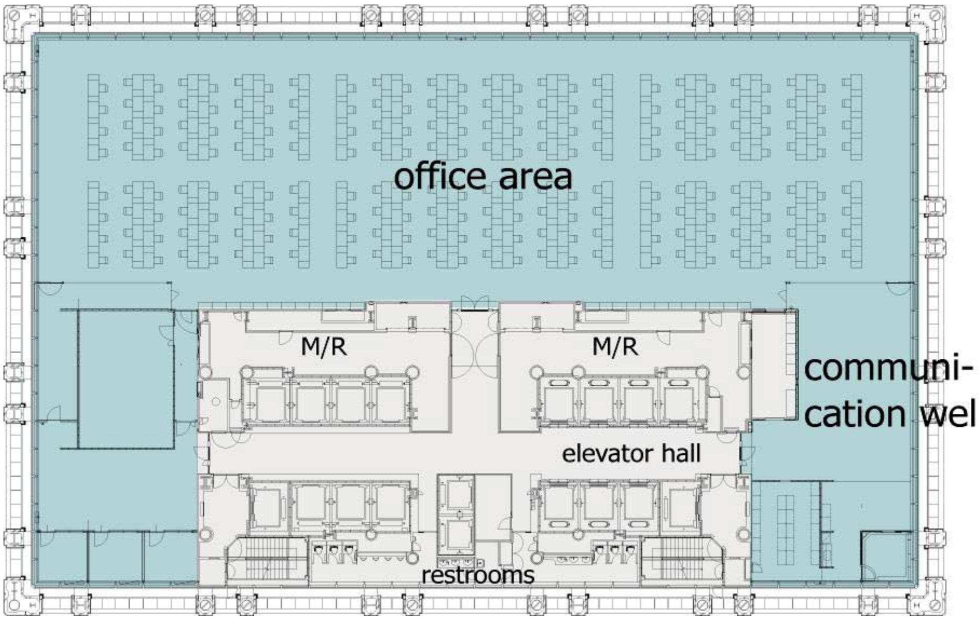
High-rise office buildings using natural ventilation system

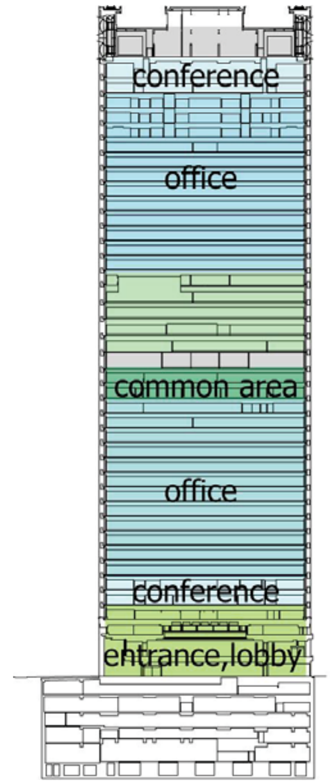
CASE 1: Building outline

- Location : Osaka, Japan
- 41-storied (GL+195m) high-rise office building
- 106,000m^2 in total floor
- Dec. 2004 completed

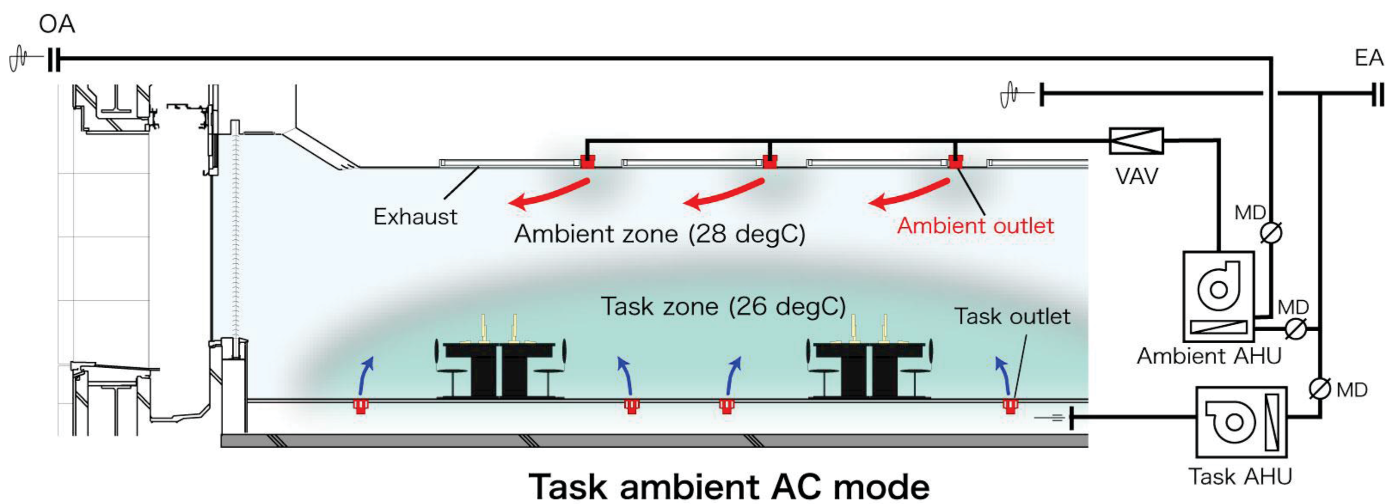
Building outline

⌘57.6m x 36m in each floor





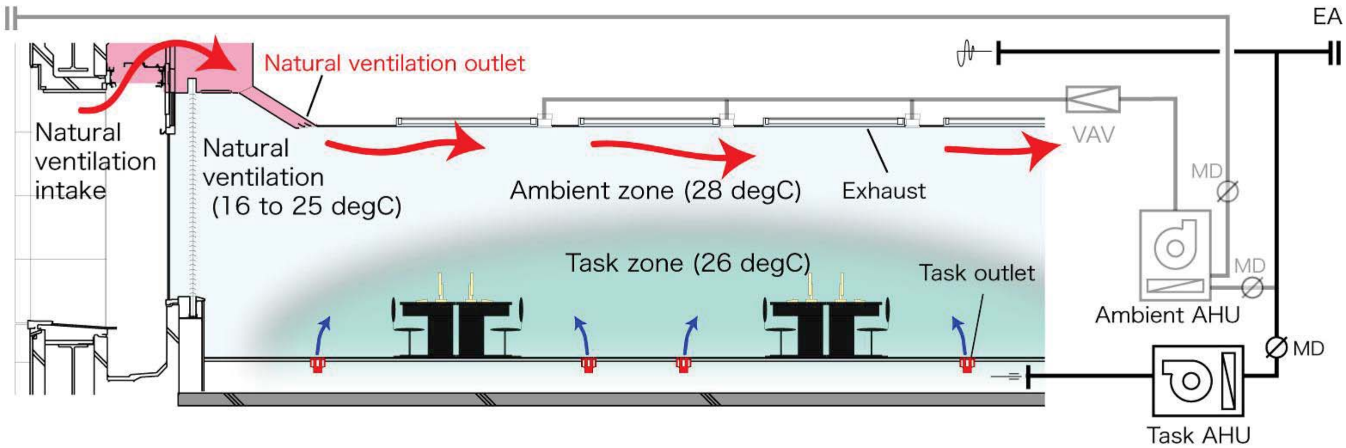
System outline : Task ambient AC mode



⌘In summer time, task and ambient zone is achieved by under floor air supply (for task zone) and ceiling outlet (for ambient zone)

System outline : Natural ventilation mode

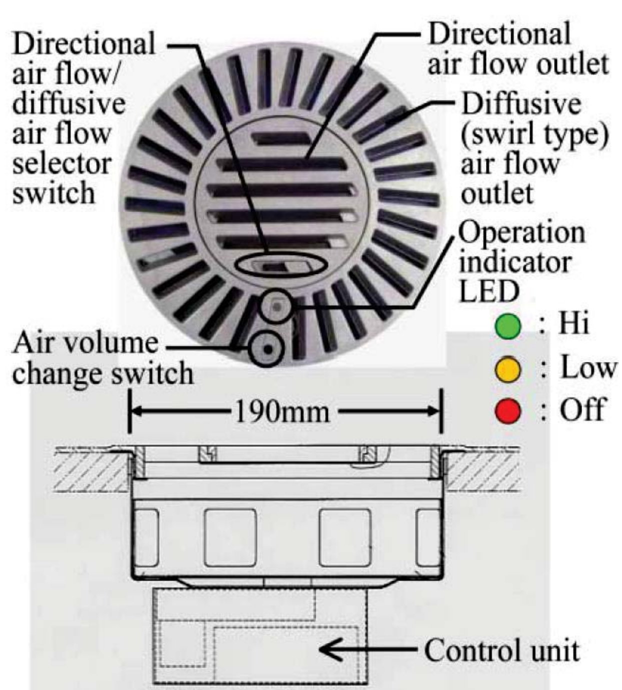
Natural ventilation mode (Spring and fall)



- Spring and Fall, ambient zone is naturally ventilated if possible (conditions are pressure difference, outside air temperature, humidity and enthalpy).

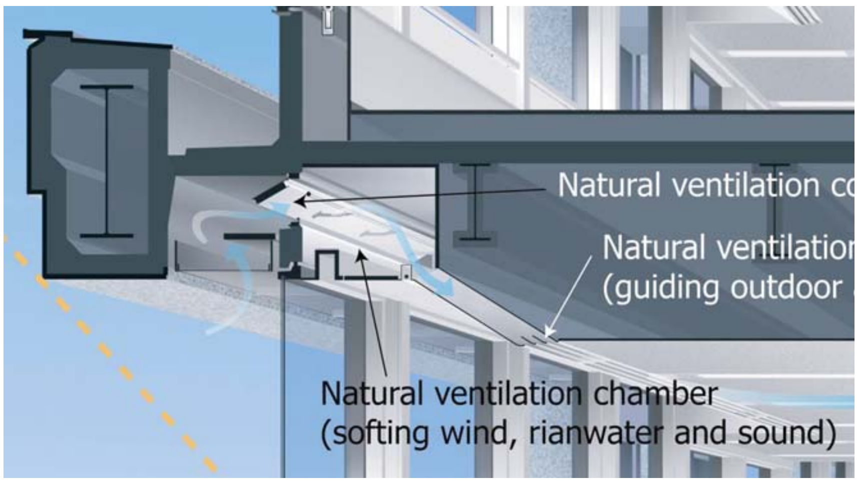
System outline : Selective task flow

- Occupants can select 'directional' or 'diffusive' airflow and flow rate of task outlets.



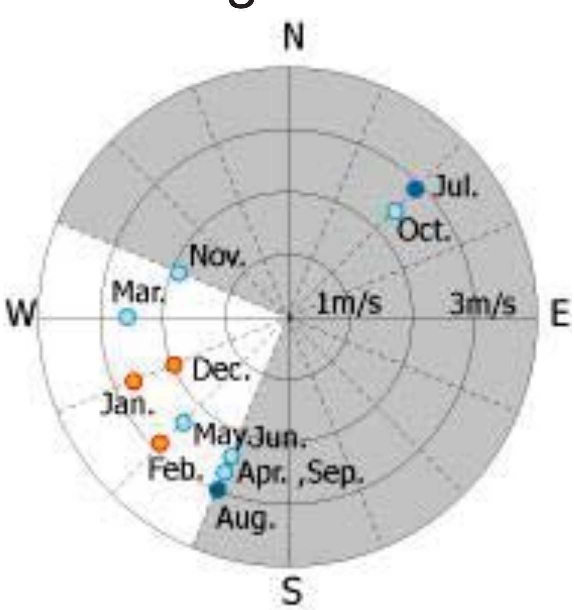
System outline : Natural ventilation outlet

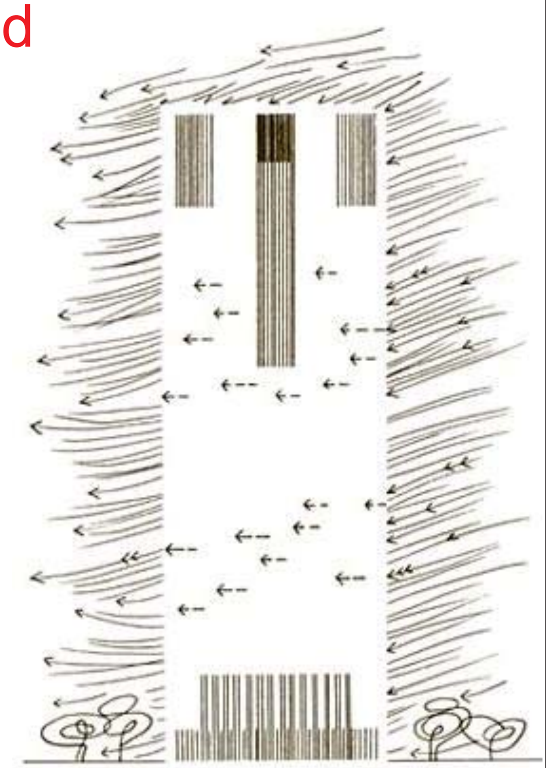
- Air outlets surround office room.
- Shape of air outlets are well-designed to guide the air to interior by Coanda effect.



System outline : Natural ventilation concept

- Challenge to use Wind-induced natural ventilation in high-rise office building.





Controlling system

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1.Natural ventilation system begins working when:

1)Indoor-outdoor pressure difference 50 Pa or less
2) Outside air temperature: 18ºC or more
3) Outside air humidity: 90% or less
4) Outside air enthalpy: Less than indoor enthalpy
5) Room temperature:
−2℃≦ Preset temperature ＜+1 ºC： Partly open
+1℃≦ Preset temperature ＜+3 ºC： Fully open

2.Task/ambient air-conditioning system control system

1)Task air-conditioning:
Constant supply air temperature and static pressure control

2)Ambient air-conditioning:
VAV control to constant indoor temperature

9 years ago: Natural ventilation performance in a week

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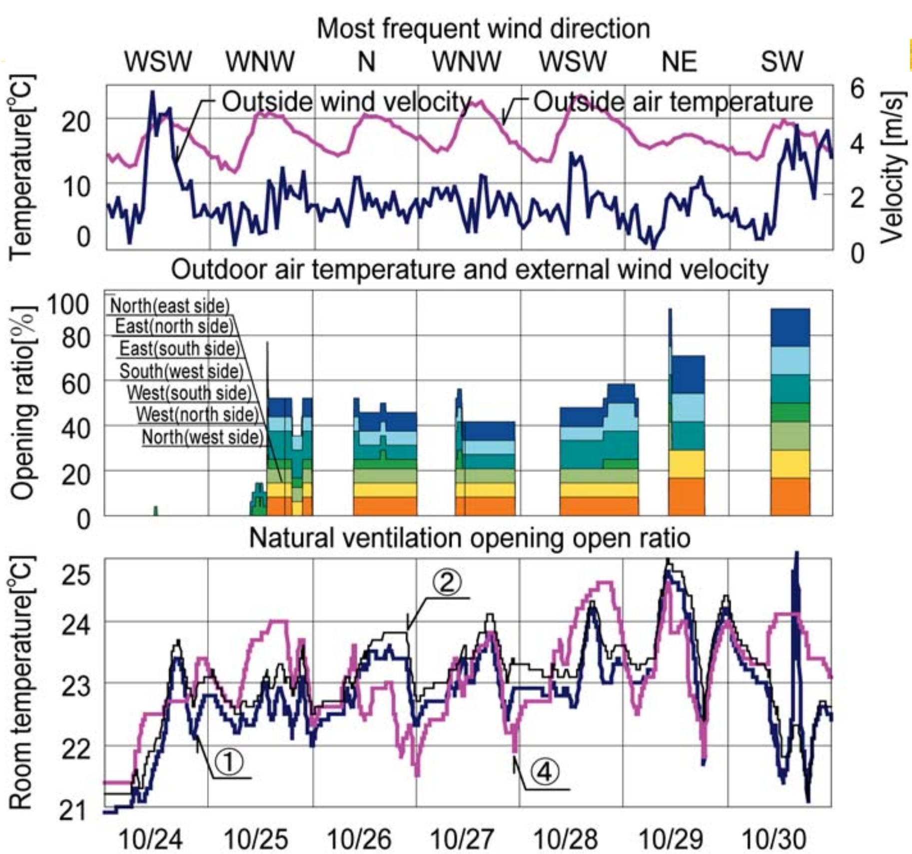
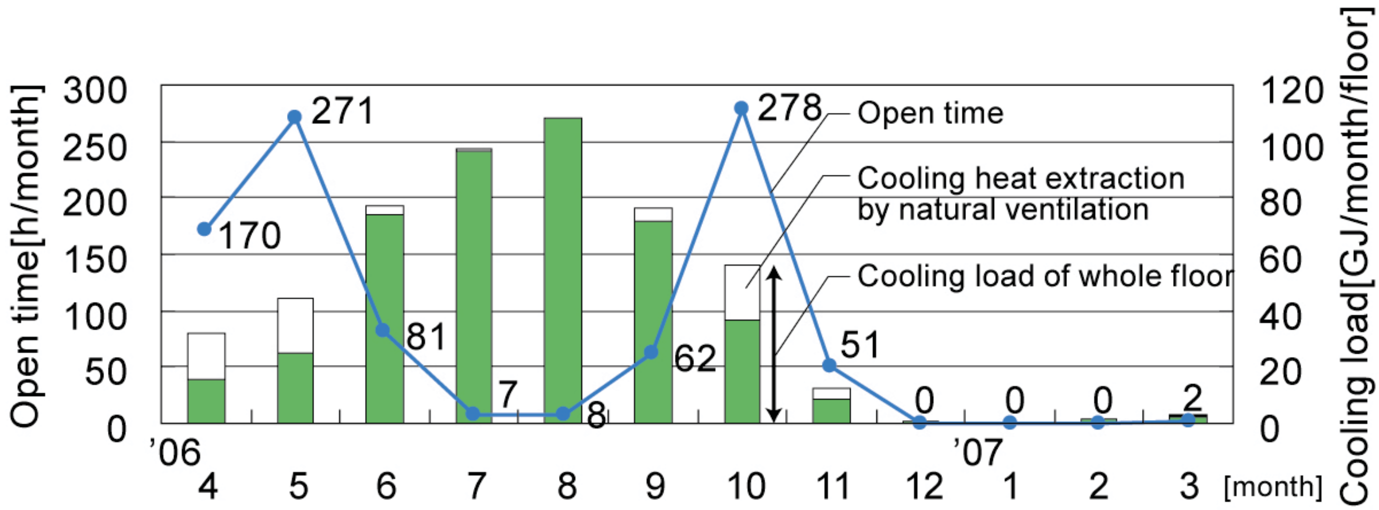


Indoor temperature
(Natural ventilation was available only on 30th.)

About 50% of natural ventilation openings were opened.

Temperature difference between the east ① and the west ② was 0.2℃ on an average.

9 years ago: Natural ventilation performance in a year

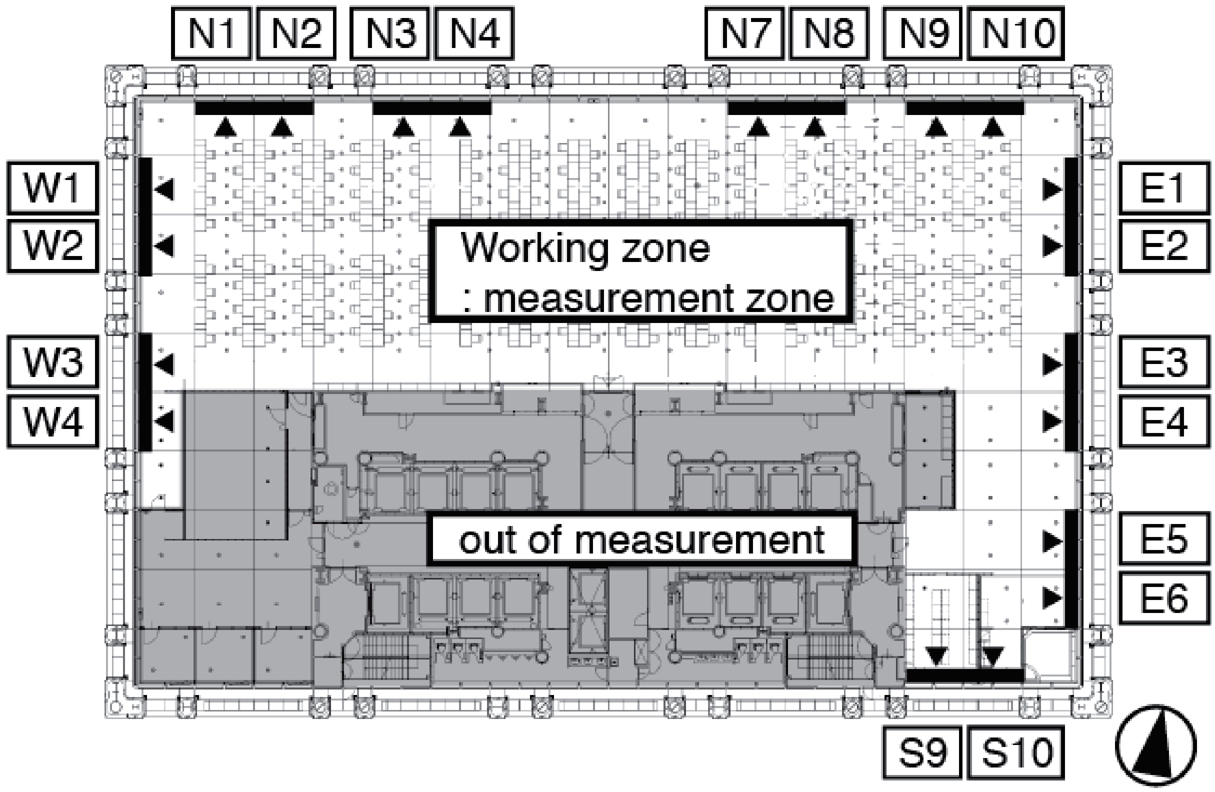


The annual open time was 918 hours.
Natural ventilation could reduce cooling load on a typical floor by 13.3%.

9 years ago in the planning stage

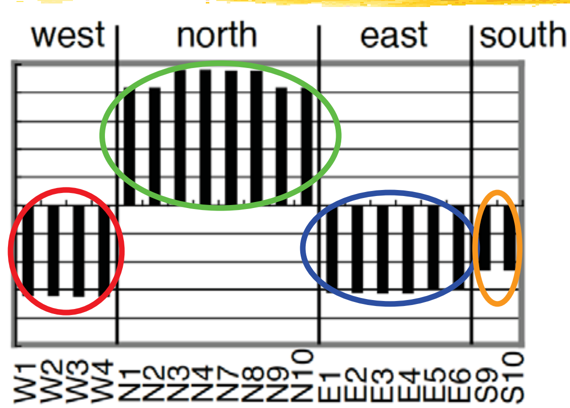
- **Calculation** of natural ventilation rate for 16 wind directions using wind pressure coefficient obtained by wind tunnel tests.
- **Measurement** of natural ventilation rate in the real building.
- **CFD analysis** using measured ventilation rates as boundary conditions.

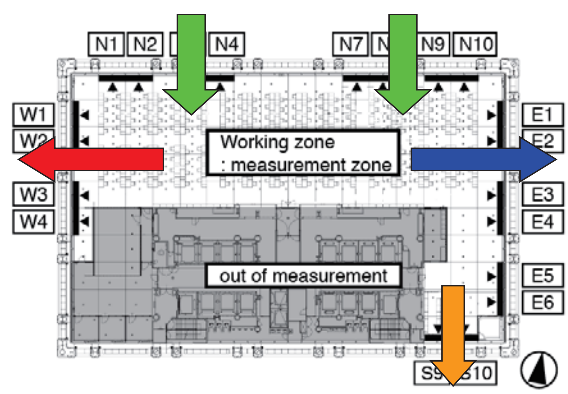
Natural ventilation openings



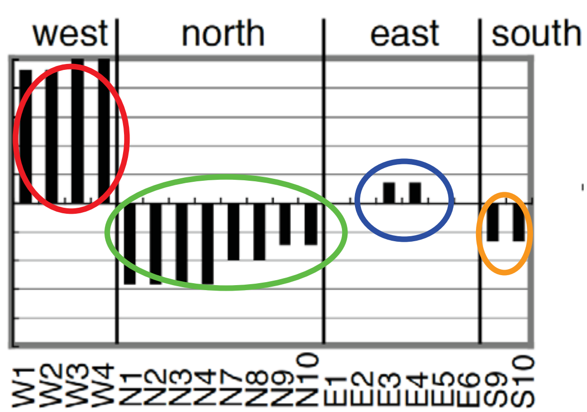
Calculation results

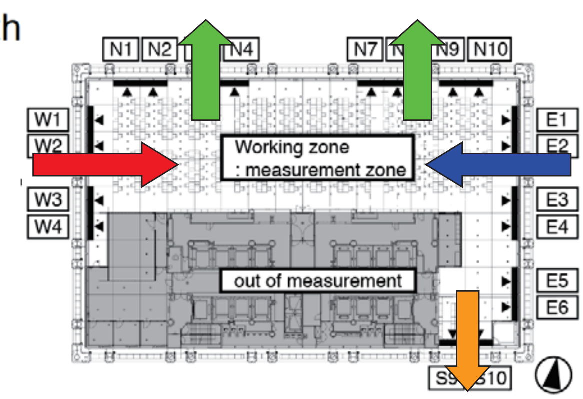
North wind



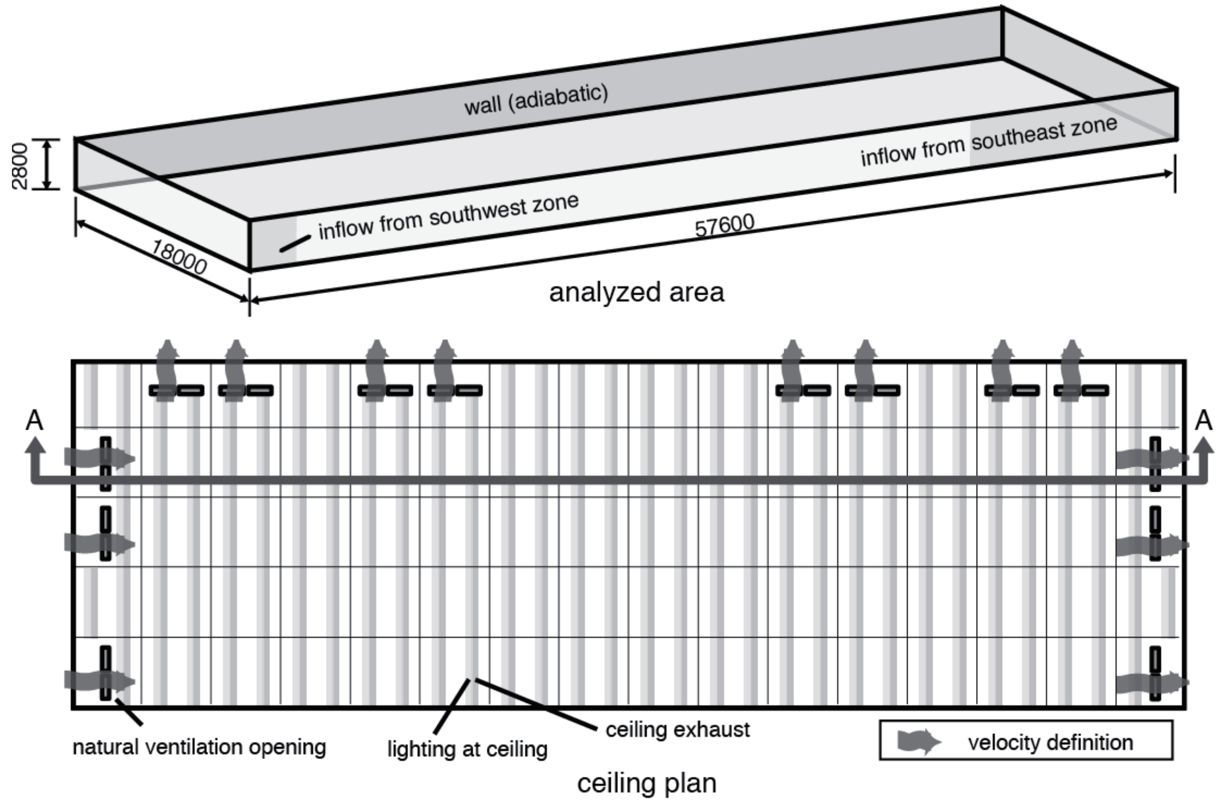


West wind

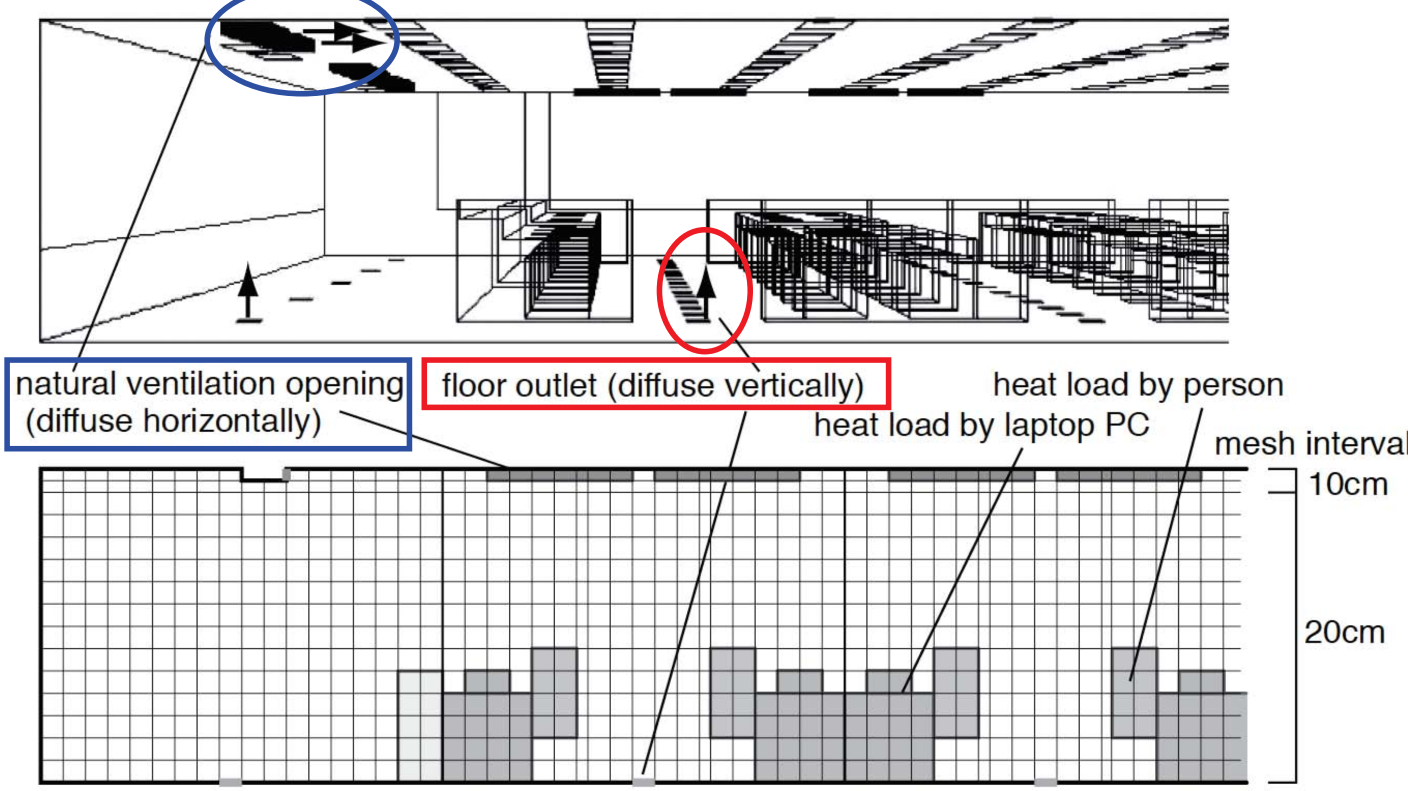




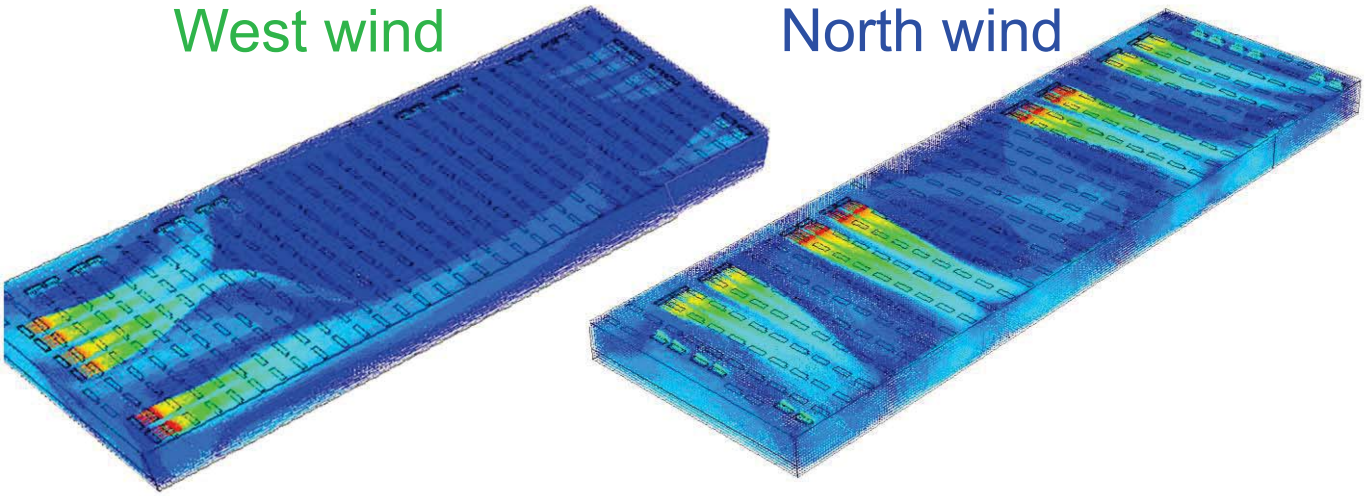
CFD Analysis using measured data



CFD Analysis using measured data

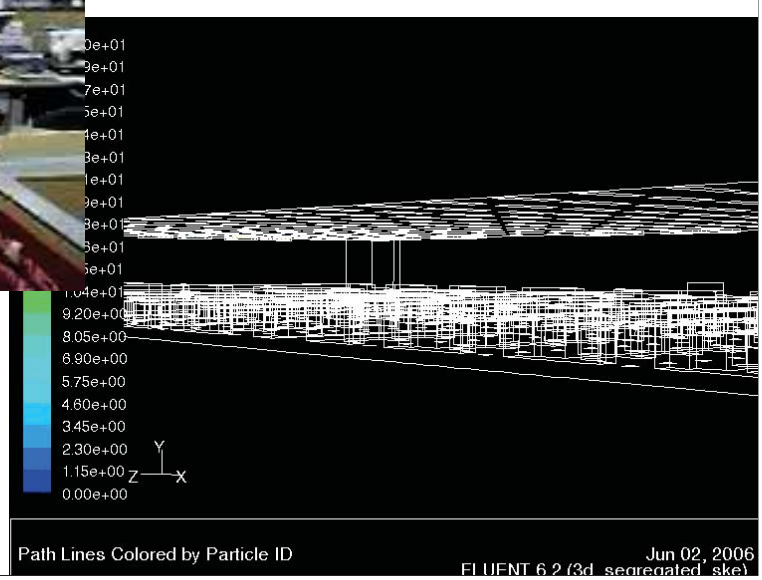


CFD Results : Wind velocities along the ceiling

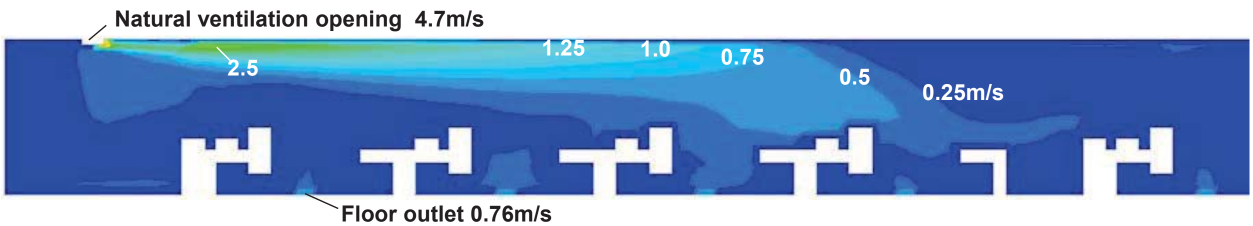


- West wind: Supplying air flows from west-side openings to north-side along the ceiling , a part of flow cannot reaches the interior zone.
- North wind: Well supplied to the whole room.

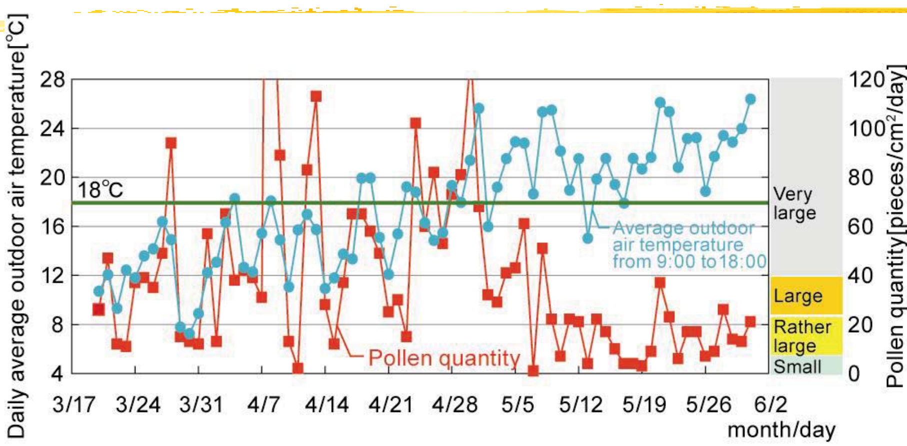
Flow visualization vs CFD analysis



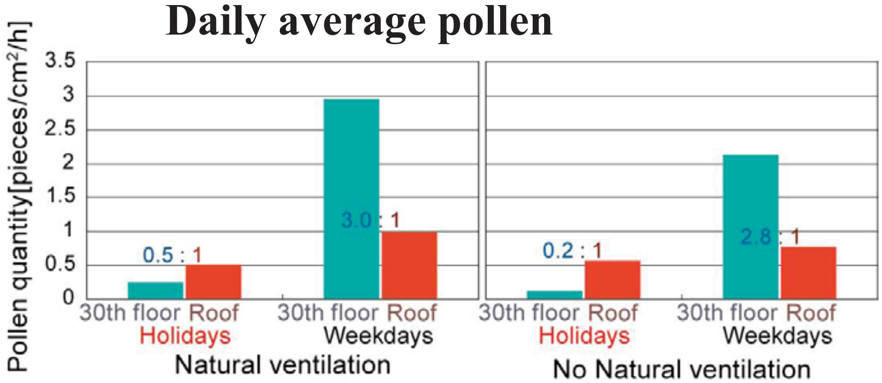
Flow visualization vs CFD analysis



Pollen measurement



Daily average pollen

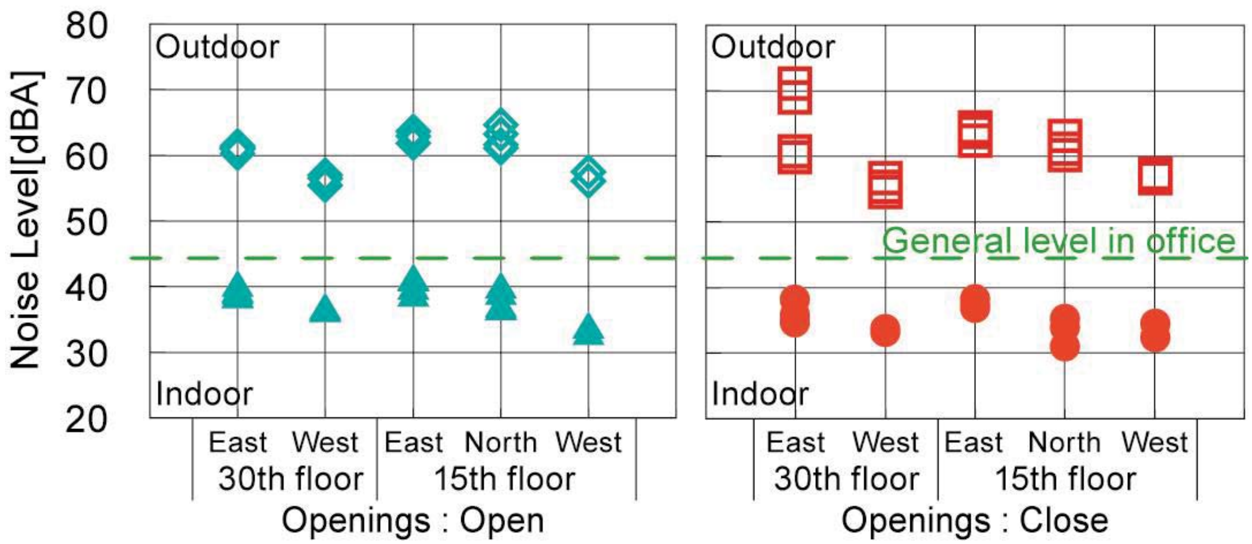


Pollen on Holidays and weekdays

- **Pollen increases in the half of April.**
- **Pollen carried by people is larger than those coming trough natural ventilation openings.**

Noise level measurement

-Natural ventilation openings can reduce noise level by 20dB(A) when opened, and 25dB(A) when closed.
-Noise entering from the outside does not spoil working conditions.



remarks

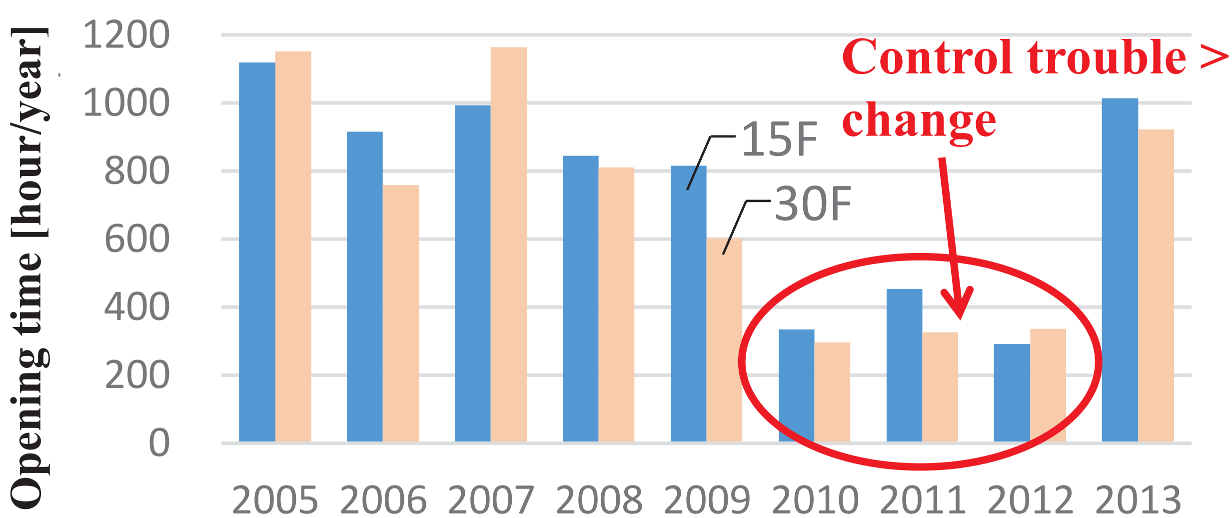
- Wind-induced natural ventilation in high-rise office building was achieved.
- Characteristics of supplying the fresh air from natural ventilation opening depends on the wind direction.
- CFD analysis for natural ventilated room using measured data or calculated flow rate by wind pressure coefficient is useful.
- Some measurements are conducted concerning the estimating problem when used NV system but it has no problem.

more..

- More interesting measurements and analyses have already conducted.
  - Long-term measurement of natural ventilation by pressure differences, we can use the "big data" of BEMS.
  - Mean age of air for task ambient AC mode and natural ventilation mode.
  - Domination or contribution ratio of each outlets (task, ambient and natural ventilation opening).
  - Modeling of outlets in CFD to improve the accuracy.

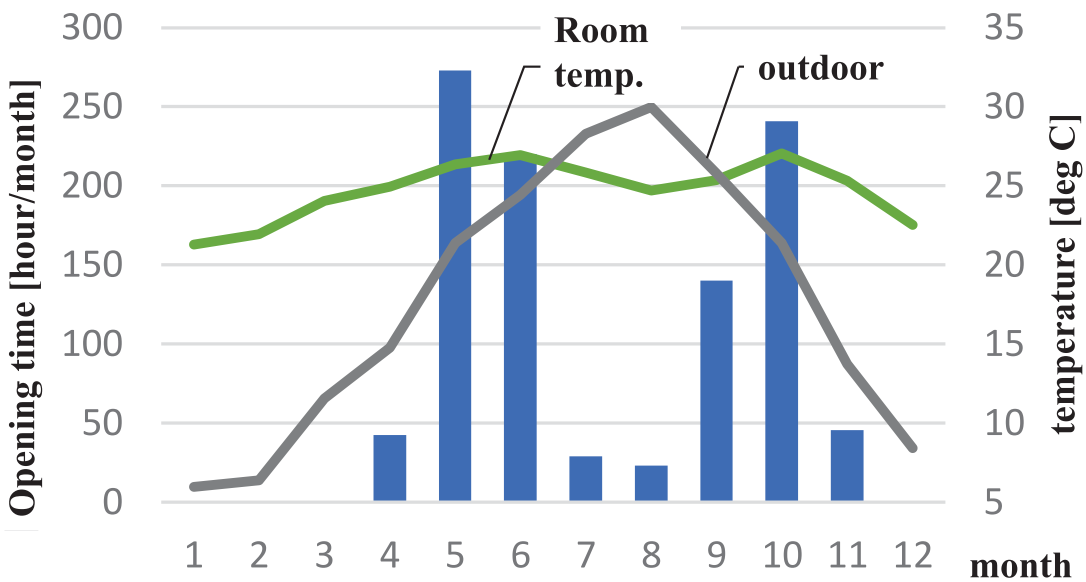
Now, 9 years after…

- It still works well.
- Social demand for saving electricity is very strong after earthquake and nuclear accident 2011.



Now, 9 years after…

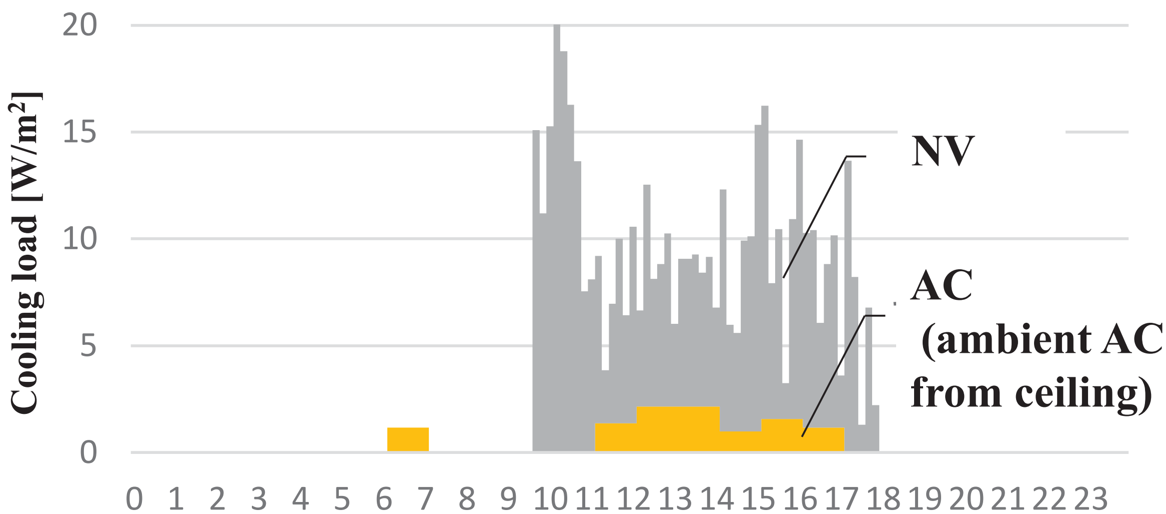
⌘Night purge by natural ventilation also works in the night of summer time.



Now, 9 years after…

⌘Not exactly NV but hybrid ventilation system.

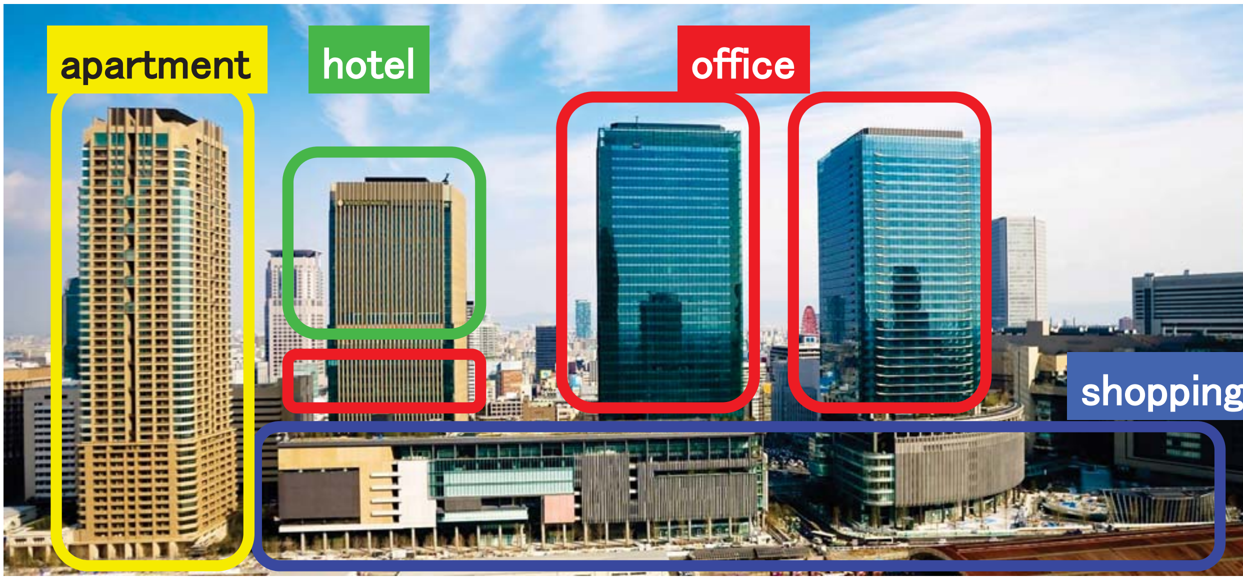
⌘Most of the cooling load is removed by natural ventilation.



Daily change of cooling load (one day in October, 2013)

CASE 2: Building outline

- Location : Osaka, Japan
- 4 buildings, 600,000m^2 in total floor
- Feb. 2013 completed, brand-new bldg.



CASE 2: Building outline

- Many sustainable technologies are used.
- Different types of natural ventilation.
- Original naming and send messages and visualization of technologies to the people.

wind-induced "sky slit"	buoyancy-induced "center void"	buoyancy-induced "corner void"	wind-induced "air intake"

CASE 2: Building outline named "air intake"

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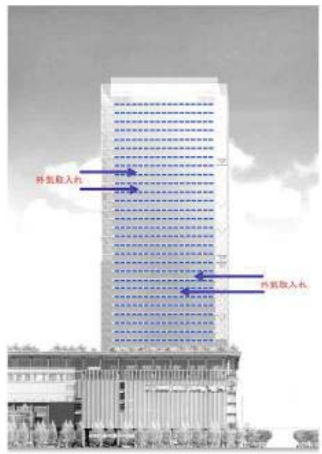

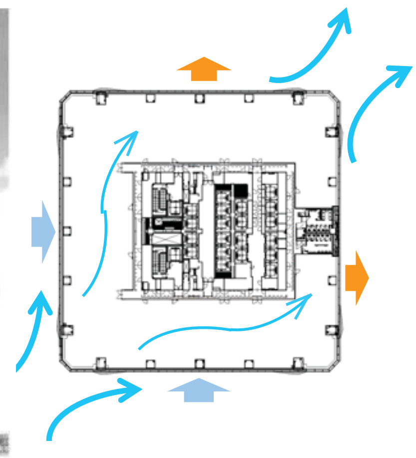

CASE 2: Building outline named "corner void"

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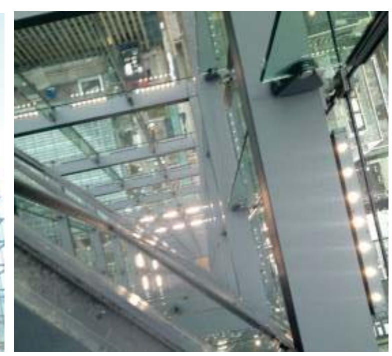

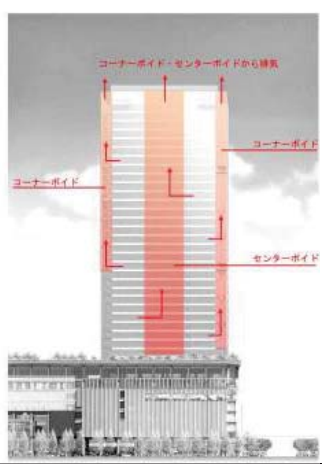

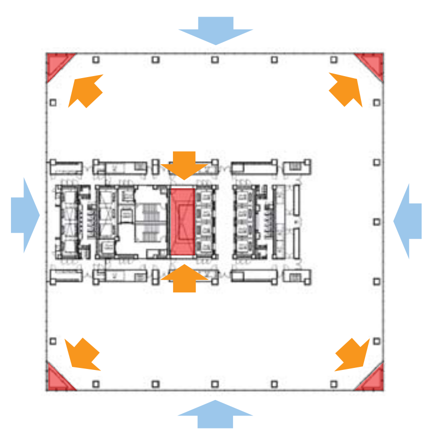

CASE 2: Building outline

CASE 2: "corner void" type

- **Occupants can select to use NV or not.**
  - **if YES, move to Full NV mode (NV)**
  - **If NO, move to three mode depending on control conditions.**
    - **Hybrid mode (HV)**
    - **Directly cooling by outdoor air (OA)**
    - **Full AC mode (AC)**

	NV	HV	OA
Outdoor temp.	10 – 20 degC Select by occupants	Over 18 deg C	10 – 24 degC
Outdoor RH	Under 90 %RH		Under 90 %RH Over 7.8 deg C in Dew temp
Outdoor air velocity	Under 15m/s (controlled by pressure differences)		
enthalpy	Outdoor < Indoor		

3 way moving device for NV opening

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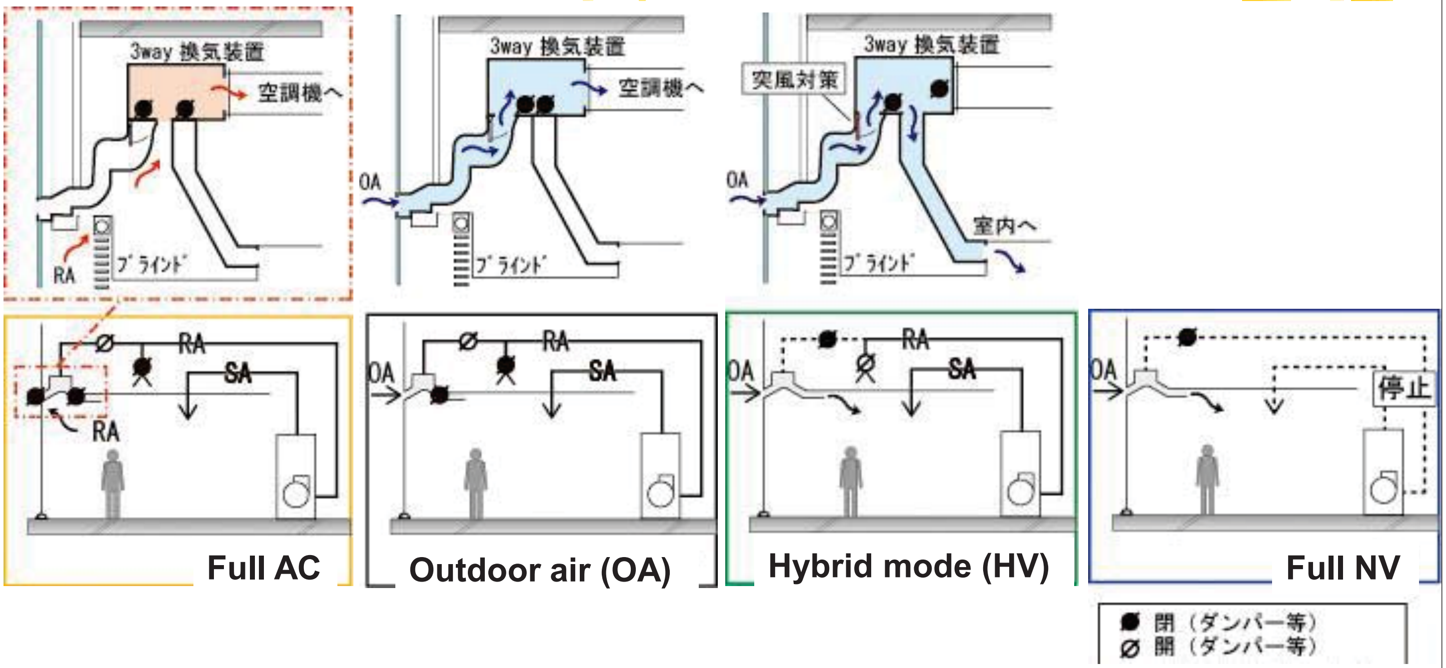
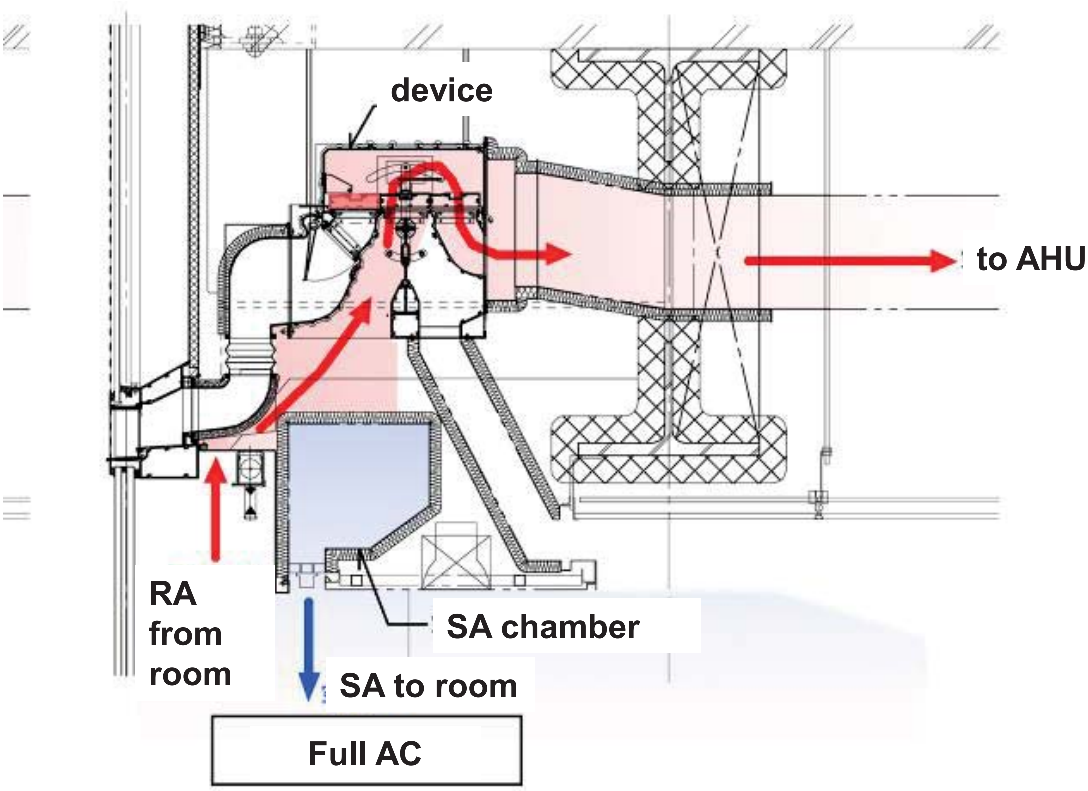
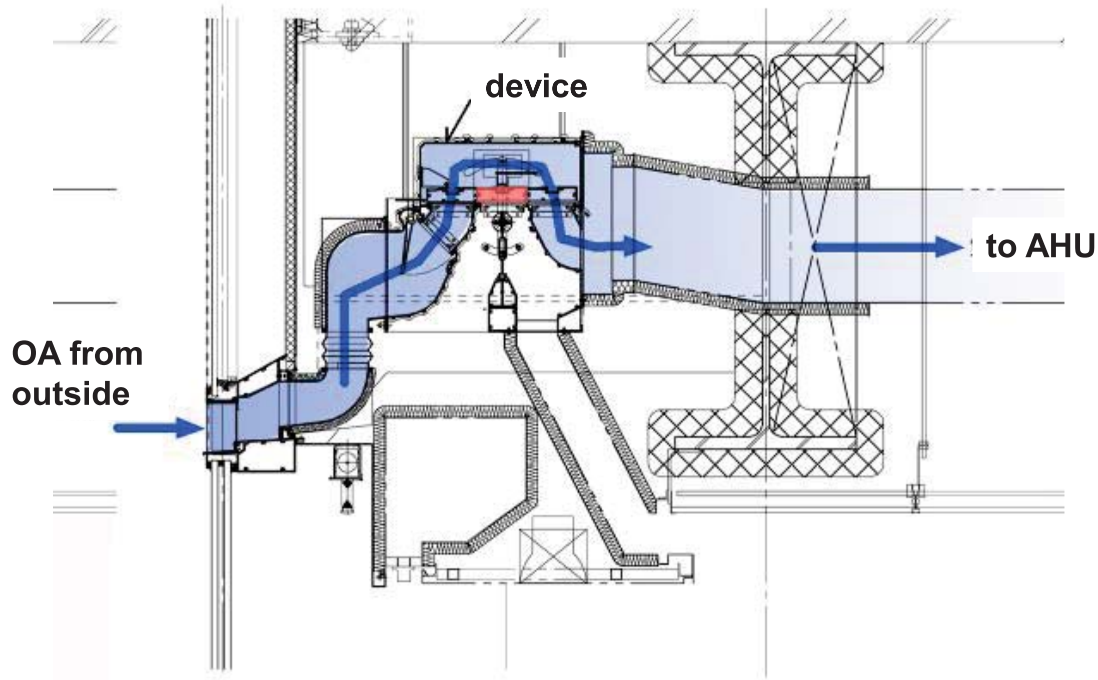


3 way moving device for NV opening

OSAKA UNIVERSITY

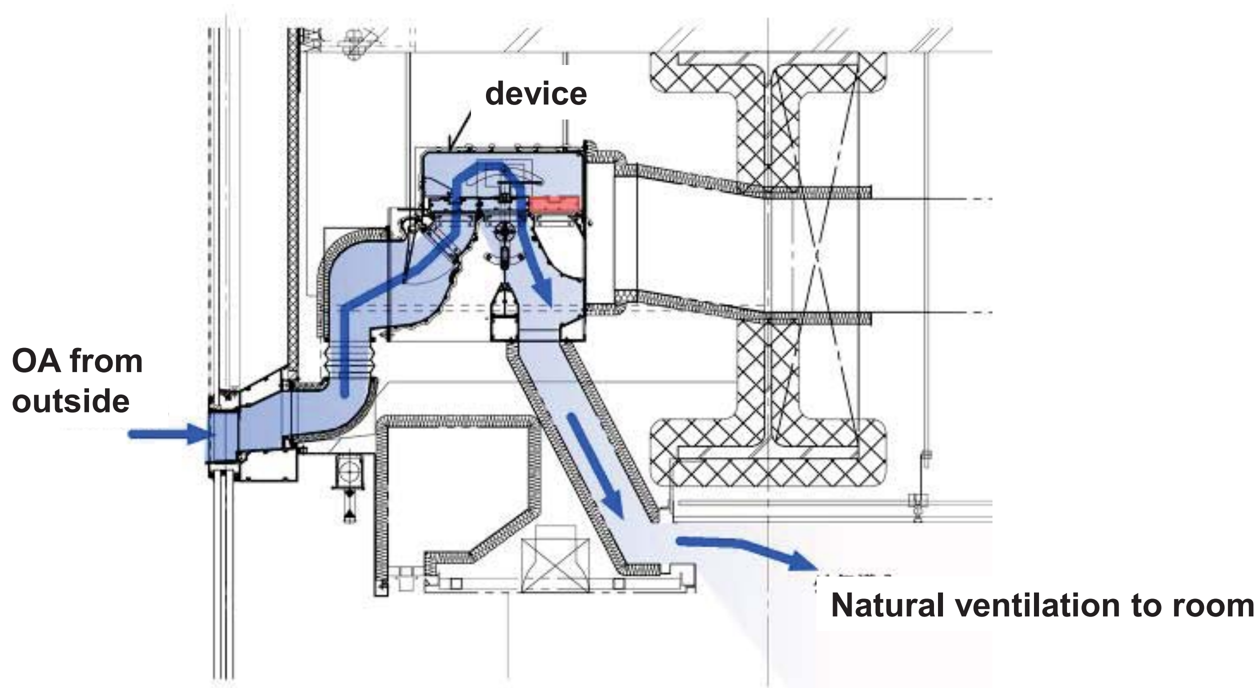


3 way moving device for NV opening



Outdoor air mode (OA)

3 way moving device for NV opening



Hybrid (HV) and Natural ventilation (NV) mode

Measurements and calculations.

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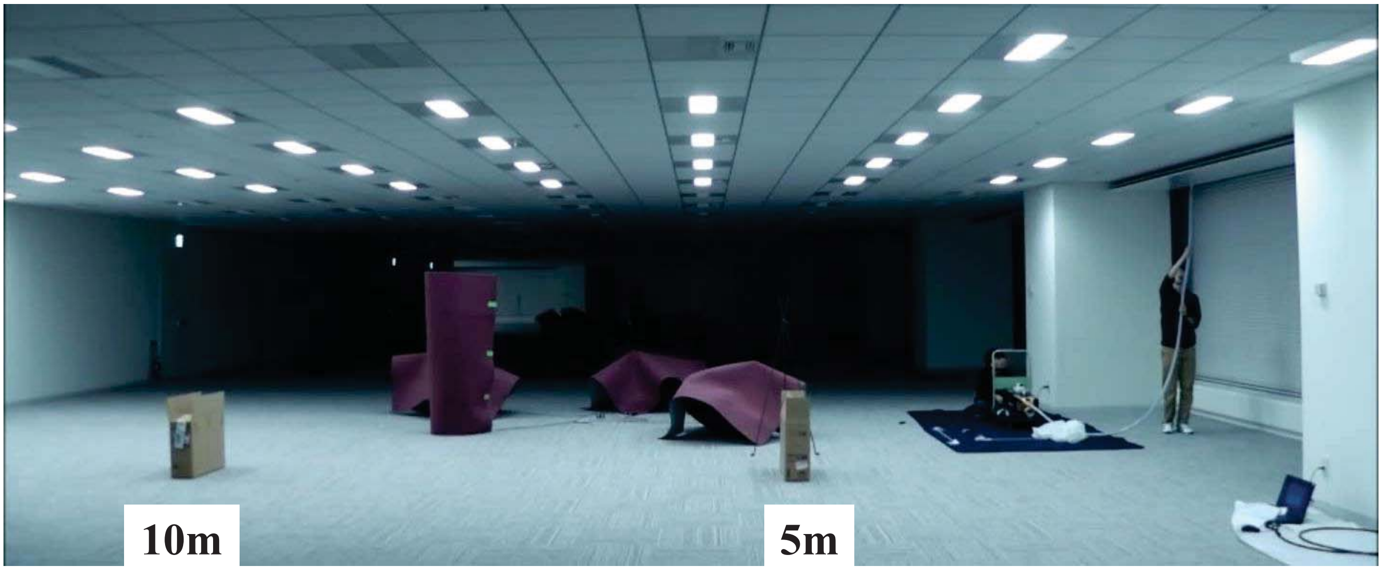

Annex 62 pilot buildings (2012, Tokyo)

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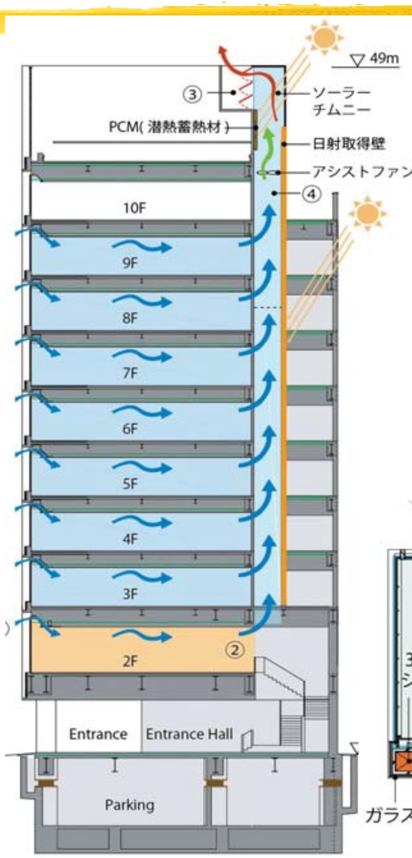
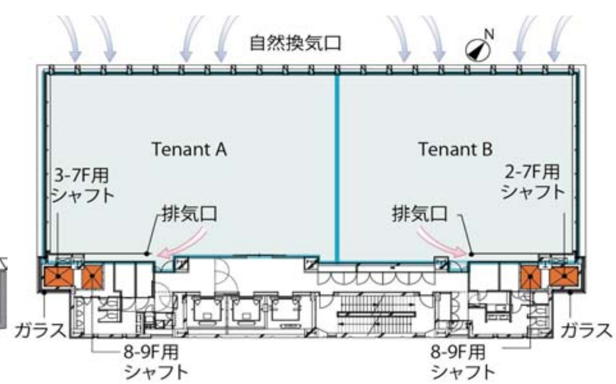
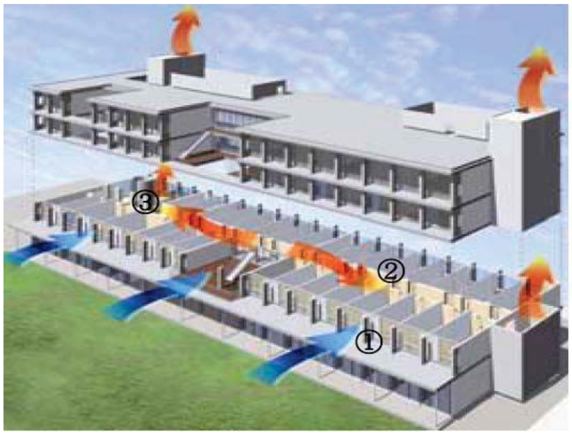
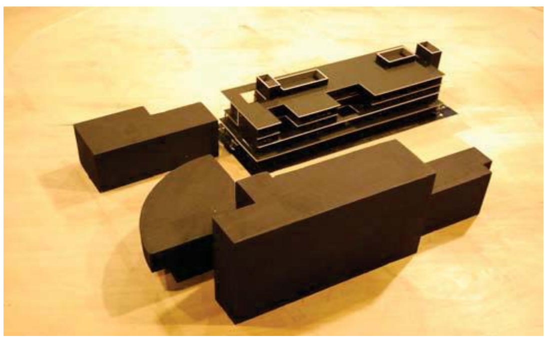
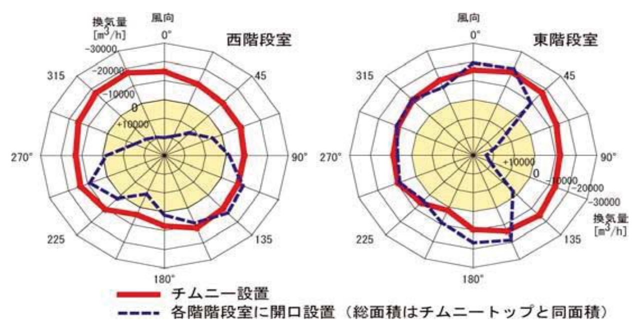




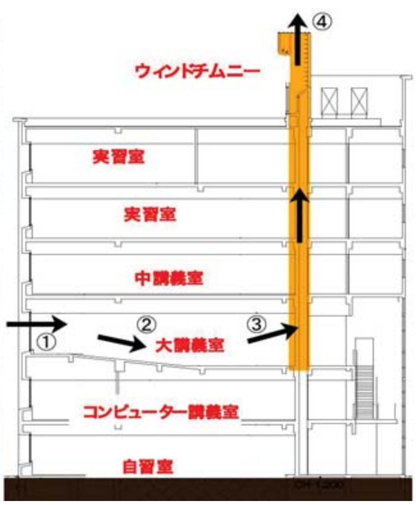
A college building (2008, Kagawa), using staircases

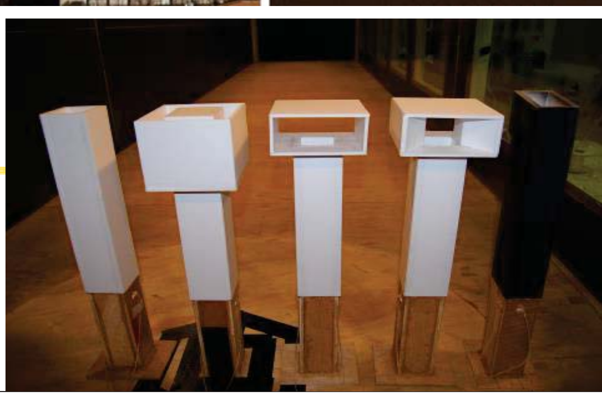


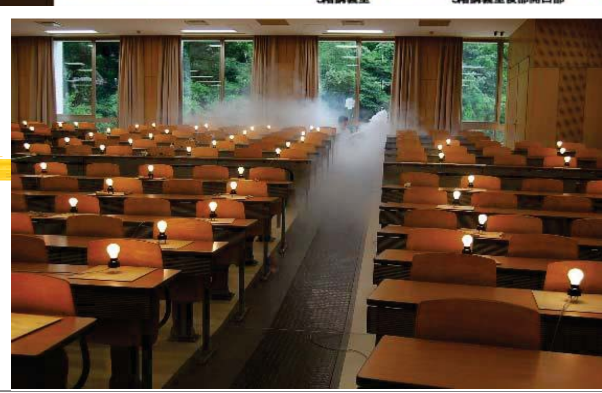




College building (2008, Kobe), shape of the chimney







remarks

- We have many interesting buildings in Japan.
- Natural ventilation and hybrid ventilation technologies are developed in these 10 years.
- Calculation in the design stage is enuogh.
- Simple long-term performance evaluation (commissioning) is needed.
- The measurement of ventilation rate (long-term, simple, toughness..) is still the problem.