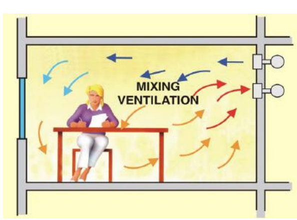
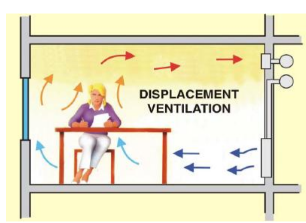
DTU

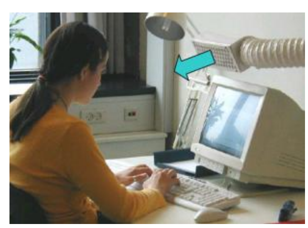
IEA EBC Annex 87 - Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems

Professor Bjarne W. Olesen, Ph.D., Dr.h.c., R.1.
Inlernational Centre for Indoor Environment and Energy
DTU.SUSTAIN
Technical University of Denmark

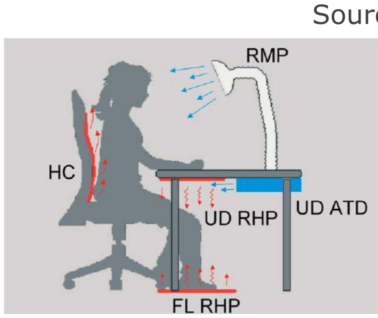
DTU



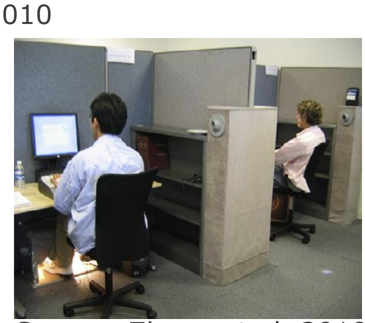




Source: Melikov 2010



Source: Watanabe et al. 2010



Source: Zhang et al. 2010

Introduction

- IEA EBC Annex 87 - Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems
- https://www.iea-ebc.org/projects/project?AnnexID=87
- https://annex87.iea-ebc.org/
- Initial idea in 2020
- Initial presentation to IEA EBC ExCo in June 2021
- Approved by IEA EBC ExCo in November 2021
- 1+3+1 = 5 year project
- 2.5 year left

Why PECS?

- Has several benefits compared to ambient (total volume) conditioning systems
  - Improved comfort, health and productivity
  - Higher satisfaction with the indoor environment, due to
    - Improvements in the immediate indoor environment experienced by the occupants
    - Possibility of personalized control
  - Potential energy savings
  - Increasing focus on individual differences between people → PECS can address these individual differences
  - Even more relevant due to COVID-19 (pandemic-proofing)

Why PECS?

- Not entirely new – significant amount of research exists
- Despite the proven benefits
  - –No design guide or manual for such systems and their integration in building HVAC systems
  - –Far from ”solved”, still several issues to be addressed
  - –Not at the level of a common solution in buildings
  - –Very limited ”real world” and commercial examples

Objectives and scope

- **The objective of the annex**
  - –To establish design criteria and operation guidelines for PECS
  - –To quantify the benefits regarding health, comfort and energy performance
  - –Including control concepts and guidelines for operating PECS in spaces with general ambient systems for heating, cooling, ventilation, and lighting

Objectives and scope

- **The scope of the present annex** includes
  - All types of PECS for local heating, cooling, ventilation, air cleaning, lighting, and acoustics
  - Desktop systems, which are mounted on desks or integrated in a furniture, chairs with heating/cooling and ventilation and other types
  - Wearables, where heating, cooling, and ventilation are included in garments or devices attached to occupants' body

Main activities

- Subtask A: Fundamentals
- Subtask B: Applications and technologies
- Subtask C: Control, operation and system integration
- Subtask D: IEQ and Energy Performance evaluation
- Subtask E: Policy and marketing actions

Intended outputs

- Guidebook on requirements for PECS (Subtask A)
- State-of-the-art report on PECS (Subtask B)
- Guidebook on PECS design, operation and implementation in buildings (including integration of PECS with ambient conditioning systems) (Subtasks C & E)
- Report on test methods for performance evaluation of PECS (Subtask D)
- Universal criteria about requirements, characteristics, and performance of PECS to be used in national and international standards (Subtask E)

Table L.1 — Example criteria for personalized systems

- 10:30 | Welcome & Introduction, *Bjarne W. Olesen (ICIEE/DTU, Denmark)*
- 10:40 | Field experiences with PECS in The Netherlands, *Marije te Kulve (bba binnenmilieu, the Netherlands)*
- 10:55 | Performance of Personalized Ventilation installed in Open-Plan Offices, *Arsen Krikor Melikov (DTU, Denmark)*
- 11:10 | Questions and answers
- 11:20 | The PECS journey in Singapore – From Field Environmental Chamber studies to Field studies, *Chandra Sekhar (NUS, Singapore)*
- 11:35 | Utilization and Evaluation of PECS in a Research Facility Office in Japan, *Shin-Ichi Tanabe (Waseda University, Japan)*
- 11:50 | Questions and answers
- 12:00 | End of the webinar

bba
building health & comfort
binnenmilieu

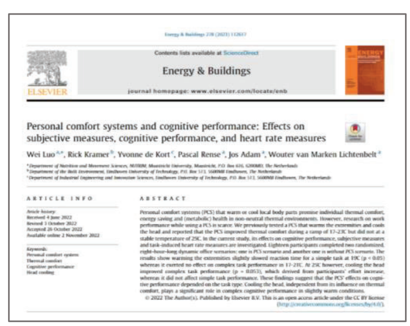
Field experiences with PECS in The Netherlands

AIVC Webinar
5 December 2024

dr. ir. Marije te Kulve (bba binnenmilieu)
prof. dr. ir. Atze Boerstra (bba & TU Delft)

Supposed advantages of microclimate control

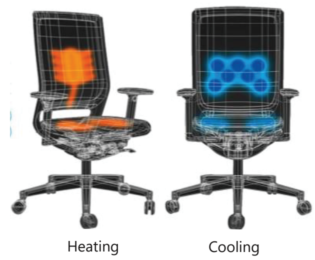
Responding better to individual differences in comfort experience (also in open office environments)
Reduce the risk of mutual transmission of infectious diseases (COVID, influenza, etc.) through the air (provided microclimate control with ventilation function)
Reduce overall energy consumption (if combined with adjustment of setpoints ambient temperature)
Increase productivity*



** Research by Maastricht University and Eindhoven University of Technology shows that the use of micro-climate control helps to improve performance; especially if the environment is a bit warmer (around 25°) (Lou et al, 2023)*

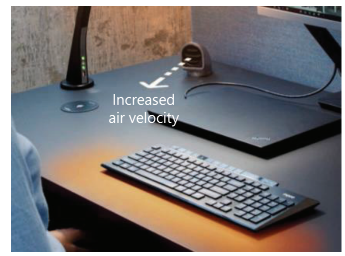
Ready-to-use products office market

- Klimastuhl Kloeber
  (developed with TU Kaiserslautern)
- JEP systeem Van Delft groep
  (developed with bba binnenmilieu)
- AHREND Balance Comfort workplace
  (a.o. tested in Rijswijk, presented fieldstudy)



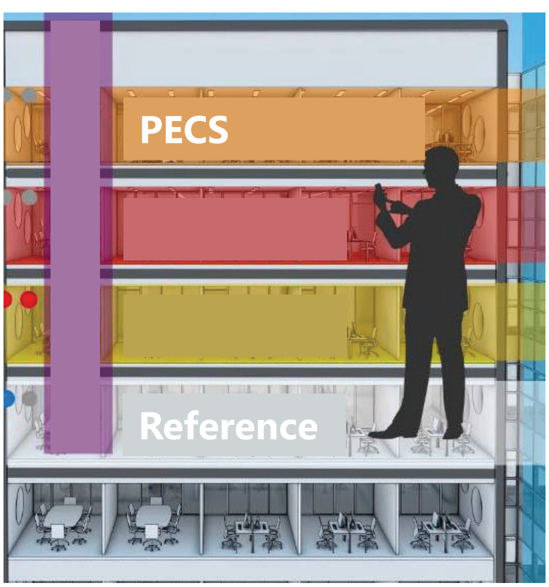
Source: Kloeber

Source: Van Delft group



Source: AHREND

Field study 'comfort desks'



Source figure: adjusted from https://www.rijksvastgoedbedrijf.nl

Office building selected for field study to test energy efficiency innovations.

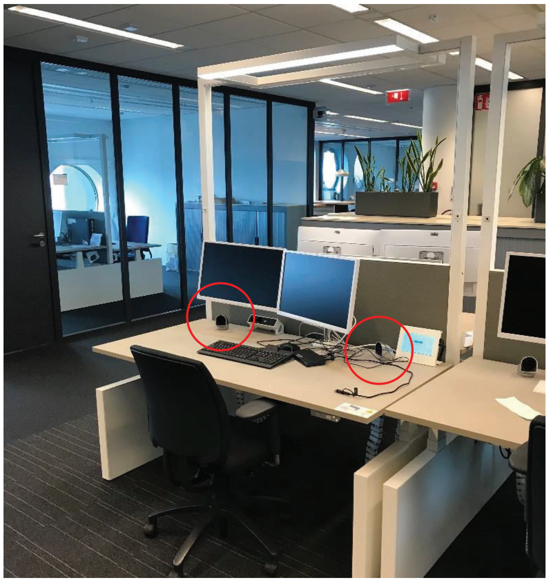
One floor served as a reference floor.
One floor was provided with Balance Comfort workplaces (PECS).

The room setpoint was adjusted from 22°C to 21°C after the placement of the 'PECS workplaces'.

Evaluation of user satisfaction:

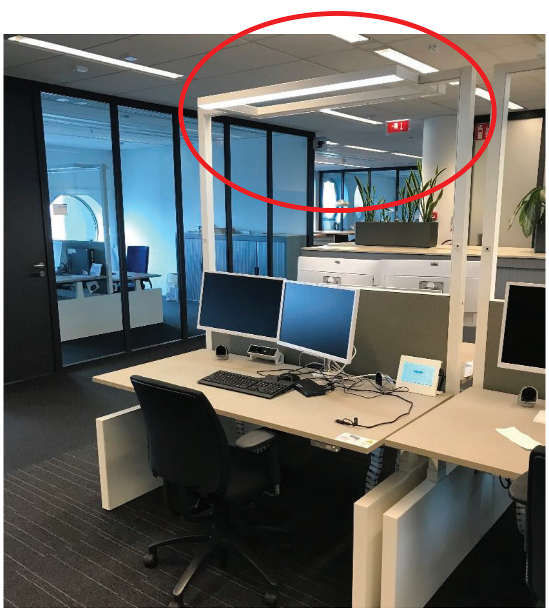
- Winter 2019 #1
- Autumn 2019 #2
- Winter 2020 #3

Field study 'comfort desks'



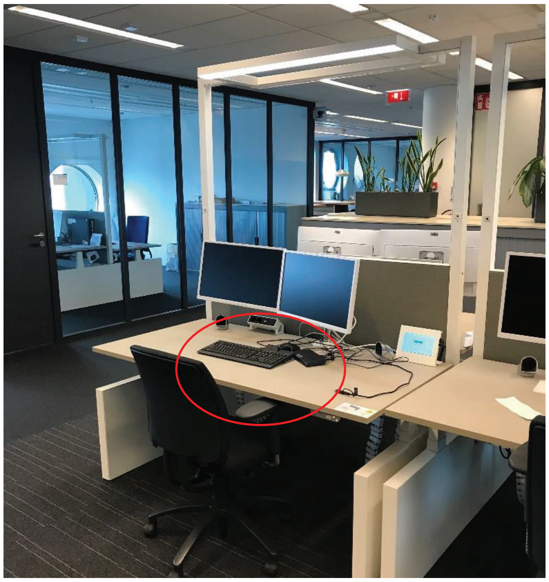
- **Fans**
- Lighting adjustable in intensity & CCT
- Desk heating
- Interface with touchscreen

Field study 'comfort desks'



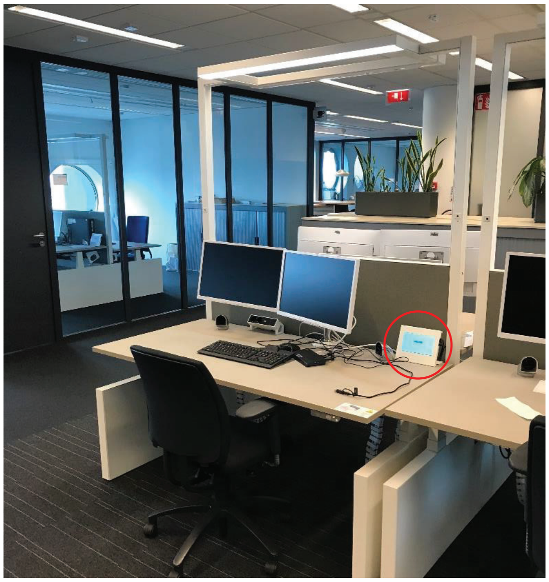
- Fans
- **Lighting adjustable in intensity & CCT**
- Desk heating
- Interface with touchscreen

Field study 'comfort desks'

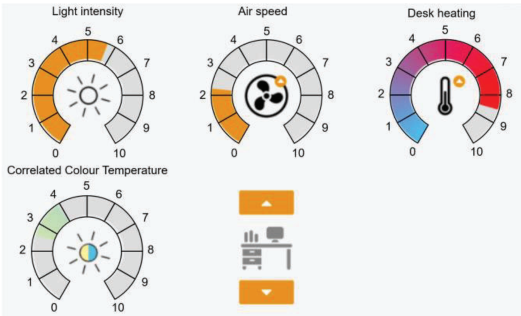


- Fans
- Lighting adjustable in intensity & CCT
- **Desk heating**
- Interface with touchscreen

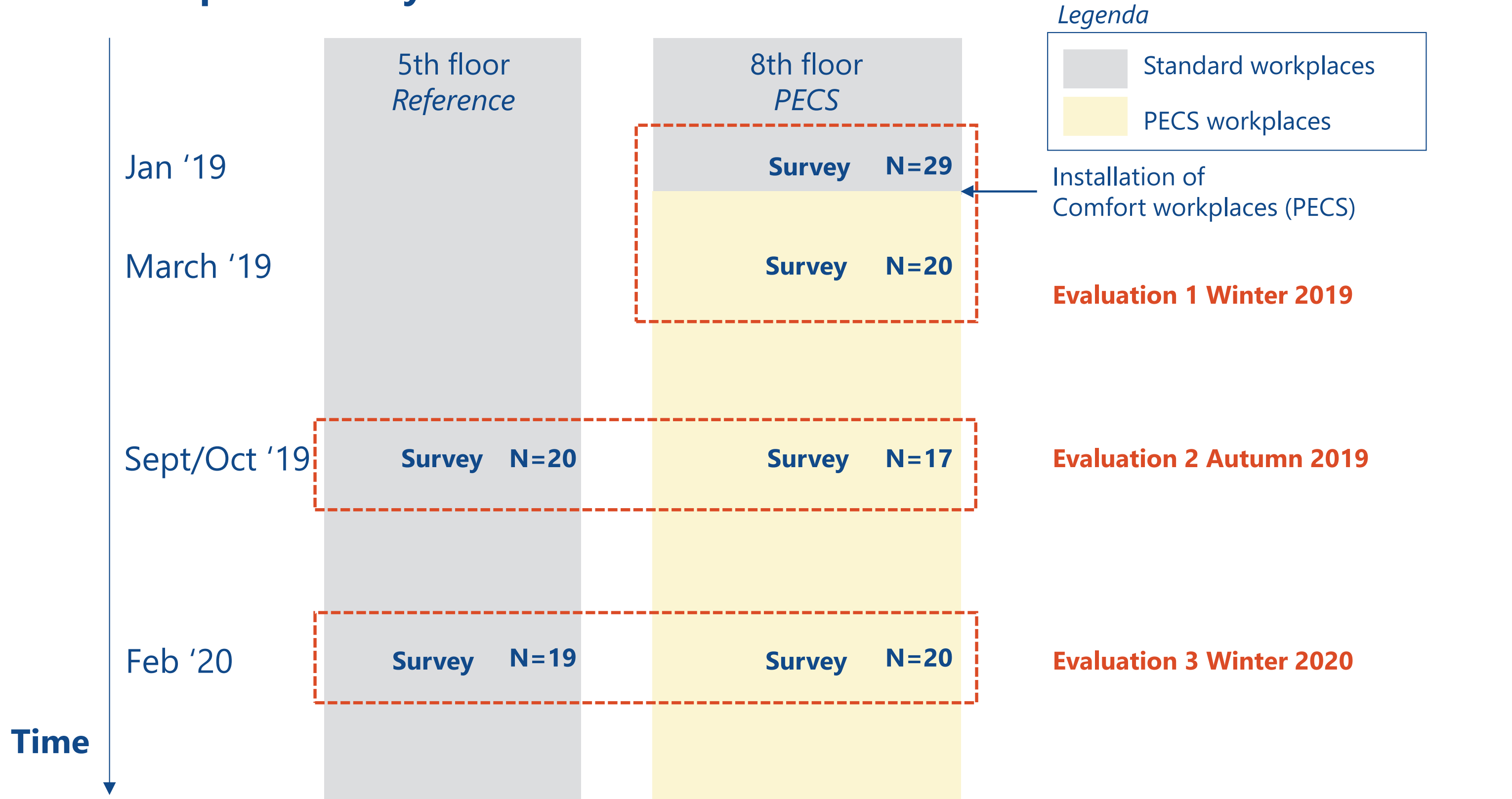
Field study 'comfort desks'



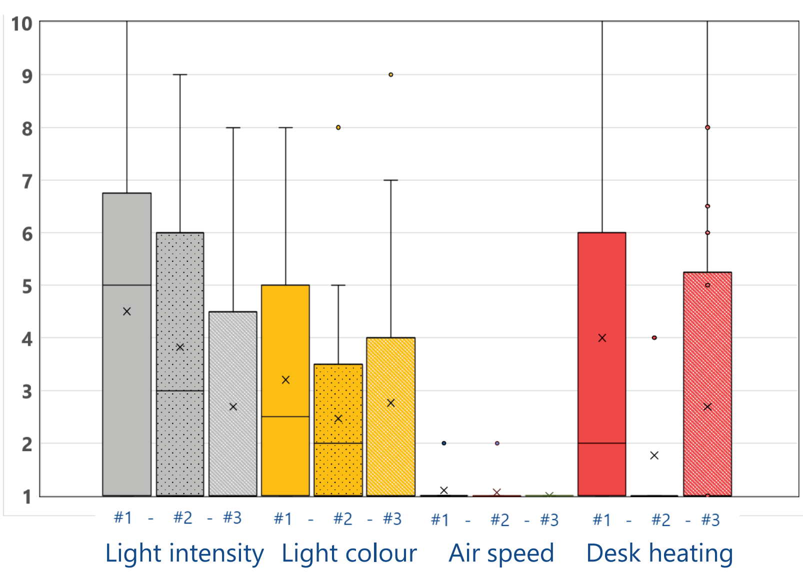
- Fans
- Lighting adjustable in intensity & CCT
- Desk heating
- **Interface with touchscreen**



Set up field study

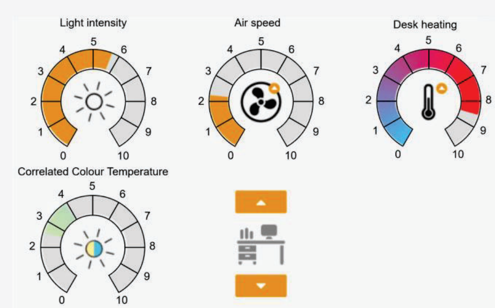


Did people use the control opportunities?

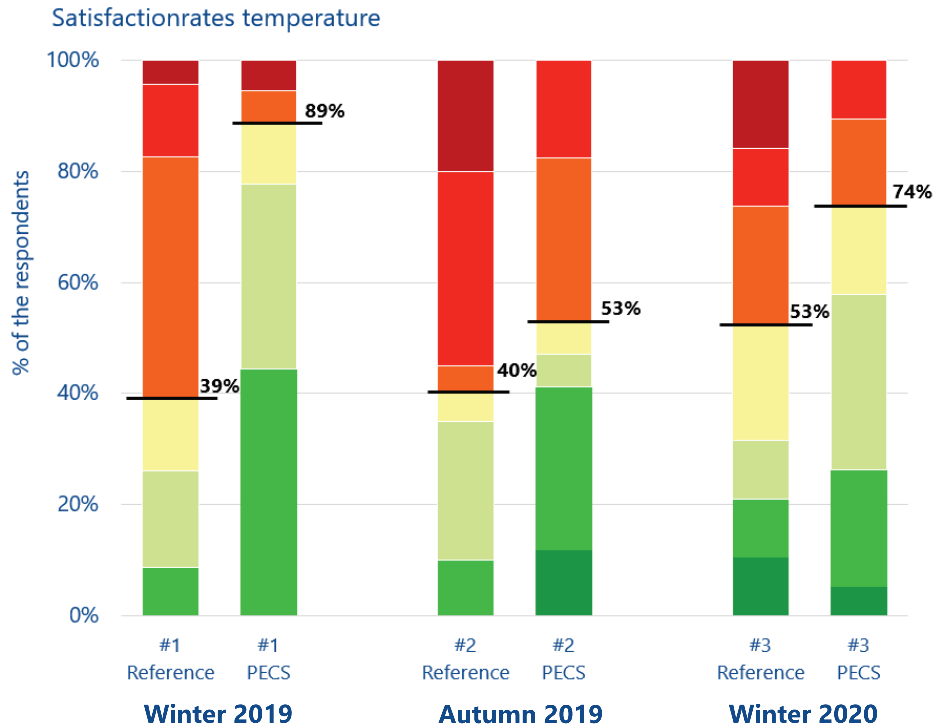


Evaluation of user satisfaction:

- Winter 2019 #1
- Autumn 2019 #2
- Winter 2020 #3

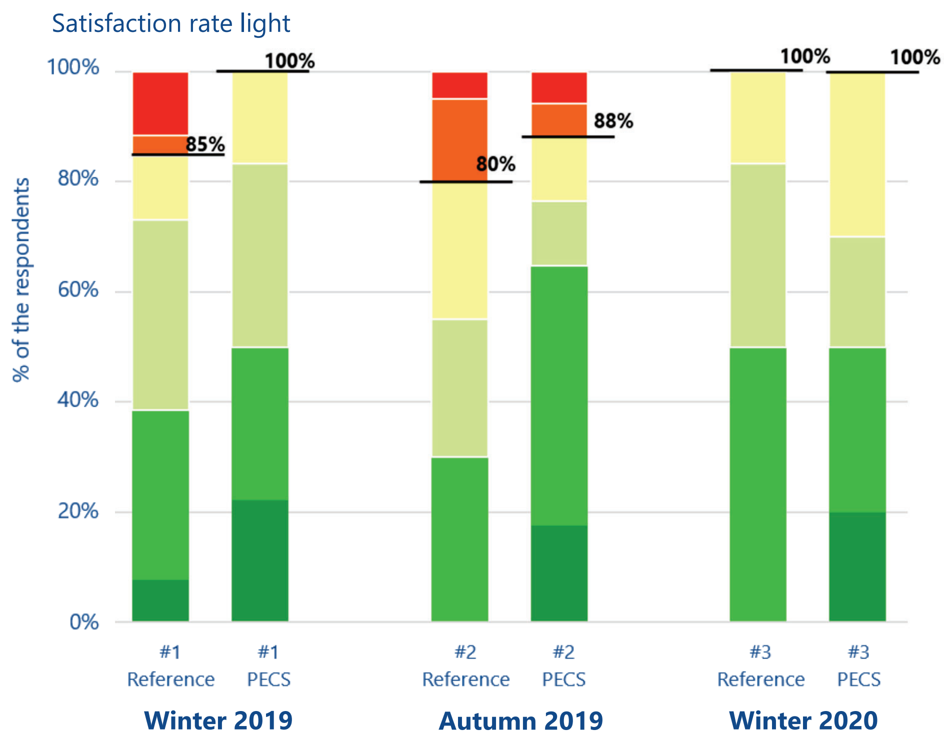


Did PECS positively affect IEQ satisfaction? - Temperature



"I'm really happy with the new desks. It's always comfortable now!"

Did PECS positively affect IEQ satisfaction? - Light



What are the learning points for application of PECS?

Room temperature setpoint:

- A gradual change in room temperature so building occupants can adapt.
- Different temperature setpoints within one building can result in a lower acceptance rate.
- Communication with the building occupant about the adjustments

Fans: noise & air speed

- Noise levels of fans should be acceptable.
- Airs speed should not be too high. E.g. to prevent paper to blow away (i.e. max 1,5 m/s at workplace).

Background light levels should be adjustable.

- Allow an adequate background light intensity also when occupancy is low.

Easy to use interface

- Touchscreen did not require connection with smartphone: no issues.

Results from other field studies

Research UC Berkeley (Zhang et al., 2015): 'Energy savings of 30% possible when using micro-climate control systems; partly dependent on local outdoor climate and on choices regarding setpoints ambient temperature; advice regarding the latter is to assume range 18-28°C (!).'

Research TU Eindhoven (Zeiler et al., 2010): 'In the Dutch climate, energy savings of 14% can be achieved with microclimate control if the setpoint range (ambient temperature) is 'widened' to range 19-25°C (if 100% satisfaction is maintained)'

Research AHREND in collaboration with Strukton in the Dutch office (field research): 'Energy savings of at least 16% possible when using micro-climate control'

Conclusions

The fieldstudy showed that the introduction of micro-climate control leads to more comfort in the workplace and an improvement in the control experience.

Research by third parties also shows that the energy saving potential (in offices) can be as high as 14 to 30%.

Suppose you want to work with wider range ambient temperature setpoint settings e.g. ranging from 18°C (winter) to 28°C, then PECS need to be used to remain thermal comfort.

Thank you for your attention

Contact:
Marije te Kulve
mk-bba@binnenmilieu.nl
www.binnenmilieu.nl

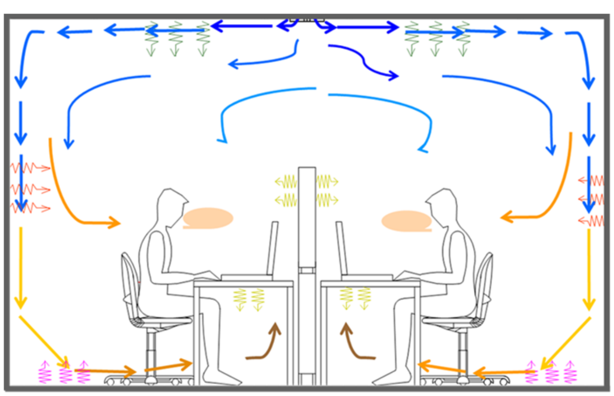
5 December 2024, Webinar – Personalized Environmental Control System (PECS) in Action: Insights from Case Studies

Performance of Personalized Ventilation Installed in Open-Plan Offices

Arsen K. Melikov

International Centre for Indoor Environment and Energy, DTU Sustain, Technical University of Denmark
akme@dtu.dk

Present Ventilation Design

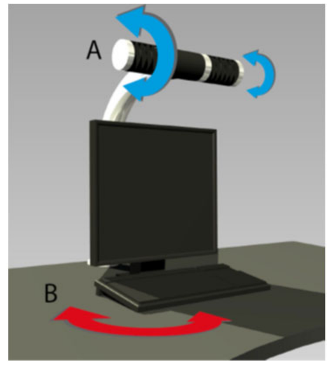


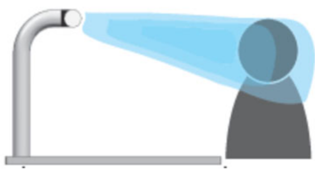
Limited improvement of IAQ and reduction of Energy!

Increased Ventilation
- Healthy Environment
- **Increased Energy Use**

Decreased Ventilation
- Energy Saving
- **Mediocre Environment**

Personalised Ventilation (PV)




Courtesy of Exhausto

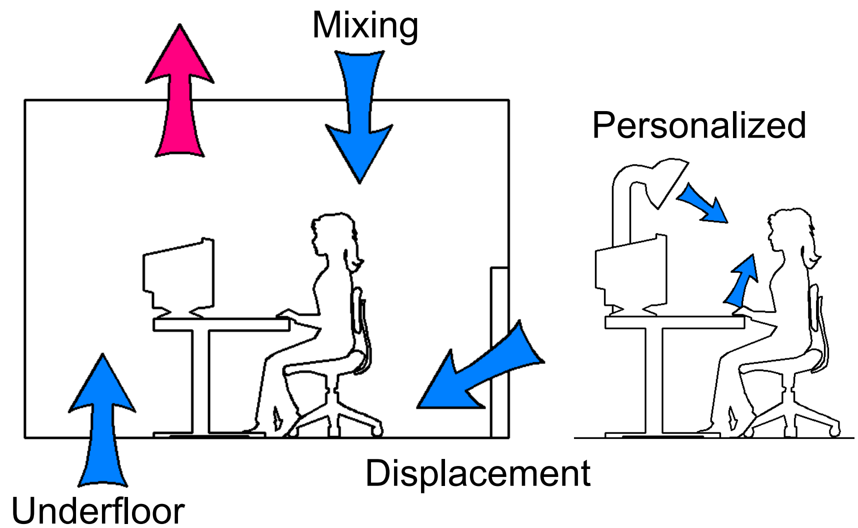
Personalised Ventilation: Performance

- Clean air to breathing zone
- Individual control

- Preferred thermal environment
- Better PAQ
- Improved health
- Increased productivity
- Energy saving

Melikov, Indoor Air J., 2004

Personalised Ventilation: Practical Implementation



PV can be implemented alone or in conjunction with background ventilation.

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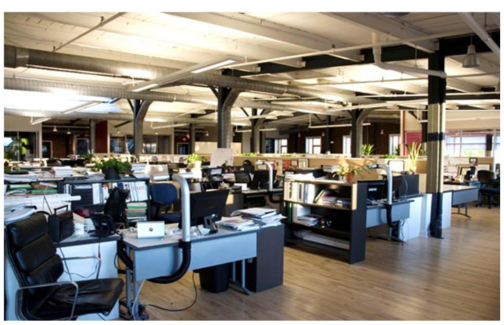
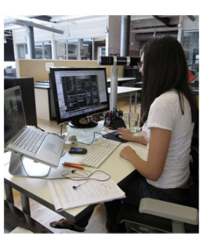
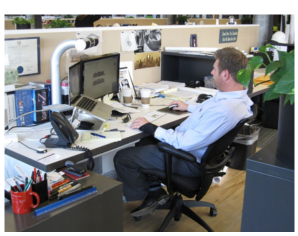
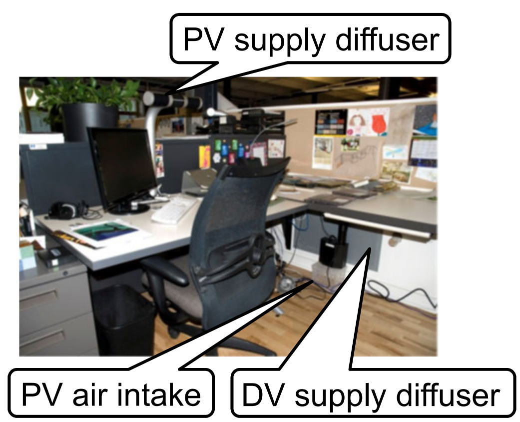
Personalised Ventilation: King & King Building



- LEED-Platinum office building (Syracuse, USA)
- 60 workstations
- 38 workstations with PV (53%)
- Average room temperature 23,5 ± 0.4°C







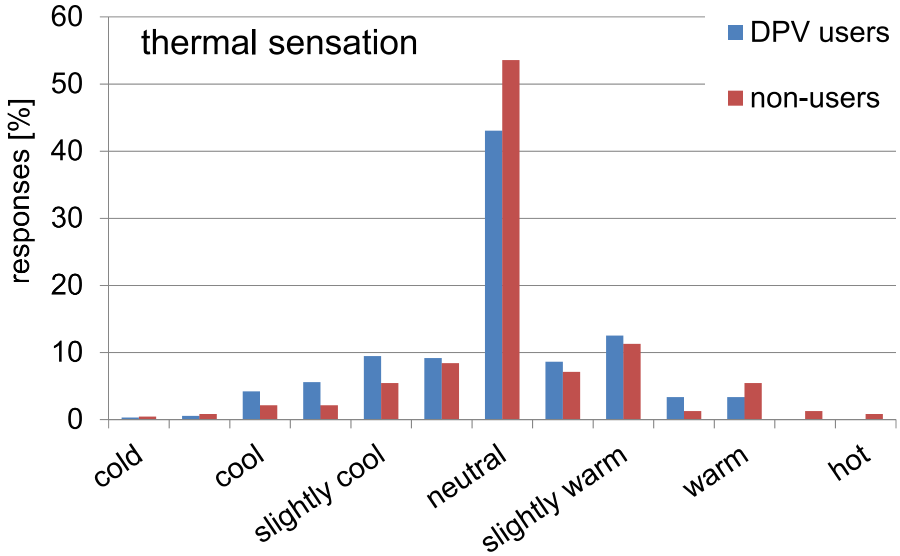
Dalewski et al. 2013, CLIMA 2013

6

Performance of PV: Field Study

ASHRAE scale

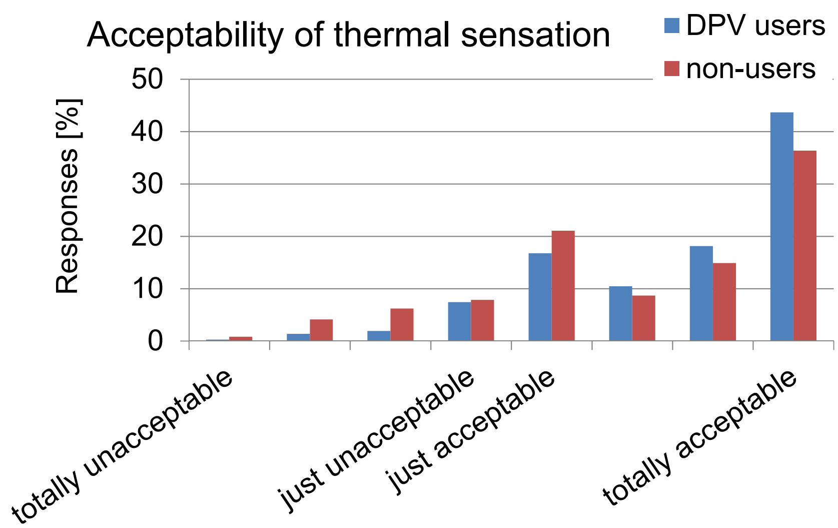
o hot
o
o warm
o
o slightly warm
o
o neutral
o
o slightly cool
o
o cool
o
o cold



Performance of the PV: Field Study

Acceptability scale

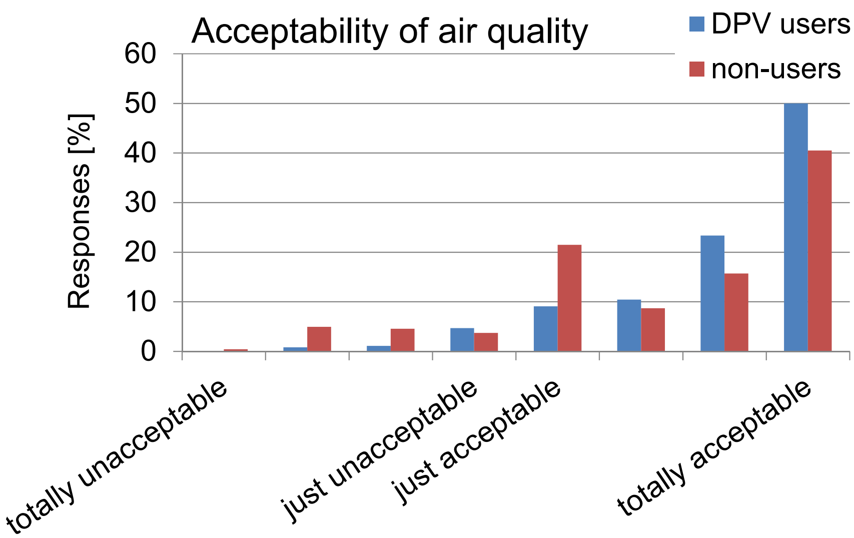
o totally unacceptable
o
o
o
o
o
o
o just unacceptable
o just acceptable
o
o
o
o
o
o
o totally acceptable



Performance of the PV: Field Study

Acceptability scale

- o totally unacceptable
- o
- o
- o
- o
- o
- o
- o just unacceptable
- o just acceptable
- o
- o
- o
- o
- o
- o
- o totally acceptable



Performance of the PV: King & King Building

Acceptability scale

- o totally unacceptable
- o
- o
- o
- o
- o
- o
- o just unacceptable
- o just acceptable
- o
- o
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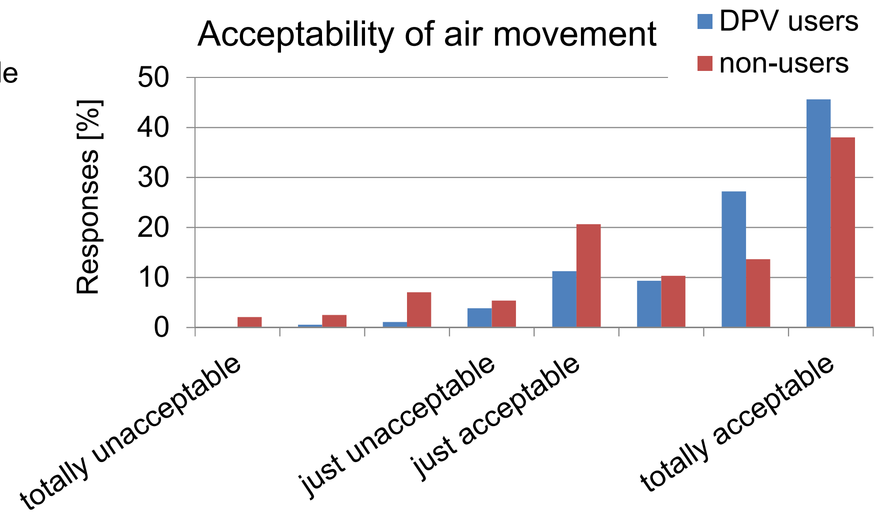
- o
- o
- o
- o totally acceptable

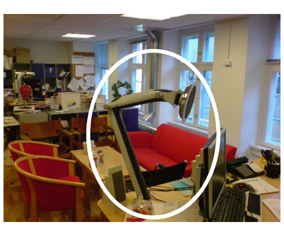


Performance of the PV in the ”King & King Building”

Conclusions

- The implementation of personalized ventilation showed potential for improving PAQ and thermal comfort
- The acceptability of thermal sensation/air quality/air movement was higher among DPV users compared to non-users
- The installation of personalized ventilation will be beneficial for providing preferred microenvironment at workstations and for increasing occupants satisfaction

Personalised Ventilation: ”Magnus Building”



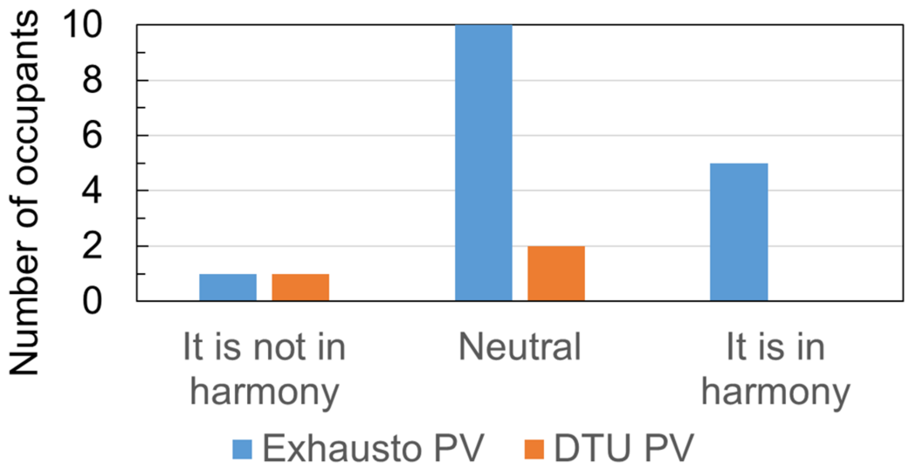
DTU PV design

Exhausto PV design

- Office building (Copenhagen, DK)
- Field Study:
  - Before renovation:
    - Natural ventilation
  - After renovation:
    - Mechanical ventilation + PV

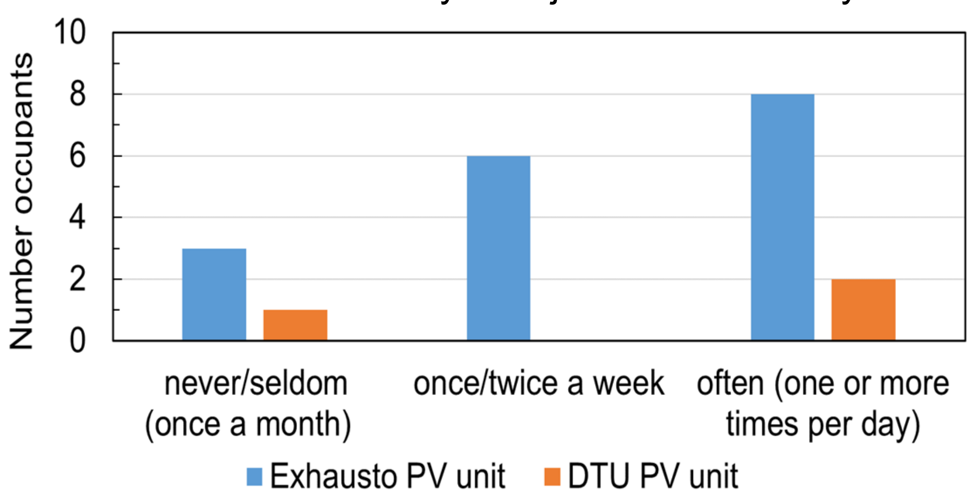
Performance of the PV: ”Magnus Building”

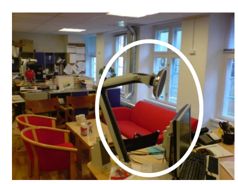
Is the PV in harmony with the surroundings at your workplace?

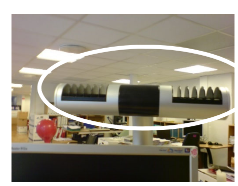


Performance of the PV: ”Magnus Building”

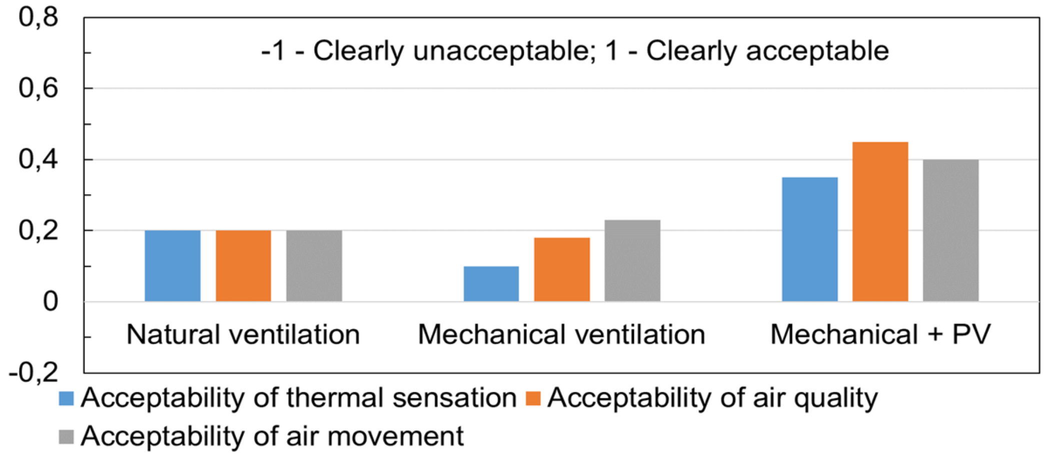
How often do you adjust the air velocity/airflow?







Performance of the PV: ”Magnus Buildig”



	Natural Vent.	Mixing Vent.	Mixing Vent. + PV
No. occupants	17	18	19
Average Temp.	24,7 ±0,3ºC	24,4 ±0,3 ºC	24,6 ±0,3 ºC

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Performance of the PV: Magnus Building

Conclusions

- The PV in conjunction with mechanical ventilation performed better than natural ventilation as well as mechanical ventilation alone
- The design of the PV is important for its acceptance by the occupants and its control
- Long term field studies are recommended to investigate the impact of PV on occupants' health, comfort and performance in office buildings

Thank you!

Personalized Environmental Control System (PECS) in Action: Insights from Case Studies

IEA-EBC Annex 87

AIVC Webinar : 5 December 2024

The PECS journey in Singapore – From Field Environmental Chamber studies to Field studies

Professor Chandra Sekhar, PhD

Fellow ASHRAE & ISIAQ, FIEAust

Department of the Built Environment

College of Design and Engineering

National University of Singapore, Singapore

The PECS journey in Singapore – From Field Environmental Chamber studies to Field studies

2001-2005

- Thermal IAQ Chamber (Room within a room)
- Dedicated AHUs (for PV and Background air) and Air distribution

2007-2010

- Field Environmental Chamber (FEC)
- Actual customised room - PECS integrated with secondary systems
- Dedicated AHUs (for PV and Background air) and Air-distribution

2009-2015

- Field installation at ZEB@BCAA
- PV integrated with UFAD in an office space

2011-2015

- Thermal IAQ Chamber (Room within a room)
- PV integrated with PE
- Simulated healthcare setting

2016-2018

- Simulation studies
- PV coupled with chilled beams

2001-2005

Desk-mounted PV System integrated with Ceiling Supply MV System

Sekhar, S C, N Gong, K W Tham, K W Cheong, A.K. Melikov, D.P. Wyon and P.O. Fanger, "Findings of personalised ventilation studies in a hot and humid climate". International Journal of Heating, Ventilating, Air-conditioning and Refrigerating Research (HVAC&R Research), 2005, Vol 11, no. 4

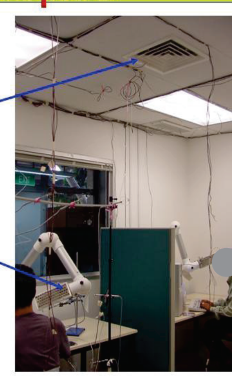
Gong, N, K W Tham, AK Melikov, DP Wyon, S C Sekhar and K W Cheong, "The acceptable air velocity range for local air movement in the Tropics". HVAC&R Research, International Journal of Heating, Ventilating and Air-Conditioning Engineers (ASHRAE), Vol 12, No. 4, pp 1065-1076, (October 2006). (United States).

2001-2005

Indoor Air Quality (IAQ) Chamber – Personalised Ventilation (PV) System in the Tropics

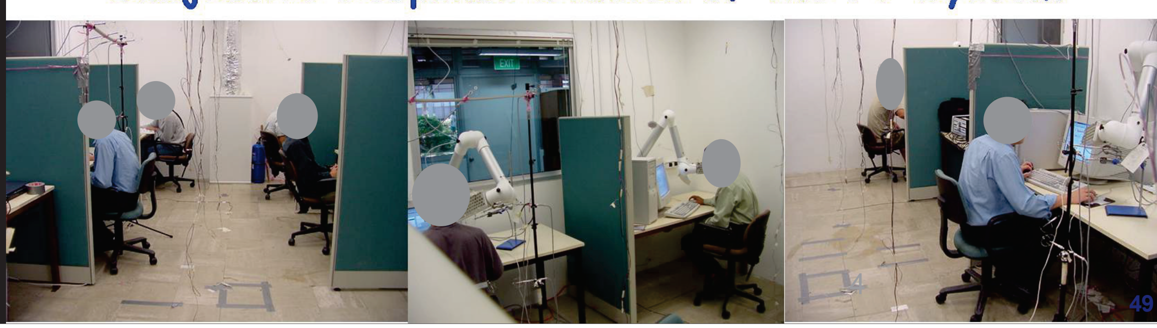
Normal Conditioned Supply air Through Ceiling Diffuser

Clean, cool and dry PV air



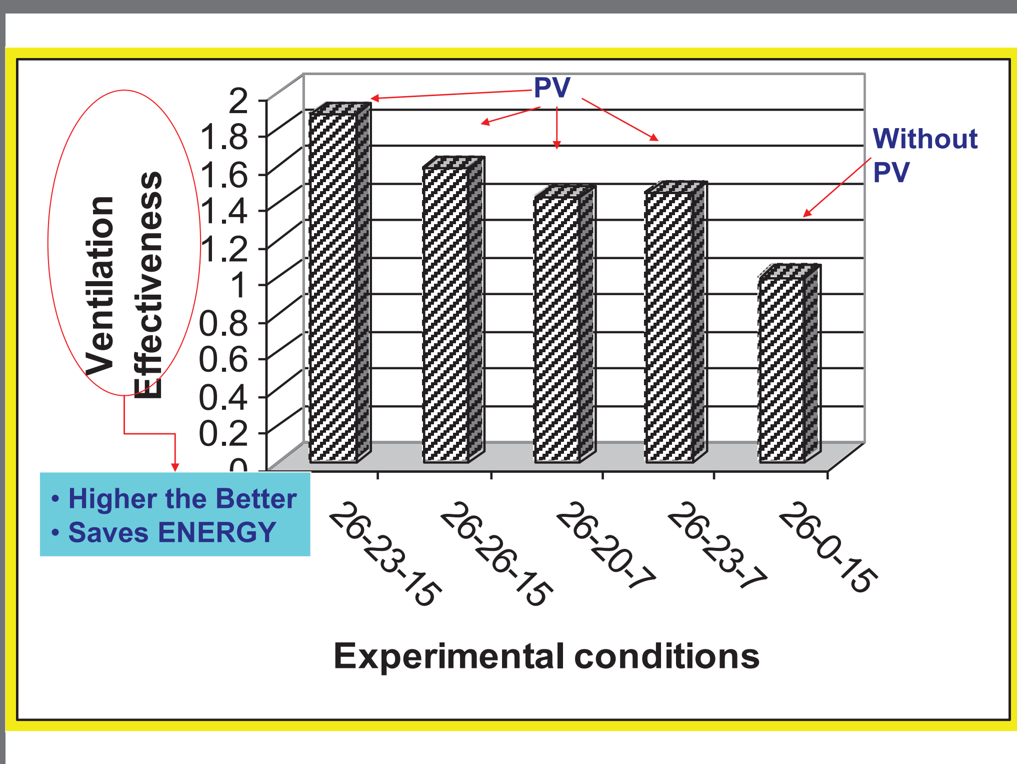
Outside the Chamber **Inside the Chamber**

Subjective Response Studies of the PV System

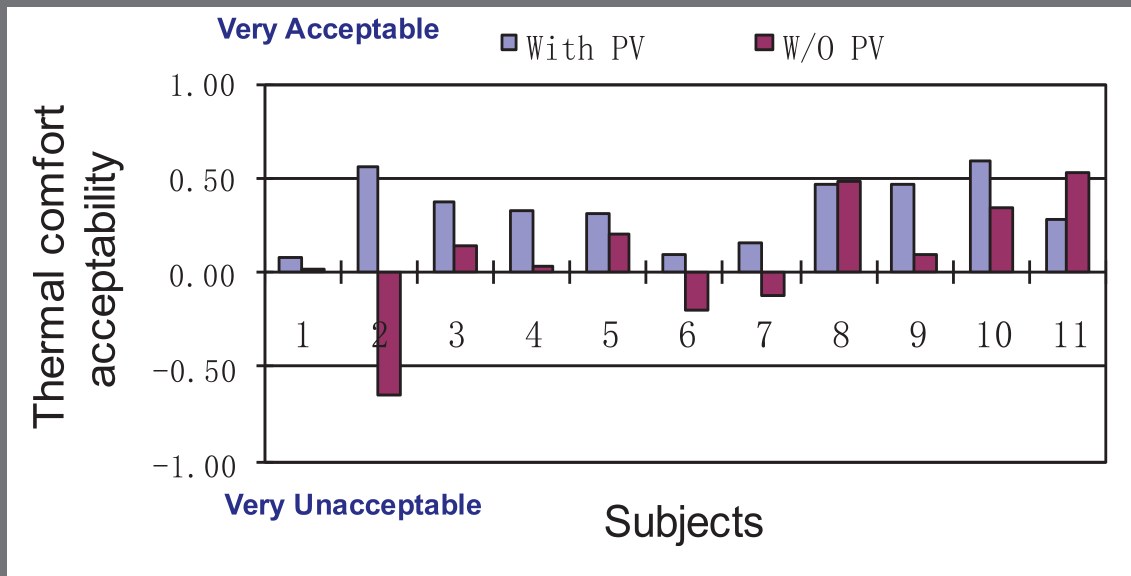


Experimental Protocol

- Ambient and PV air temperatures
- Thermal comfort parameters within the occupied zone
- Breathing temperature in the occupant breathing zone
- Concentration levels of various indoor pollutants
- SF_6 tracer gas measurements - ventilation effectiveness
- Questionnaire responses

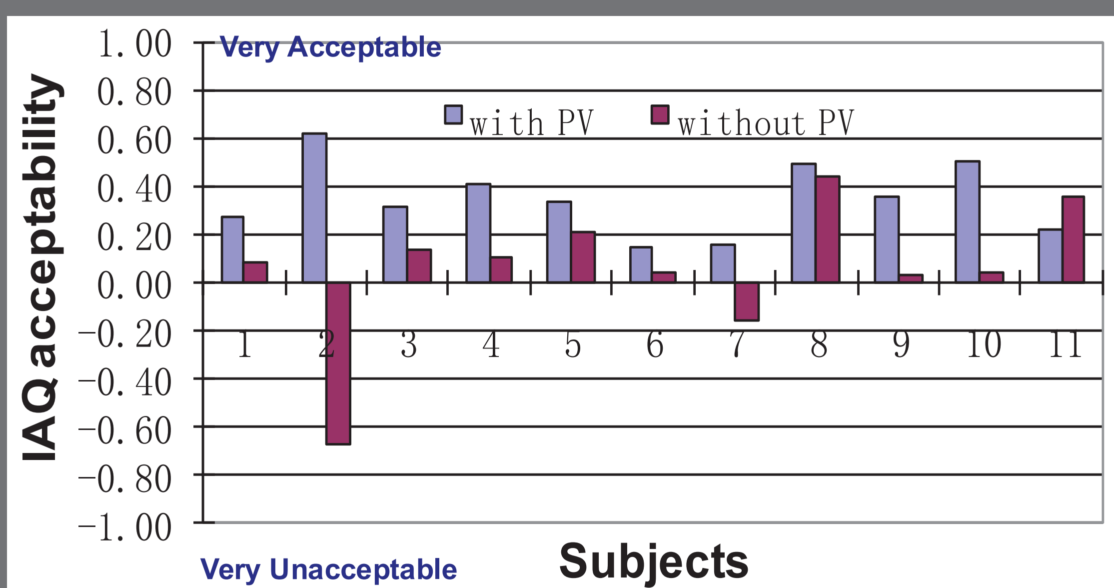


2001-2005

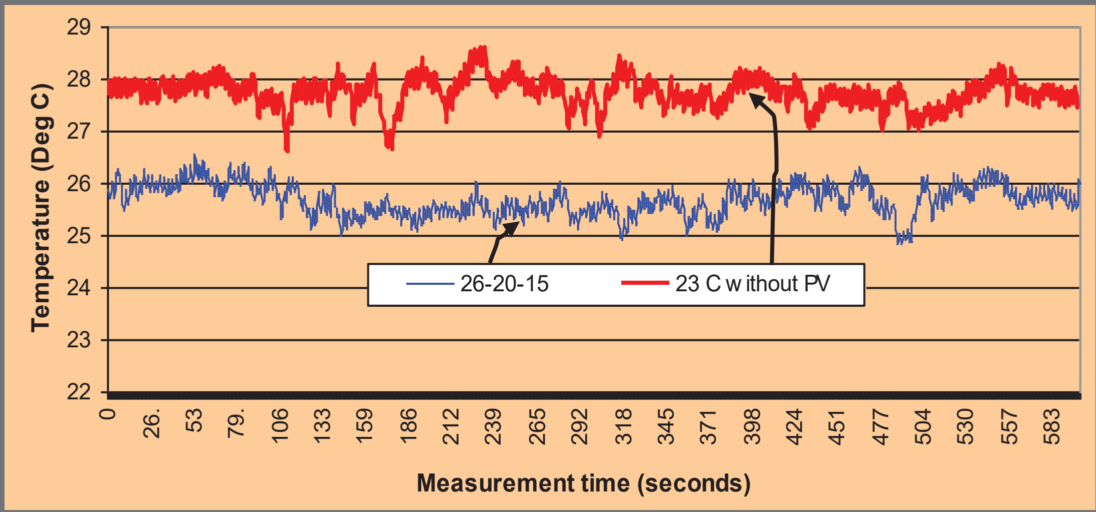


Mean responses of Thermal Comfort acceptability

2001-2005



Mean responses of IAQ acceptability



A comparison of breathing temperatures at 23 °C and 26 °C ambient temperatures

2001-2005

Energy savings occur due to

- A warmer space temperature, such as 26 °C, accompanied by a PV air temperature of 23 °C, implies that the space cooling load is reduced in comparison with a conventional air-conditioning system in which the space is typically maintained at 23 °C.
- An absolute reduction in the total outdoor air quantity provided is possible, as it is now directly supplied as inhaled air to the occupant breathing zone.

2007-2010

Ceiling-Mounted PV System integrated with Ceiling Supply MV System

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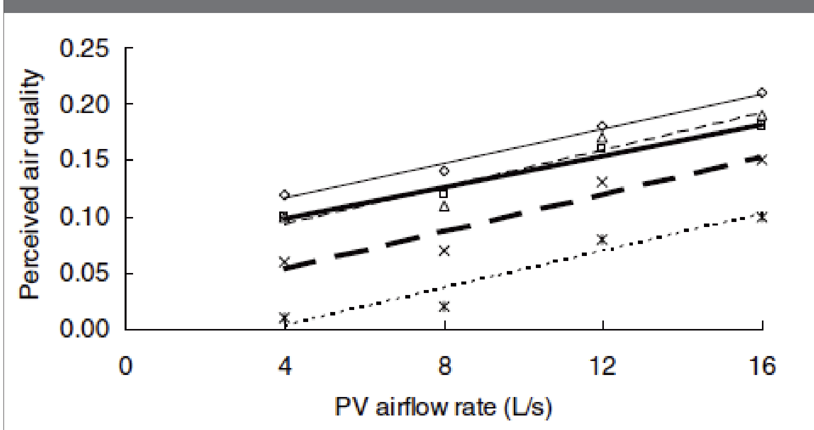
2007-2010

Ceiling-mounted PV system in conjunction with ceiling supply mixing ventilation system



◊		23.5/21
□		23.5/23.5
Δ		26/21
X		26/23.5
*		26/26

Y-axis
-1 = very unacceptable,
0 = just unacceptable/acceptable,
+1 = very acceptable

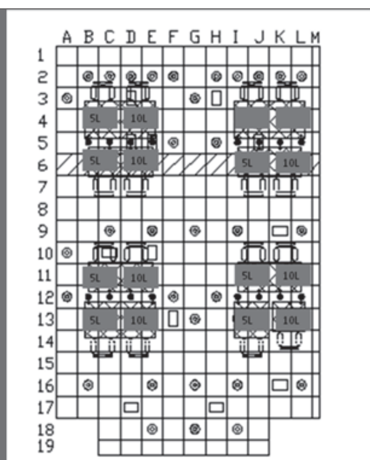
2007-2010

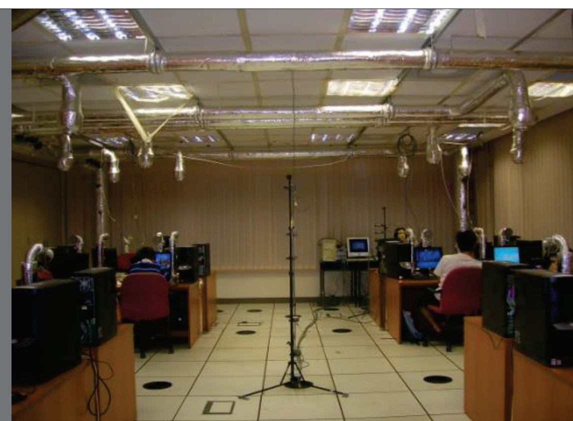
Desk-mounted PV System Integrated with UFAD System

Li, Ruixin, S.C.Sekhar and A.K.Melikov, 2011. Thermal Comfort and Indoor Air Quality in rooms with Integrated Personalized Ventilation and Under-Floor Air Distribution Systems. HVAC&R Research, Volume 17, Number 5, pp 829-846 ,*ASHRAE* .

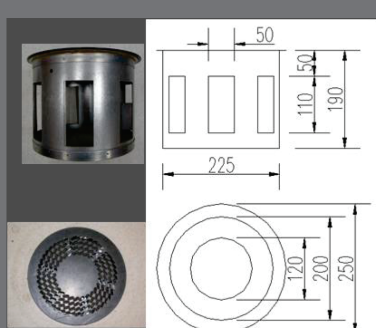
Li Ruixin, S.C.Sekhar and Arsen Melikov, "Thermal comfort and IAQ assessment of under-floor air distribution system integrated with personalized ventilation in hot and humid climate". Building and Environment journal, Vol 45 (2010): 1906-1913. (United Kingdom).

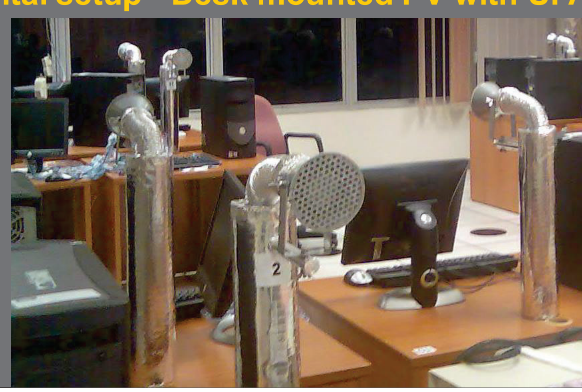
2007-2010

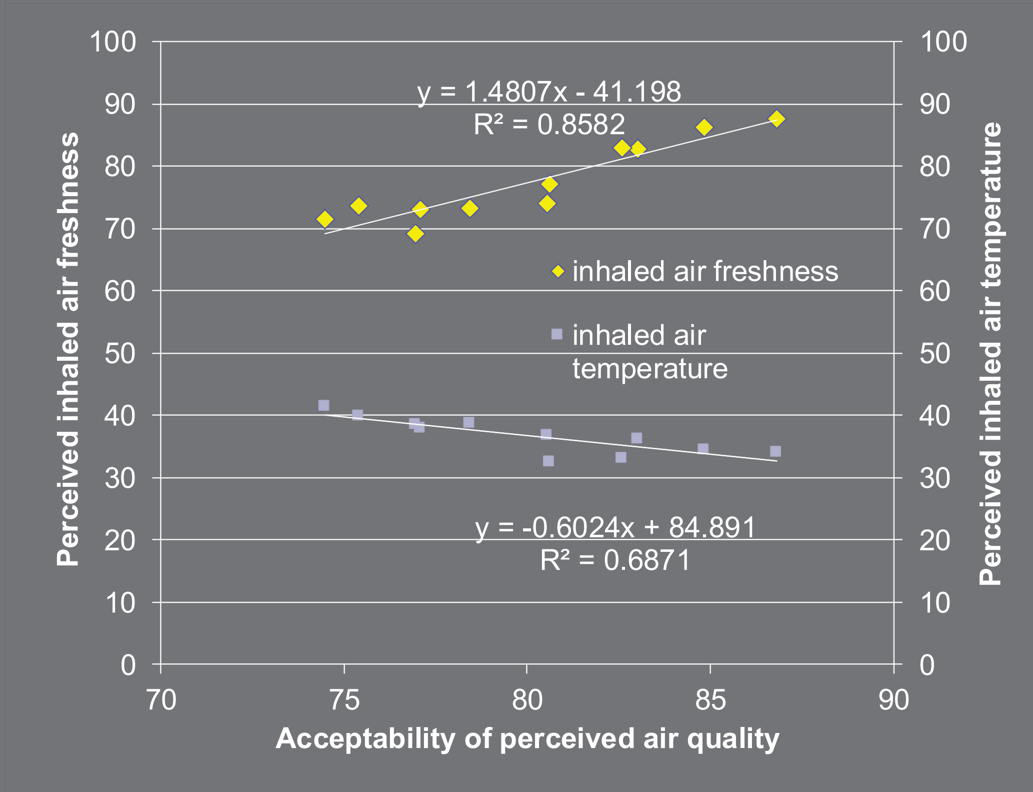




Field Environmental Chamber (FEC) experimental setup - Desk mounted PV with UFAD system

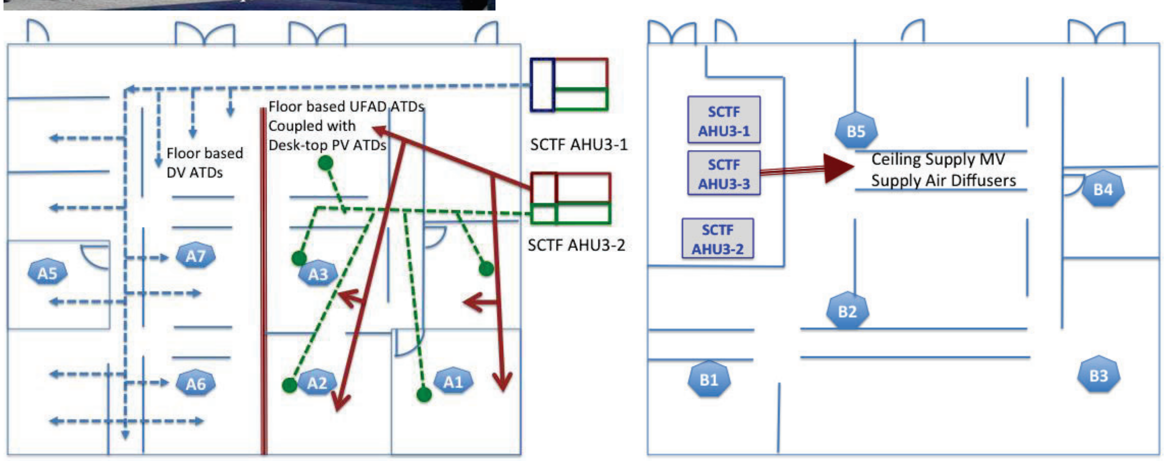






2009-2015

Zero Energy Building @ BCA Academy



PV-UFAD and DV strategies **Ceiling Supply MV strategy**

SEKHAR, S. C., CHEONG, K. W., & Tham, K. W. (2016). Single Coil Twin Fan Air-conditioning and Air Distribution System - Enhanced Air Exchange Effectiveness through DV and integrated Personalised Ventilation-UFAD strategies. In Indoor Air 2016 - The 14th Int Conference on Indoor Air Quality and Climate (Ghent, Belgium, July 3-8, 2016)

2009-2015

Table 1. ACH and AEE characteristics of the three different office spaces

Location	29 July 2013		31 July 2013		Location	31 July 2013	
	ACH	AEE	ACH	AEE		ACH	AEE
A1 (PV-UFAD)	0.97	1.65	0.85	1.72	B1 (MV)	0.94	1.14
A2 (PV-UFAD)	0.89	1.68	0.85	1.75	B2 (MV)	0.92	1.16
A3 (PV-UFAD)	0.75	1.72	0.72	1.69	B3 (MV)	0.92	1.16
A5 (DV)	0.91	1.59	0.74	1.72	B4 (MV)	0.90	1.16
A6 (DV)	0.91	1.61	0.79	1.73	B5 (MV)	0.95	1.10
A7 (DV)	0.87	1.65	0.75	1.72			

2011-2015

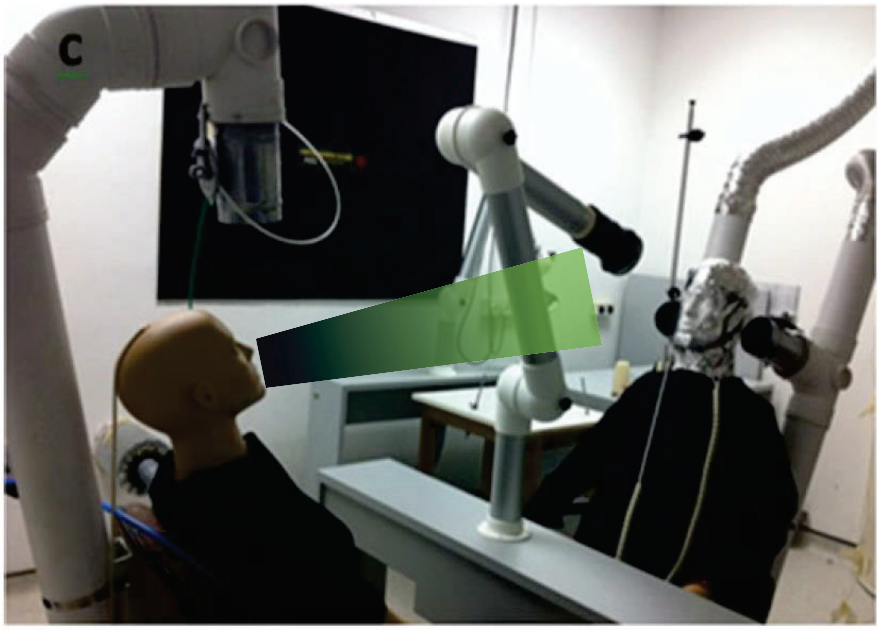
Personalised Ventilation – Personalised Exhaust System

Yang, J., Sekhar, C., Cheong, D., & Raphael, B. (2014). Performance evaluation of an integrated Personalized Ventilation-Personalized Exhaust system in conjunction with two background ventilation systems. *BUILDING AND ENVIRONMENT*, *78*, 103-110. doi:10.1016/j.buildenv.2014.04.015

Yang, J., Sekhar, S. C., Cheong, K. W. D., & Raphael, B. (2015). Performance evaluation of a novel personalized ventilation-personalized exhaust system for airborne infection control. *INDOOR AIR*, *25*(2), 176-187. doi:10.1111/ina.12127

Personalised Ventilation with Personalised Exhaust

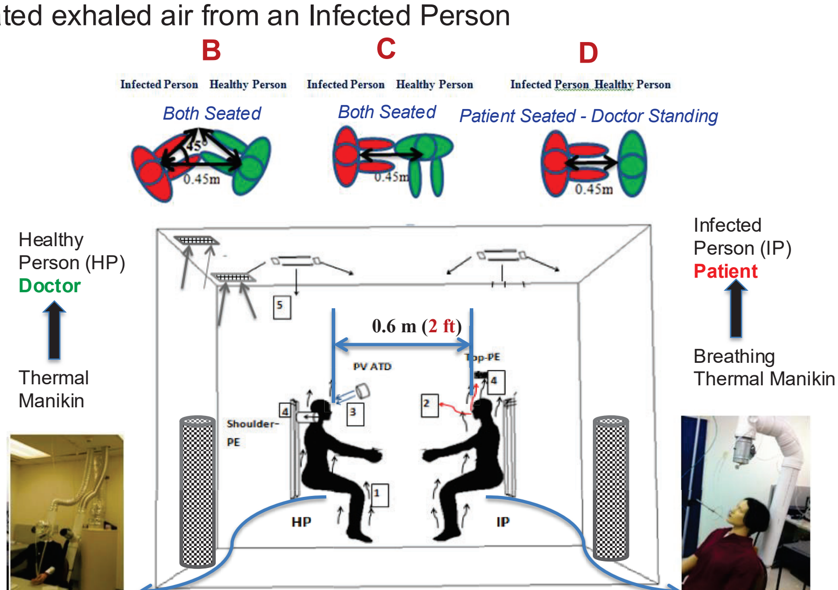
2011-2015



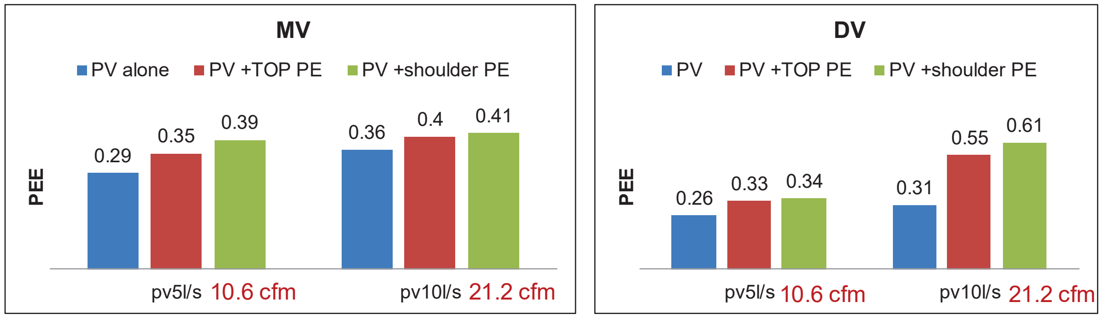
Perf of PV-PE system - Airborne infn control

2011-2015

Objective: Effectiveness of airborne infection control in healthcare settings - combined PV-PE system with background MV or DV systems - localized extraction of the contaminated exhaled air from an Infected Person



Performance of combined PV and PE for Healthy Person



Combined PV and PE for healthy person can achieve the highest PEE

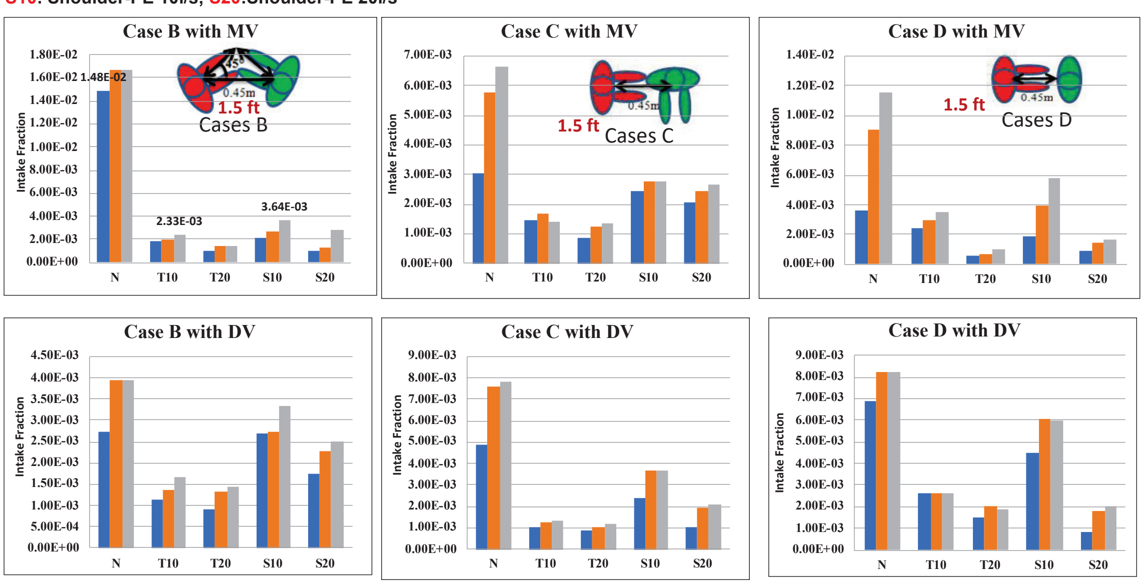
Shoulder-PE performs better than top-PE in terms of pulling more PV air towards the breathing zone

Change of intake fraction over time

21 cfm 42 cfm

N: No PE; **T10**: Top-PE 10l/s; **T20**: Top-PE 20l/s
S10: Shoulder-PE 10l/s; **S20**:Shoulder-PE 20l/s

10mins 20mins 30mins



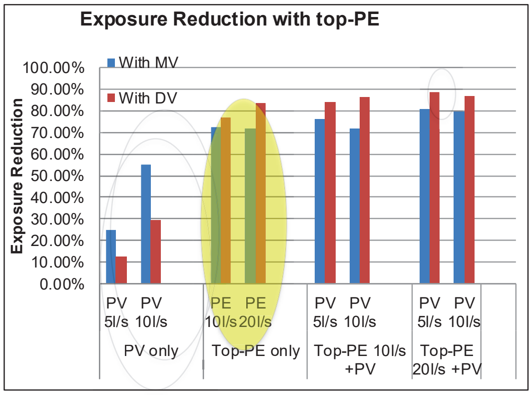
Overall - Infection risk reduced with PE - by reducing exposure amount for longer exposure time

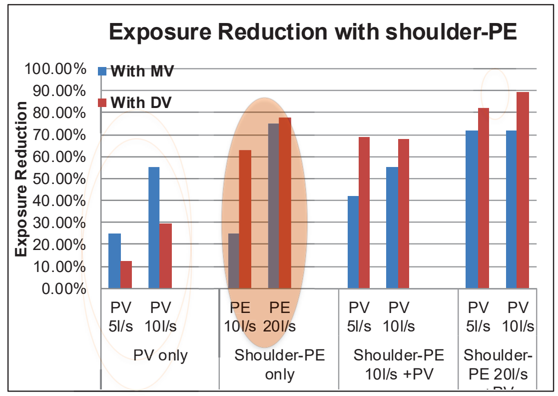
IF by using top-PE is lower than that when using shoulder-PE at the same flow rate at any time interval for most cases, especially at 10 l/s flow rate.

- **top-PE is better than shoulder-PE in terms of infection control**

Exposure Reduction

5 l/s = 10.6 cfm   10 l/s = 21 cfm   20 l/s = 42 cfm





- Use of PV alone can protect the Healthy Person from inhaling contaminated air from the Infected Person
  - ➢ PV for healthy person helps to reduce exposure from Infected Person
- Top-PE can greatly reduce the exposure of exhaled air at a lower flow rate compared with shoulder-PE
  - ➢ Top-PE is better than shoulder-PE in terms of infection control;
- PE for Infected Person with PV for Healthy Person provides the best exposure reduction; PE for Infected Person is more effective than PV for Healthy Person

Performance evaluation of PV-PE system - Airborne infection control

Performance Indicators

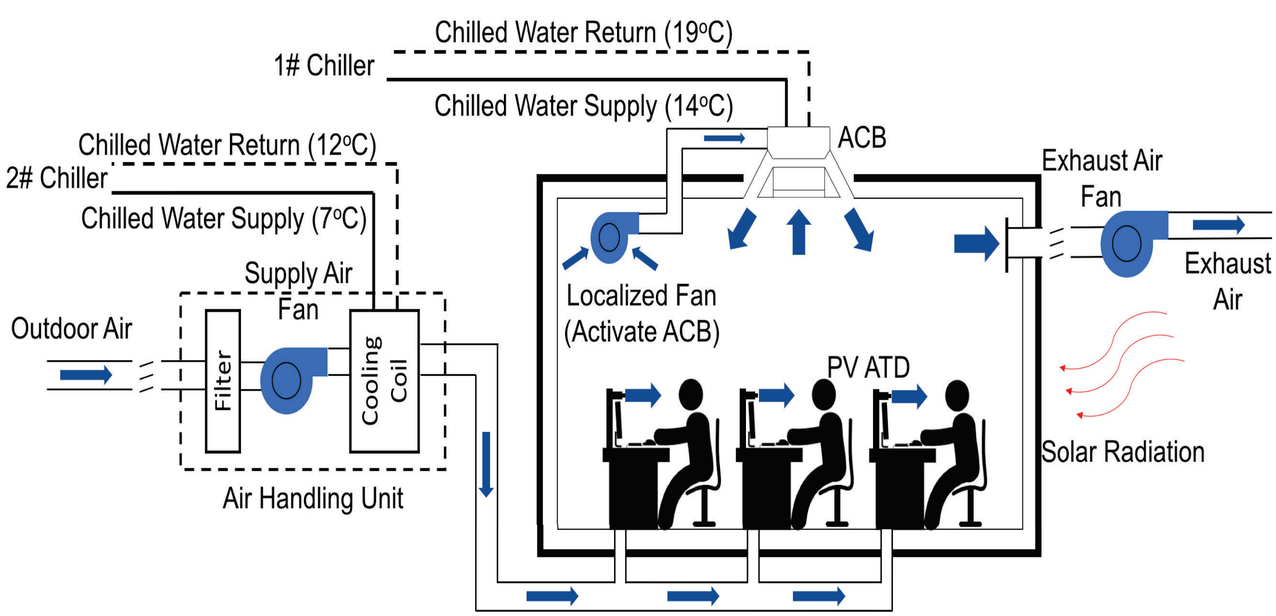
- Personalised Exposure Effectiveness (PEE) ↑
- Intake Fraction (iF) ↓
- Exposure Reduction (ε) ↑

2016-2018

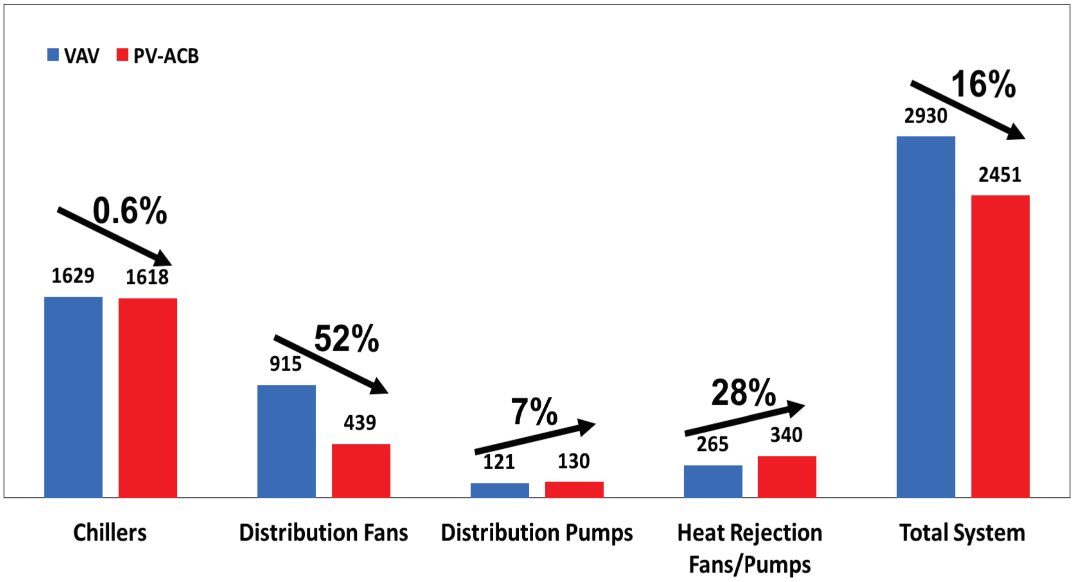
PV System coupled with Chilled Beams

Sekhar, C. & Zheng, L. Study of an integrated personalized ventilation and local fan-induced active chilled beam air conditioning system in hot and humid climate. Build. Simul. (2018) 11: 787.
https://doi-org.libproxy1.nus.edu.sg/10.1007/s12273-018-0438-8

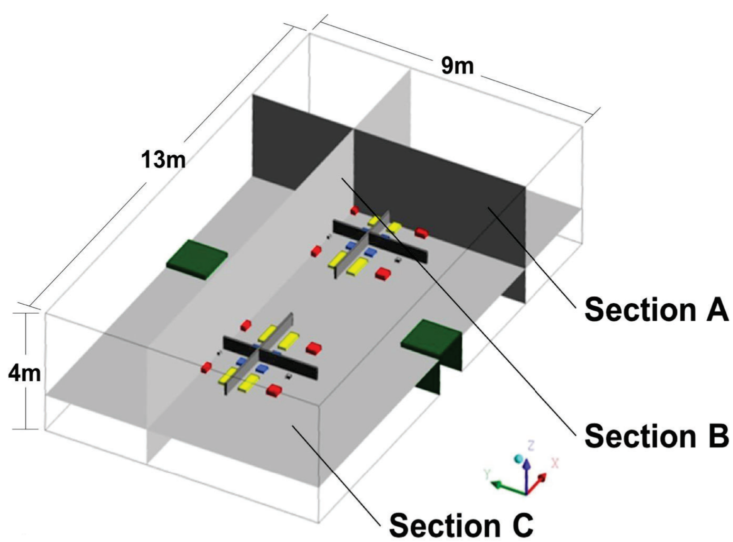
2016-2018



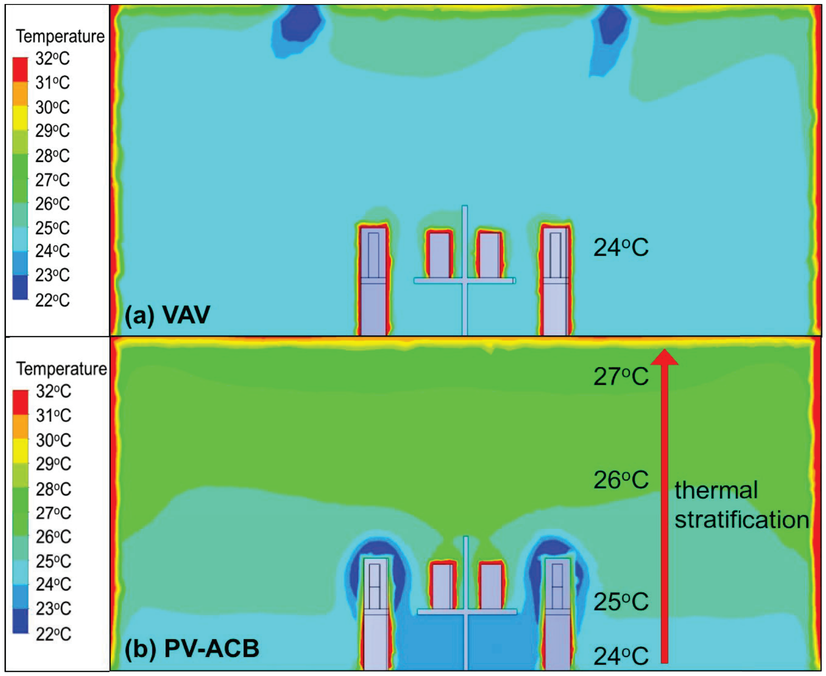
Schematic of integrated personalized ventilation and fan-induced active chilled beams (PV-ACB) air conditioning system



Annual Energy Consumptions of Main Components in VAV and PV-ACB Air Conditioning Systems (Unit: MWH)

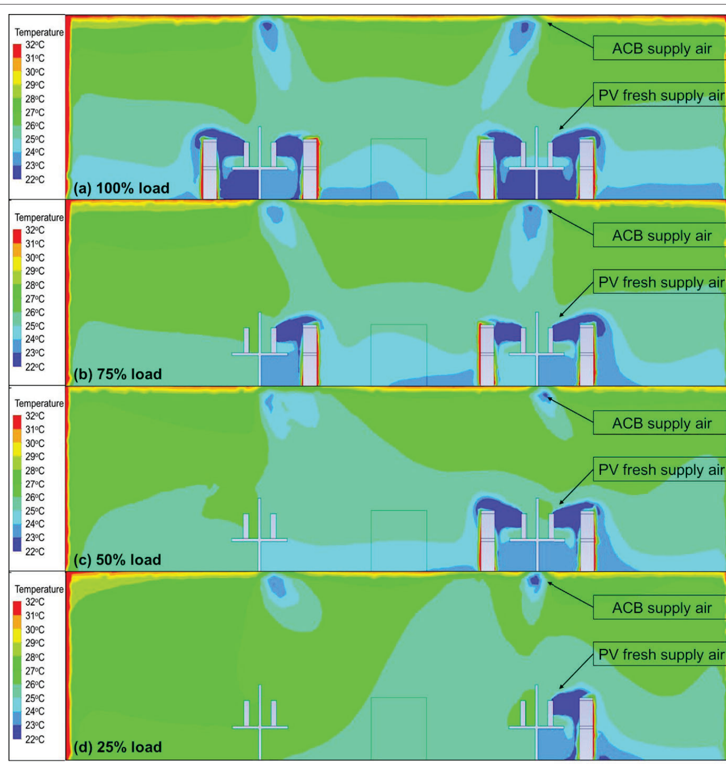


Section A, B and C



Temperature Contours of Section A: (a) VAV, (b) PV-ACB

2016-2018



Temperature Contours of Section B: (a) Peak Load (100%) and Part Loads (b) 75%, (c) 50%, (d) 25%

The PECS journey in Singapore – From Field Environmental Chamber studies to Field studies

2001-2005
- Thermal IAQ Chamber (Room within a room)
- Dedicated AHUs (for PV and Background air) and Air distribution

2007-2010
- Field Environmental Chamber (FEC)
- Actual customised room - PECS integrated with secondary systems
- Dedicated AHUs (for PV and Background air) and Air-distribution

2009-2015
- Field installation at ZEB@BCAA
- PV integrated with UFAD in an office space

2011-2015
- Thermal IAQ Chamber (Room within a room)
- PV integrated with PE
- Simulated healthcare setting

2016-2018
- Simulation studies
- PV coupled with chilled beams

The PECS journey in Singapore – From Field Environmental Chamber studies to Field studies

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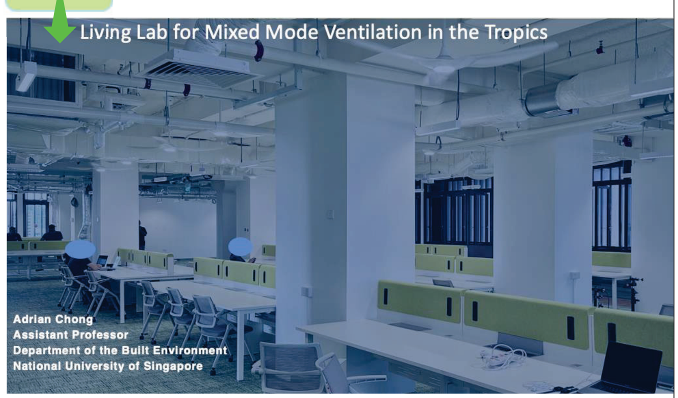
- PV integrated with PE
- Simulated healthcare setting

2016-2018
- Simulation studies
- PV coupled with chilled beams

2023 & Beyond
- Field applications



Thank You for your Attention

Q & A

Professor Chandra Sekhar
bdgscs@nus.edu.sg

Utilization and Evaluation of PECS in a Research Facility Office in Japan

Shin-ichi Tanabe, Prof. Dr., FASHRAE
Waseda University

1

T Innovation Center

Takasago Thermal Engineering   WASEDA University

Department of Architecture, WASEDA University

2

2

T Innovation Center

WASEDA University

Location	Tsukubamirai-city, Ibaraki, Japan
Hight	2-story building (15.5m)
Target office	2nd floor with Activity Based Working (ABW)
Floor Area	Office building: 4,750m^2 Laboratory building: 6,050m^2
Energy System	Groundwater heat exchange Wood biomass heat and power supply system (CHP) PV panels 200 kW Battery power storage 4,600kWh

Certification in 2020 (5 stars, Nearly ZEB)

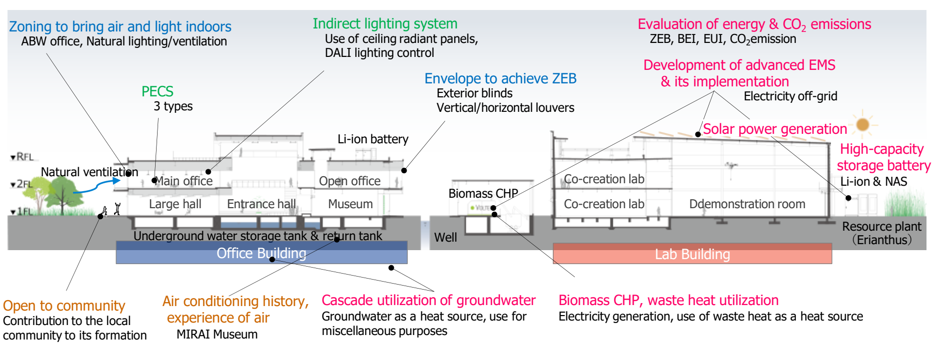
Certification in 2020 (Gold)

Certification in 2020 (Superior (S) rank)

ASHRAE Technology Award 2024 (Commercial Building, New), Second Place

Planning of the Research Facility

WASEDA University



ABW: Activity-Based Working
DALI: Digital Addressable Lighting Interface
BEI: Building Energy Index
CHP: Combined heat and power
EMS: Energy Management System

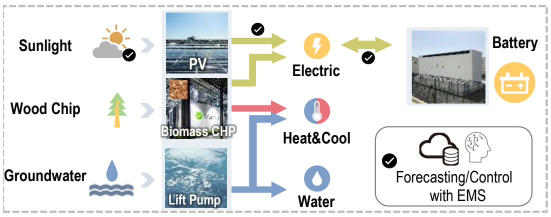
1. Architectural plan
2. Heat source & energy plan
3. Indoor environmental planning
4. Contribution to the community & transfer of technology

Net Zero Energy

WASEDA University

Wood biomass gasification CHP（Biomass CHP）
Wood chip-fueled combined heat and power system

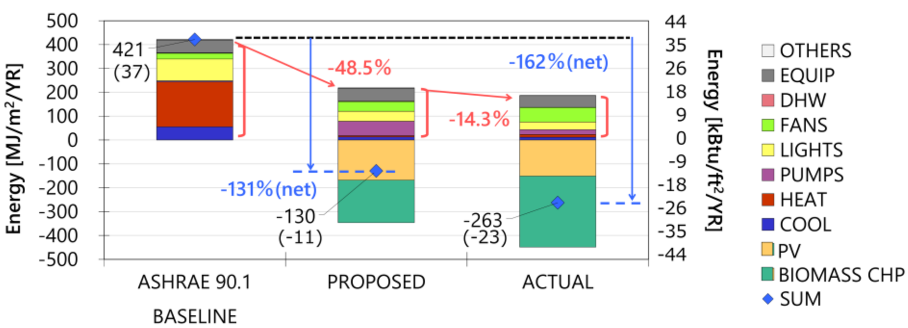
Major issues to achieve net zero in the future ➡ the introduction of large-scale renewable energy and off-grid energy



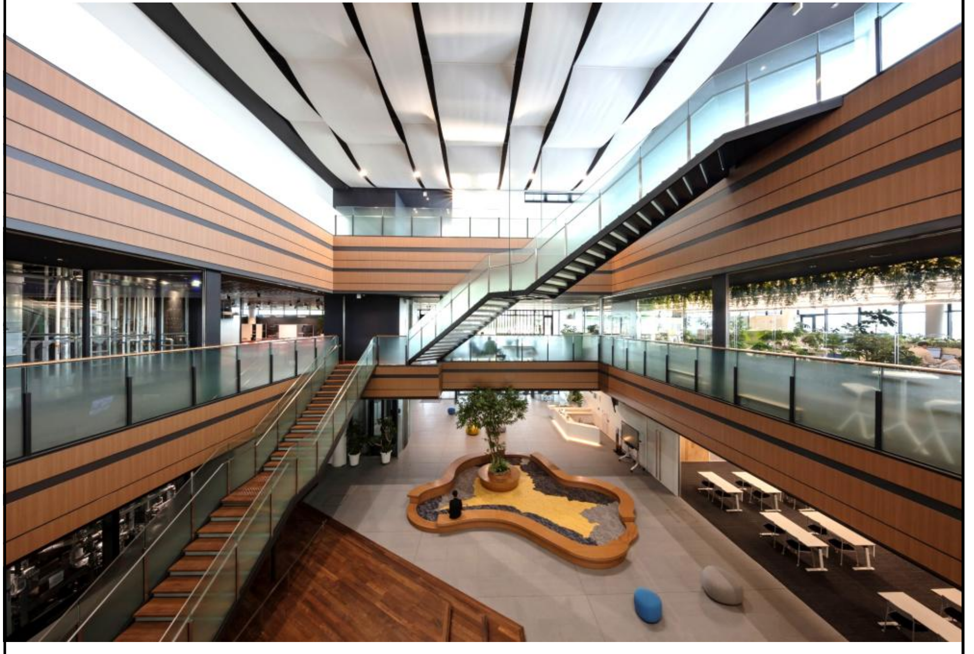
Additional batteries installed for the effective use of renewable energy after the construction completion

Net Zero Energy

WASEDA University



✓ **The actual 2021 records showed a 162% reduction from the baseline value. (Simulations based on ASHRAE90.1_2010)**



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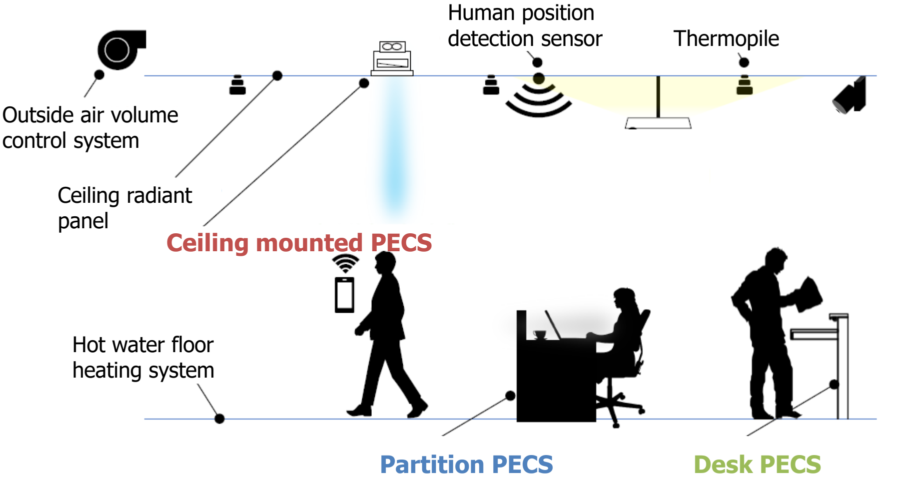
Three Types of PECS

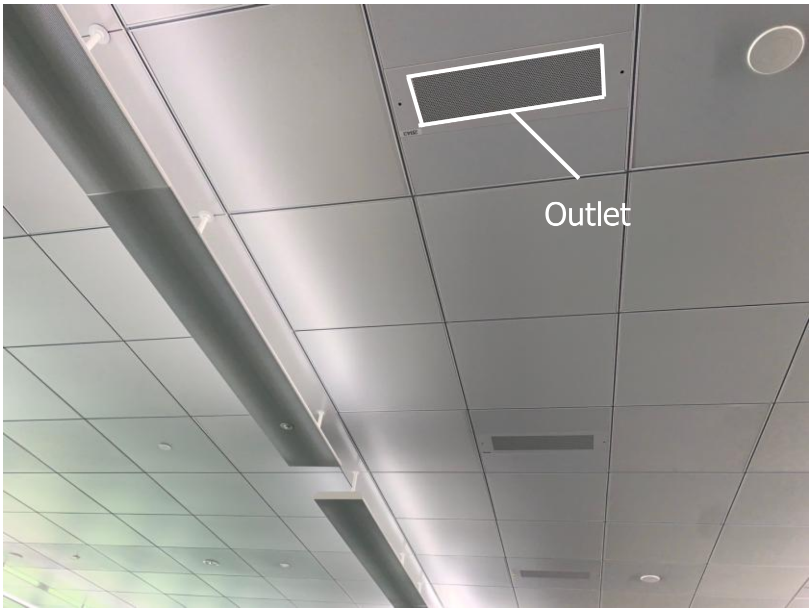
WASEDA University



Energy Efficiency: using groundwater as a cold heat source in summer and exhaust heat from biomass CHP as a heat source in winter

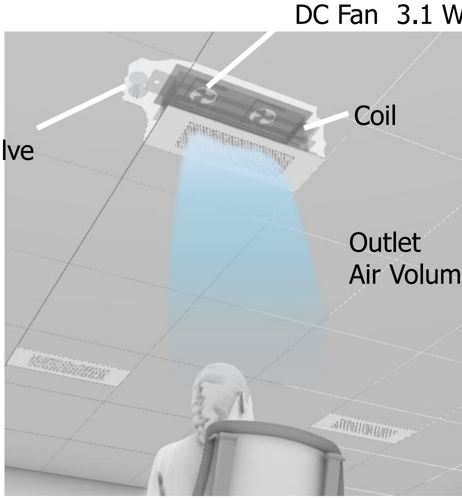
Ceiling installed PECS

WASEDA University



Ceiling installed PECS

WASEDA University



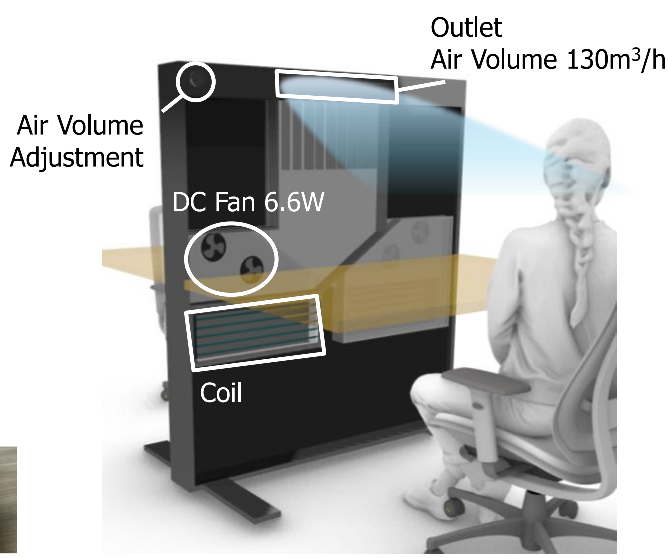
Cooling capacity 470W

Partition PECS

WASEDA University

Partition PECS

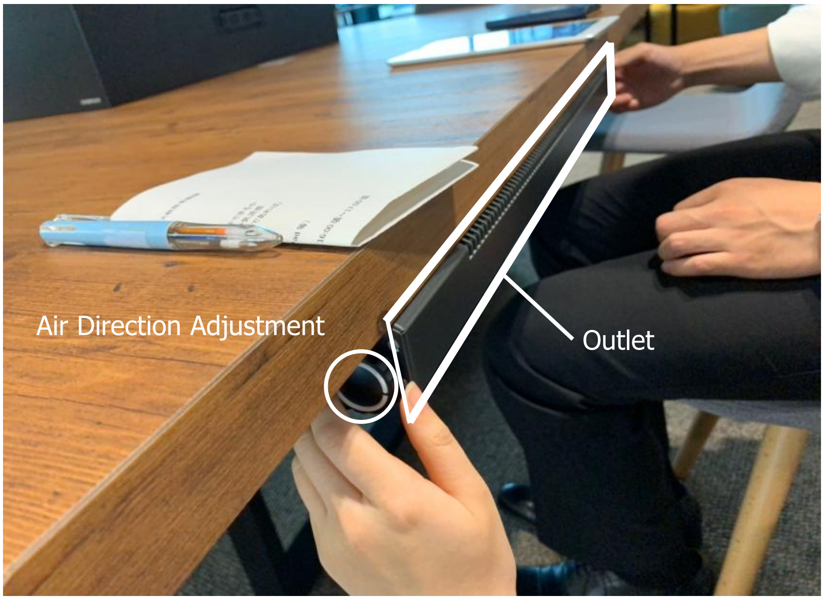
WASEDA University



Cooling capacity 150W

Desk PECS

WASEDA University



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Desk PECS

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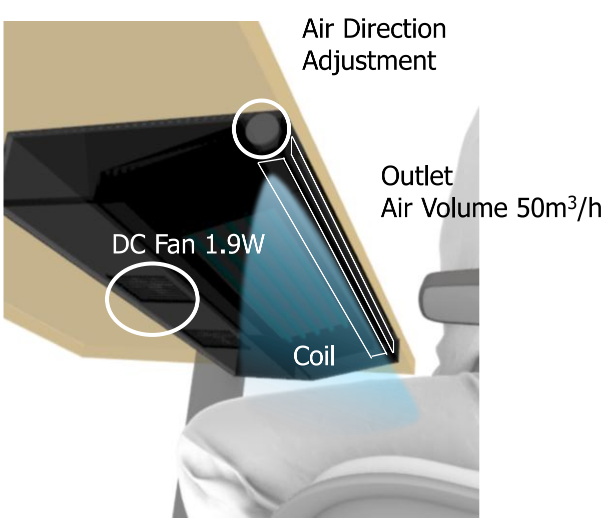

Cooling capacity 70W

Department of Architecture, WASEDA University

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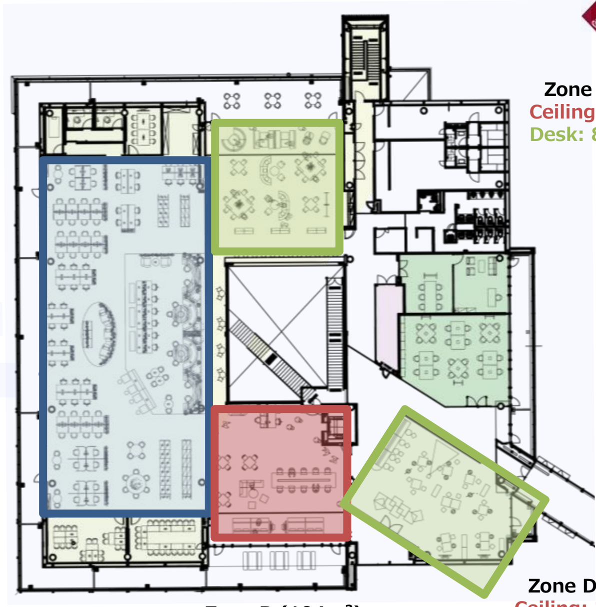
Zone A (634m²)
Ceiling: 57 units
Partition: 30 units
Desk: 28 units

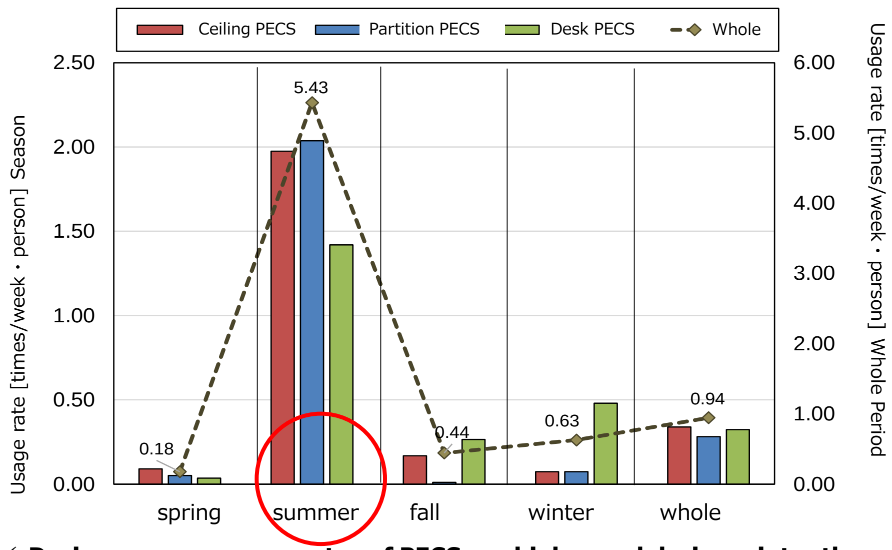


Zone C (204m²)
Ceiling: 36 units
Desk: 8 units

Zone B (194m²)
Ceiling: 34 units
Partition: 10 units
Desk: 18 units

Zone D (274m²)
Ceiling: 38 units

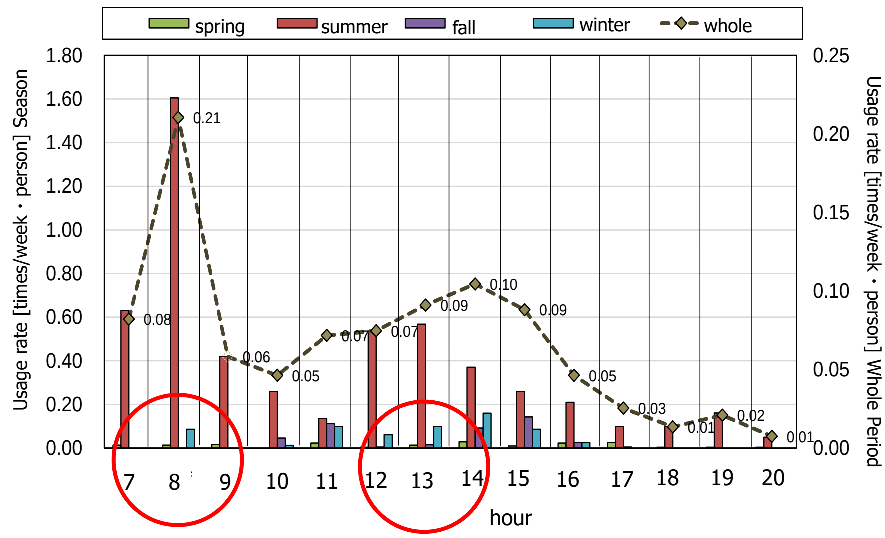
Season Usage Rates of PECS



✓ **During summer usage rates of PECS are higher and during winter they use desk type PECS for warming.**

Daily Usage Rate of PECS

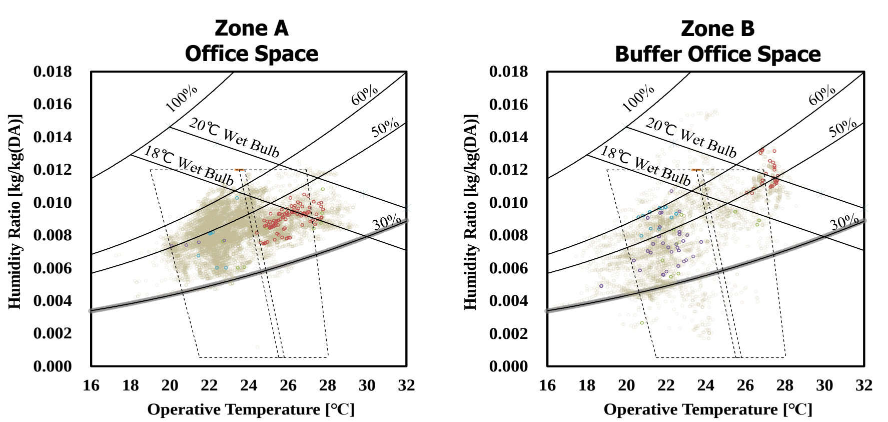
WASEDA University



✓ **More use in the morning and after lunch due to high metabolic rate.**

Ambient Thermal Conditions

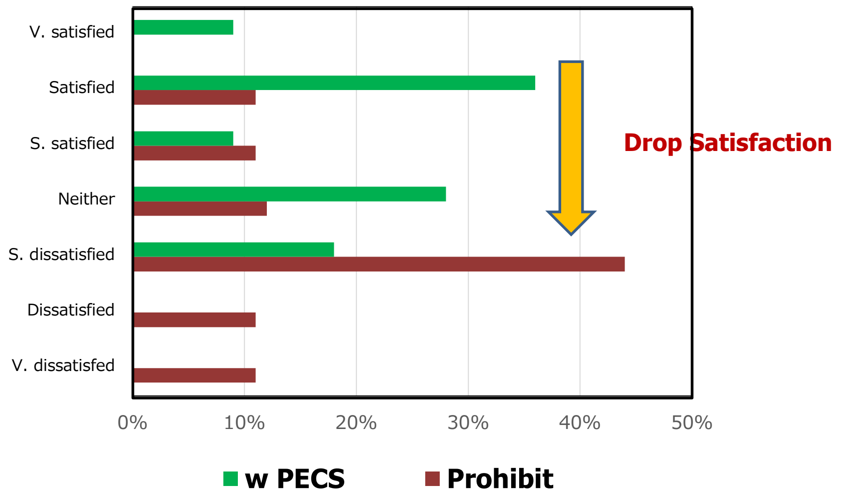
WASEDA University



: w/o PECS
: Spring with PECS
: Summer with PECS
: Fall with PECS
: Winter with PECS

- ✓ **In office space (Zone A), they use PECS in the morning and after lunch due to high metabolic rate.**
- ✓ **Buffer office space (Zone B), they use PECS to compensate thermal sensation.**

Percentage of Satisfied



We prohibit to use PECS system during certain period.

Conclusions

T Innovation Center opened in January 2020
- ✓ In office building unit net Zero Energy and Emission were achieved during 2021.
- ✓ Three types of PECS are installed in the different area.
- ✓ System specifications are described.

Usages of PECS are investigated
- ✓ During summer usage rates of PECS were higher and during winter they use desk type PECS for warming.
- ✓ They used PECS more in the morning and after lunch due to high metabolic rate.
- ✓ In office space (Zone A), they used PECS in the morning and after lunch.
- ✓ Buffer office space (Zone B), they used PECS to compensate thermal sensation.

We prohibited to use PECS system during a certain period.
- ✓ Percentage of dissatisfied significantly increased w/o PECS.

Acknowledgments

Presented Project and Research are conducted in collaboration with the following companies and universities:

- ✓ Takasago Thermal Engineering Co., Ltd.
- ✓ Mitsubishi Jisho Design
- ✓ Takenaka Cooperation
- ✓ Kandenko Co., Ltd.
- ✓ Yamato Co., Ltd.
- ✓ Shin-ichi Tanabe, Waseda University
- ✓ Masanari Ukai, Waseda University
- ✓ Yasunori Akashi, The University of Tokyo
- ✓ Shohei Miyata , The University of Tokyo