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

IEA-EBC Annex 87

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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

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2001-2005

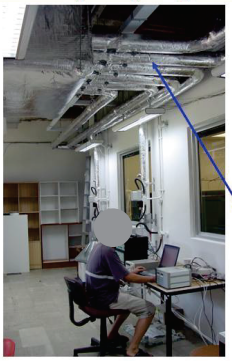
Desk-mounted PV System integrated with Ceiling Supply MV System

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).

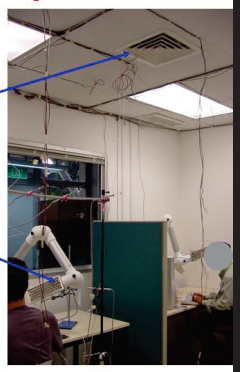
2001-2005

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



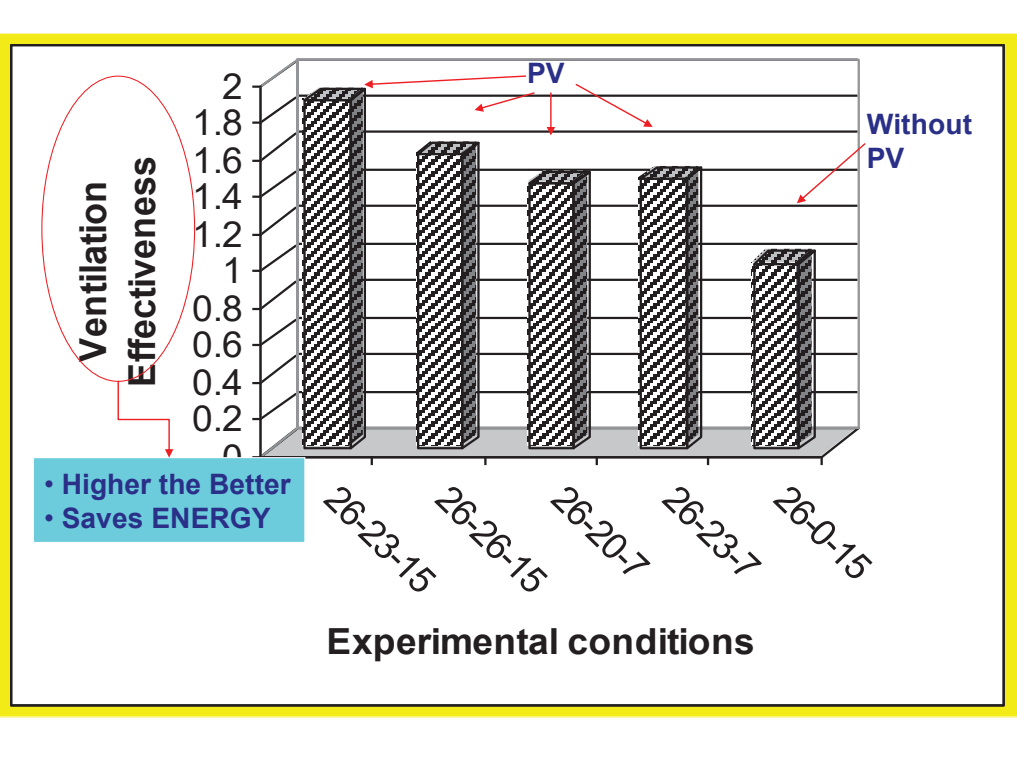
Outside the Chamber

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



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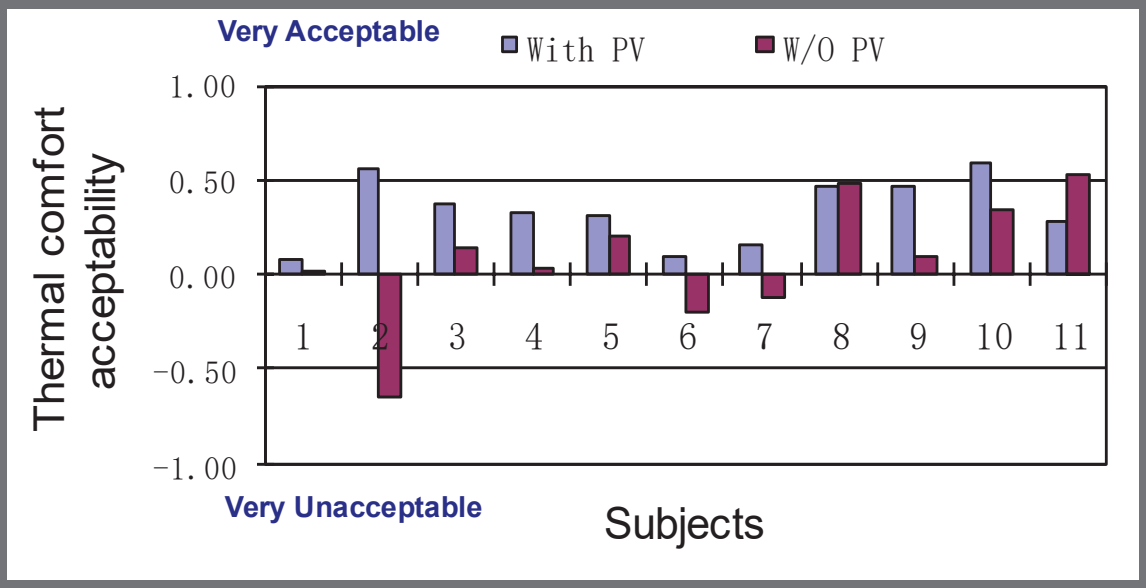
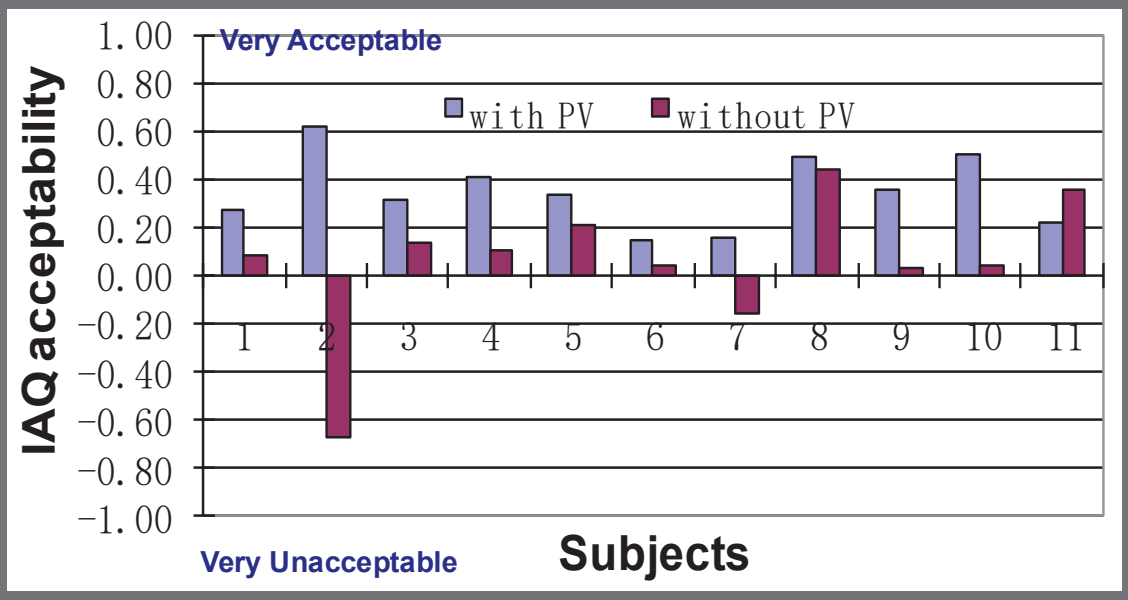
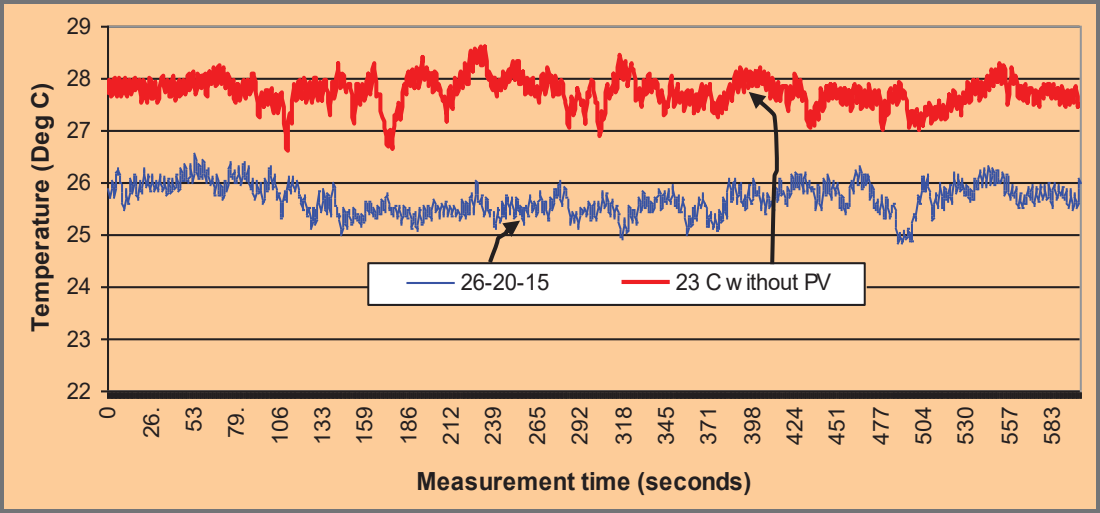


Mean responses of Thermal Comfort acceptability

2001-2005



Mean responses of IAQ acceptability



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

2001-2005

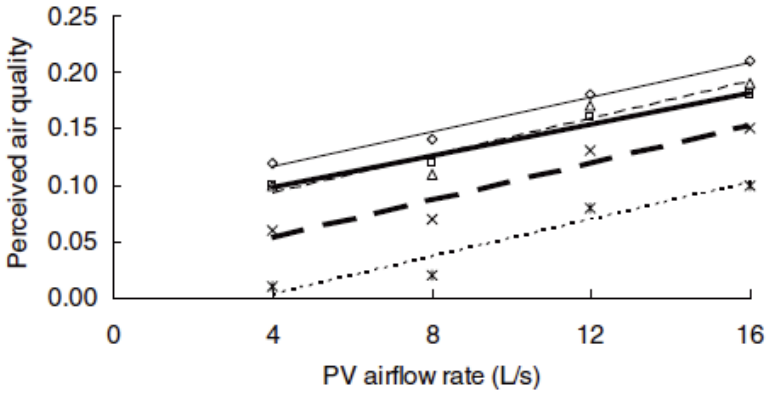
Energy savings occur due to

- 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

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

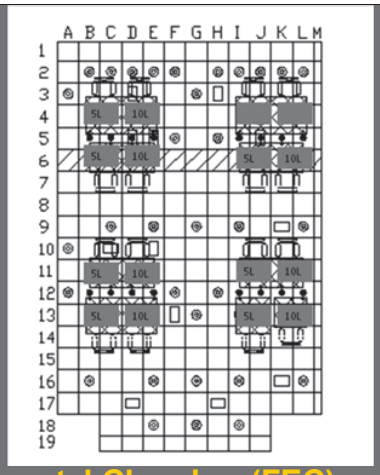
2007-2010

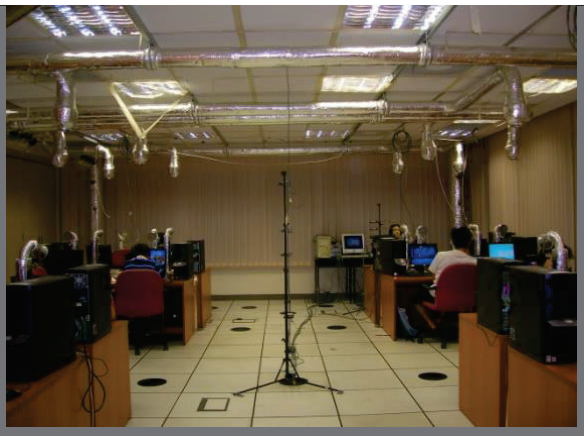
Desk-mounted PV System Integrated with UFAD System

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 .

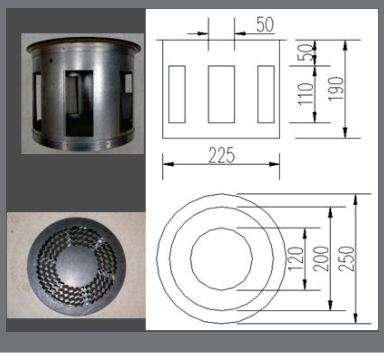
Li Ruixin, S.C.Sekhar and Arsen Melikov, "Thermal comfort and IAQ assessment of under-floor air distribution system integrated with personalized ventilation in hot and humid climate". Building and Environment journal, Vol 45 (2010): 1906-1913. (United Kingdom).

2007-2010

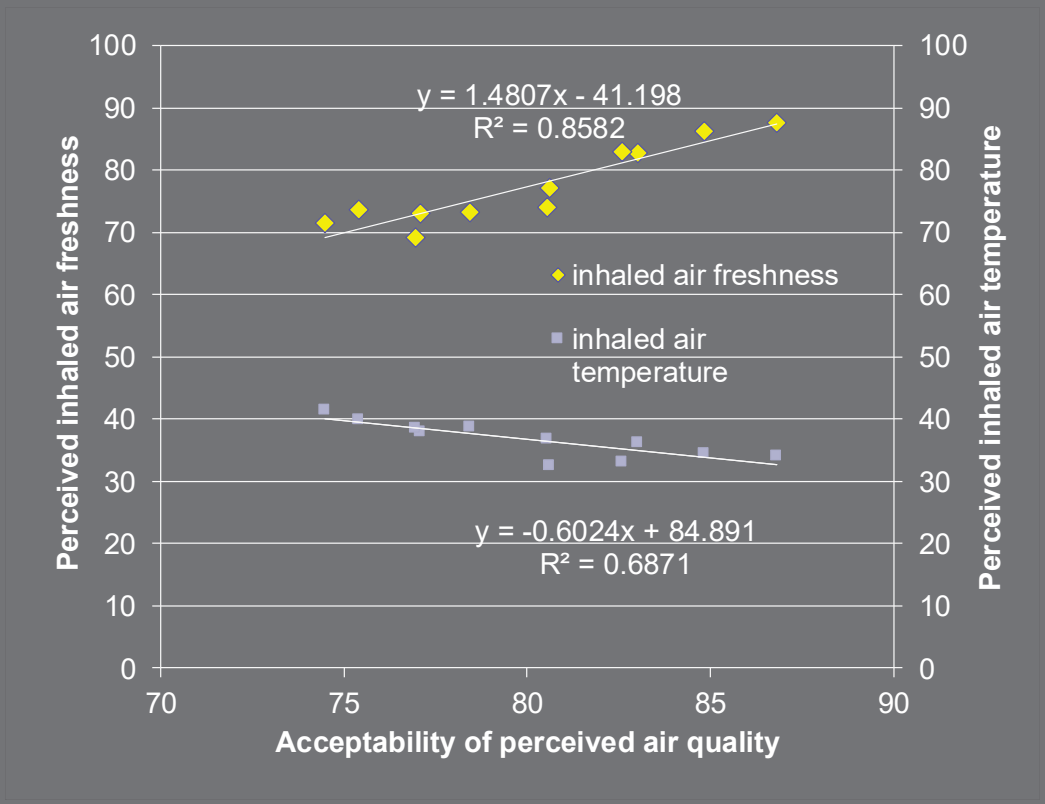




Field Environmental Chamber (FEC) experimental setup - Desk mounted PV with UFAD system

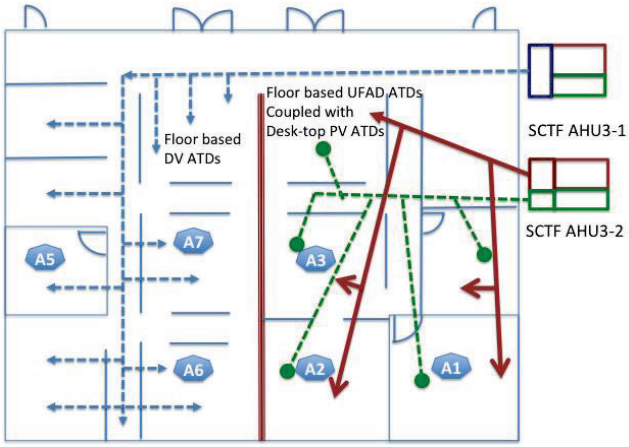


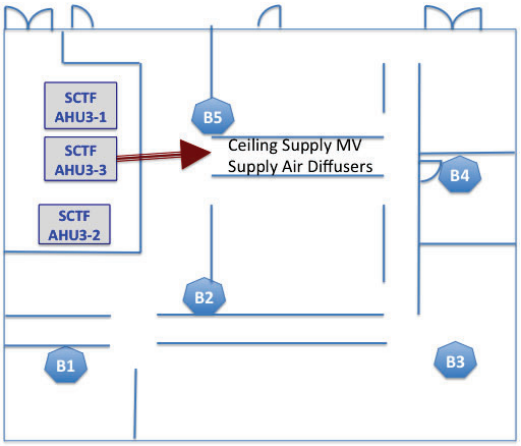
2007-2010



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

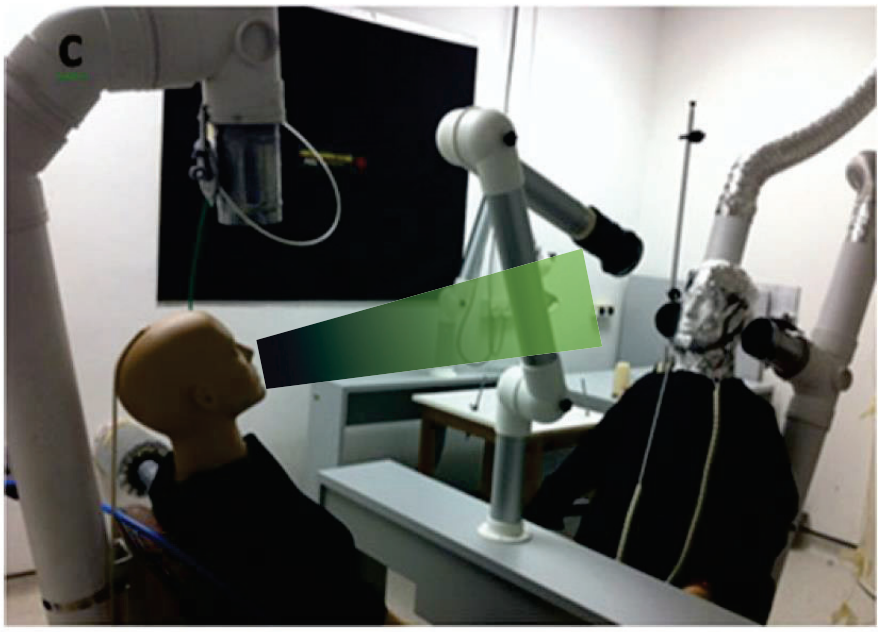
Personalised Ventilation – Personalised Exhaust System

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

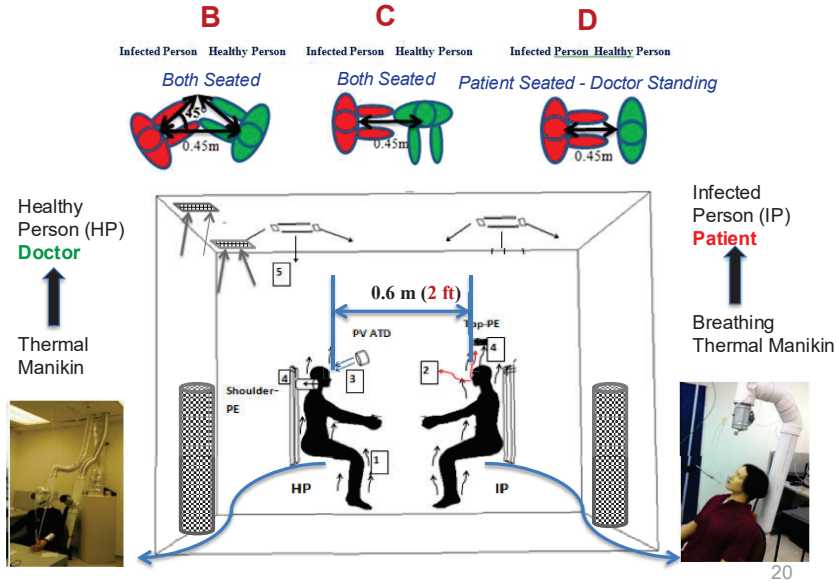
2011-2015



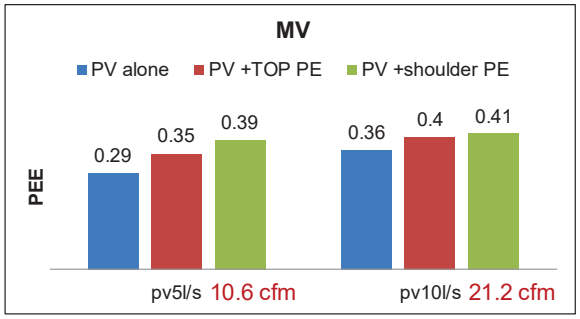
Perf of PV-PE system - Airborne infn control

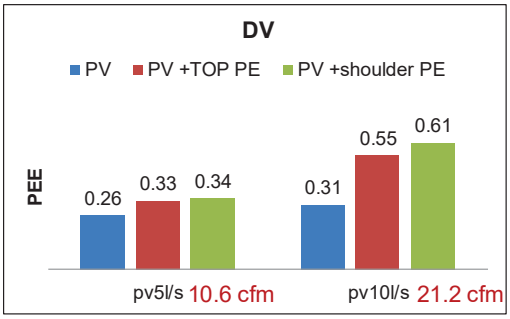
2011-2015

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





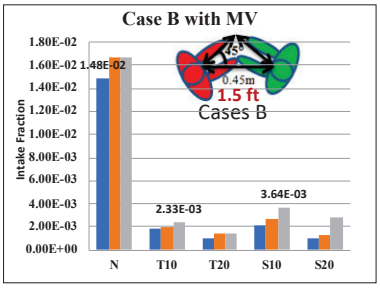
Combined PV and PE for healthy person can achieve the highest PEE

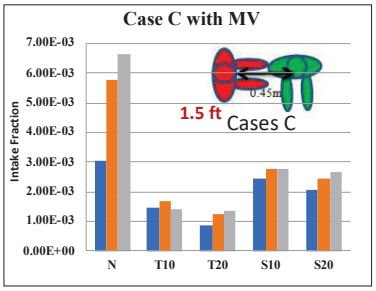
Shoulder-PE performs better than top-PE in terms of pulling more PV air towards the breathing zone

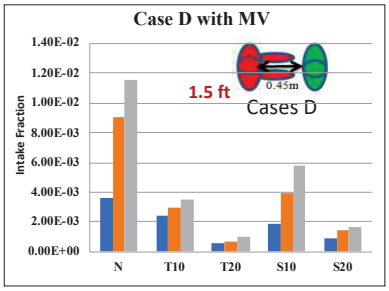
Change of intake fraction over time

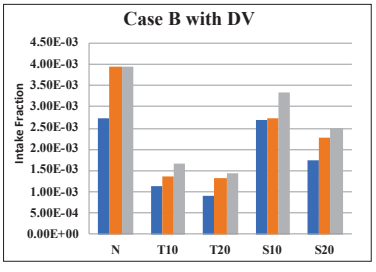
21 cfm 42 cfm

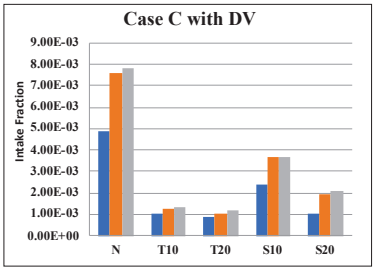
N: No PE; T10: Top-PE 10l/s; T20: Top-PE 20l/s
S10: Shoulder-PE 10l/s; S20:Shoulder-PE 20l/s

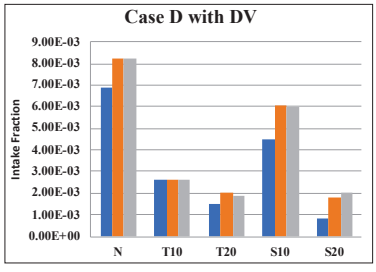












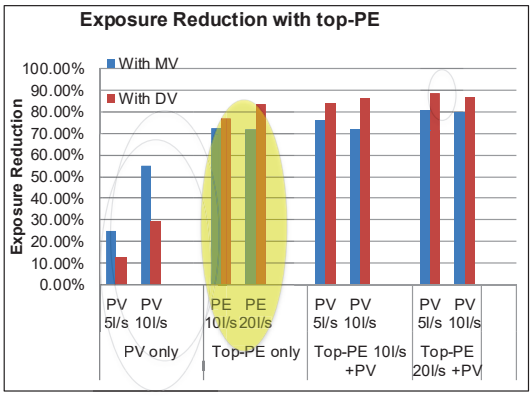
Overall - Infection risk reduced with PE - by reducing exposure amount for longer exposure time

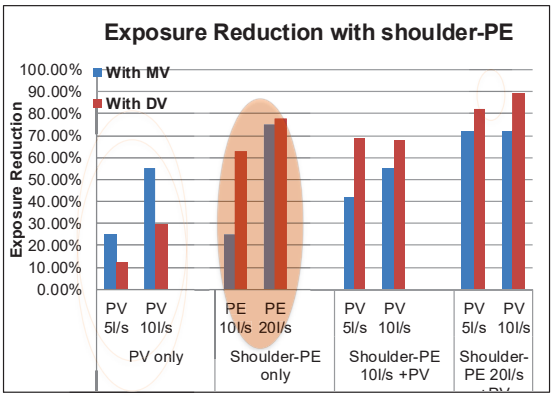
IF by using top-PE is lower than that when using shoulder-PE at the same flow rate at any time interval for most cases, especially at 10 l/s flow rate.

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

Exposure Reduction

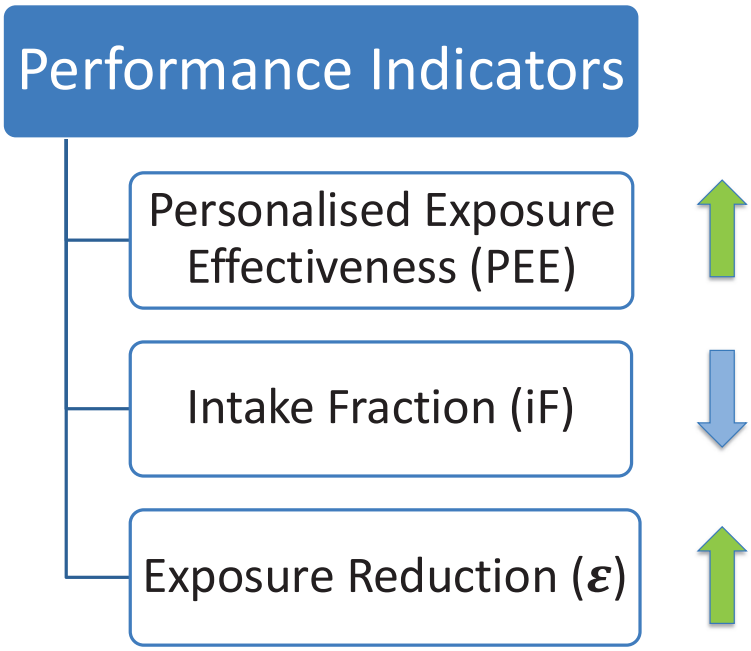
5 l/s = 10.6 cfm 10 l/s = 21 cfm 20 l/s = 42 cfm





- 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

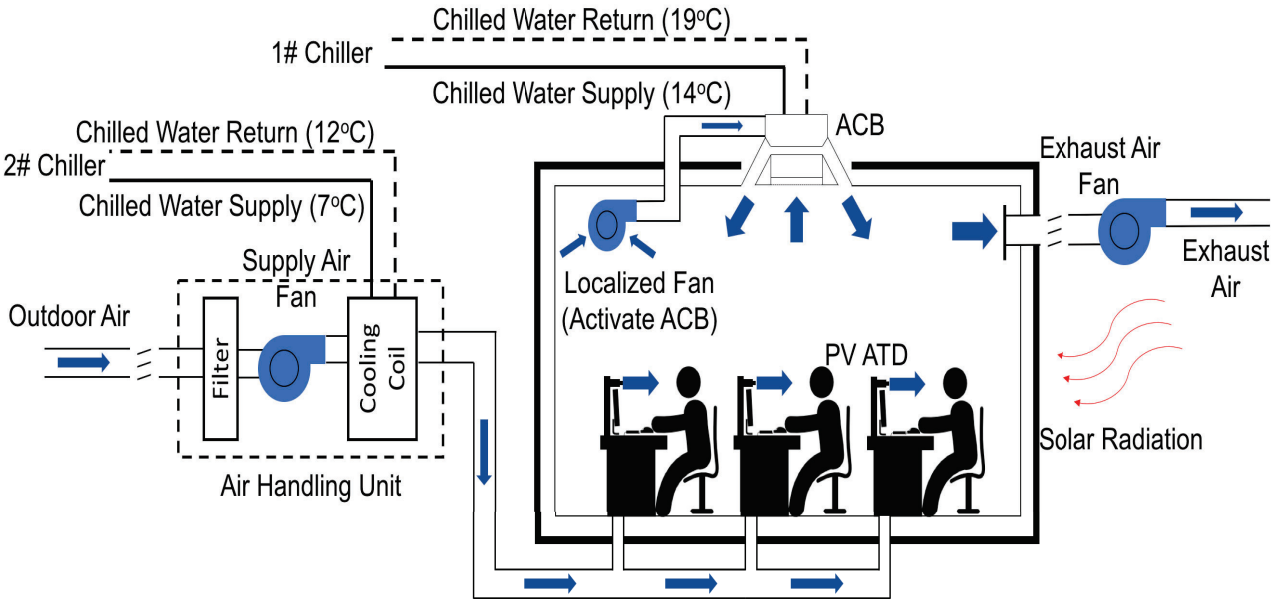


2016-2018

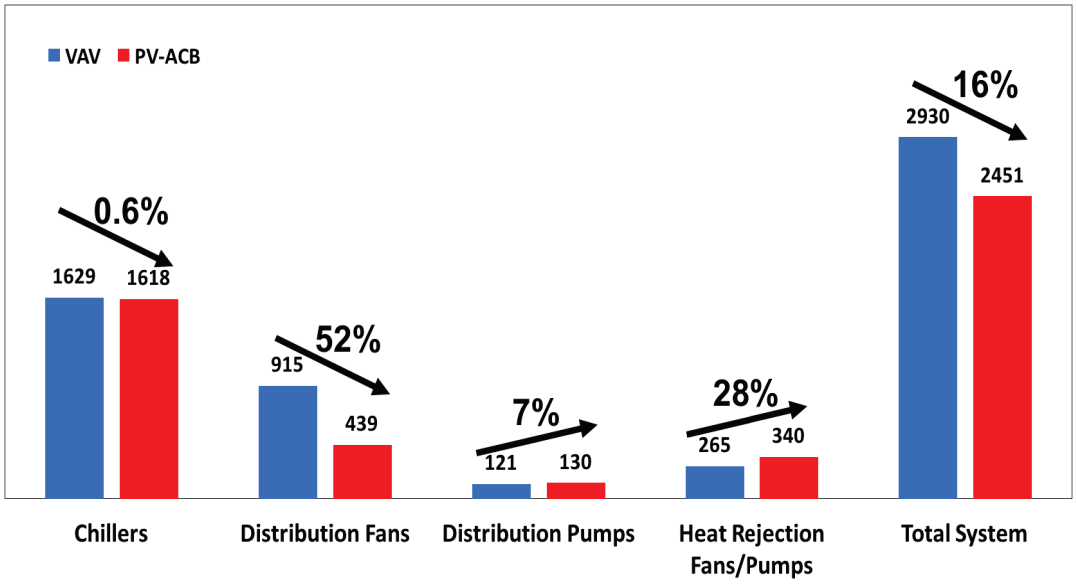
PV System coupled with Chilled Beams

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

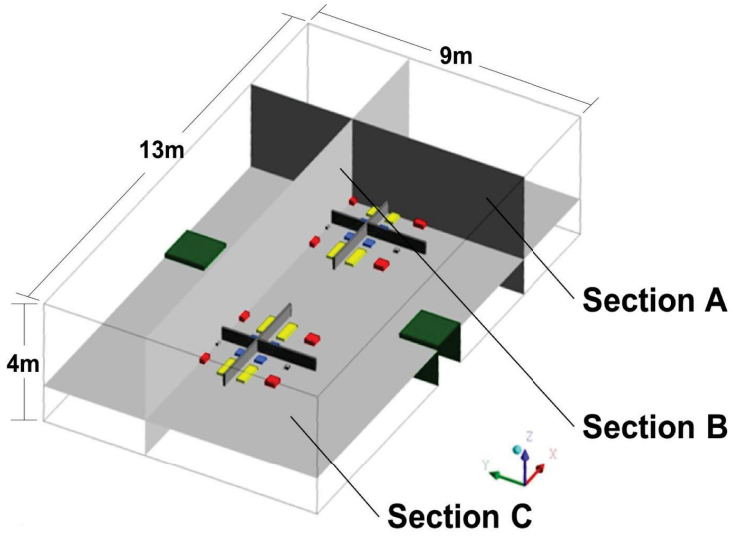


Schematic of integrated personalized ventilation and fan-induced active chilled beams (PV-ACB) air conditioning system

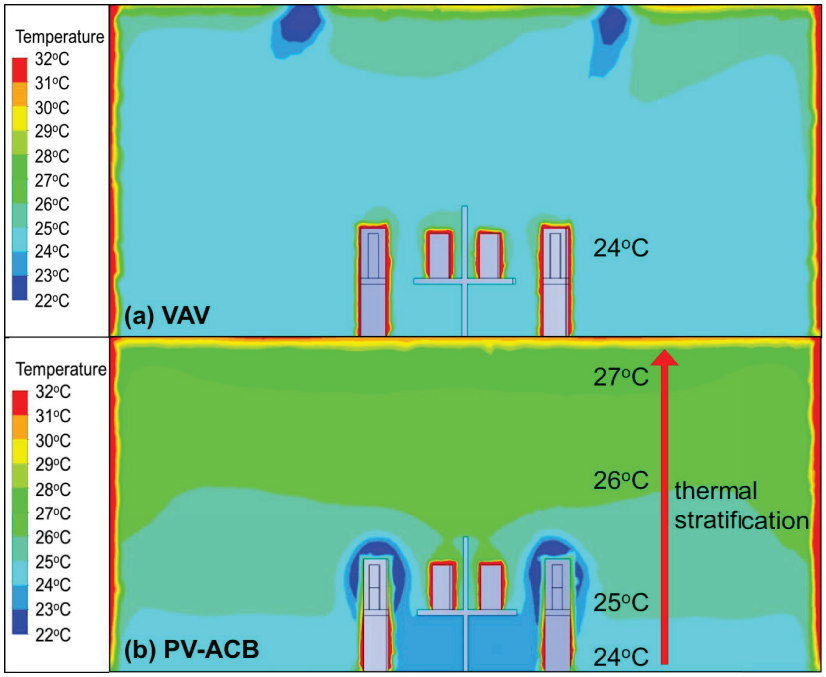


Annual Energy Consumptions of Main Components in VAV and PV-ACB Air Conditioning Systems (Unit: MWH)

2016-2018

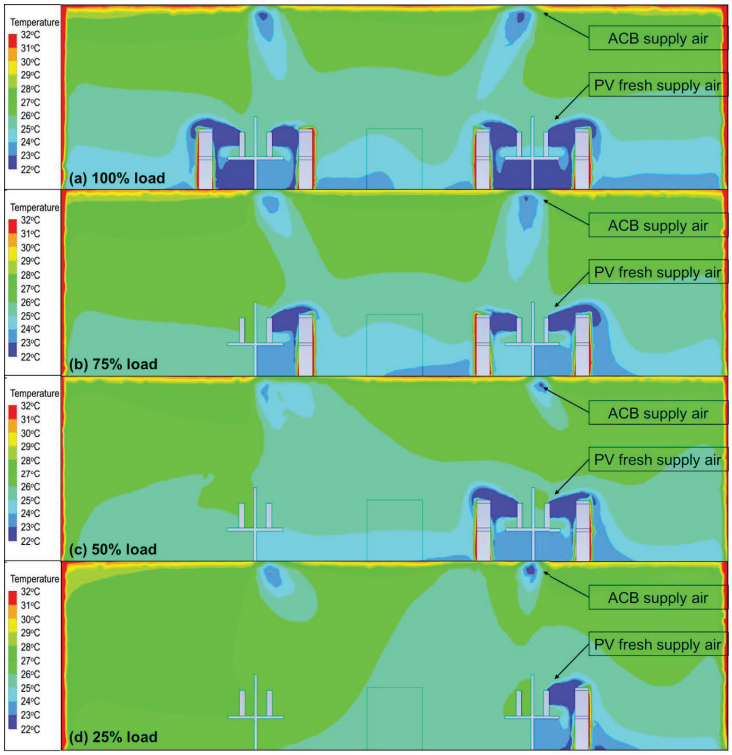


Section A, B and C



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%

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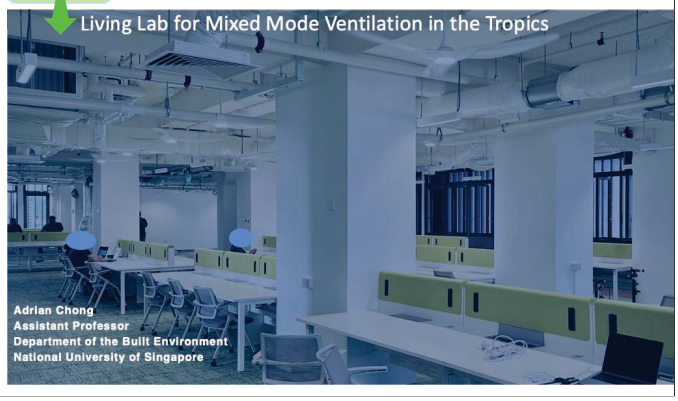
2023 & Beyond
- Field applications



Thank You for your Attention

Q & A

Professor Chandra Sekhar
bdgscs@nus.edu.sg