
DTU

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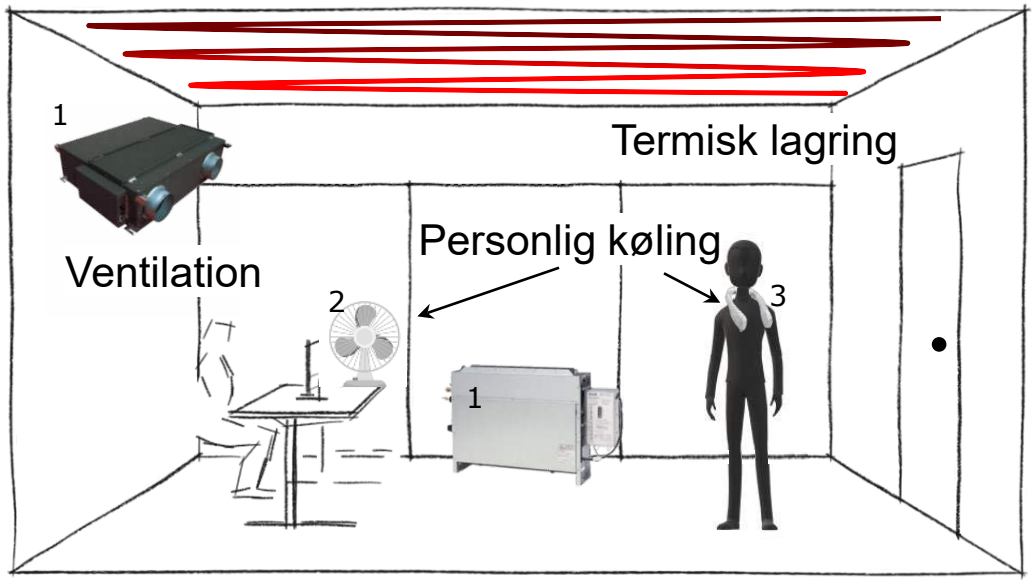
Resilient cooling and ventilation for buildings and people

Baggrund

- B.Sc. Power Engineering, Politehnica University of Bucharest, 2016
- M.Sc. Bæredygtig Energi, Danmarks Tekniske Universitet, 2018

- Ph.D. studerende, 2020
- *Resilient cooling and ventilation for buildings and people*



[1] Mitsubishi Electric
[2] Freepik.com
[3] Coolpriser.dk Neck Fan

Agenda

1. Resilient (modstandsdygtige) bygninger
2. Macro-encapsulated PCM ceiling panels (PCM)
3. Personal environmental control systems (PECS) og luftrensning
4. Konklusion og yderligere undersøgelser

Resilient (modstandsdygtige) bygninger

Klimaforandring

Storme

Smeltende gletsjere

Varmebølger

(Strømafbrydelser)

Skovbrande

Tørke

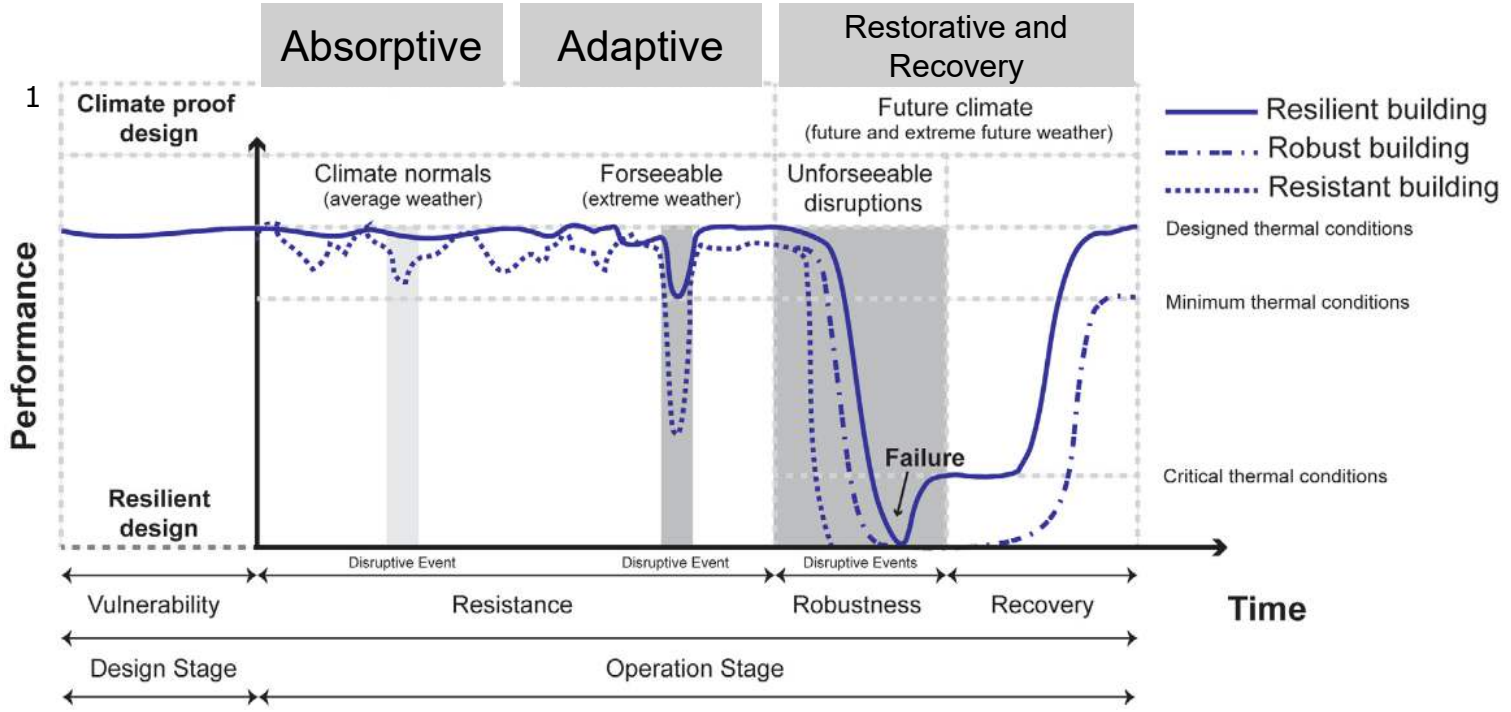
Oversvømmelser

[1] https://www.noaa.goveducationresource-collectionsclimateclimate-change-impacts

Resilient (modstandsdygtige) bygninger

- Modstandsdygtige bygninger overfor klimaforandringer - Annex 80

1



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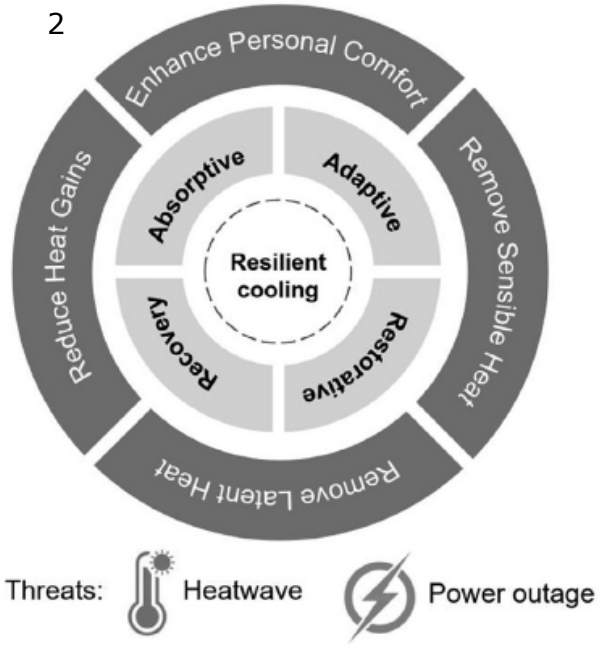
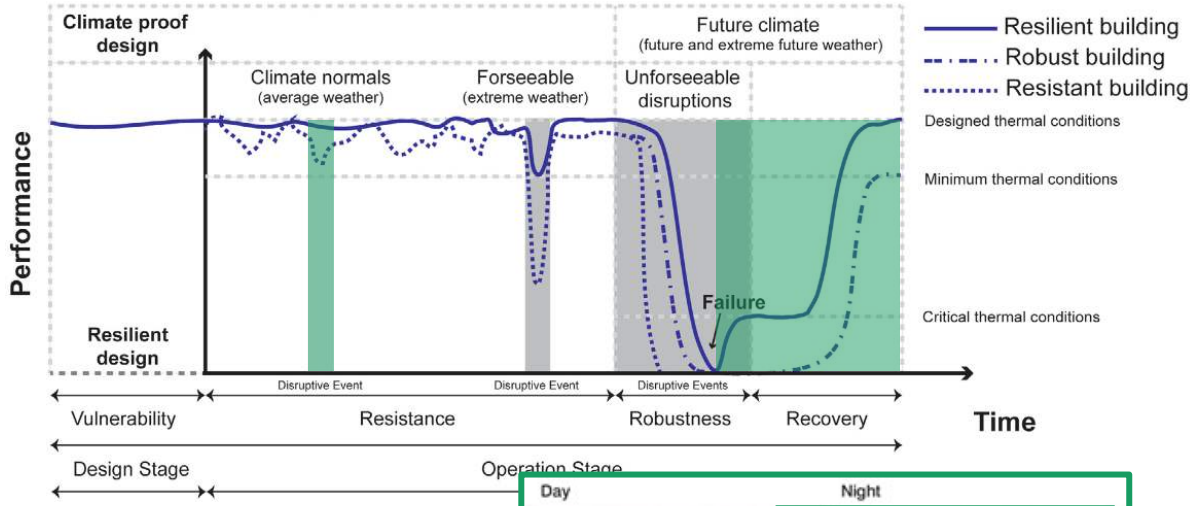


- Hvilke systemer kan vi bruge til at **fremtidssikre vores bygninger**?

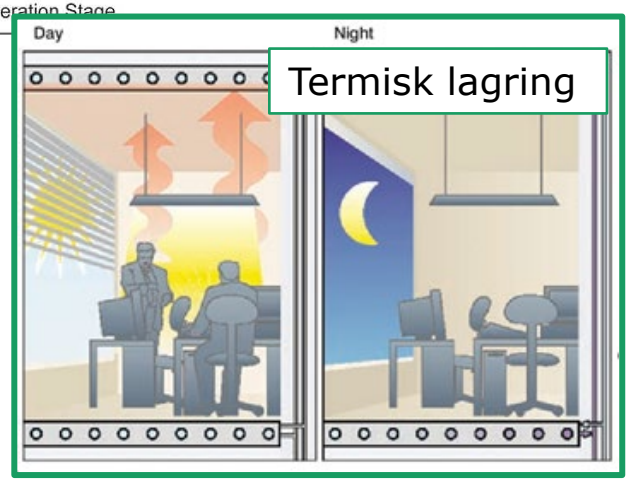
[1] Attia et al., Resilient cooling of buildings to protect against heat waves and power outages: Key concepts and definition, doi.org/10.1016/j.enbuild.2021.110869
[2] Zhang et al., Resilient cooling strategies – A critical review and qualitative assessment, doi.org/10.1016/j.enbuild.2021.111312

Brug af termisk lagring

- Thermo active building systems (TABS)
  - Lav/høj temperatur varme/køle systemer
  - Brug af naturlige varmekilder (RES)
  - Høj effektivitet (f.eks. COP)
  - Peak shaving



- Kan køle uden aktiv varmeafledning (absorberende) med høj genopretningsevne



➢ **Kan kun gennemføres i den indledende byggefase**

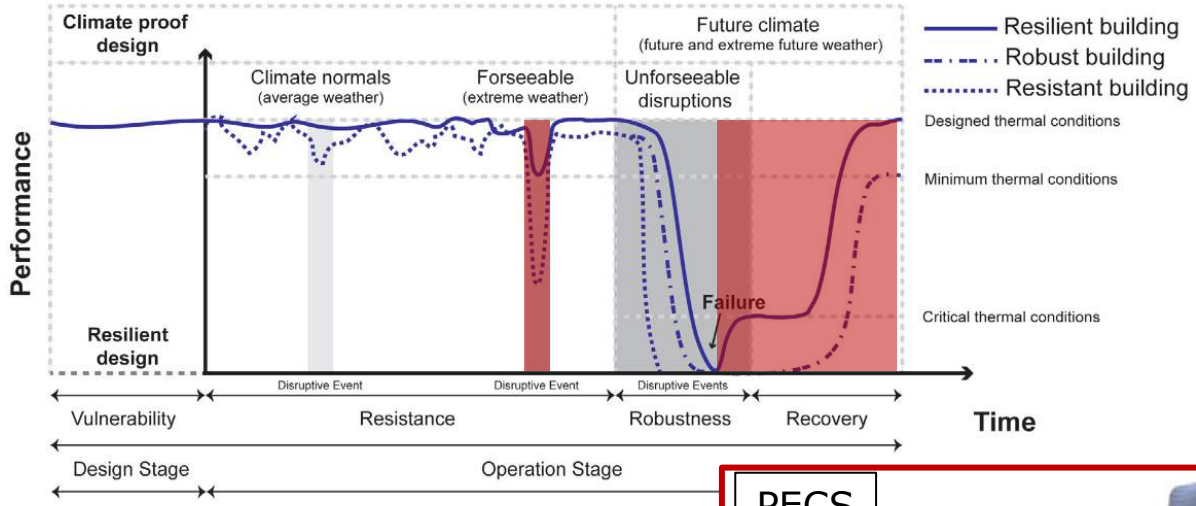
[1] Attia et al., Resilient cooling of buildings to protect against heat waves and power outages: Key concepts and definition, https://doi.org/10.1016/j.enbuild.2021.110869
[2] Olesen, B. W., Thermo Active Building Systems - Using Building Mass To Heat and Cool, ASHRAE Journal 54.2 (2012): 44-52

Personal environmental control system (PECS)

- Konditionering i umiddelbar nærhed og luftrensning
  - Udvidet område med behagelige temperaturer
  - Energi besparelser (10% pr. K)
  - Imødekomme interpersonelle forskelle
  - Ren luft

- Ikke absorberende, adaptive, høj genopretningsevne

➢**Varmeudveksling princip, design, styring**

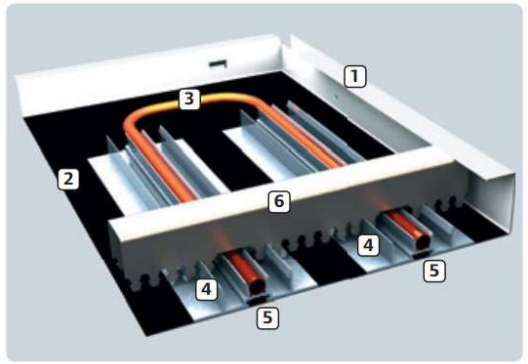


[1] Attia et al., Resilient cooling of buildings to protect against heat waves and power outages: Key concepts and definition, doi.org/10.1016/j.enbuild.2021.110869
[2] https://portalfield.com/news/economy/2244
[3] Philips 800 Air cleaner
[4] Shinoda, A qualitative evaluation of the resiliency of PECS, AIVC 2022

Macro-encapsulated PCM ceiling panels (MEP)

MEP design

Markedsprodukt



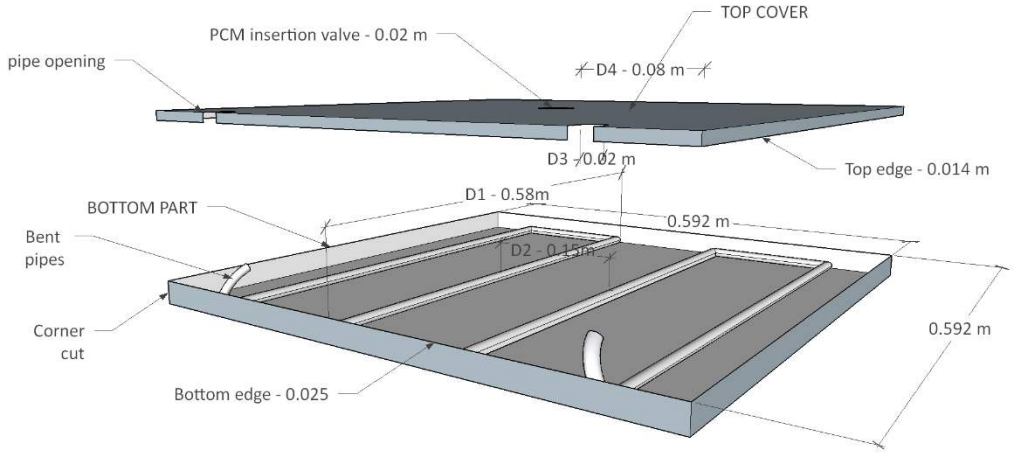
Structure of VARICOOL Spectra M

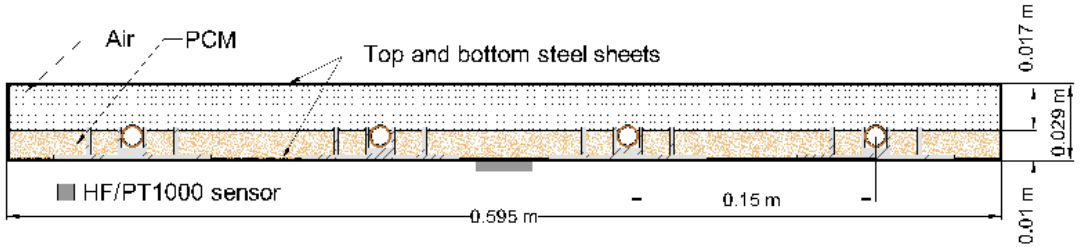
1. Sheet steel ceiling panel
2. Acoustic fleece
3. Copper serpentine pipework d_a = 10 mm
4. Aluminium heat-conducting profile
5. Magnetic strip
6. U-mounting rail

PCM (Paraffin)

- Macro-indkapsling
- 21 – 25 °C faseændringsområde

Prototype





[1]VARICOOL Spectra, Uponor, "Download-centre," [Online]. Available: https://www.uponor.co.uk/services/download-centre. [Accessed 6 May 2018].

[2]Bogatu et al., An experimental study of the active cooling performance of a novel radiant ceiling panel containing phase change material (PCM) 2021

MEP konstruktion

- Ny opbygning med **direkte kontakt** mellem de indlejrede rør til vandcirkulationen og **faseændringsmaterialet** (PCM)
- **Paraffin** som PCM – ikke korroderende materiale med **høj latent varmekapacitet** og **ingen underafkølingseffekt** med faseændringsområde på mellem 21 °C og 25 °C.
- Den **varmekapacitet pr. volumen** for **PCM'en** inden for smelteområdet er **~15 gange** af **cement**.

[1]R. T. GmbH, "rubitherm.eu," Rubitherm, 2020. [Online]. Available: https://www.rubitherm.eu/media/products/datasheets/Techdata_-RT24_EN_09102020.PDF. [Accessed 02 February 2019].

[2]Bogatu et al., An experimental study of the active cooling performance of a novel radiant ceiling panel containing phase change material (PCM) 2021

TABS lighed

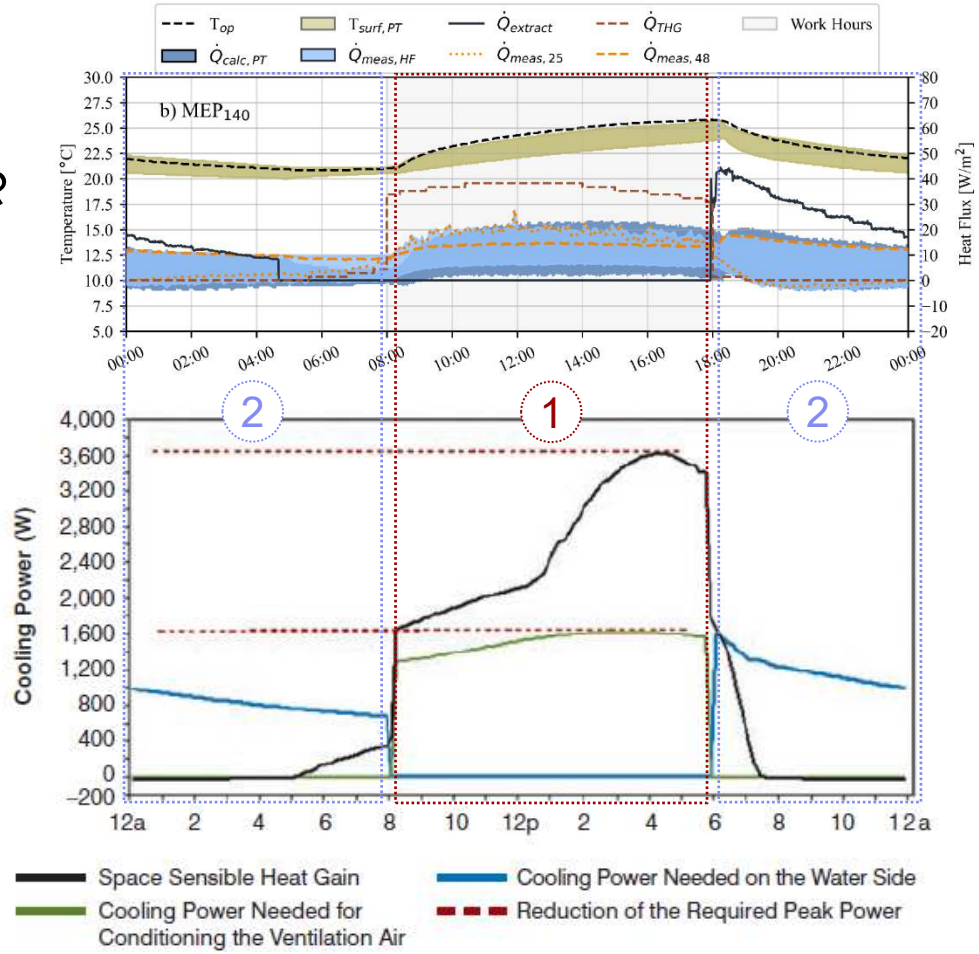
1 <u>Arbejdstid</u> – bygningsmasse absorberer varme

2 <u>Udenfor arbejdstiden</u> – vand cirkulering til varmeudvinding; cyklus genstart

<u>TABS ≈ PCM</u> – lignede drift, varmefjernelse profil **og energiforbrug** med ingen signifikant forskel i det resulterende **termisk miljø**

MEP

TABS



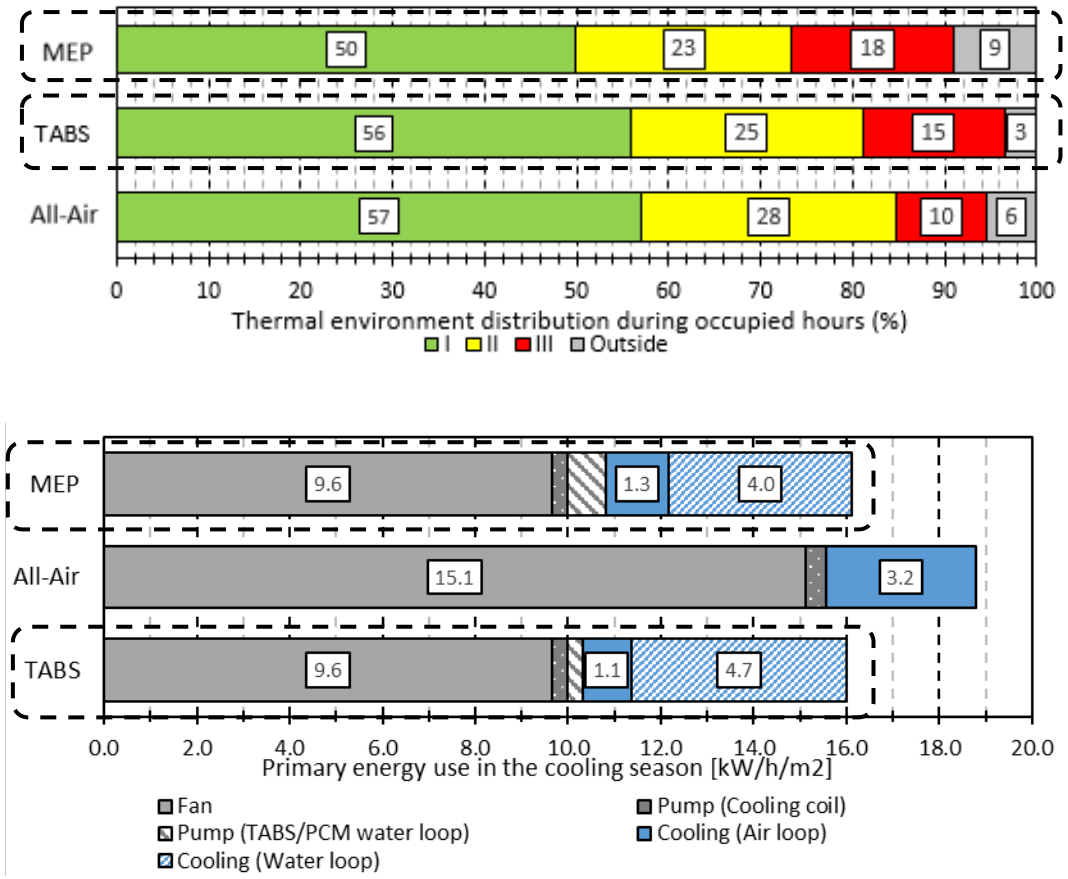
*$\dot{Q}_{extract}$: varmeudvinding gennem vand; $\dot{Q}_{meas}$: varmestrøm gennem rum og MEP; T_{op}; operativ temperatur; T_{surf}: overfladetemperatur;

[1]Bogatu et al., An experimental study of the active cooling performance of a novel radiant ceiling panel containing phase change material (PCM) 2021

[2]B.W. Olesen, Thermo Active Building Systems Using Building Mass to Heat and Cool, ASHRAE 54 (2) (2012) 44–52.

TABS lighed

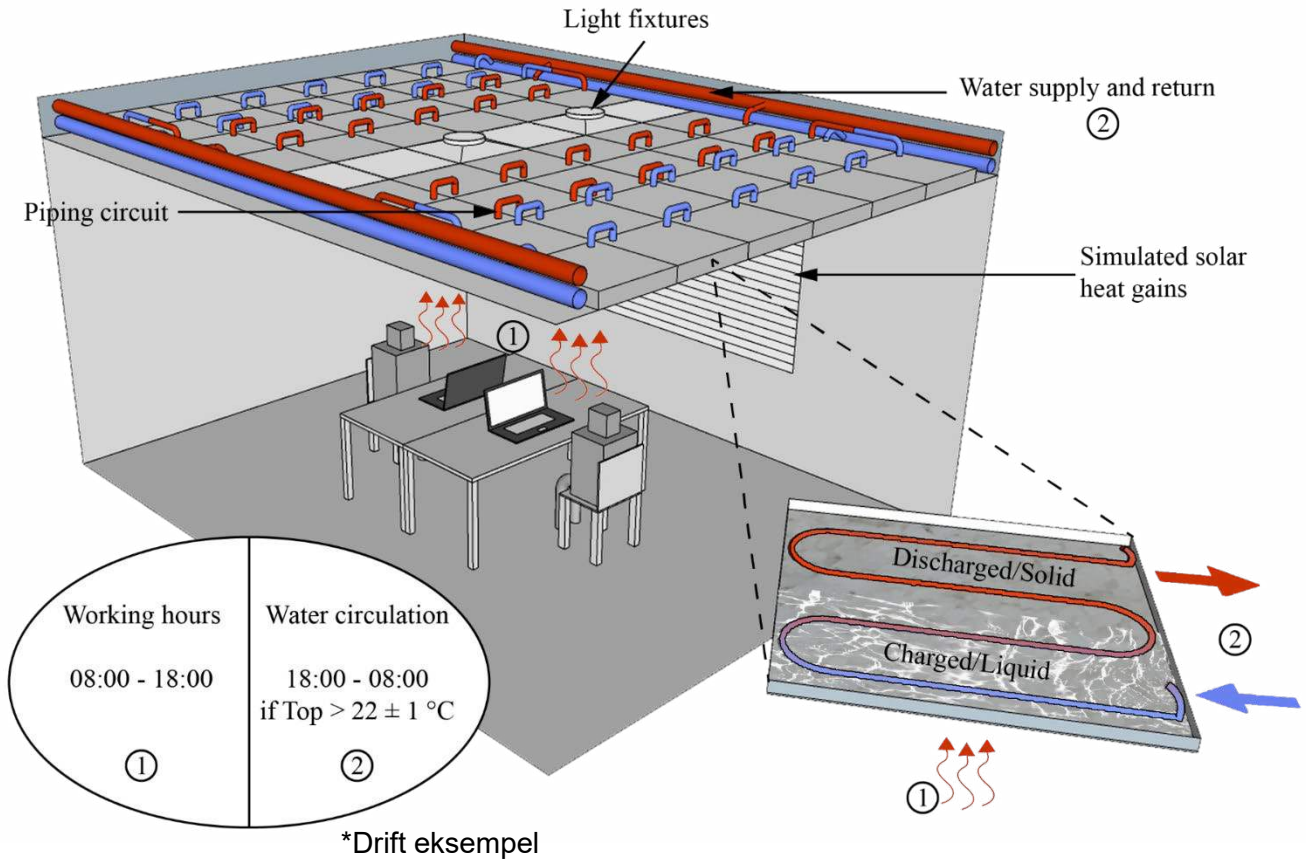
- Simulering af en åben-plans kontor (51 m^2) med en ydervæg
- Samme termiske indeklima som TABS; EN16798-1:2019 Kategorier I (23.5 - 25.5 °C), II (23 - 26°C), III (22 - 27°C)
- Samme primær energiforbrug
- Høj temperatur kølesystem ($T_{sw} \cong 20°C$)



[1]Allerhand et al., "Energy and Thermal Comfort Performance Evaluation of PCM Ceiling Panels for Cooling a Renovated Office Room," Proceedings of CLIMA 2019, p. https://doi.org/10.1051/e3sconf/201911103020, 2019.

Drift

- Fordelene ved både strålingspaneler og thermo active building systems (TABS)
- Load shifting og fleksibilitet



*Drift eksempel

[1]Bogatu et al., An experimental study of the active cooling performance of a novel radiant ceiling panel containing phase change material (PCM) 2021

Personal environmental control systems (PECS)

PECS eksempler

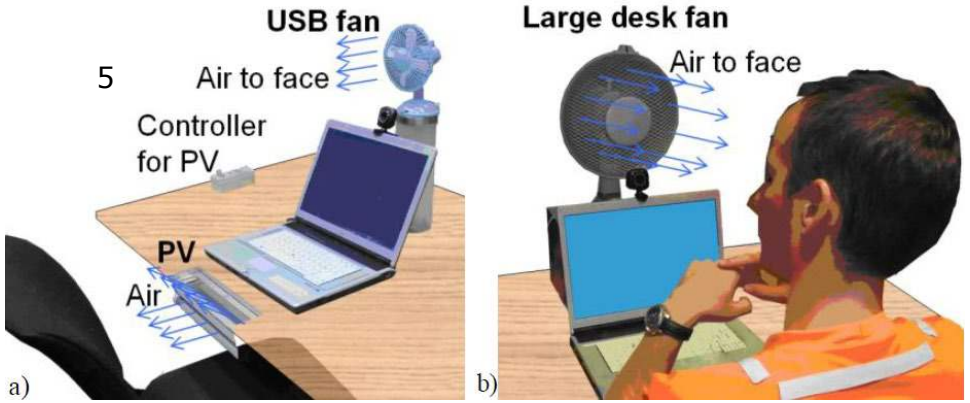
1

2

3

4

5



[1] https://www.ahrend.com/en/collection/desks/balance-comfort/#specifications

[2] https://embrlabs.com/

[3] https://portalfield.com/news/economy/2244

[4] Melikov et al. 2013, "Impact of Air Movement on Eye Symptoms", Proceedings of 11th REHVA World Congress and the 8th International Conference on Indoor Air Quality, Ventilation and Energy Conservation in Buildings

[5] A. K. Melikov, Advanced air distribution: improving health and comfort while reducing energy use, Keynote: Indoor air 2014

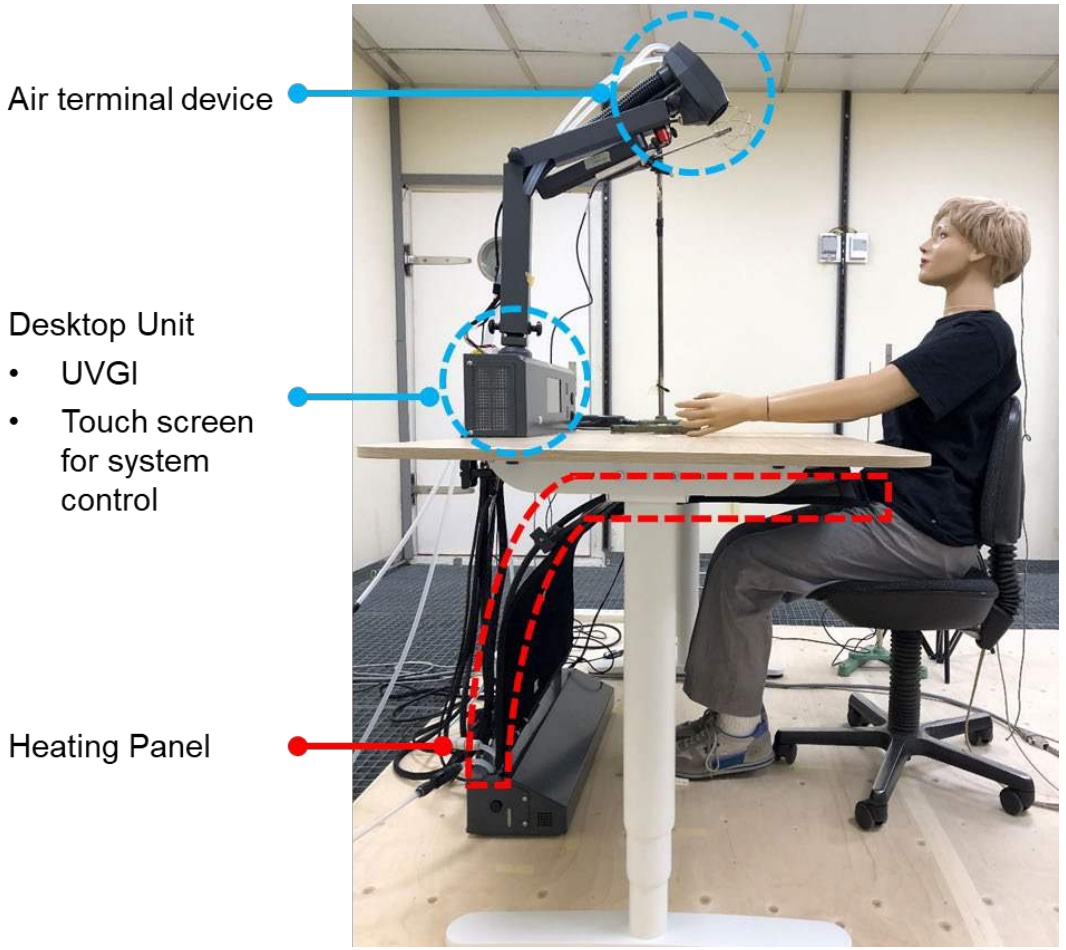
Design

- Diskomfort ved varmeforsyning til hovedet

  Varm underkrop (ekstremiteter)

- Kølig fornemmelse til hovedet er behagelig

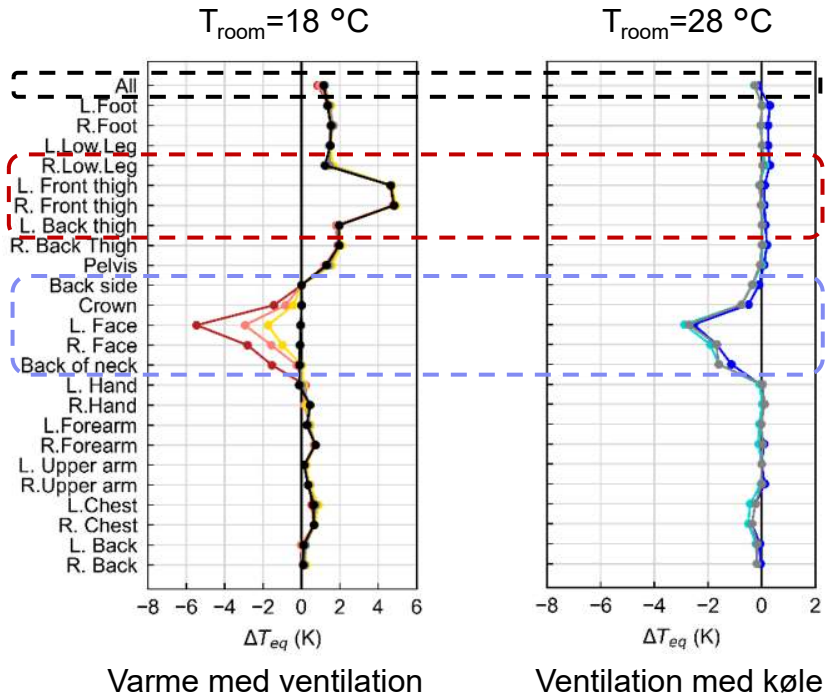
  Køle overkrop



[1] Kazanci et al., Development and initial testing of a Personalized Environmental Control Systems (PECS), CLIMA 2022

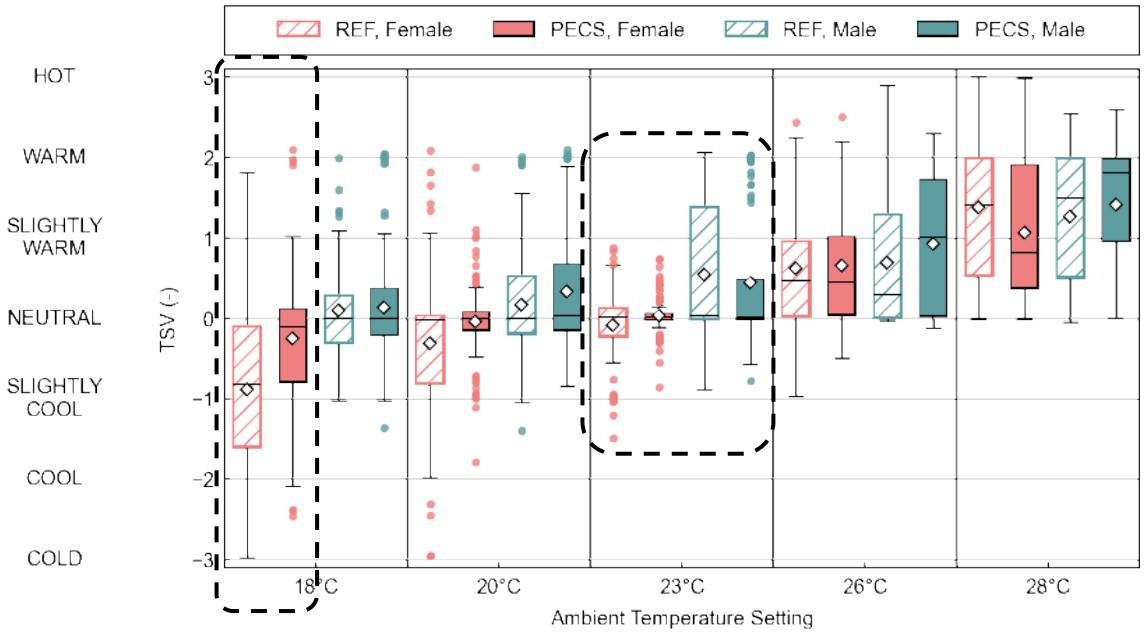
Evaluering

- Termisk vejrtræknings manikin eksperiment



Varme med ventilation Ventilation med køle

- Eksperiment med forsøgspersoner (18 – 28 °C)



➢ Samlet set stærkere varme- end køleeffekt

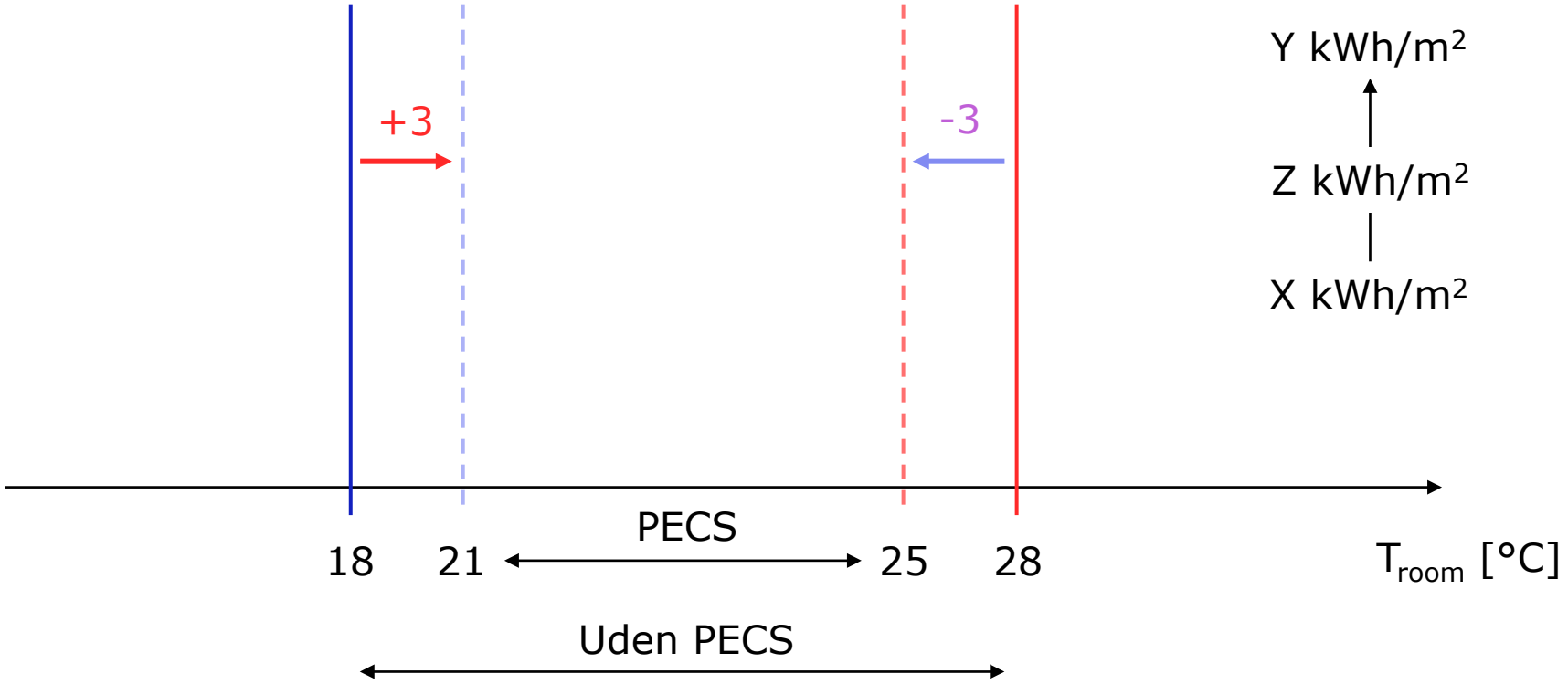
➢ Ventilationseffektivitet > 1

➢ Flere “neutral” stemmer mellem 18 og 23 °C

[1] Kazanci et al., Development and initial testing of a Personalized Environmnetal Control Systems (PECS), CLIMA 2022

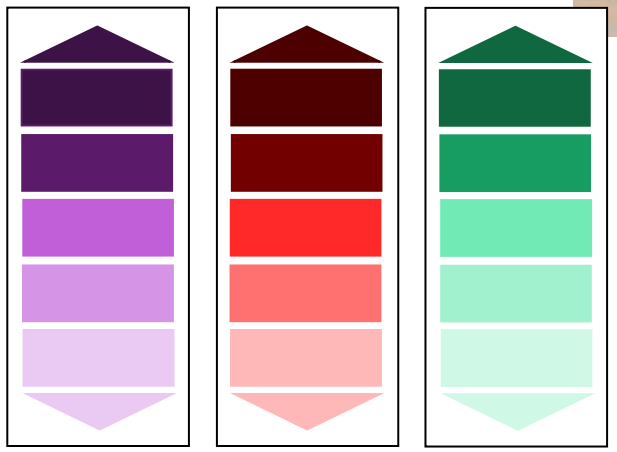
Drift

Udvidet område med behagelige temperatur

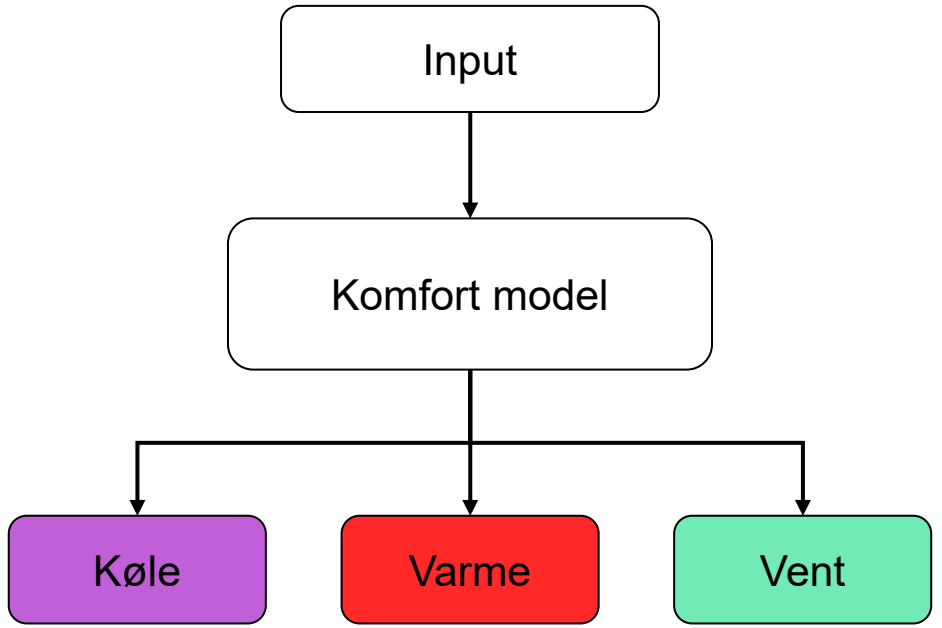


Styring

Manuel styring



Automatisk styring

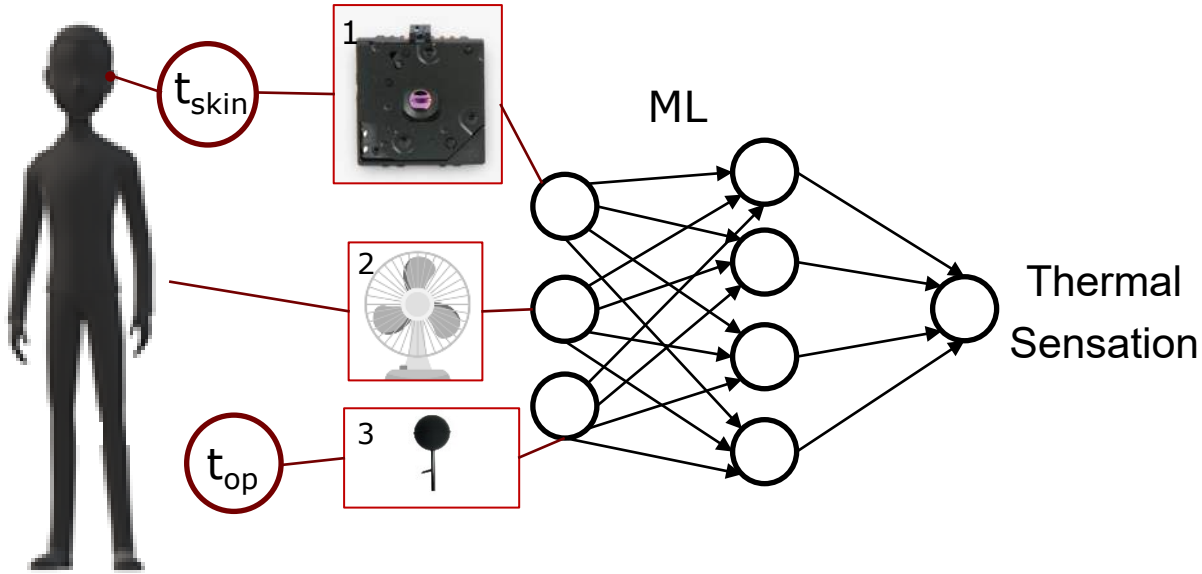


[1] https://www.danfoss.com/da-dk/products/dhs/radiator-and-room-thermostats/radiator-thermostats/radiator-sensors/

Automatisk styring

PMV ...

... skift til **personlig**



- Find de meste relevante termiske indikatorer (miljø, fysiologisk, adfærd, egenskaber)
- Data driven - machine learning (ML)
- Forudsige termisk fornemmelse

Komfort model

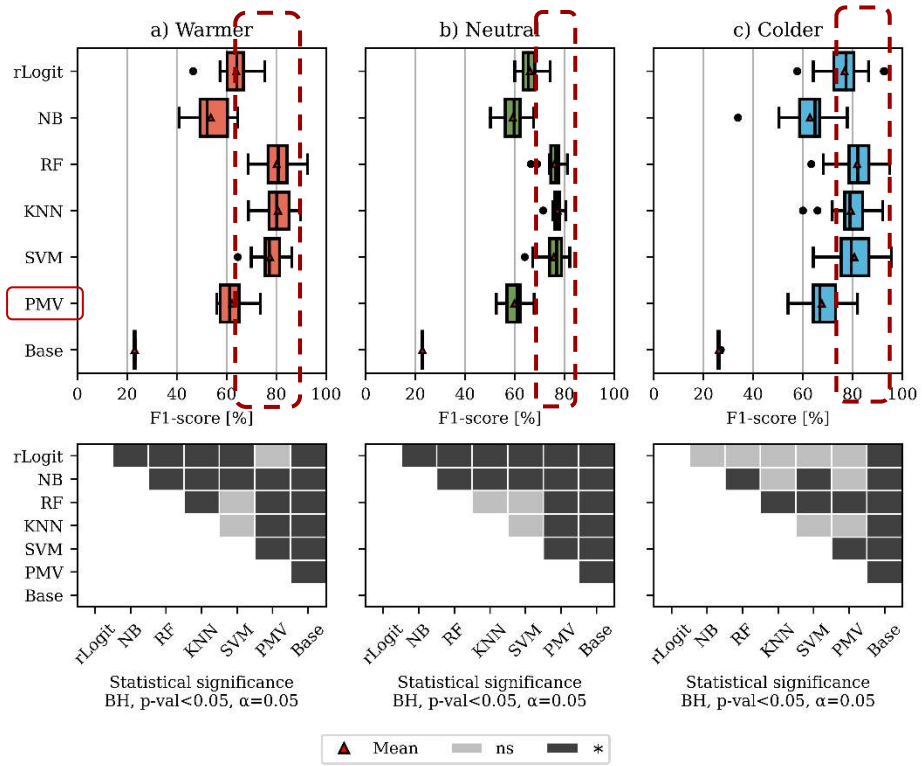
Miljø | Fysiologisk | Adfærd | Egenskaber

T | T_h | Varme | BMI

RH | RH_h | Køle | Alder

Vent

Evaluering



➢ Men forventet - PMV designet til at forudsige den termisk komfort af en gruppe mennesker

[1] Personalised Thermal Comfort Model for the Automatic Control of a Newly Developed Personalised Environmental Control System (PECS), Dragos-Ioan Bogatu et al., In Press: IAQVEC 2023

Konklusioner og fremtidige retninger

Konklusion

- **Vi kan fremtidssikre vores bygninger…**

- **MEP**

  Resilient - termisk lagring

  Alsidighed - nye og renoverede bygninger

  Tilpasning - fordele ved TABS og strålingspaneler

  Bæredygtighed - høj temp. kølesystem, RES

  Effektivitet og fleksibilitet - fleksibilitet der gavner energisystemet og forbedrer effektiviteten

  Økonomi - marginalt dyrere (2%) end et ventilationssystem ved høje kølebelastninger

- **PECS og luftrensning**

  Resilient - udvidet område med behagelige temperaturer; filtrering

  Besparelser - mindre køle- og varme forbrug

  Komfort og luftkvalitet - imødekomme personlige ønsker; effektiv ventilation

Yderligere undersøgelser

- Optimering
- Test og simulering
- Enkel gennemførelse
- Showcase
- Konkurrenceevne og bæredygtighed

Tak!

Vejledere: Assoc. Prof. Ongun B. Kazanci, Ph.D.
Prof. Bjarne W. Olesen, Ph.D.

Kontakt

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