Mainstreaming Personal Comfort Devices (PCDs):

Enabling Modular Personal Controls for a Wide Range of Energy and Comfort Applications

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Introduction

Goal
Provide guidance on integrating Personal Comfort Devices (PCDs) (a zero GWP technology) in large commercial buildings to provide targeted occupant comfort and reduce HVAC energy and resulting emissions.

Objectives
Develop and test at least **two novel PCDs**

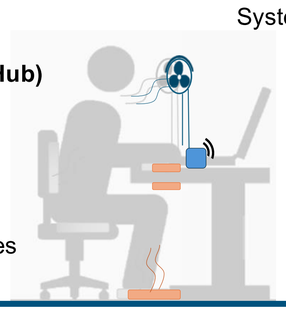
Develop and test a personal deskspace hub called the **Personal Control Hub** (PC Hub)

Create and test a customizable **Personal Control Ecosystem** that integrates the PC Hub with other PCDs, other devices, and/or building management system, and

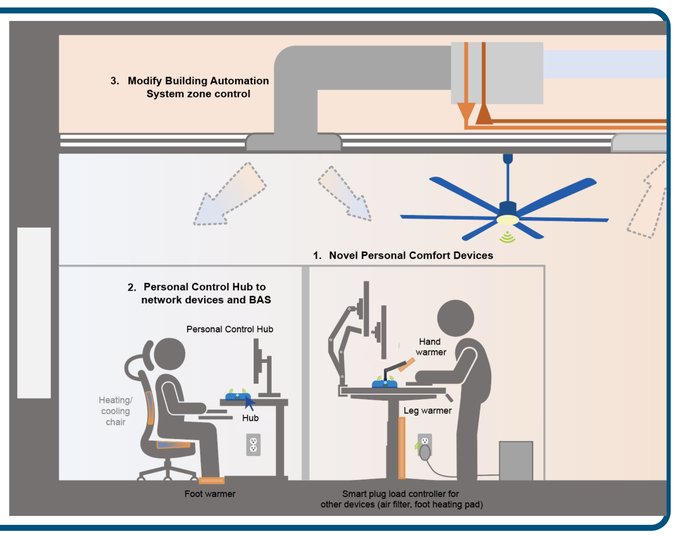
Create a web-based **PCD Design Guidebook** for HVAC engineers and real estate managers to choose and specify the best PCD for their application and context.

Personal Comfort Devices (PCDs)
- Wrist heated/cooled desktop pad
- Hand warmer
- Under desk foot/leg warmer
- Heated/cooled chair
- Desktop fan (cooling)
- Air purifier

Personal Control Hub (PC Hub)
- Sensors: Occupancy (IR), Temperature, Relative Humidity, PM2.5, CO2, VOCs
- User Interface
- Network to local PC Devices
- Local computation

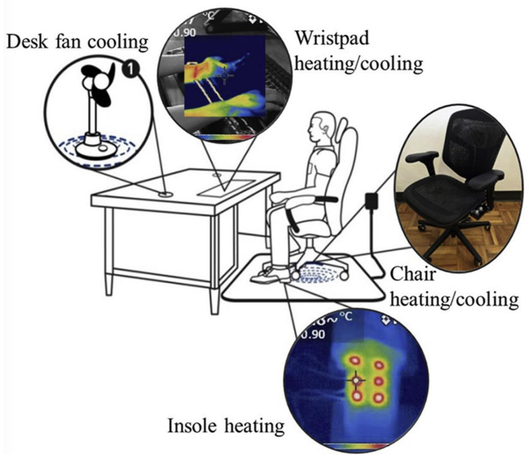


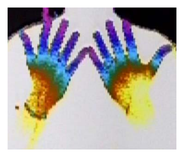
PC Ecosystem
- Connect PC Hub with:
  - other devices (air purifiers via smart plug)
  - other PC Hubs in zone
  - Building Management Systems



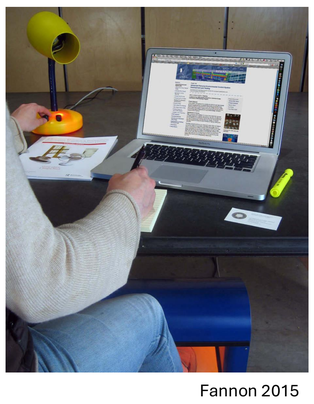
Background

Certain parts of the body dictate overall satisfaction with thermal comfort (Zhang 2004).
- Warm face dictates overall discomfort comfort vote in warm environments
- Cold feet/hands dictates overall discomfort vote in cool environments
- Fast way to cool/warm body: wrist





Early PCD prototypes



Fannon 2015

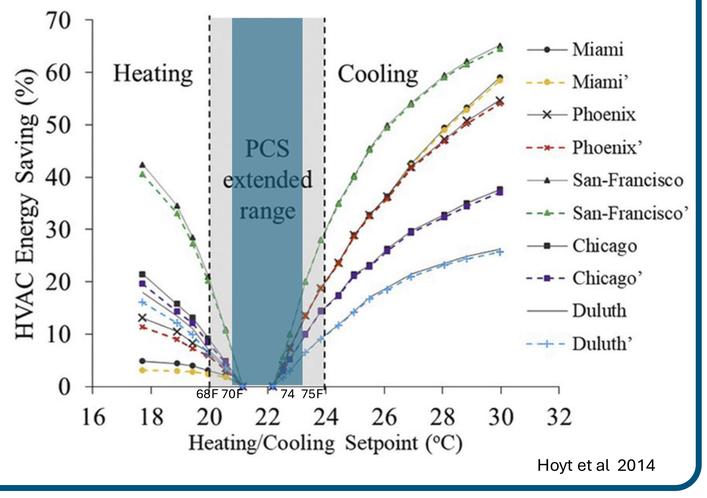
Integrating PCDs with Building Systems can increase comfort and save energy

- Large commercial buildings often have 70F heating setpoint and 74F cooling setpoint year round
- Expanding the setpoints reduces energy consumption
- Use of PCS can expand the range while keeping people comfortable and reduce HVAC energy use

Field study in building in winter
- Provided footwarmers to 25 occupants
- Lowered heating setpoint from 21.5°C (70.7F) to 19°C (66.2F)
- Surveyed occupants' satisfaction
- Monitored HVAC energy consumption

Results
- Equivalent comfort was maintained
- Over **30% savings** in heating energy over winter

Zhang et al 2015



Hoyt et al 2014

PCD Use Case Development

Outlined commonly available PCDs and categorize (by modality (heating, cooling), cost, interface, power consumption/ interface, network capability).

Desk Fan	Neck Fan	Heated Floor Mat	Heated Insoles	Heated and Cooled Chair	Pocket fan	Hand heater
						
40 watts	4-5 watts	55 watts	10 watts	25 – 100 watts	5 watts	50 watts

Use cases
- **Solving HVAC system problems**

Fix energy issues caused by "Rogue Zone" (single zone that drives whole building HVAC calls), incorrect setpoints, inadequate air distribution, poor system design, poor or incomplete systems commissioning.

- **Resolving thermal preference conflicts among users**

Cater to differences between and among people rather than the building itself: individual differences in preference, clothing and/or metabolic rate, hoteling/hot desking, frequent movement between thermally different spaces.

- **Improving comfort and energy for**
  - **Lobby/reception areas:** Improve comfort of intermittent visitors/patients as well as permanent occupants (receptionist/guard) in spaces impacted by outdoor air.
  - **Conference rooms**: Reduce energy when unoccupied; improve comfort when occupied, especially long meetings.
- **Marketing (comfort for VIPs)**
- **Responding to an emergency or utility signal**

Reduce the intake of outside air due to wildfire, smog, or pollen; load-shifting or curtailment due to a demand response signal from the utility.

- **Saving energy, money, or reducing emissions**

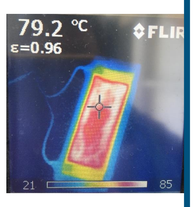
Operating the building efficiently from a cost, energy consumption, or climate perspective: reduce energy consumption in diminished occupancy zone, widening HVAC temperature deadbands, time averaged ventilation, curtailing central equipment operation during high-cost periods, and turning off the boiler to reduce natural gas consumption.

Interviews suggest a PCD must be: Plug and play, easy to manage at scale, durable (like pens or staplers), integrated into expected office work environment, quiet, not powered by batteries, or background rechargeable, and delivered with robust data security if connected to BMS.

Novel PCD Development

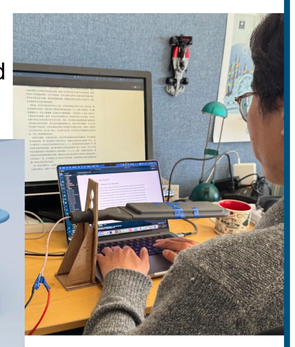
Nanofabric handwarmer

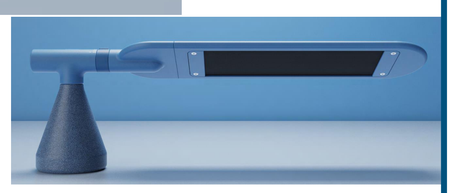
Nanotube material heats up quickly and radiates heat, but does not burn on contact with skin



We settled on the "feather" design: warms hands but stays out of the way of keyboard and screen.

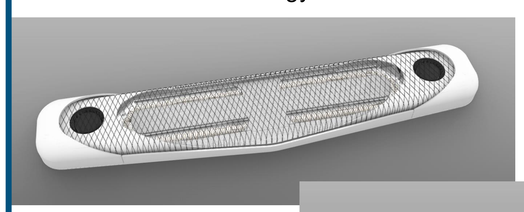
The material is sandwiched between printed circuit boards.

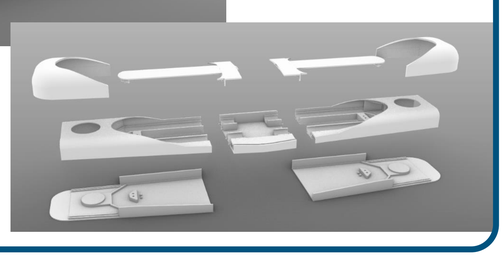




Heated and cooled desktop pad

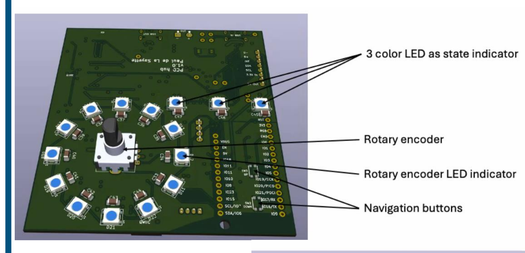
The wrist sits on the pad when typing; the pad provides heating or cooling to the wrist to provide comfort. We decided to use fan cooling and a heating strip element because it was cheaper than thermoelectric technology.

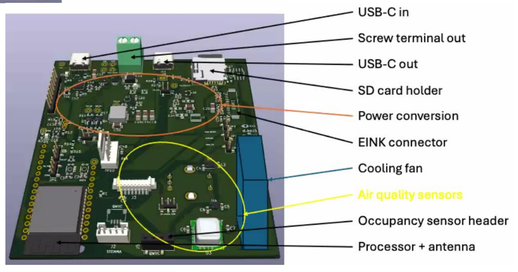




PC Hub Development

We developed an opensource hub with sensors, control interface, LEDs, microcomputer, and network. Built around an ESP32 microcontroller, we are leveraging the integration with Home Assistant.

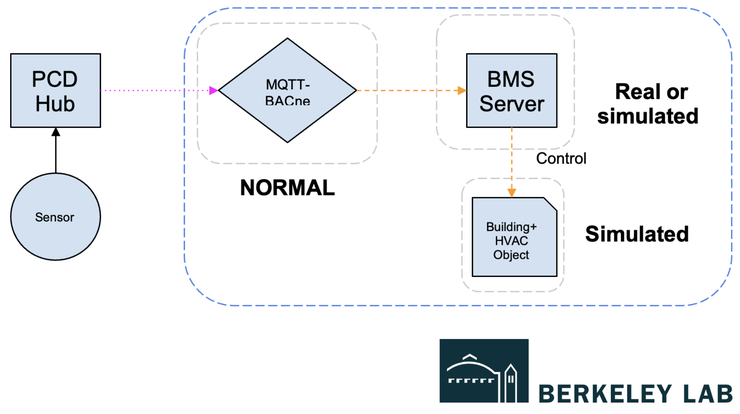




Building Management System Integration

Marco Pritoni, Lazlo Paul, Anand Prakash (LBNL); Carlos Duarte (CBE)

We developed the integration strategy with a BMS: networking layer (e.g., BACnet or device API) and semantic layer (e.g., Brick or ASHRAE standard 223). We developed a simulated testbed (BOPTEST and are developing a testbed in the CBE Chamber as well as Sutardja Dai Hall at UC Berkeley for future testing.



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