The Human-Dimension of Net-Zero Energy Research at the SDE4 NZEB

Dr. Clayton Miller
BUDS Lab is a scientific research group that leverages data sources from the built and urban environments to improve the energy efficiency and conservation, comfort, safety and satisfaction of humans.

http://budslab.org/
Data Science for Construction, Architecture and Engineering

This course introduces data science skills targeting applications in the design, construction, and operations of buildings. You will learn practical coding within this context with an emphasis on basic Python programming and the Pandas library.

Estimated 7 weeks
4–6 hours per week

Self-paced
Progress at your own speed

Free
Optional upgrade available

There is one session available:
24,358 already enrolled! After a course session ends, it will be archived.

Net Zero by Design
Comfortable and Energy Efficient, Building Performance by Design

VISION
high-comfort
net-zero
energy building

Slide Credit: Thomas Auer– Transsolar https://transsolar.com/
Implement adaptive comfort approach

Net Zero by Design
Comfortable and Energy Efficient, Building Performance by Design

conventional approach

adaptive comfort approach

operative Temperature 24°C

operative Temperature 29°C
tempered air + elevated air speed

Slide Credit: Thomas Auer – Transsolar [https://transsolar.com/](https://transsolar.com/)
Net Zero by Design
Comfortable and Energy Efficient, Building Performance by Design

- **Photovoltaic**
  - renewable energy
- **Hybrid Tempered, 26%**
  - library, design studios
  - Theatrette, offices
- **Full AC,17%**
  - green building technology lab
  - energy lab, computer lab
- **Natural Cross Ventilated, 46%**
  - with elevated air speed
  - social Plaza and social interaction spaces
  - modeling areas, work shops
  - smart green home
- **Circulation**
  - micro climate, wind
  - vegetation, green and blue
- **Mech and aux rooms 10%**

NUS
National University of Singapore
## Thermal Comfort without elevated air speed

**Operative Temperature**: 29°C  
**Air speed**: 0.15 m/s  
**PMV**: 1.2

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**CBE Thermal Comfort Tool**

<table>
<thead>
<tr>
<th>Select method:</th>
<th>PMV method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td>29°C</td>
</tr>
<tr>
<td>Mean radiant temperature</td>
<td>29°C</td>
</tr>
<tr>
<td>Air speed</td>
<td>0.15 m/s</td>
</tr>
<tr>
<td>Humidity</td>
<td>50%</td>
</tr>
<tr>
<td>Metabolic rate</td>
<td>1.2 met</td>
</tr>
<tr>
<td>Clothing level</td>
<td>0.5 clo</td>
</tr>
</tbody>
</table>

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**Psychrometric Chart (Air Temperature)**

- **PMV**: 1.2  
- **PPD**: 37%  
- **Sensation**: Slightly Warm  
- **SET**: 29.3°C  

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**Slide Credit**: Thomas Auer – Transsolar [https://transsolar.com/](https://transsolar.com/)
Thermal Comfort with elevated air speed

Operative Temperature 29°C
Air speed 0.7 m/s
PMV<sub>eas</sub> 0.3

Slide Credit: Thomas Auer – Transsolar [https://transsolar.com/]
Key Wellness and Sustainability Categories of SDE4

- WATER
- WELLNESS
- TROPICAL ARCHITECTURE
- HYBRID COOLING
- NET ZERO ENERGY
- BIOPHILIC DESIGN
The Age-Old Question in the Built Environment

What do occupants want?

How do we understand what makes them feel satisfied/be productive in their indoor environment?

How does this impact the Net-Zero Energy Paradigm?
There are so many factors to consider...

Can we create effective ways to measure or infer all of these environment, physiological, psychological, and behavioral attributes?

Digitization of human perception in a scalable way!

Social media companies capture human perception using innovation in the way they collect information:

They create digital platforms that provide value to users

And capture specific preference feedback in that context
How do we make a *like button* for spaces and cities?

How do we get in-context preference data collection that is specific to objectives related to satisfaction with spaces?

The built environment has increased complexity due to the relevance of **temporal and spatial dimensions**
Growth of Quantified Self and Wearable Devices

“In America smartwatches are catching on as fast as did early mobile phones. In 2021 about one in four Americans was estimated to own a smartwatch or fitness tracker.”

https://www.economist.com/technology-quarterly/2022/05/01/wearable-devices-are-connecting-health-care-to-daily-life
Cozie Platform: Collecting Occupant Data at Scale in the Built Environment

Cozie An iOS application for IEQ and physiological data collection

Allows building occupants to provide feedback in real time

• Leverage smart watch and phone occupant interaction quickly and easily to characterize built environments
  • **Open-source**, scalable and available for FitBit and Apple Watch
  • **Collaboration with UC Berkeley SinBerBest2/CBE**

https://cozie-apple.app/

https://cozie.app/

https://github.com/cozie-app
Micro-survey (EMA) Watch-based Question Flows


Scalable Field-based Data Collection

Building New Types of ML-driven Comfort Preference Prediction Models

Train a Classification Model to Predict Individual Preference

Possible due to Field-based Longitudinal data

- Room (Spatial Context)
- Preference History
- Peer Preference Group
- Features from each Individual Only
- Features from
- Wearable Temp
- Env. Sensors
- Heart Rate

Thinking Beyond Thermal Comfort

New Deployment on Noise Distraction and Thermal Comfort across Singapore

Detect and Learn Occupants’ Preferences

Understand Context

Nudge Occupants to Improve their Situation (Just-in-Time Adaptive Interventions or JITAI)

Just-in-time Adaptive Intervention (JITAI) Messages for Buildings

Scalability of Data Collection across Singapore

NUS Mixed Mode Ventilation – Using Fans in Commercial Buildings

Collab. with Dr. Adrian Chong (PI) at NUS
SinBerBEST2 Laboratory – NUS-Berkeley - Indoor Thermal Comfort ML


Collab. with Prof. Stefano Schiavon (PI) from UCB
NUS Digital Twin Project – Participatory Urban-Building-Human DT

Collab. with Dr. Filip Biljecki (PI) at NUS
NUS BEAM Project – Reducing Urban Heat Islands on Campus

Collab. with Prof. Wong Nyuk Hien (PI) at NUS
The Vision: Community-driven Scaled-up Data Collection and Sharing!

The dream is to collect millions of data points from hundreds of thousands of people worldwide to determine what makes people tick when it comes to satisfaction in buildings.

Acknowledgements

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