BUILDING TO NET-ZERO
COMMUNITY OF PRACTICE

ICLEI
Local Governments for Sustainability
Les gouvernements locaux pour le développement durable
CANADA

PRESENTATIONS

Building to Net-Zero Community of Practice

Staying Cool, Staying Healthy: Designing high-performance buildings with health and comfort in mind

SPEAKER SLIDES

UNIVERSITY OF TORONTO | Building Energy and Indoor Environment (BEIE) Lab

HAMMERSCHLAG & JOFFE INC.
Consulting Engineers

Summer Health and Comfort in High-Performance Buildings

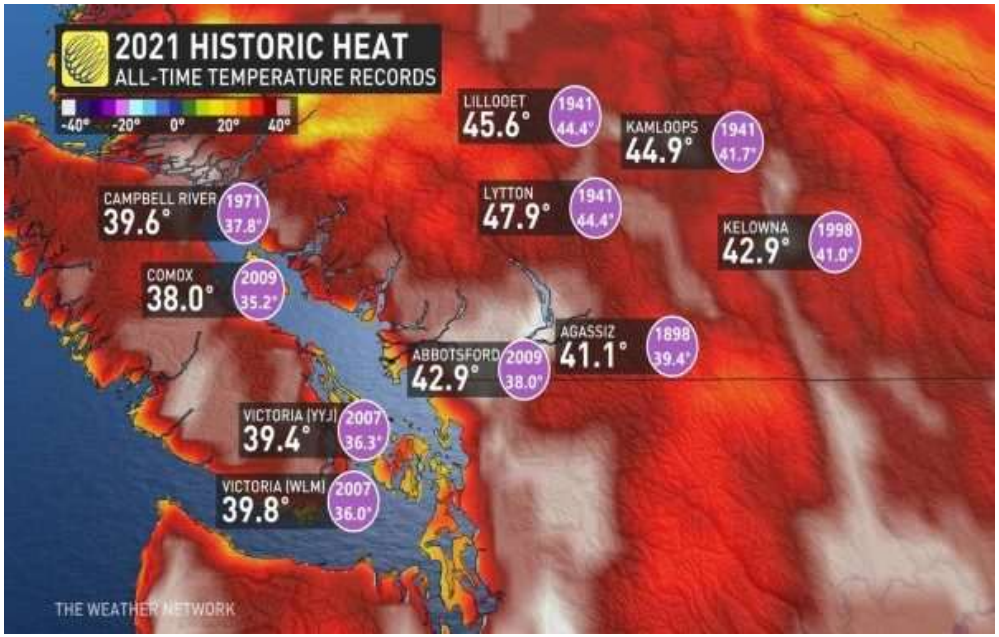
Building to Net-Zero Community of Practice – July 30, 2026

Marianne Touchie, Associate Professor, Jointly appointed in Civil & Mineral Engineering and Mechanical & Industrial Engineering
Cara Sloat, Mechanical Principal, Hammerschlag & Joffe

Today's outline

- Risks of indoor overheating
- Real world overheating root causes and examples
- Design adaptations to consider

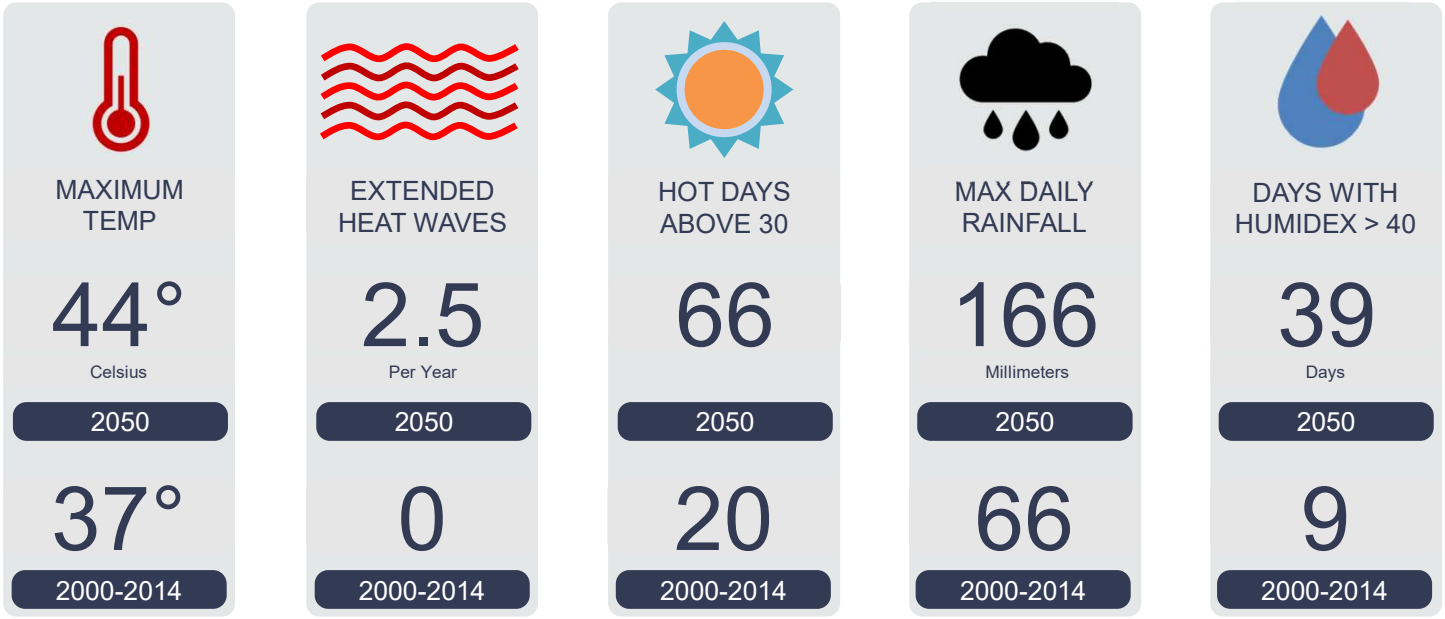
5 years ago…



UNIVERSITY OF TORONTO | Hub for Advancing Buildings | Building Energy and Indoor Environment (BEIE) Lab

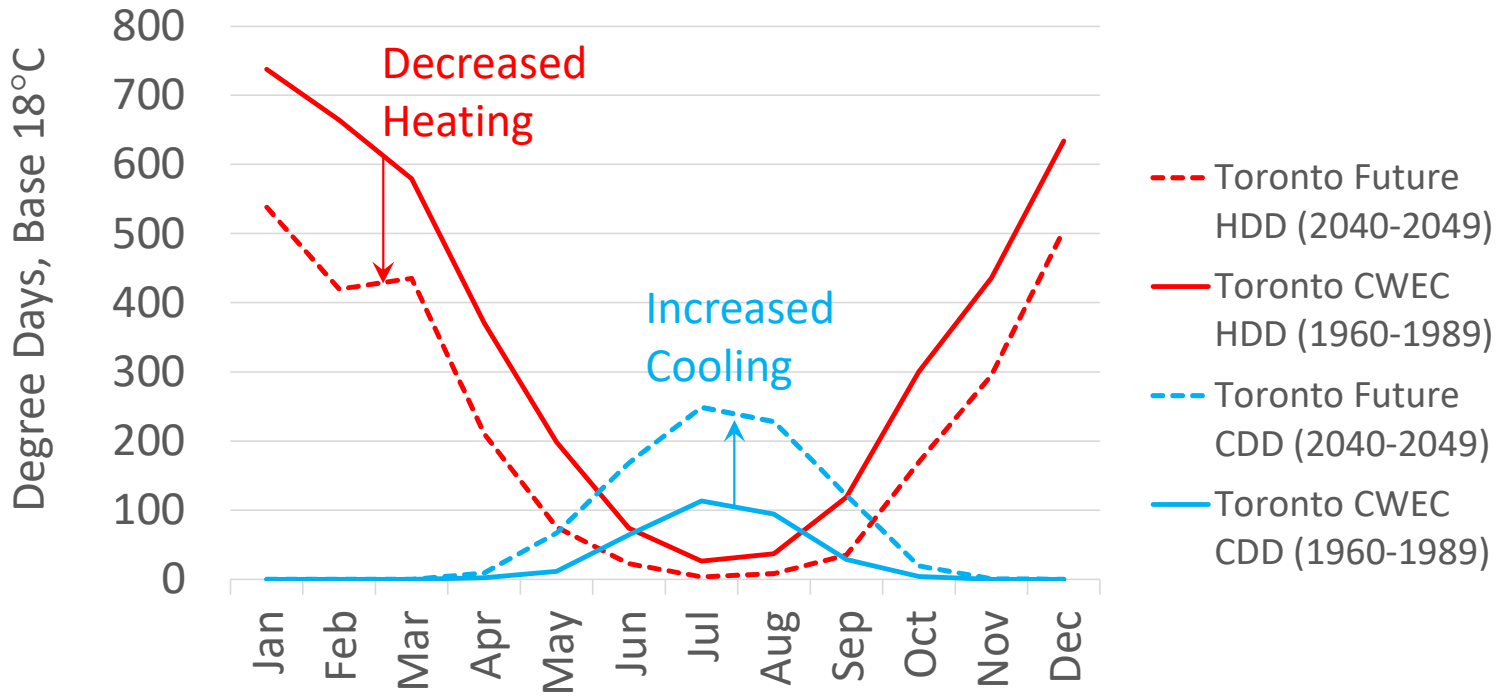
Image source: https://energi.media/news/how-the-2021-summer-heat-dome-affected-electricity-demand-in-western-canada/

Looking to the future: GTA in 2050

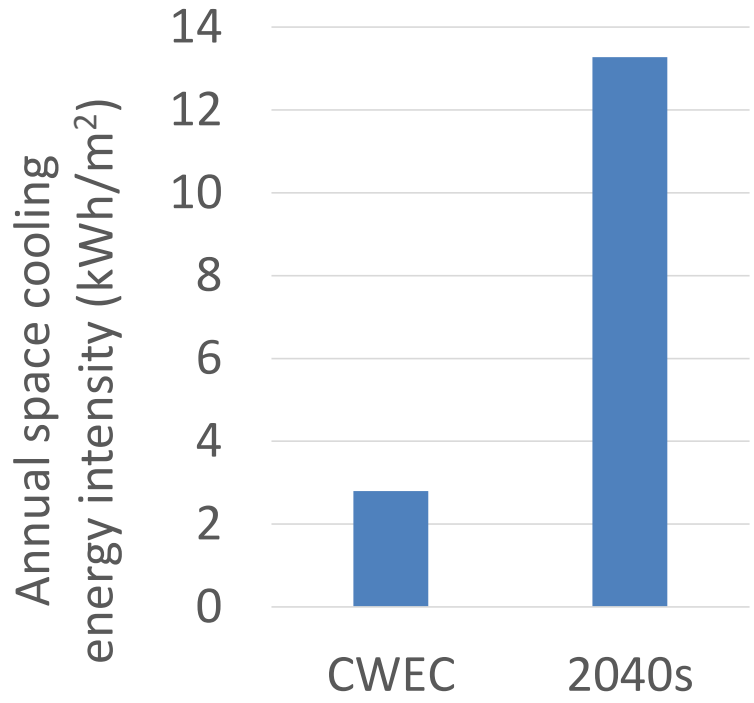


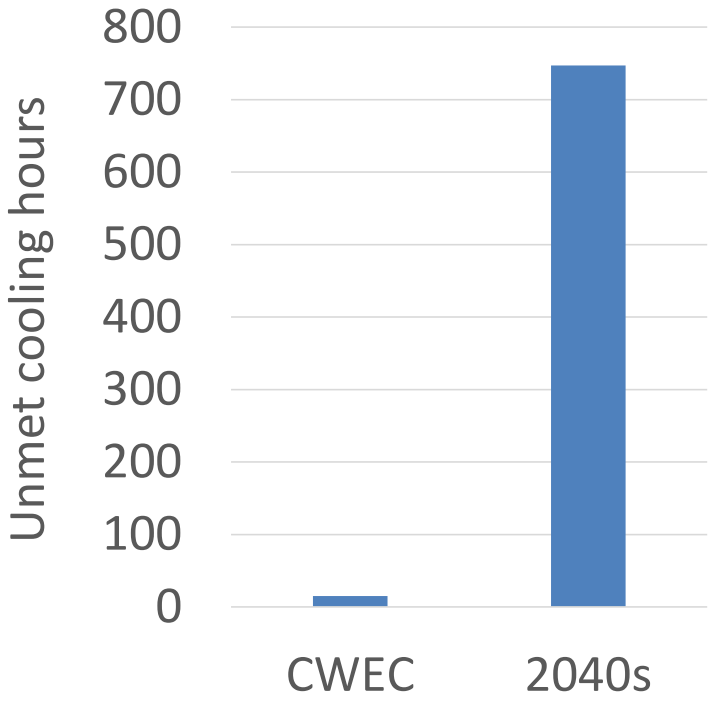
Source: Toronto Environment Office: Future Weather and Climate Driver Study

How will climate change impact buildings?

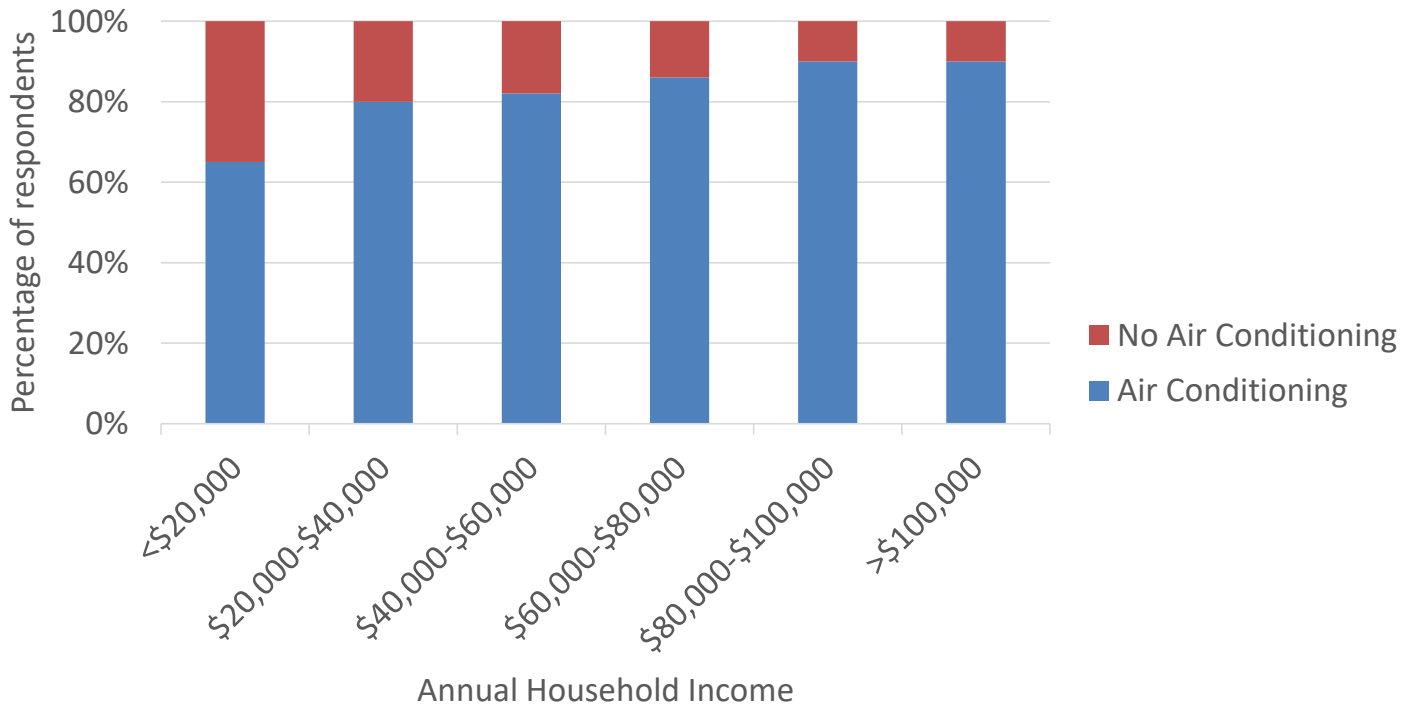


Impact on cooling need in buildings



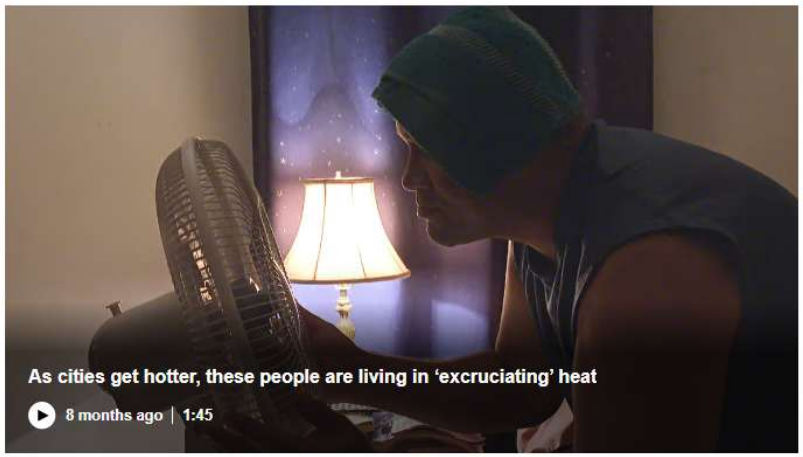


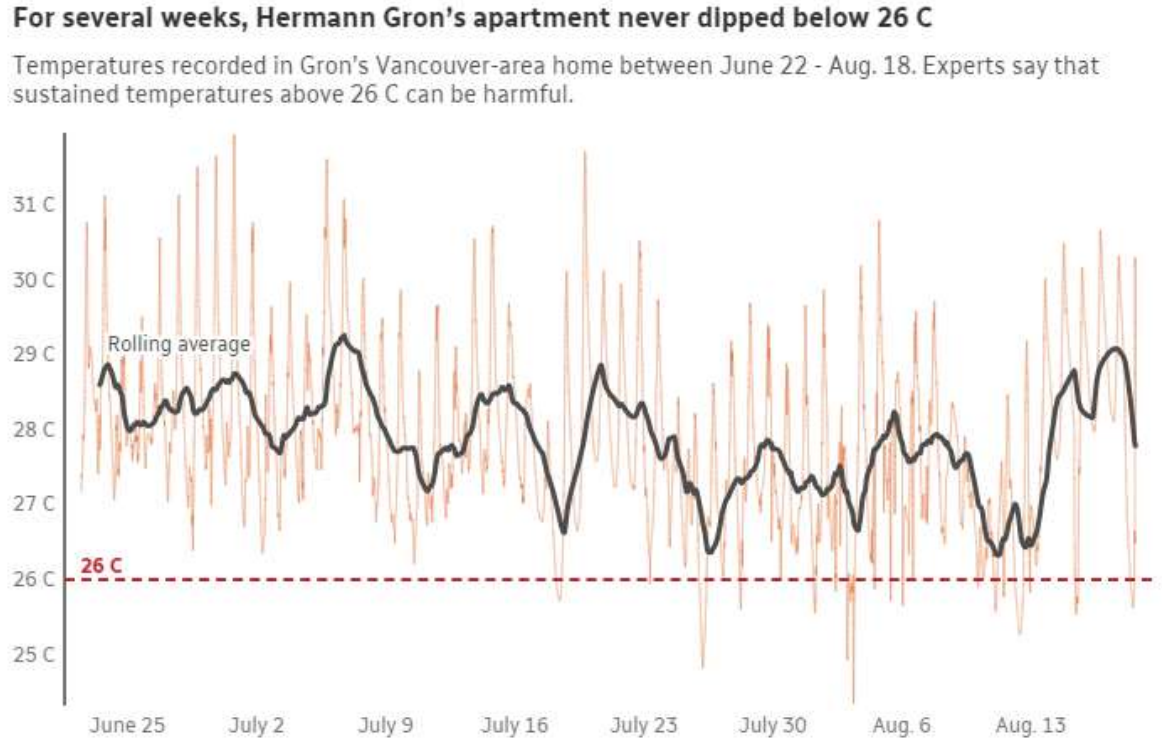
Impact on people



Source: Toronto Public Health

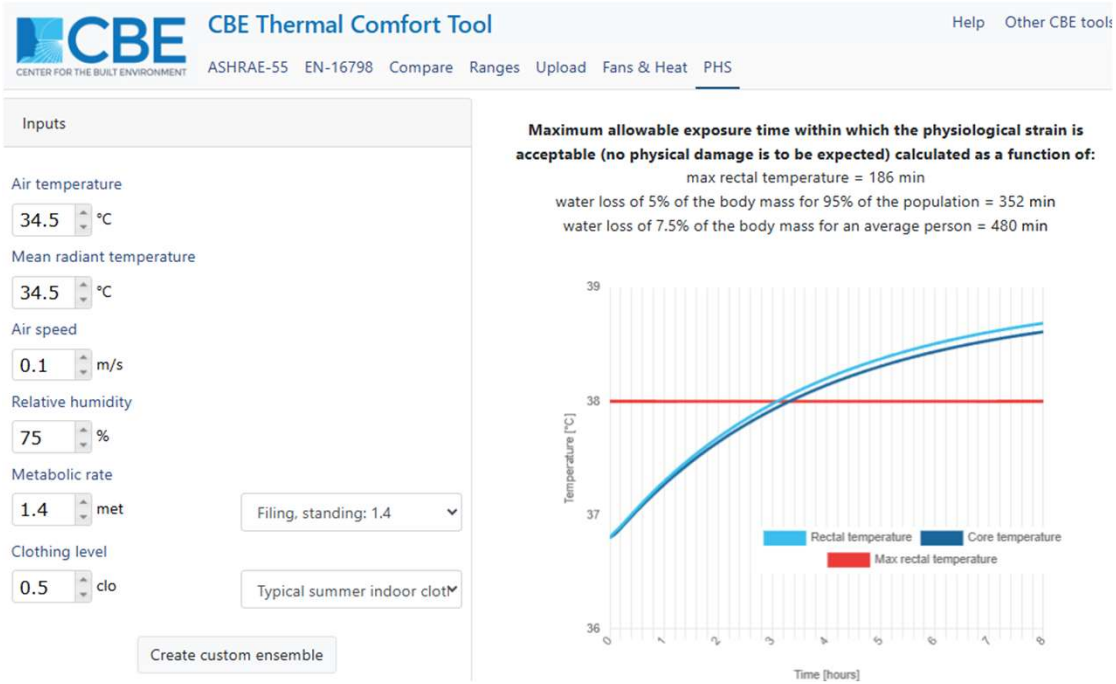
Lived Experience: “No escape from the heat”





Source: https://www.cbc.ca/newsinteractives/features/no-escape-from-the-heat

In Canada, cooling is more important for occupant welfare than heating is



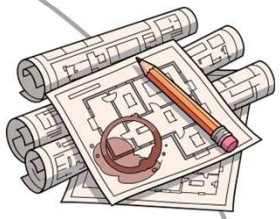
- Chance of **death** from under heating indoor is low.
- Chance of health issues from under cooling is high

CONTRIBUTING BELIEFS

Overheating is a particularly high risk for **high-performance** new buildings.

causes

PLANNING ISSUES



ARCHITECTURE

CONTRIBUTING BELIEFS

SYSTEM MALFUNCTIONS

REAL PEOPLE LIVE THERE

before active A/C, buildings were designed to move light and air passively

we should still do this

Hammerschlag & Joffe

WIND CATCHER IN AL FAHIKI SITORID NEIGHBOURHOOD, OLD DUBAI

UNIVERSITY OF WATERLOO SCHOOL OF ARCHITECTURE - PHOTO COURTESY OF LGA ARCHITECTURAL PARTNERS (CONVERTED SILK MILL BUILT IN 1919)

Problem: architecture designed for heating, not cooling

Many Canadian MURBs lack:

- deliberate, engineered natural ventilation
- overhangs on south facing windows (often value-engineered)
- ultra-low SGHC glazing for east/west windows (since it harms winter performance)
- plantings that shade windows in summer (they are too tall; plantings are optimized for curb appeal, not function)

ARCHITECTURE

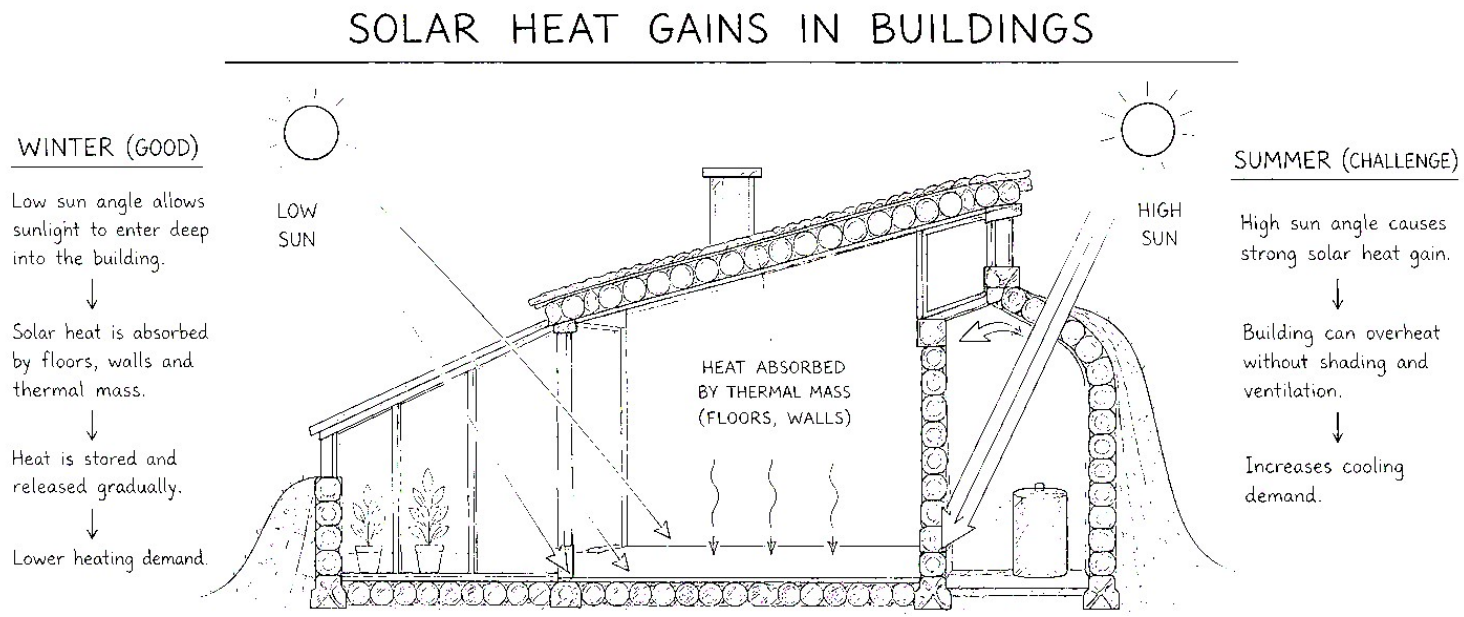
Exterior shading is underused in North America

- In Germany, exterior blinds are commonplace, easily available and an understood design feature

- In Canada, exterior shading ..
  - is high cost and often value engineered out during design or construction
  - there is low confidence in its resilience to freeze/thaw cycles
  - there are few available products
  - Functional design of the product isn't well understood

ARCHITECTURE

High solar heat gain windows are encouraged by TEDI & PH calculations – but increase overheating risk

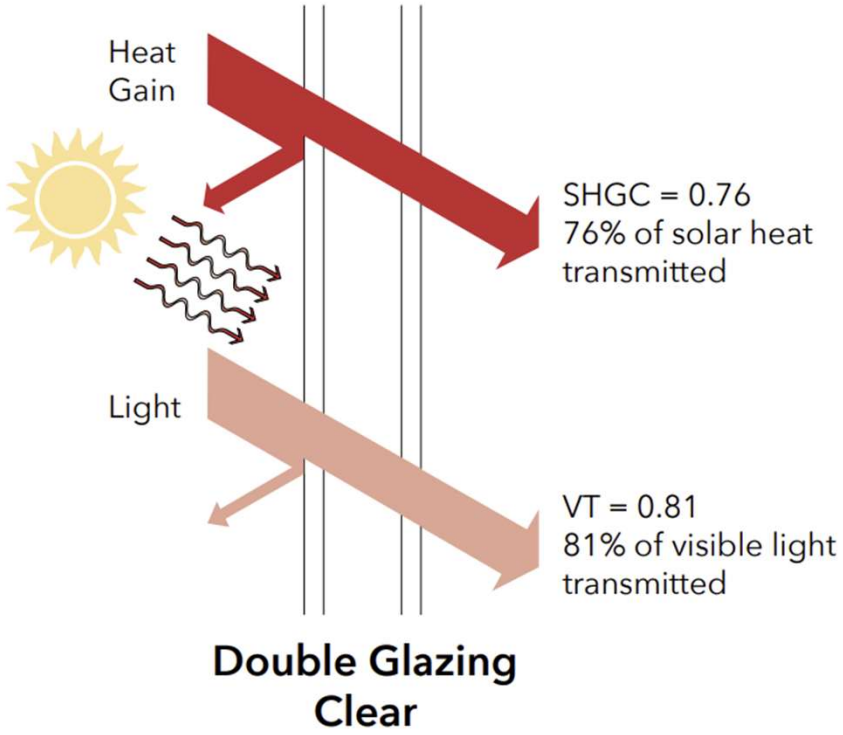


CONTRIBUTING BELIEFS

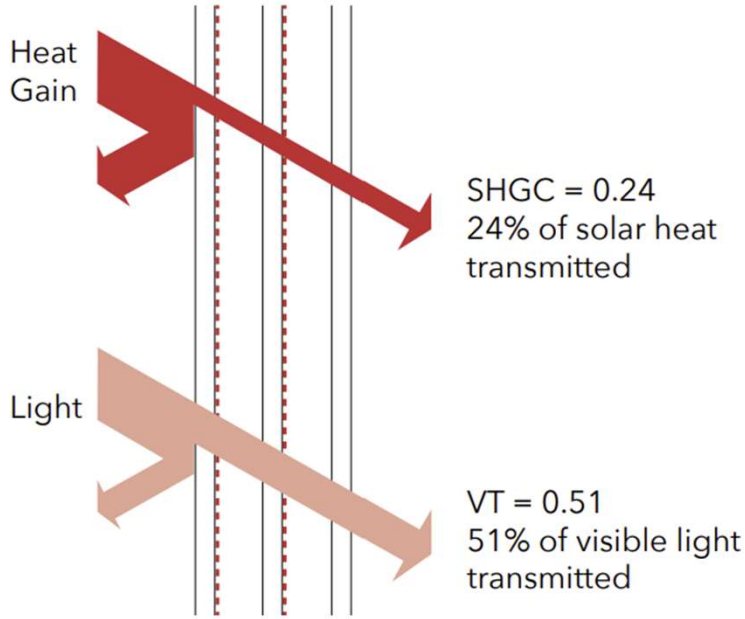
Design strategies to reduce overheating

- Passive Measures
  - Reduce solar gains
  - Promote nighttime cooling/natural ventilation
- Active Measures
  - Increase efficiency of mechanical equipment
  - Alternative cooling measures like fans
  - Improving controls

Passive: Reduce solar heat gain using window coatings



Double Glazing Clear



Triple Glazing, Argon Low-Solar-Gain Double Low-E

Image source: https://pbs.daniels.utoronto.ca/faculty/kesik_t/PBS/Kesik-Resources/Thermal-Resilience-Guide-v1.0-May2019.pdf

Passive: Reduce solar heat gain with fixed exterior shading

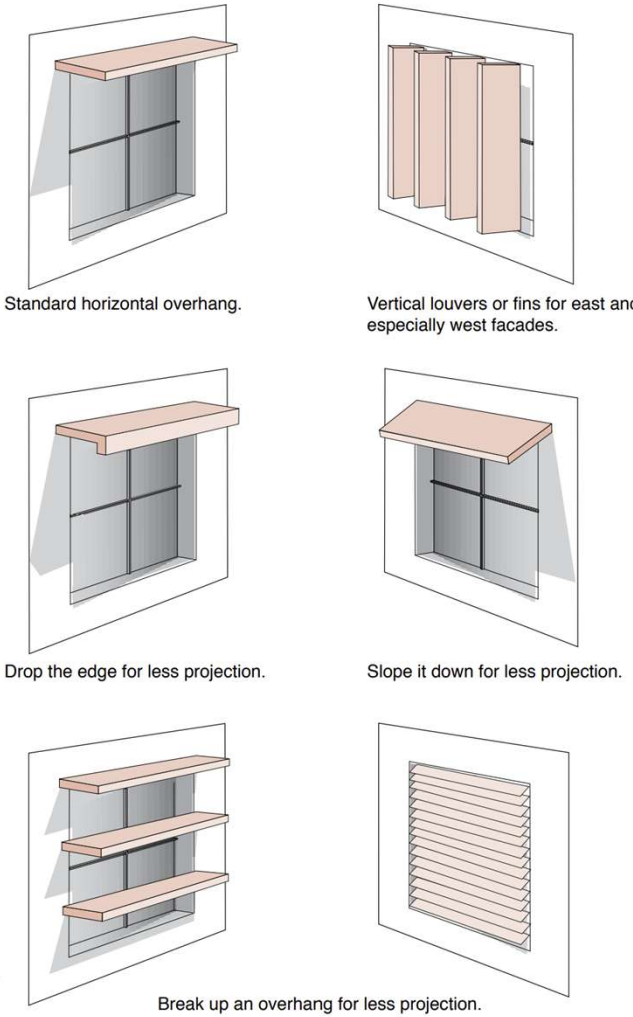
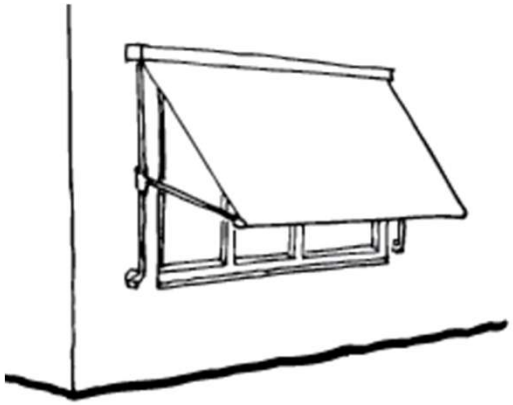
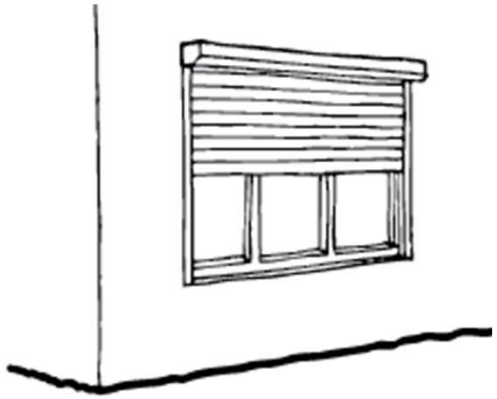


Image sources:
https://pbs.daniels.utoronto.ca/faculty/kesik_t/PBS/Kesik-Resources/Thermal-Resilience-Guide-v1.0-May2019.pdf;
http://www.zefyrgroup.com/gallery.asp?galleryID=21;

Passive: Reduce solar heat gain with operable exterior shading



Awning blind



Roller shutter

Image sources: https://www.yourhome.gov.au/passive-design/shading; http://www.balconyblinds.com/

solution

Passive: Increase Natural Ventilation for nighttime cooling

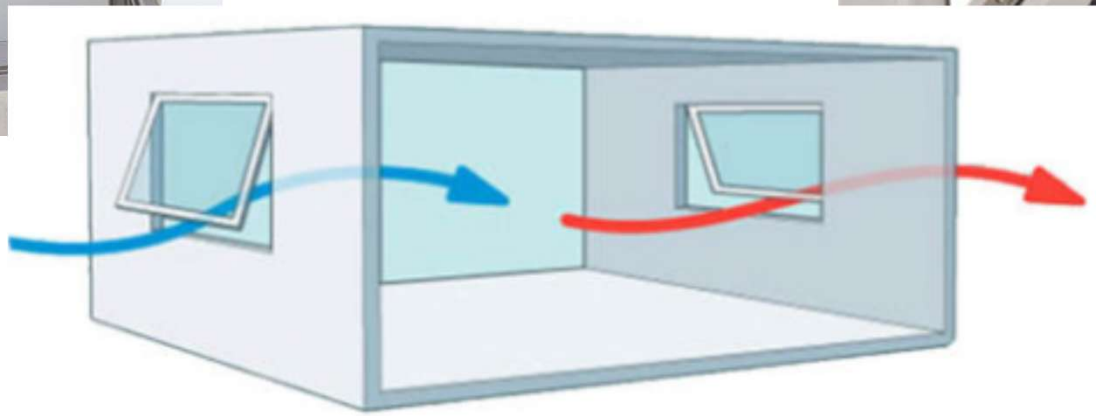


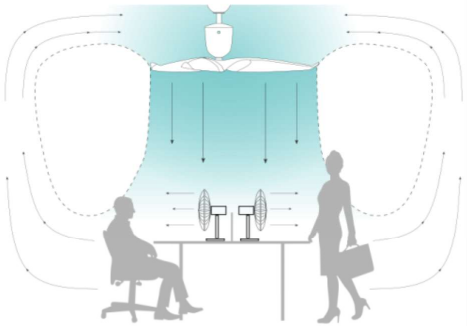
Image sources: http://www.onestepahead.com/Health-and-Safety/Guards-and-Protectors/guardian-angel-window-guard-extra-small.pro?fpi=114924&catCd=2I&prefixCode=2I http://www.advancedwindow.com/hopper.html; https://www.specifiedby.com/sovereign-group-ltd/windows-aluminium-smart-horizontal-pivot https://www.beepindia.org/technologies-n-tools/natural-ventilation/;

solution

Active: More widespread use of fans

Can electric fans be safely used during heatwaves? Yes

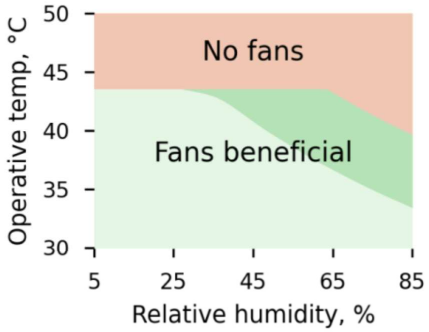
Fans are an effective, affordable, and sustainable cooling technology



Current health guidelines discourage the use of fans at temperatures above 35°C

- WHO
- CDC
- EPA
- Ready.gov

Fans can safely be used by healthy individuals in the following conditions



https://doi.org/10.1016/j.buildenv.2021.108437

AWARENESS

- Fans add heat to the space.
- Ceiling fans have best performance and noise
- Fans should be turned off when leaving a room.
- A continuously running fan could increase air temperatures by 1-2°C/day

UNIVERSITY OF TORONTO | Hub for Advancing Buildings | Building Energy and Indoor Environment (BEIE) Lab

Source: Tartarini F, Schiavon S, Jay O, Arens E, and Huizenga C (2021) Application of Gagge's energy balance model to determine humidity-dependent temperature thresholds for healthy adults using electric fans during heatwaves. Building and Environment 207 (B), 108437.

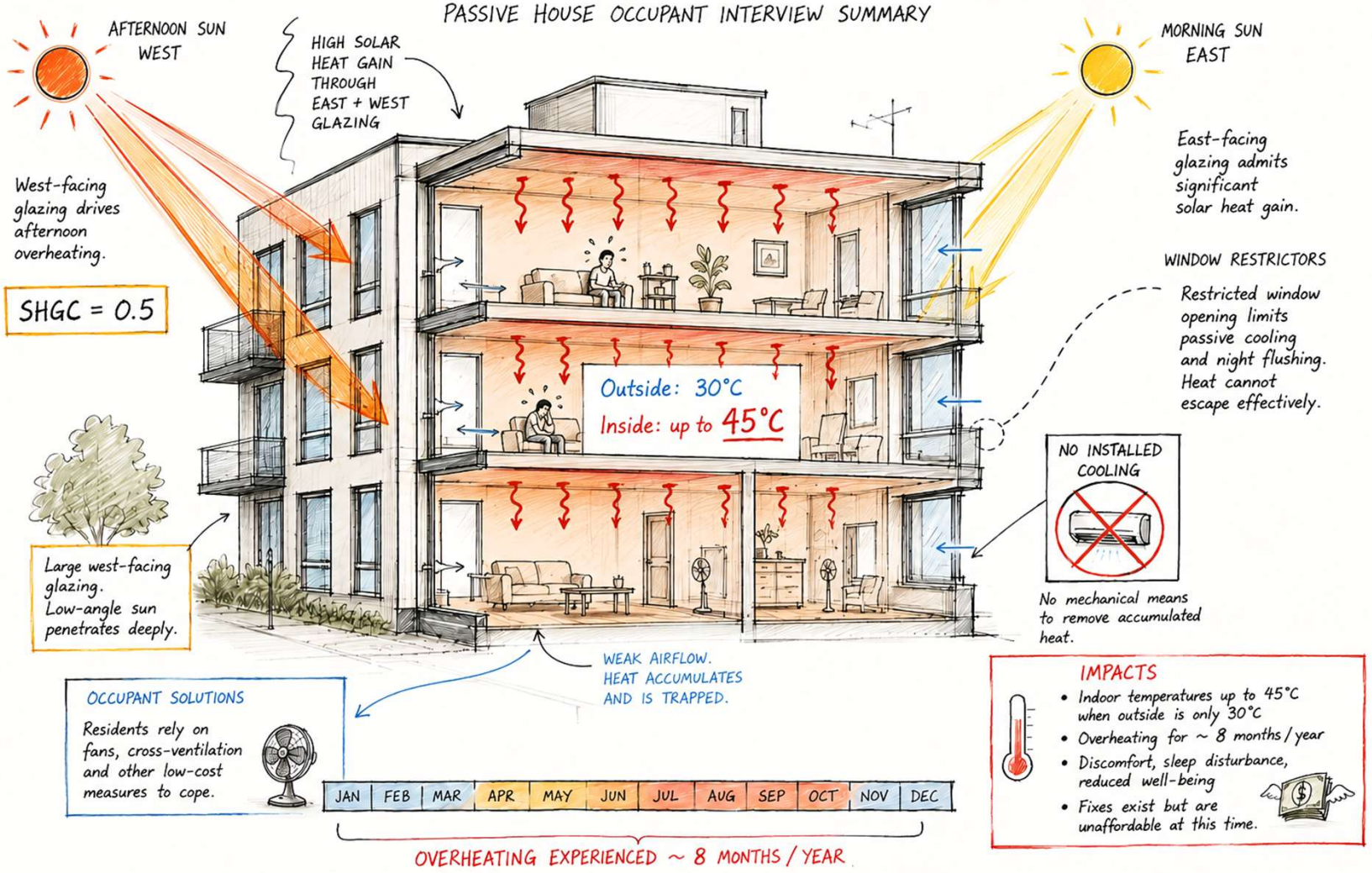
Although passive measures are important…

The literature also shows consistent
Under-estimated air-conditioning needs
in high-performance buildings.

PLANNING & DESIGN

OBSERVED OVERHEATING CONDITIONS

PASSIVE HOUSE OCCUPANT INTERVIEW SUMMARY



ARCHITECTURE

Myth that more cooling can be added later, if needed…

REALITY:

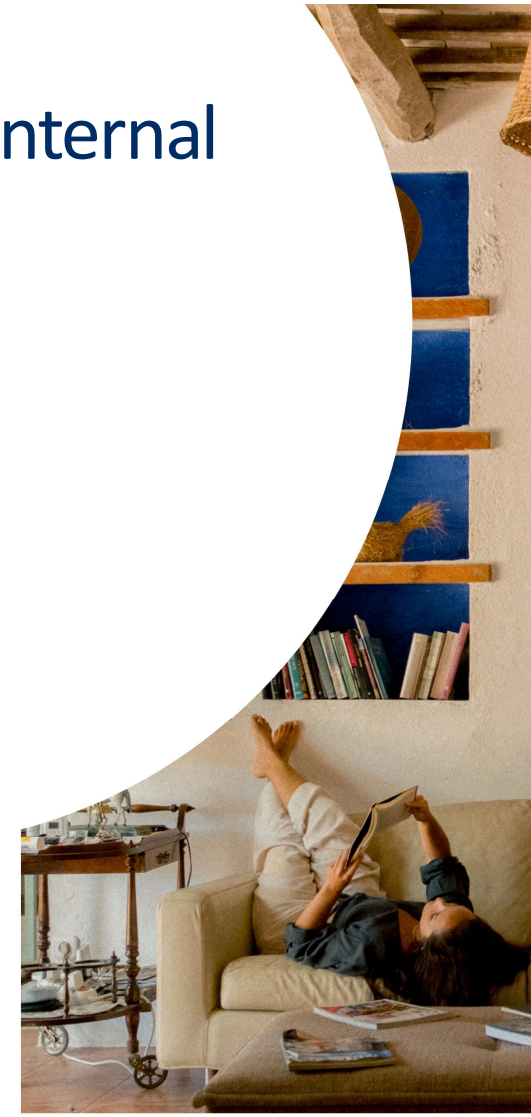
- Modern and high-performance buildings walls and windows typically do not have walls and windows that easily accommodate window, portable or retrofit A/C
- Operators don't have capital budgets for more air conditioning
- Electrical capacity may not be available

CONTRIBUTING BELIEFS

Undersizing Cause: Underestimating varied Internal Gains

Different people use their homes differently.

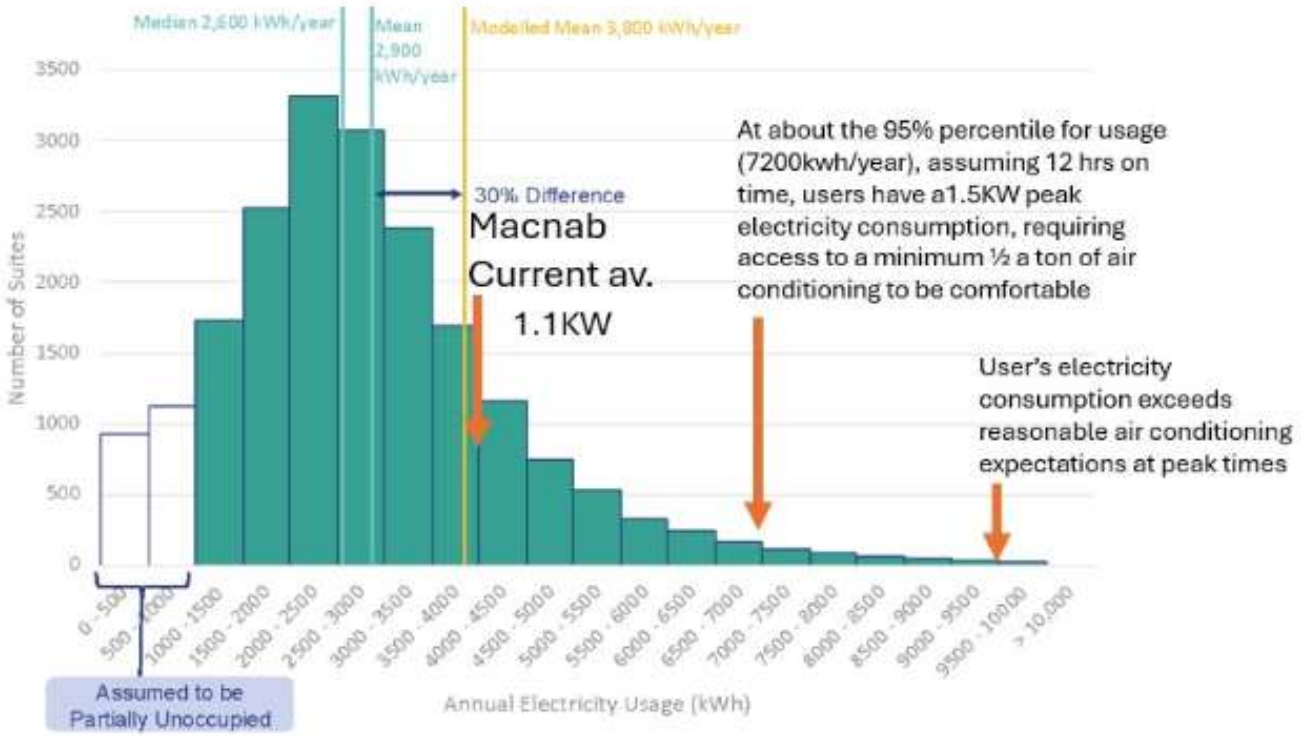
Furthermore, it's normal for occupants to temporarily prioritize required or desired home use over thermal comfort; but in a highly insulated building with low installed A/C capacities, it can take much longer than expected to correct an overheating event.



REAL PEOPLE LIVE HERE

Analyzing internal gains and comparing to industry norms

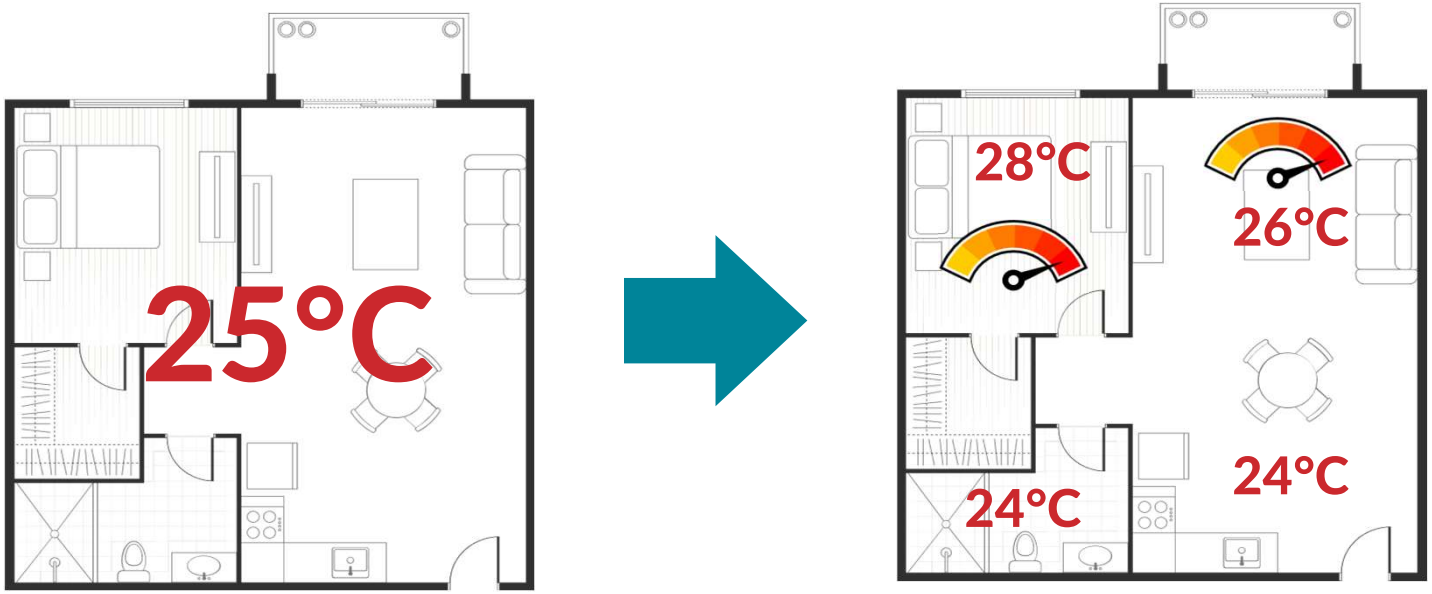
PLANNING CAUSES



Monitored Data – 22,000 GTA-area suites (published 2019 by EQ Building, Sidewalk Labs)

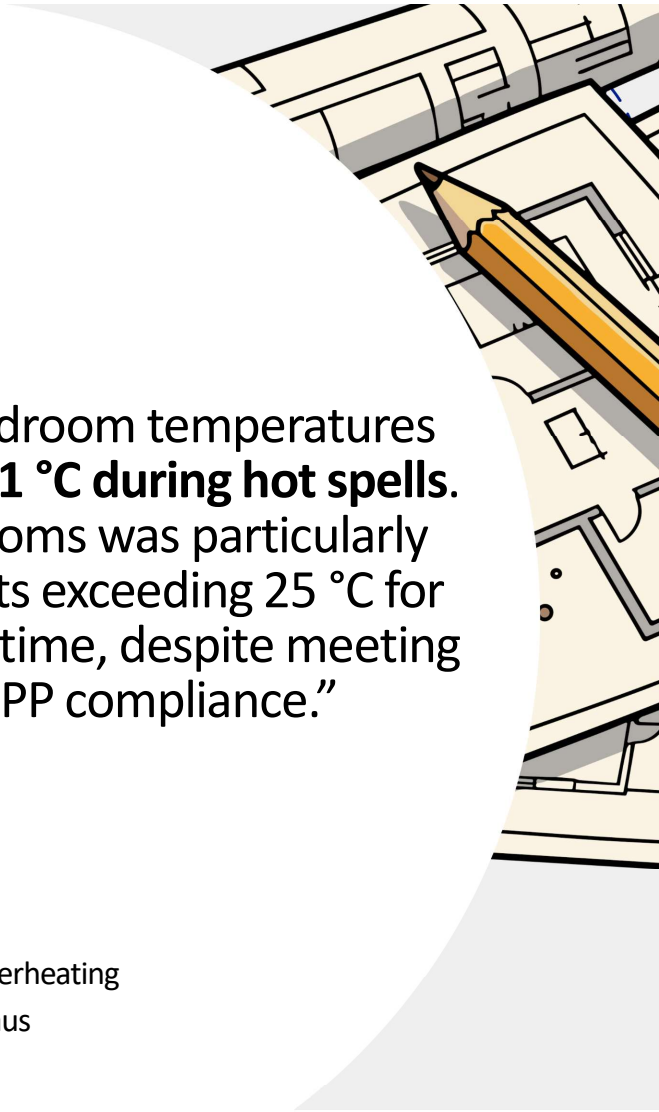
Under-estimating cooling needs: whole suite modelling

PHPP modelling, as well as some other less granular tools, use whole-suite energy model; variation between rooms isn't modelled.



PLANNING & DESIGN

Tools and standards may ignore peak demand, providing false confidence



PHI – Passive House requirements page (PassiveHouse.com) states:

"Thermal comfort must be met … with not more than 10 % of the hours in a given year over 25 °C."

(10% of 8760 hours = 876 hours => 7.3 hours / day for 4 months

"Measured indoor bedroom temperatures reached **peaks of 30–31 °C during hot spells**. Overheating in bedrooms was particularly severe, with some units exceeding 25 °C for more than 20 % of the time, despite meeting dwelling-level PHPP compliance."

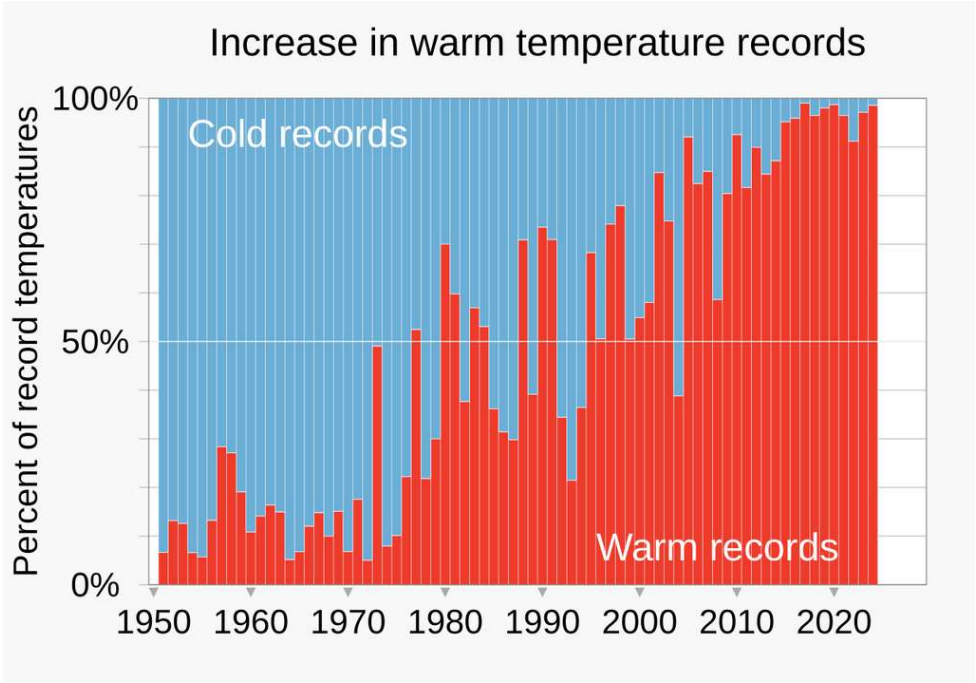
— Botti et al, Thermal comfort and overheating investigations on a large-scale Passivhaus affordable housing scheme, 2017.

PLANNING & DESIGN

Cause: weather files may not portray heat waves well

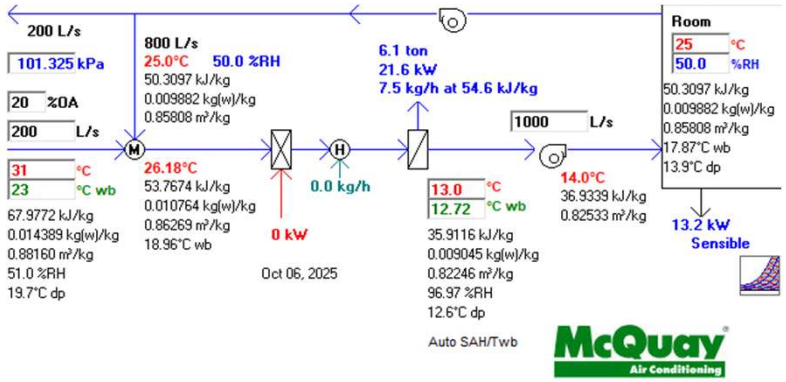
future weather files used for resilience studies are typically designed to predict a “typical” year’s energy use; not to predict a “bad heat wave event in 2040”.

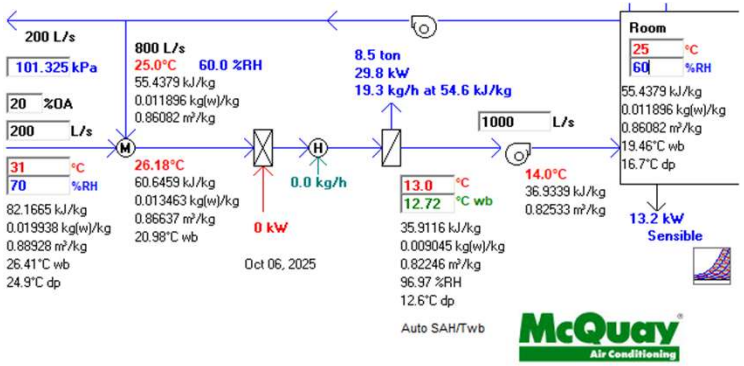
We need the buildings to work even in heat waves.



NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION, MONTHLY GLOBAL CLIMATE REPORT FOR SEPTEMBER 2023, PUBLISHED ONLINE OCTOBER 2023, RETRIEVED ON OCTOBER 13, 2023 FROM HTTPS://WWW.NCEI.NOAA.GOV/ACCESS/MONITORING/MONTHLY-REPORT/GLOBAL/202309/SUPPLEMENTAL/PAGE-3.

Required A/C capacity increases exponentially in above design-day humid days





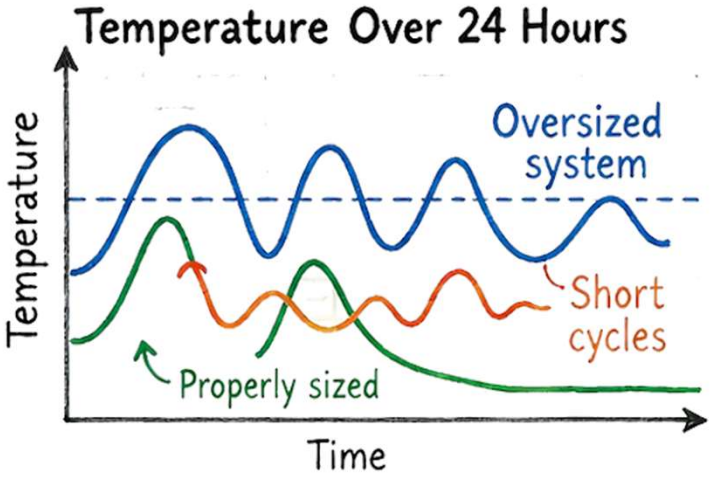
Delivering the same summer supply air temperature when it's humid out can take 40%+ more cooling coil capacity then when it isn't. Sizing that ignores both the ASHRAE cooling design day AND the dehumidification design day will result in underperformance in humid climates, especially on days hotter than design.

PLANNING & DESIGN

designers fear oversizing cooling systems

Oversized System

- Short cycling
- Poor humidity control
- Higher energy bills
- Uneven temperatures



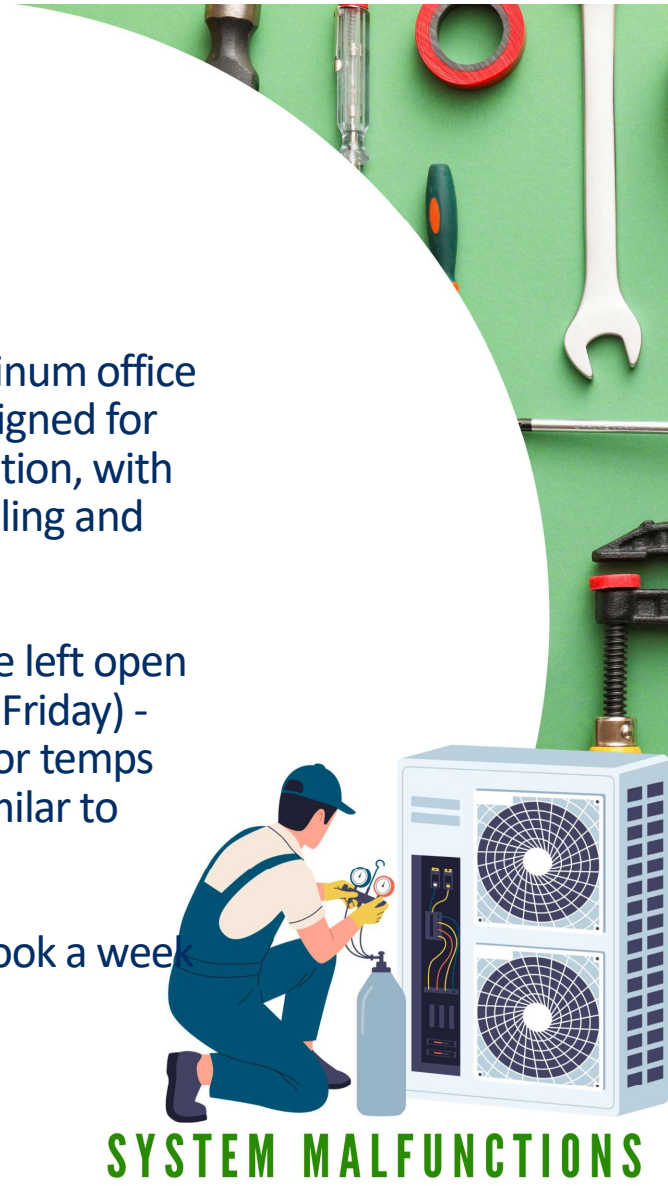
CONTRIBUTING BELIEFS

Designers fail to imagine what happens to temperatures when things go wrong

- **Run-away thermal gains**
  a temporary A/C outage lets temperatures climb. If our A/C capacity is 50-80% heat recovery in a high-performance building, the building has to be re-cooled using less than half of the design cooling capacity
- When we conduct **thermal resilience energy modelling**, we should look at both:
  - three days of heat wave with power off, and,
  - three days of heat wave with power **on** but A/C off.

Case Study: what happens to temperatures when things go wrong

- This LEED platinum office building is designed for natural ventilation, with right sized cooling and ERVs.
- Windows were left open on a nice day (Friday) - Monday, indoor temps were 31°C (similar to outdoors)
- The building took a week to cool down



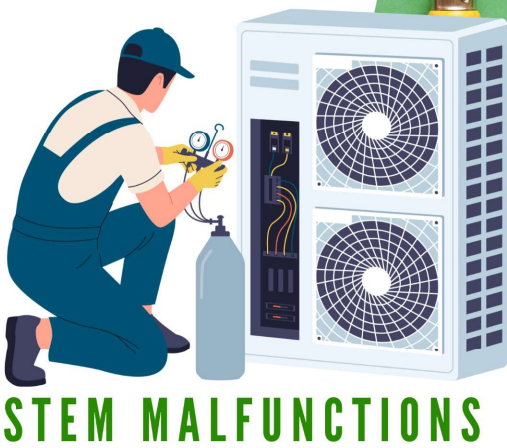
Cause: it might not be working (yet)

Many high-performance MURB HVAC systems:

- are different than the operator's typical systems
- require specialized training and controls sequencing
- appear undersized to persons unfamiliar with high-performance buildings

These factors can slow down identification and resolution of operations problems.

jo1

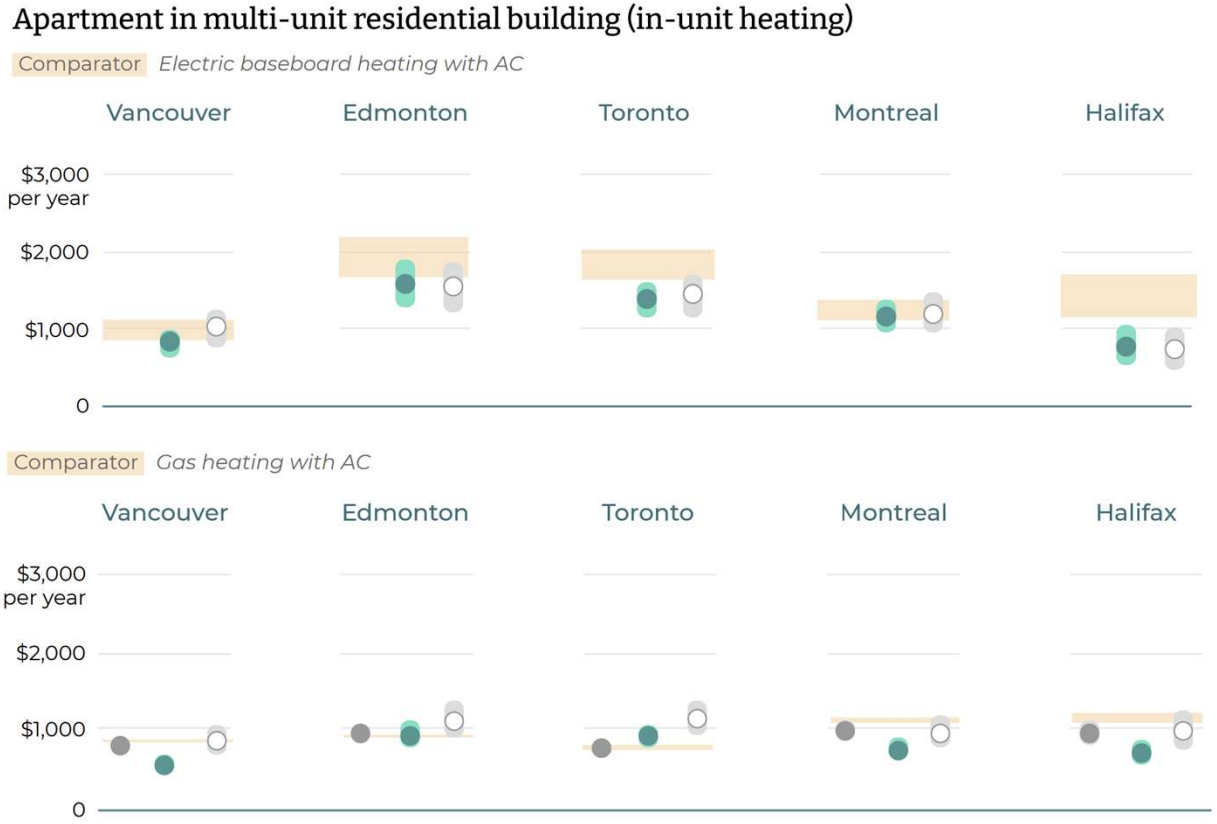


jo1 We also just have units that are failing (controller boards frying but operators not getting feedback, VAVs breaking, VRFs not providing designed capacity.

josh@jmvconsulting.ca, 2026-05-25T21:00:28.618

solution

Active: Switching to air source heat pumps



HEAT PUMPS

- *Standard heat pump with gas backup*
- *Standard heat pump with electric backup*
- *Cold-climate heat pump with electric backup*

UNIVERSITY OF TORONTO | Hub for Advancing Buildings | Building Energy and Indoor Environment (BEIE) Lab

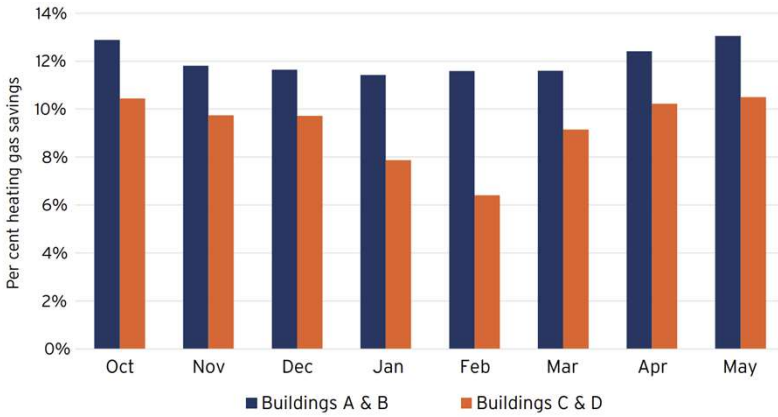
Source: https://climateinstitute.ca/wp-content/uploads/2023/09/Heat-Pumps-Pay-Off-Unlocking-lower-cost-heating-and-cooling-in-Canada-Canadian-Climate-Institute.pdf

solution

Active: Smart thermostats

- Smart thermostats increased programming rates (83% vs 30% for standard programmable thermostats)
- TAF study showed space heating needs lowered by 8.8-11.8%
- Occupancy based control can significantly reduce avoidable demand by almost 80% from as-scheduled scenario
- Can potentially be used to alert residents in dangerous conditions

Figure 4. Monthly natural gas space heating savings stemming from smart thermostats.



Stopps, H. (2021) "Smart Thermostat Use in Multi-Unit Residential Buildings: Impacts on Occupant Behaviour, Thermal Comfort, and Energy Performance " Ph.D. Thesis, University of Toronto; https://taf.ca/custom/uploads/2019/04/Smart-Thermostats-White-Paper-March-2019.pdf

occupants & building operators are perfectly rational actors

Even when a building has all the needed physical attributes to keep cool, occupants can be at risk because they are real people and may not use the building exactly as the designers imagined.

- Are the home at the right time to act?
- Do they understand thermodynamics?
- Do they understand airflow?
- Are they allergic to anything outside?
- Is it smokey outside?
- Can they operate the windows (accessibility)?
- Are windows limited due to safety concerns?

Contributing factor: designers who don't understand occupant vulnerability & ability limitations

- Opening triple glazed windows can takes more grip strength than a traditional window
- Perceiving that it's cooler outside requires mental acuity and physical availability; being able to be home and awake at the right time to open and close windows and blinds may not be available to some occupants
- Understanding what behaviors heat up a suite, or even being able to operate a thermostat with a 'boost mode', can be a challenge with language or cognitive barriers.

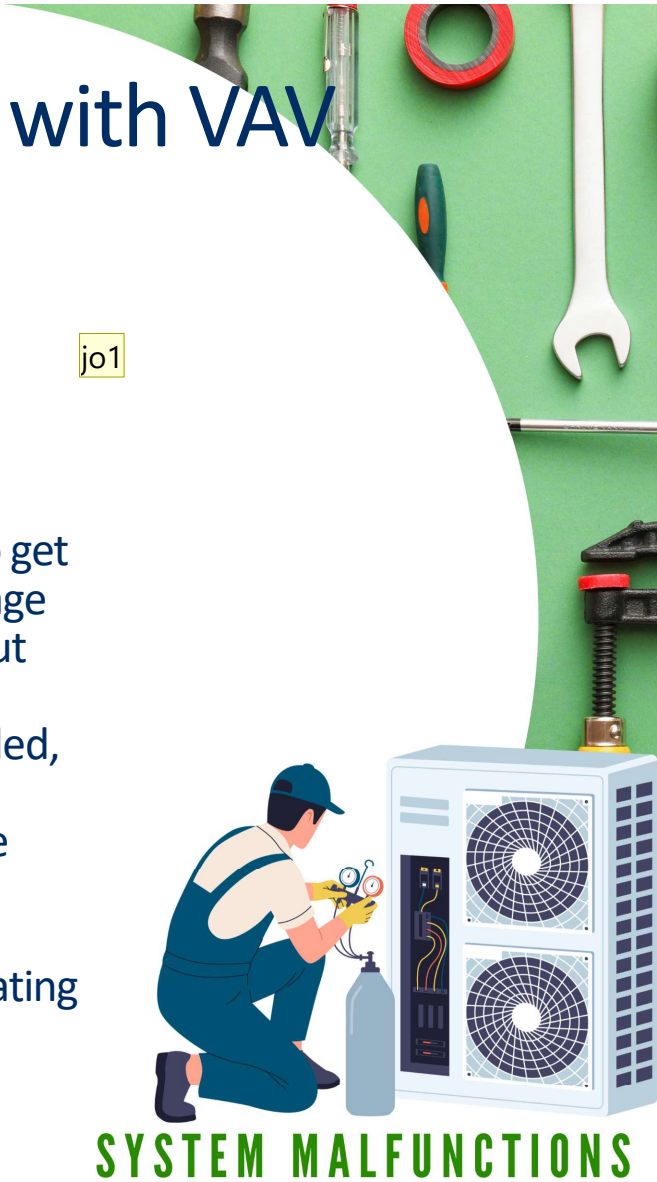
REAL PEOPLE LIVE HERE

Case Study: Passive House Tower with VAV cooling

jo1

- VAV system was new to operators
- Operable windows with shades and ceiling fans available to occupants
- Programming of ventilation system required recommissioning to get right, but this wasn't obvious - HVAC techs locked out second stage of cooling to minimize variability in discharge air temperature, but this reduced air conditioning output by about 40%
- Air conditioning system was 'right sized' with ERV capacity included, so if the building overheats, it takes a long time to recover
- No provision for after-construction air conditioning retrofit in the design – limited ability to provide spot fixes for specific tenants.

Result: generally acceptable (22C – 26C temperatures, but overheating in some suites (26C-29C) when things go wrong.



jo1 We also just have units that are failing (controller boards frying but operators not getting feedback, VAVs breaking, VRFs not providing designed capacity.

josh@jmvconsulting.ca, 2026-05-25T21:00:28.618

solution

Improving community wellbeing

- Increase resilience during extreme events
- Improve safety
- Less isolation

Image source: https://viennahouse.ca/about-the-project/

Cause: designers don't get feedback on what didn't work in the past

- Too often we don't know if our buildings are performing as designed.
- Commissioning takes time. Follow projects for at least a year, ideally 2 – 3 years.
- Ask for measured data and include detailed metering where possible
- Include follow up in your proposal

Study on reflective practice in the building industry

- Industry changes are often reactive not proactive
- POEs aren't publicly available
- Need to share lessons across industry
- We want to change this!

Initial recommendations

- **Legislation:** require energy reporting (e.g. b
  programs)
- **Certifications:** include LEED or WELL
- **Guidance:** how to conduct POEs
- **Strategies:** Soft Landings (UK), exte
- **Warranties:** extend existing 2-5-10 year e
  British Columbia, Canada) to other aspe
  performance

Stay tuned!

We're developing a standardized residential POE tool and open source, anonymized database

Source: K. Vella

Summary: strategies to reduce harm from overheating

- Passive Design Measures
  - Reduce solar gains
  - Design for natural ventilation
  - Promote nighttime cooling/natural ventilation
- Active Design Measures
  - Provide appropriate capacity for air conditioning equipment
  - Alternative cooling measures like fans
  - Improving controls
- Community Resilience
  - Teach occupants how to use the building, including shading, night-cooling and air conditioning
  - Community resilience makes people safer
  - Understand active cooling is among the most reliable safety measures for vulnerable adults.

Key takeaways

- First, model real overheating risk: use real occupant loads and future weather
- Next, integrate passive low-carbon strategies to reduce overheating risk
- Then, fans
- Then, AC (with resilience measures)
- Then, follow up and find out how the design performed

MW1

Acknowledgements

Thank you to students, collaborators and funders:

Vakalis, D., Diaz Lozano Patino, E., Opher, T., Burrows, K., MacLean, H.L., Siegel, J.A, Stopps, H., Fine, J., Ruiz, L., Lozinsky, C., Liu, J., Li, C., Andargie, M., Robinson, R., Jakubiec, A., Poland, B., Josh VanWyck

JMV CONSULTING

ecobee

ENBRIDGE

TORONTO HYDRO

ieso

Sustainable Buildings Canada

YWCA HAMILTON

TAF

ASHRAE

NSERC CRSNG

INTERNATIONAL WELL BUILDING INSTITUTE™

Toronto Community Housing

CITYHOUSING HAMILTON

SSHRC CRSH

CMHC SCHL

FirstService RESIDENTIAL

UNIVERSITY OF TORONTO | Hub for Advancing Buildings | Building Energy and Indoor Environment (BEIE) Lab

Thank you!

Marianne Touchie
marianne.touchie@utoronto.ca
hab.civmin.utoronto.ca

Cara Sloat, P. Eng
cara.sloat@hamjof.com
416-871-2272