Thermal Comfort

Harry Schroeder

Manitoba Building Envelope Council

January 17, 2018

Manitoba Hydro

LEED® Commercial Buildings

INTEGRATED DESIGN PROCESS

- Location and Transportation
- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Materials and Resources
- **Indoor Environmental Quality**
- Innovation
- Regional Priority

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WELL is the first building standard to focus exclusively on the health and wellness of the people in buildings

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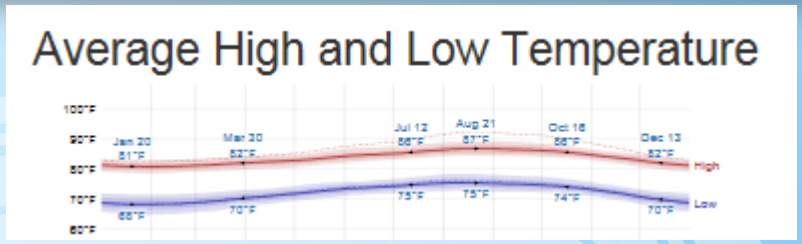

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Overview

- What is thermal comfort
- Why thermal comfort is important
- How to measure thermal comfort
- Thermal comfort and the building envelope
- Practical tools for solutions

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What is Thermal Comfort

Light/Sun	46%
Temperature/Warmth	**35%**
Fresh/clean air/smell	21%
Sound/noise	16%
Peace/silence	15%
Nature	15%
View	14%

Human comfort and self-estimated performance in relation to indoor environmental parameters and building features

Monika Frontczak Ph.D. thesis Technical University of Denmark 2011

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What is Thermal Comfort

Thermal comfort: the **condition of mind** that expresses satisfaction with the thermal environment and is assessed by **subjective** evaluation

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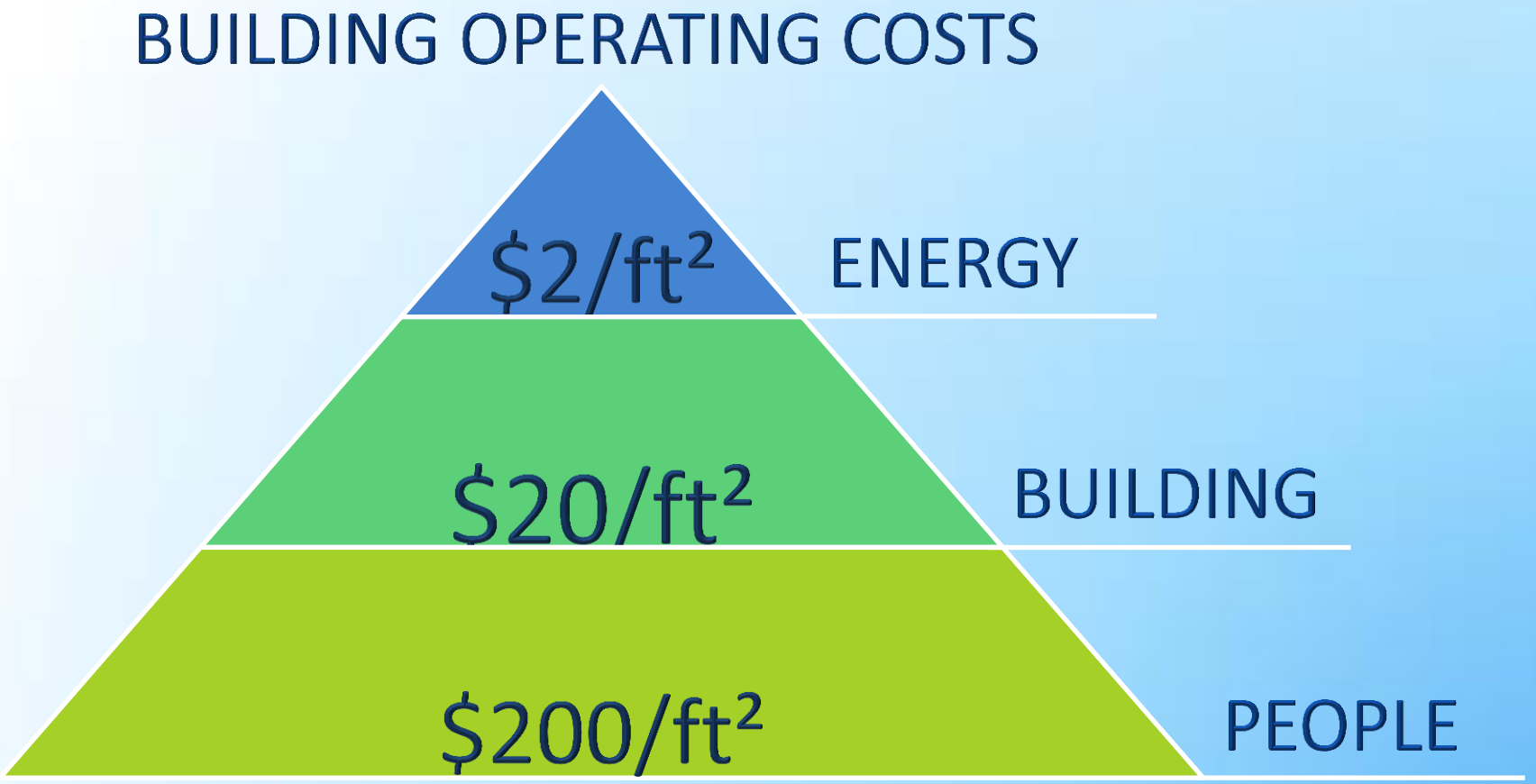
Why Thermal Comfort is Important



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Why Thermal Comfort is Important

Chilly workers not only make more errors but cooler temperatures could increase a worker's hourly labor cost by 10 percent, estimates Alan Hedge, professor of design and environmental analysis and director of Cornell's Human Factors and Ergonomics Laboratory.

"The results of our study also suggest raising the temperature to a more comfortable thermal zone saves employers about $2 per worker, per hour," says Hedge, who presented his findings this summer at the 2004 Eastern Ergonomics Conference and Exposition in New York City.

Cornell Chronicle
Oct 19, 2004

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Why Thermal Comfort is Important

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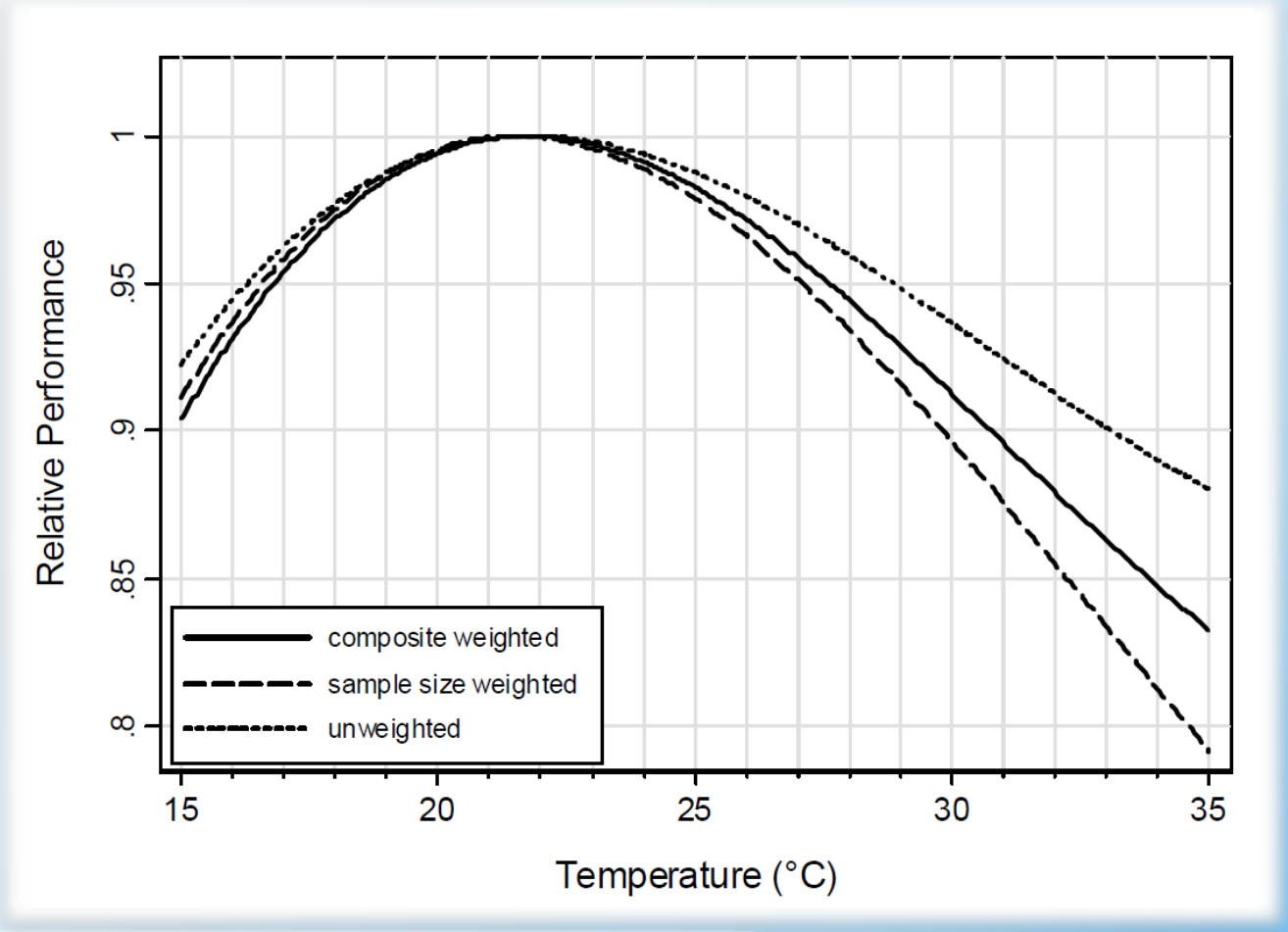
Why Thermal Comfort is Important



Effect of Temperature on Task Performance in Office Environment
Helsinki University of Technology & Lawrence Berkeley National Laboratory, 2006

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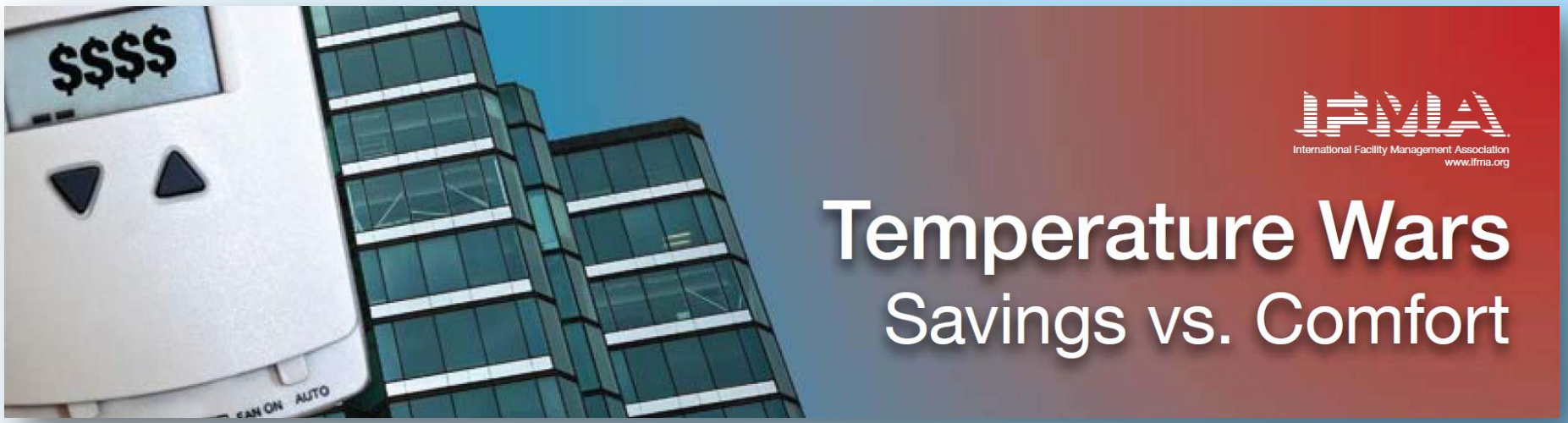
Why Thermal Comfort is Important



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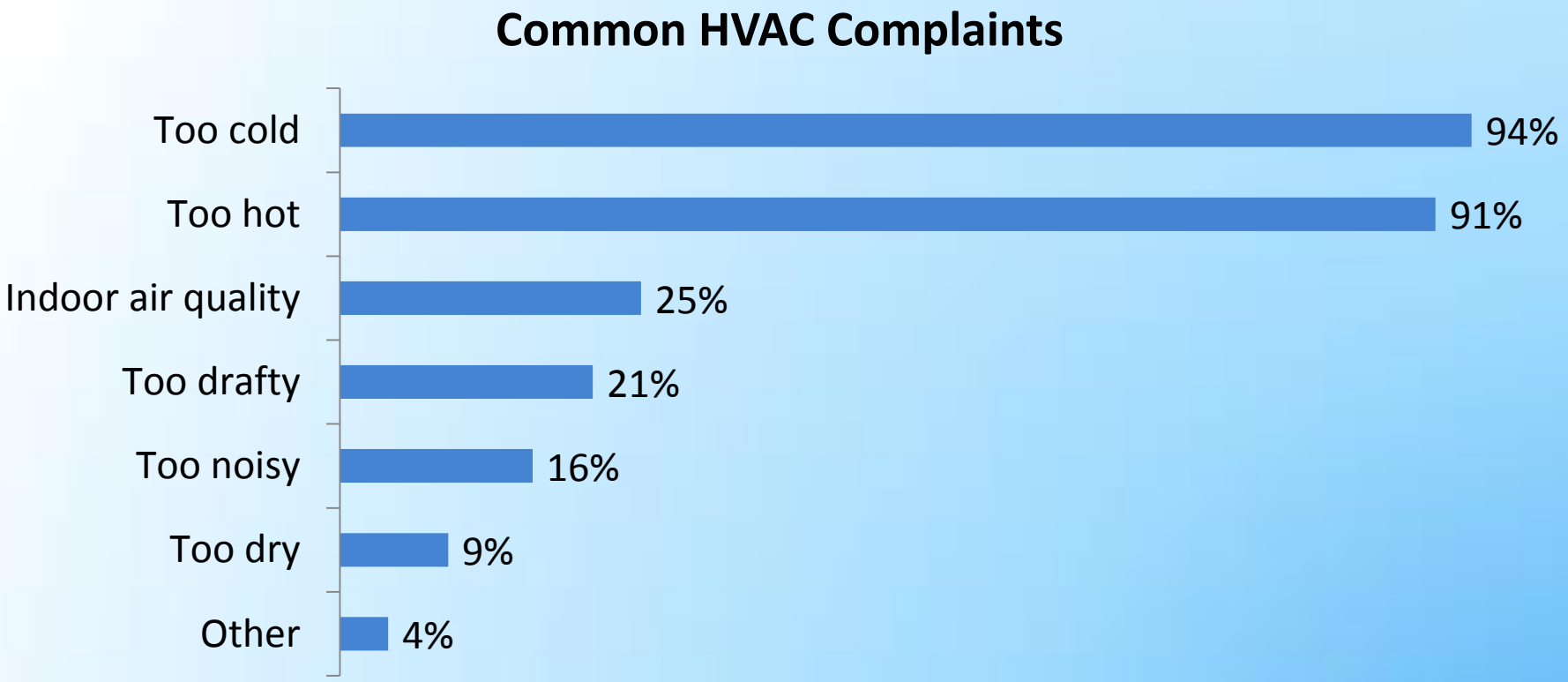
Why Thermal Comfort is Important



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Indoor air quality = headache, dry throat, allergies

Other = smells detected, lack of air circulation

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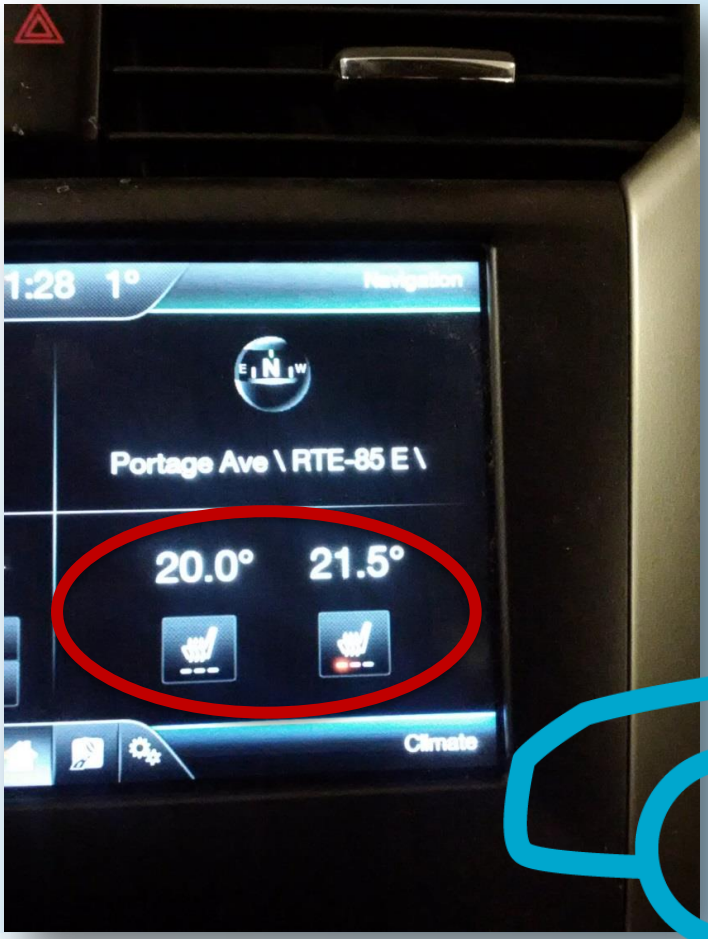
Why Thermal Comfort is Important



The automotive industry recognizes the importance of thermal comfort - some manufacturers are enhancing temperature/climate options

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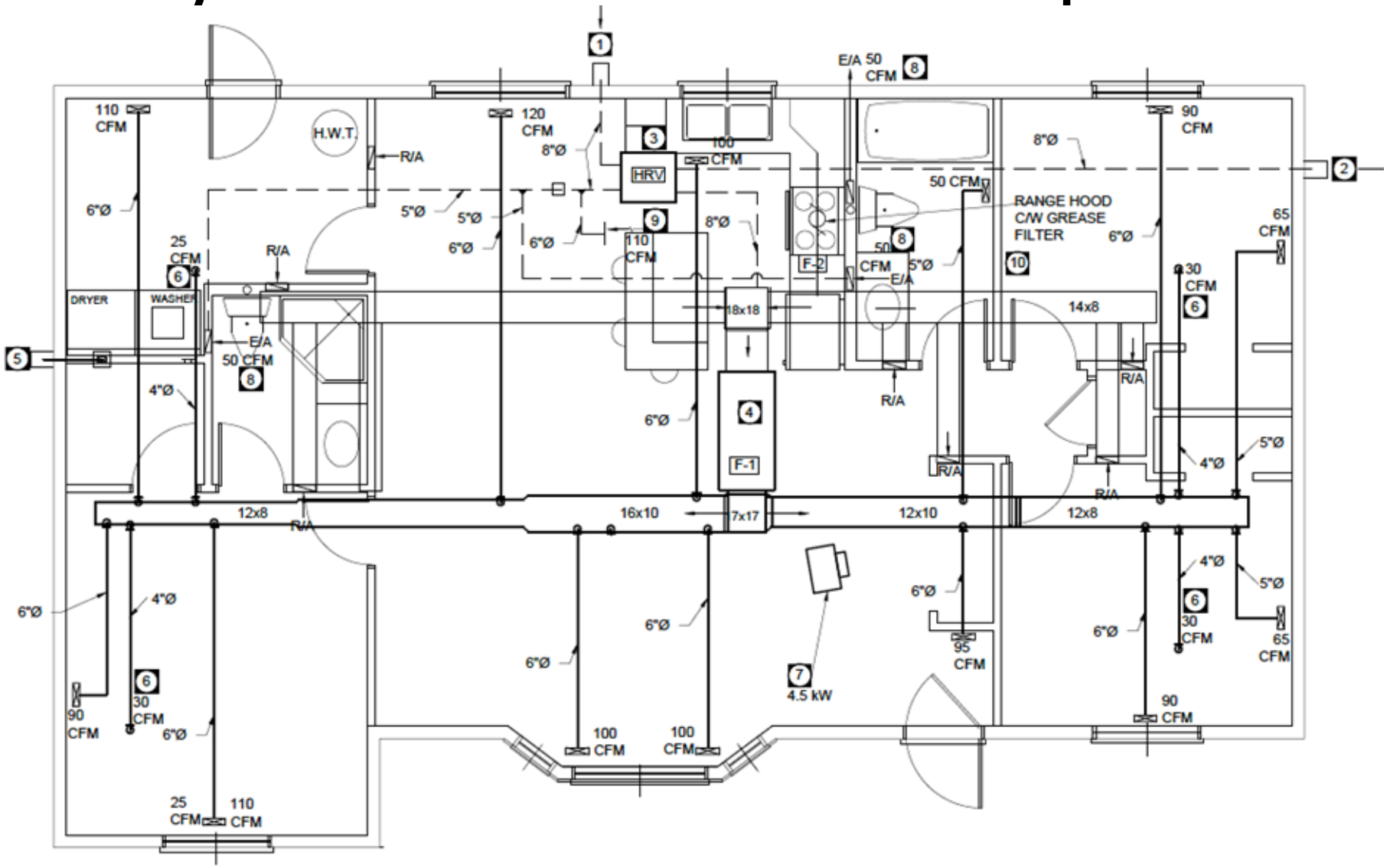
Why Thermal Comfort is Important



How to Measure Thermal Comfort

- The average adult body is covered by a nominal 20 ft^2 of skin, which has over 166,000$^{+/-}$ thermal sensors connected to the brain via the nervous system

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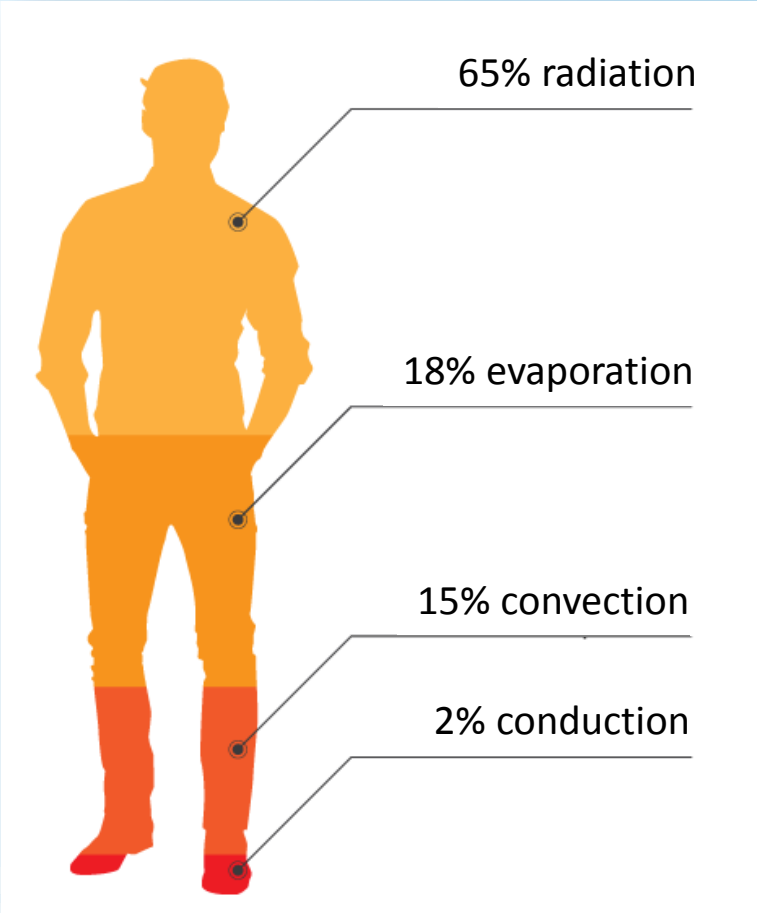
How to Measure Thermal Comfort

How the body loses heat



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Monika Frontczak Ph.D. thesis Technical University of Denmark, 2011

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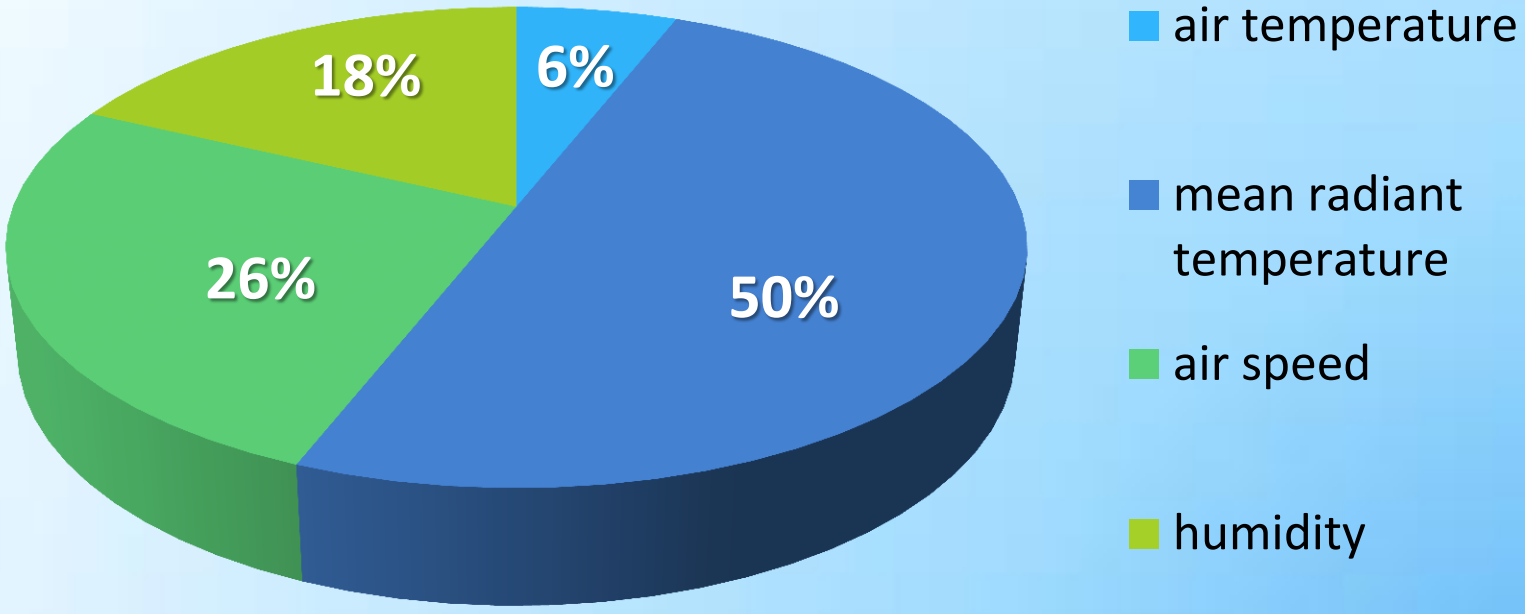
How to Measure Thermal Comfort

Contribution to thermal comfort



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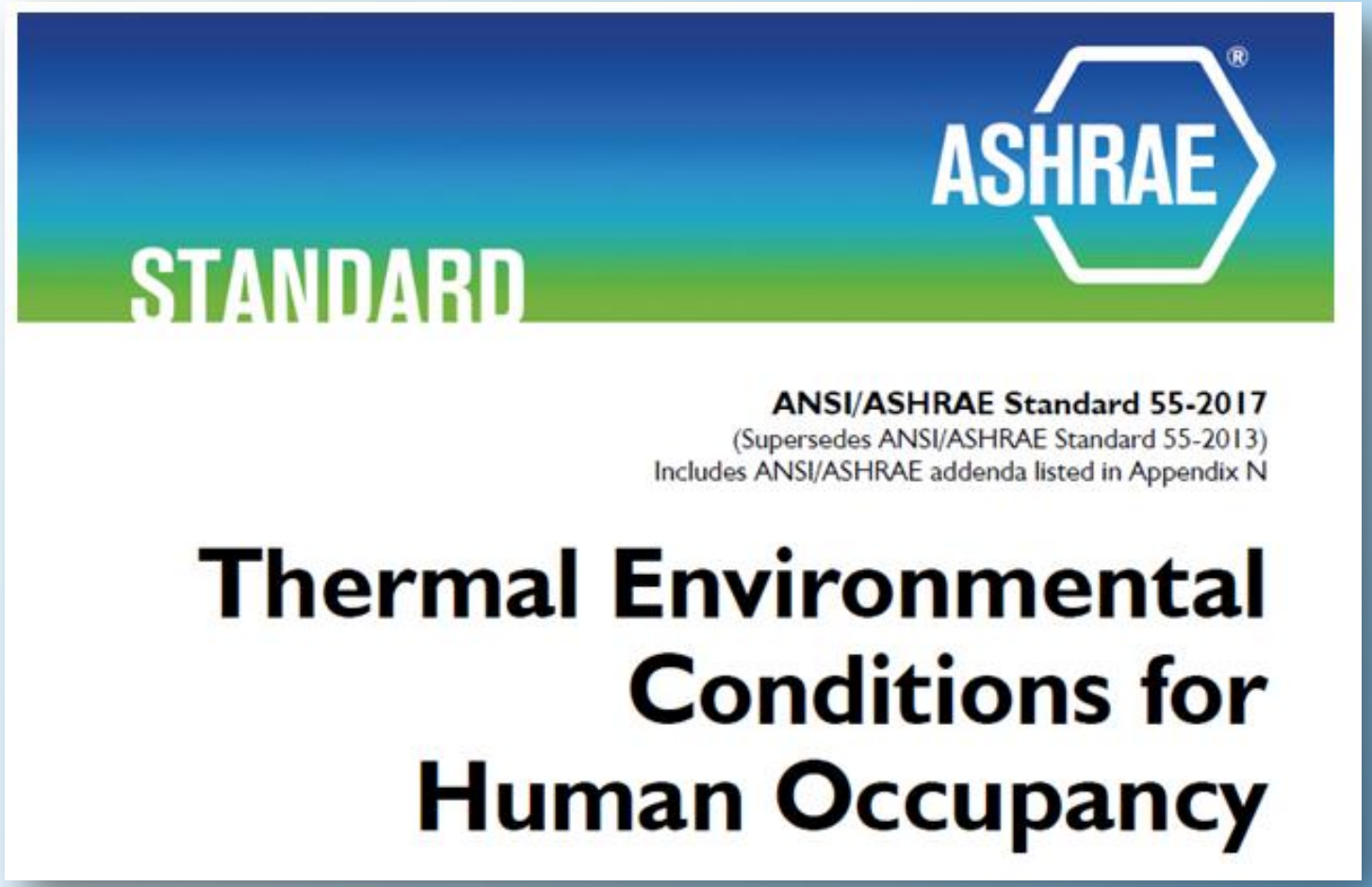
How to Measure Thermal Comfort



First published in 1966

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How to Measure Thermal Comfort

Mean radiant temperature (tr): the uniform surface temperature of an imaginary black enclosure in which an occupant would exchange the same amount of radiant heat as in the actual non-uniform space

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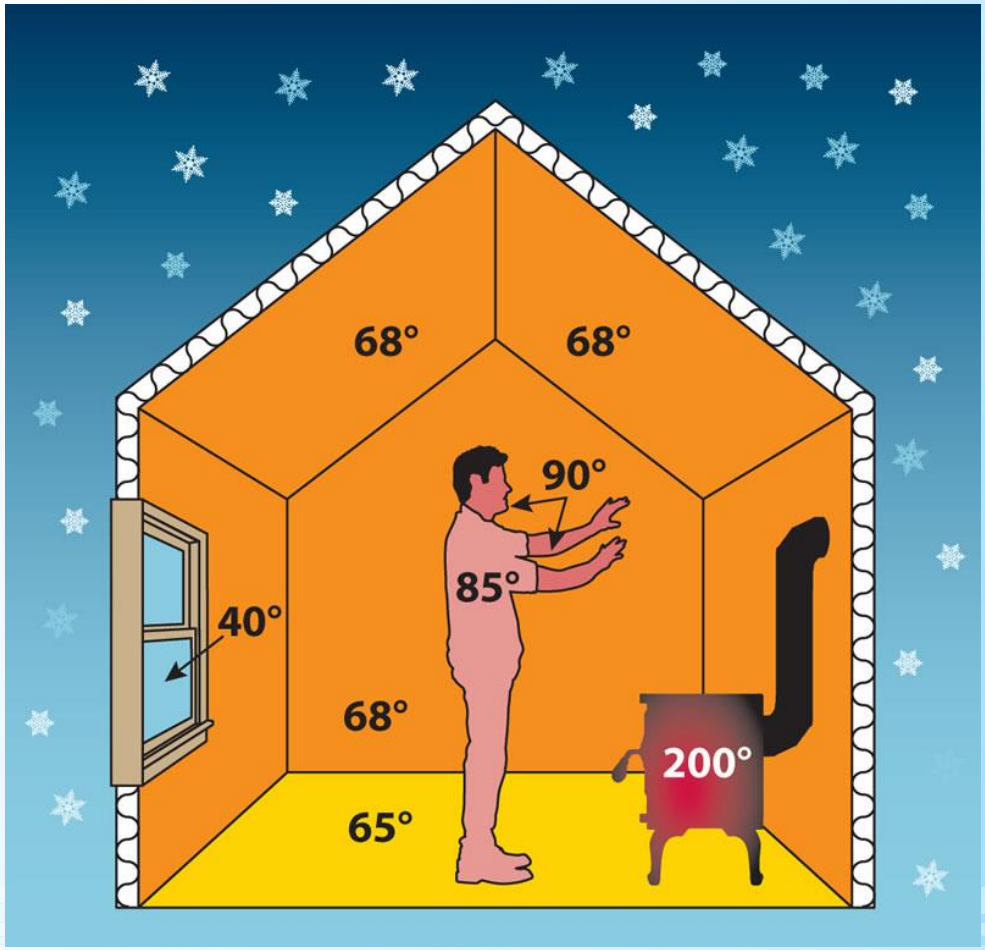
How to Measure Thermal Comfort



- **Temperature (°F)**
- **Area**
- **Distance**

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How to Measure Thermal Comfort

Operative temperature (to): the uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of heat by **radiation plus convection** as in the actual non-uniform environment

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How to Measure Thermal Comfort

- ***predicted mean vote (PMV):*** an index that predicts the mean value of the votes of a large group of persons on the seven point thermal sensation scale

+3	hot
+2	warm
+1	slightly warm
0	neutral
–1	slightly cool
–2	cool
–3	cold

- ***predicted percentage of dissatisfied (PPD):*** an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people determined from PMV

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How to Measure Thermal Comfort

Factors Affecting Thermal Comfort	
Mechanical	**Building Envelope**
• Dry Bulb (Air) Temperature	• Mean Radiant Temperature
• Humidity	• Radiant Temperature Asymmetry
• Air Speed	• Drafts
	• Floor Surface Temperature
• Vertical Air Temperature Difference	
• Temperature Variation with Time	
Personal Factors	
• Clothing and Metabolic Rate	

ASHRAE 55

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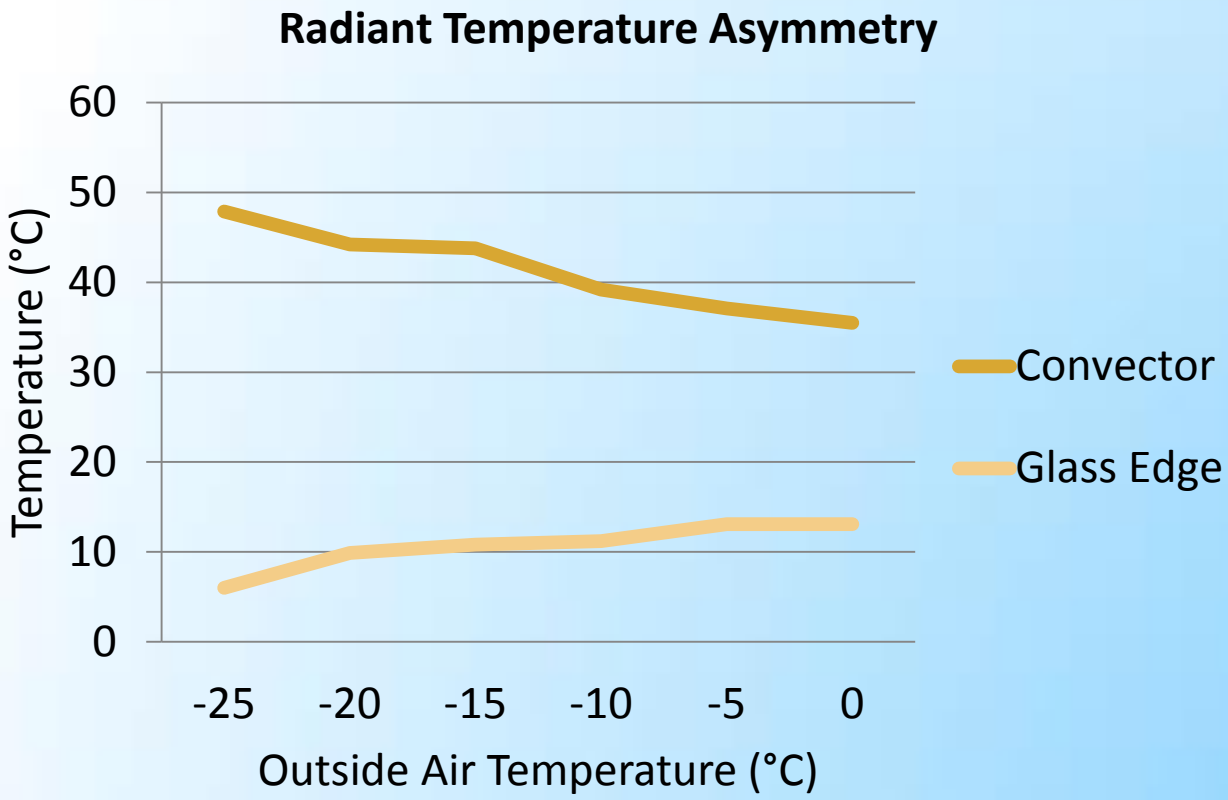
How to Measure Thermal Comfort



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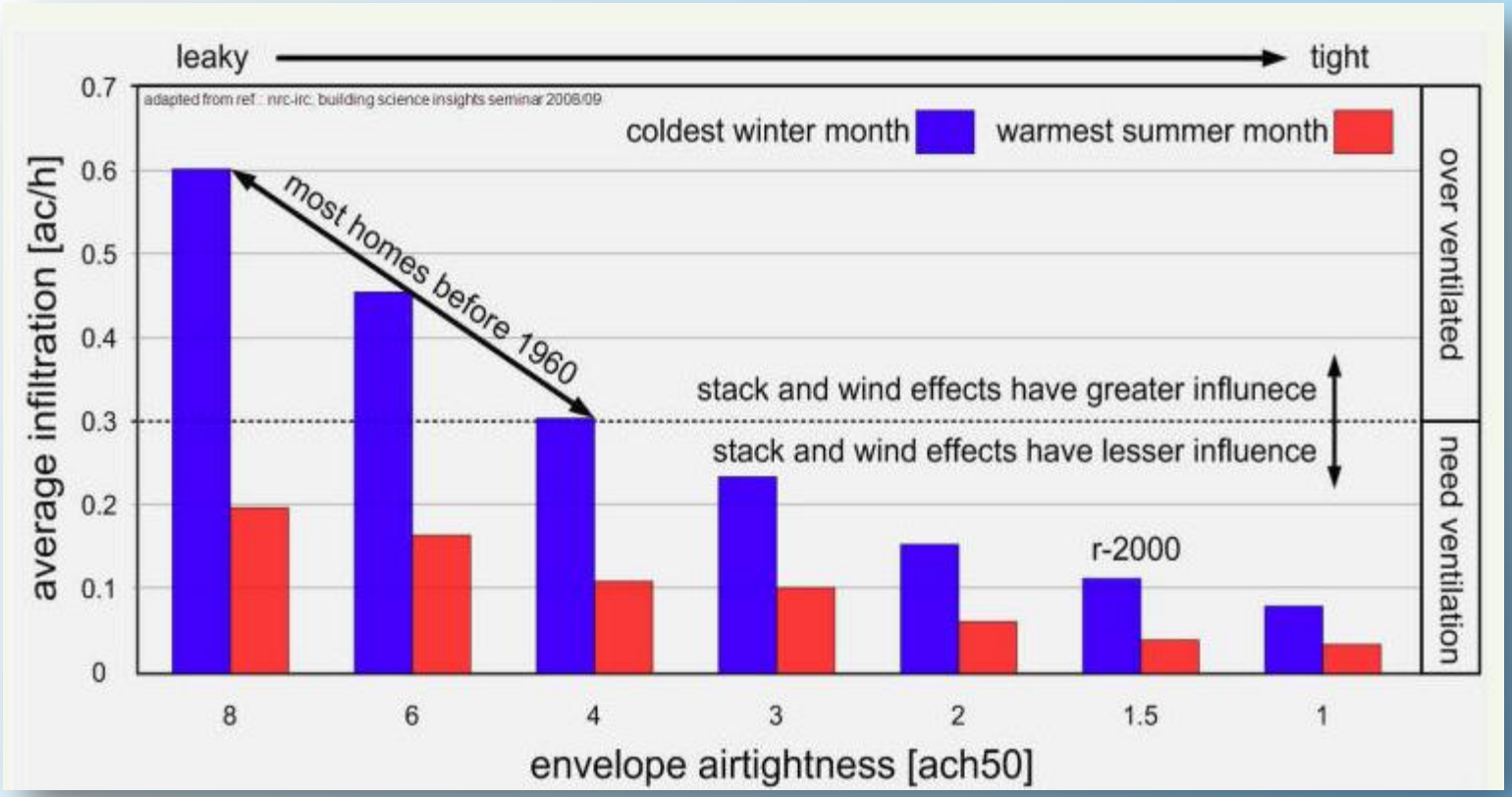

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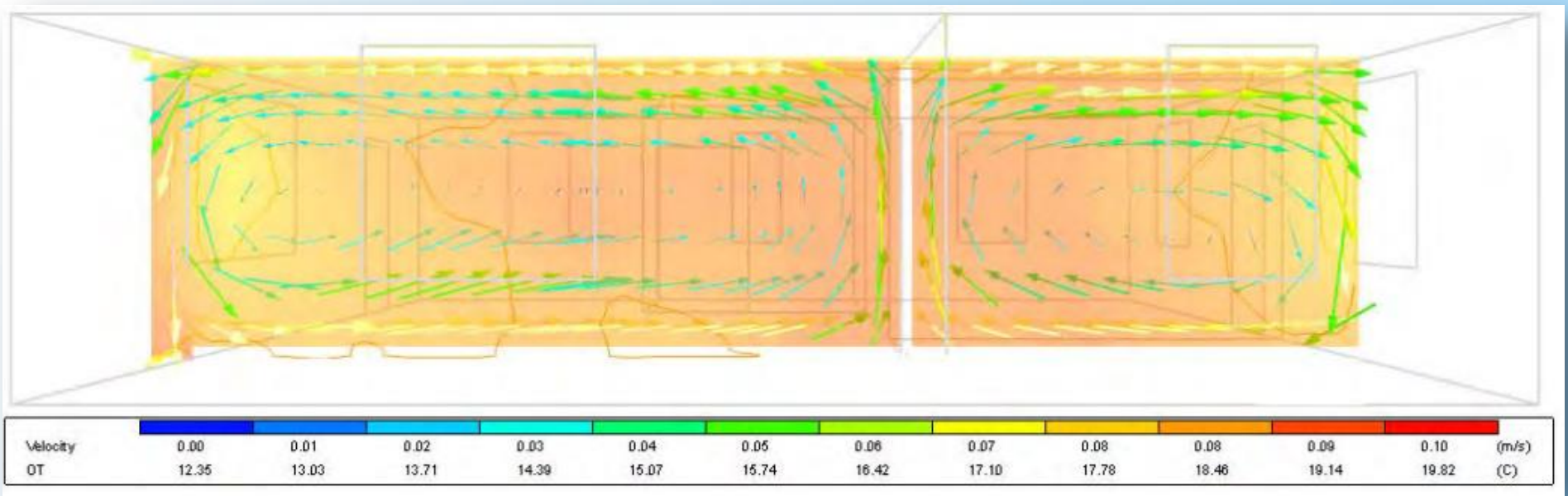
How to Measure Thermal Comfort

Computational Fluid Dynamics (CFD) Analysis



Review of Window Energy Rating Procedure in Canada; co-funded by Manitoba Hydro –January 2013

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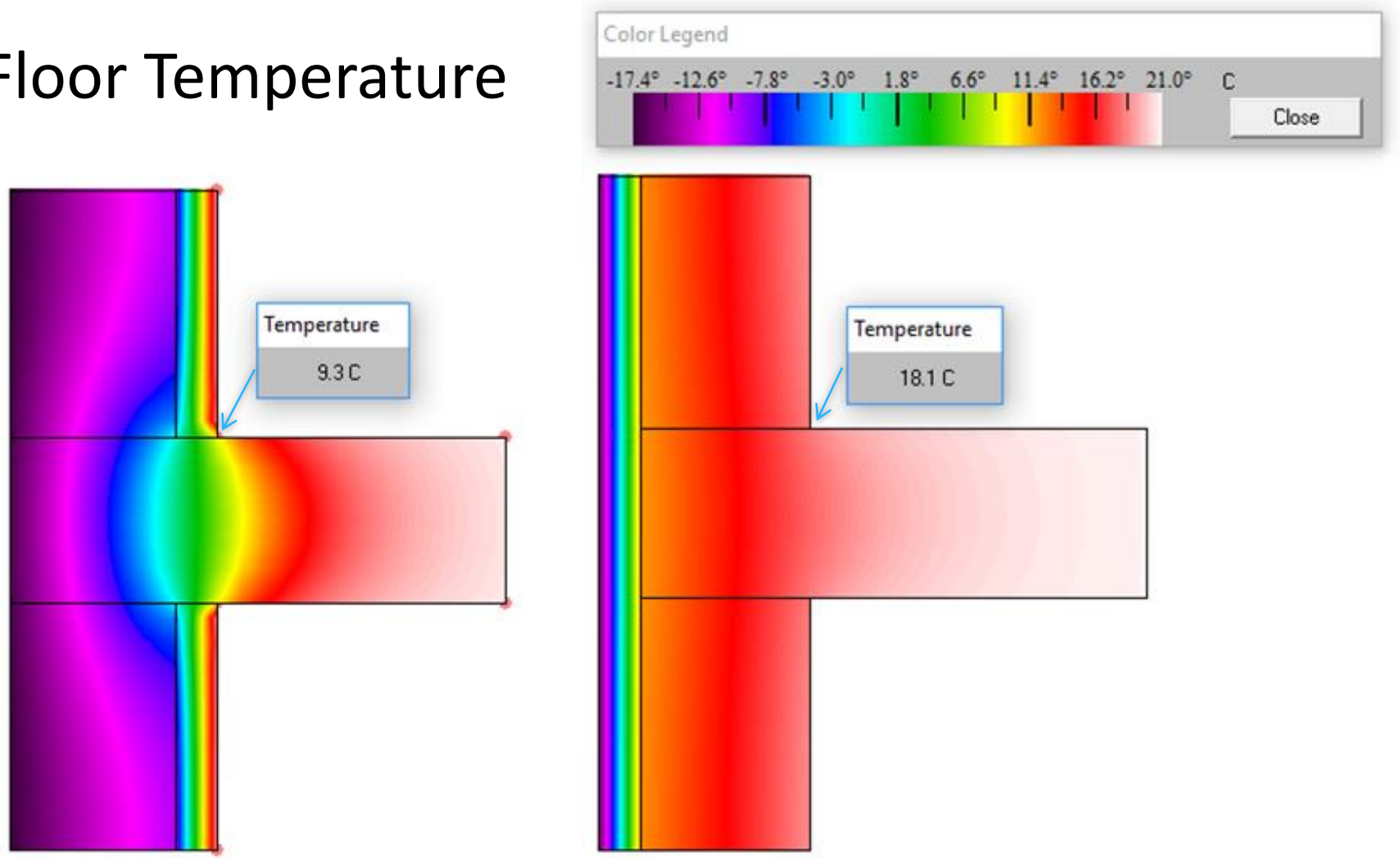
Thermal Comfort and the Building Envelope

Floor Temperature



Thermal Comfort and the Building Envelope

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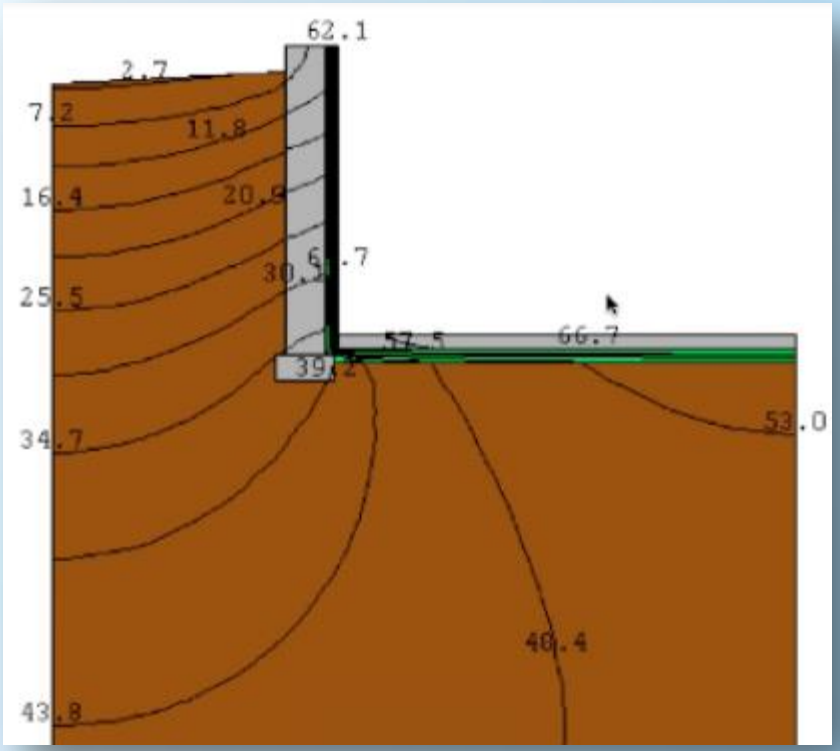

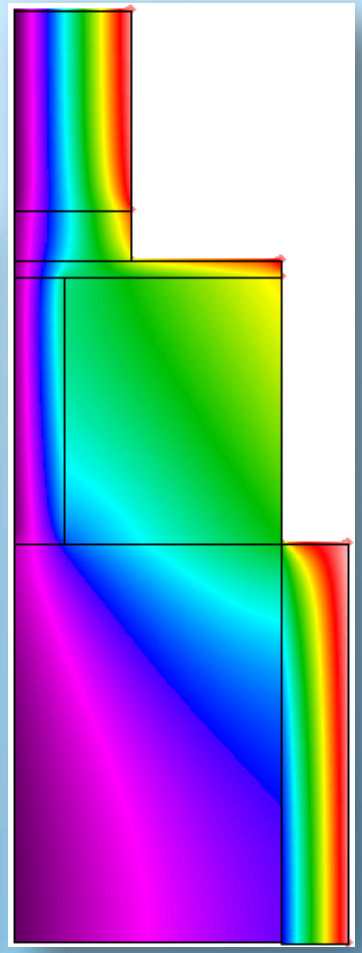

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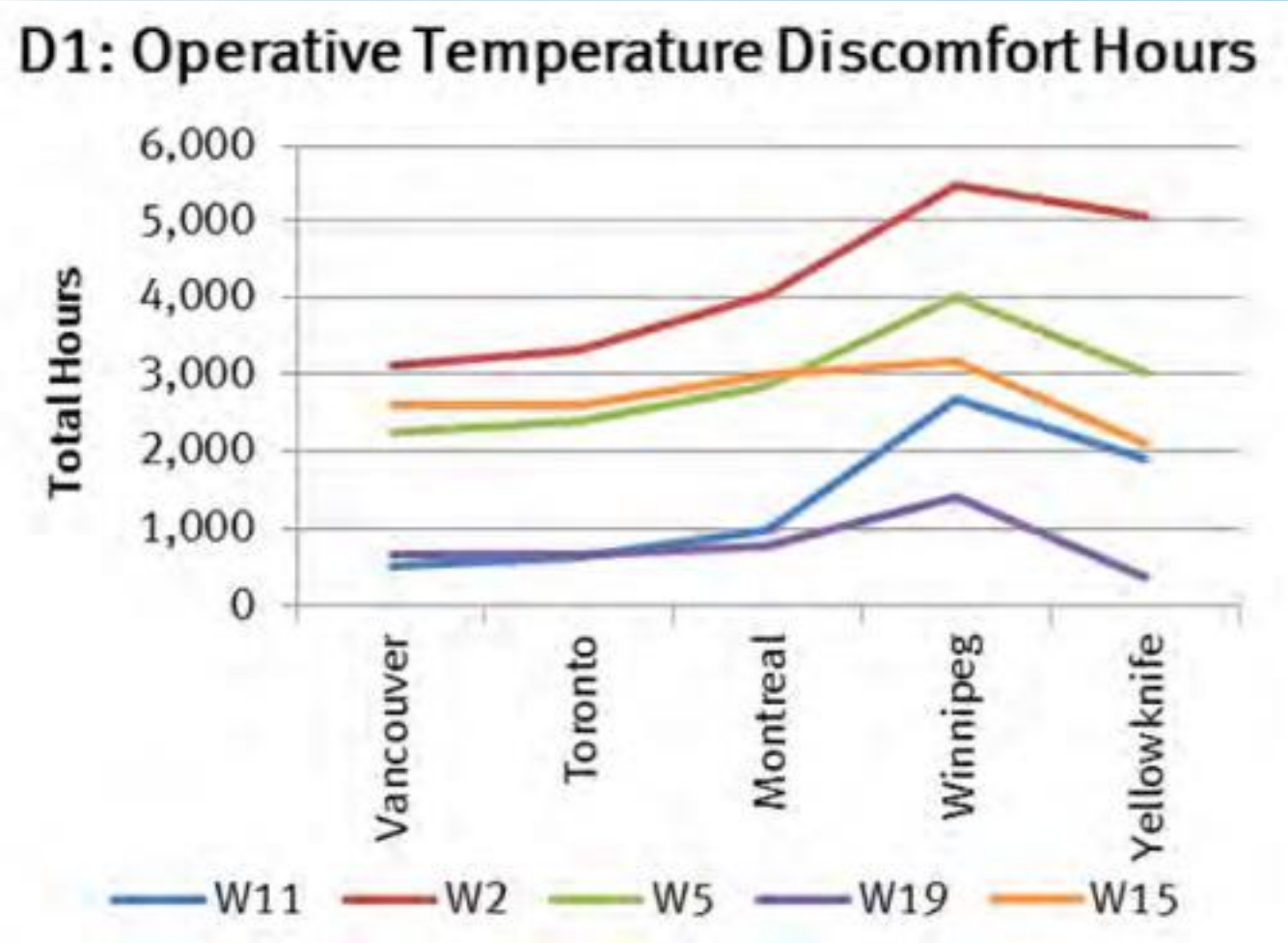

Review of Window Energy Rating Procedure in Canada; co-funded by Manitoba Hydro –January 2013

Thermal Comfort and the Building Envelope

Window	Representative Window	U-value, W/m²-K (Btu/h-ft²-F)	SHGC
W2	Double-glazed, clear, air fill, wood or vinyl frame (existing house in cold climate)	2.83 (0.50)	0.64
W5	Double-glazed, high U-value, high SHGC	2.00 (0.35)	0.50
W11	Double-glazed, high U-value, low SHGC	2.00 (0.35)	0.20
W15	Triple-glazed, low U-value, high SHGC	0.90 (0.16)	0.50
W19	Triple-glazed, low U-value, low SHGC	0.90 (0.16)	0.20

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Thermal Comfort and the Building Envelope

Description	Indoor Glass Temp (°C)	
	Winter	Summer
2-pane clear	7	32
2-pane low-e argon	13	28-31
3-pane clear	12	33
3-pane low-e argon	16	28-38
3-pane 2*low-e argon	17	28-34
Outdoor Temperature	-18	complicated

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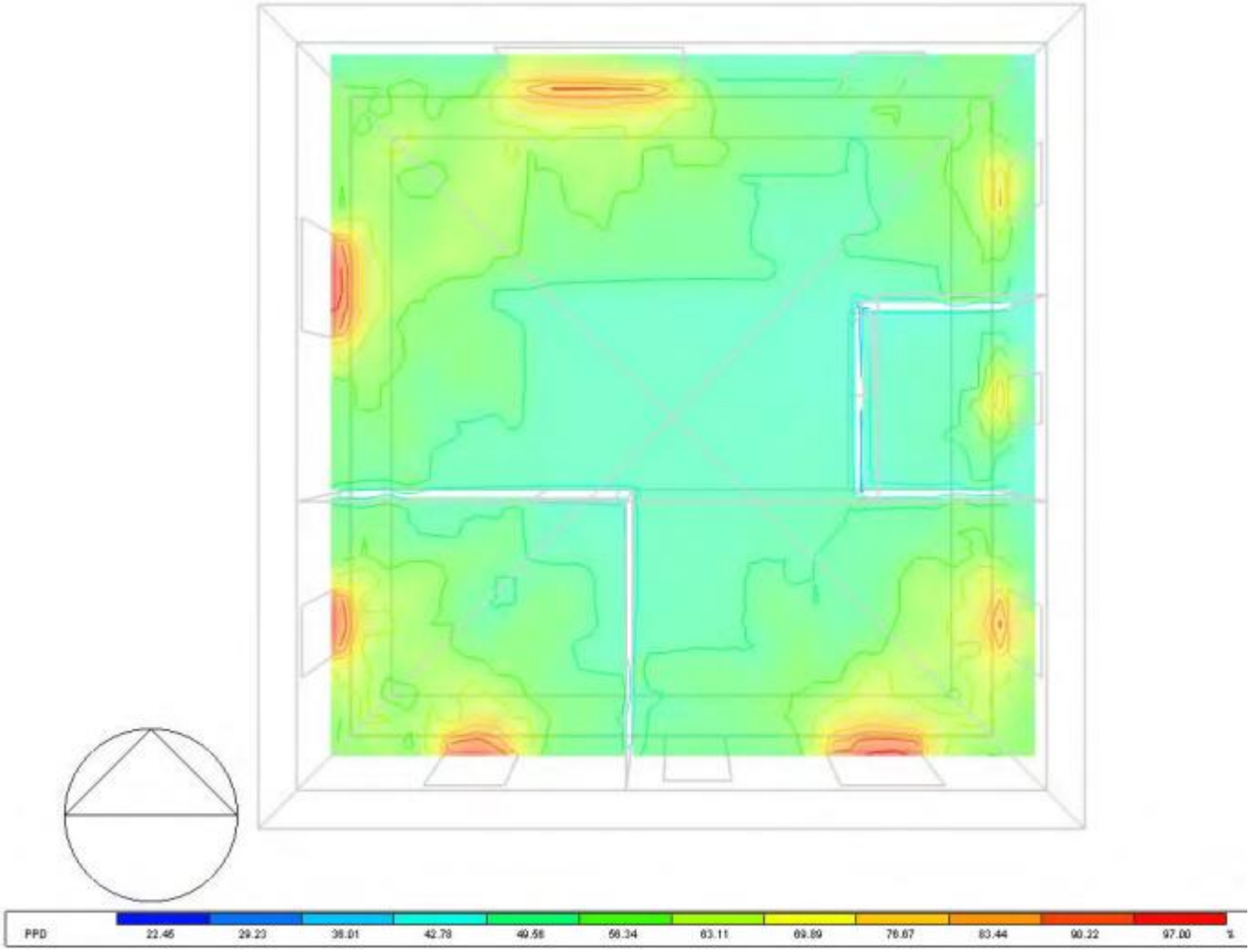
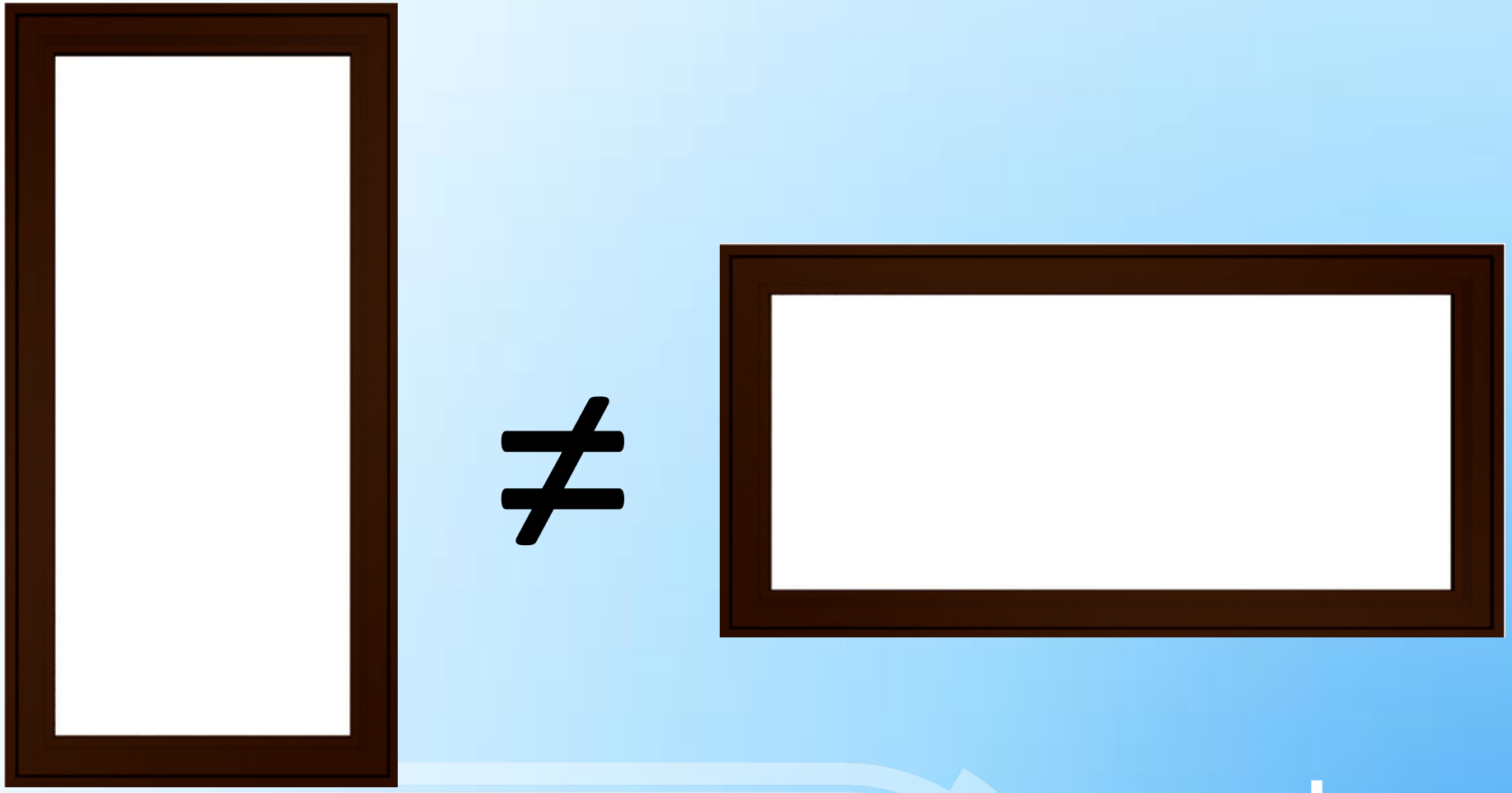
Thermal Comfort and the Building Envelope



Thermal Comfort and the Building Envelope

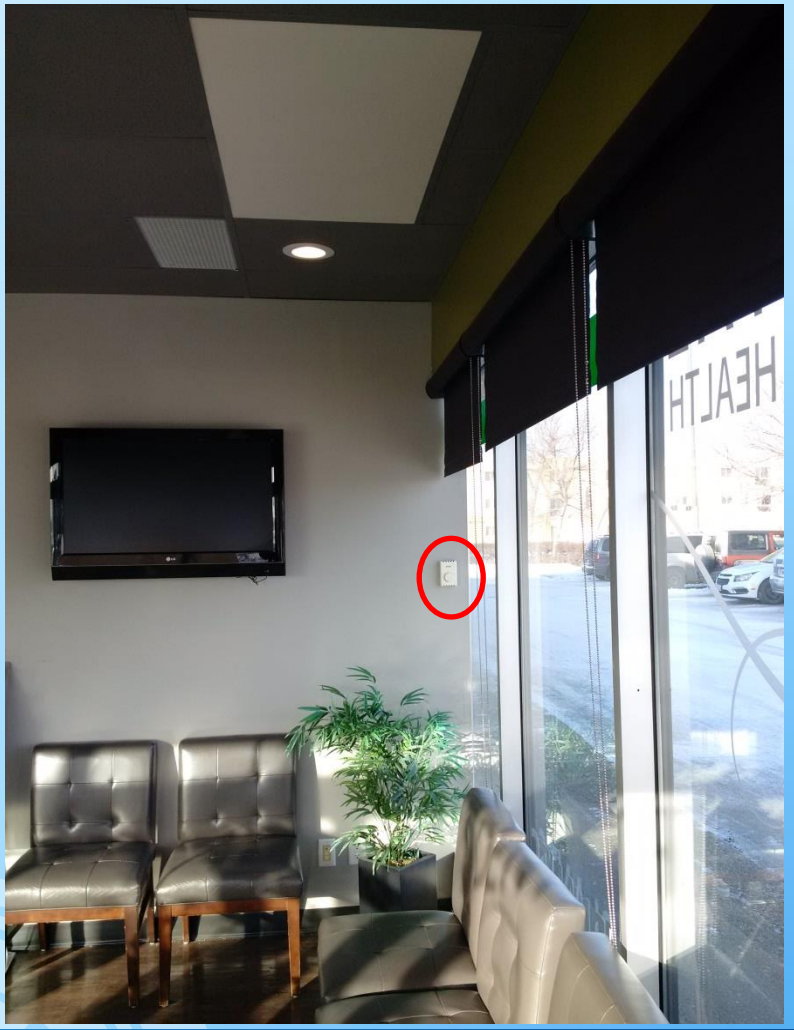


Thermal Comfort and the Building Envelope

BEFORE

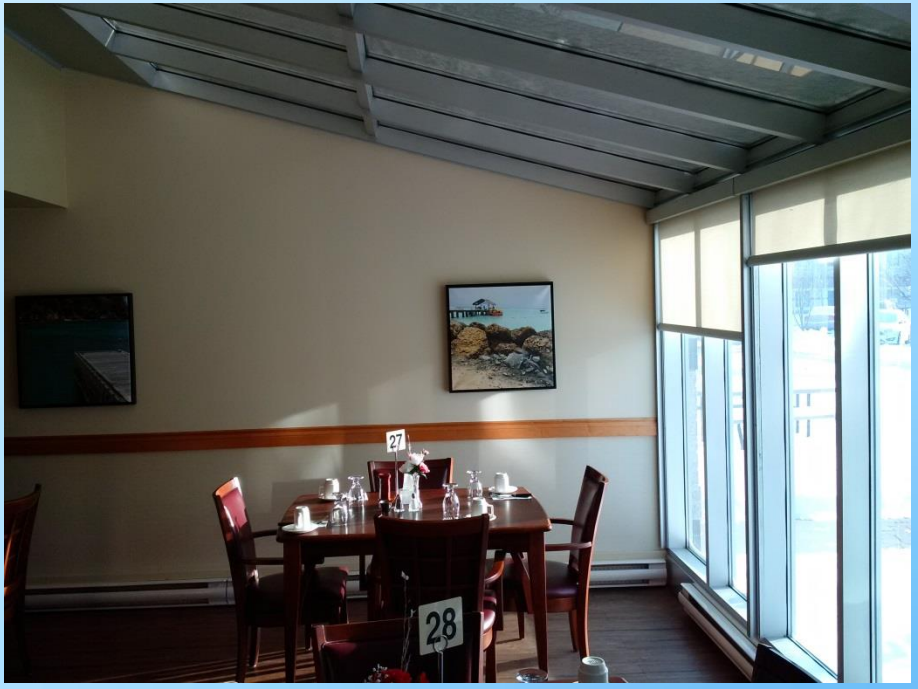
AFTER

Thermal Comfort and the Building Envelope



Thermal Comfort and the Building Envelope

North



South

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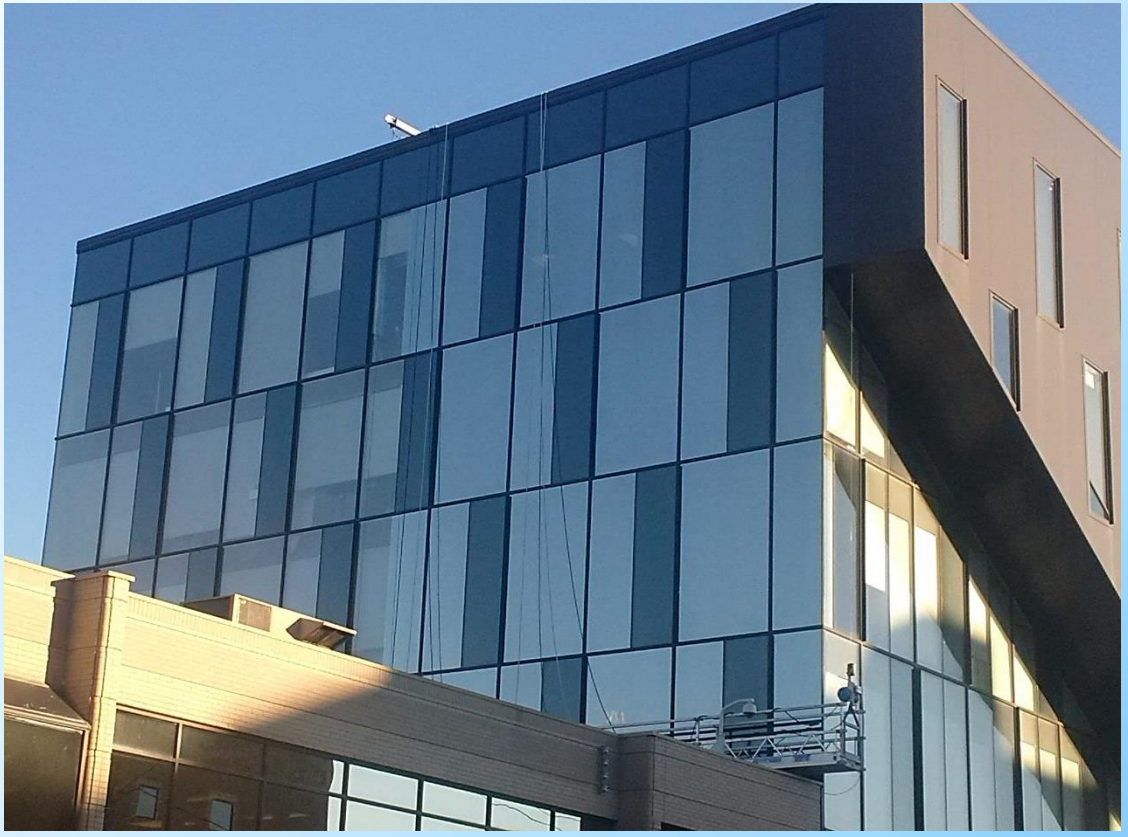

Solar gain - overheating

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Thermal Comfort and the Building Envelope

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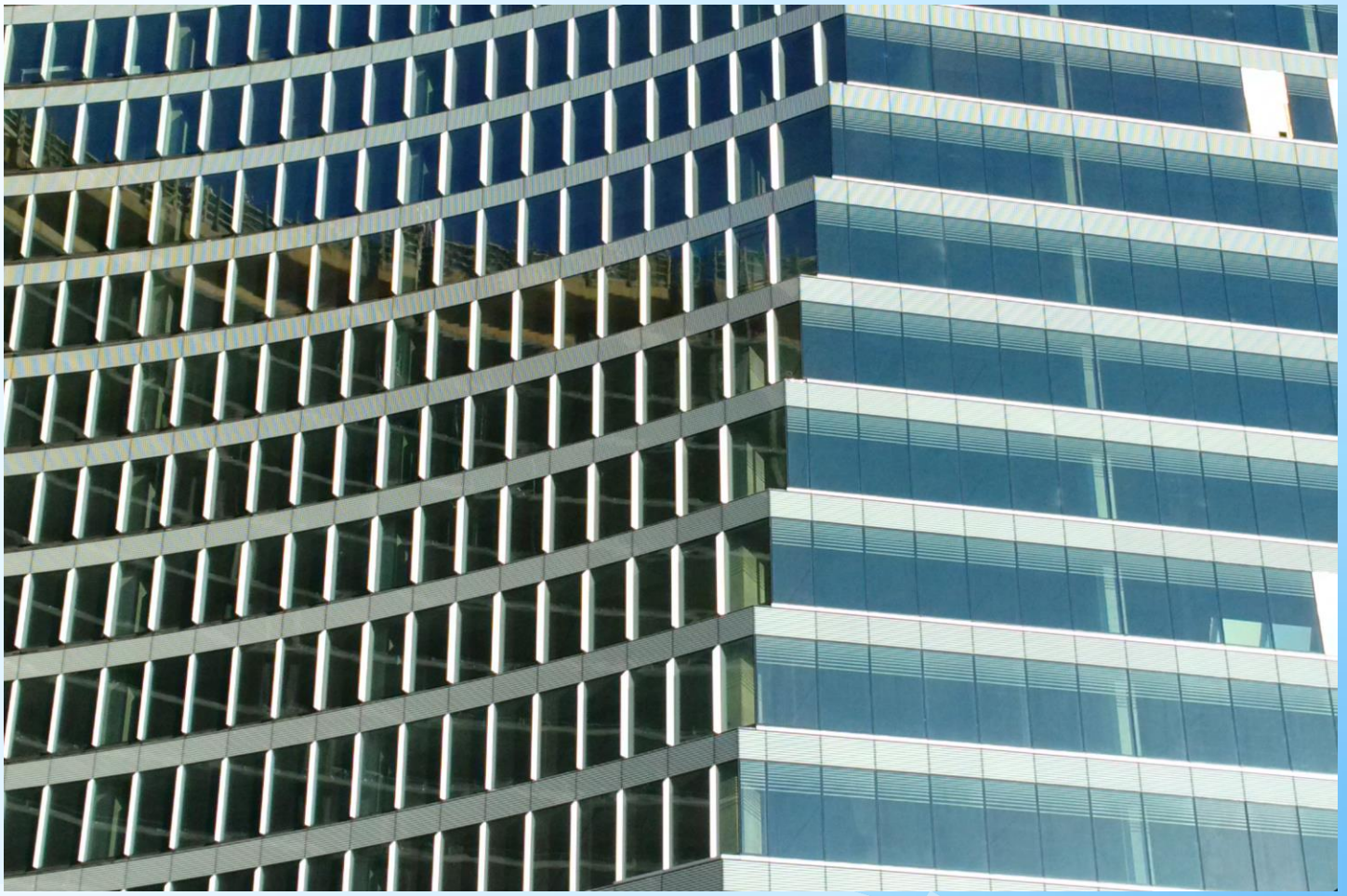

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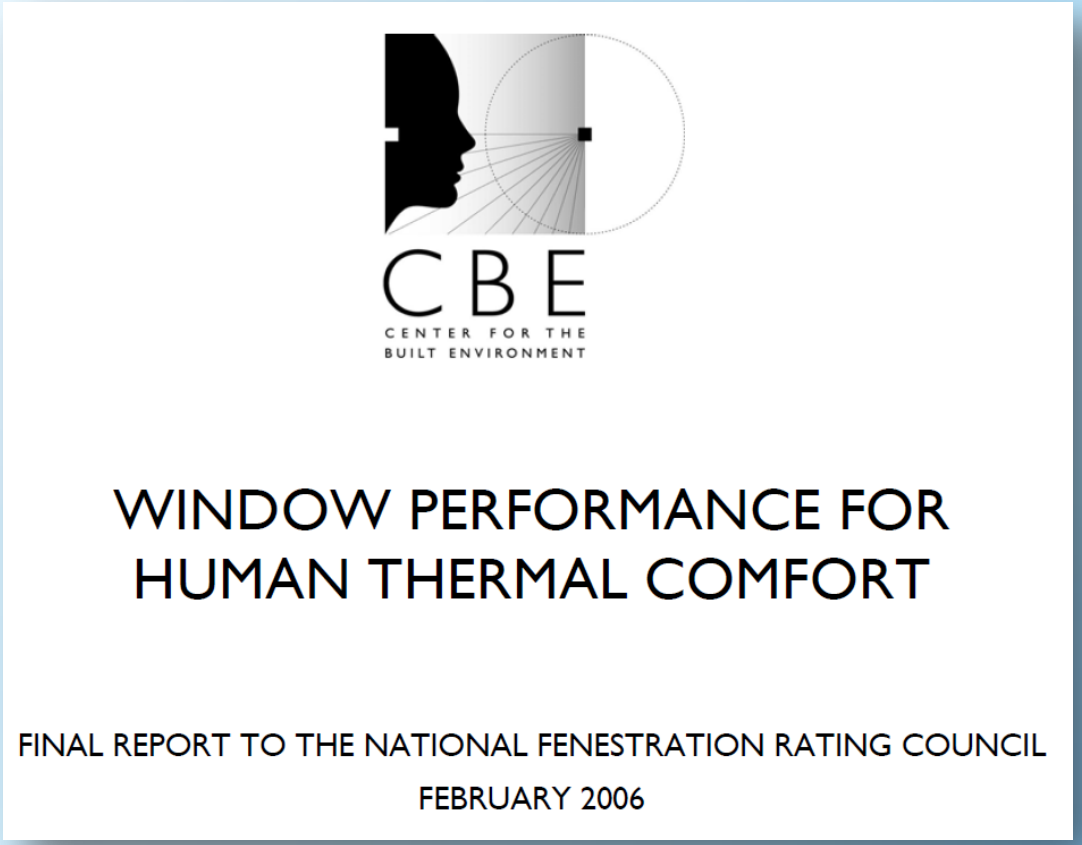

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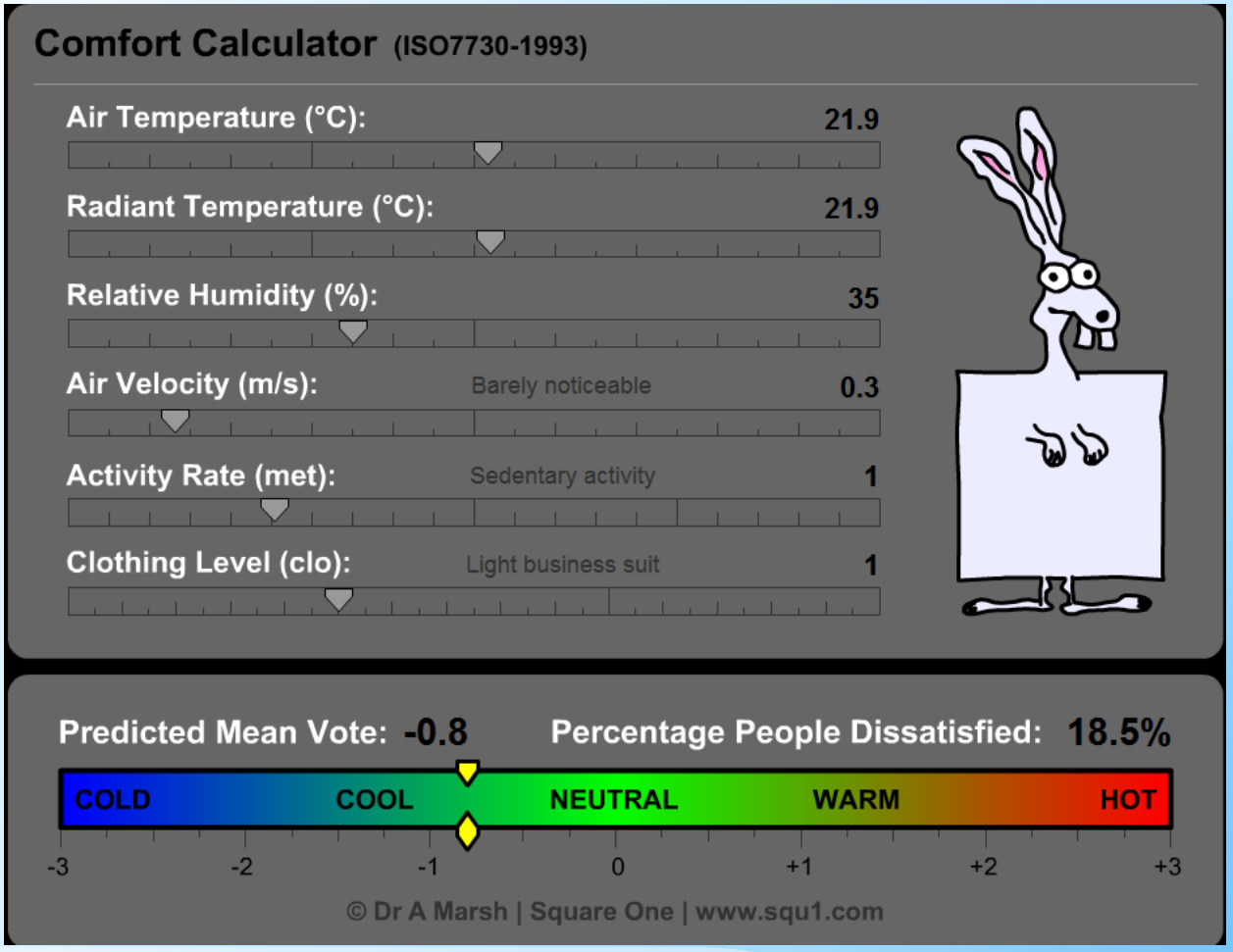
Practical Tools for Solutions



http://www.healthyheating.com/solutions.htm#.Wl4JvK3fO38

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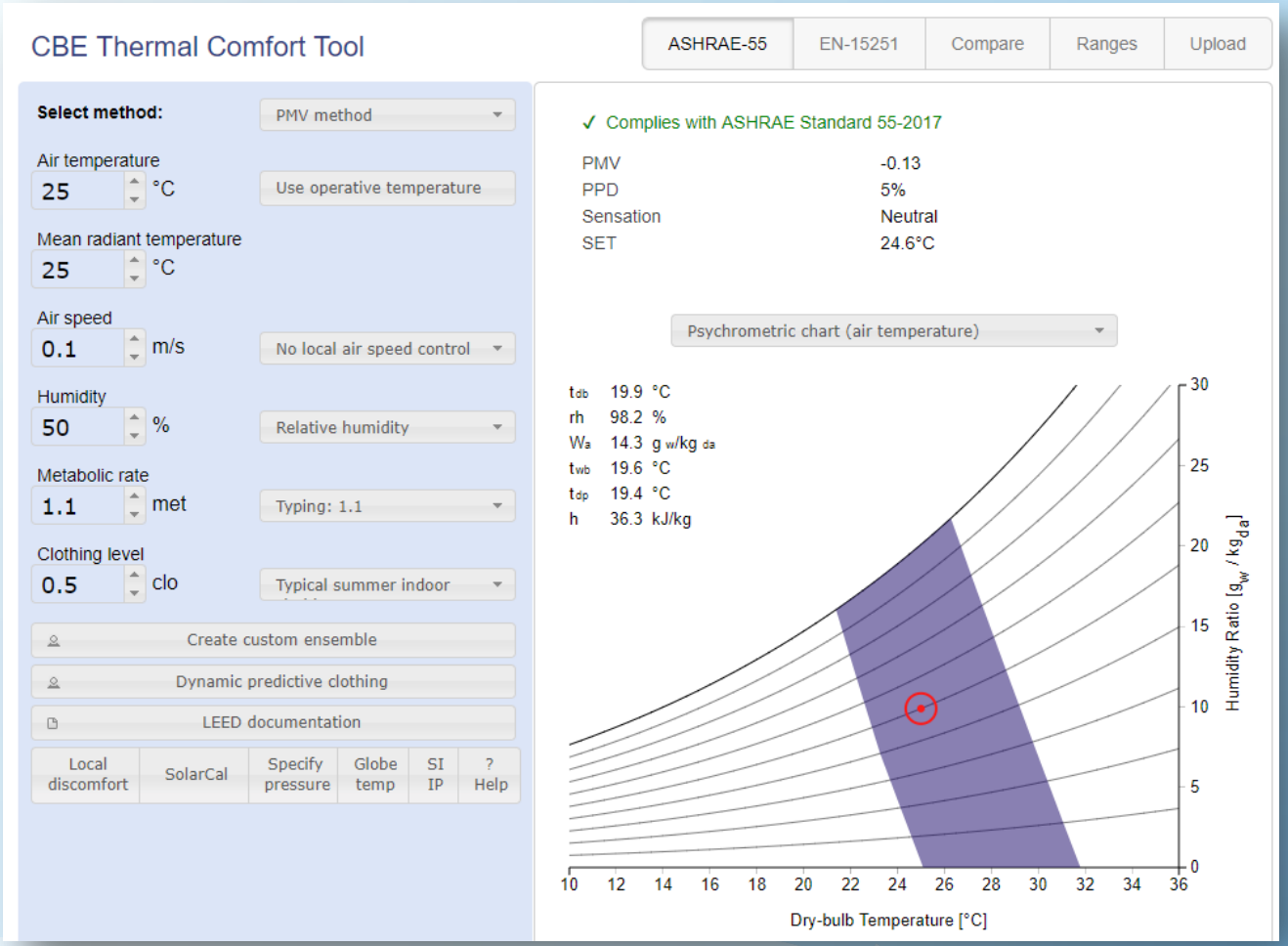

http://comfort.cbe.berkeley.edu/

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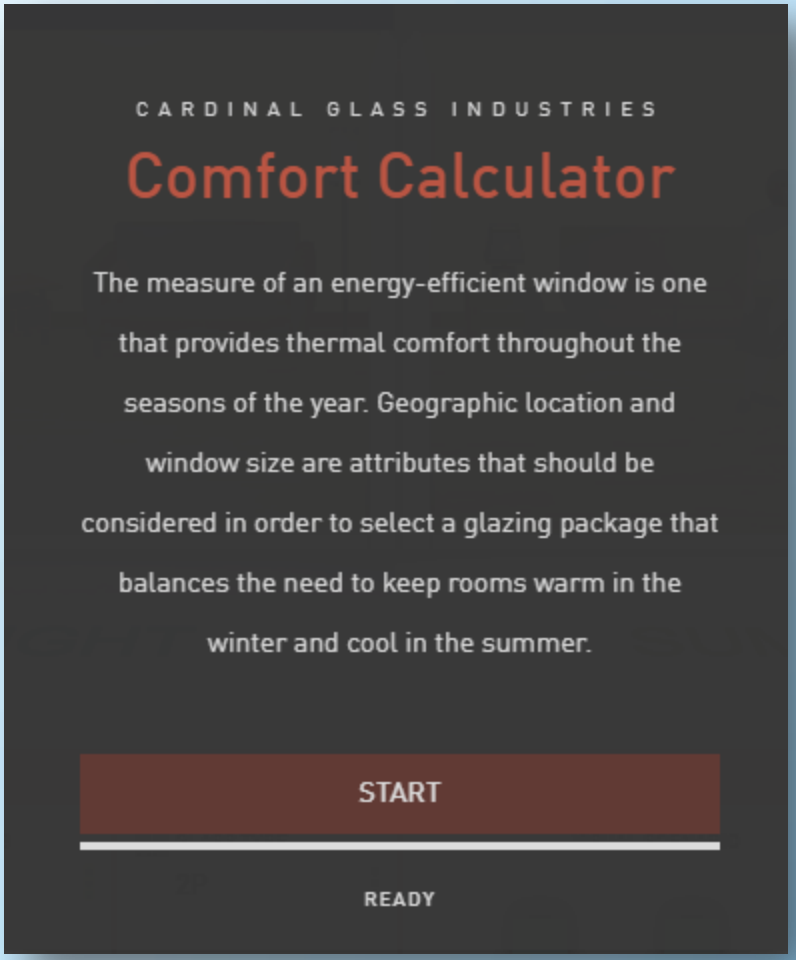

http://www.cardinalcorp.com/technology/applications/comfort-calculator/

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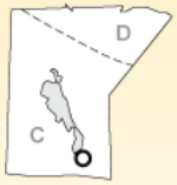

ORIENTATION
- ○ Equal
- ○ North
- ○ East
- ◉ South
- ○ West

WINDOW AREA
- ◉ Small
- ○ Moderate
- ○ Large

SHADING TYPE
- ◉ Typical
- ○ None
- ○ Interior
- ○ Overhangs
- ○ Maximum

LOCATION: Winnipeg, Manitoba
HOUSE TYPE: 1 Story
WINDOW TYPE: Windows

NEW SEARCH

MODIFY SEARCH

Summary | Energy | COMFORT | Condensation

Window System							Comfort			Info
ID	Panes	Glass	Frame	U-factor	SHGC	VT	Summer and Winter Comfort	Summer	Winter	Manufacturers
18	3	HSG Low-E	Non-metal, Improved	≤0.22	0.41-0.60	0.41-0.50	Cold Neutral Hot	Slightly Warm	Neutral	products
21	2	HSG Low-E	Non-metal, Improved	0.23-0.30	0.41-0.60	0.51-0.60	Cold Neutral Hot	Slightly Warm	Cold	products
15	2	HSG Low-E	Non-metal, Improved	0.23-0.30	0.41-0.60	0.51-0.60	Cold Neutral Hot	Slightly Warm	Cold	products

http://www.efficientwindows.org/existing_selection1.php

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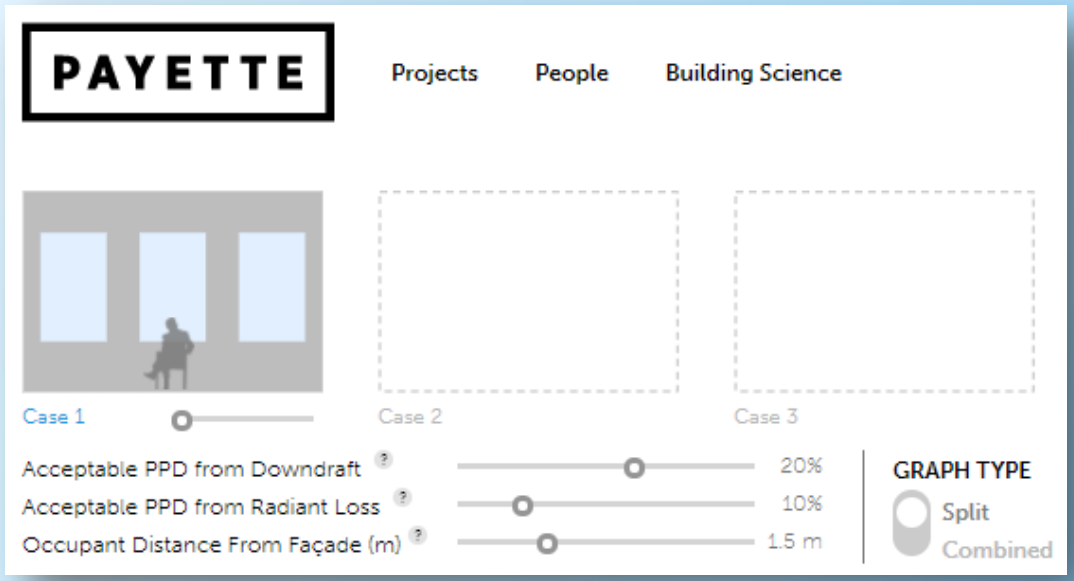
Practical Tools for Solutions

Glazing and Winter Comfort Tool



https://www.payette.com/building-science/glazing-and-winter-comfort-tool/

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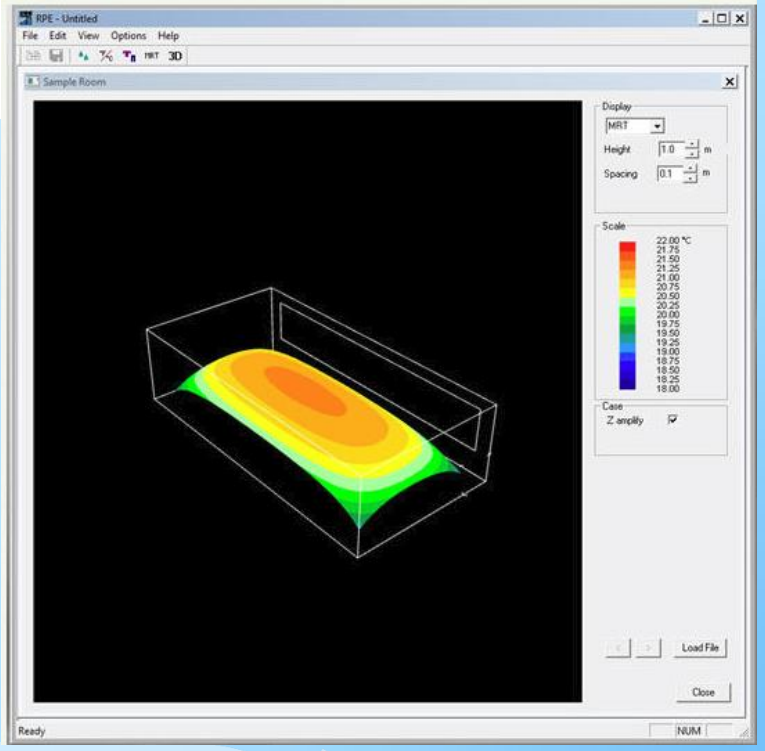
Practical Tools for Solutions

RP-1383 -- DEVELOP A RADIANT SYSTEM MODULE FOR THE SIMULATION AND ANALYSIS OF SPACES AND SYSTEMS

REPORT / SURVEY by ASHRAE, 2015

Charles Barnaby, Curtis Pedersen

- Radiant Performance Explorer
- Compatible with
  - Sketch Up
  - EnergyPlus



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Thank you!

Harry Schroeder, P. Eng.

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