Resilient Building Design for Projected Morphed Climate Data: Lifetime Thermal Comfort and Energy Demand

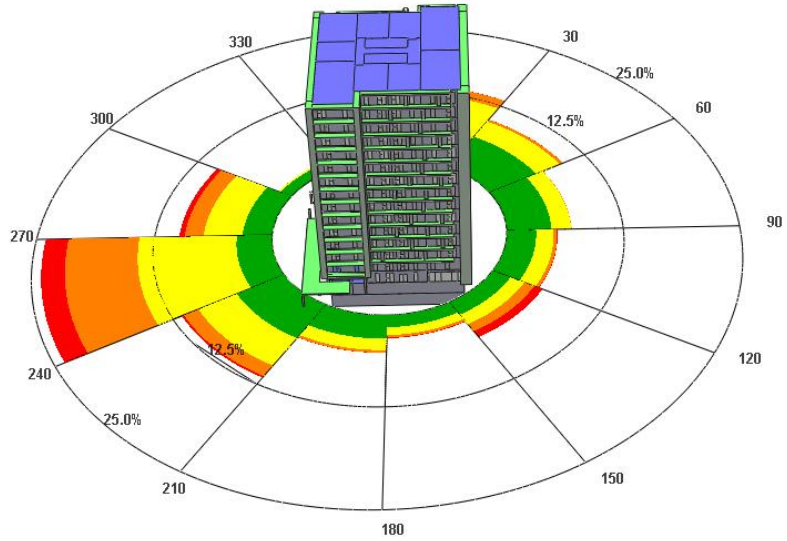
October 30, 2020

Mohammad Fakoor, PhD, CEA, P.Eng., CPHD
Senior Building Performance Engineer

Read Jones Christoffersen Ltd.
Creative Thinking Practical Results

Outline

- Climate Change
- Future Warmer Weather Data
- Thermal Comfort Standards
- Case Study- Thermal Comfort
- Case Study- Energy Consumption



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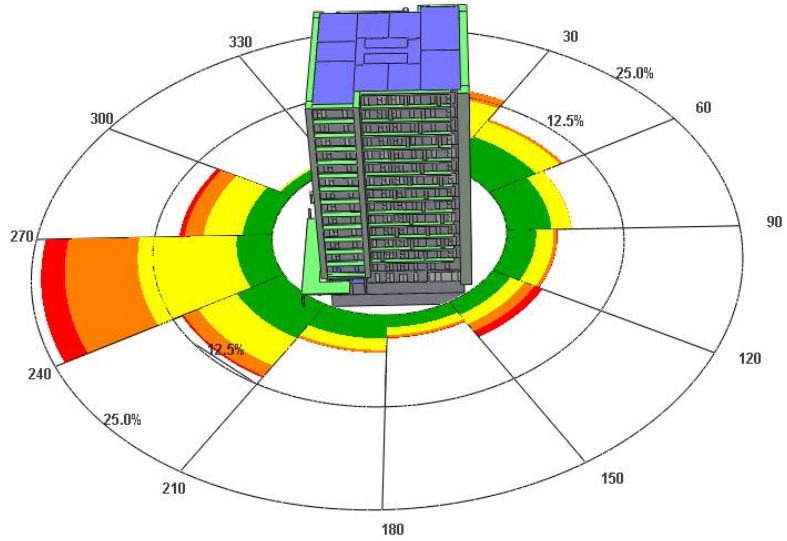
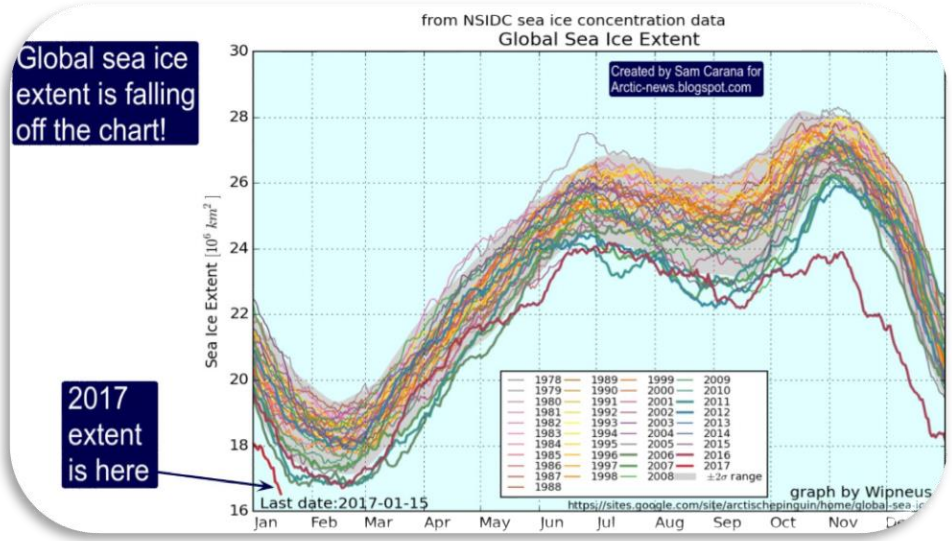


https://www.sciencenews.org/article/climate-change-economic-cost-united-states

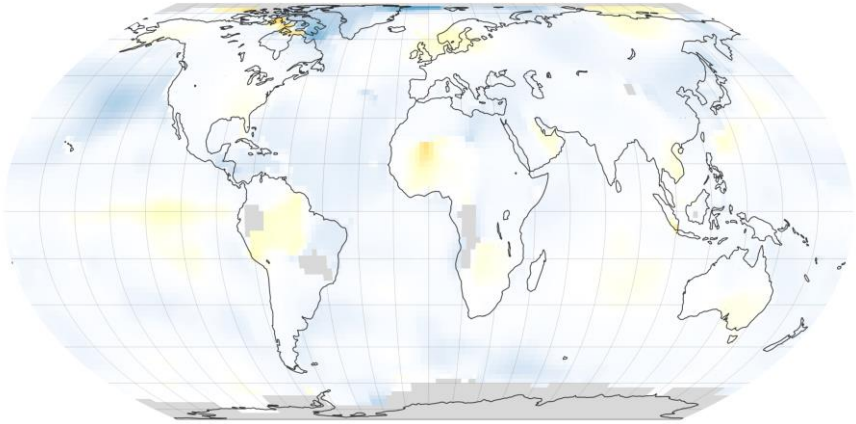
https://climate.nasa.gov/news/2315/study-fire-seasons-getting-longer-more-frequent/

http://news.mit.edu/2017/climate-change-drought-corn-yields-africa-0316

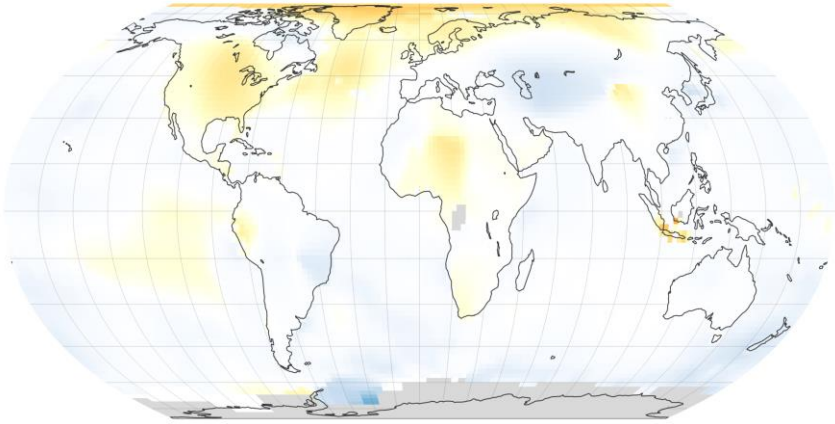


http://arctic-news.blogspot.com/2017/01/global-sea-ice-extent-falling-off-chart.html

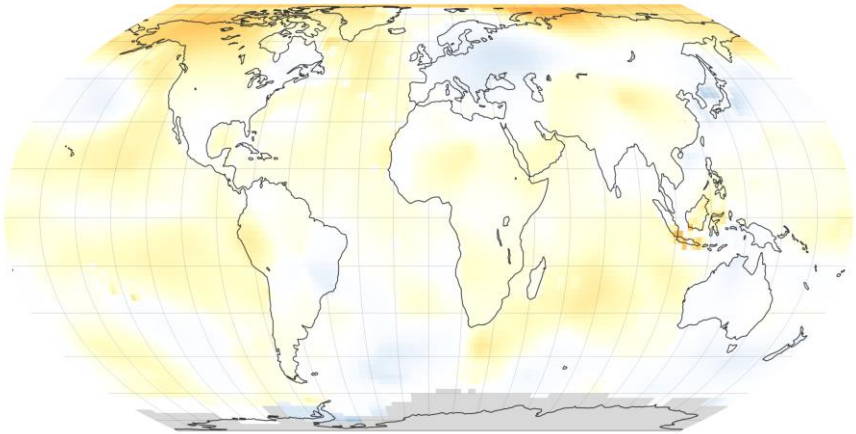
World of Change: Global Temperatures



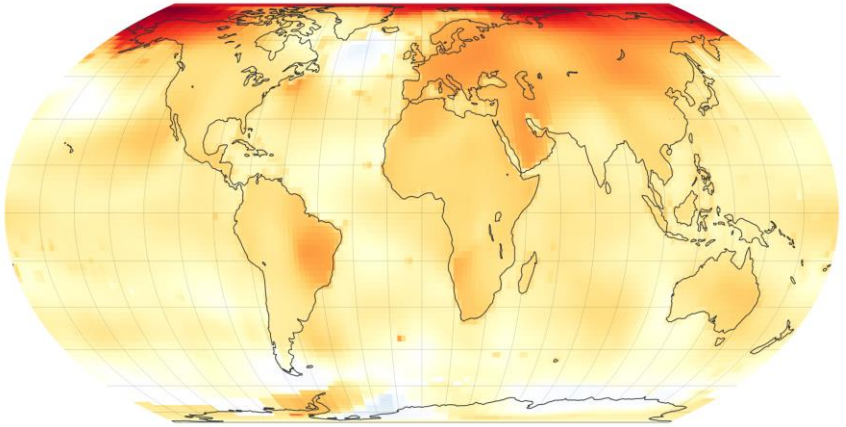
1910-1914



1930-1934



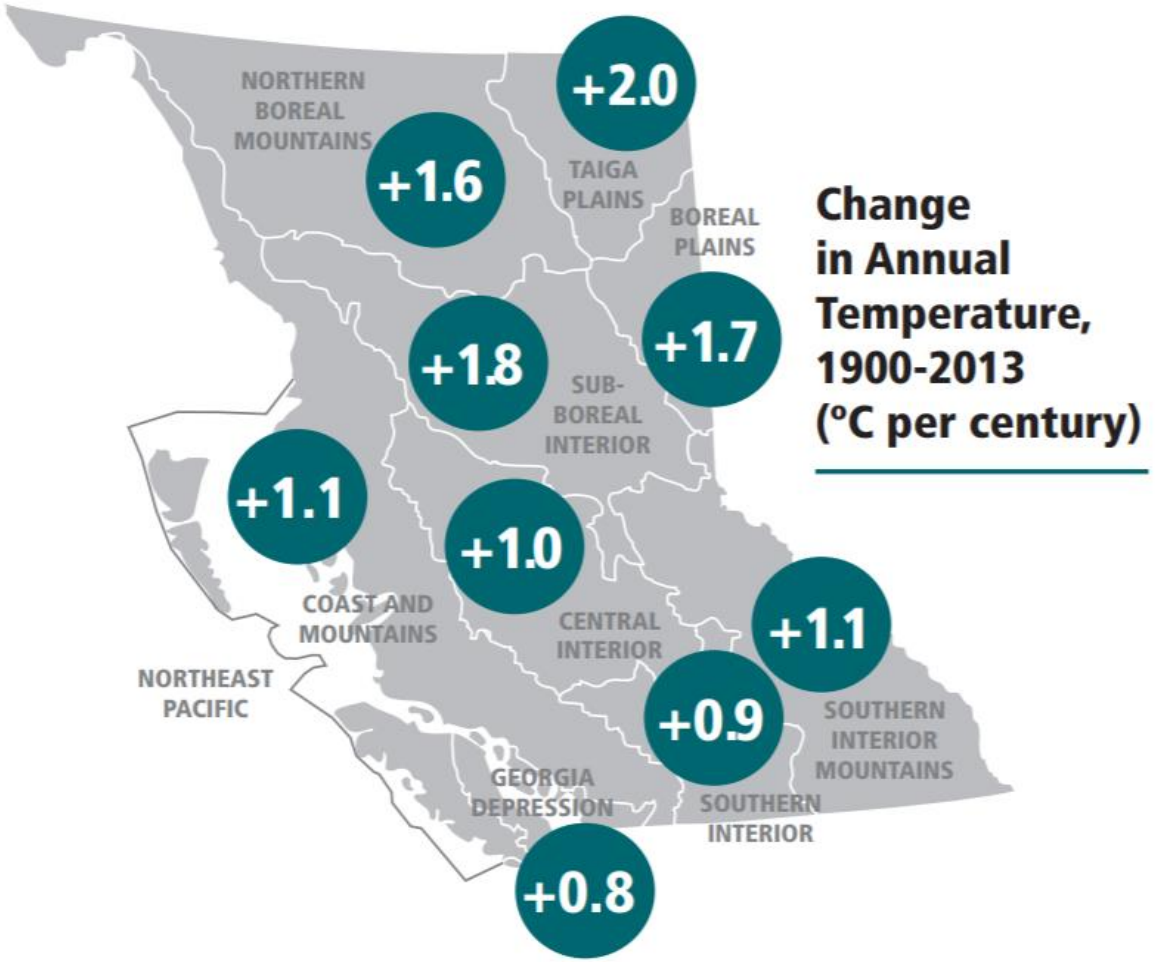
1940-1944

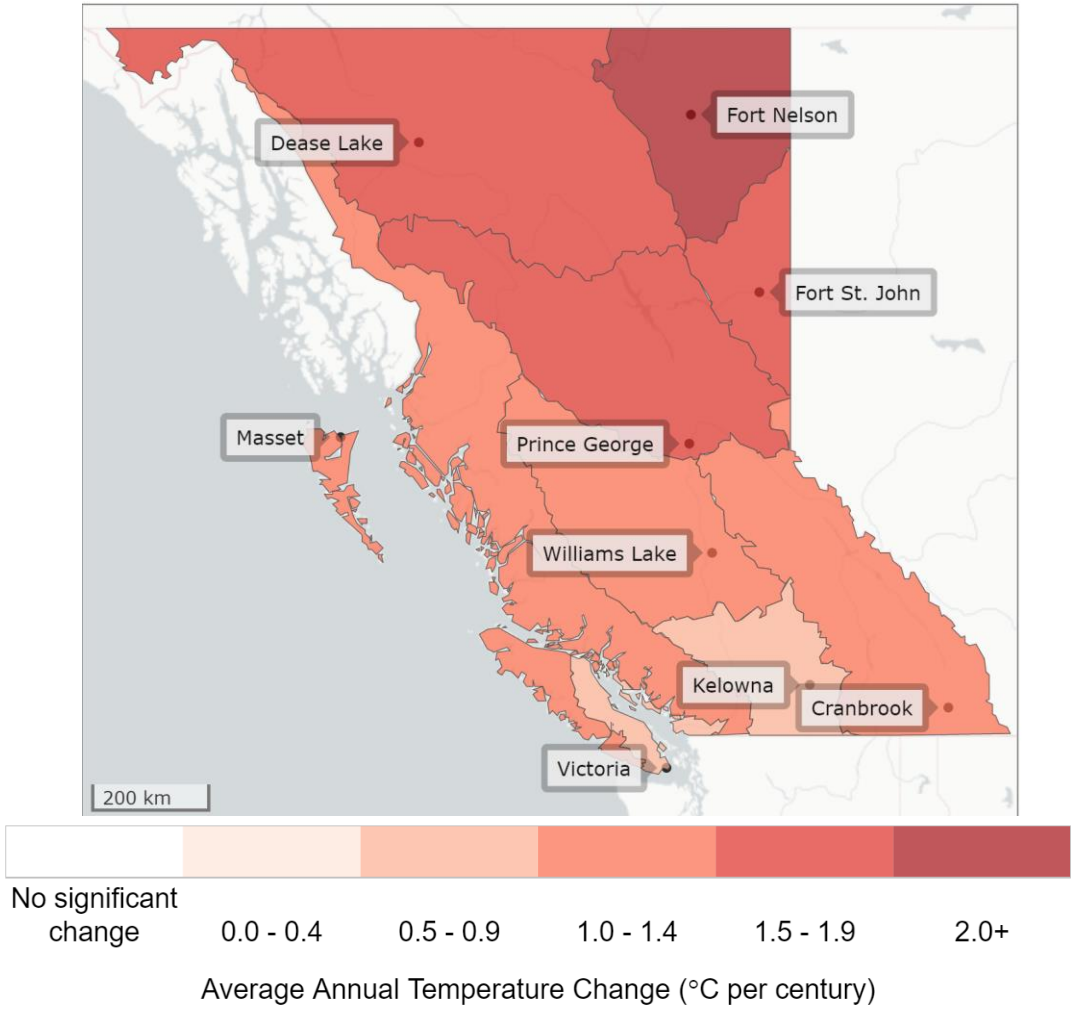


2015-2019

https://earthobservatory.nasa.gov/world-of-change/global-temperatures

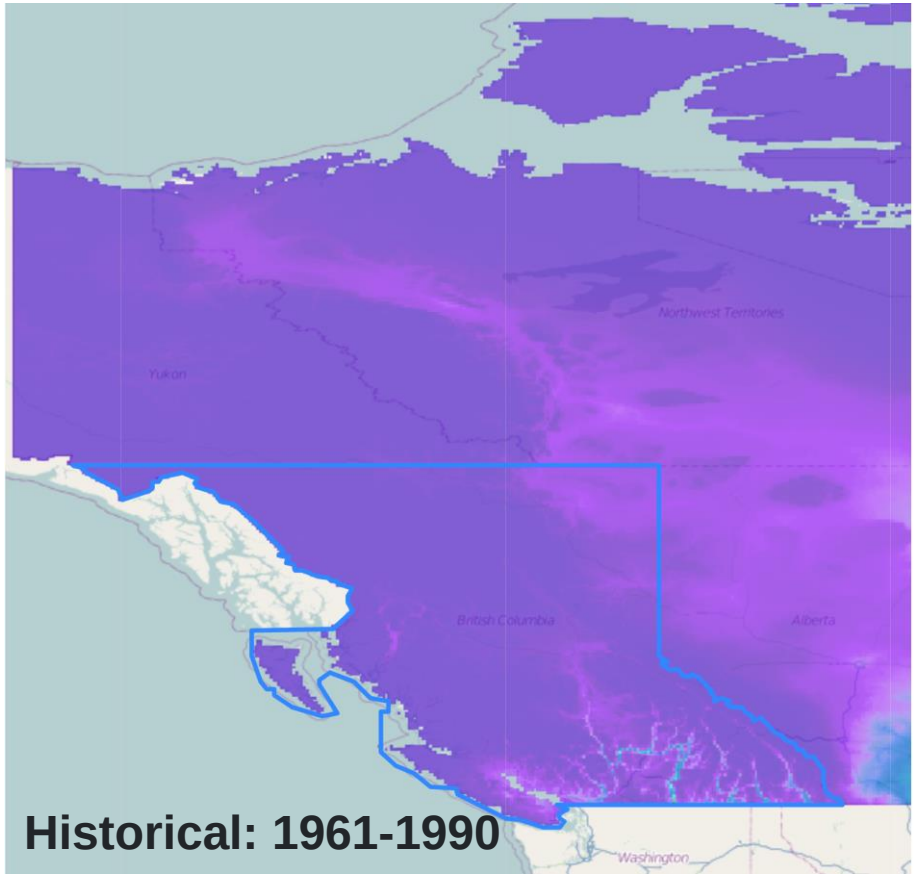
World of Change: British Columbia

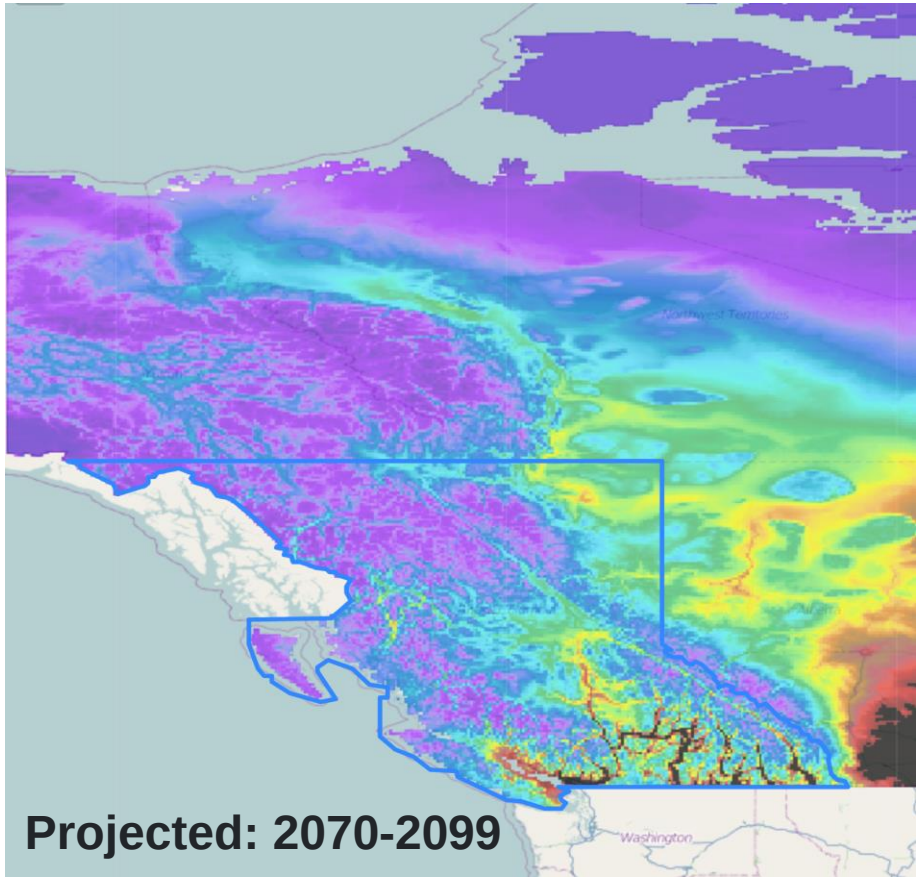




http://www.env.gov.bc.ca/soe/indicators/climate-change/temp.html

World of Change: British Columbia

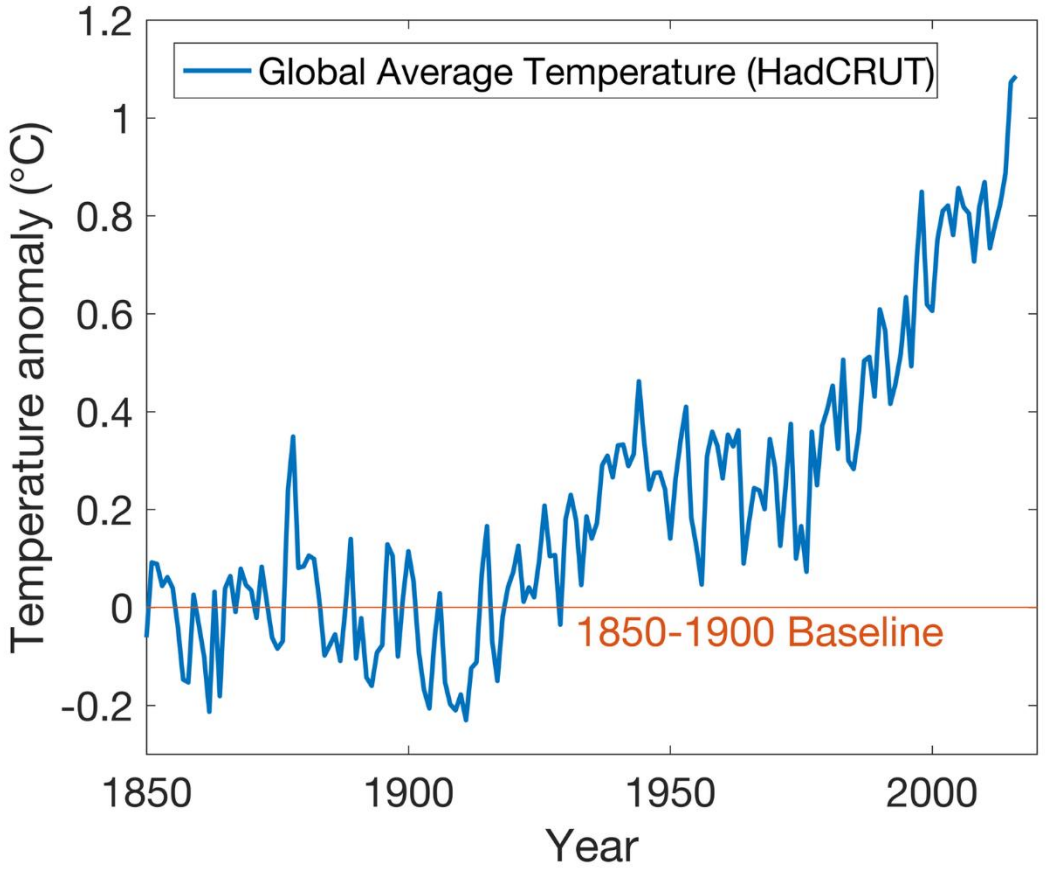




Cooling Degree-Days* (degree-days)

< 0 | 0 | 100 | 200 | 300 | 400 | 500 | > 500

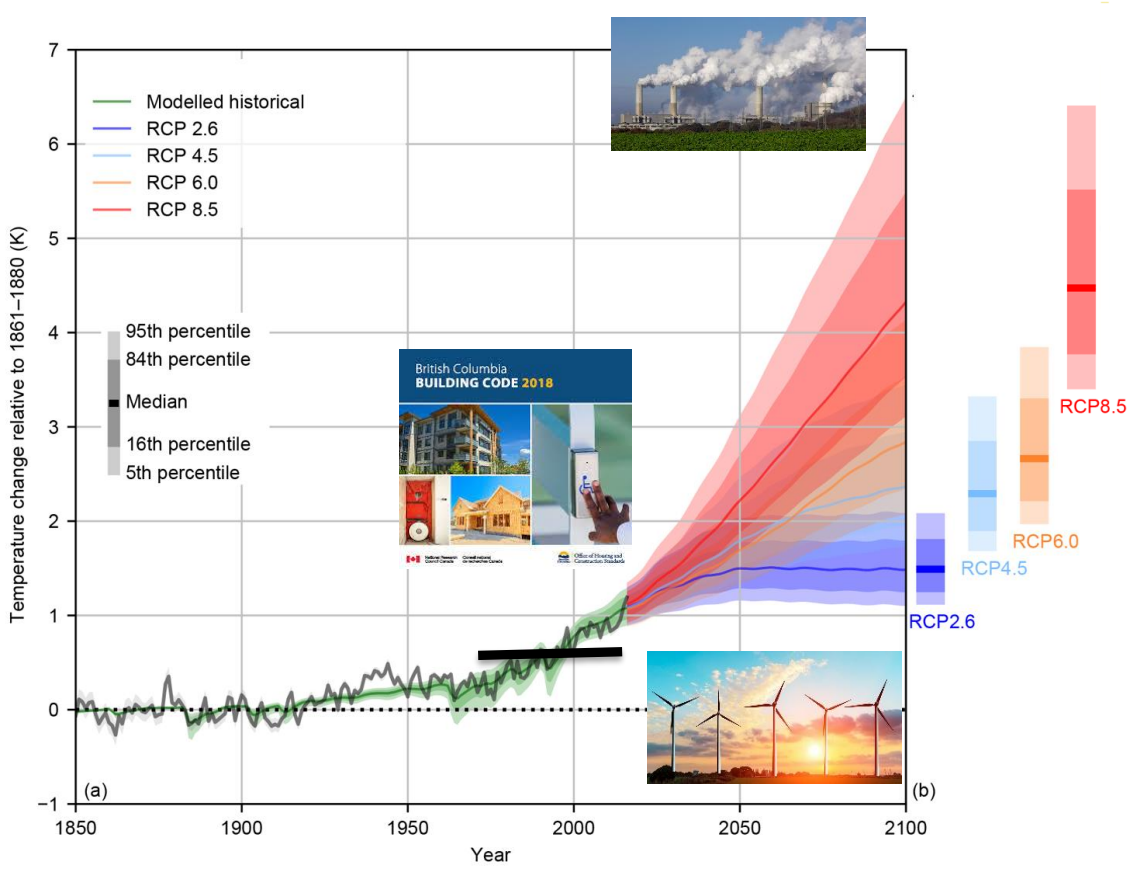
https://services.pacificclimate.org/plan2adapt/app/



annual mean global SAT (relative to the pre-industrial baseline 1861–1900) under RCP2.6, RCP4.5, RCP6.0 and RCP8.5

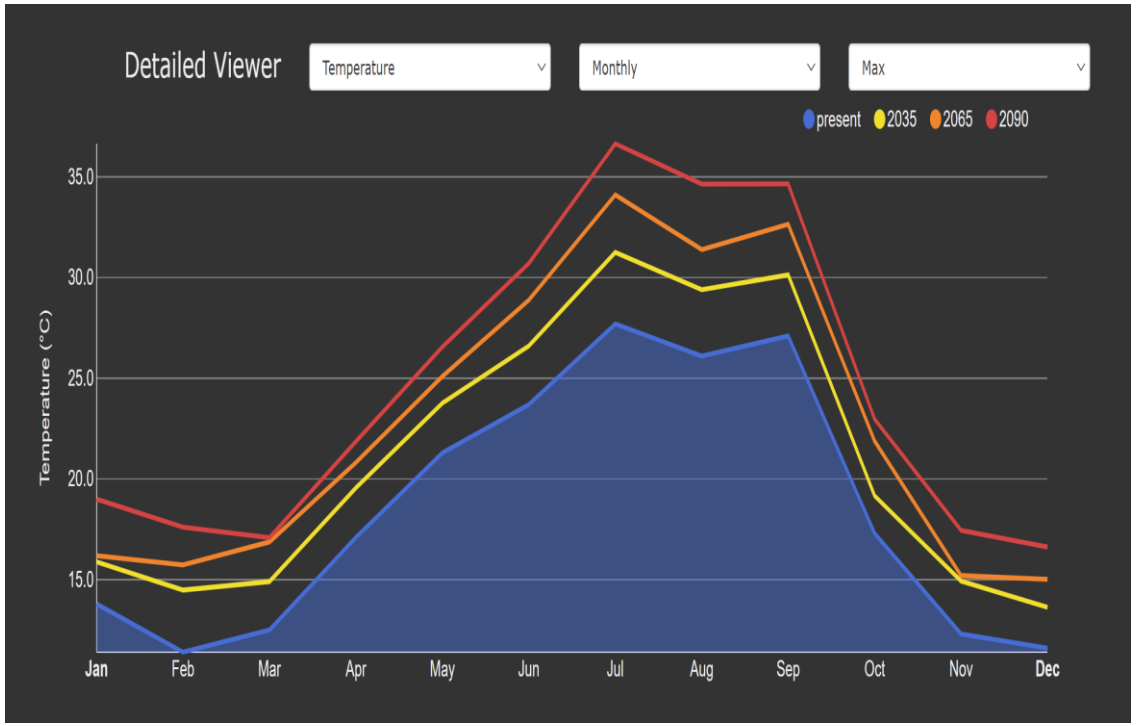
The Paris Agreement's long-term goal:

- To keep the increase in global average temperature to well below 2 °C above pre-industrial levels; and to limit the increase to 1.5 °C.



https://gmd.copernicus.org/articles/11/2273/2018/#&gid=1&pid=1

RCP8.5 95th Percentile : Vancouver Monthly Max Temperature



https://www.weathershift.com/heat

RCP: Representative Concentration Pathway

- ✓ RCP 2.6: Paris Goal
- ✓ RCP 4.5 & 6: Intermediate scenarios
- ✓ RCP 8.5: “Business as usual”

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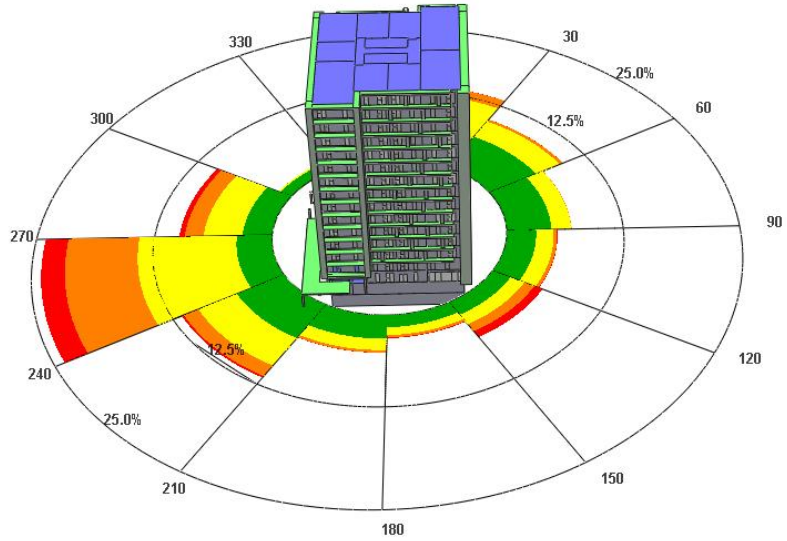


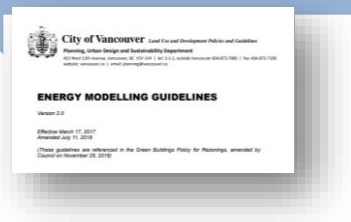
Landscape of Weather Files

TMY3 [1991-2005]

2020

2003 | 2005 | 2007 | 2009 | 2011 | 2013 | 2015 | 2017 | 2019 | 2021

CWEC- City of Vancouver EMG [2000-2016]

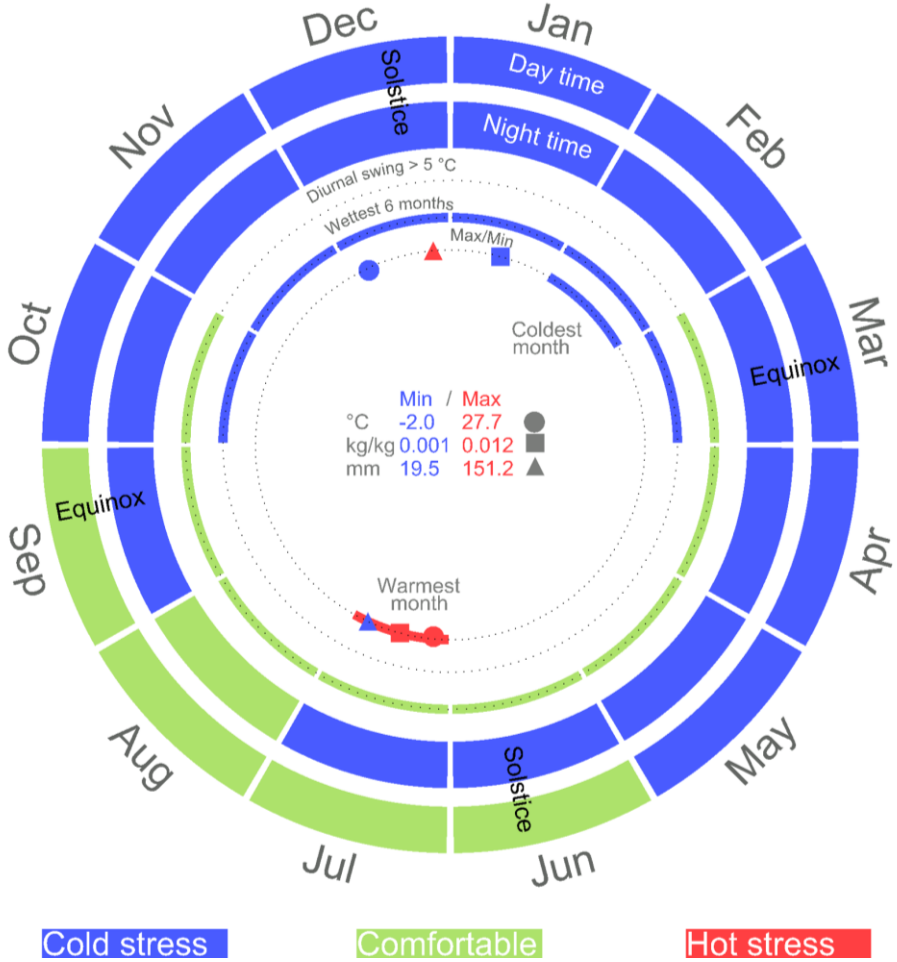

City of Vancouver
Planning, Urban Design and Sustainability Department
ENERGY MODELLING GUIDELINES

2030, 2060, 2090

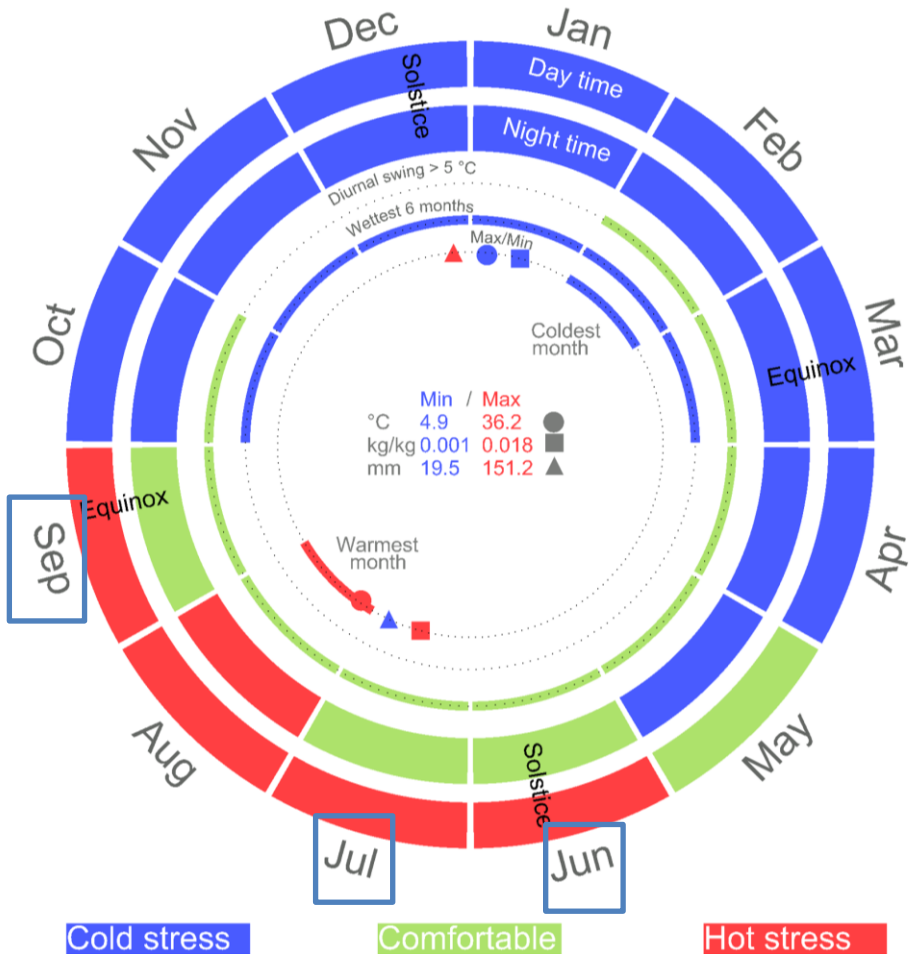
WEATHERSHIFT™

PACIFIC CLIMATE IMPACTS CONSORTIUM

Mahoney Analysis (Monthly Average)

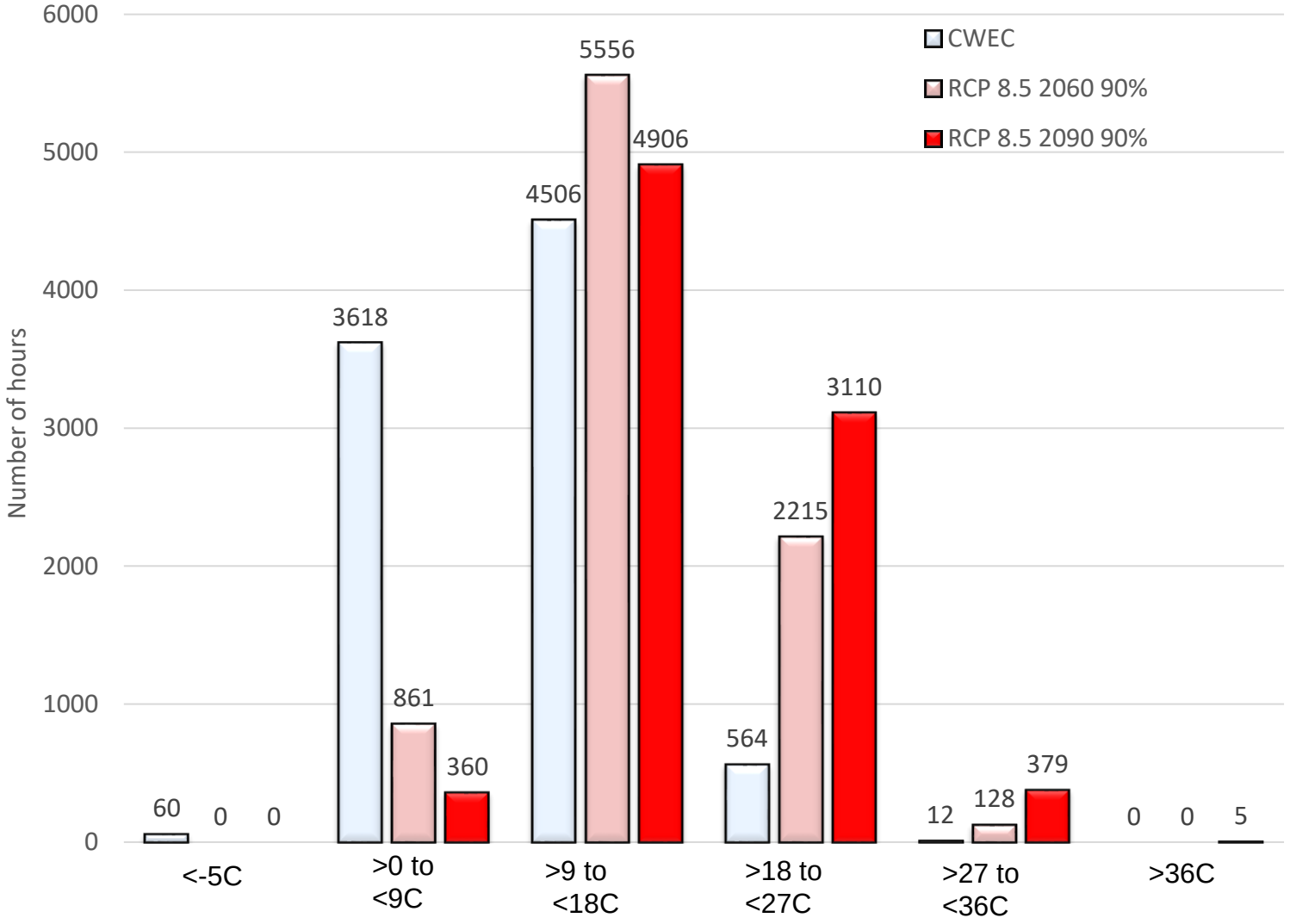


CWEC- ASHRAE CZ 4 C



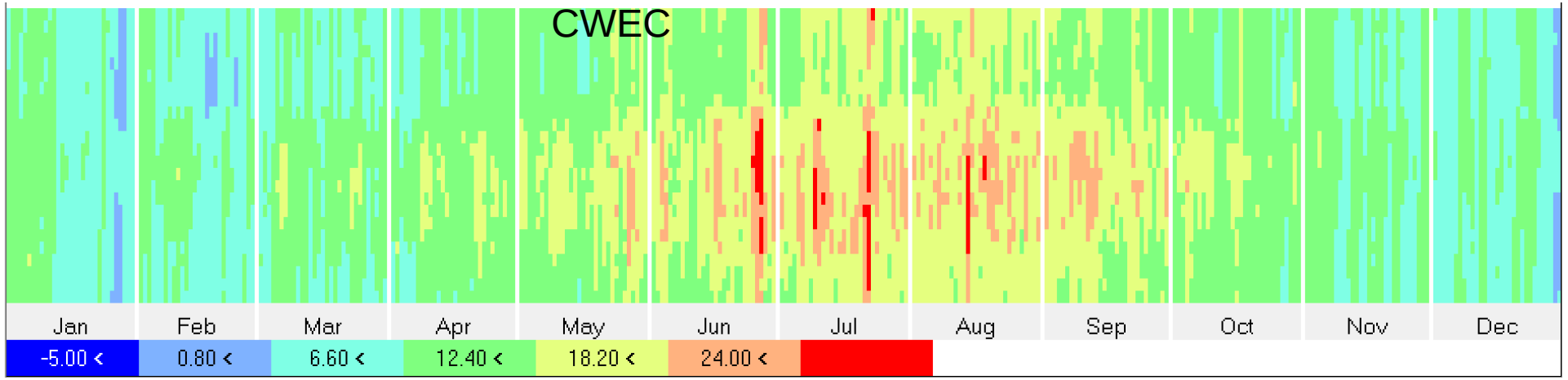
RCP 8.5 2090 90%- ASHRAE CZ 3 C

Dry-bulb temperature- Frequency Distribution

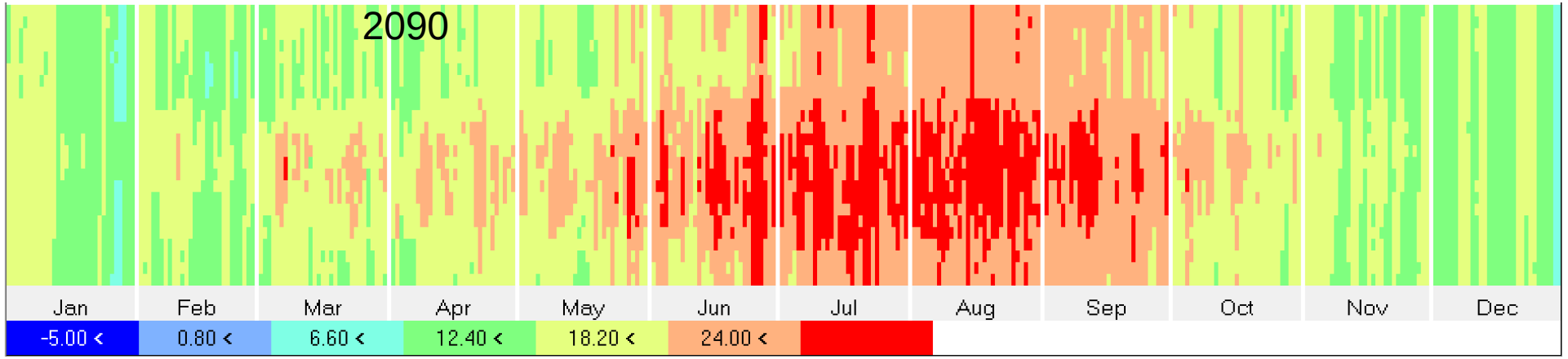


Duration of Warm Temperatures ($T_{db} > 24C$)

Victoria (Gonzales)- CWEC



Victoria (Gonzales)- RCP 8.5 90th percentile 2090



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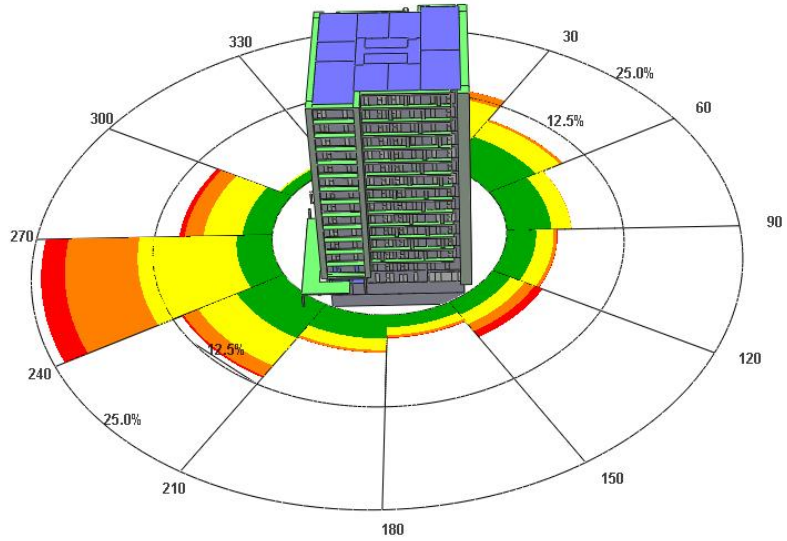


STANDARD

ASHRAE

ANSI/ASHRAE Standard 55-2017
(Supersedes ANSI/ASHRAE Standard 55-2013)
Includes ANSI/ASHRAE addenda listed in Appendix N

Thermal Environmental Conditions for Human Occupancy

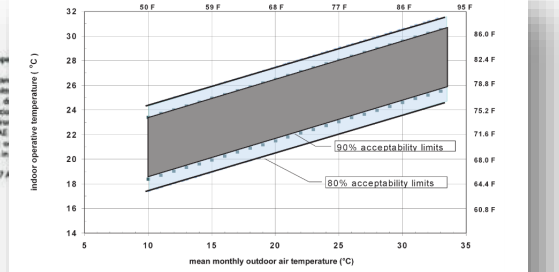


Figure 5.3 Acceptable operative temperature ranges for naturally conditioned spaces.

City of Vancouver *Land Use and Development Policies and Guidelines*

Planning, Urban Design and Sustainability Department
453 West 12th Avenue, Vancouver, BC V5Y 1V4 | tel: 3-1-1, outside Vancouver 604.873.7000 | fax: 604.873.7100
website: vancouver.ca | email: planning@vancouver.ca

ENERGY MODELLING GUIDELINES

Version 2.0

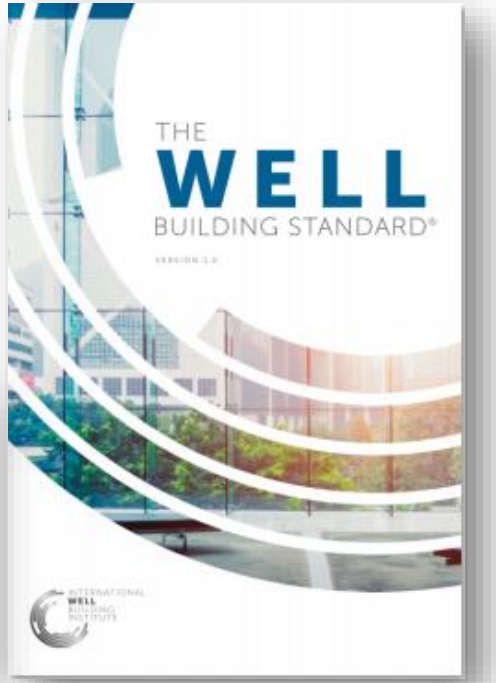
Effective March 17, 2017
Amended July 11, 2018

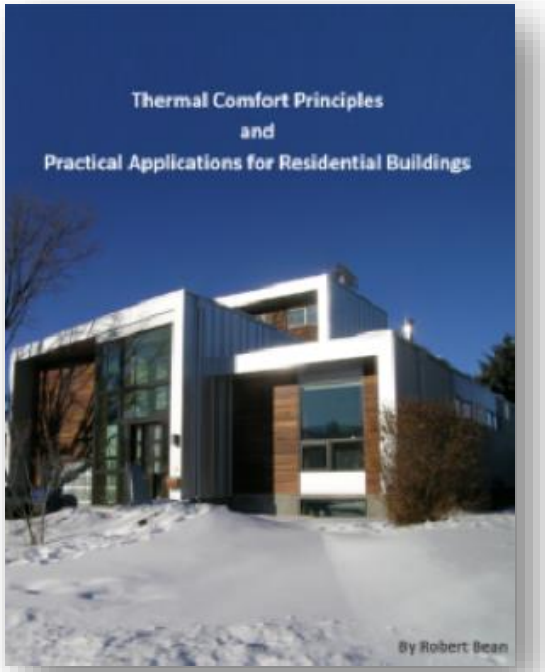
(These guidelines are referenced in the Green Buildings Policy for Rezonings, amended by Council on November 29, 2016)

Table 4 Acceptability Limits for Naturally Conditioned Spaces in Vancouver[1]

Month	80% Acceptability Limit
April	N/A (Mean temperature too low)
May	25.2 °C
June	26.1 °C
July	26.9 °C
August	26.9 °C
September	25.2 °C
October	N/A (Mean temperature too low)

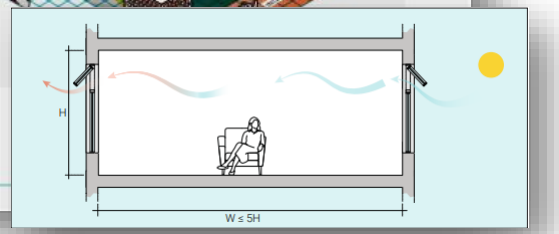
Notes:
[1] Acceptability limits for other locations must be derived from the weather file for that location.





BC Energy Step Code
Design Guide Supplement S3 on Overheating and Air Quality

June 2019

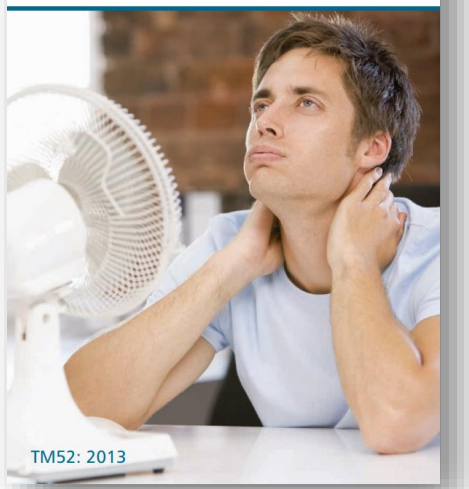


SUPPLEMENT S3
Version 1.0

BRITISH COLUMBIA
BC HOUSING RESEARCH CENTRE

The limits of thermal comfort: avoiding overheating in European buildings

CIBSE



TM52: 2013

Natural ventilation in non-domestic buildings

CIBSE Applications Manual AM10

CARBON TRUST

CIBSE

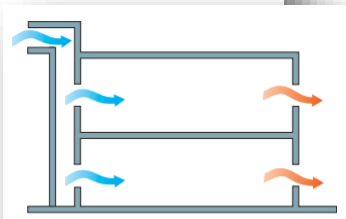


Figure 2.21 Wind scoop

Creative Thinking **Practical Results** rjc

ASHRAE 55-2010: Adaptive Method

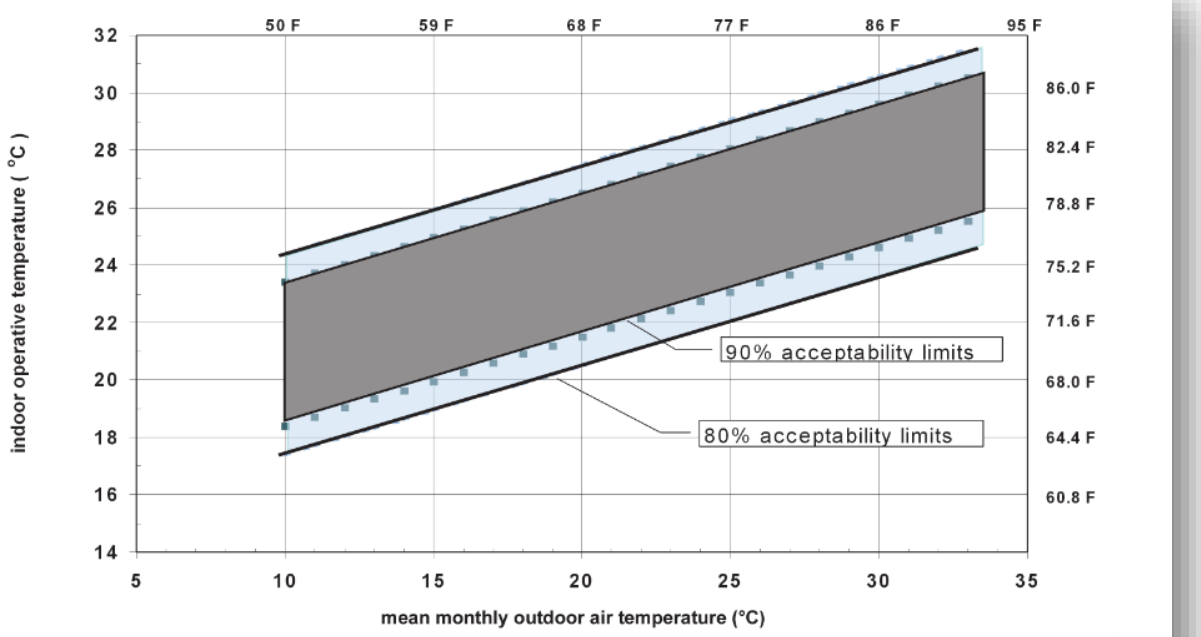


Figure 5.3 Acceptable operative temperature ranges for naturally conditioned spaces.

- Indoor operative temperatures to be maintained within 80% acceptability limits.
- Acceptable temperature range is based on the mean monthly outdoor air temperature (Monthly OAT>=10C).
- Upper 80% acceptability limit:
  0.31× Monthly OAT+21.3
- Lower 80% acceptability limit:
  0.31× Monthly OAT+14.3

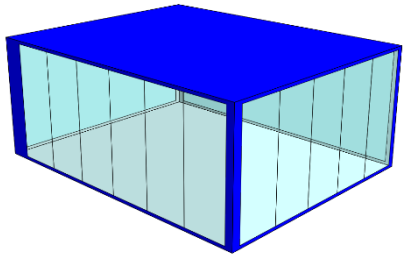
Comparing ASHRAE 55 and COV EMG Criteria

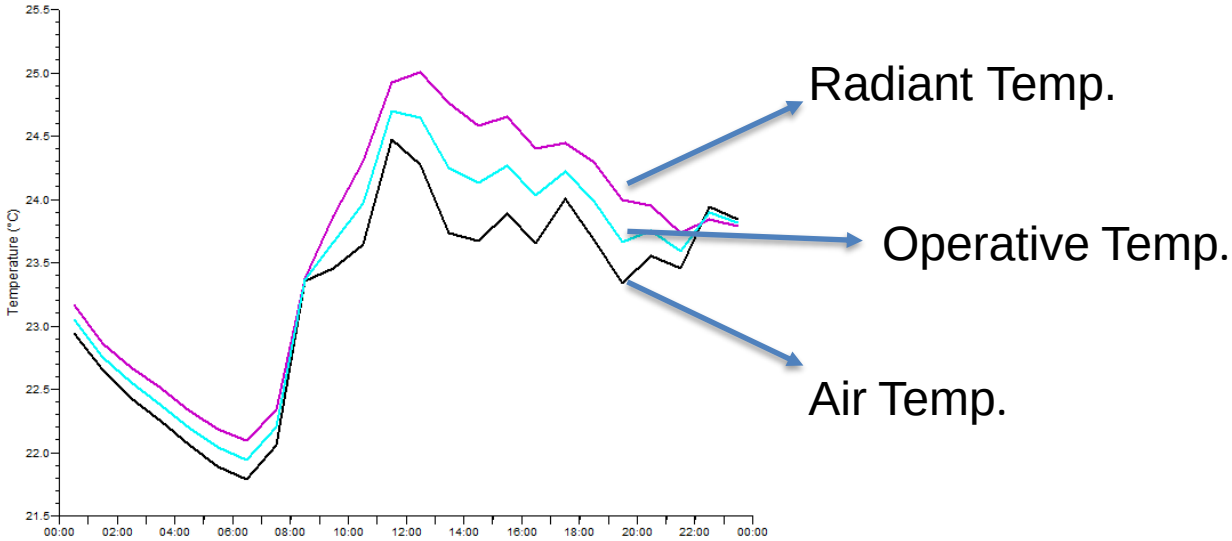
- ASHRAE 55-2010: Indoor operative temperature

$$t_o = \frac{t_a + \overline{t_r}}{2}$$

  - t_o= Operative temperature
  - t_a = Air Temperature
  - $\overline{t_r}$ = Mean Radiant Temperature

- COV EMG V2: Interior dry-bulb temperature
- Spaces with large areas of glass can demonstrate greater variation between mean radiant temperature and air temperature
- High SHGC can lead to high radiant temperature





COV EMG Overheating Threshold

CWEC

Month	80% Acceptability Limit
April	N/A (Mean Temp too low)
May	24.9 ˚C
June	25.7 ˚C
July	26.2 ˚C
August	26.1 ˚C
September	25.6 ˚C
October	24.5 ˚C
November	N/A (Mean Temp too low)

Upper 80% acceptability limit: 0.31× Monthly OAT+21.3

RCP 8.5 2060 90%

Month	80% Acceptability Limit
February	N/A (Mean Temp too low)
March	24.42 ˚C
April	24.82 ˚C
May	25.63 ˚C
June	26.74 ˚C
July	27.38 ˚C
August	27.23 ˚C
September	26.2 ˚C
October	25.3 ˚C
November	24.49˚C
December	N/A (Mean Temp too low)

Location: Victoria,

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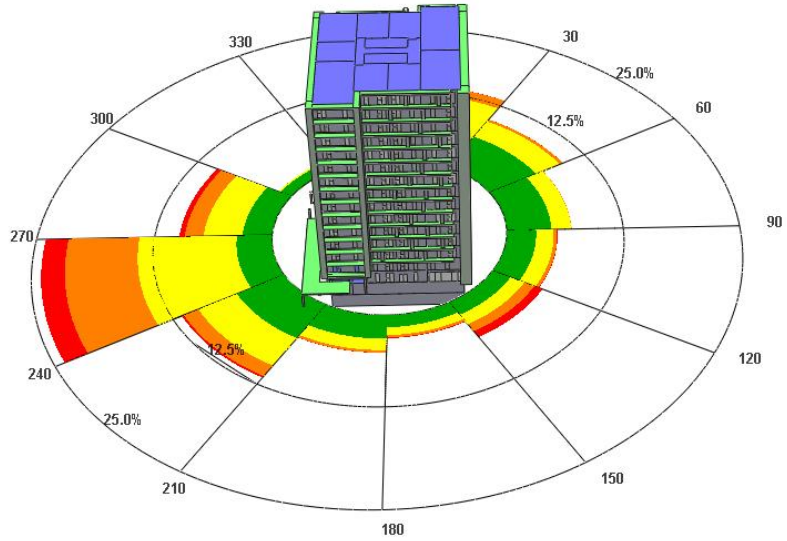
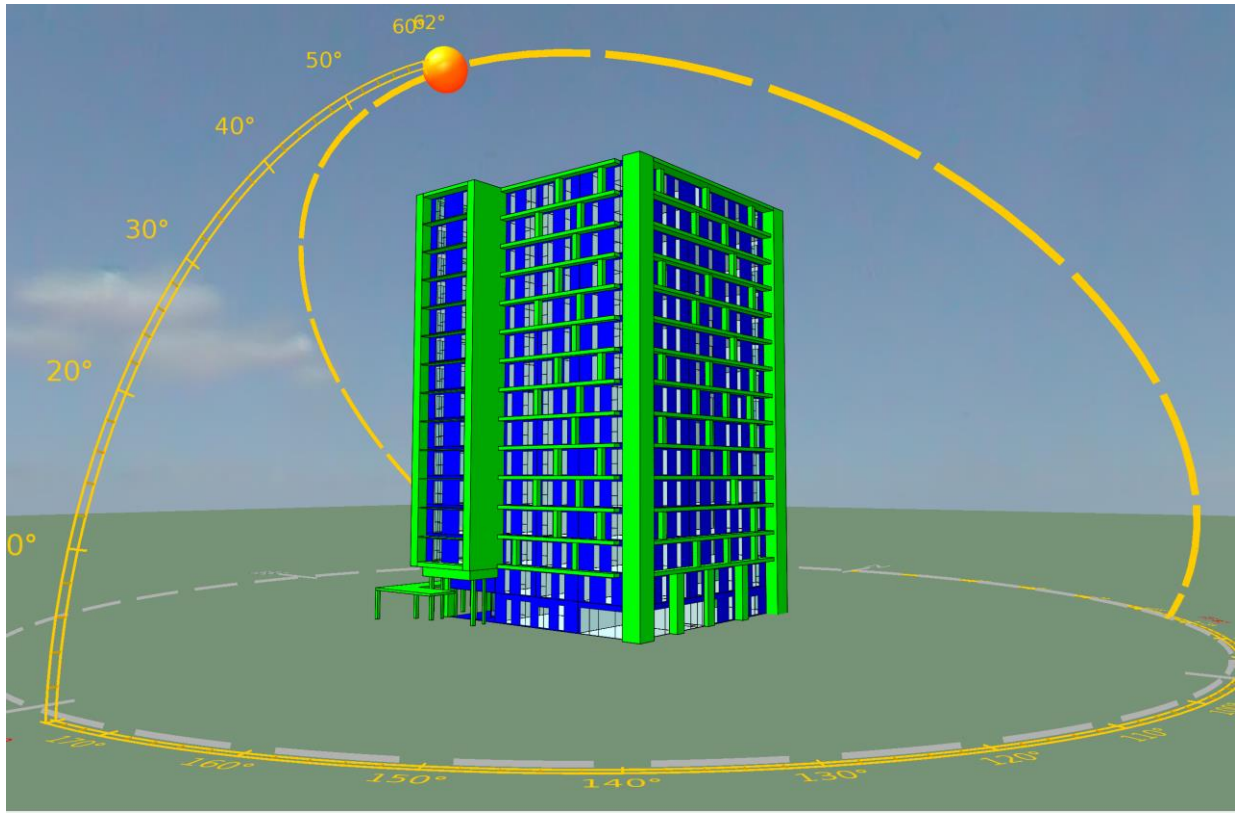


Case Study: High-Rise Residential Building



Location: Victoria, BC

Building Type: Residential, Mass timber

Number of Storeys: 15

Owner: Greater Victoria Housing Society (GVHS)

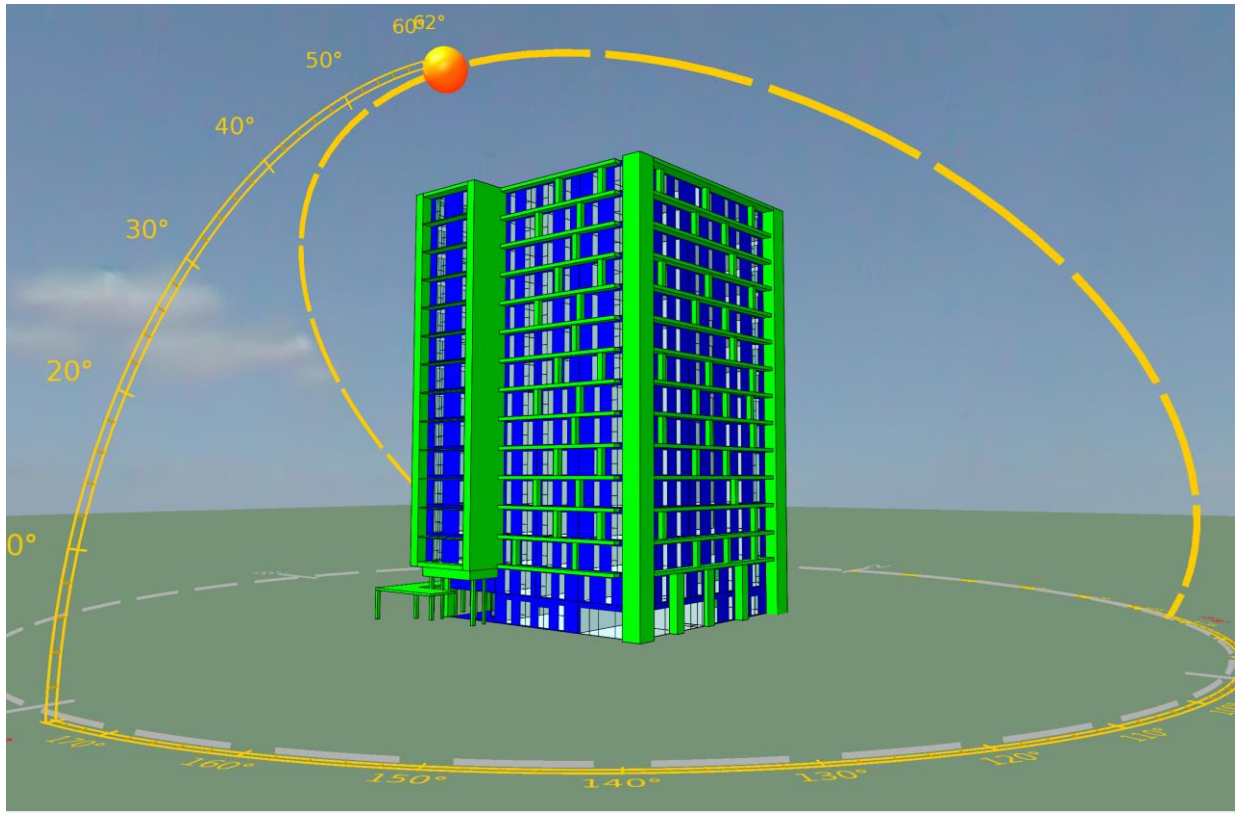
Architect: Cascadia Architects Inc.

Mechanical Consultant: M3 Mechanical Consultants Inc.

Electrical Consultant: AES Engineering

Structural/Building Enclosure/Building Performance Consultant: RJC Engineers

Case Study: High-Rise Residential Building



Project Requirements:

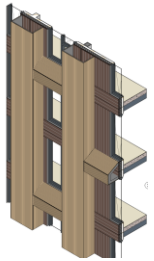
- Compliance with Step 3 of the BC Energy Step Code
- Demonstrating less than 200 overheating hours

Voluntary Approach:

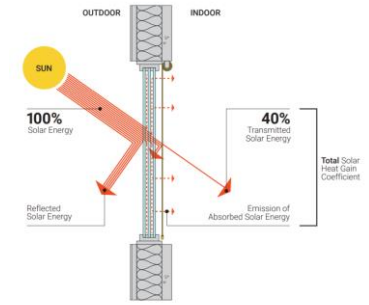
- Compliance with Step 4 of the BC Energy Step Code
- Demonstrating less than 20 overheating hours

Case Study: Thermal Comfort Measures (TCM)

- TCM 1: Incorporating exterior vertical/horizontal shades

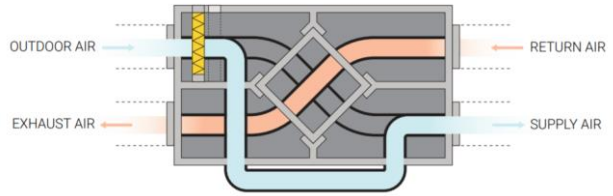


- TCM 2: Reducing Solar Heat Gain Coefficient (SHGC)

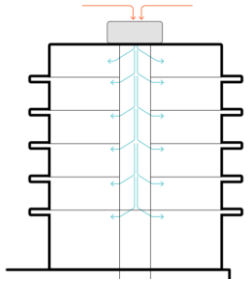


- TCM 3: Utilizing operable windows

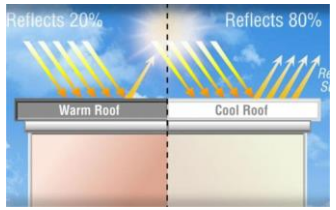
- TCM 4: HRV bypass



- TCM 5: Central cooling

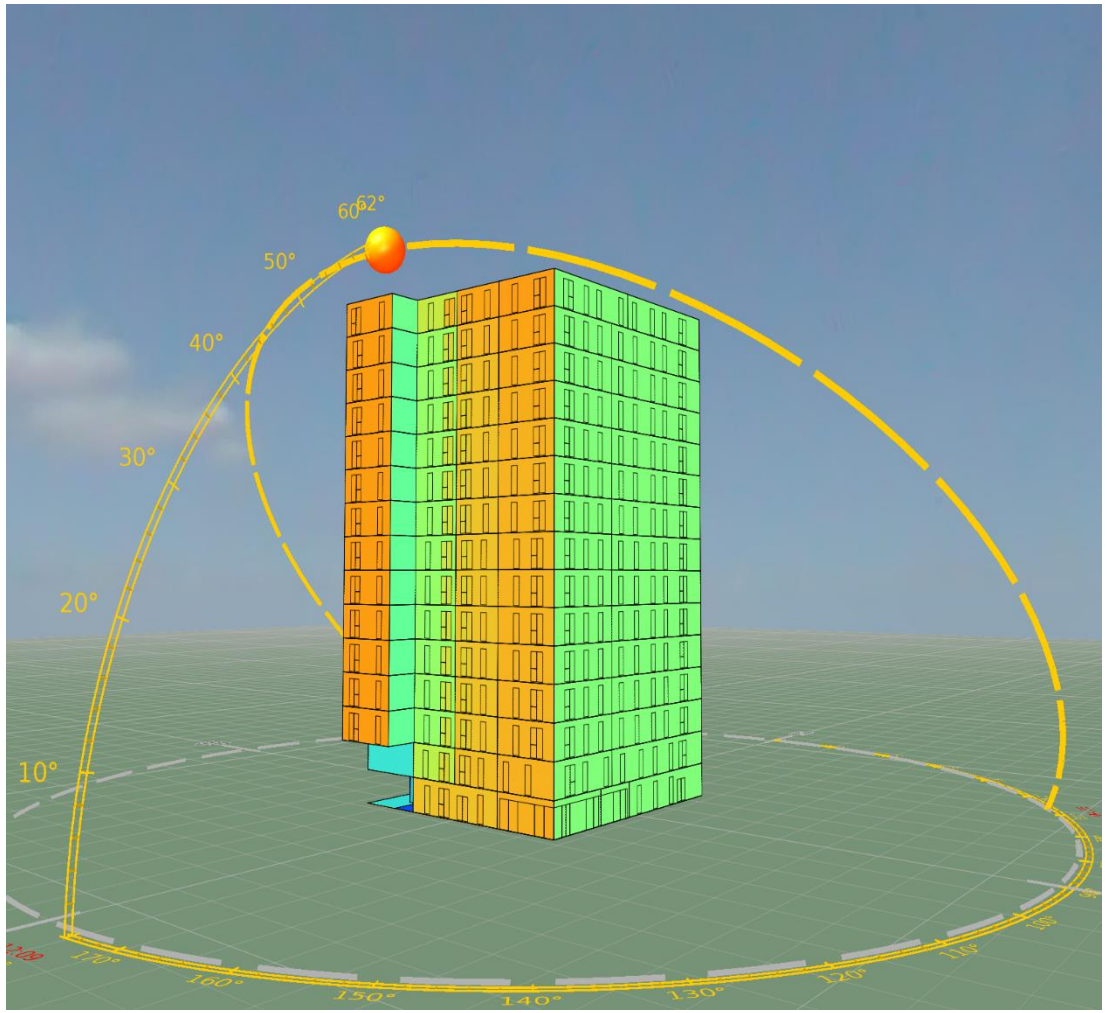


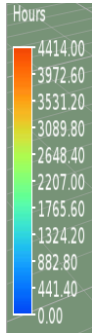
- TCM 6: Reflective roof

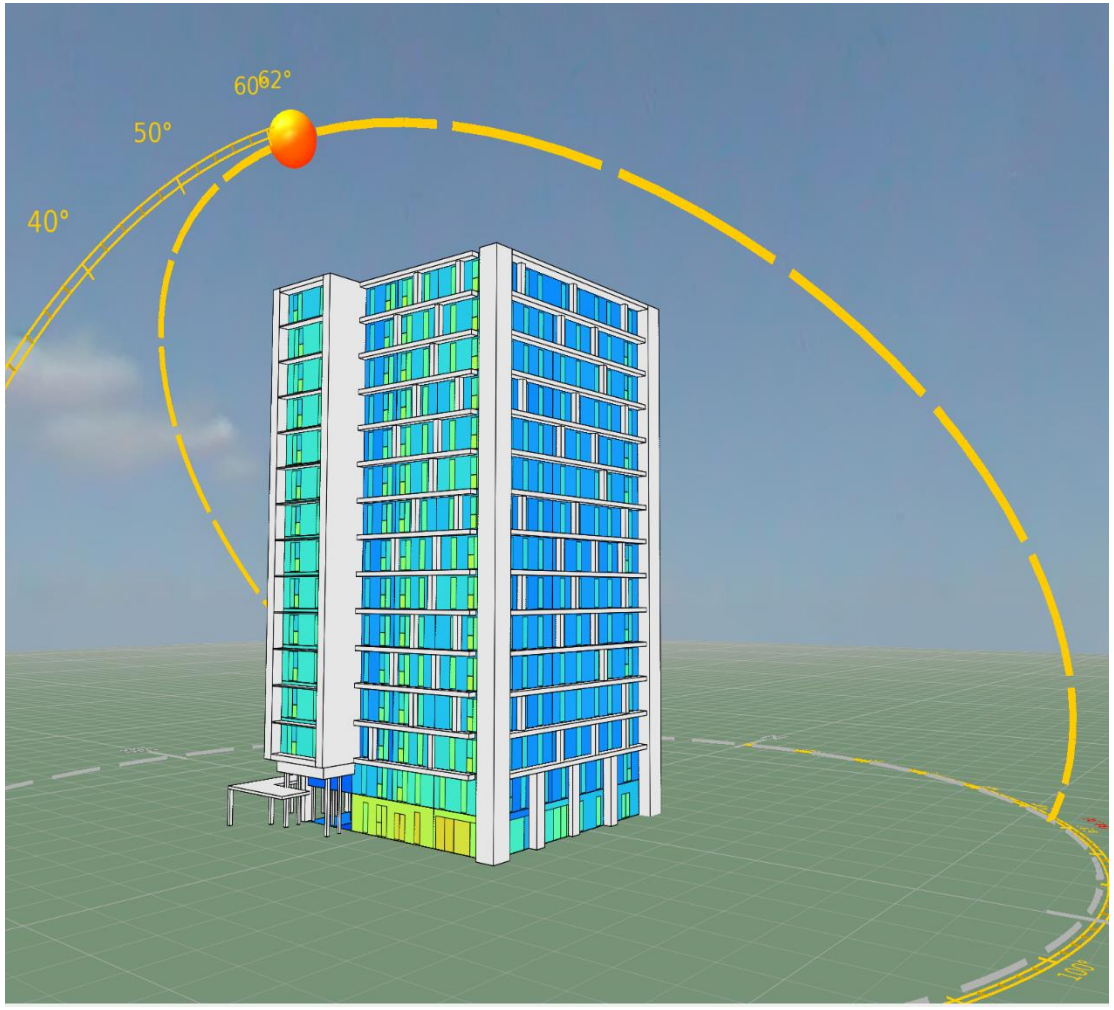


Images 1, 2

TCM 1: Impacts of Shades







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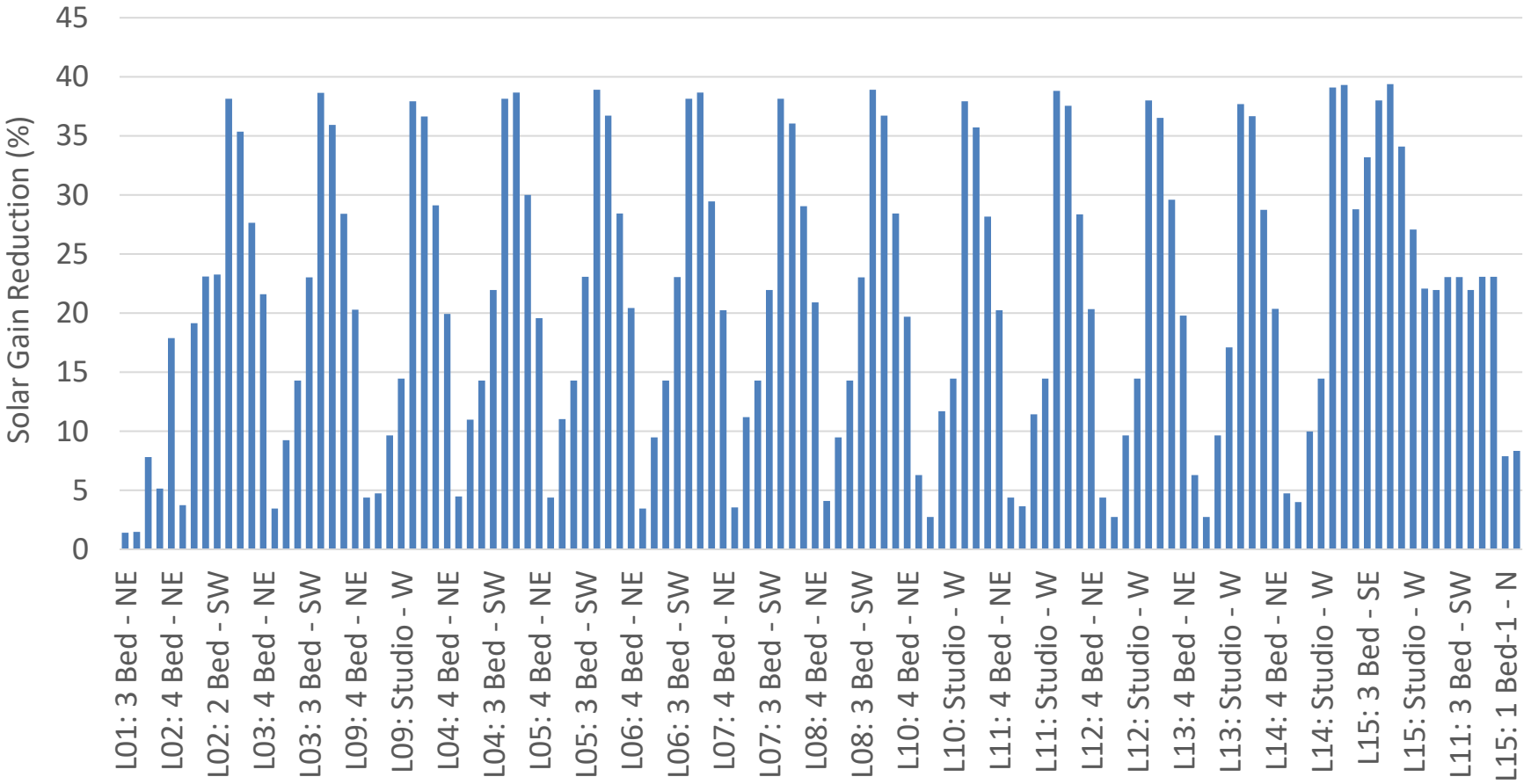
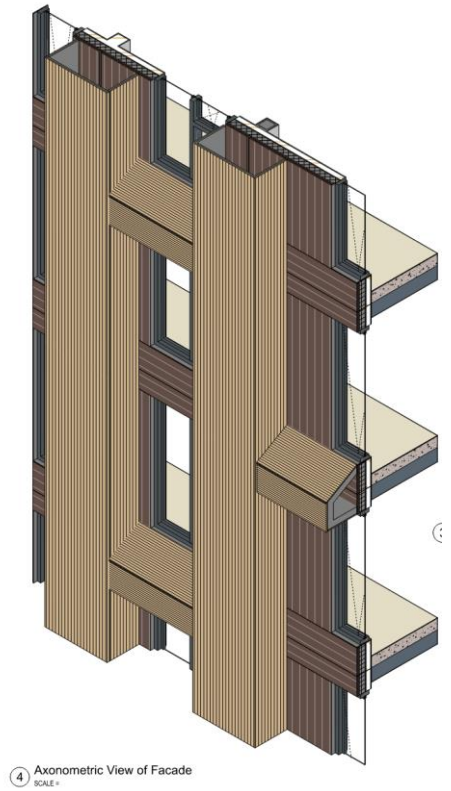
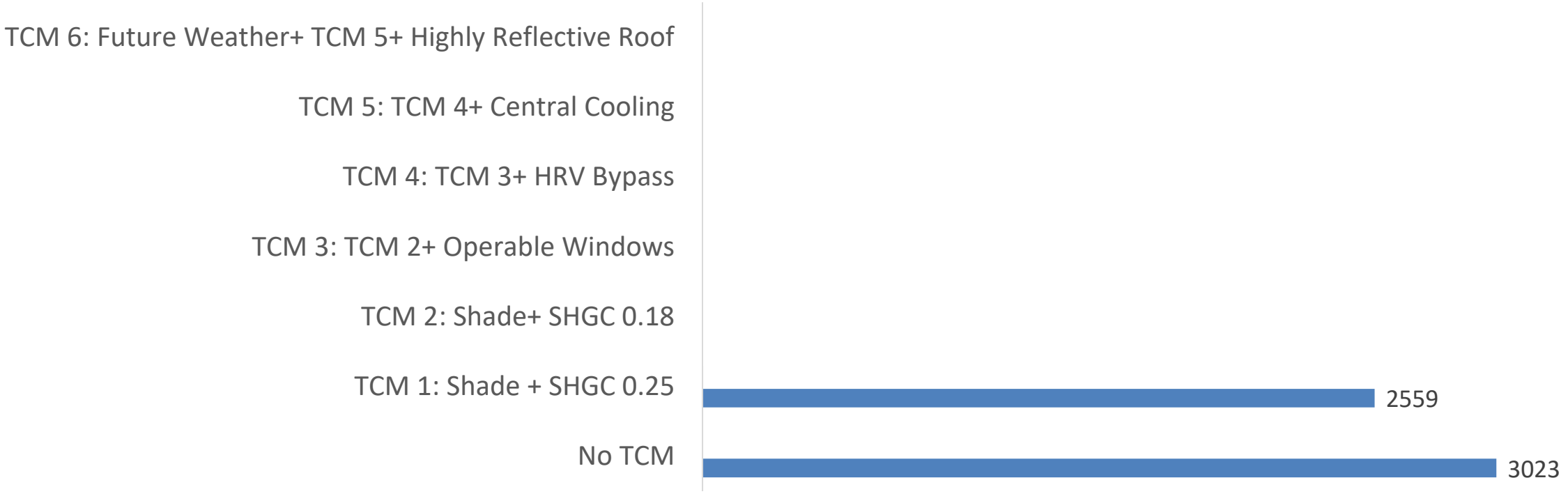
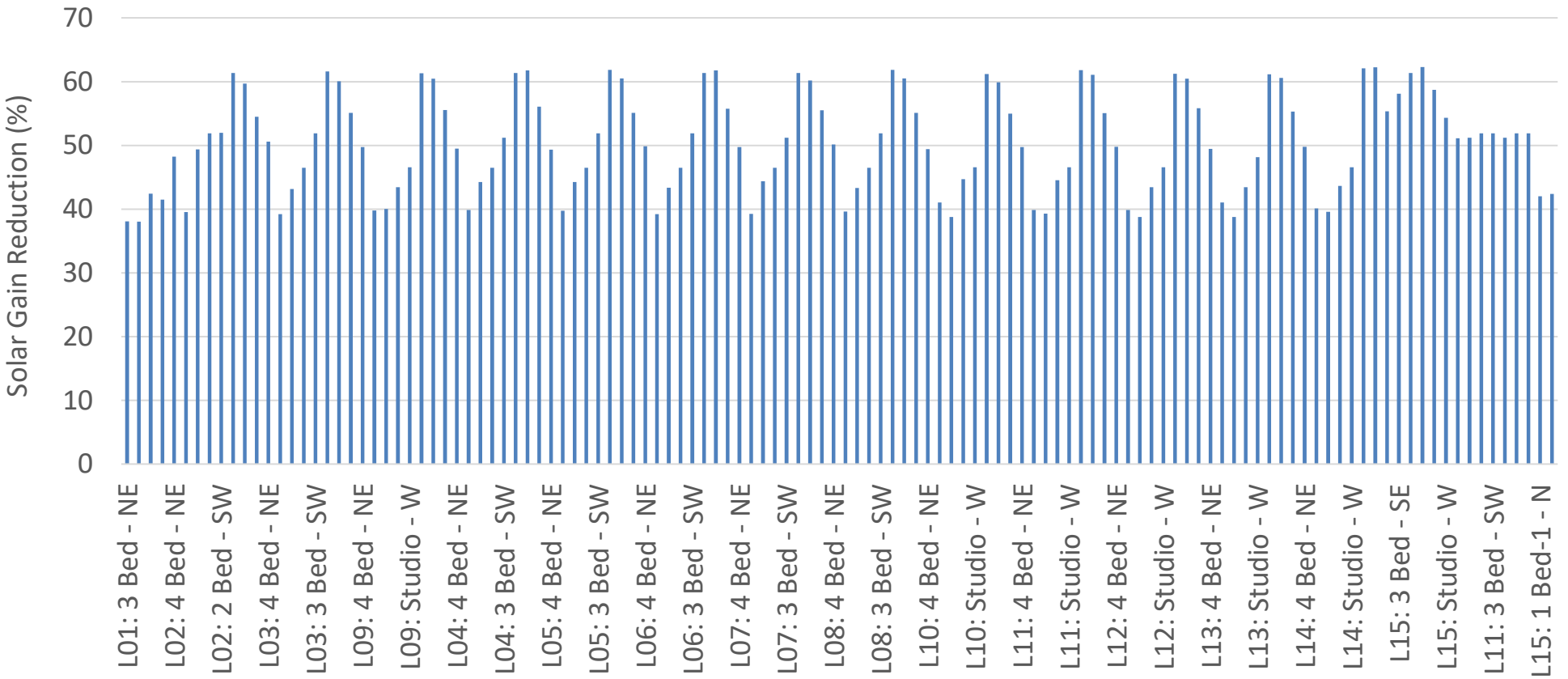


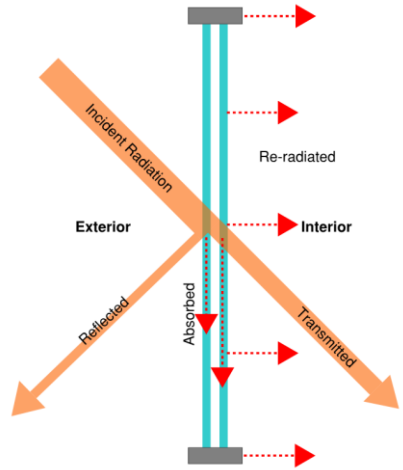


Overheating hours

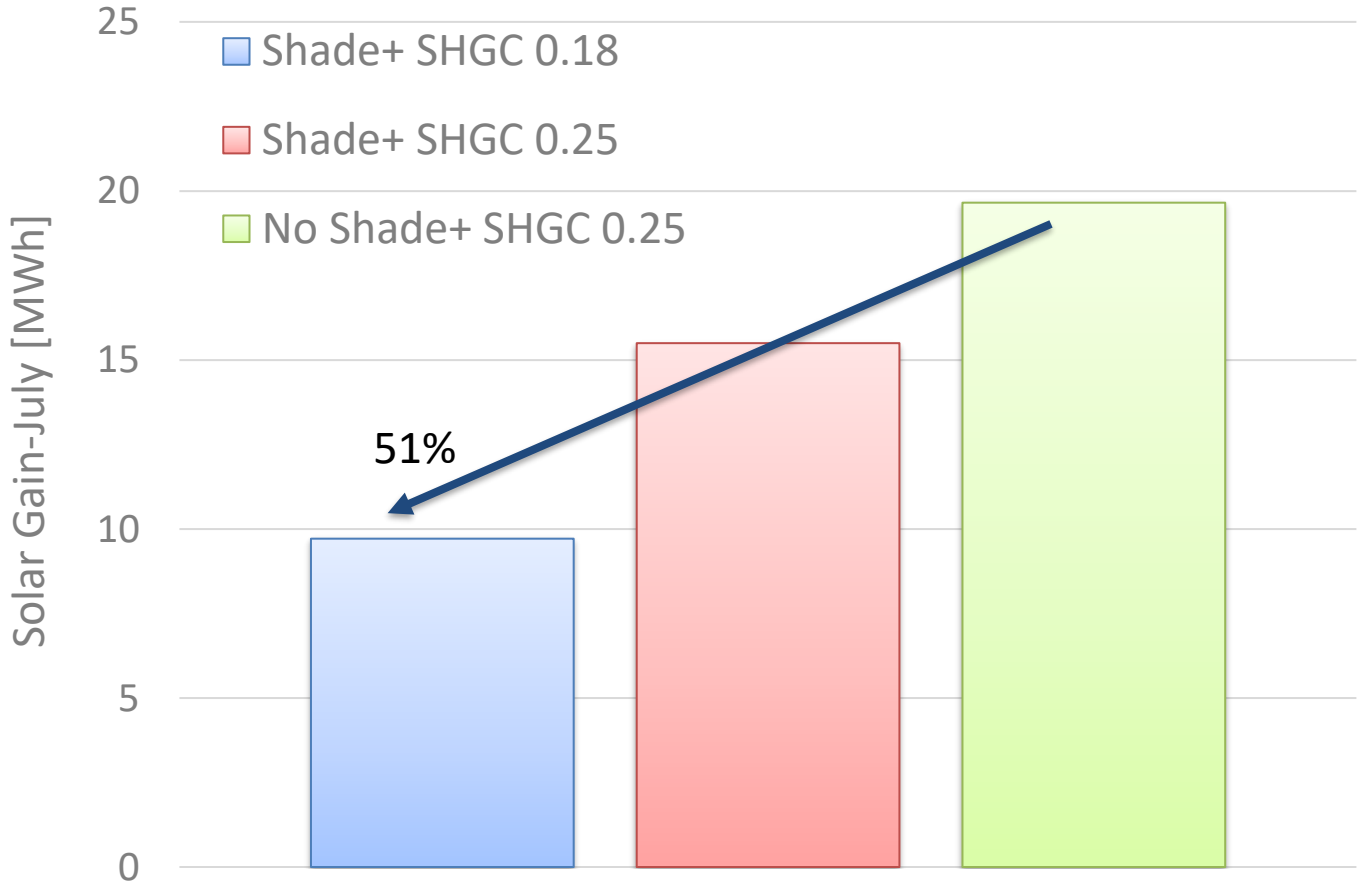


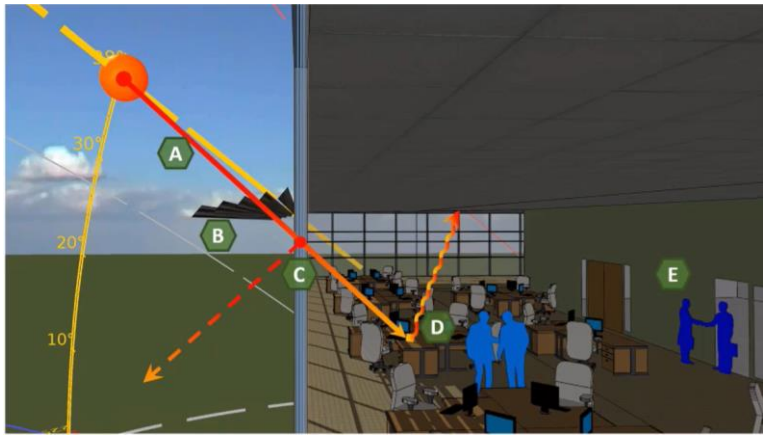
TCM 2: Impacts of SHGC (0.25 ⟶ 0.18)

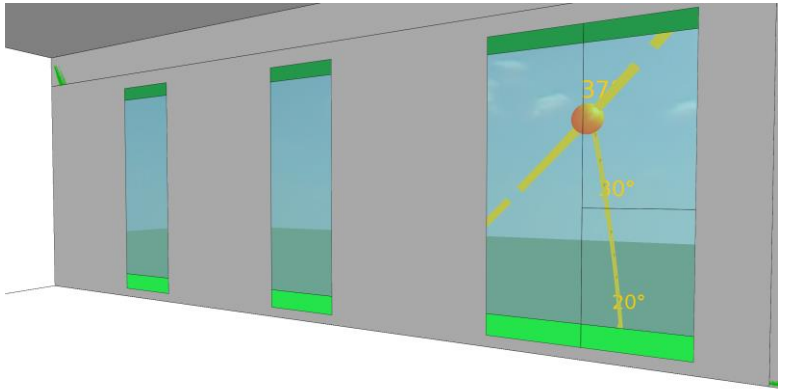




TCM 2: Impacts of SHGC (0.25⟶ 0.18)

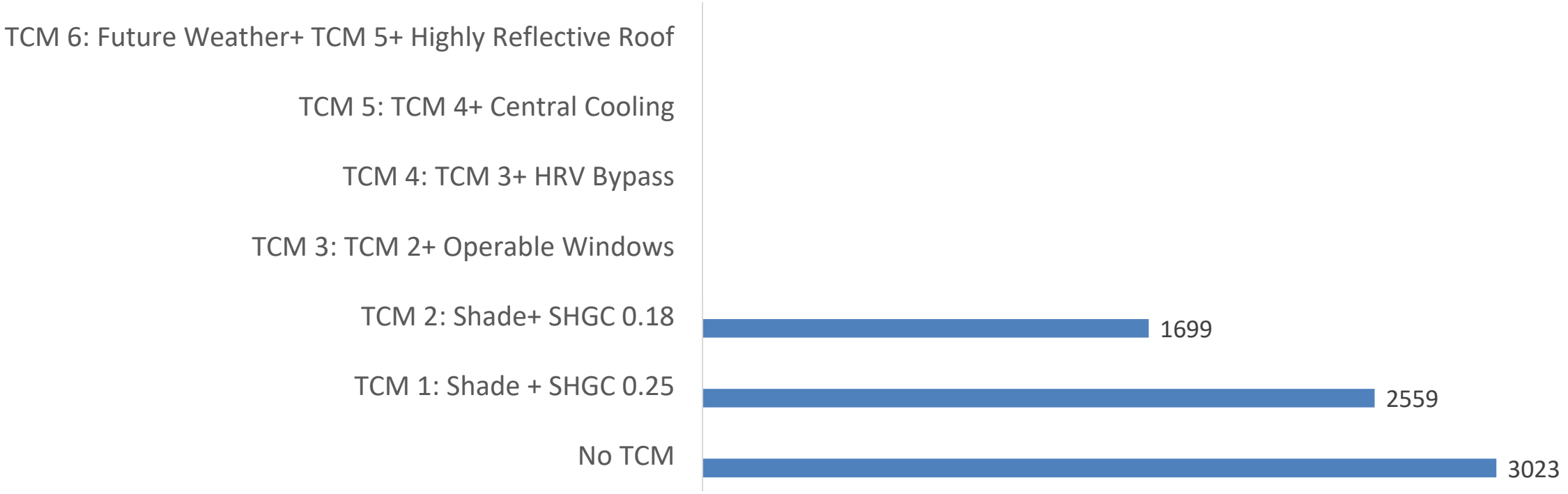






Image

Overheating hours

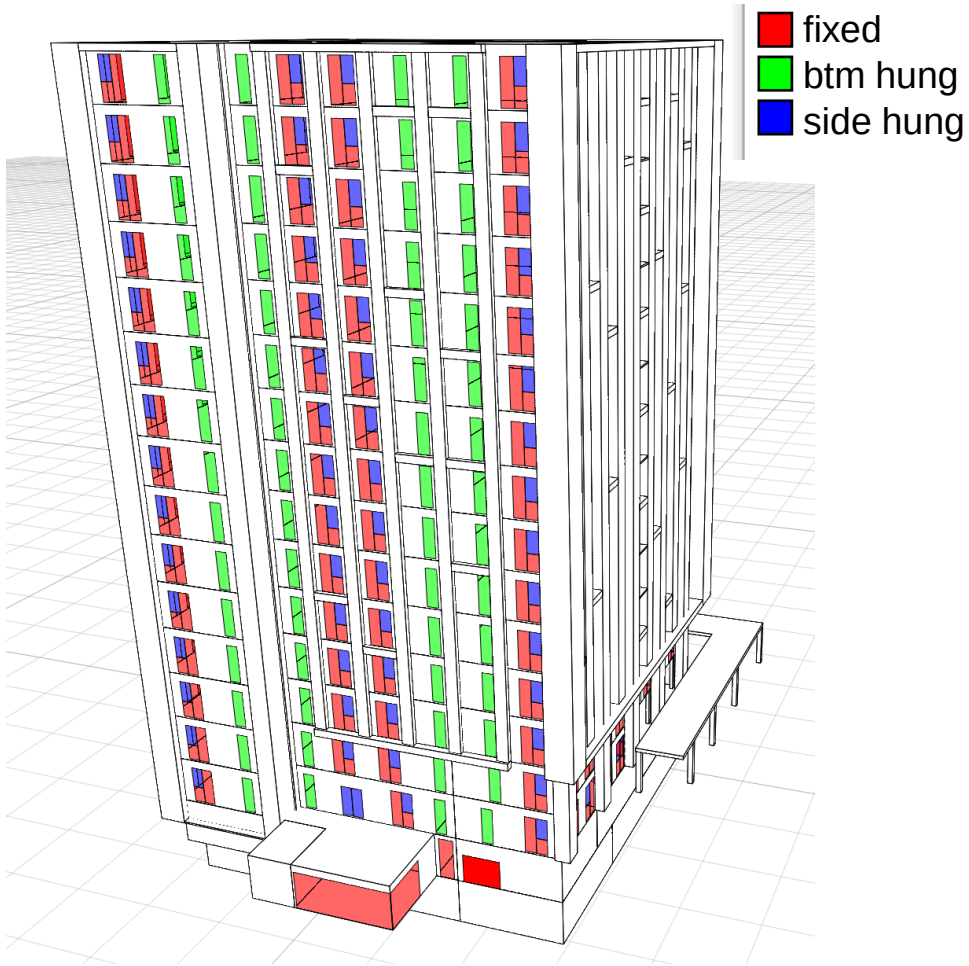


TCM 3: Impacts of Operable Windows

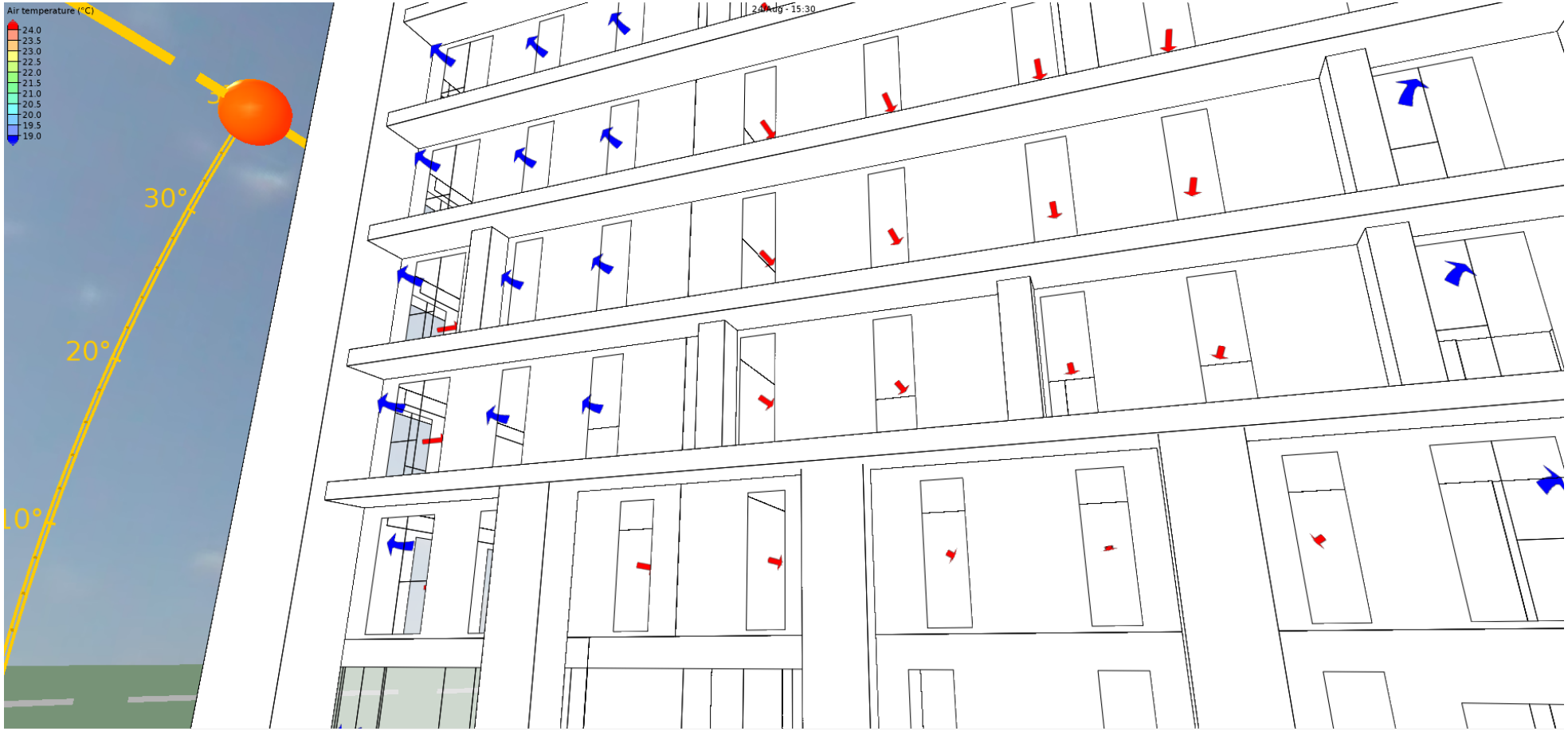
- Large openings for all suites
- Large opening angle for windows above guardrail
- Cross ventilation through windows for corner suites
- Utilizing multiple openings for effective single sided ventilation

Window operation logic:

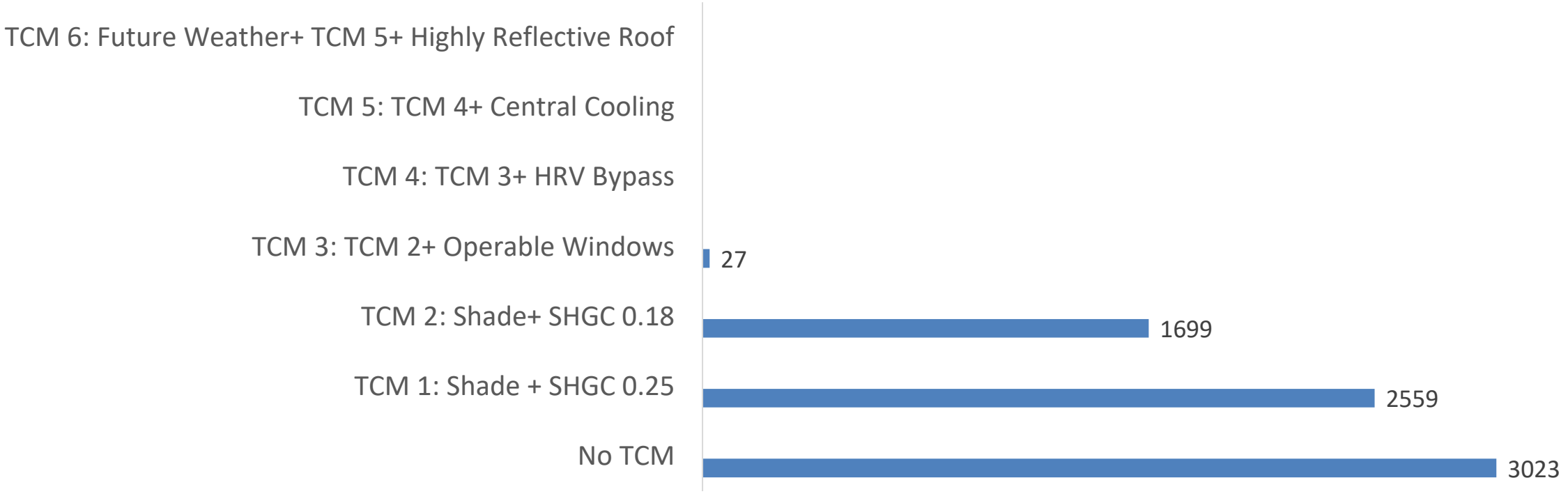
- Windows are open when room temp. >24C AND
- Outside air is cooler than interior temp.



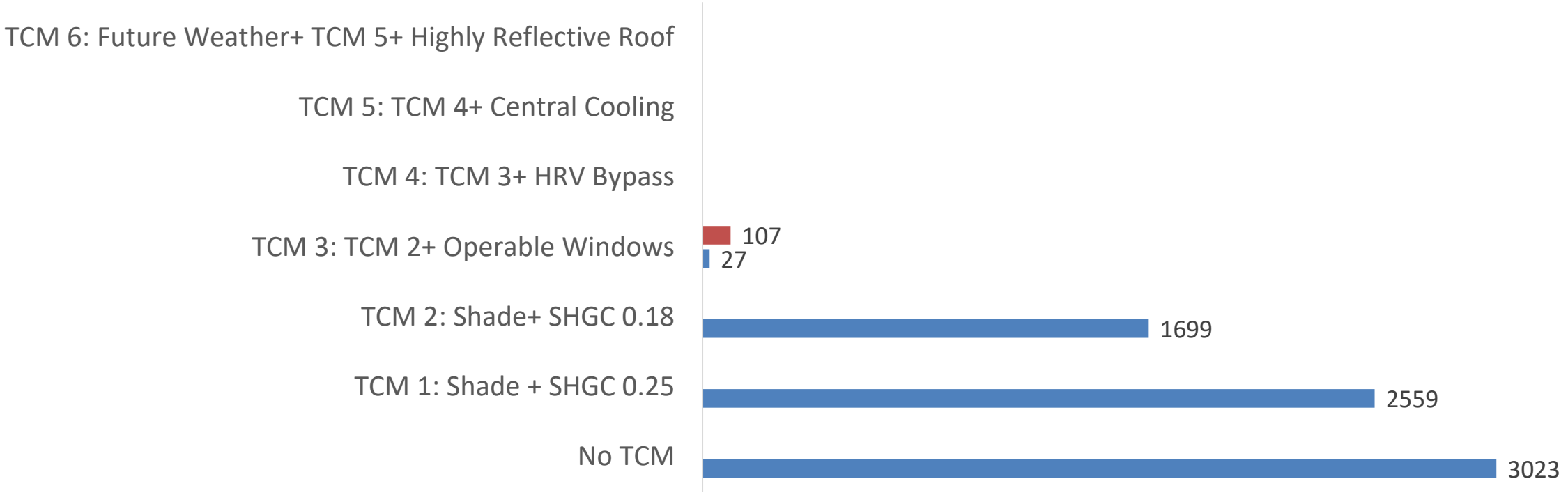
TCM 3: Impacts of Operable Windows



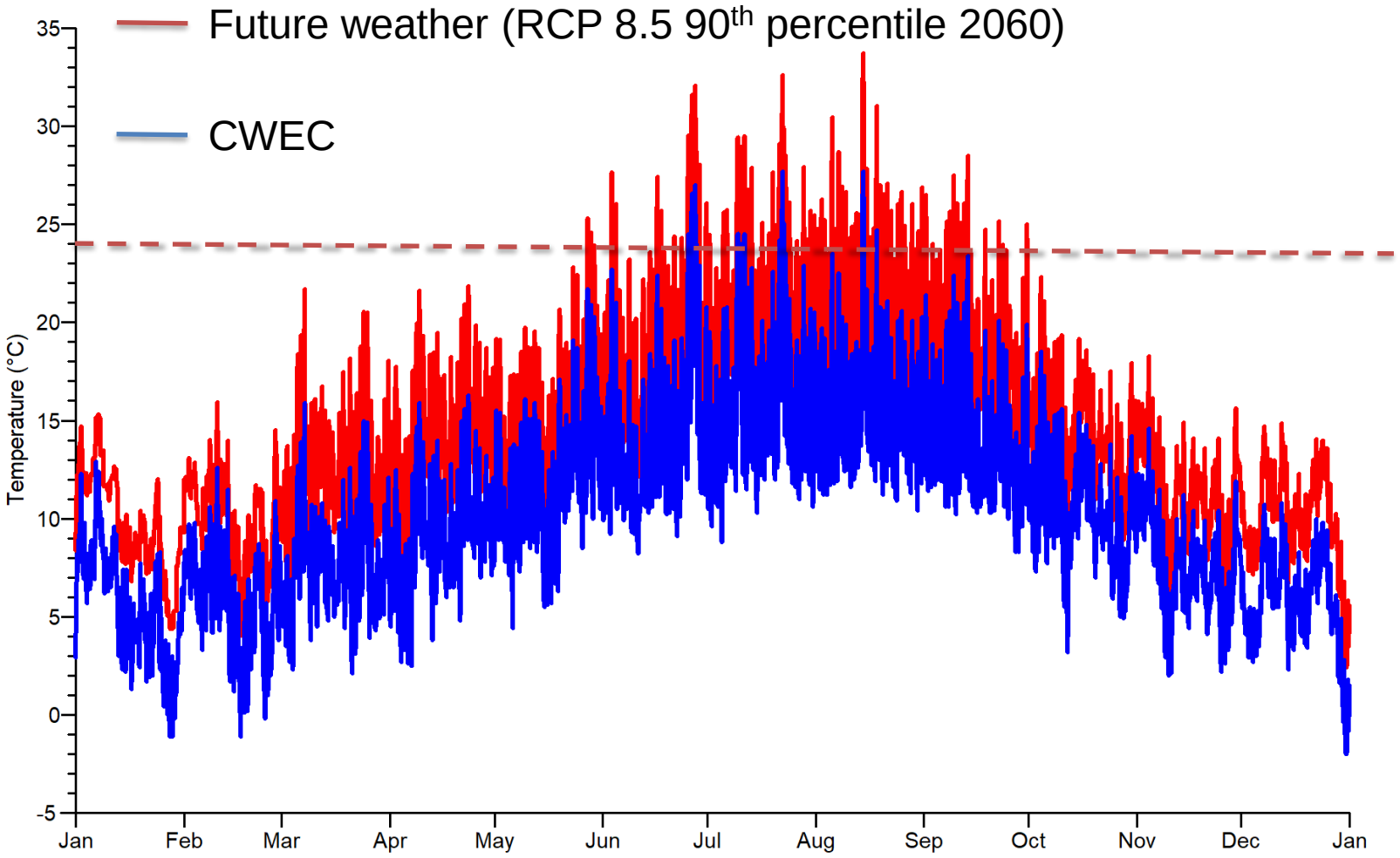
Overheating hours



Overheating hours- Future Weather



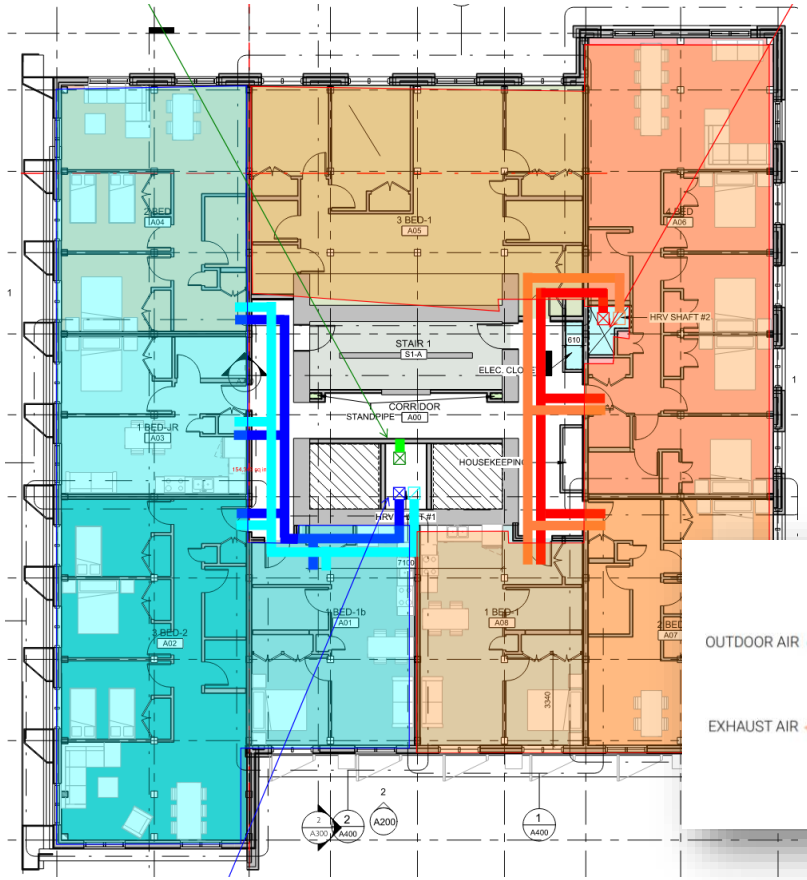
Overheating - Natural Convection Potential

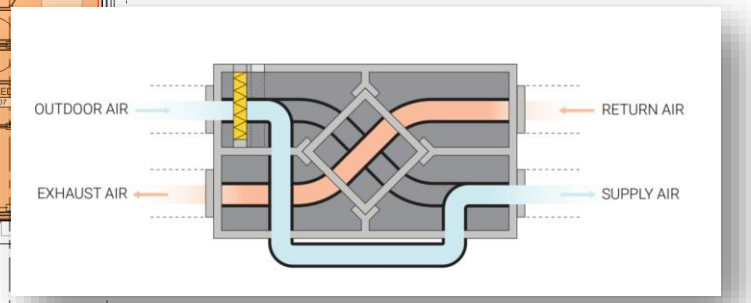


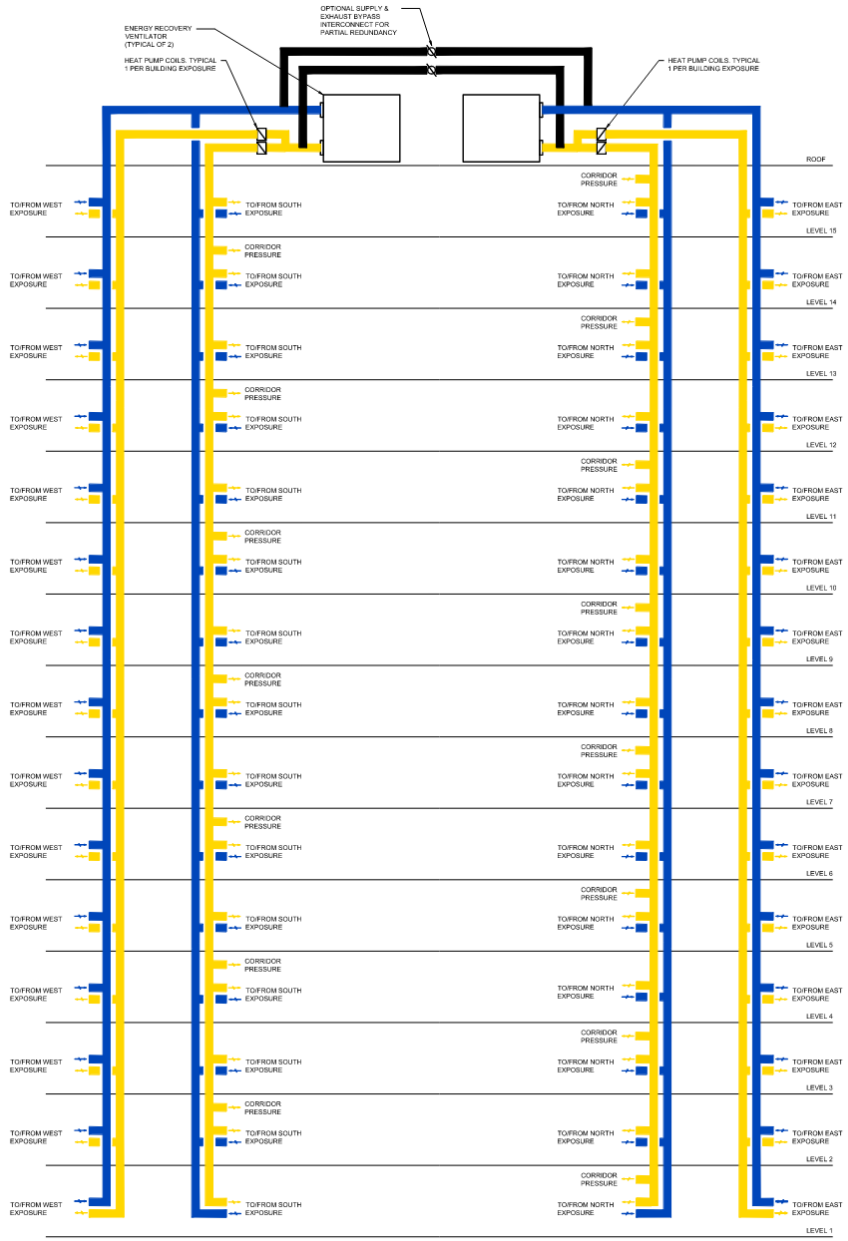
TCM 4: HRV Bypass

HRV bypass logic:

- HRV is bypassed when return air temp. >24C AND
- Supply air is tempered to 20C

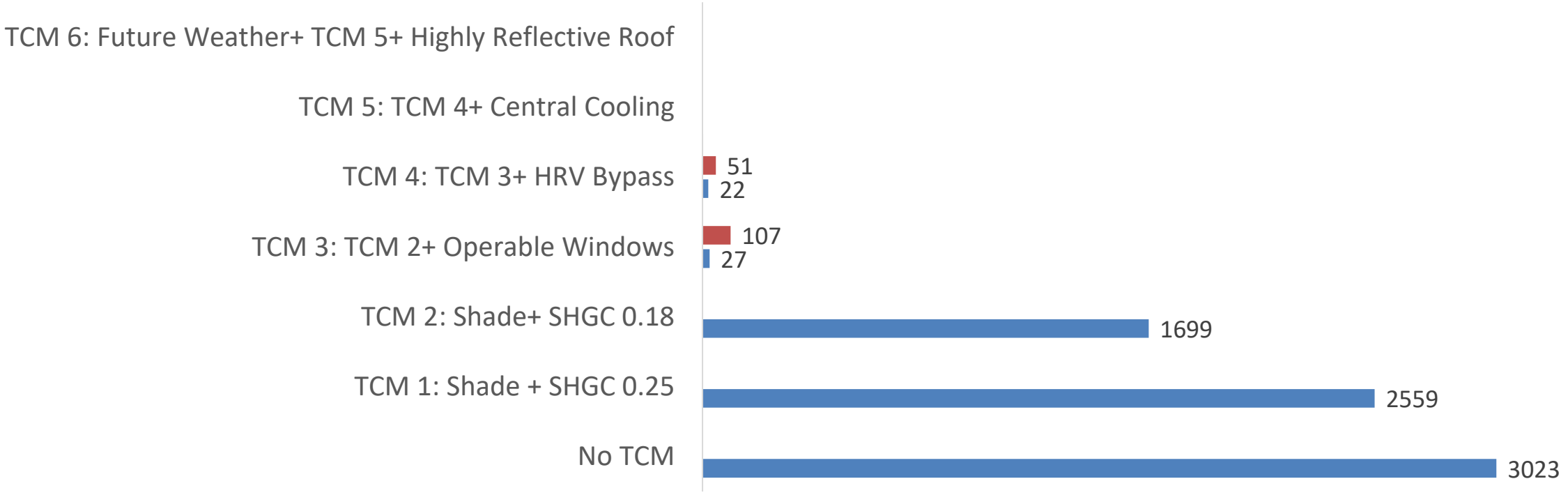






Mechanical design by m3 mechanical consultants inc.

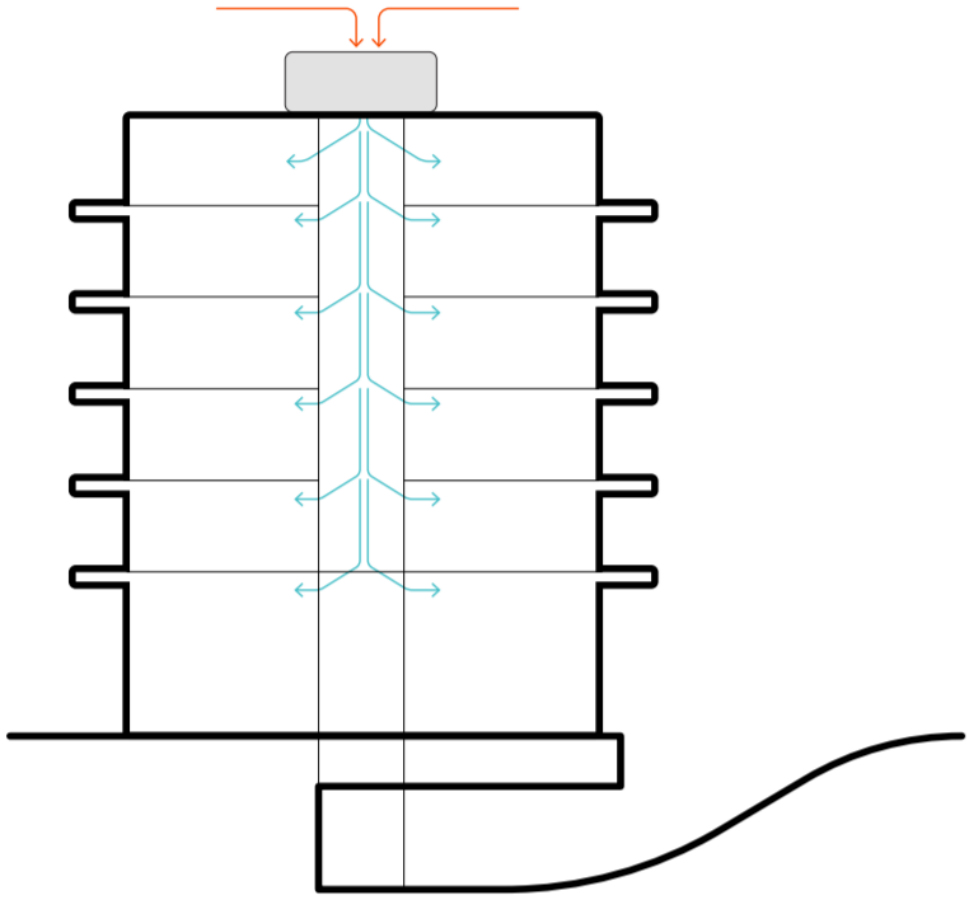
Overheating hours



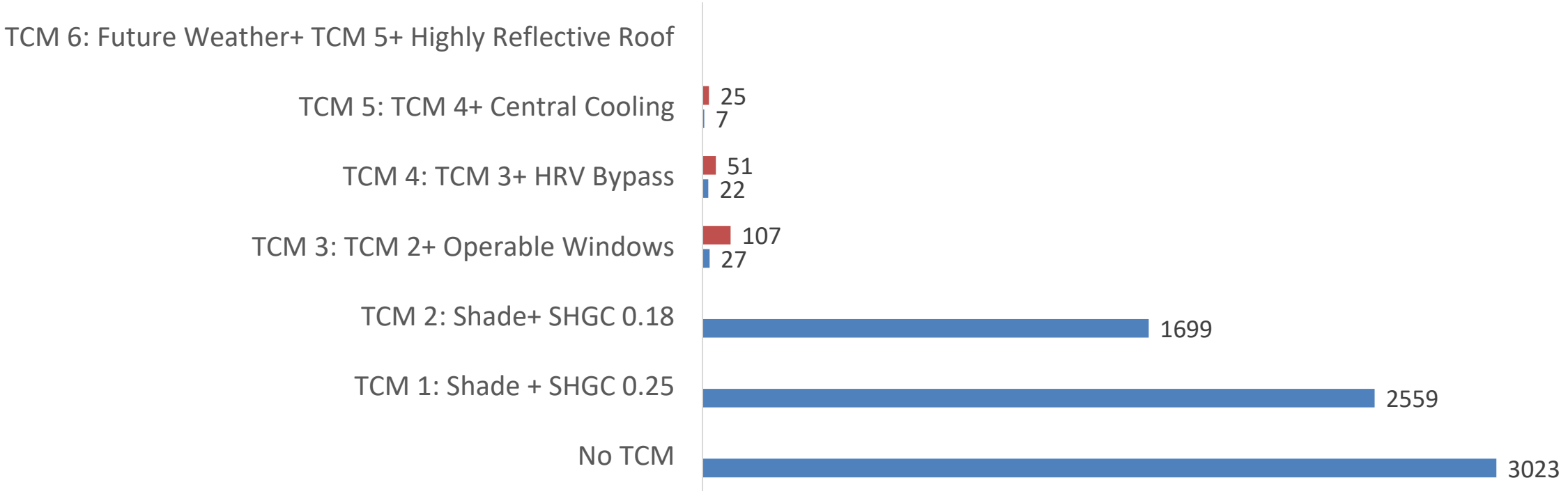
TCM 5: Central Cooling

Central Cooling logic:

- HRV is bypassed when return air temp. >24C AND
- Supply Air is tempered to 12C

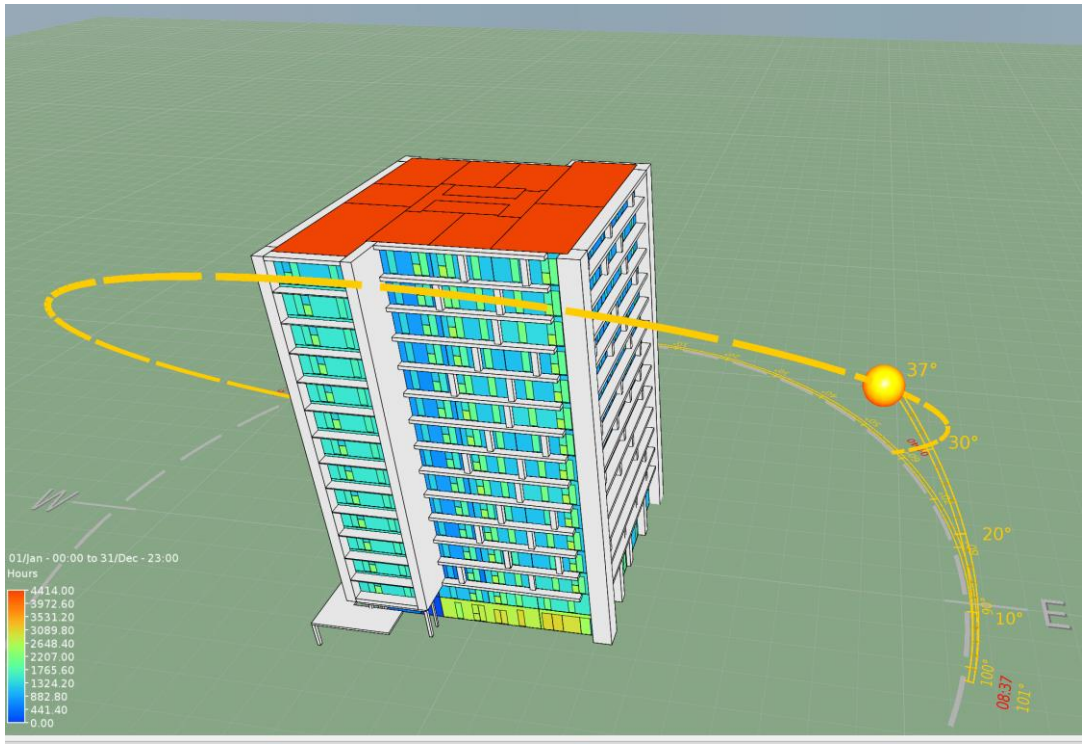


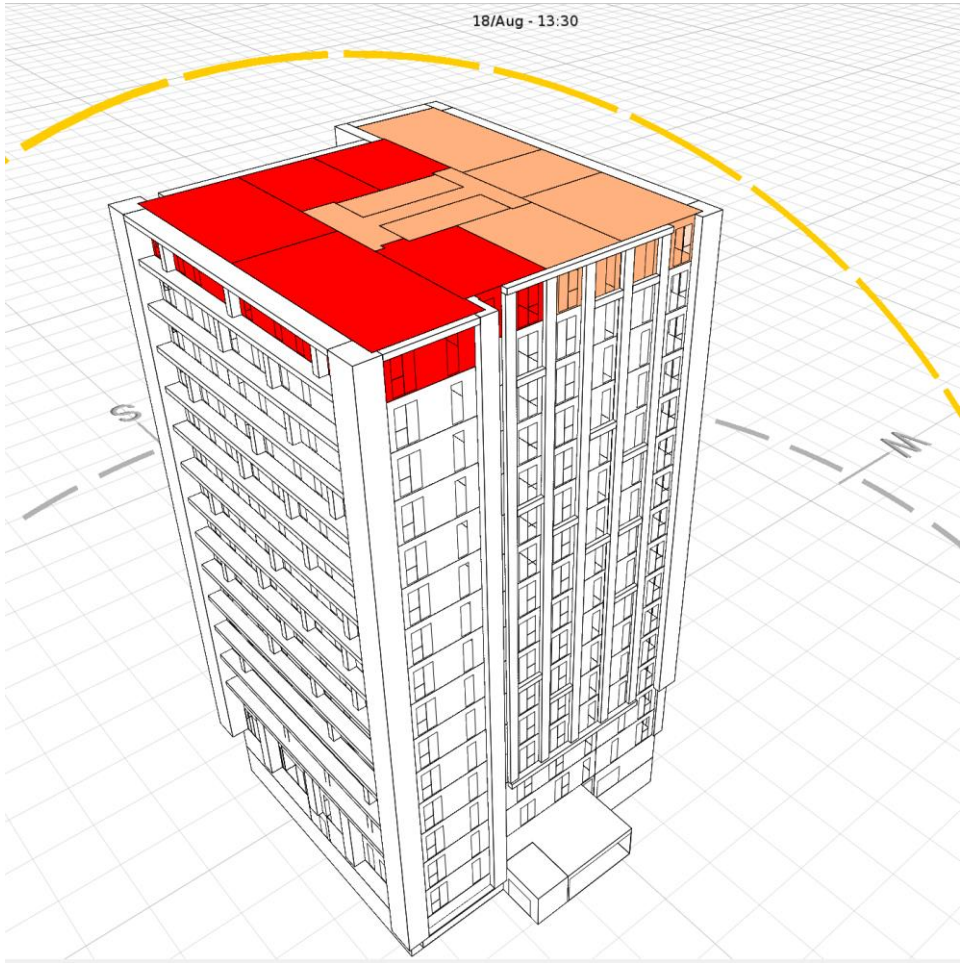
Overheating hours



Overheating study for future warmer climate

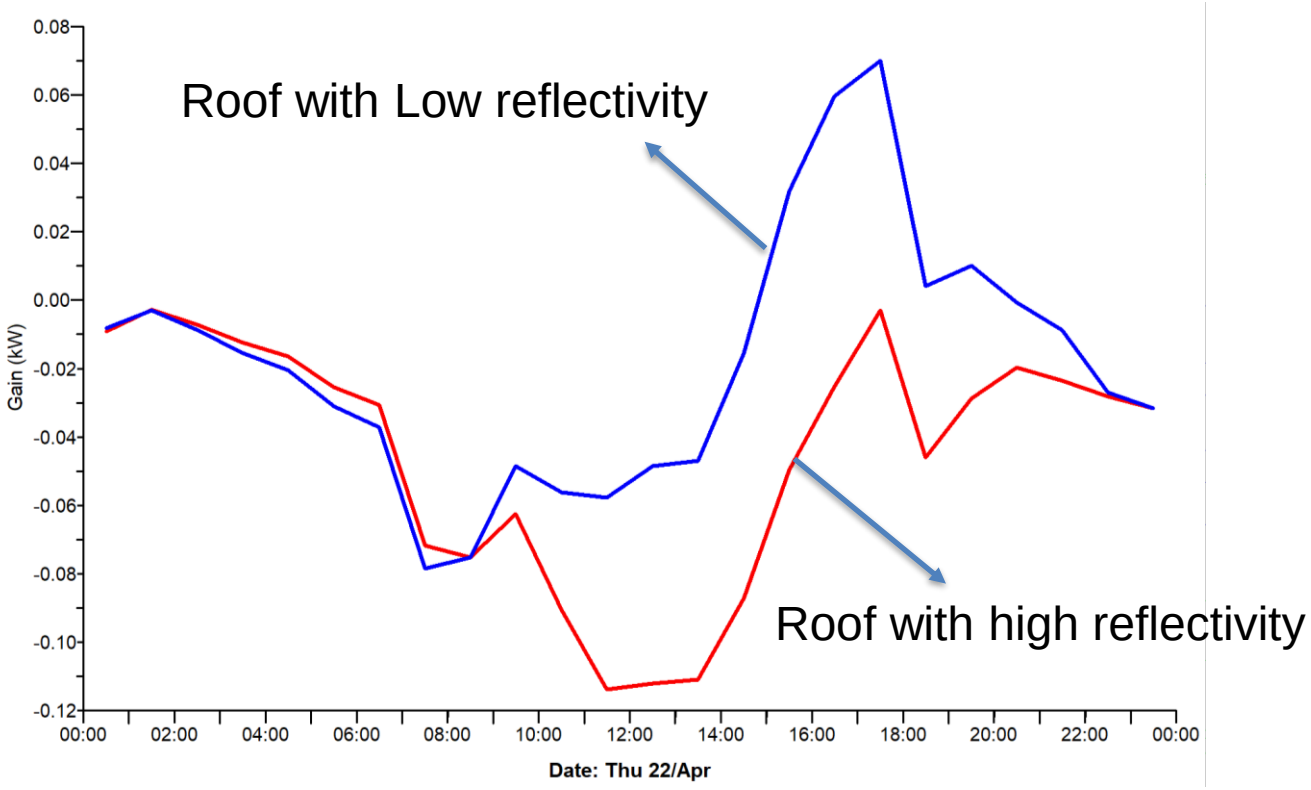
- We studied TCM 5 for RCP 8.5 90% for 2060
- The critical zones were found to be at <u>top floor</u>
- The maximum overheating hours were calculated 25 hours

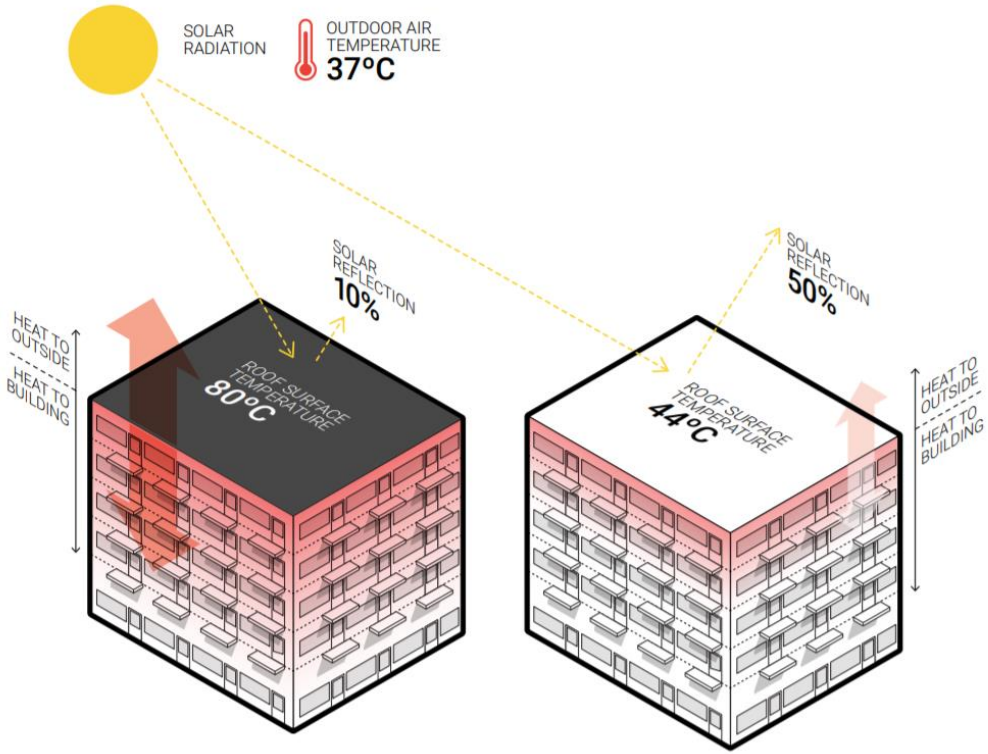




Application of Cool Roofs

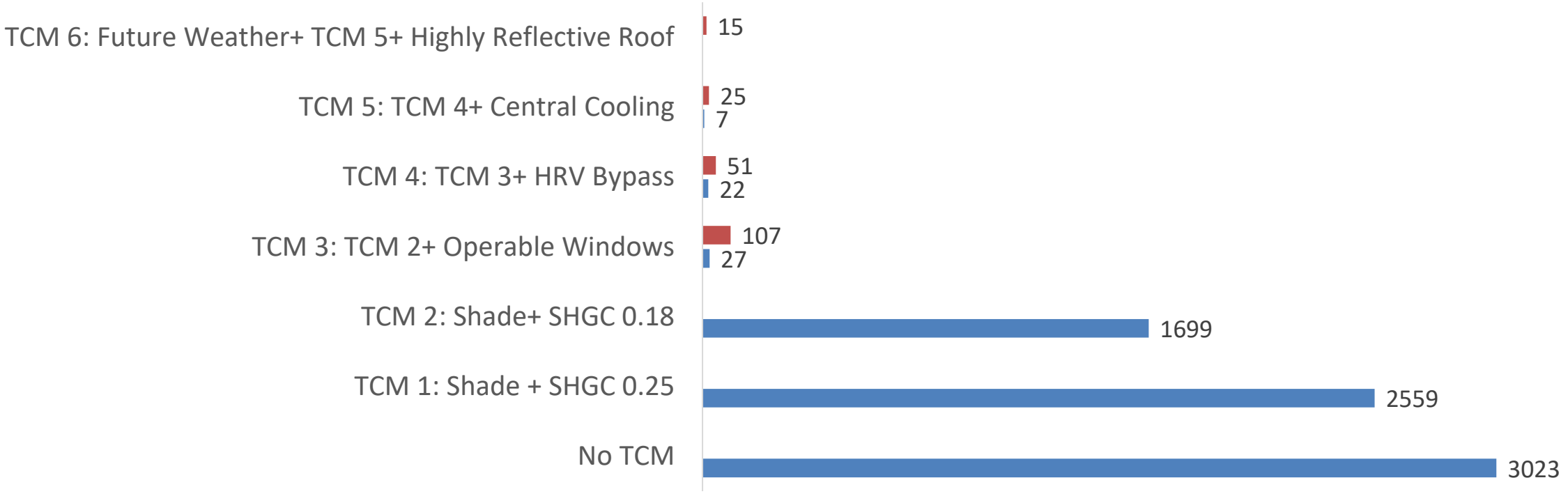
- Using roofs with highly reflective material decreases overheating significantly





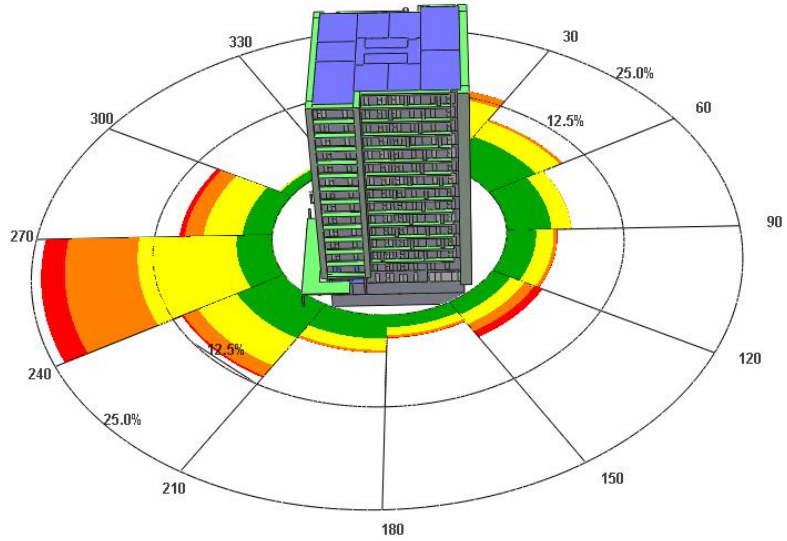
Conduction heat gain/loss for a south-facing suite at top floor

Overheating hours

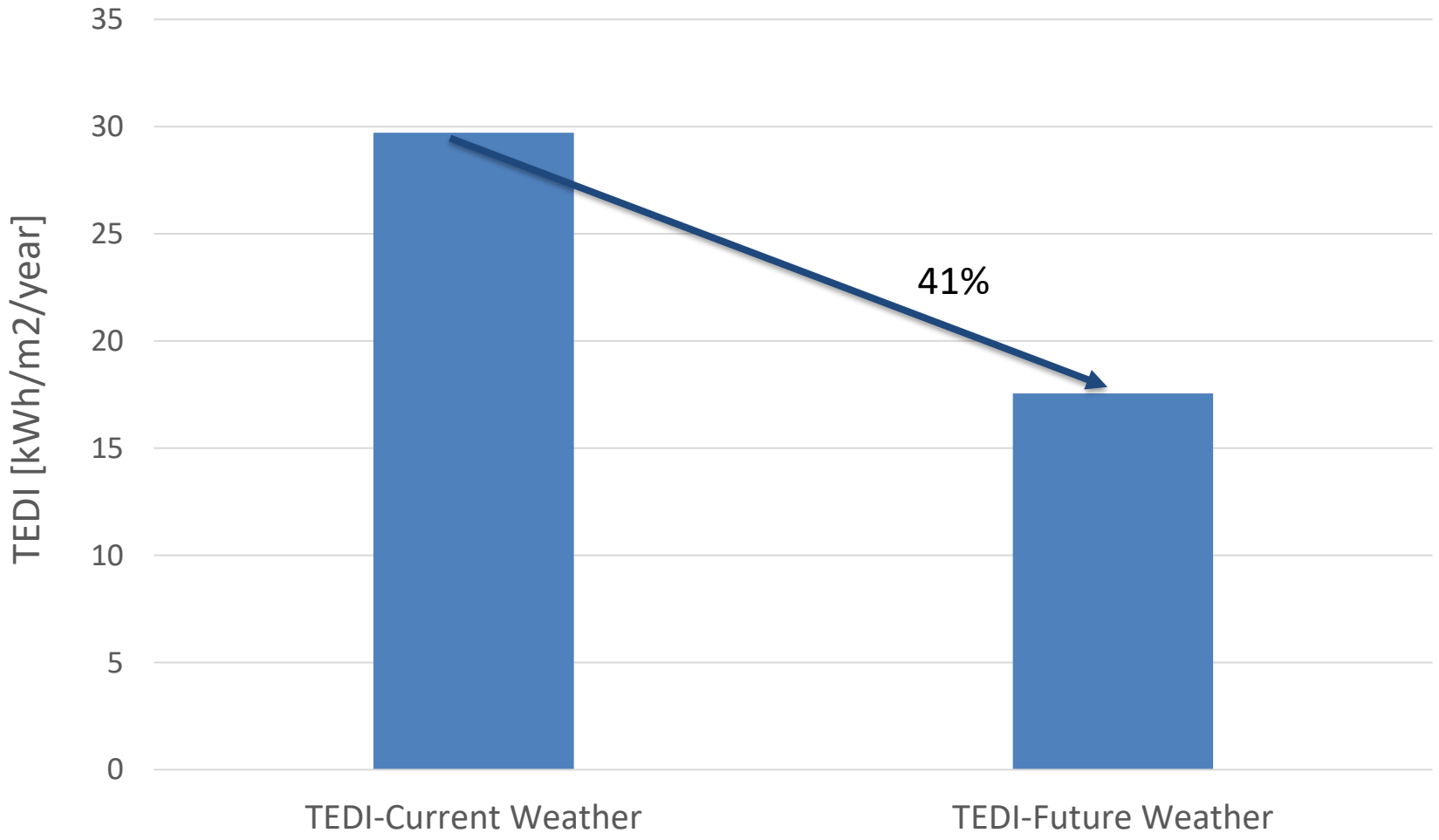


Outline

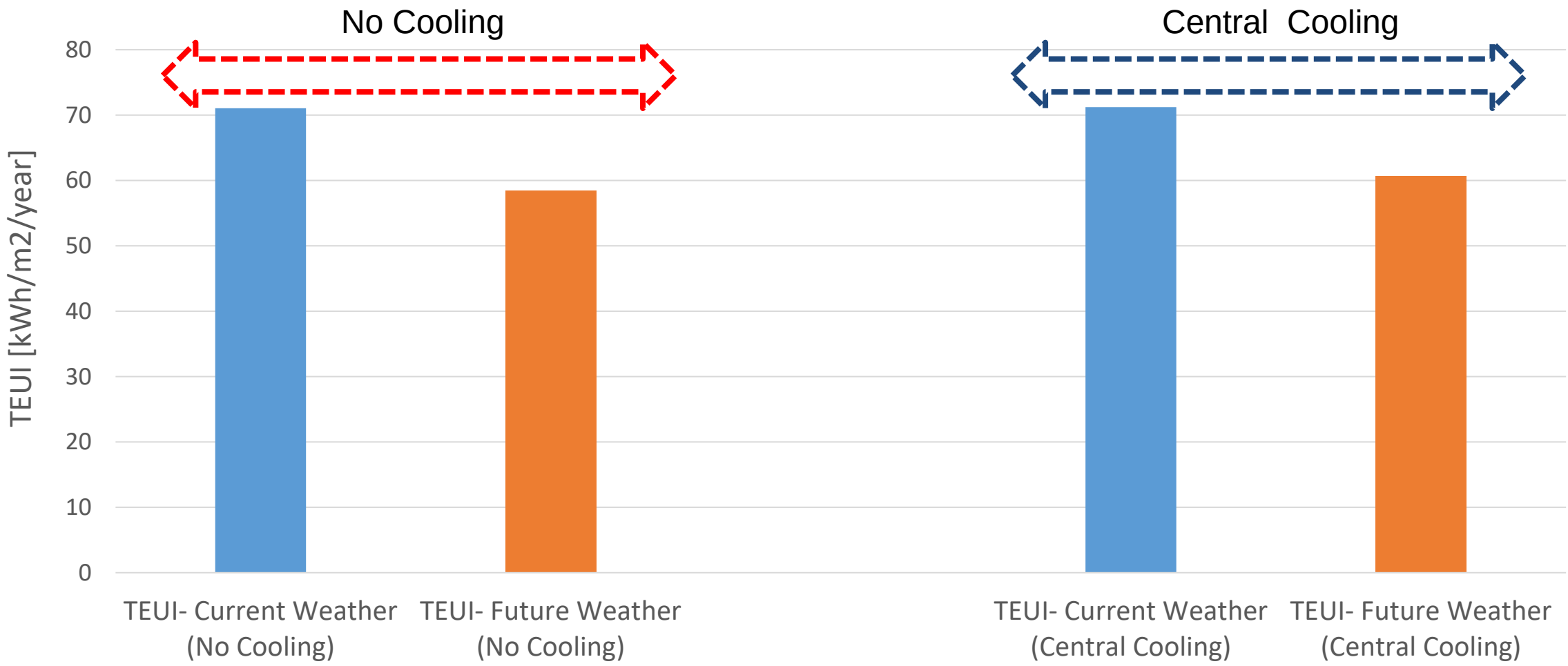
- Climate Change
- Future Warmer Weather Data
- Thermal Comfort Standards
- Case Study- Thermal Comfort
- Case Study- Energy Consumption



Thermal Energy Demand Intensity (TEDI)



Total Energy Use Intensity (TEUI)



Thank you!

Let’s be in touch…

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