BC BUILDING ENVELOPE COUNCIL
NOVEMBER 4, 2022

How Hot is Too Hot?

Lessons learned about multi-family overheating

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Learn Building Science

1

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2

How Hot is Too Hot?*

- We're all explorers now
- #1: Design lessons
- #2: New peak loads
- #3: Rethink refrigerants
- Conclusions

* Indoor temp between 26°C-30°C

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We're all explorers now

No one has ever lived on a +2.5°C planet

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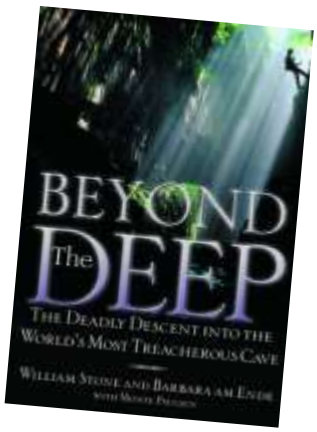
4

As a child, I wanted to explore the unknown…

Robert Peary, North Pole.

James Cameron, Mariana Trench.



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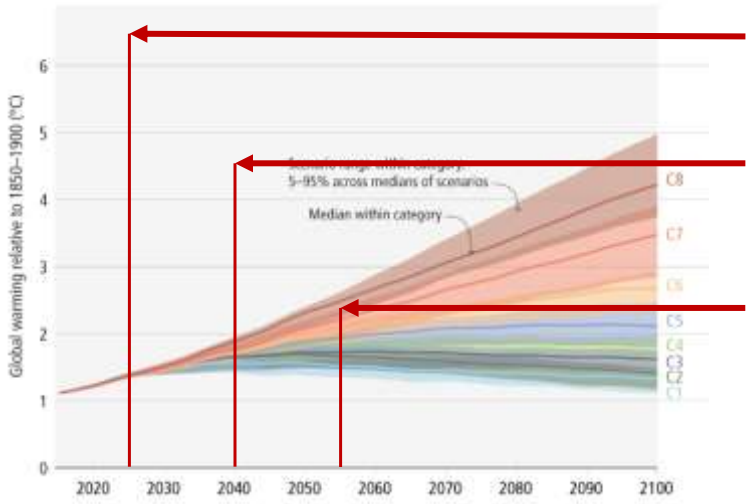
Most of us in this room will live on +2.5°C planet



By **2025** we will cross the **+1.5°C** "safe" threshold (2.7°F) triggering "tipping points" such as release of methane from permafrost.

By **2040** we will likely cross the **+2.0°C** threshold at which parts of the Middle East become too hot for survival.

By **2055**, if we continue on the "business as usual" emission path, we will likely cross the **+2.5°C** threshold and enter a climate unlike any homo sapiens have ever experienced.

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Source: Intergovernmental Panel on Climate Change, Assessment Report 6, Working Group III, page SPM-29, Spring 2022.

6

We're all explorers now. In next 20 years…

- Heatwaves that used to occur 1x per 10 years will occur 6x every 10 years.
- Droughts will happen more often.
- Sea-level rise will surpass 0.5 meters, more if land ice melts faster.
- Air quality will worsen, mortality from air pollution will rise.

Note: Many of IPCC's previous predictions happened years ahead of schedule.

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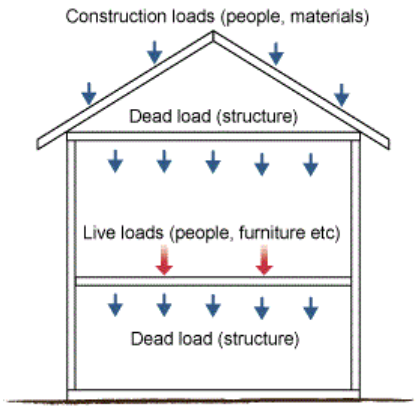
Probabilities for SSP5 (RCP 8.5) scenarios extracted from AR6 reports.

7

That said, forget about "global" temperatures

- We don't design buildings for "average" loads. We design for dead loads *plus* live loads plus a margin for safety.
- We don't size heating & cooling systems for "average" temperatures. We size for peak winter and summer conditions.
- Likewise, we can not think about future weather in terms of +2.5ºC average global temperature rise.
- We need to redesign buildings for peak climate loads: intense rain, higher floods, hotter heat waves, and dirtier outdoor air.



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8

Lesson #1: Design errors (2018)

Value engineering led to millions in cooling costs

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9

Harding Heights
Smithers, B.C.

- Cornerstone Architects
- Yellowridge Construction
- Smith + Anderson
- RDH Building Science

- Cold climate
- Seniors Housing
- 19 small suites

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10

Designed to be capable of either modular or on-site construction

Drawings courtesy Cornerstone Architecture

11

Harding Heights

12

Harding Heights
Mechanical Systems

VENTILATION

→ Two HRVs per floor

→ Each serves 3-4 suites

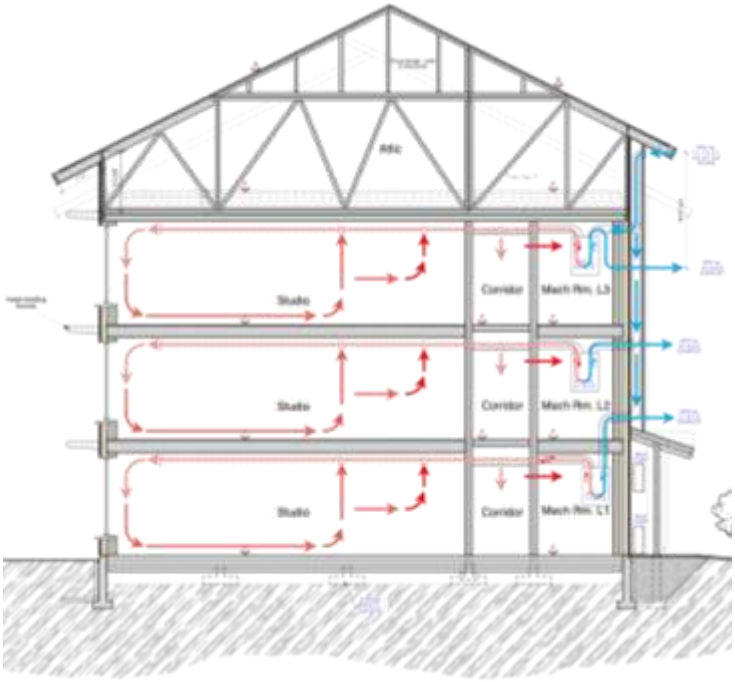
DHW

→ Three Sanden C02 systems

→ Storage in AC back-up tanks

HEAT

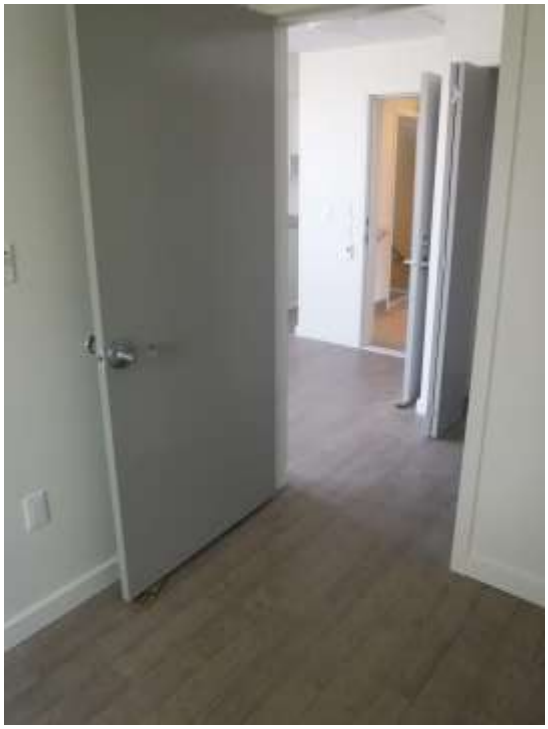
→ AC baseboards



Drawings courtesy Cornerstone Architecture

13

14



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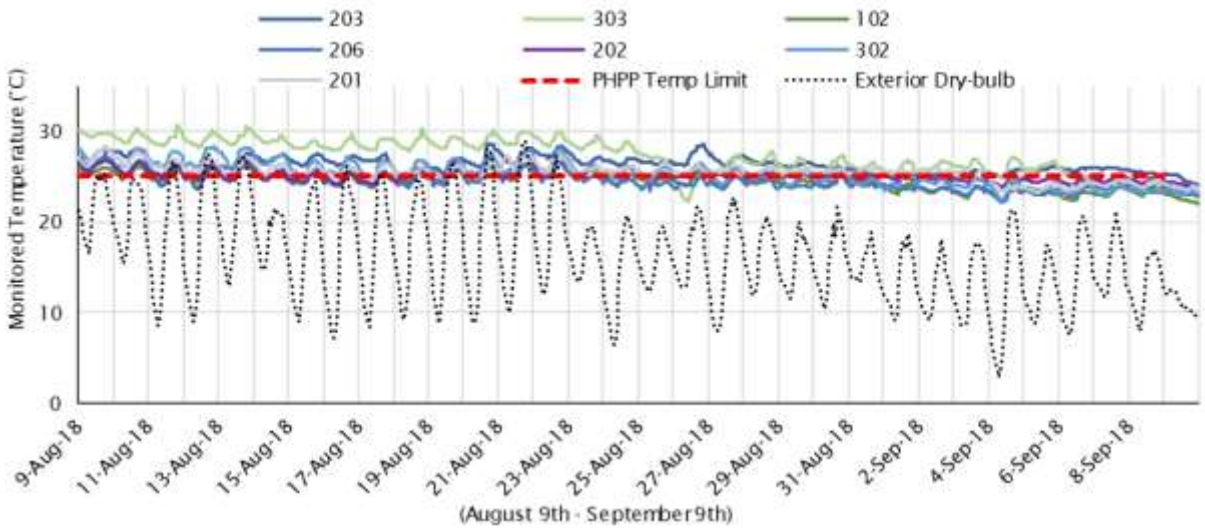
16

July 2018: Mayor cuts ribbon, seniors move in, big smiles until…

17



Aug-Sept 2018 temperatures in Harding Heights

18

Seven factors that contributed to overheating

- → **No operable exterior shading**
- → Fixed shading inadequate
- → Tree removed
- → Glazing substitution
- → Insect screen substitution
- → Warm ducts = No night flush
- → Weather warmer than predicted

→ Operable exterior shades would have kept the building comfortable even if the other seven mistakes had persisted.

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19

Seven factors that contributed to overheating

- → No operable exterior shading
- → **Fixed shading inadequate**
- → Tree removed
- → Glazing substitution
- → Insect screen substitution
- → Warm ducts = No night flush
- → Weather warmer than predicted

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20

Seven factors that contributed to overheating

- No operable exterior shading
- Fixed shading inadequate
- **Tree removed**
- Glazing substitution
- Insect screen substitution
- Warm ducts = No night flush
- Weather warmer than predicted

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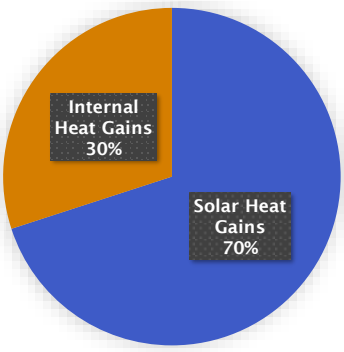
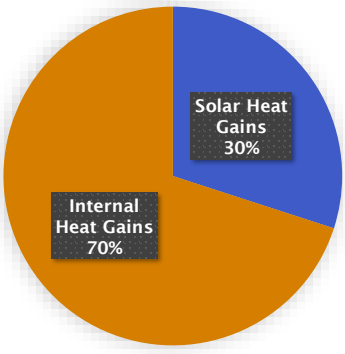
21

Multi-family buildings need exterior shading



Small Building

Solar Heat Gains



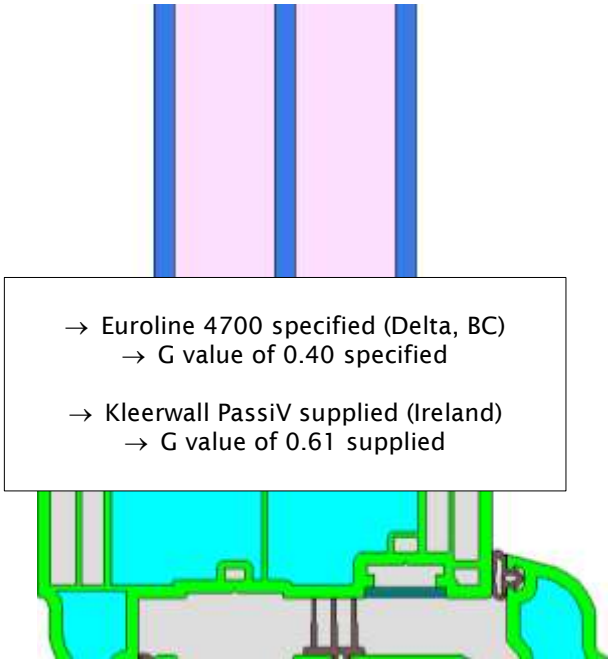
Large Building

Internal Heat Gains

22

Seven factors that contributed to overheating

- → No operable exterior shading
- → Fixed shading inadequate
- → Tree removed
- → **Glazing substitution**
- → Insect screen substitution
- → Warm ducts = No night flush
- → Weather warmer than predicted



→ Euroline 4700 specified (Delta, BC)
→ G value of 0.40 specified

→ Kleerwall PassiV supplied (Ireland)
→ G value of 0.61 supplied

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Seven factors that contributed to overheating

- → No operable exterior shading
- → Fixed shading inadequate
- → Tree removed
- → Glazing substitution
- → **Insect screen substitution**
- → Warm ducts = No night flush
- → Weather warmer than predicted

→ Because there were no screens, most residents closed windows at night. This prevented natural night flush

→ People are doing the same during smoke events.

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24

Seven factors that contributed to overheating

- No operable exterior shading
- Fixed shading inadequate
- Tree removed
- Glazing substitution
- Insect screen substitution
- **DHW tanks warmed ducts**
- Weather warmer than predicted

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25

Seven factors that contributed to overheating

- No operable exterior shading
- Fixed shading inadequate
- Tree removed
- Glazing substitution
- Insect screen substitution
- Warm ducts = No night flush
- **Weather warmer than predicted**

The 30-year average August temperature for Smithers is 14.2˚C

In 2018, August averaged 16.4˚C

- August 2017: **17.0°C**
- August 2016: **16.0°C**
- August 2015: **13.9°C**
- August 2014: **15.5°C**
- August 2013: **16.4°C**
- August 2012: **14.5°C**
- August 2011: **12.6°C**
- August 2010: **15.0°C**

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The midpoint of many 30-year climate files is 1985.
Care to guess what the top movie & show were that year?

Are we designing Passive House & Step Four buildings for a Marty McFly climate?

27

Lesson #2: New peak loads (2021)

What happens in the Arctic does not stay in the Arctic

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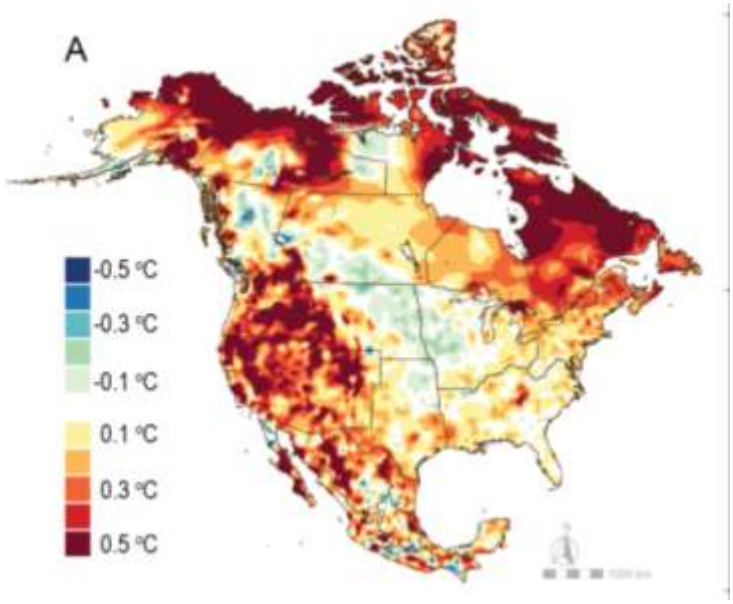
28

Global heating is not evenly distributed

- The planet has heated +1.1°C since the pre-industrial era
- Canada has warmed almost twice as much



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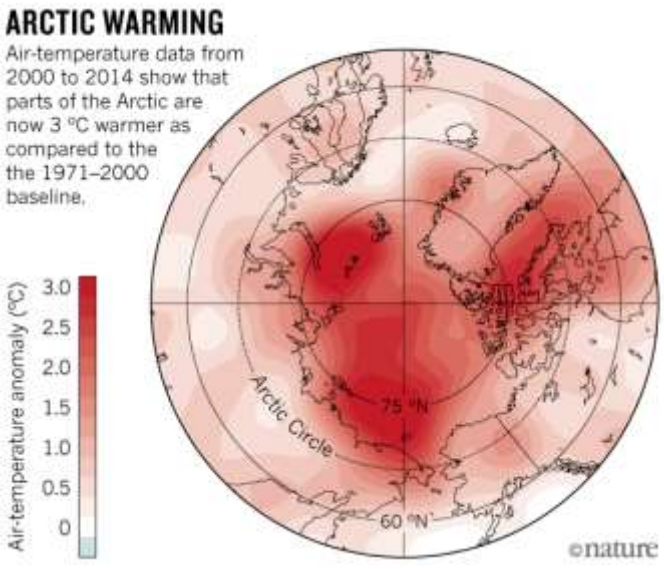
Mean temperature trend from 1980 to 2015. Source: IPCC AR6 WG2 report, page 2511.

29

Global heating is not evenly distributed

- The planet has heated +1.1°C since the pre-industrial era
- Canada has warmed almost twice as much
- **The Arctic has warmed three times as much**



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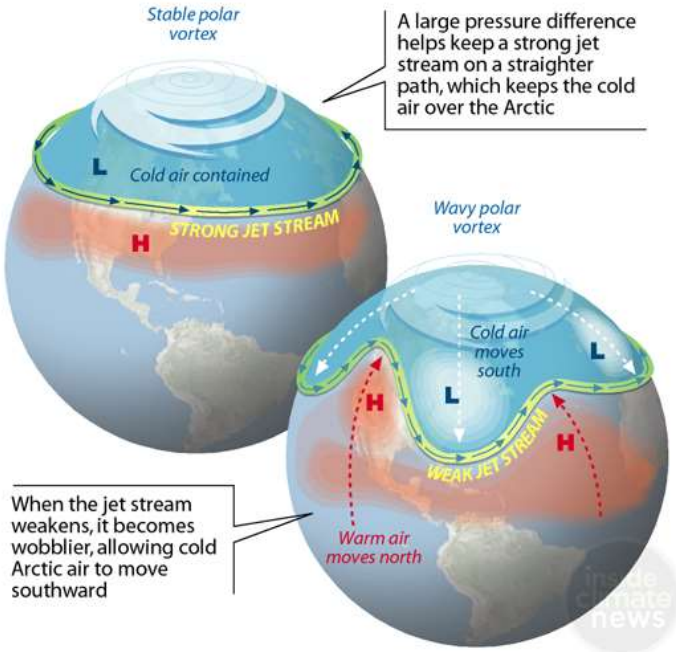
2021 results from Arctic Monitoring and Assessment Programme (AMAP)

30

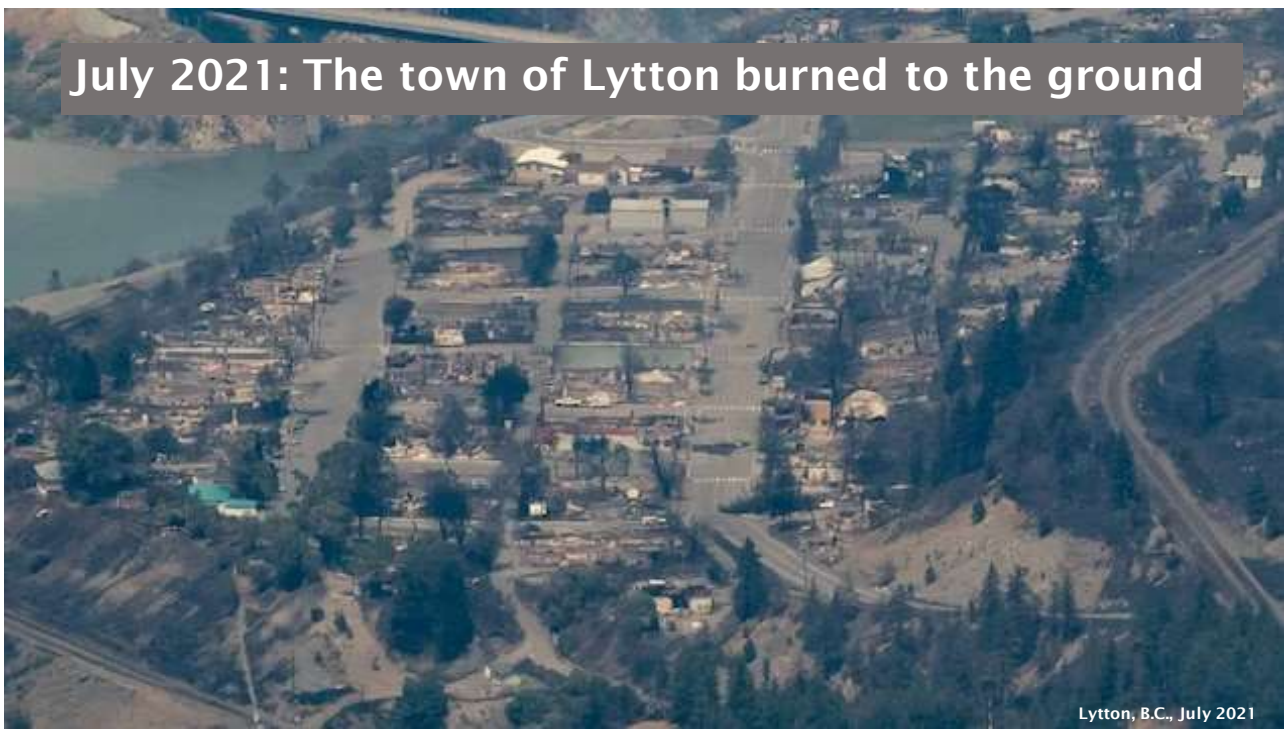
Hot Arctic = Weak jet stream

- The jet stream weakens as the Arctic heats
- A weak jet stream leads to both heat domes and Arctic blasts
- This is how a +3˚C Arctic climate can lead to +/- 30˚C weather in the U.S. & Canada.



Graphic by Paul Horn for Inside Climate News. Sources: NOAA & Scientific American

31

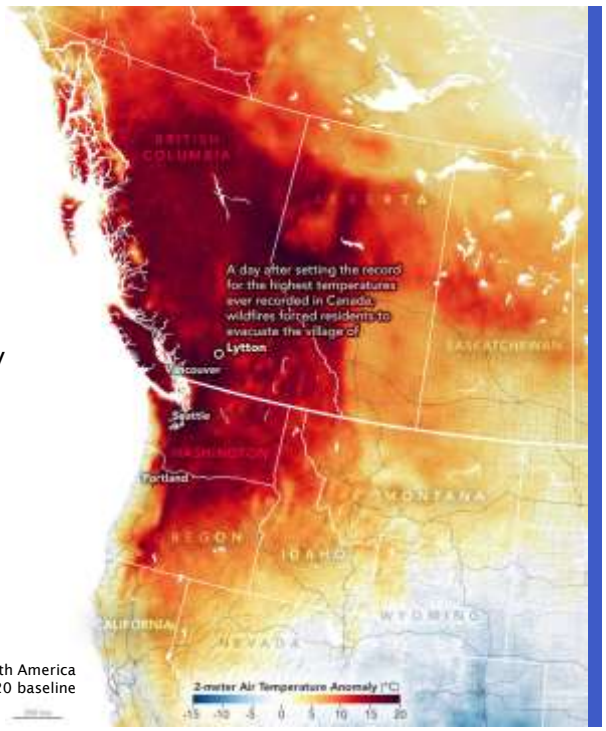


32

33

Weak jet stream = heat dome of 2021

- 619 people died in B.C. from June 25–July 1, 2021
- The majority were seniors. We lose the ability to shed heat via sweat as we age.
- Nearly all died in their homes. Most houses and all apartments trap heat inside, making them hotter than outdoors.



Map: Air temperature anomalies across North America on June 29, 2021, compared to 2014–2020 baseline

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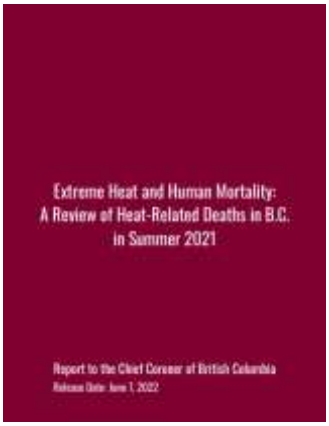
34

Heat dome = High indoor temps = Death and injury



"**High indoor temperature was the primary cause of injury and death during the extreme heat event**. During this time, hot air became trapped indoors and continued to rise over time. Although outdoor temperatures decreased overnight, residences did not cool off, exposing people to harmful high temperatures for extended periods of time.

"The B.C. Centre for Disease Control (BCCDC) identified that **people were most in danger when indoor temperatures remained above 26 degrees** throughout the heat event." (79ºF)

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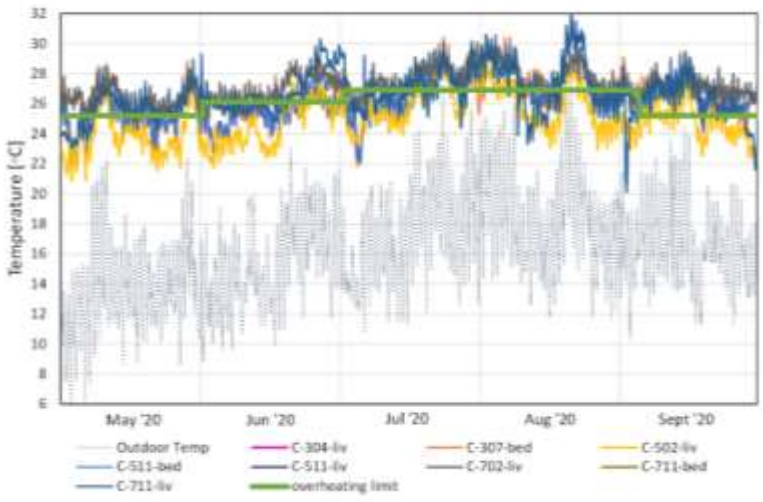
"Extreme Heat and Human Mortality: A Review of Heat-Related Deaths in B.C. in Summer 2021"

35

Indoor temperatures often above 26ºC (79ºF)



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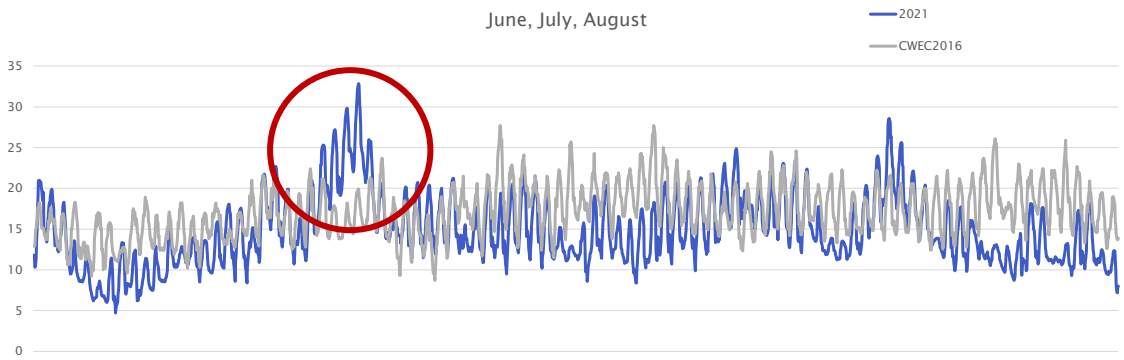
"Indoor Environmental Quality of Social Housing Buildings in British Columbia" BC Housing Research Centre

36

Summer 2021 vs average summer (CWEC 2016)



During the heat dome. night-time lows were above historic daytime highs.

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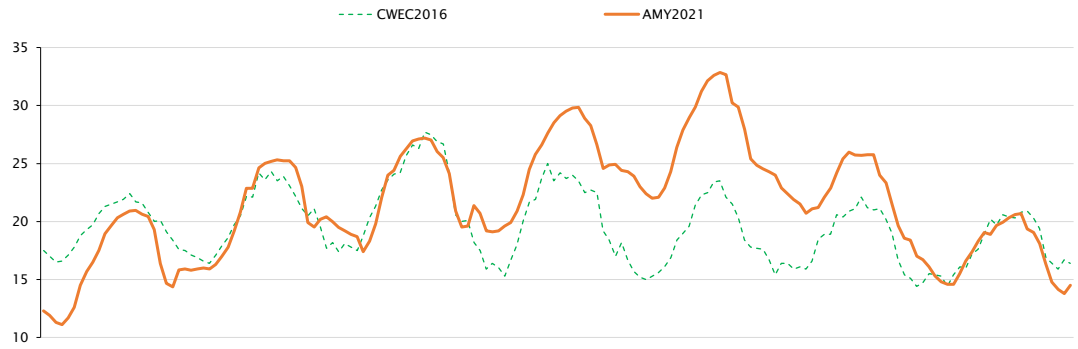
July 2021 vs hottest week in CWEC 2016 (Aug)



Passive cooling will not work when outdoor temps remain above 20ºC

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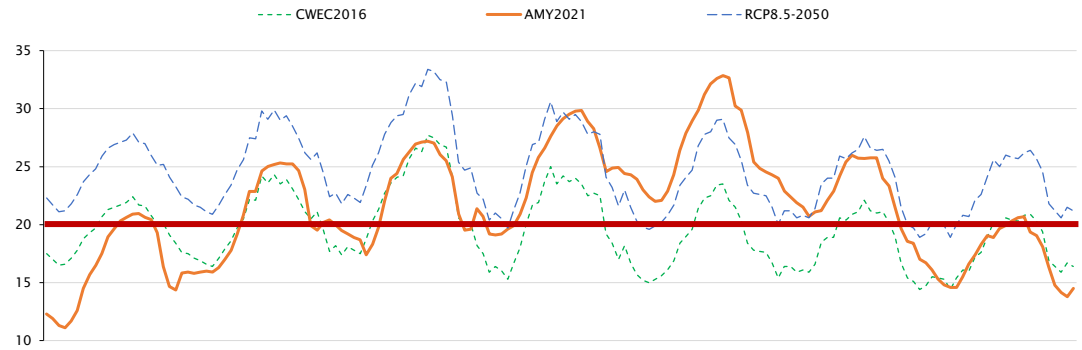
38

By 2050, hottest weeks to exceed 2021 heat dome



Hottest Weeks in CWEC 2016 and IPCC 2050 compared to actual weather of July 2021 heat dome

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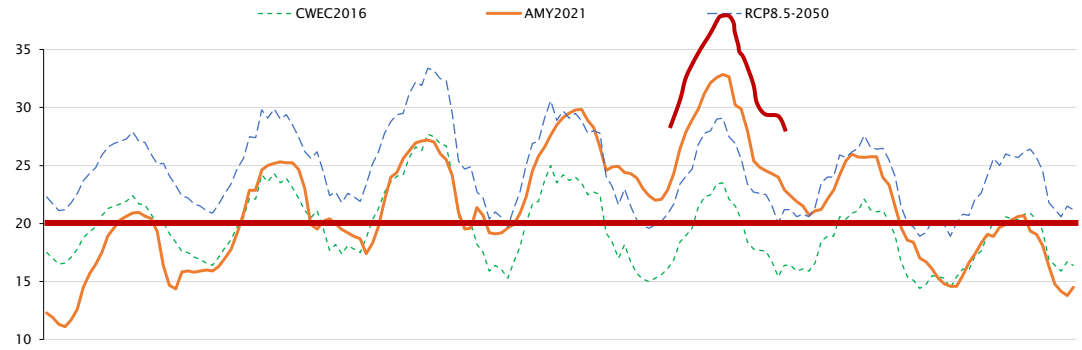
39

2040 heat dome? Days in 40s? Nights in 30s?



Hottest Weeks in CWEC 2016 and IPCC 2050 compared to actual weather of July 2021 heat dome

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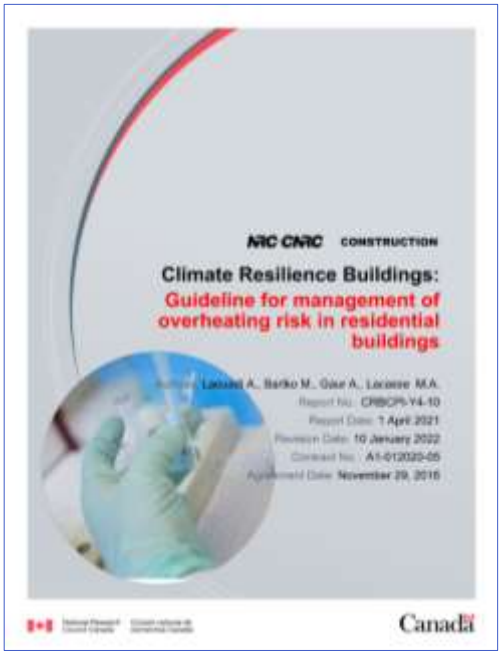
40



"Guideline for management of overheating risk in residential buildings"

- → Effects of heat on human health
- → Standard Effective Temperature (SET): Still air at 50% RH.
- → New assessment method based on modelling for peak loads (i.e., heat waves) rather than modelling to 30-year average weather data.

"Guideline for management of overheating risk in residential buildings," Laouadi et al, NRCan 2022

41

Table 5. Suggested threshold values of SET_d and SET_n for un-acclimatized (acclimatized) occupants by type of buildings under free-running or partially air-conditioned modes[+]

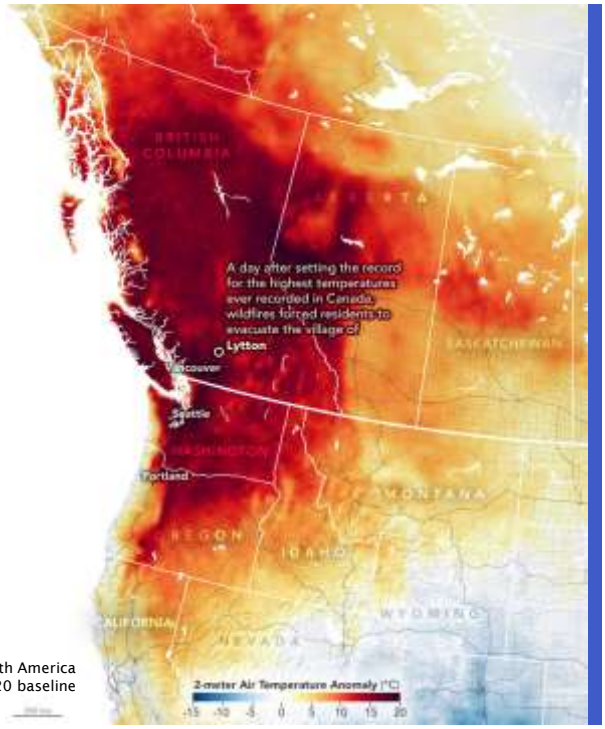
Building Type ↓	SET_d (°C)					SET_n (°C)
	Reference young occupant	Young adults		Older adults		Young / Older adults
		with adaptation	without adaptation	with adaptation	without adaptation	
Residential	1 met & 0.5 clo (wake); 0.8 met & 1.38 clo (sleep)	30 (31.2)	27 (28.2)	28.2 (29.4)	26.8 (29)	30/32
Office	1.1 met & 0.57 clo (wake)	30 (31.2)	27 (28.2)	28.2 (29.4)	26.8 (29)	N/A
High school	1.2 met & 0.57 clo (wake)	30 (31.2)	27 (28.2)	N/A	N/A	N/A
Primary school	1.2 met & 0.57 clo (wake)	27 (28.2)	25 (26.2)	N/A	N/A	N/A
Senior home	1 met & 0.5 clo (wake) 0.8 met & 1.64 clo (sleep)	N/A	N/A	28.2 (29.4)	N/A	32
LTCH	1 met & 0.5 clo (wake) 0.8 met & 1.64 clo (sleep)	N/A	N/A	N/A	26.8 (28)	32
Hospital (Patient room)	1 met & 1.57 clo (wake) 0.8 met & 1.64 clo (sleep)	N/A	27 (28.2)	N/A	26.8 (28)	30/32

"Guideline for management of overheating risk in residential buildings," Laouadi et al, NRCan 2022

42

NRCan: Model to the hottest weather of the past 30 years

- "Reference Summer Weather Years" (RSWY) show three types of heat events: long, intense, severe.
- Select the overheating events that have the highest severity and intensity values.
- Apply the overheating criteria to those extreme overheating events.
- Note this is NOT the same as modelling to a so-called "future climate file" of just 1.5ºC or 2ºC warmer. (ie, peak load vs average)



Map: Air temperature anomalies across North America on June 29, 2021, compared to 2014–2020 baseline

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Lesson #3: Rethink refrigerants

Buildings emit three greenhouse gasses.
We track only one.

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44

Greenhouse gasses make the Earth habitable

- A natural blanket of water vapor, carbon dioxide, and methane keeps the Earth about 30°C (54°F) warmer than it would be otherwise.
- Without this blanket, the Earth would be an uninhabitable ball of ice.
- By burning massive amounts of fossil fuel since the Industrial Revolution, we've wrapped an extra blanket around the planet.
- This extra blanket traps heat that would otherwise radiate to space.

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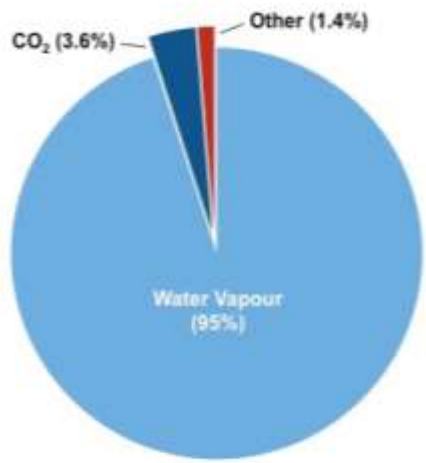
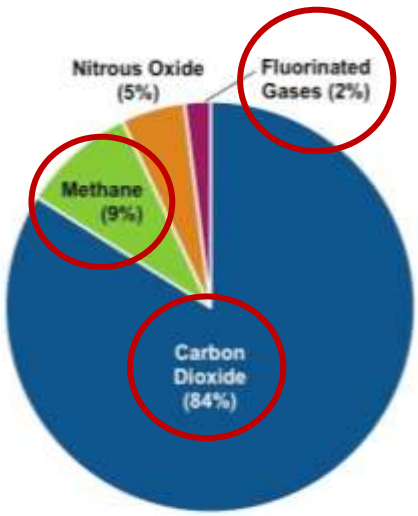


Greenhouse Gases in Atmosphere



Anthropomorphic (Man-Made) Greenhouse Gases

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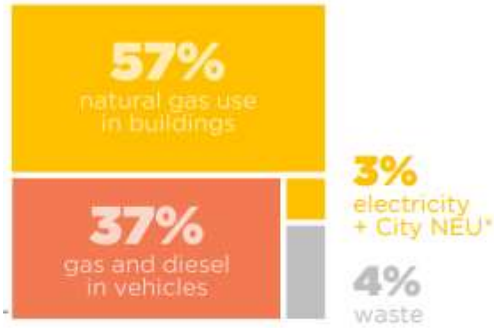
46

Carbon Dioxide (CO_2)

- The combustion of fossil fuels to heat buildings is the leading source of greenhouse gas emissions in urban areas.
- In Vancouver, for example, buildings contribute 57% of GHG emissions.
- When calculating "Global Warming Potential" (GWP) of various gasses, carbon dioxide is the baseline.



Combustion of "Natural Gas" in buildings accounts for 57% of C02 emissions in Vancouver. (But methane not included.)

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Chart by City of Vancouver

47

CO_2 flows from furnaces, boilers, DHW heaters

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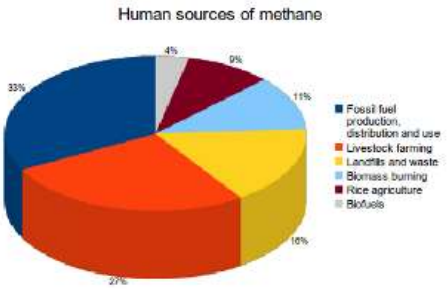
48

Methane (CH_4)

- "Natural Gas" is about 95% methane. (87%-98%)
- Methane comes from fossil fuels (33%), livestock farming (27%), and landfills (16%).
- Methane heats atmosphere **86 times faster** than CO_2 in first 20 years.
- Methane is responsible for 30%+ of global heating.



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"Chemical composition of natural gas," Enbridge web site

49

An estimated 2.7% of methane gas leaks

- "The fugitive methane rate is at least **2.7%,** double what is reported in the National Inventory Report."
- Because methane has a Global Warming Potential (GWP) of 86, the leaked methane roughly doubles the climate impact of the burned methane.
- "Emissions from buildings" estimates do not include methane leakage.

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"Fugitive Methane: New guidelines determine need to curb natural gas emissions in Ontario," The Atmospheric Fund

50

"Electrify everything" will reduce methane

- Electric heat pumps to deliver cooling and heating.
- A separate heat pumps to provide DHW.
- Induction cooktops. (These also significantly improve indoor air quality.)
- **If we "Electrify Everything," does that eliminate building emissions?**

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51

No. Because buildings also leak refrigerants

- Fluorinated gases have no natural sources.
- The most common refrigerant, HFC-410a, carries **2,088 times more Global Warming Potential** compared to CO_2.
- Two litres of leaked HFC-410a does as much climate damage as driving a car for a year.

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Typical passenger vehicle emits about 4.6 metric tons of carbon dioxide per year: U.S. EPA.

52

Is a leaky heat pump worse than a great boiler?

Elementa Consulting Study for CIBSE Technical Symposium 2019, published in LETI Embodied Carbon Primer

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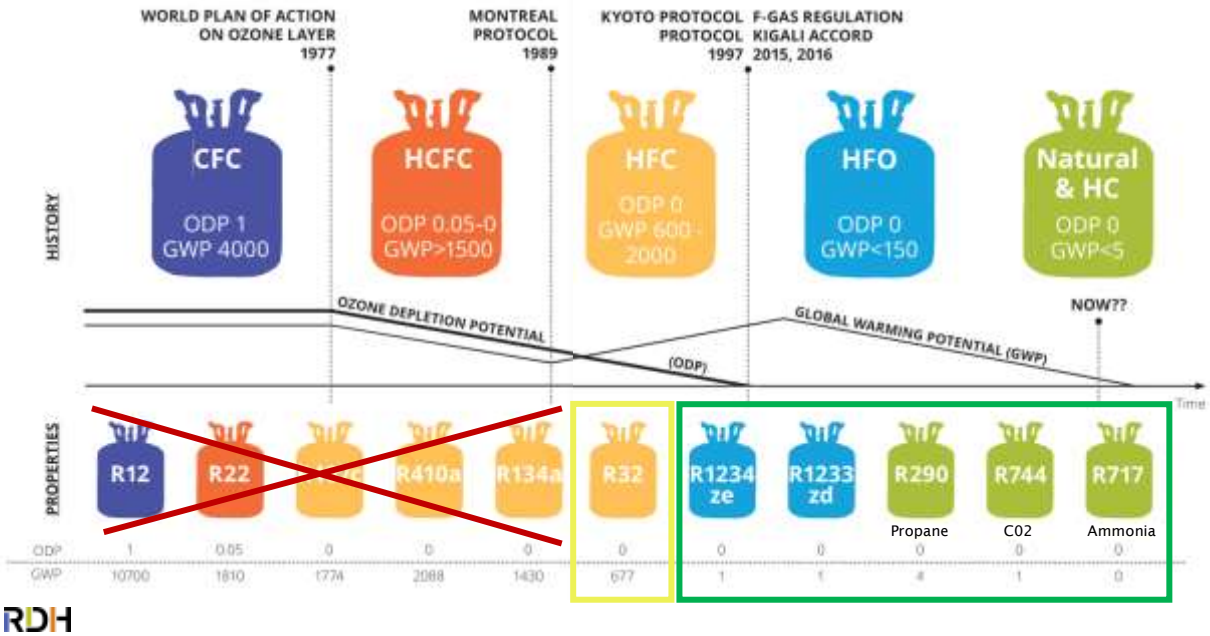
Graphic & Data: "Refrigerants & Environmental Impacts: A Best Practice Guide," Elementa Consulting (Integral Group) September 2020

53



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Graphic & Data: "Refrigerants & Environmental Impacts: A Best Practice Guide," Elementa Consulting (Integral Group) September 2020

54

Reduce Refrigerant Need. Implement passive measures to reduce need for active cooling & heating.

Specify Low-GWP Refrigerants. Low means GWP below 10 kgCO2e, such as C02, Propane, or Ammonia. If low GWP refrigerant not available, specify a medium-GWP product below 750 kgCO2e, such as R-32.

Reduce Refrigerant Charge. Design for hydronic distribution to fan coil units. Avoid VRF systems.

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"Refrigerants & Environmental Impacts: A Best Practice Guide," Elementa Consulting (Integral Group) September 2020

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Reduce Refrigerant Charge. Design for hydronic distribution to fan coil units. Avoid VRF systems.

Mitigate Refrigerant Leakage. Require leak-free installation by a manufacturer registered installer of the specific product.

Enhance Refrigerant Recovery. Require 100% recovery and reuse of the refrigerant undertaken by a manufacturer-trained contractor.

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"Refrigerants & Environmental Impacts: A Best Practice Guide," Elementa Consulting (Integral Group) September 2020

56

Conclusion: Practice & policy suggestions

Every building needs cooling or an evacuation plan

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57

Suggestions for building owners & design teams

- Every building needs passive cooling to lower annual cooling demand and improve ability to shelter in place during power-outs.
- Every building needs active cooling so that occupants can survive heat waves.
- Until every building has active cooling, every residential building needs an evacuation plan for heat waves.
- Every building needs a 20-year plan to adapt to and mitigate changing climate.

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58

Suggestions for practice & policy


PRACTICE ADVISORY

OVERHEATING CONSIDERATIONS FOR EXISTING MULTI-UNIT RESIDENTIAL BUILDINGS

- Engineers & architects need to update guidance on overheating. Recent notices from AIBC and EGBC require clarification.
- Guidance should be based on modelling for future peak loads, as proposed by Laouadi et al in "Guideline for management of overheating risk in residential buildings."
- Policymakers should add a requirement for an upper temperature limit to the Residential Tenancy Act (RTA).

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59

Suggestions for Premier Eby & BC Housing

- B.C. Housing could install a heat pump in every one of its 12,800 units for about $100 million.
  - Save lives: Roughly 50% of those who died during the 2021 heat dome were either in B.C. Housing, regulated seniors housing, or regulated rentals.
  - Cut emissions: Boiler replaced with heat pumps
  - Kick-start industry: RFPs would kick-start the multi-unit heat pump installation sector in B.C.
- Accelerate implementation of the Kigali Accord and the phase-out of high GWP refrigerants. In the mean time, stop paying "incentives" for heat pumps with high-GWP refrigerants.

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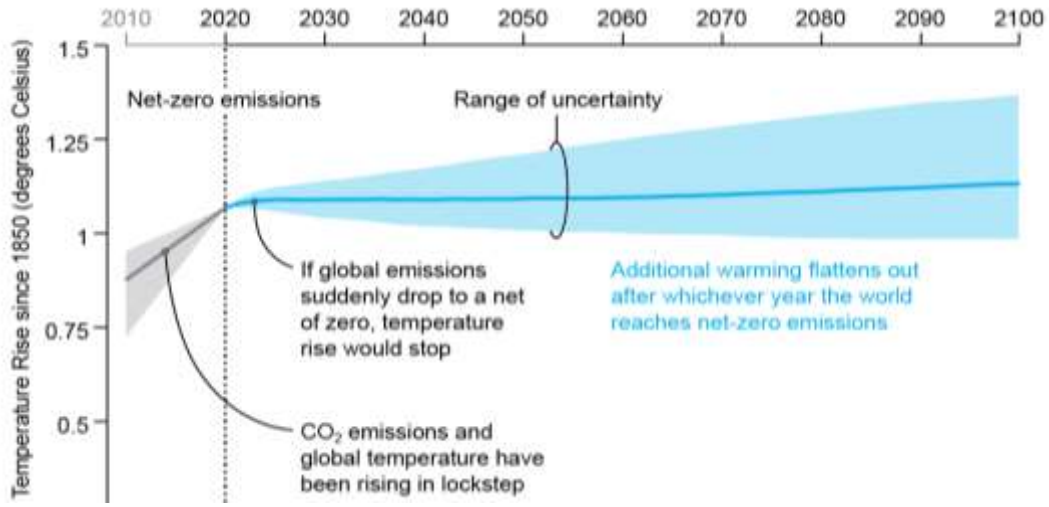
60

What will happen when we stop emitting CO_2?



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Source: "Global Warming of 1.5°C: An IPCC Special Report" edited by V. Masson-Delmotte et al, Intergovernmental Panel on Climate Change, 2018

61

BC BUILDING ENVELOPE COUNCIL
NOVEMBER 4, 2022

Discussion

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62