BUILDING SCIENCE LIVE

NOVEMBER 16, 2022

Net-Zero Energy and Carbon Building Design: Feasibility in Northern Canada and Alaska

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- Some FAQs:
  - You will get a follow-up email regarding how to access the recording and a pdf of slides.
  - **If you need a completion certificate for self-reporting or Phius CPHC, EPP, and/or AIA or AIBC credits**, please follow the link in the chat box to let us know.
- Please use chat for housekeeping questions.
- Please use Q&A box for questions for the speaker.
  - We will break at the end for questions.
  - Use upvote feature to let us know what you're most curious about!

More questions? Please contact us at events@learnbuildingscience.com.

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Robin Urquhart

Robin is a building scientist, certified energy advisor and carpenter and has been with RDH since 2013. He is also the Building Science Specialist on staff at Yukon University. Born and raised in Whitehorse, YT he has specialized in northern construction practices, material testing, building diagnostics and guide development. With a background in construction, Robin is focused on practical solutions that work in the North. Robin is completing work on his own house that will be British Columbia's northernmost Energy Step Code - Step 5 (net-zero ready) building.

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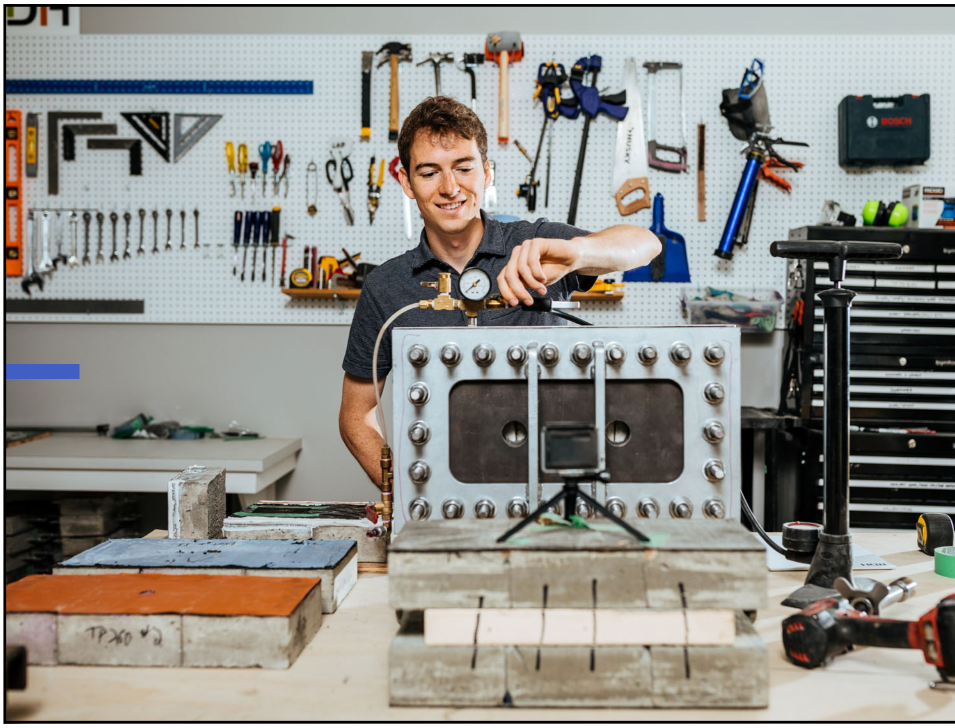

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Projects across North America

Focus on building science
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Education for Professionals

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Poll Question: Where do you primarily practice or operate?

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Agenda and Key Questions

1. Definition net-zero and 'the North'
2. Net-zero Energy design approach
3. Net-zero Energy case studies
4. Net-zero Carbon design approach
5. Net-zero Carbon case study
6. Key takeaways

→ **How feasible is net-zero in the North?**

→ **What does it look like?**

→ **Why are we doing this?**

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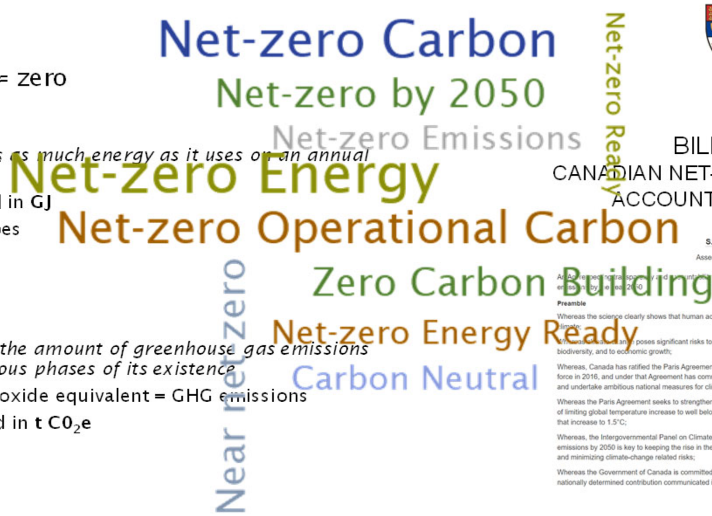
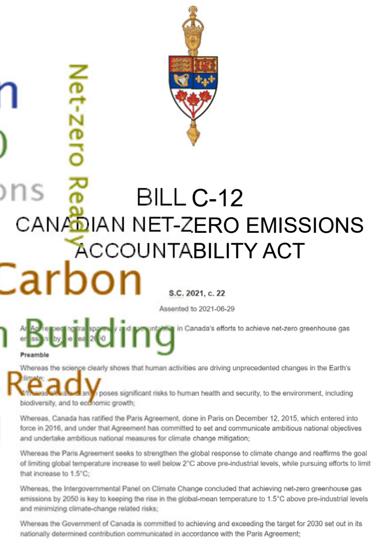
What does Net-zero mean?

- → Inputs – outputs = zero
- → Net-Zero Energy
  - → *a building produces as much energy as it uses on an annual basis*
  - → Energy is measured in **GJ**
  - → Includes all fuel types
- → Net-zero Carbon
  - → *A building negates the amount of greenhouse gas emissions resulting from various phases of its existence*
  - → Carbon = carbon dioxide equivalent = GHG emissions
  - → Carbon is measured in **t CO_2e**
  - → *Net-zero Emissions*
  - → *Carbon Neutral*





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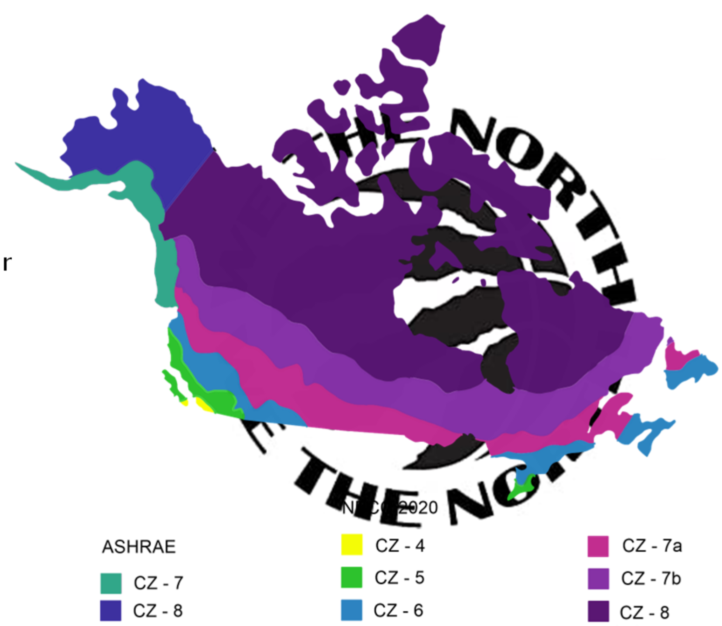
Where is the North?

- → Depends on the context
- → Canadian/American building science context = climate zones 7 and higher
- → Also defined by challenges
  - → Cold
  - → Dark
  - → Big
  - → Remote
  - → Decentralized
  - → Lacks resources



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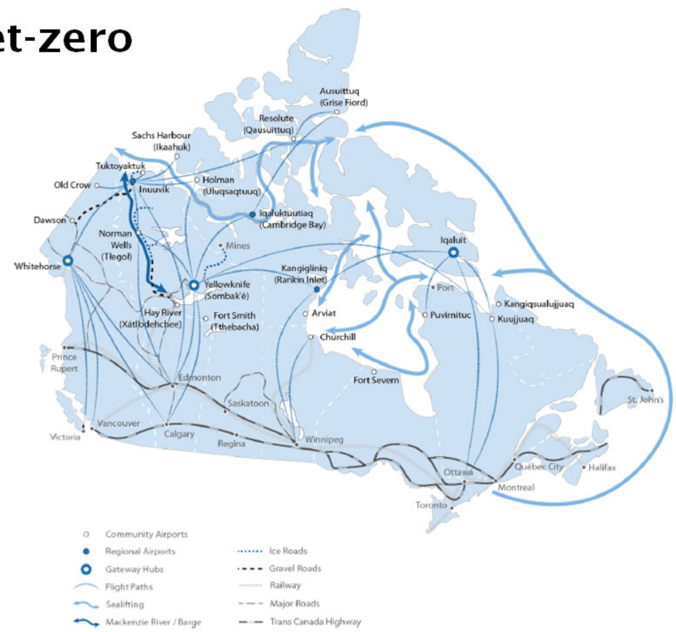
How do we approach net-zero design in the North

- Approach net-zero design the same for all regions
- Specific considerations have to be taken into account that inform design
  - Site
  - Transportation
  - Practical limitations
  - Building season
  - Energy production capacity
  - Building standards
  - Cost



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Approach for Net-zero Energy

Step 1	Building form/function
Step 2	Determine applicable codes/standards and performance metrics
Step 3	Model baseline
Step 4	Select enclosure and mechanical Energy Conservation Measures
Step 5	Iteratively apply and document ECM bundles to meet targets
Step 6	Design renewable energy system

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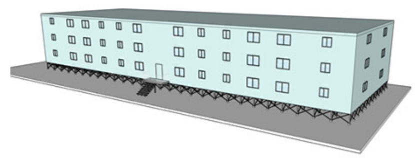
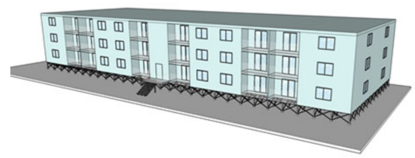
Net-zero Energy

Step 1: Design building form and function

- → Type
- → Functional program
- → Massing
  - → Articulations matter!
  - → Fenestration/door-to-wall ratio (FDWR) and orientation matter!
- → Material selection





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Net-zero Energy

Step 2: Determine applicable codes/standards and performance metrics

- → Code minimum
- → Choose the right performance metrics

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Net-zero Energy

Energy efficiency building direction

- Canada
  - National Building Code (NBC) 2020
  - BC Step Code 2018 (Steps 1-5)
  - National Energy Code for Buildings (NECB)
  - Passive House Institute (PHI)/PHIUS
  - Municipal bylaws/requirements
- Alaska
  - Patchwork of building codes by municipality/borough (International Building Code 2018)
  - Alaska Housing Building Energy Efficiency Standard (not-statewide, required for state financial assistance)
  - PHI/PHIUS

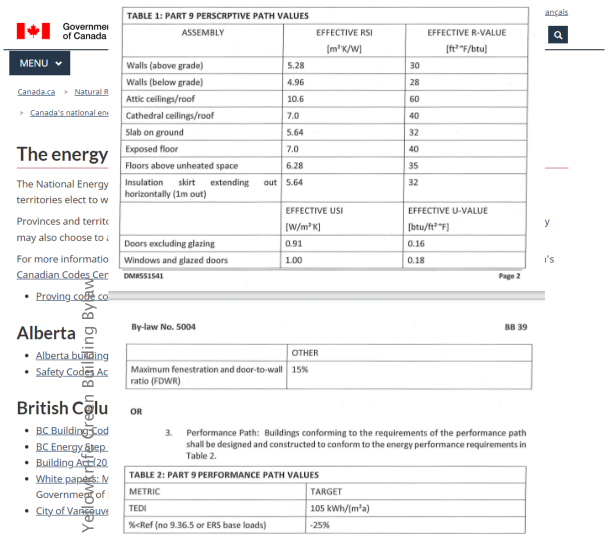

TABLE 1: PART 9 PERSCRPTIVE PATH VALUES

ASSEMBLY	EFFECTIVE RSI [m²K/W]	EFFECTIVE R-VALUE [ft²°F/btu]
Walls (above grade)	5.28	30
Walls (below grade)	4.96	28
Attic ceilings/roof	10.6	60
Cathedral ceilings/roof	7.0	40
Slab on ground	5.64	32
Exposed floor	7.0	40
Floors above unheated space	6.28	35
Insulation skirt extending out horizontally (1m out)	5.64	32
	EFFECTIVE USI [W/m²K]	EFFECTIVE U-VALUE [btu/ft²°F]
Doors excluding glazing	0.91	0.16
Windows and glazed doors	1.00	0.18

By-law No. 5004 BB 39

	OTHER
Maximum fenestration and door-to-wall ratio (FDWR)	15%

OR

3. Performance Path: Buildings conforming to the requirements of the performance path shall be designed and constructed to conform to the energy performance requirements in Table 2.

TABLE 2: PART 9 PERFORMANCE PATH VALUES

METRIC	TARGET
TEDI	105 kWh/(m²a)
%<Ref (no 9.36.5 or ERS base loads)	-25%

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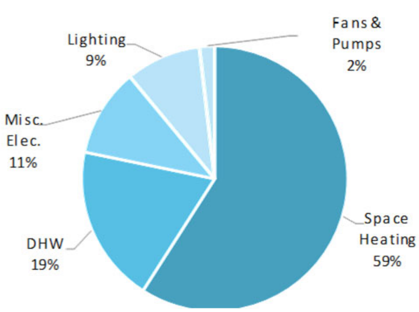
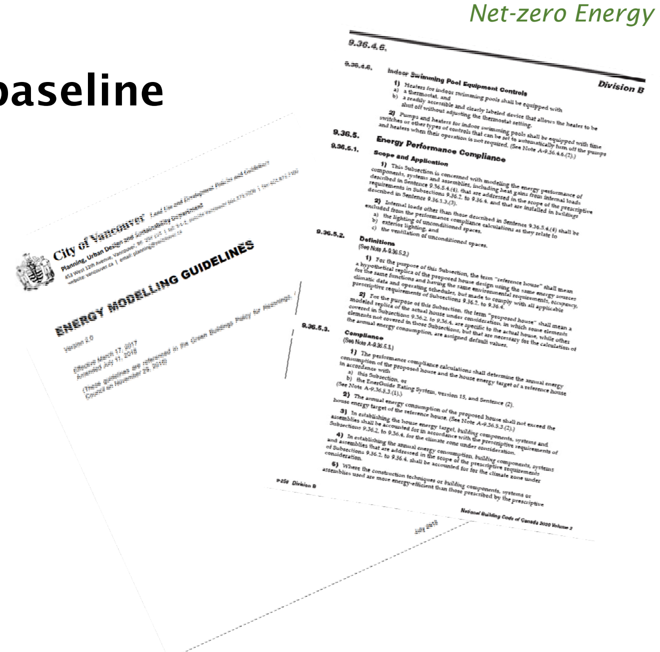
Net-zero Energy

Step 3: Model baseline





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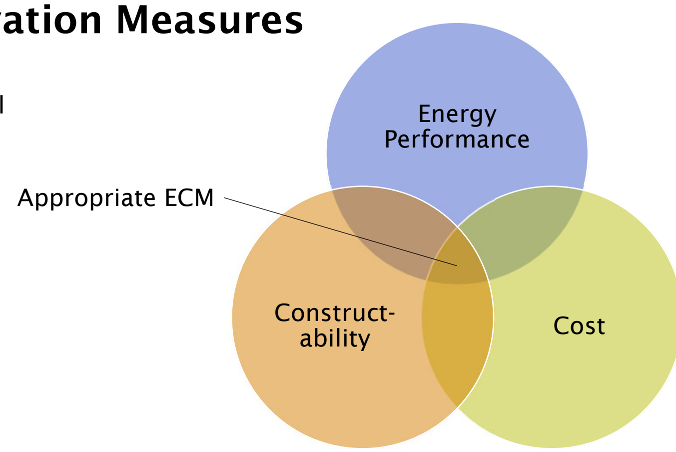
Net-zero Energy

Step 4: Select appropriate enclosure and mechanical Energy Conservation Measures

→ Refer to baseline model



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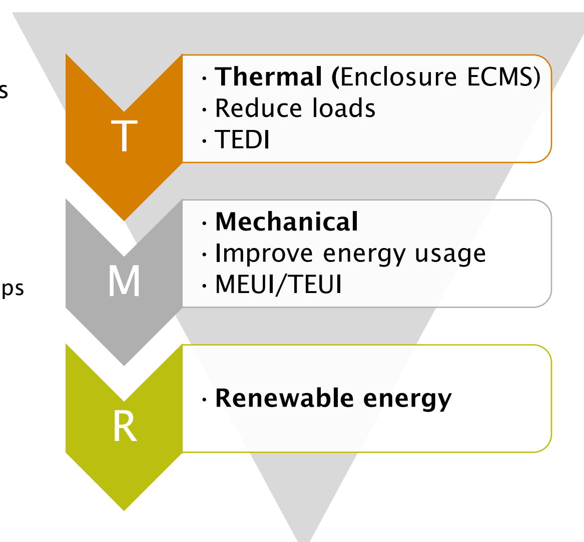
Net-zero Energy

ECM selection

- Building enclosure ECMs as levers to reduce loads
  - R-values within wall, roof, floor assemblies
  - Airtightness
  - Window U-values (double, triple, quad pane)
  - FDWR and orientation
- Mechanical system ECMs to improve energy use
  - Heating systems – fuel, electric resistance, heat pumps
  - Domestic hot water – fuel, electric, heat pump
  - Heat Recovery



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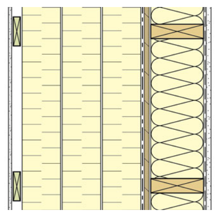
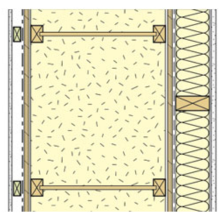
Net-zero Energy

Practical limits



Constructability limits & depreciating returns to insulation thickness



Technology limits to triple/quad glazing, HRV efficiency and pre-heat

Technology limits to cold climate performance of heat pumps

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Net-zero Energy

Practical limits continued…

Component	Upper Limit of Performance & Why
Roof R-value	R-100 (36” of fibrous insulation)
Wall R-value	R-80 (2x6+16” ext. insulation w/ long screws or 24” double wall)
Slab on Grade R-value	R-40 (8-10” of foam)
Suspended Floor R-value	R-80 (24” deep truss)
Window U-value	U-0.12 (best available quad pane unit)
Door R-value	R-8 (best available insulated units)
Airtightness	Large commercial 0.15 to 0.30 ACH_{50} Small SFD 0.30 to 0.60 ACH_{50}
Space Heating	Up to 1.5-2.1 COP CCASHP
HRV Efficiency	Up to 81% (best avail cold-climate w/o pre-heat)
DHW	Up to CO2 Heat Pump, 2.5-3.0 COP
Drain Water HR	65%

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Net-zero Energy

Step 5: Iteratively apply and document ECM bundles to meet performance target minimums

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Net-zero Energy

Step 6: Design renewable energy generation system

- → Buildings in the North always use more energy in the winter than they can produce
- → Seasonal demand/supply are inverse
  - → Cold temps
  - → Higher occupancy loads (plugs, lighting, DHW, etc.)
  - → Less sun
- → ***Need to think bigger than the building***

Annual Solar Generation Potential - Whitehorse
Winter
Nov
Dec
Jan
= 4%
Summer
May
June
July
= 41%

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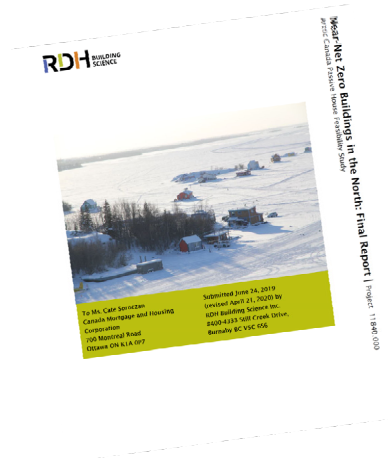
What does Net-zero Energy look like?

- RDH feasibility study
- Examined three archetypes for four locations

- **Can buildings meet net-zero energy requirements in the North?**
- **What are the practical limitations?**
- **What considerations must be taken into account?**


RDH BUILDING SCIENCE
Near-Net Zero Buildings in the North: Final Report | Project 11840.000
Arctic Canada Passive House Feasibility Study
To Ms. Cate Soroczan
Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa ON K1A 0P7
Submitted June 24, 2019 (revised April 21, 2020) by
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Natural Resources Canada / Ressources naturelles Canada
Canada
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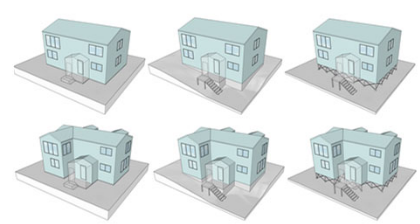
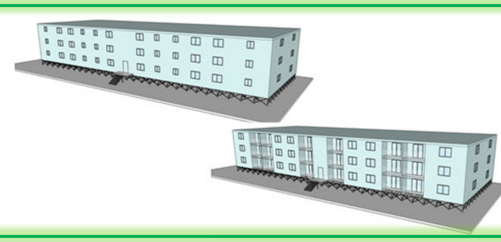
Representative archetypes

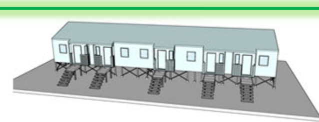
- **Single Family Dwelling (SFD)**
  - Simple & Articulated Form Factors
  - Slab on grade, footing on bedrock and elevated permafrost foundation options by location



- **Multi-Unit Residential Building (MURB)**
  - Simple & Articulated Form Factors



- **5-Plex Row House**



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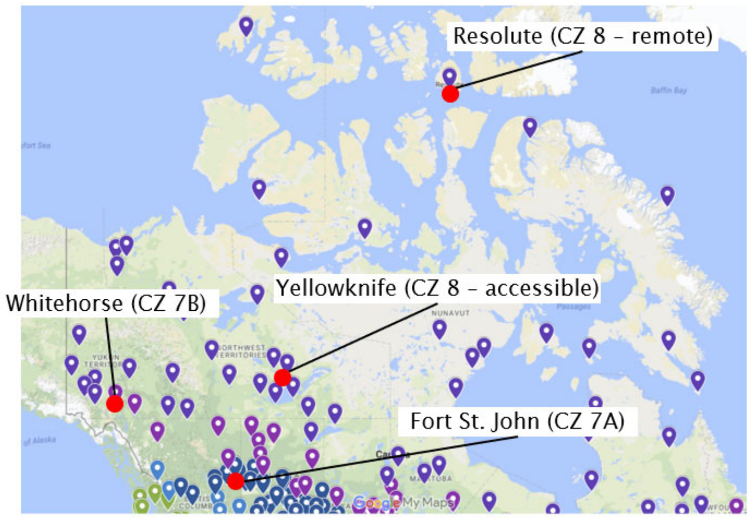
Locations for Energy and Cost Analysis

- Fort St. John
  - CZ - 7a
  - 5750 HDD
- Whitehorse
  - CZ - 7b
  - 6580 HDD
- Yellowknife
  - CZ – 8
  - 8170 HDD
- Resolute
  - CZ – 8
  - 12 360 HDD



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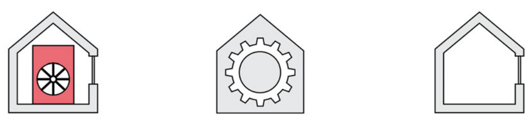
Performance Metrics – BC Step Code as Goals for Net Zero Ready



	Airtightness	Equipment & Systems	Thermal Performance
Step Code for SFD: Step 5	≤1.0 ACH_{50}	MEUI ≤ 55-75 kWh/m²	TEDI ≤ 15-60 kWh/m²
Step Code for MURB: Step 4	N.R.	TEUI ≤ 100 kWh/m²	TEDI ≤ 15 kWh/m²

MEUI = Mechanical Energy Use Intensity
TEDI = Thermal Energy Demand Intensity
TEUI = Total Energy Use Intensity

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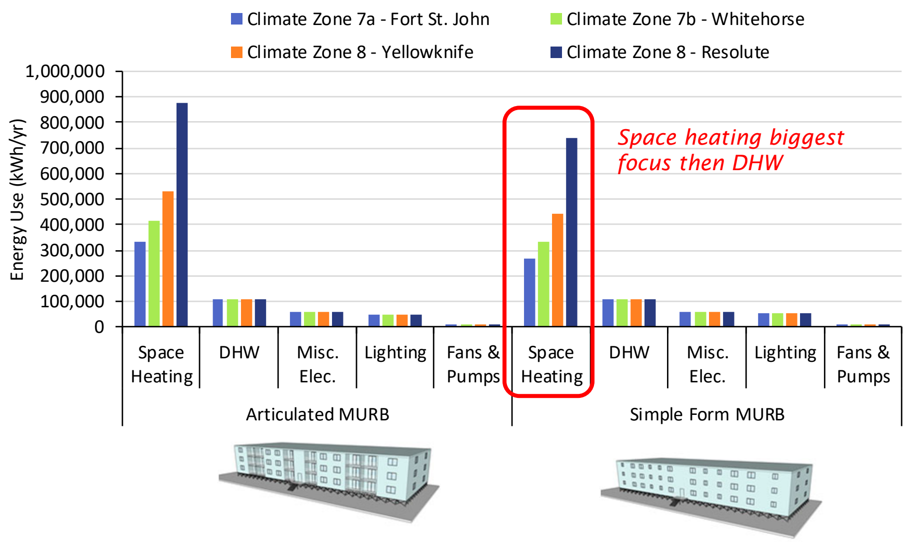
MURB Energy Modeling Baseline Results



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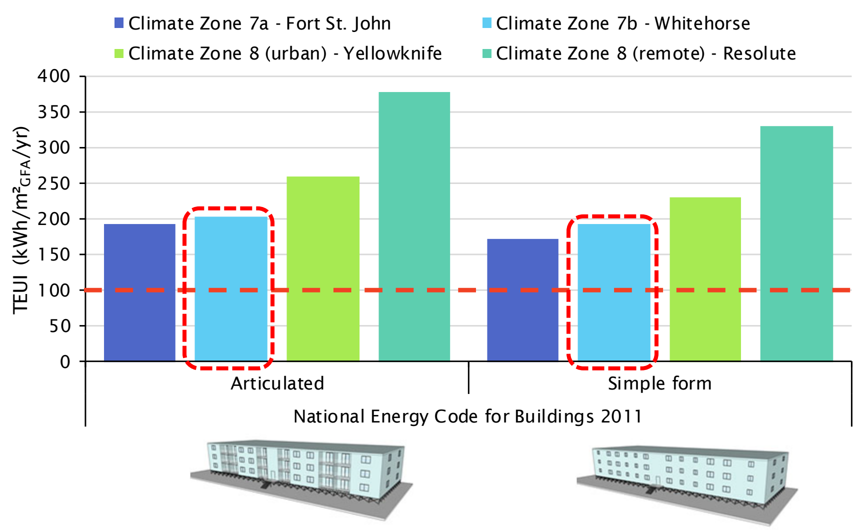
MURB Energy Modeling Results - TEUI



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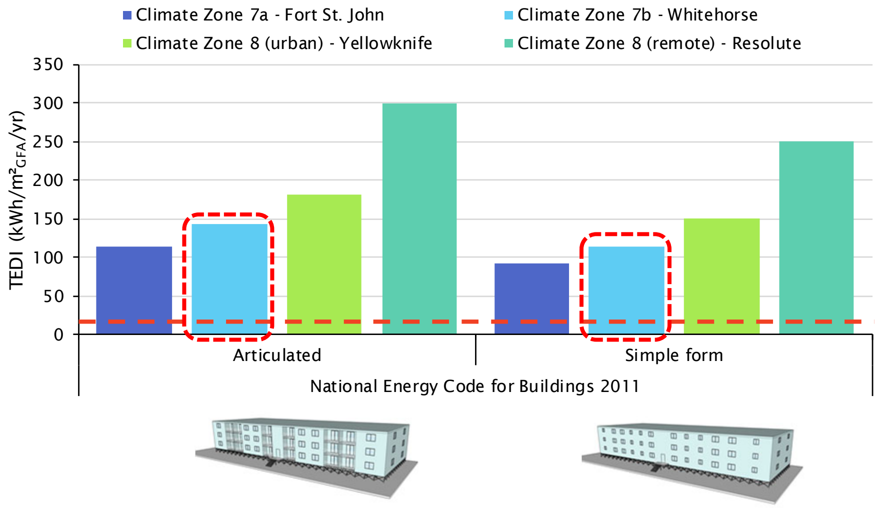
MURB Energy Modeling Results - TEDI



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Upper Step of Energy Step Code – Near Net Zero

- MURB Baseline, NECB 2011
- Air Tightness: from 2.2 ACH50 to 0.15 ACH50
- Insulation:
  - Roof from R-40 to R-76 (articulated) or R-48 (simple form)
  - Walls from R-31 to R-61 (articulated) or R-40 (simple form)
  - Exposed floors from R-40 to R-70 (articulated) or R-41 (simple form)
  - Windows from double glazed (U-0.39) to quadruple glazed (U-0.12)
- Ventilation strategy changed from in-suite HRVs and MAU supplying corridors to centralized/zoned ventilation system with 81% heat recovery (by dual core units with no preheat required) for suites and corridors.
  - Reduced make-up air flow rate to corridor from 20 cfm/door to 10 cfm/door (articulated)

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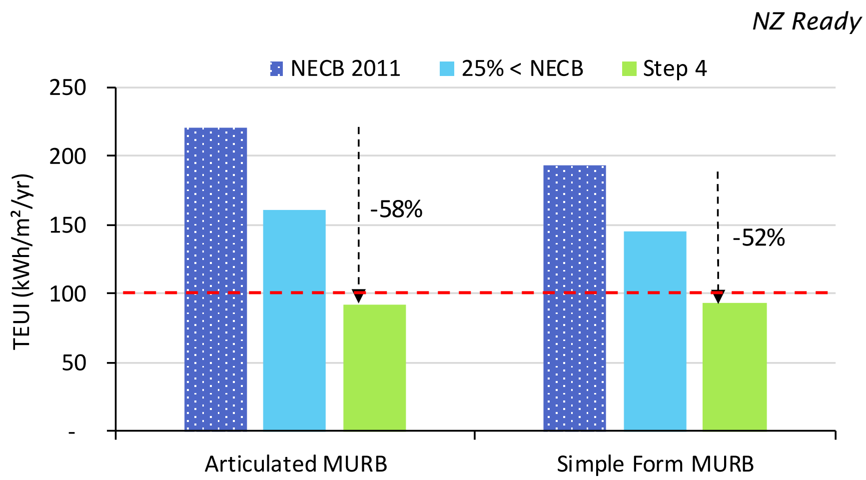
Total Energy Use Intensity (TEUI)



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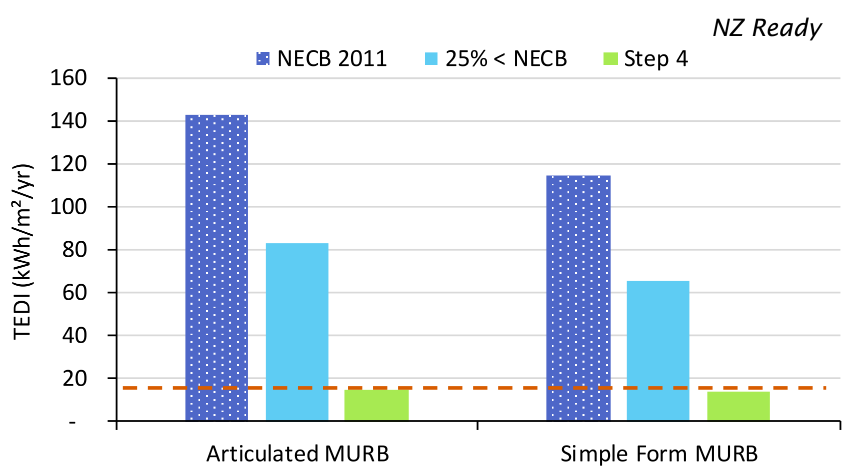
Thermal Energy Demand Intensity (TEDI)



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Climate Zones 7a, 7b results

		BC STEP CODE (2018)	
		Step 4	Step 5
Fort St. John CZ 7a	SFD – articulated	YES	YES
	SFD – simple	YES	YES
	MURB – articulated	YES	n/a
	MURB – simple	YES	n/a
	5-Plex	YES	YES
Whtehorse CZ 7b	SFD – articulated	YES	YES
	SFD – simple	YES	YES
	MURB – articulated	YES	n/a
	MURB – simple	YES	n/a
	5-Plex	YES	YES

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Climate Zone 8 results

		BC STEP CODE (2018 rev)	
		Step 4	Step 5
Yellowknife CZ 8	SFD – articulated	YES	YES
	SFD – simple	YES	YES
	MURB – articulated	YES	n/a
	MURB – simple	YES	n/a
	5-Plex	YES	YES
Resolute CZ 8	SFD – articulated	YES	YES
	SFD – simple	YES	YES
	MURB – articulated	YES	n/a
	MURB – simple	YES	n/a
	5-Plex	YES	YES

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Net-zero Energy design takeaways

- → Metrics and Practical Limitations
- → Articulation
- → FDWR and orientation
- → Diminishing insulation returns
- → Air tightness
- → Electrical generation

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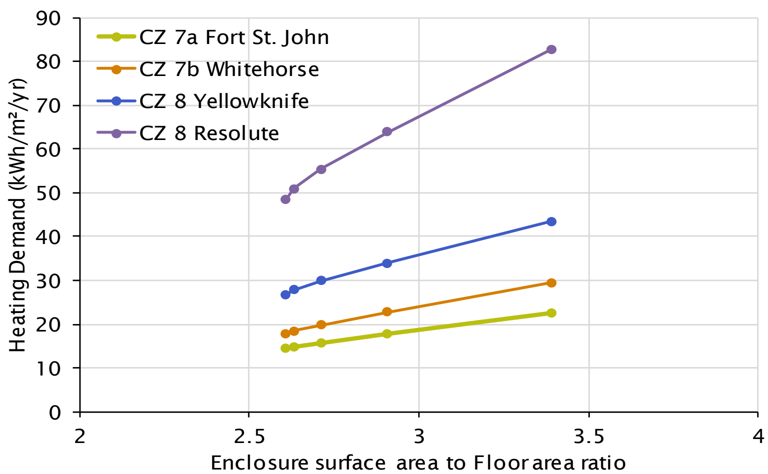
Impact of Articulation on Heating Demand



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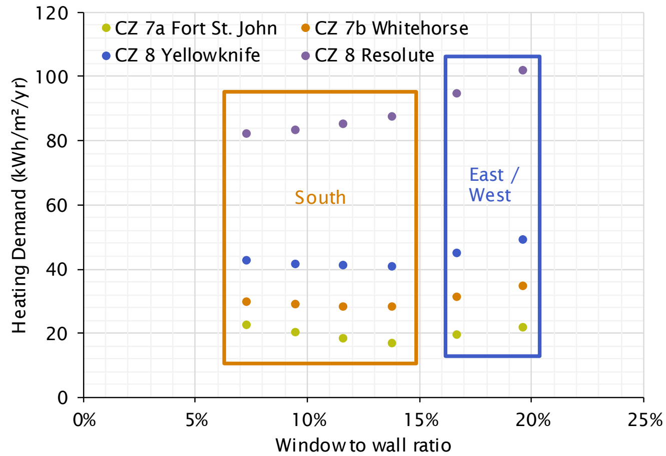
Window to Wall Ratio is Critical



Heating Demand versus window to wall ratio for the simple form SFD in Yellowknife. Each dot represents an addition of a 1.5m x 1.9m window to the façade as indicated on the graph.

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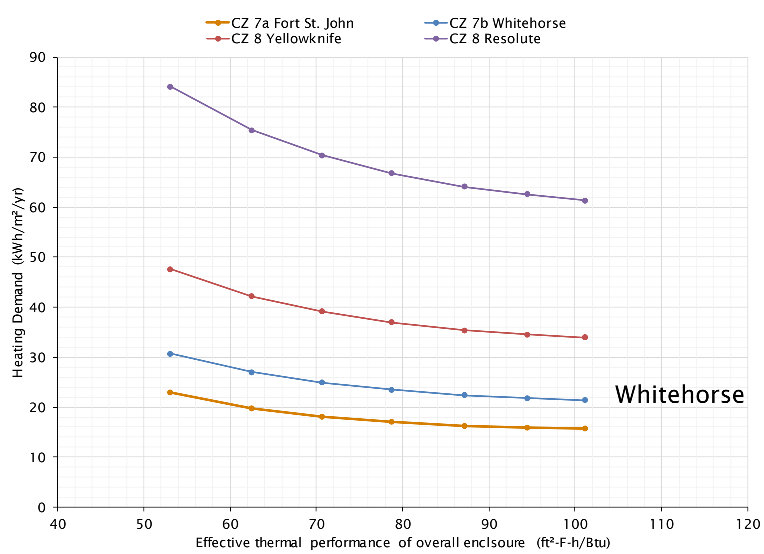
Depreciating Returns



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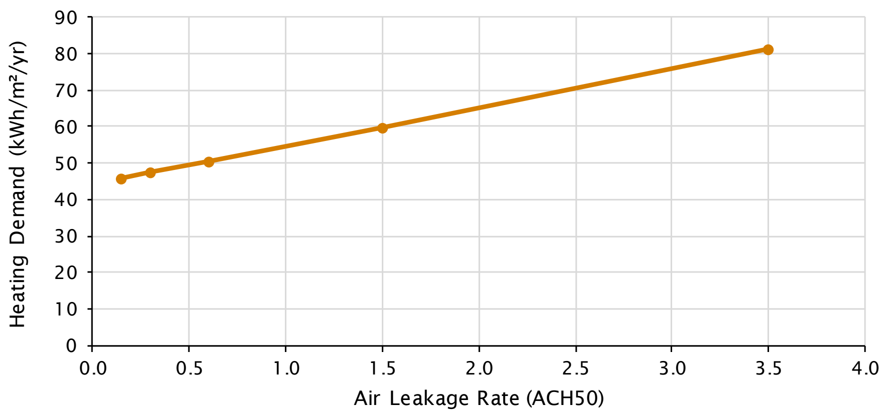
The Continued Importance of Airtightness



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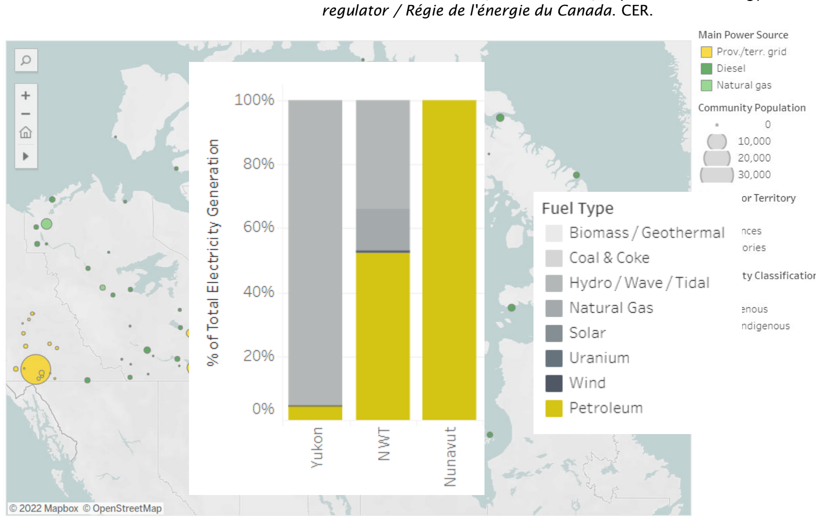
Stand alone electrical grid

Government of Canada, C. E. R. (2022, July 8). *Canada energy regulator / Régie de l'énergie du Canada*. CER.

- → Much of the North is not grid connected to the rest of Canada
- → Same for Alaska with the lower 48
- → Inverse power/consumption relationship for solar
- → Power Corps have generation caps



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Step 5 SFD in CZ 7b – Case Study

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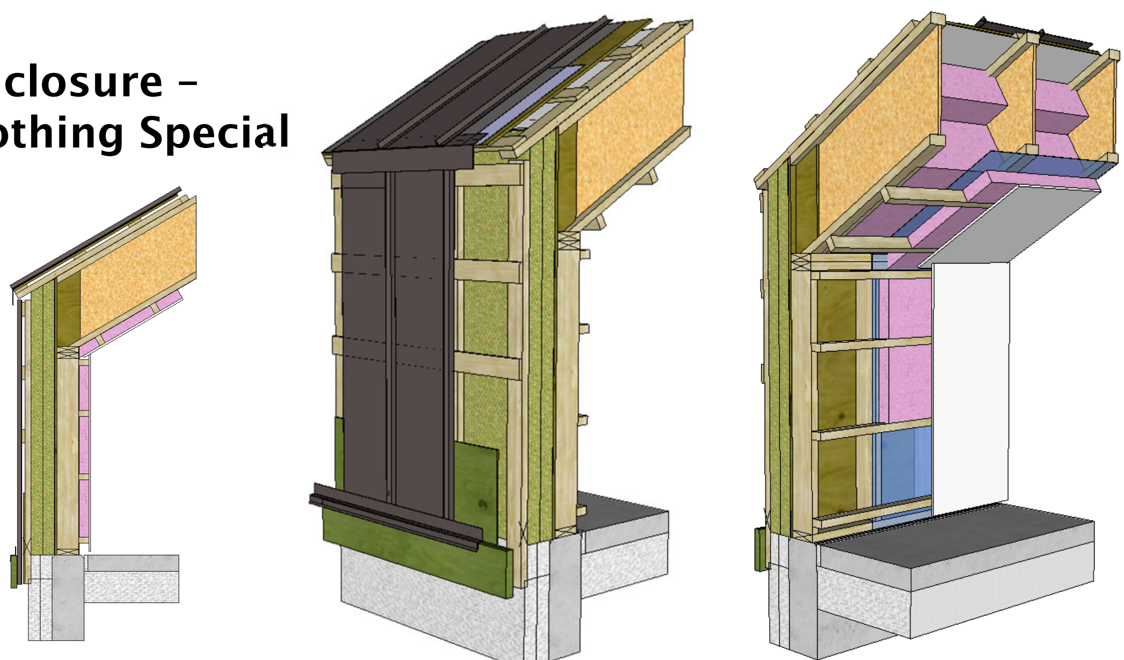
Enclosure – Nothing Special



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Images not to scale

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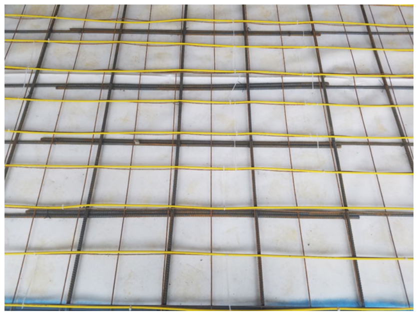
Mechanical – Nothing Special

- Electric radiant heat
- ERV
- Wood stove
- Conventional electric water heater



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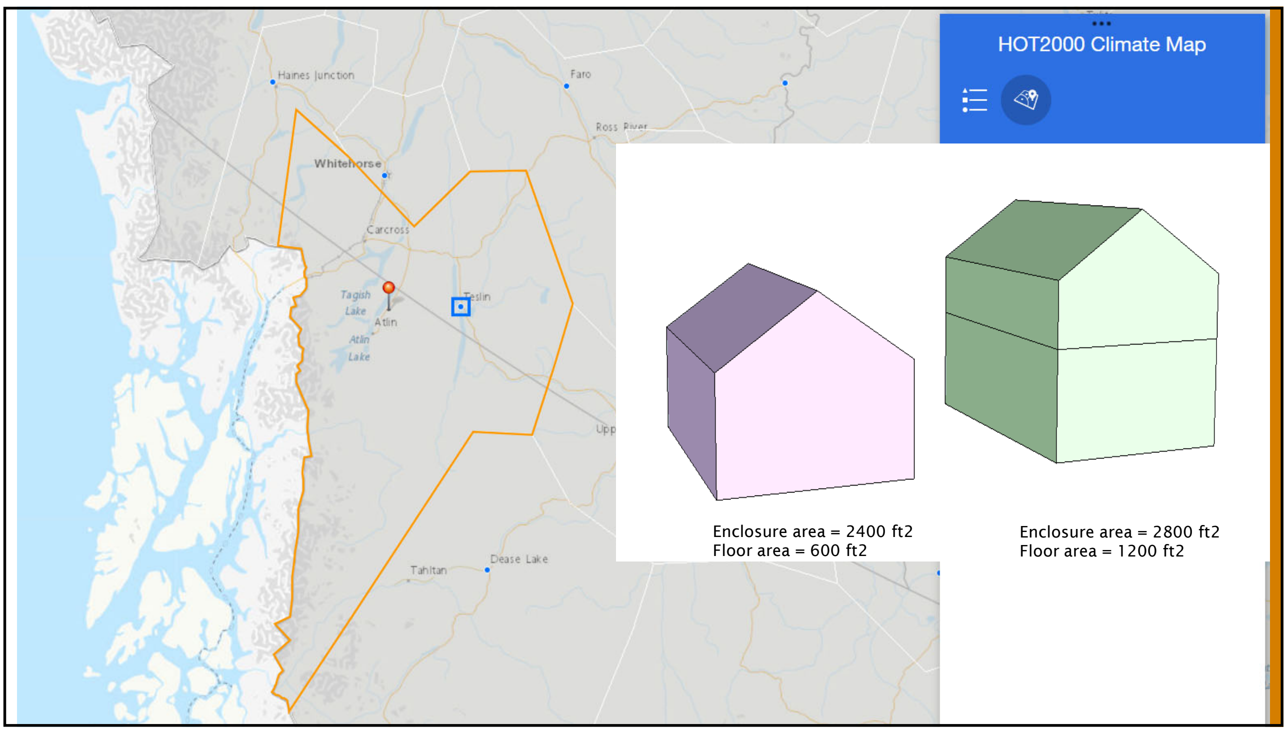

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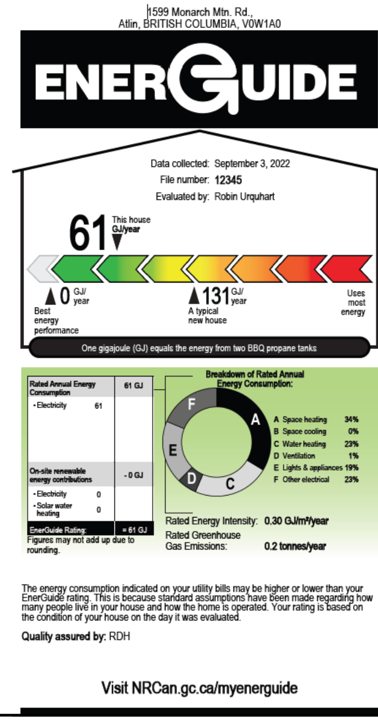
Performance

National Building Code 2020	Proposed House	Reference House
Within Scope	Yes	
Annual Energy Consumption (GJ)	35.38	105.07
Gross Space Heat Loss (GJ)	56.53	131.63
Peak Cooling Load (W)	2236	2611
Airtightness (ACH @ 50 Pa)	0.78	2.5

Overall Energy Performance Improvement (%)	66
Envelope Performance Improvement (%)	57
Peak Cooling Validation	Pass
Energy Performance Tier	1

Other Compliance Metrics		
Thermal Energy Demand Intensity (kWh/(m².year))	28	≤ 50
Mechanical Energy Use Intensity (kWh/(m².year))	48	≤ 65
Greenhouse Gas Emissions Intensity (kg of CO_2/(m².year	1	



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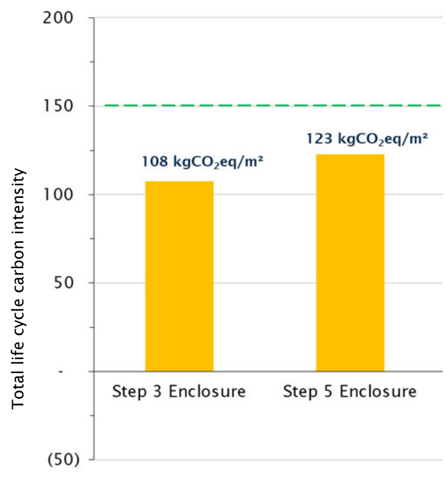
Why are we trying to save energy

- → Save money
- → **Reduce environmental impact**
- → **Reduce/eliminate greenhouse gas emissions (GHGs)**
- → **Energy as proxy for GHGs**

The most energy efficient building is often not the most carbon efficient building



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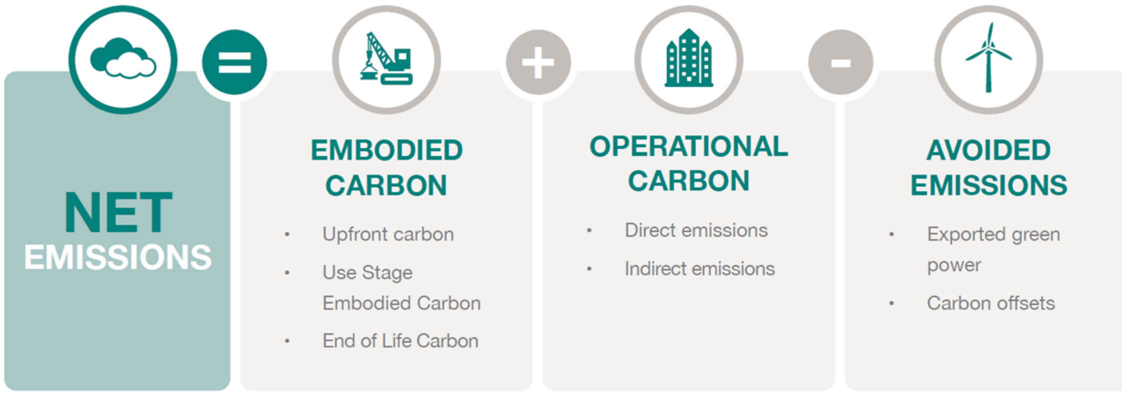
Goal for Low Net Carbon Emissions Buildings



Source: Canadian Green Building Council (CaGBC) Zero Carbon Building Standard V2

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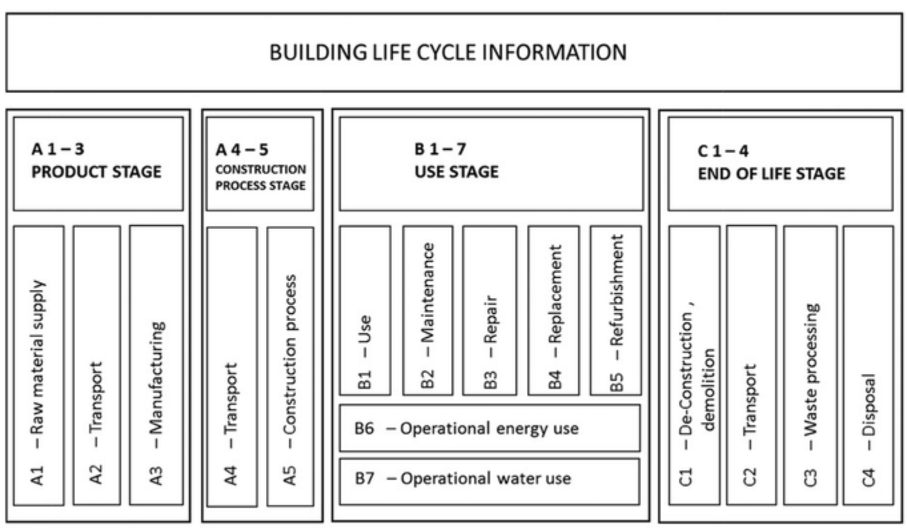
Building Life Cycle



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Approach for Net-zero Carbon

Step 1	Building form/function
Step 2	Determine applicable codes/standards and performance metrics
Step 3a	Model energy baseline
Step 3b	Model carbon baseline (Life Cycle Assessment)
Step 4	Select ECMs and Emission Reduction Measures (ERMs)
Step 5	Iteratively apply and document ECM/ERM bundles to meet targets
Step 6	Design renewable energy system/purchase carbon offsets

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Step 2: Determine applicable codes/standards and performance metrics

- → Code minimum
- → Choose the right performance metrics
- → *CaGBC Zero Carbon Building Standard*

		ZCB-Design v2 One-time certification for new buildings and major renovations
Carbon	Zero carbon balance	Model zero carbon balance
	Embodied carbon	Report embodied carbon
	Refrigerants	Report total quantity
	RECs and carbon offsets	Provide quote
	Onsite combustion	Provide transition plan
Energy	Energy efficiency	Meet one of three approaches
	Peak demand	Report seasonal peaks
	Airtightness	Report and justify modelled value
Impact and Innovation		Apply two strategies

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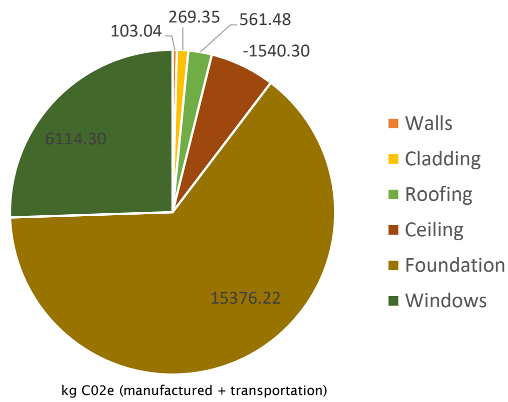
Step 3: Model baseline

- Model energy baseline
  - Output energy intensity and greenhouse gas emissions
  - Depends on emissions factors (how dirty/clean energy source is)
- Model carbon baseline
  - Conduct life cycle assessment (LCA)
  - Athena, MCE2, BEAM



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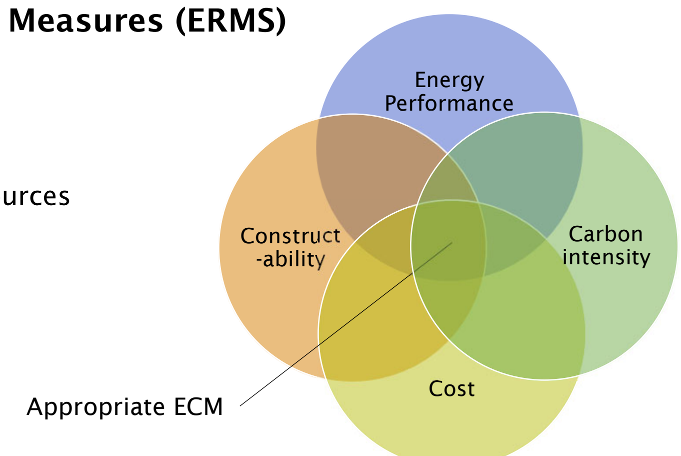
Step 4: Select appropriate Energy Conservation Measures (ECMs) and Emission Reduction Measures (ERMS)

- Refer to baseline models
- Select low carbon materials
- Select low carbon energy sources



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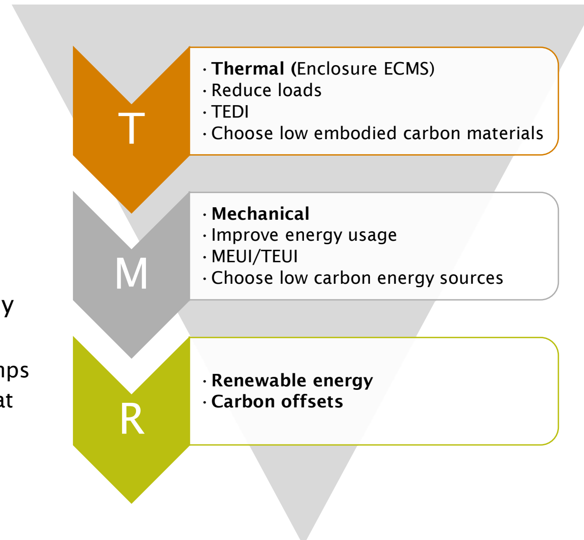
ECM selection

- Building enclosure ECMs/ ERMs as levers to reduce loads
  - R-values within wall, roof, floor assemblies
  - Airtightness
  - Window U-values (double, triple, quad pane)
  - FDWR and orientation
  - Low carbon intensity materials
- Mechanical system ECMs/ERMs to improve energy use
  - Heating systems – fuel, electric resistance, heat pumps
  - Domestic hot water – fuel, electric, heat pump & heat recovery
  - Heat Recovery Ventilation
  - Low emission factor energy sources



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Step 5: Iteratively apply and document ECM/ERM bundles to meet performance target minimums

- Refer to baseline to see where energy/carbon intensity is high

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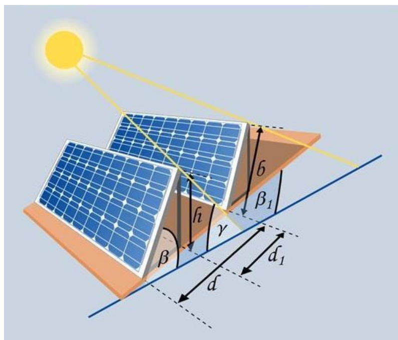
Step 6: Design renewable energy generation system and/or purchase carbon offsets



Gold Standard

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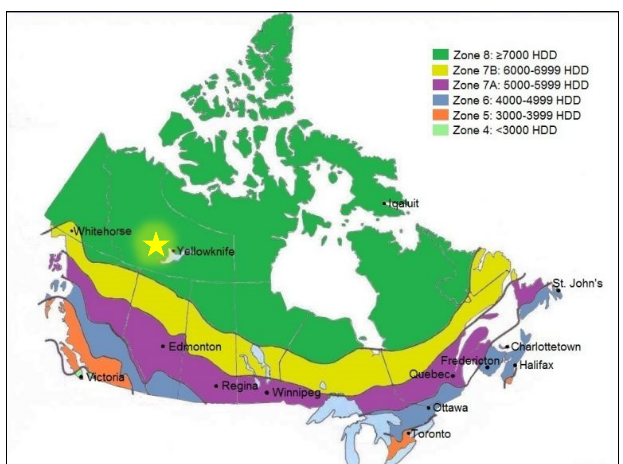
Net-zero Carbon Case Study

- 2 new construction
- 2 existing construction
- Remote location in Northwest Territories
- No road access
- Isolated grid
- Climate zone 8: ≥ 7000 HDD
  - HDD 8300



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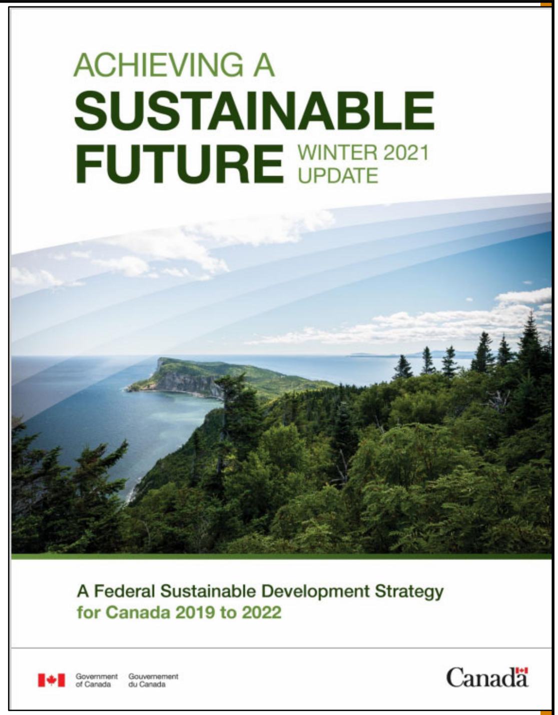
Performance metrics

- Federal Government has net-zero carbon mandate
  - **FSDS** – Federal Sustainable Development Strategy
  - **DSDS** – Departmental Sustainable Development Strategy
- Owner's Statement of Requirements
  - Net-zero emissions
  - Energy metrics
    - BC Energy Step Code 5 – new buildings
    - BC Energy Step Code 3 – existing buildings



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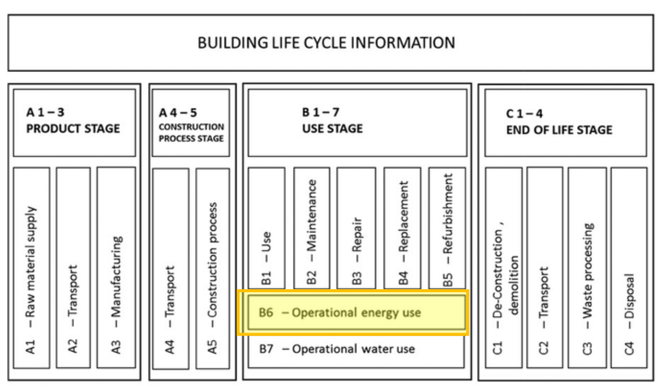
Energy vs Carbon

- BC Energy Step Code targets impossible to meet
- Client confirmed only GHG emissions during building operation (NZOC)
  - tonnes of equivalent carbon dioxide (tC02e)
  - Does not take embodied carbon of materials into account
- Minimize carbon offset purchase



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Energy vs Carbon

- NZOC means maximizing energy efficiency and minimizing operational emissions
  - Maximize insulation (don't need to target low carbon materials)
  - Maximize air tightness
  - Select low carbon energy sources (heat)
  - Maximize renewable energy production

Step 1	Building form/function
Step 2	Determine applicable codes/standards and performance metrics
Step 3a	Model baseline
Step 3b	Conduct Life Cycle Assessment
Step 4	Select enclosure and mechanical Energy Conversation Measures
Step 5	Iteratively apply and document ECM bundles to meet targets
Step 6	Design renewable energy system/purchase carbon offsets

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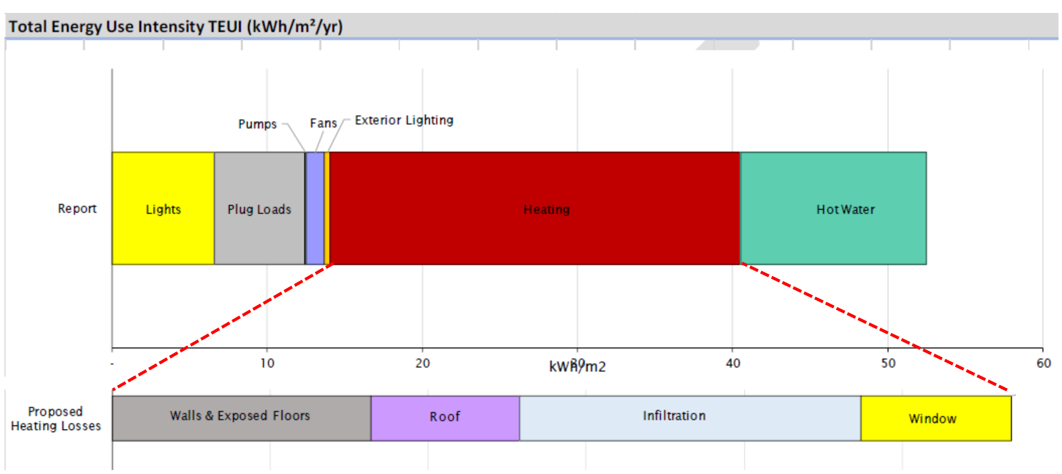
Building 1 - performance



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Energy source emissions factors for NWT

FUEL SOURCE	GHG/Unit	ENERGY DENSITY	GHG kgC02e/GJ
Electricity	200 g/kWh	2.78E-04 (kWh/GJ)/(g/t)	**55.6**
Wood pellets	131 g/kg	18 MJ/kg	**7.3**
Wood chips	18 g/kg	10 MJ/kg	**1.8**
Light Fuel oil	2762 g/L	35.7 MJ/L	**77.4**

	Electricity	Combustion
Consumption (GJ/a)	61.9	169.0
GHGs (kgC02e/a)	**3400**	**1200**

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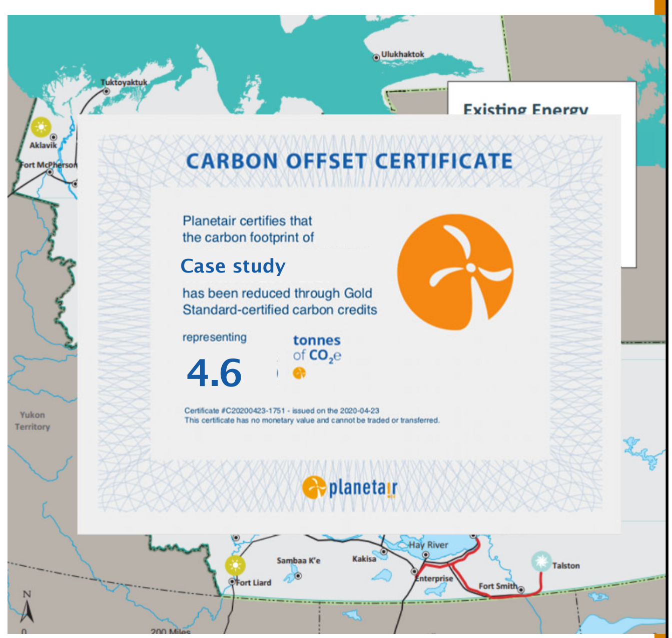
Offsetting carbon

- Net metering and carbon equivalent offsets
  - Not possible in many communities in NT
    - Closed grid
    - NTPC limits uninterrupted power generation
- Carbon offset purchasing
  - Supports offset projects in other regions
    - Solar farm in India to replace coal-fired generators
    - Reforestation in Brazil
    - Wind farm in Dawson Creek
- **2023 market price = $21.00/tC02e**
- **~ $98/a for 4.6 tC02e**



Opsit. Government of Canada. Slide 41

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Life Cycle Cost Analysis

- Carbon offsetting may be more economical than choosing more energy efficient materials/technology

Life Cycle Cost =

Capital investment + operating cost + maintenance cost + disposal cost - residual value

- Used to compare materials, technologies, etc.
- Can be used to compare ECM bundles including carbon as a shadow cost ($/tC02e)
  - Treasure Board of Canada sets out a carbon price of $300/tC02e

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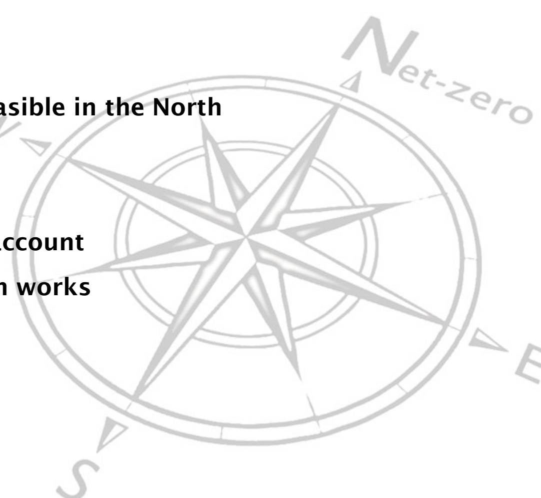
Key takeaways

1. **Net-zero Energy and Net-zero Carbon are feasible in the North**
2. **Define Net-zero at the outset of a project**
3. **Use metrics judiciously**
4. **Take northern-specific considerations into account**
5. **Don't get lost in the noise – simple approach works**
6. **Need to think bigger than the building**
7. **The aim is not always the goal**



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