

As Canada strives to reduce emissions from the built environment through energy efficiency improvements, there are many uncertainties with the feasibility of reaching near-net zero performance in the challenging climate of Canada's North due to factors such as availability of resources and high heating demand. This presentation outlines the results of research to understand solutions for achieving goals such as Net Zero Ready construction, Passive House and the upper steps of the BC Energy Step Code for residential buildings in Canada's north. This research is also highly impactful for in setting energy efficiency targets within Yukon and across Canada. Specifically, the presentation will outline:

- Challenges with, and key solutions for, using different energy modelling tools for code compliance in the north, with a focus on aligning assumptions for northern regions.
- Practical building enclosure and mechanical design solutions to overcome the challenges of implementing near-net zero energy targets in Canada's Far North.
- Where the near-net zero energy targets cannot be feasibly met with current practices or cost-effective means, potential new technologies and adaptations to energy performance targets will be discussed to assist policy makers.

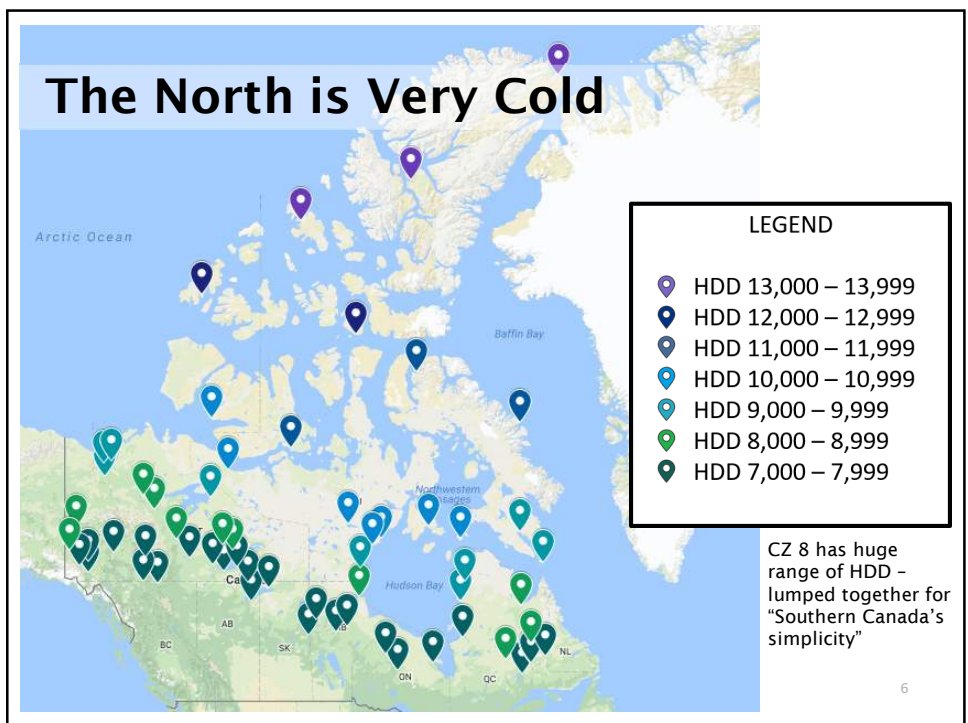
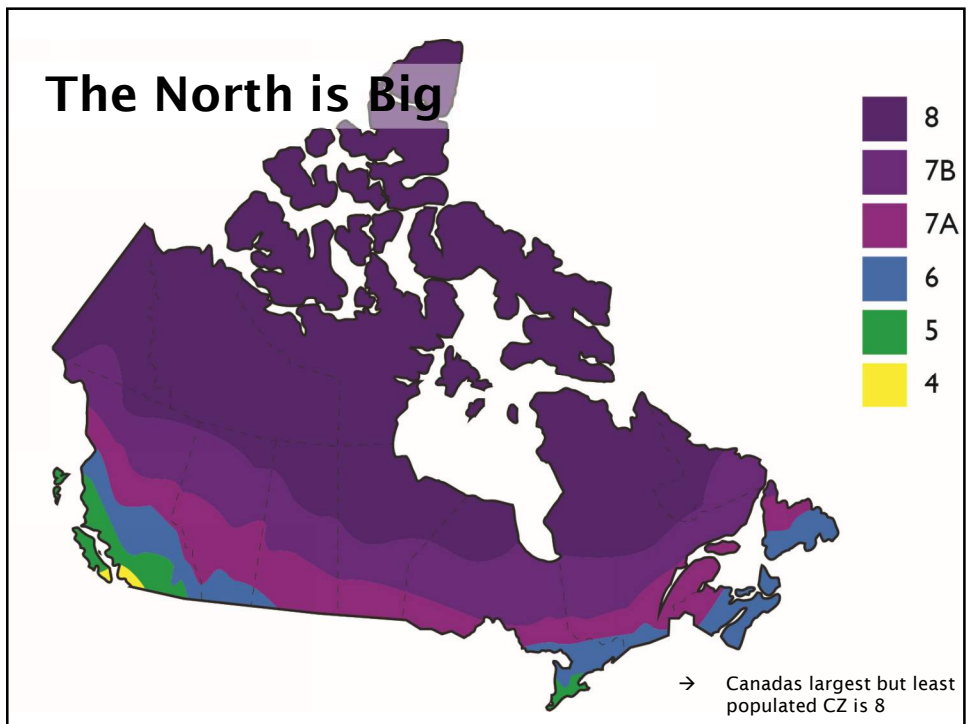
Outline

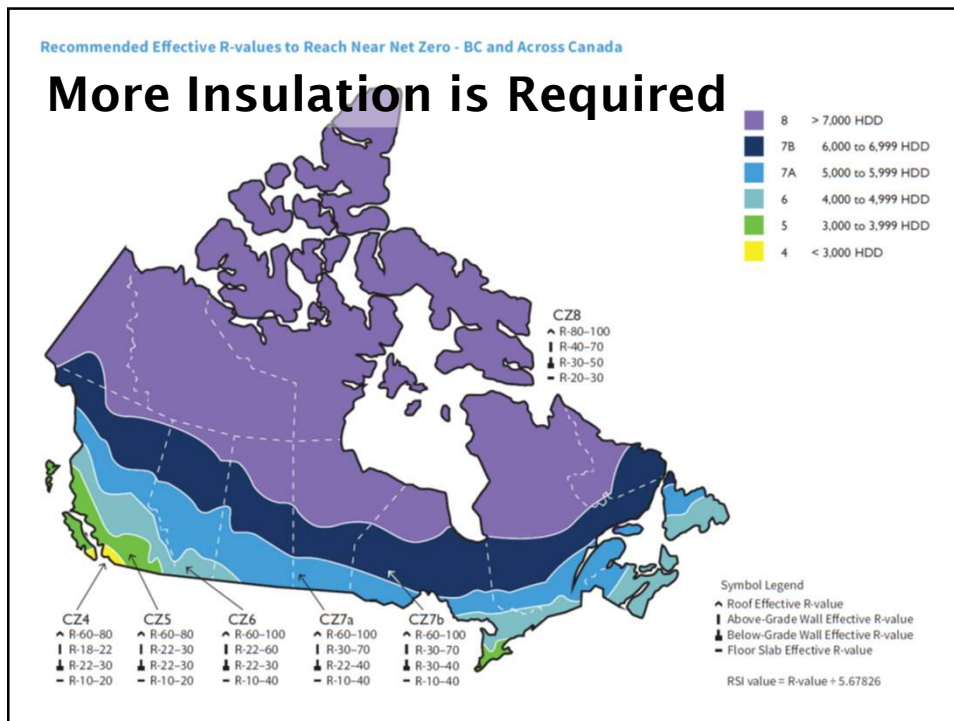
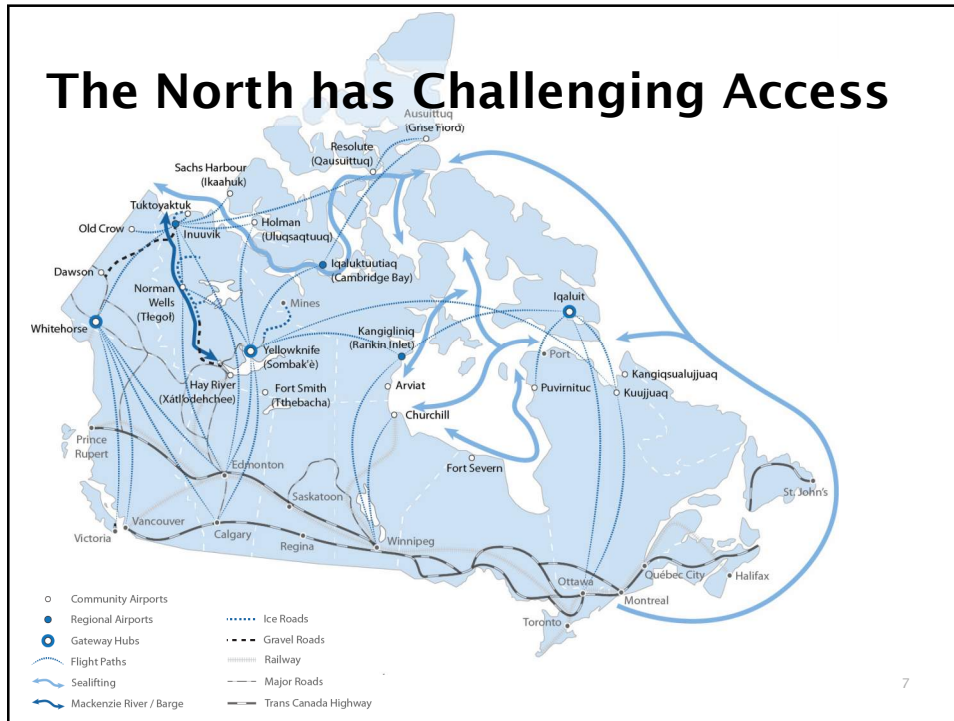
- Background for the Research
- Energy Modeling Tools
- Achieving High Performance
- Incremental Cost Estimates
- Northern Barriers and Solutions
- Further Work



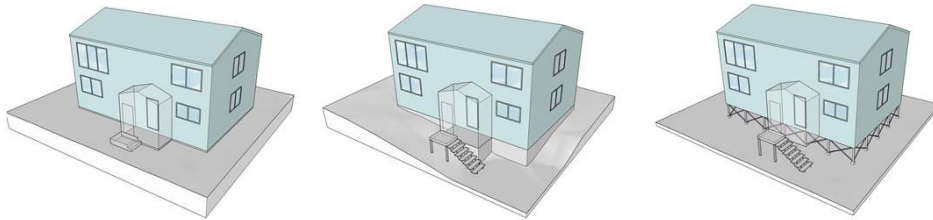
Overarching Research Question

- What is the feasibility of achieving Passive House and near-net zero levels of energy performance (e.g. Steps 4 & 5 of the BC Energy Step Code) for residential buildings within Canada's challenging northern climate including all communities and regions within the Yukon, Northwest Territories and Nunavut (climate zones 7A to 8).





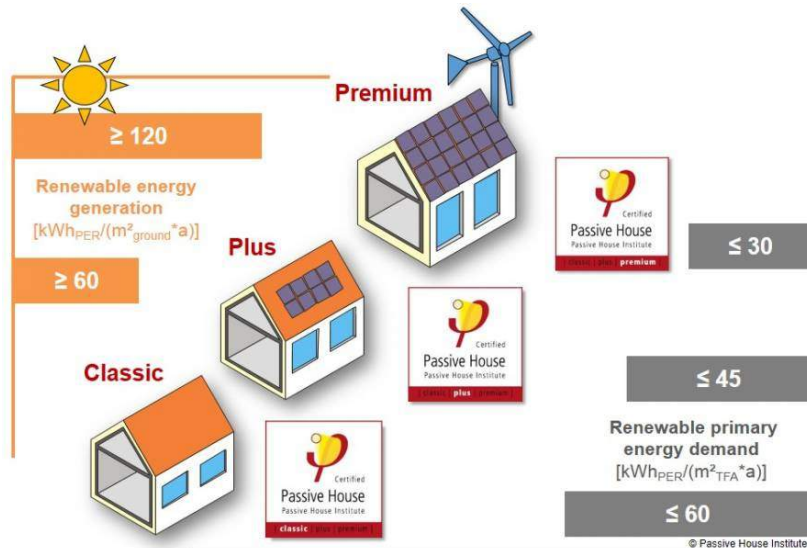
Challenged by the Terrain



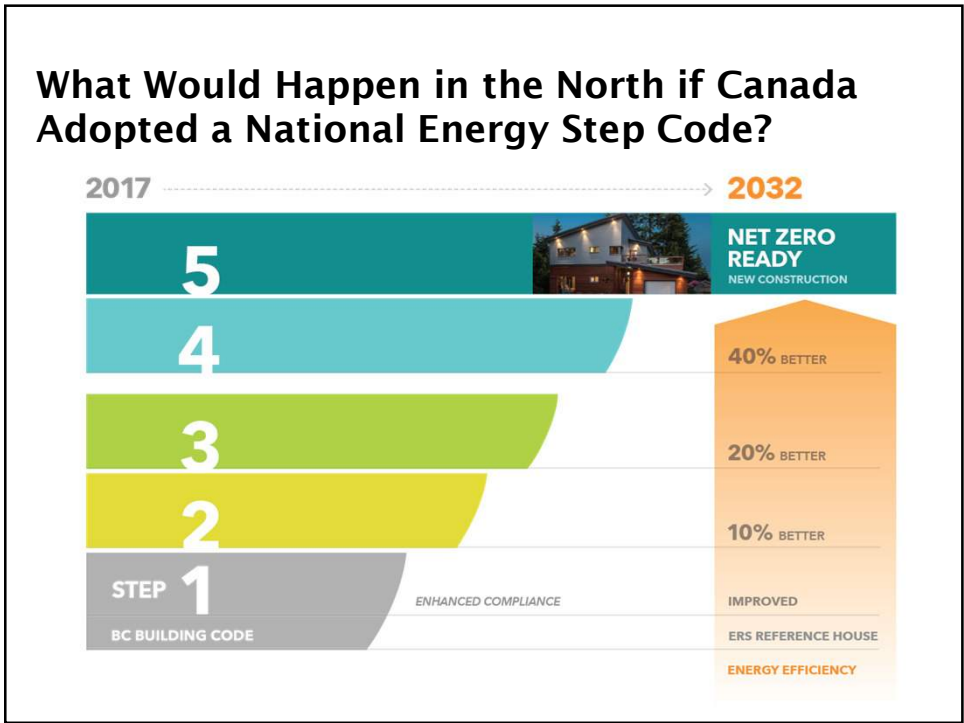
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What Would it Take in the Far North to Build to Passive House or Net Zero Standards?



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Initiatives that led to the Energy Step Code in BC

- Climate Leadership Plan**
 BC Building Code
 - Net Zero Ready by 2032
- Pan Canadian Framework**
 National Building Code
 - Net Zero Ready by 2030
 - National “Stretch” Code
- Clean Efficient Buildings – Intentions Paper**
 BC Building Code proposed changes
 - Step 3 - 2022
 - Step 4 - 2027
 - Step 5 - 2032

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National Building Code of Canada Direction

→ Pan-Canadian Framework on Clean Growth and Climate Change calls for adoption of “net-zero energy ready” by 2030

GOAL: Federal, provincial, and territorial governments will work to develop and adopt increasingly stringent model building codes, starting in 2020, with the goal that provinces and territories adopt a “net-zero energy ready” model building code by 2030.

Critical Path to 2030

nrcan.gc.ca/pathwayto2030



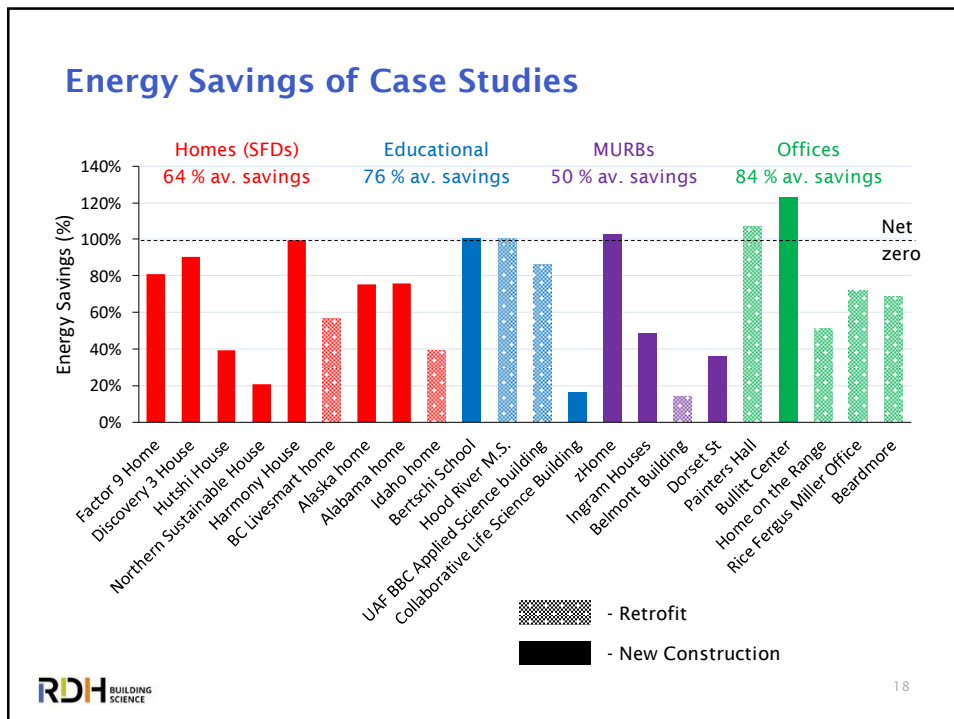
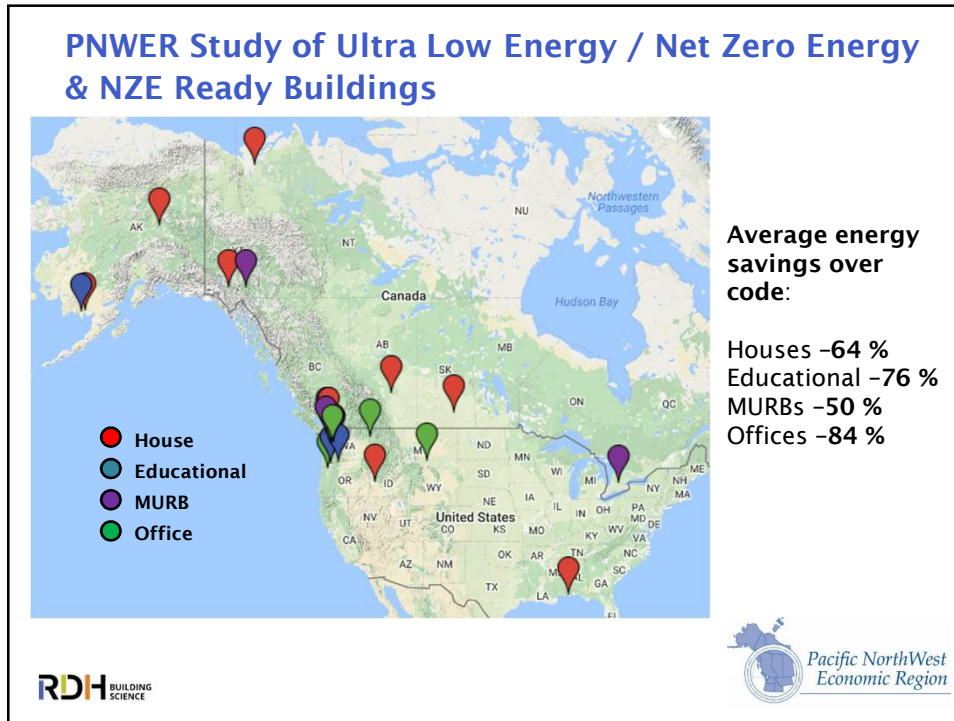
Definitions: Near Net Zero, Net Zero Energy Ready, & Net Zero Energy

- **Near Net Zero:** A building with low energy usage such that it approaches the annual energy consumption of Net Zero Energy buildings, and, with additional measures, COULD produce nearly as much renewable energy as it uses on an annual basis
- **Net Zero Energy Ready:** A building with low energy usage such that, with additional measures, it could generate as much renewable energy as it uses on an annual basis
- **Net Zero Energy:** A building with low energy usage such that, with the use of active energy generation equipment (i.e. solar PV etc.), it can generate as much renewable energy as it uses on an annual basis

The Problem with the “Net Zero Energy” Definition



Common Attributes of Net Zero Energy Buildings



Case Example 3: Single-family home

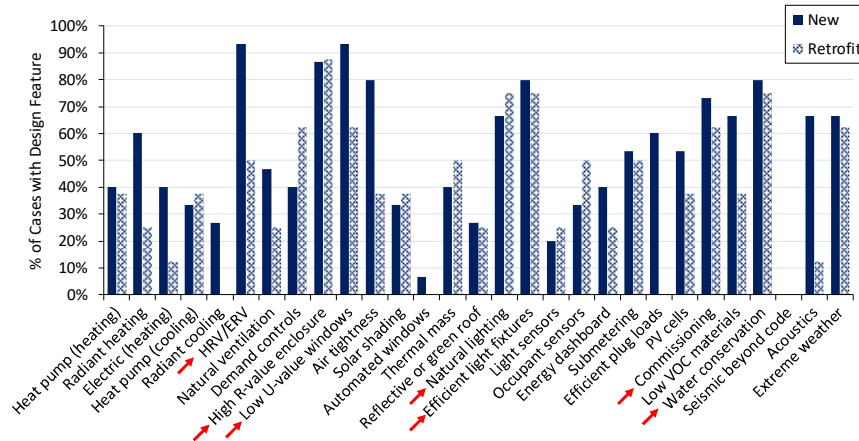
Strategy	Small, airtight home, based on Passive House standard, 590 sf
HVAC	HRV, heat pump water heater, electric space heater is barely needed (internal heat from occupants, lighting etc.)
Walls	28" thick walls R-90, ceiling R-140, air sealed,
Window	Triple-pane, argon-filled, two low-E coatings, with fiberglass frame



- 0.05 ACH50 air tightness - world record for tightest residential building (at the time)
- When it's 0 °F outside, it's still 50 °F inside (without heating)
- Solar-ready

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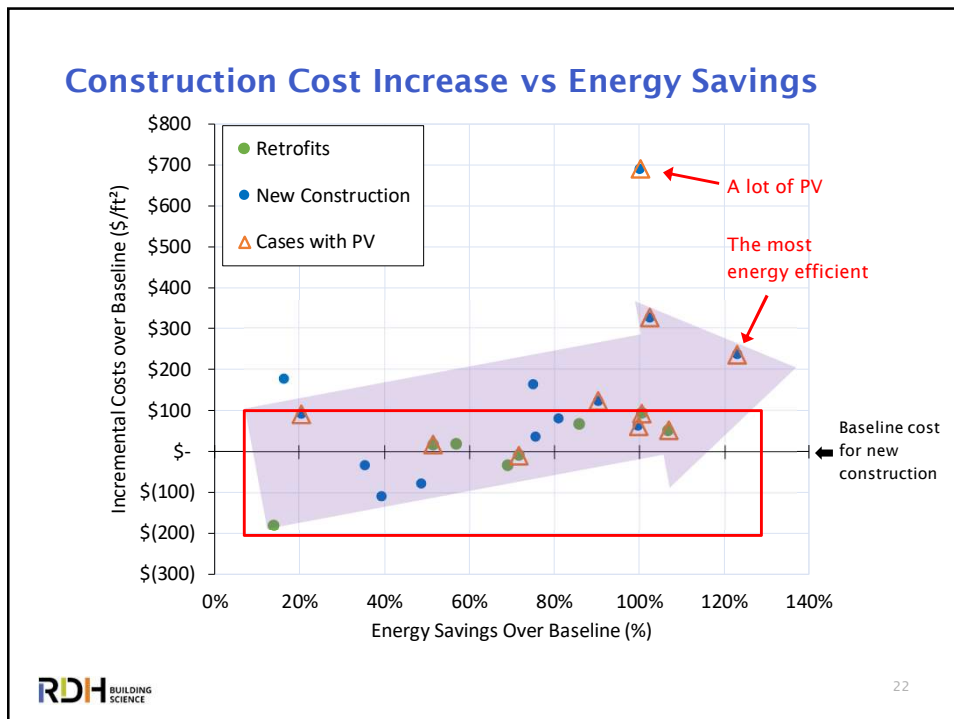
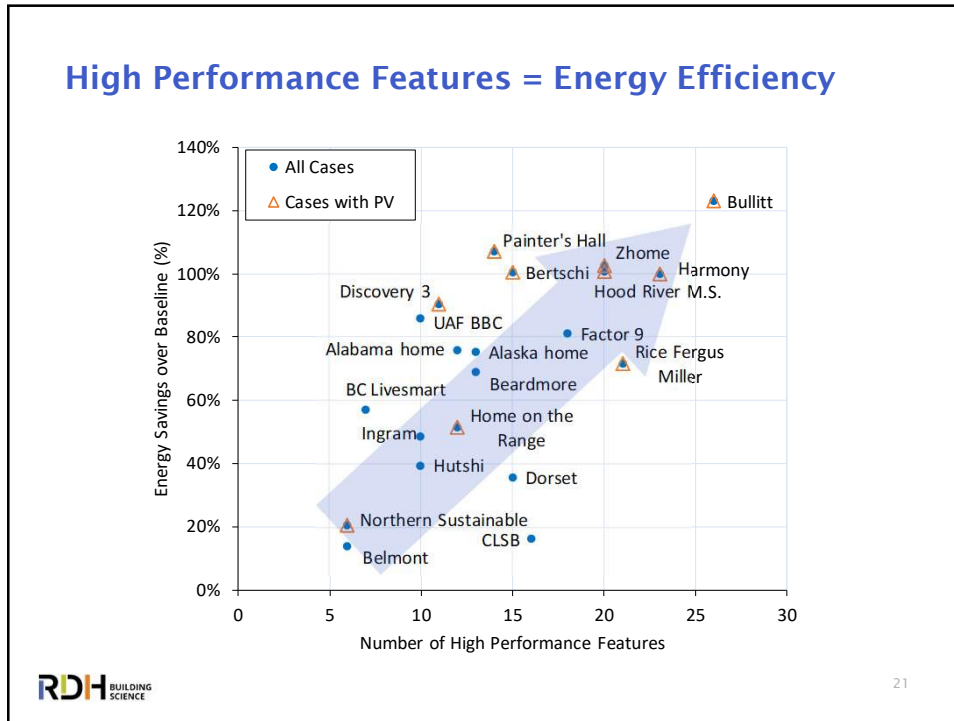
Common Design Features of NZE Buildings

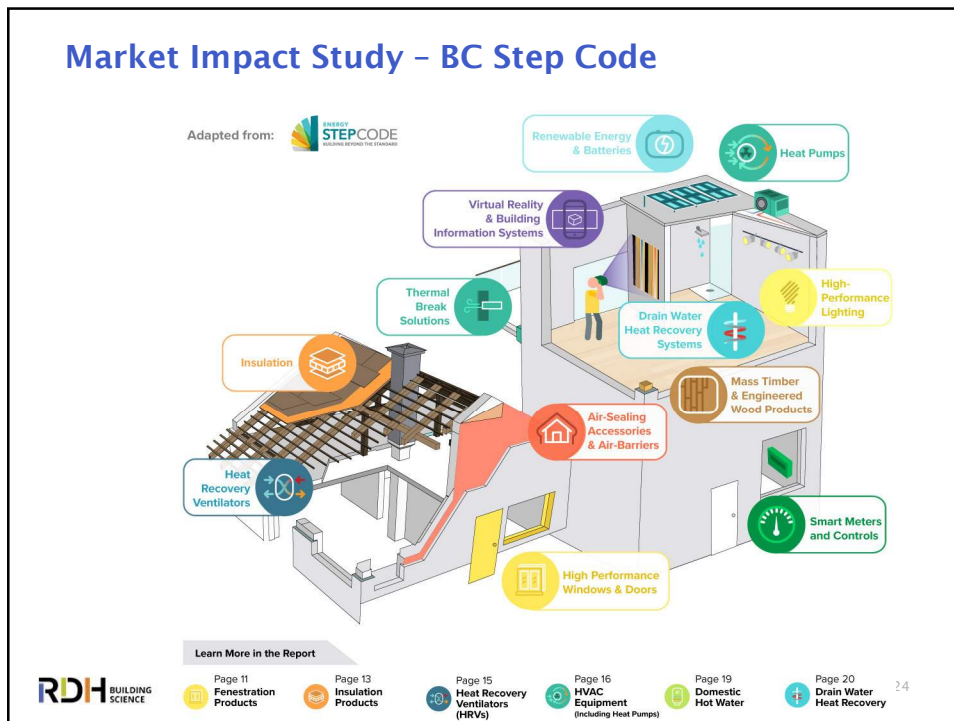
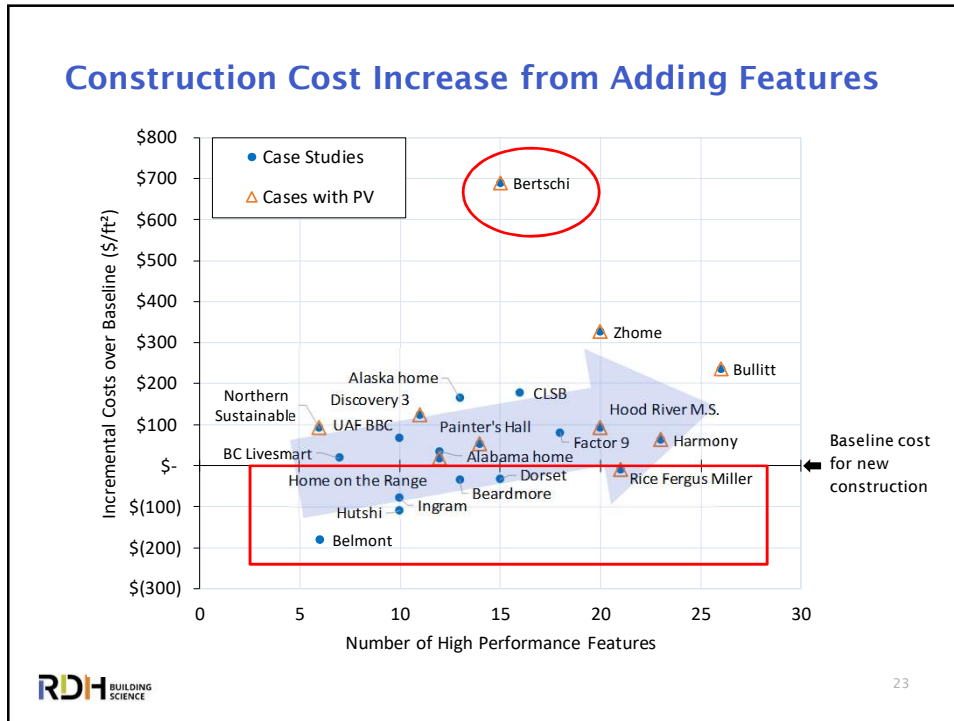


Most common high performance design features for new and retrofit buildings



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Passivhaus / Passive House

- Voluntary design standard for highly energy efficient buildings with prescriptive targets for whole building airtightness, thermal energy demand and total energy use. Plus requirements to achieve thermal comfort criteria, avoid overheating and maintain mould-free indoor environment.
- Two Standards and Certification Bodies: Passive House Institute (PHI) and Passive House Institute US (PHIUS) with similar though different metrics

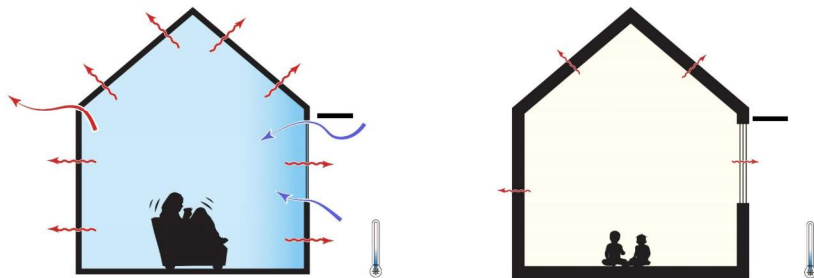


- In Canada, Passive House Canada is an organization that provides education and promotion for Passive House Projects



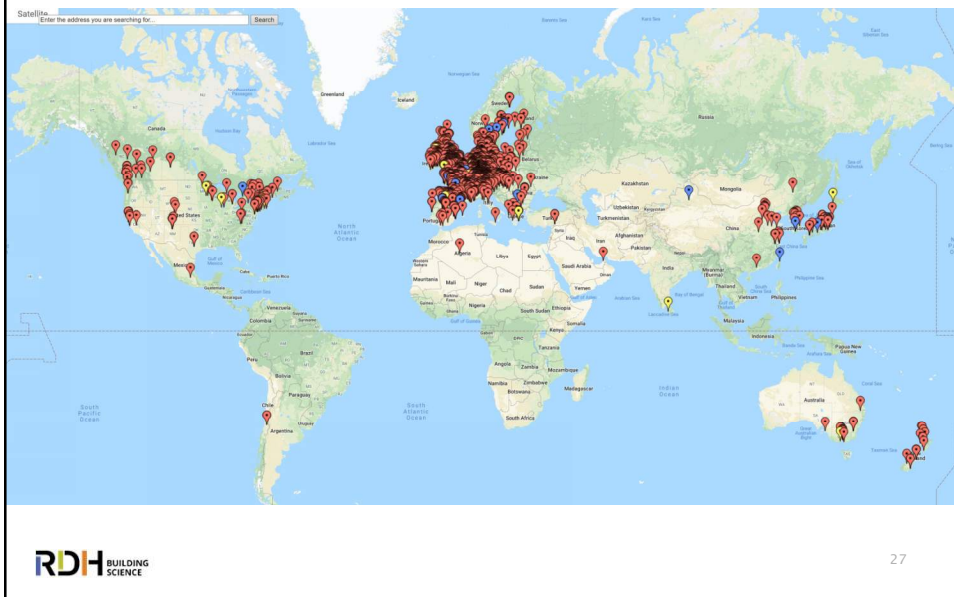
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Other Benefits to Passive and Net Zero Energy Ready – Thermal Comfort, Future-Proof, Resilience



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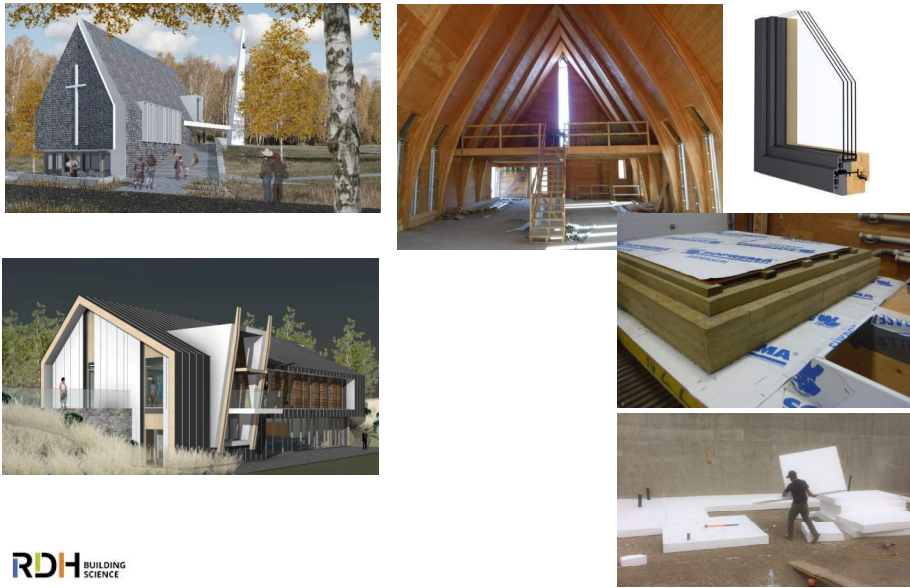
Passive House Certification Worldwide



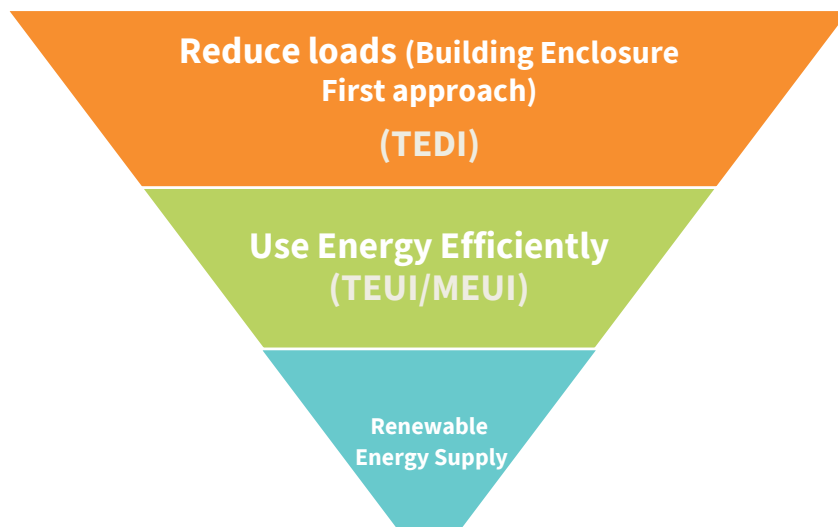
Passive House Certification in the North?



Some of our Northern BC Passive House Projects (CZ 7A/7B)



Whatever The Goal - The Approach is the Same





Northern Canada Research Study Questions

1. What are major challenges to achieving near net zero or passive house levels of energy efficiency in Canada's North
 - Are there locally available resources (labour, materials) and do technologies exist to hit targets

2. What are strategies to achieve targets including changes to design, enclosure or mechanical systems
 - What is practical or feasible in Northern construction?
 - What kind of future technologies need to be developed to hit targets in colder climates?
 - Do the targets need to be adjusted?

Northern Canada Research Study Questions

3. How do different energy modeling tools compare at assessing these energy efficiency targets, do standard assumptions apply to housing in Northern Canada
 - Can results from PHPP, HOT2000, and EnergyPlus™ be used as comparable compliance paths?
4. What are the incremental costs of such high performance buildings in Northern Canada, including remote locations?
 - How could costs compare between different architectural styles and levels of articulation and between remote and urban locations?

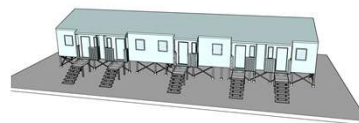
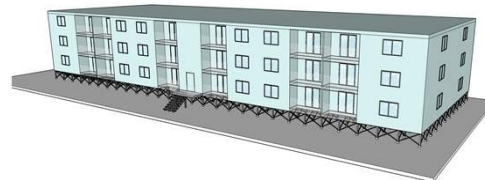
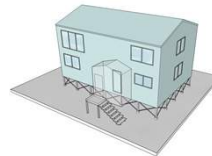
Research Study Methodology

- Literature Review
 - What has been done in other Arctic and Antarctic buildings worldwide to achieve very high levels of energy efficiency?
 - How have other countries adapted energy targets/requirements?
- Energy Modelling Tool Comparison
 - How do different tools compare? Do they align?
- Compliance Modeling
 - What Energy Conservation Measures (ECMs) are needed to hit different levels of energy efficiency?
- Costing Analysis
 - What does it cost across the North to hit different energy targets?
- Analysis of Barriers
 - What challenges exist, what solutions are or could be available?

Step 1: Select Representative Housing Archetypes Appropriate for the North and Consider Full Range of Northern Climate Zones

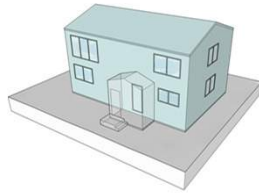
Representative Housing Archetypes for Modeling

- Single Family Dwelling (SFD)
 - Simple & Articulated Form Factor
- Multi-Unit Residential Building (MURB)
 - Simple & Articulated Form Factor
- 5-Plex Row House

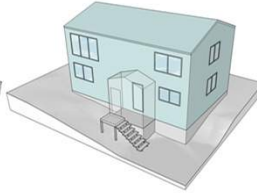


SFD Archetypes & Foundations

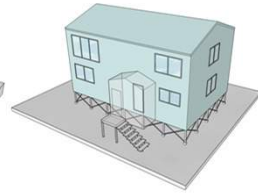
SIMPLE



Slab on Grade

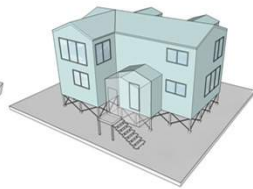
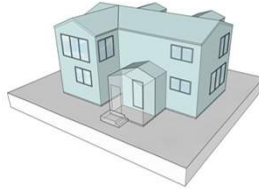


Footing on Bedrock



Elevated (Permafrost)

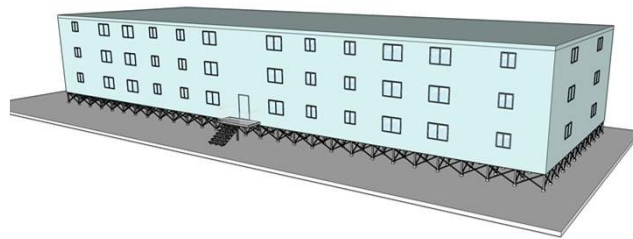
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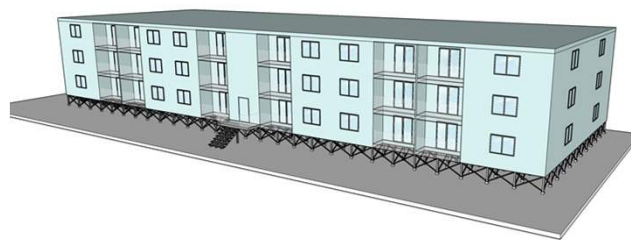
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MURB Archetypes

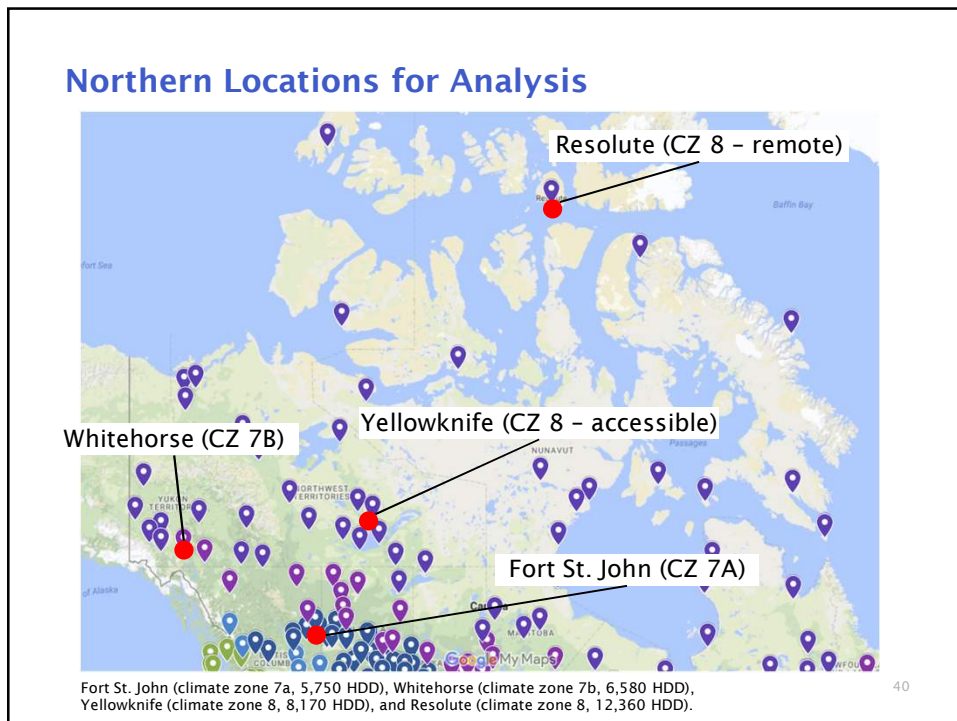
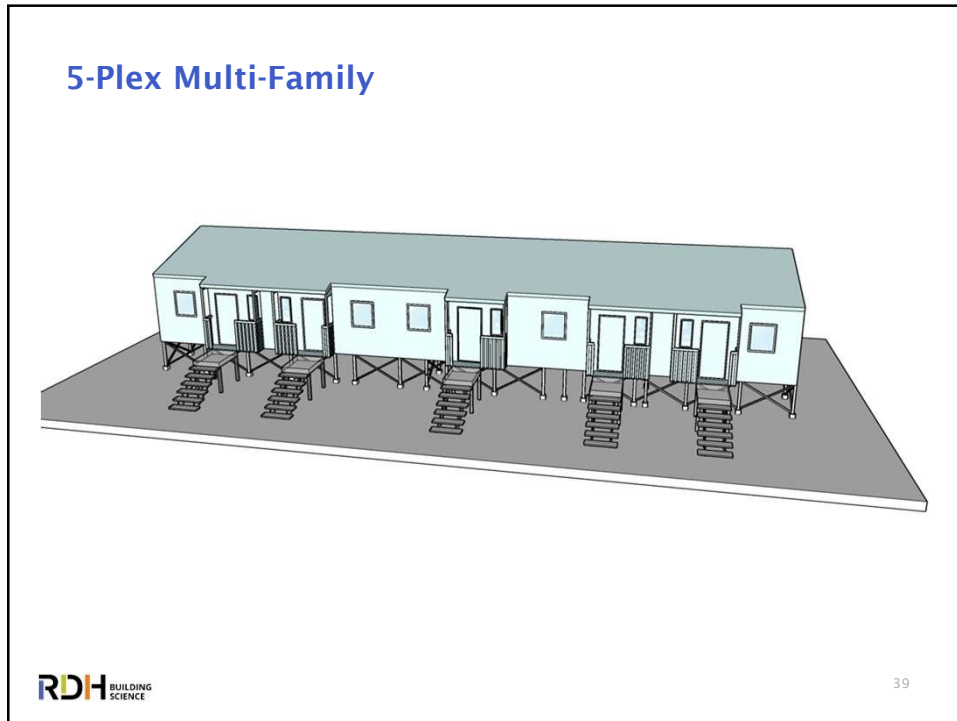
SIMPLE




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Step 2: Select Appropriate Building Enclosure and Mechanical Equipment Energy Conservation Measures Applicable to Northern Housing

Energy Conservation Measures (ECMs)

- Start with National Building Code (NBC 2015) and National Energy Code of Canada (NECB 2011) as minimum criteria for building enclosure & mechanical equipment efficiencies
- Building enclosure ECMs as levers to reduce loads to meet more stringent targets
 - Increasing insulation R-values within wall, roof, floor assemblies
 - Improving airtightness
 - Improving window U-values (double, triple, quad pane)
- Mechanical system ECMs to improve energy use efficiencies to meet targets
 - Heating systems - fuel, electric resistance, heat pumps
 - Domestic hot water - fuel, electric, heat pump & heat recovery
 - Ventilation Heat Recovery


Practical Limits to Upper ECMs in the North

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	0.15 to 0.30 ACH ₅₀ (SFD to MURB, 4x tighter than PH, extremely tight)
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%



Why Practical Limits? What About Future Tech?




Step 3: Assess Net Zero Energy Ready Performance Targets


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Energy Standards Targeting Net Zero Ready

Program	Target Type	Compliance Structure	End Goal	Applicability	Origin
BC Energy Step Code 	Energy metrics	4 or 5 Steps, targets vary by climate	Net-zero ready	BC*	BC
Passive House 	Energy metrics, & comfort	Classic, Plus, Premium	Net-zero ready	All	Germany

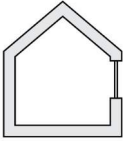
*May be adopted on National scale


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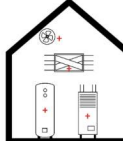
Metrics to Evaluate Energy Efficiency




Airtightness



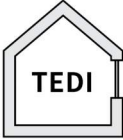
Building Enclosure




Mechanical Equipment & Systems




Total Energy Use & Greenhouse Gas Emissions




TEDI



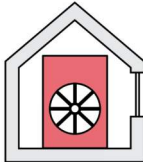
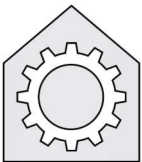
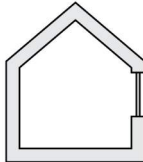
MEUI




TEUI / GHGe


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Performance Metrics – Step Code & Passive House

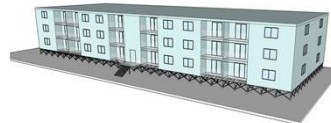
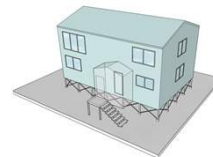
	Airtightness	Equipment & Systems	Thermal Performance
Step Code for SFD: Step 5	$\leq 1.0 \text{ ACH}_{50}$	$\text{MEUI} \leq 55\text{-}75 \text{ kWh/m}^2$	$\text{TEDI} \leq 15\text{-}60 \text{ kWh/m}^2$
Step Code for MURB: Step 4	N.R.	$\text{TEUI} \leq 100 \text{ kWh/m}^2$	$\text{TEDI} \leq 15 \text{ kWh/m}^2$
Passive House	$\leq 0.6 \text{ ACH}_{50}$	$\text{PER} \leq 60 \text{ kWh/m}^2$	$\text{TEDI} \leq 15 \text{ kWh/m}^2$


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Problem: Different Energy Modeling Tools Estimate Different Energy Consumption

Energy Modeling Tools in Canada

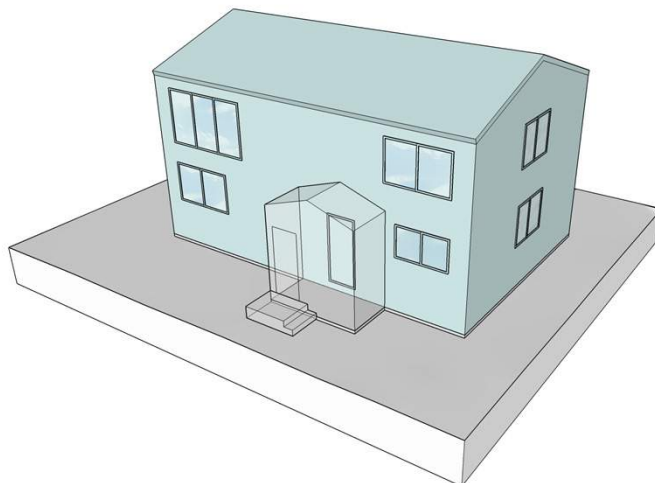
- SFDs (Part 9 of code)
 - HOT2000 for Part 9 Energy Code Compliance/EnerGuide Program using NBC/NRCan baseline assumptions and protocols
 - PHPP used for Passive House certification using European baseline assumptions and protocols
- MURBs (Part 3 of code)
 - Hourly energy models such as Energyplus™ used for Part 3 Energy Code Compliance using NECB baseline assumptions and protocols
 - PHPP used for Passive House certification using European baseline assumptions and protocols

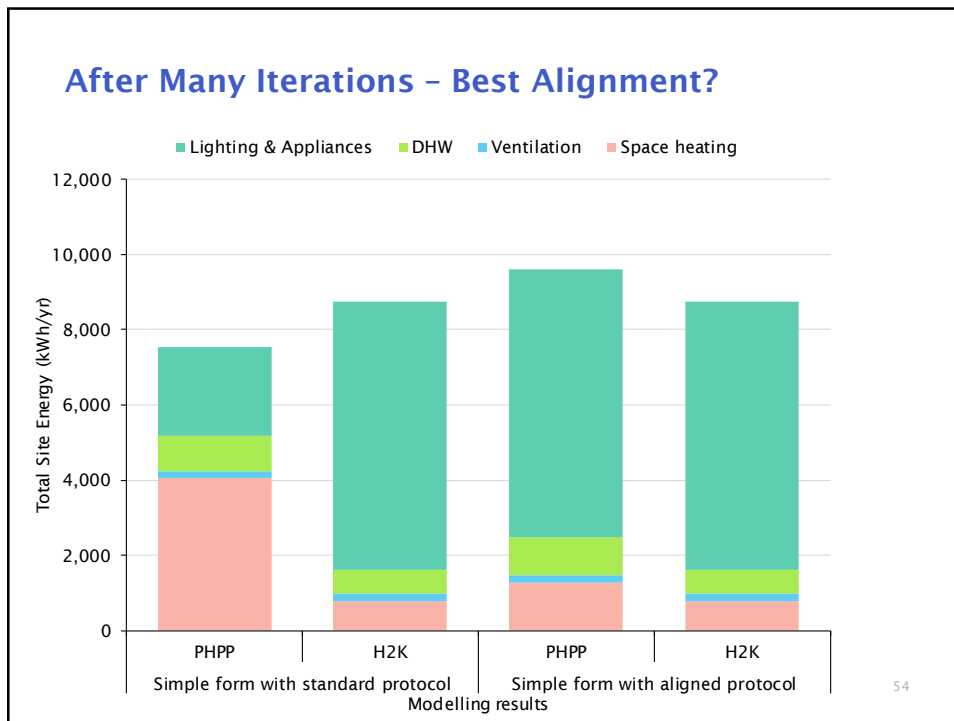
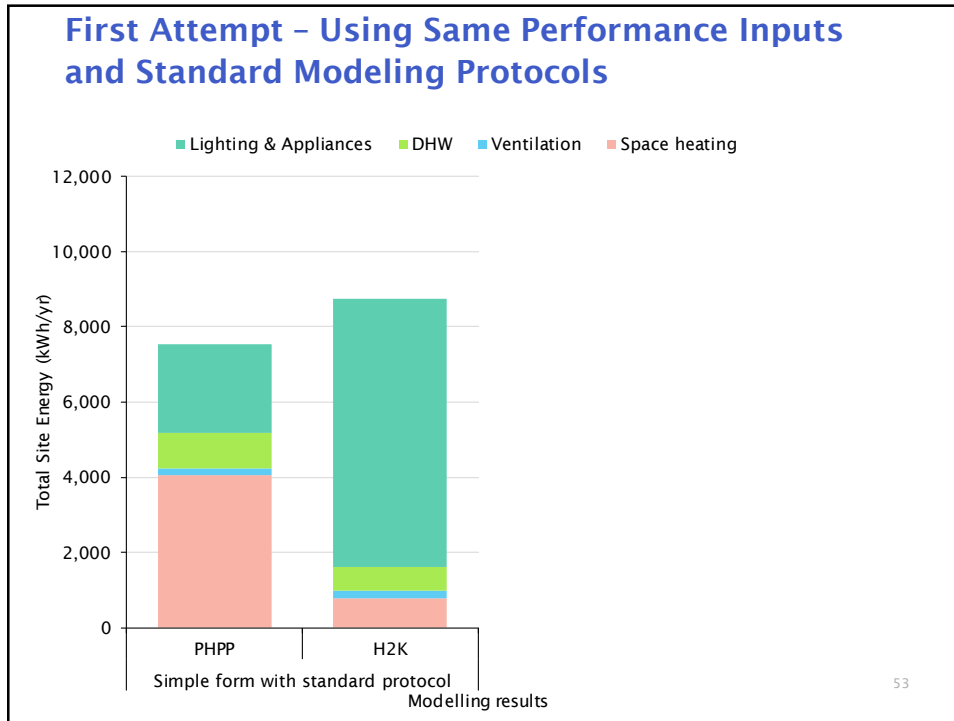


Research Questions

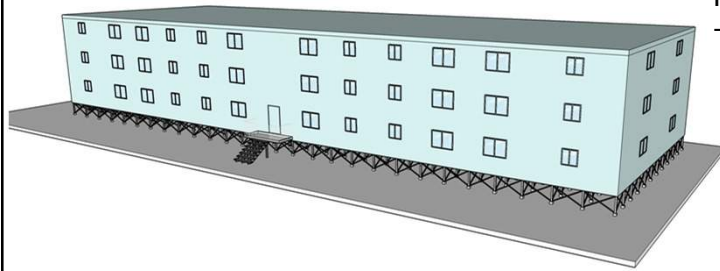
- Acknowledgement that different energy models using different calculation procedures with different inputs will produce different results
- Research undertaken to assess whether models could be aligned and better understand why differences do exist
 - Alignment attempts made, but still large differences exist due to different calculation algorithms
- Why? To assess whether different tools could be used for energy code compliance and if PHPP can be used as alternate to HOT2000?
- Which model is more accurate for modeling low energy building consumption in the North?

Example - Differences in Energy Efficient SFDs using Part 9 Software





Example - Differences in High Performance MURBs using Part 3 Software

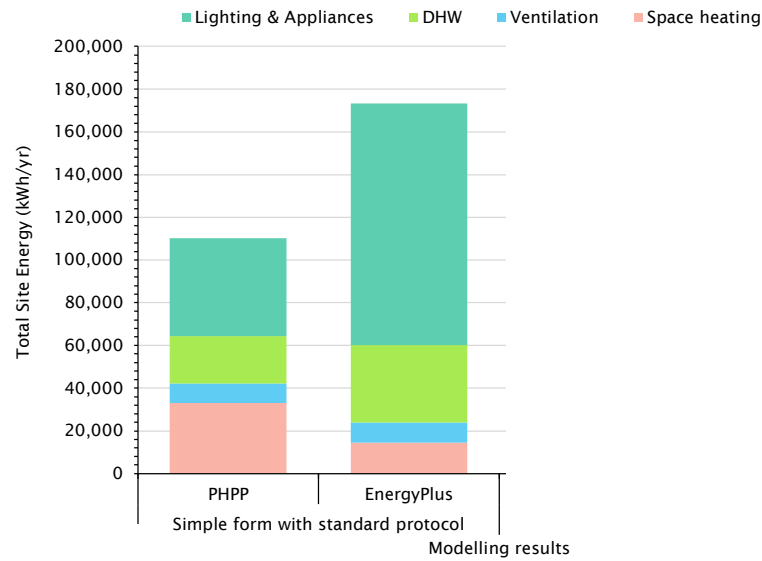


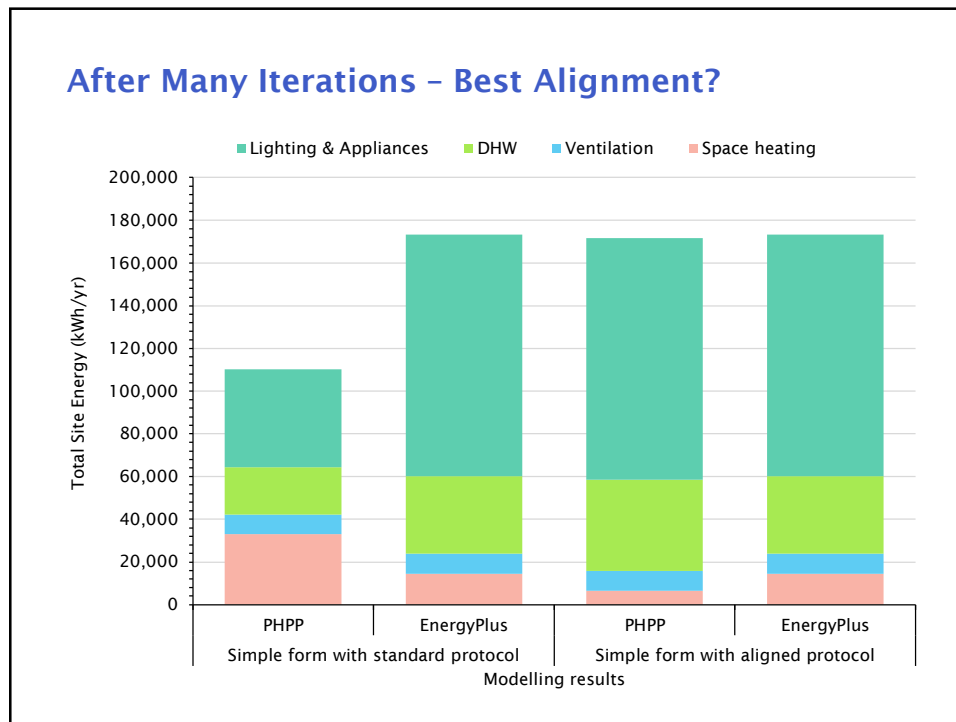
Hourly Software
- EnergyPlus™



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First Attempt - Using Same Performance Inputs and Standard Modeling Protocols

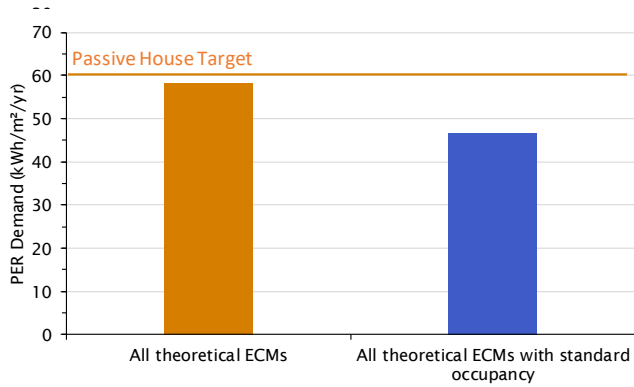




Further Challenges: Northern Considerations

- Standard occupancy assumptions within HOT2000 and PHPP not always applicable to the North
 - 3 people (@50% of time) per dwelling unit. Tend to see higher occupancies and home more of the time in remote regions. Plus animals
 - Impacts interior gains (offsets heat) and increases ventilation requirements (adds energy)
- Lack of standard assumptions for plug loads in the North
 - Car block heaters, heat tracing equipment, cooking practices etc.
- Ventilation air pre-heat/HRV defrost calculations?
- Performance of Cold Climate ASHP equipment at low temperatures?

What if Northern Occupancy Densities Were Included within Energy Modeling?

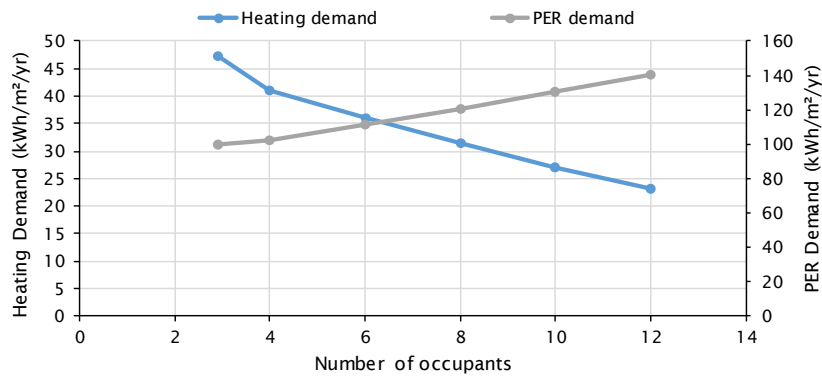


PER for the SFD in Yellowknife using the theoretical ECMs beyond the highest performing practical ECMs, using double the standard occupancy rate (orange) vs with standard occupancy (blue).



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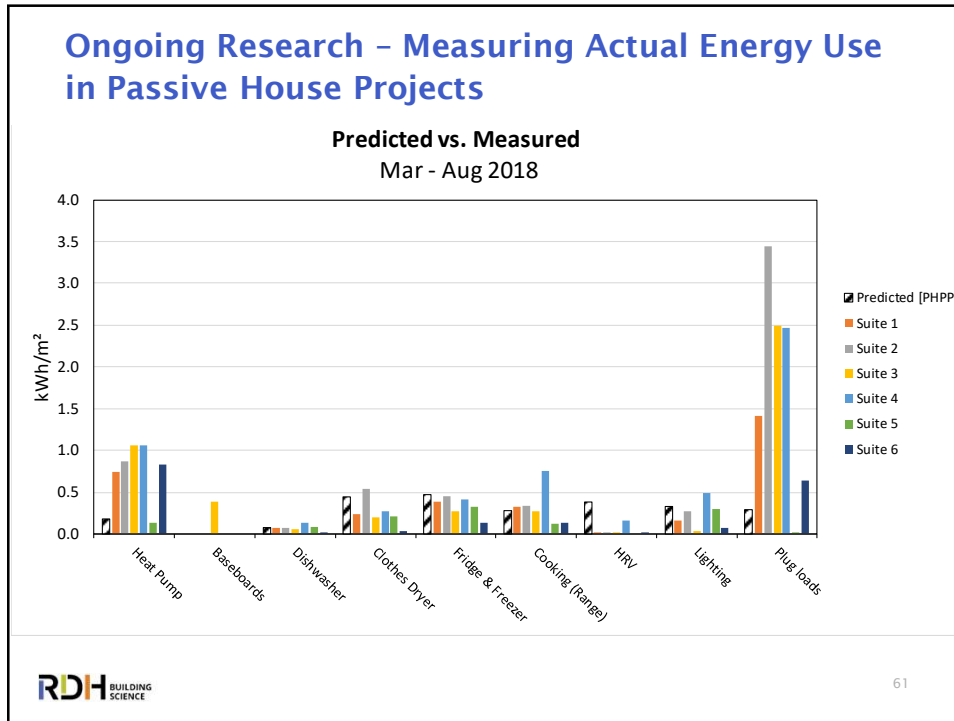
Does Increasing Occupant Density Actually Reduce Energy?



Sensitivity analysis for occupancy for the SFD in Yellowknife. The PER increases with increased occupancy, while the heating demand decreases.




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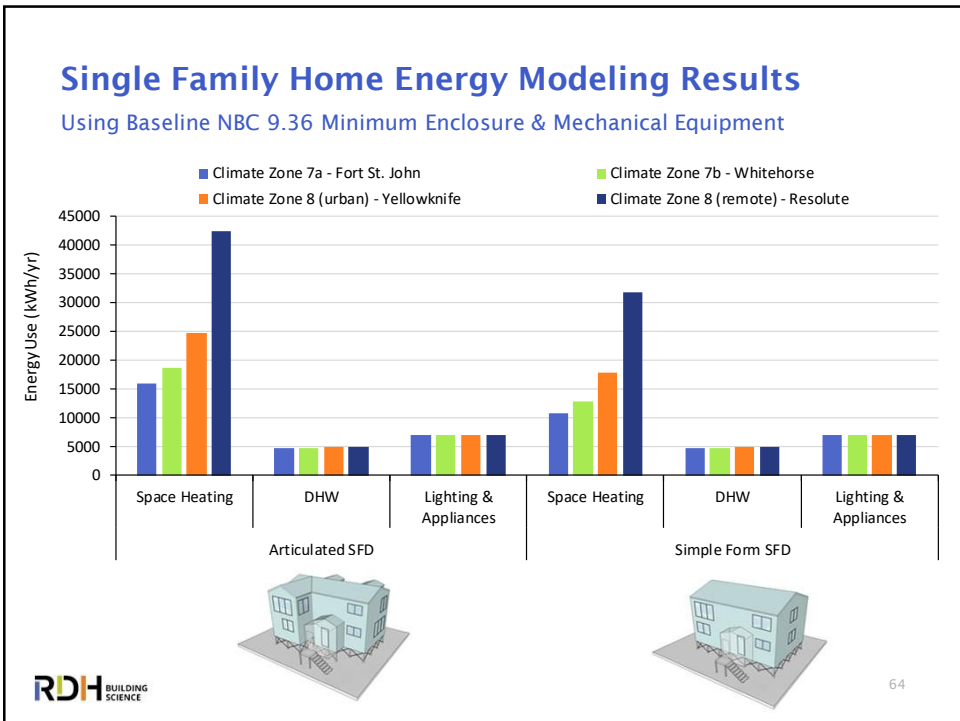


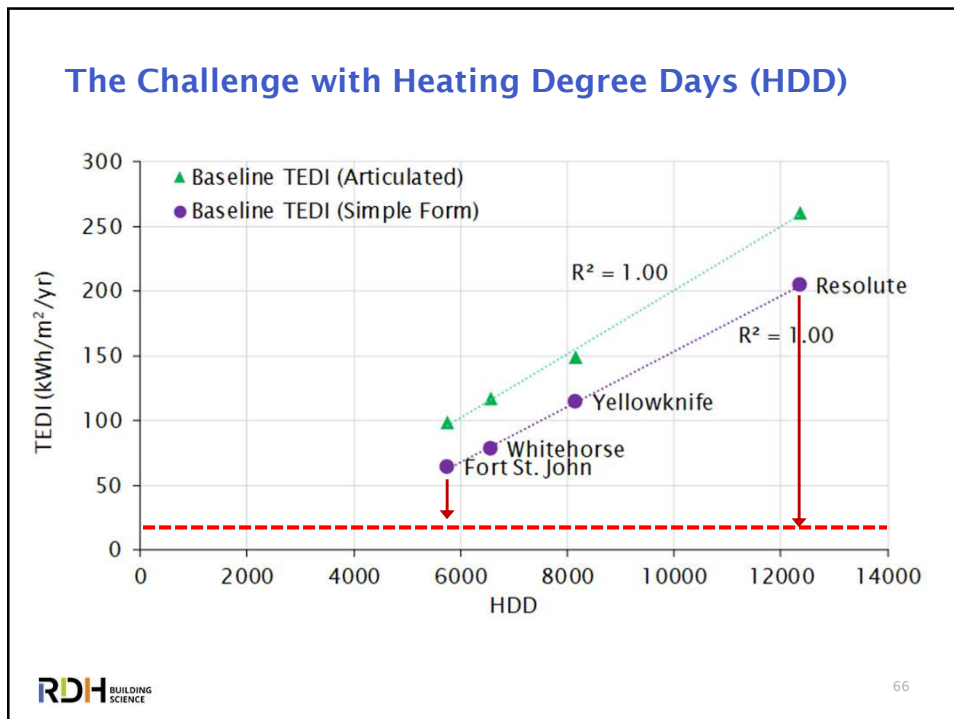
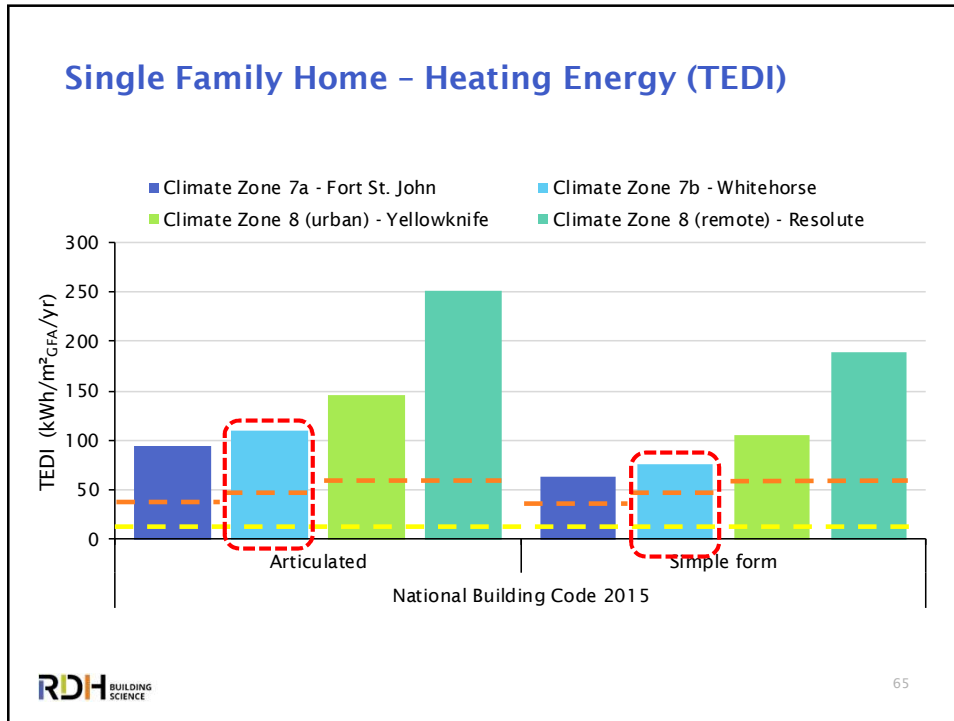
Conclusion: Available models are not perfect, though the best tools we currently have for code compliance. Need to measure actual energy use in high performance / net zero northern homes to refine future model inputs.

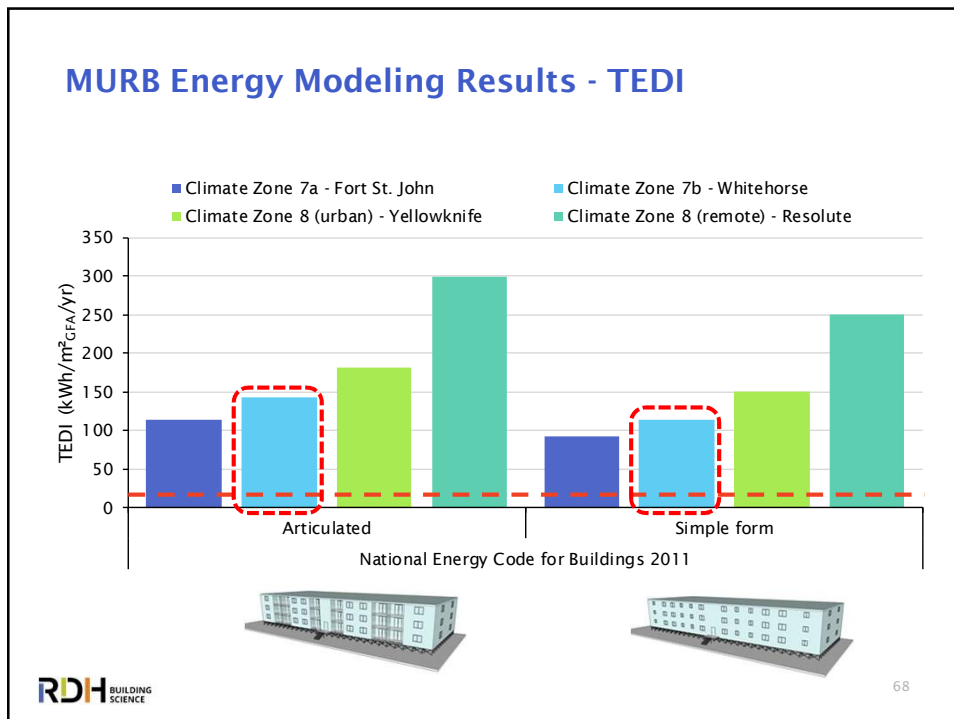
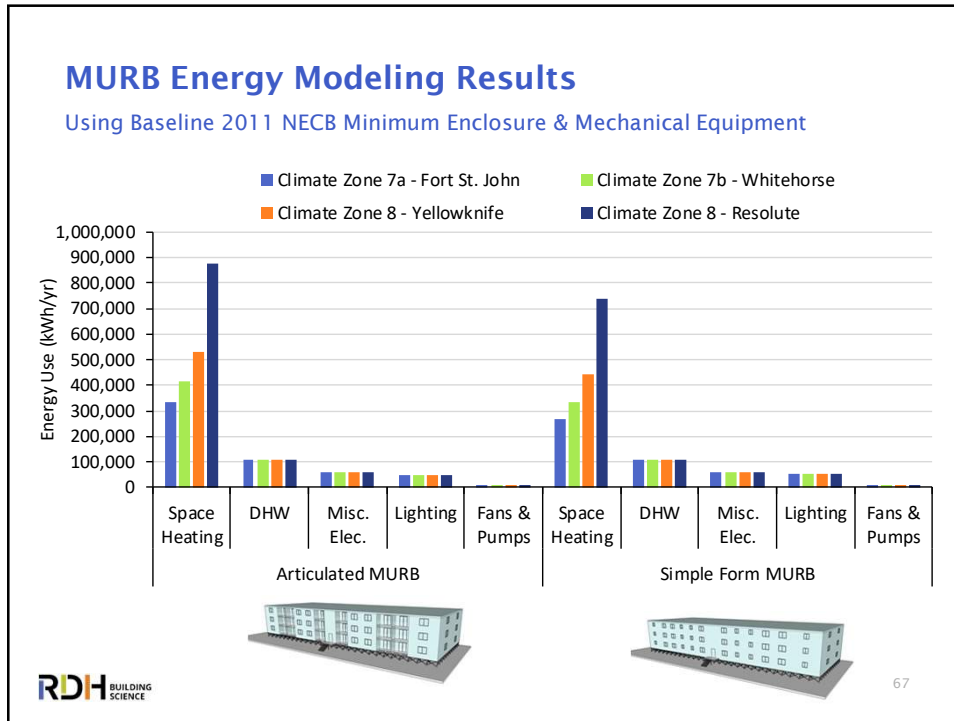
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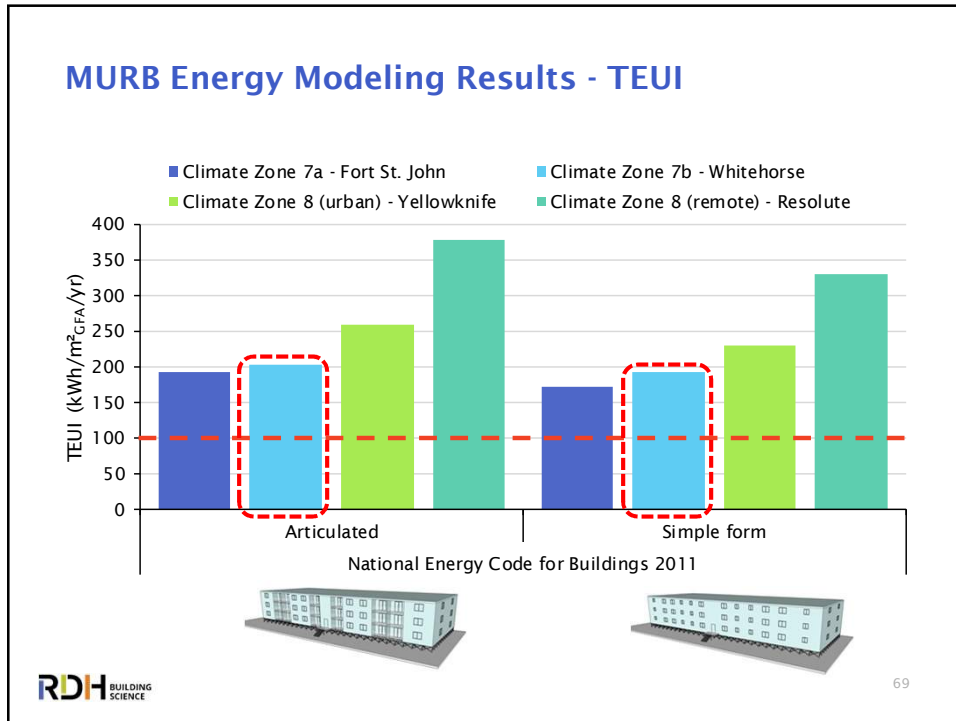
Step 4: Model the Baseline (Code Minimum) Energy Consumption


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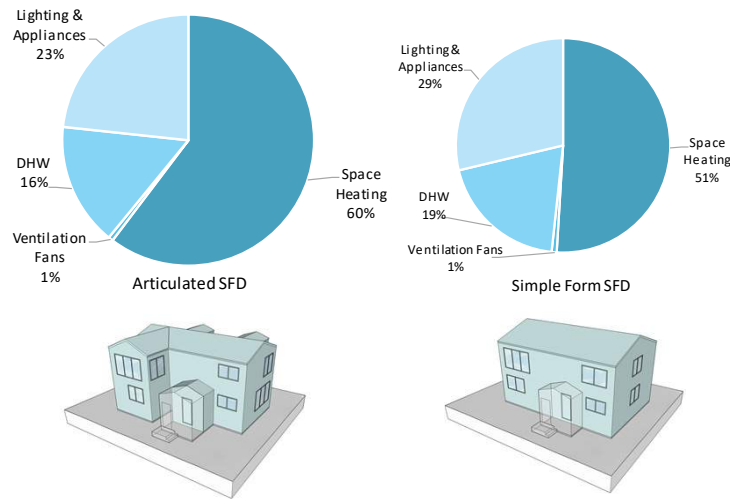
Step 5: Iteratively Apply & Document Potential ECMs to Achieve Step Code & Passive House Energy Use Targets

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Whitehorse Energy Modeling Results - SFDs

→ Baseline Energy Consumption: Articulated and Simple Form SFD

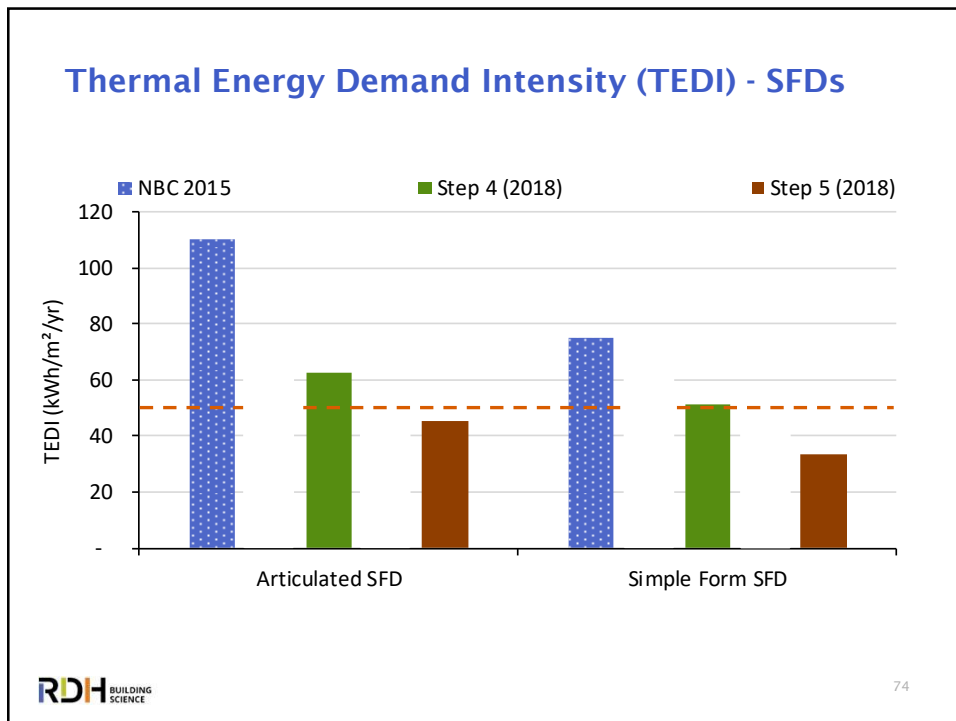
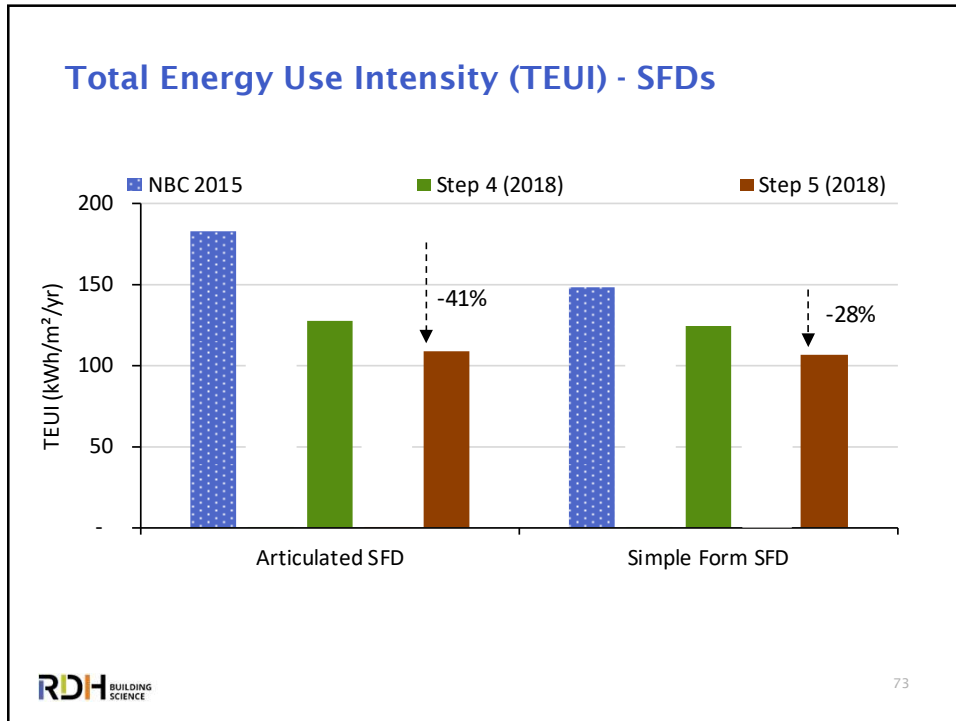


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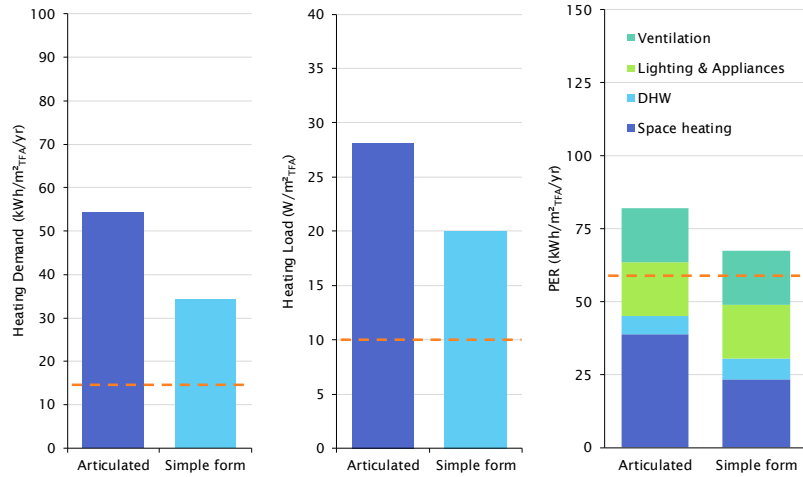
Upper Steps of Step Code – Near Net Zero SFDs

- Baseline, NBC 2015 (9.36)
- Reduction in air leakage rate from 2.5 ACH50 to 0.3 ACH50 (articulated) or 1.0 ACH50 (simple form)
- Increased insulation levels within enclosure
 - Walls from R-17.5 to R-30 (articulated) or R-25 (simple form)
 - Slab from R-16 to R-35 (articulated) or R-30 (simple form)
 - Windows from low-conductivity doubles U-0.25 to triples U-0.17
 - Doors from R-4 to R-6
- Increase HRV efficiency from 60% to 81% dual core no preheat (articulated) or 70% (simple form)
- Add R-12 blanket to DHW tank (articulated, only)
- Add drain water heat recovery at 65% effectiveness (articulated, only)

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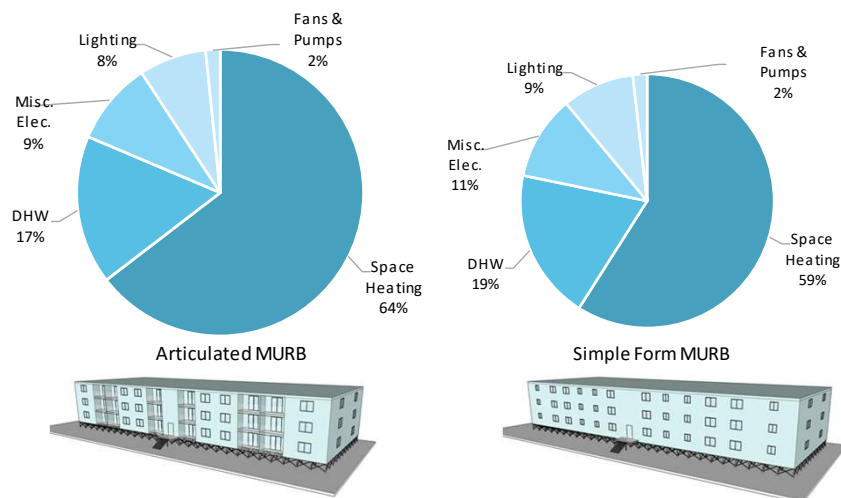
SFD Passive House Targets - Not Achieved with Highest Practical ECMS in Whitehorse



The heating demand (left), heating load (middle), and PER (right) of both articulated and simple form SFD models in Whitehorse. The Passive House targets are shown in orange dashed lines.

Whitehorse Energy Modeling Results - MURBs

→ Baseline Energy Consumption: Articulated and Simple Form MURB

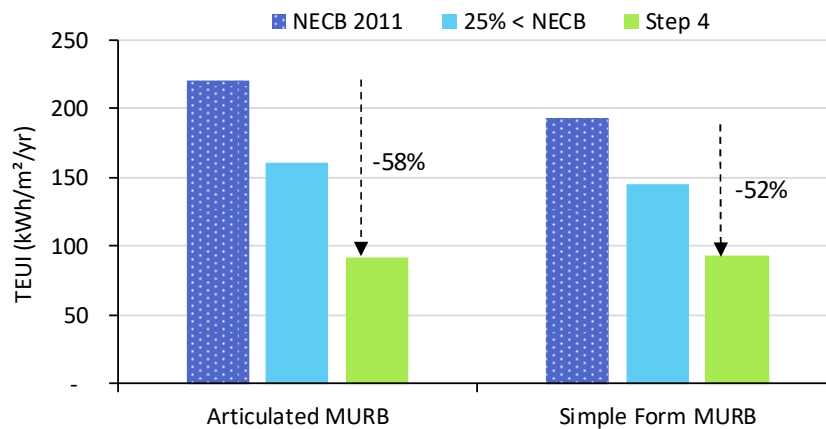


Upper Steps of Step Code – Near Net Zero MURBs

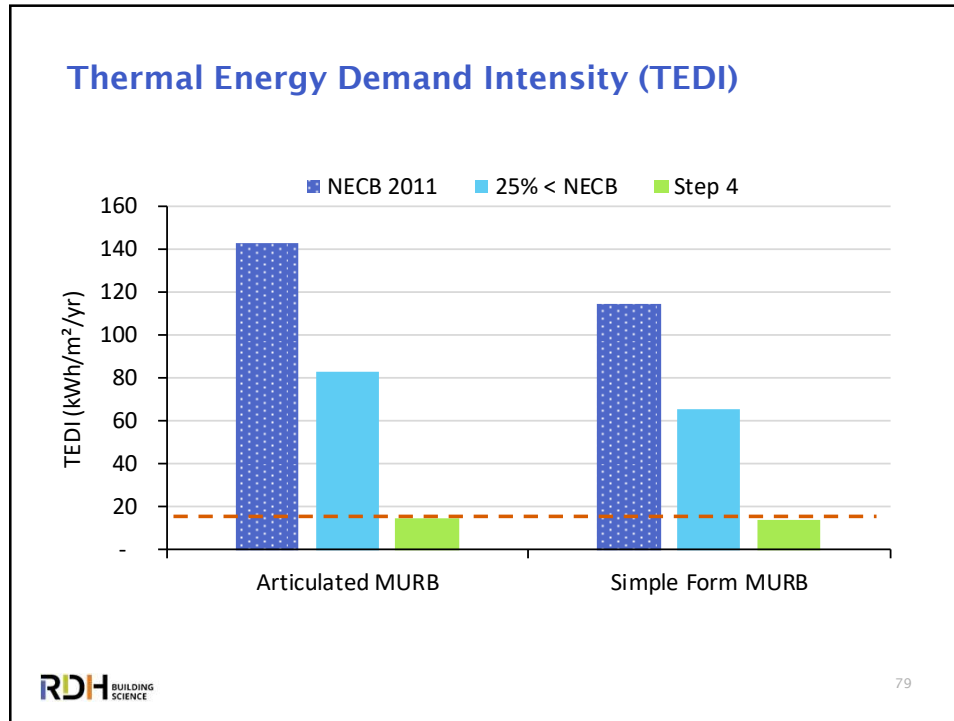
- Baseline, NEBC 2011
- Reduction in air leakage rate from 0.25 L/s-m² at 5 Pa (2.2 ACH50) to 0.020 L/s-m² at 5 Pa (0.15 ACH50)
- Increased insulation of opaque assemblies:
 - Roof from R-40 to R-76 (articulated) or R-48 (simple form)
 - Walls from R-31 to R-61 (articulated) or R-40 (simple form)
 - 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 with pre- and post-heat and MUA unit supplying corridors with tempered air, 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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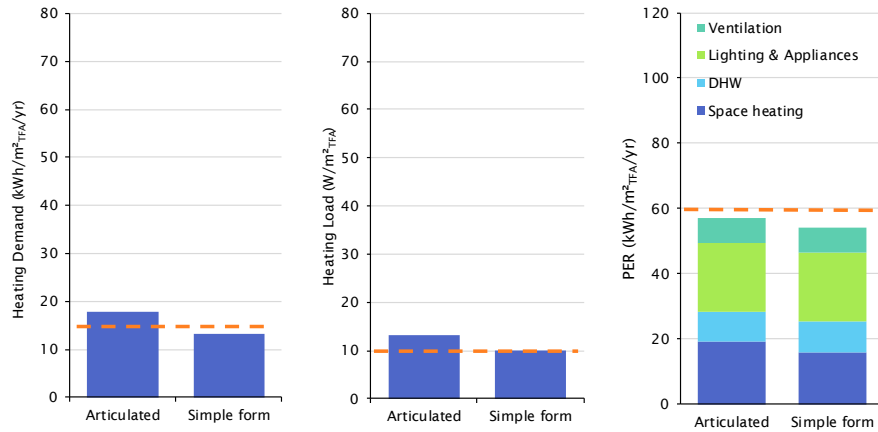


Passive House Levels of Performance

- Articulated MURB:
 - **Did not meet Passive House**
- Simple form MURB:
 - Reduction in air leakage rate from 0.25 L/s-m² at 5 Pa (2.2 ACH50) to 0.020 L/s-m² at 5 Pa (0.15 ACH50)
 - Increased insulation of opaque assemblies:
 - Roof from Reff-40 to Reff-100
 - Walls from Reff-31 to Reff-80
 - Exposed floors from Reff-40 to Reff-80
 - Windows from double glazed (U-0.39) to quadruple glazed (U-0.12)
 - Ventilation system changed from in-suite HRVs with pre- and post-heat and MUA unit supplying corridors with tempered air, to centralized/zoned ventilation system with 81% efficient dual core HRV for suites and corridors.
 - Reduced outdoor air rate to corridors from 20 cfm/door to 10 cfm/door.
 - Space heating system changed from electric baseboards to cold climate air source heat pumps with a VRF distribution system.
 - Domestic hot water system changed from electric tank to CO2 heat pumps.

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Passive House Levels of Performance



The heating demand (left), heating load (middle), and PER (right) of both articulated and simple form MURB models in Whitehorse with the maximum ECMs. The Passive House targets are shown in orange dashed lines—only the simple form MURB meets the Passive House targets

Northern BC Smithers & Ft St John MURB Passive House Projects



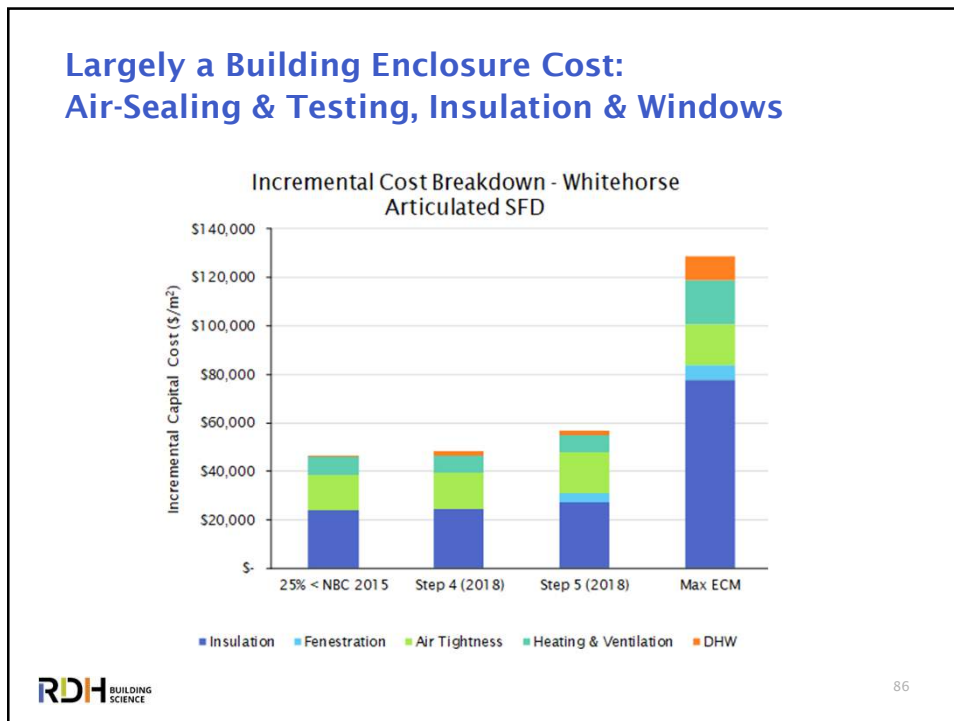
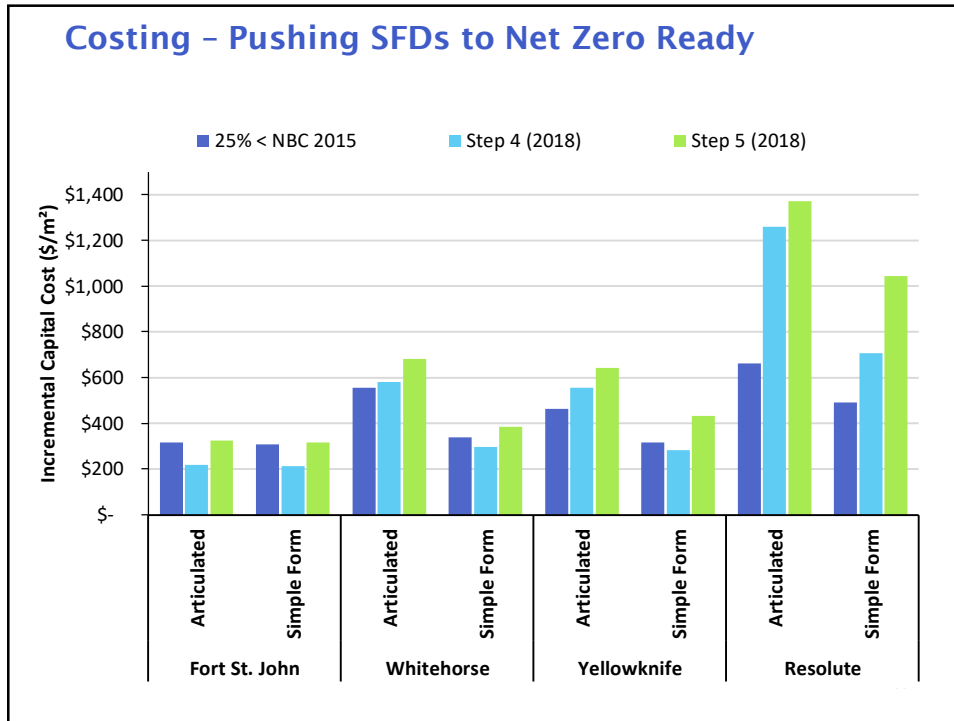
Whitehorse Summary of Compliance Results

SUMMARY OF COMPLIANCE WITH HIGH PERFORMANCE TARGETS USING HIGHEST PERFORMANCE PRACTICAL ECMS FOR THE NORTH					
		25% < CODE	STEP CODE		PASSIVE HOUSE (PHI)
			STEP 4	STEP 5	
Whitehorse CZ 7b	SFD - articulated	Yes	Yes	Yes	No
	SFD - simple form	Yes	Yes	Yes	No
	MURB - articulated	Yes	Yes	N/A*	No
	MURB - simple form	Yes	Yes	N/A*	Yes
	5-Plex	Yes	Yes	Yes	No

*The highest compliance target for Part 3 buildings within the BC Energy Step Code is Step 4

Incremental Costing Analysis

- Energy Conservation Measures Costed using Northern Canadian costing data (Previous CMHC Costing Study), with local input and 2019 information
- Focus on incremental material and labour costs (i.e. adding extra insulation plus associated detailing) and various mechanical equipment upgrade costs (or savings)



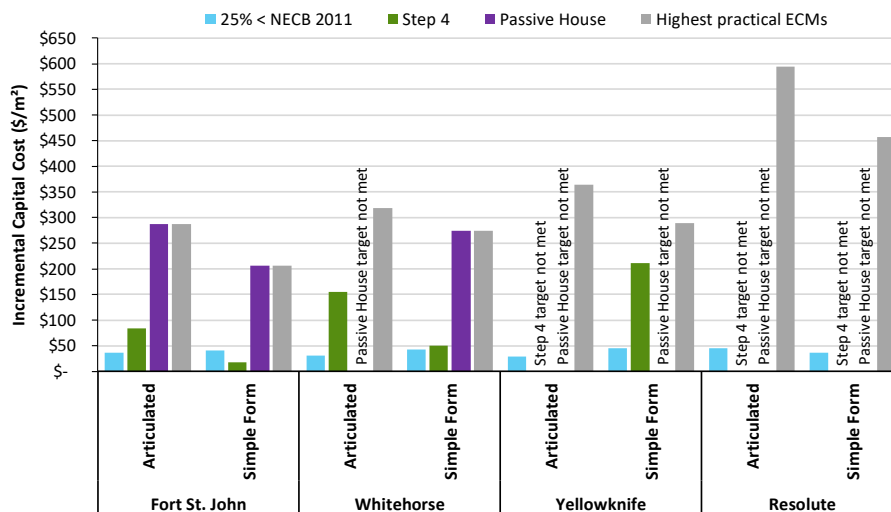
Costing - Pushing SFDs to Net Zero Ready

Target	Geometry	Location	ICC (\$/m2)	Total Project Cost (\$/m2)	% Incremental Cost
Step 5 (2018)	Articulated	Fort St. John	324	2227	15%
		Whitehorse	681	2580	26%
		Yellowknife	642	2927	22%
		Resolute	1370	4734	29%
	Simple Form	Fort St. John	315	2227	14%
		Whitehorse	384	2580	15%
		Yellowknife	432	2927	15%
		Resolute	1043	4734	22%
Highest Practical ECM	Articulated	Fort St. John	1186	2227	53%
		Whitehorse	1542	2580	60%
		Yellowknife	1526	2927	52%
		Resolute	2478	4734	52%
	Simple Form	Fort St. John	1150	2227	52%
		Whitehorse	1295	2580	50%
		Yellowknife	1272	2927	43%
		Resolute	2194	4734	46%

→ Recall Passive House targets were not met for SFD Archetypes in Whitehorse or Further North

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Costing - Pushing MURBs to Net Zero Ready



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Costing - Pushing MURBs to Net Zero Ready

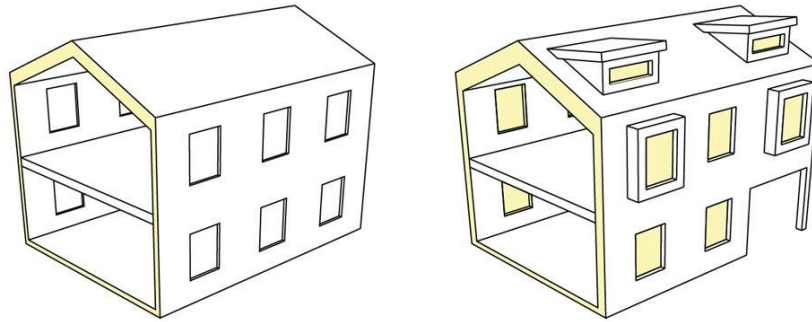
Target	Geometry	Location	ICC (\$/m2)	Total Project Cost (\$/m2)	% Incremental Cost
Step 4	Articulated	Fort St. John	84	1887	4%
		Whitehorse	156	2186	7%
		Yellowknife		Target not met	
		Resolute		Target not met	
	Simple Form	Fort St. John	19	1887	1%
		Whitehorse	51	2186	2%
		Yellowknife	212	3110	7%
		Resolute		Target not met	
Passive House	Articulated	Fort St. John	287	1887	15%
		Whitehorse		Target not met	
		Yellowknife		Target not met	
		Resolute		Target not met	
	Simple Form	Fort St. John	206	1887	11%
		Whitehorse	274	2186	13%
		Yellowknife		Target not met	
		Resolute		Target not met	
Max ECM	Articulated	Fort St. John	287	1887	15%
		Whitehorse	319	2186	15%
		Yellowknife	364	3110	12%
		Resolute	594	5030	12%
	Simple Form	Fort St. John	206	1887	11%
		Whitehorse	274	2186	13%
		Yellowknife	289	3110	9%
		Resolute	457	5030	9%



Challenges & Solutions


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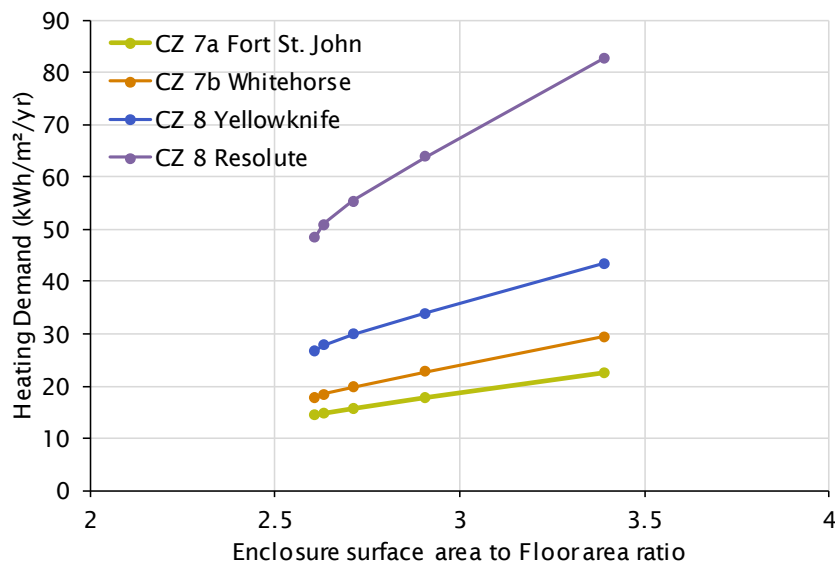
Building Articulation Has Profound Impact on TEDI and Ability to Hit Energy Targets Cost Effectively

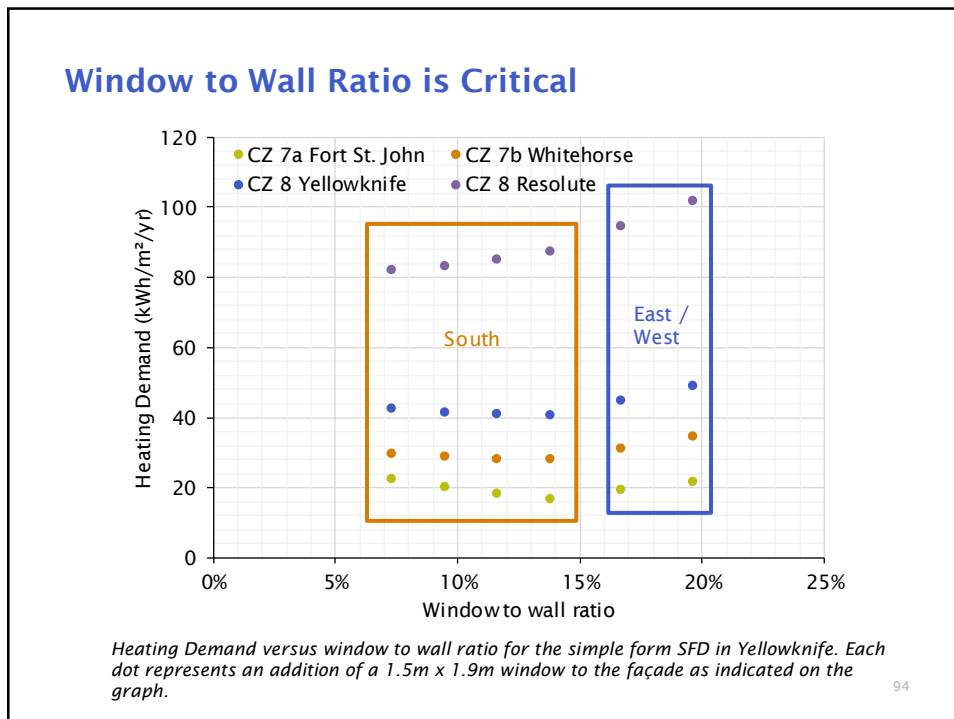
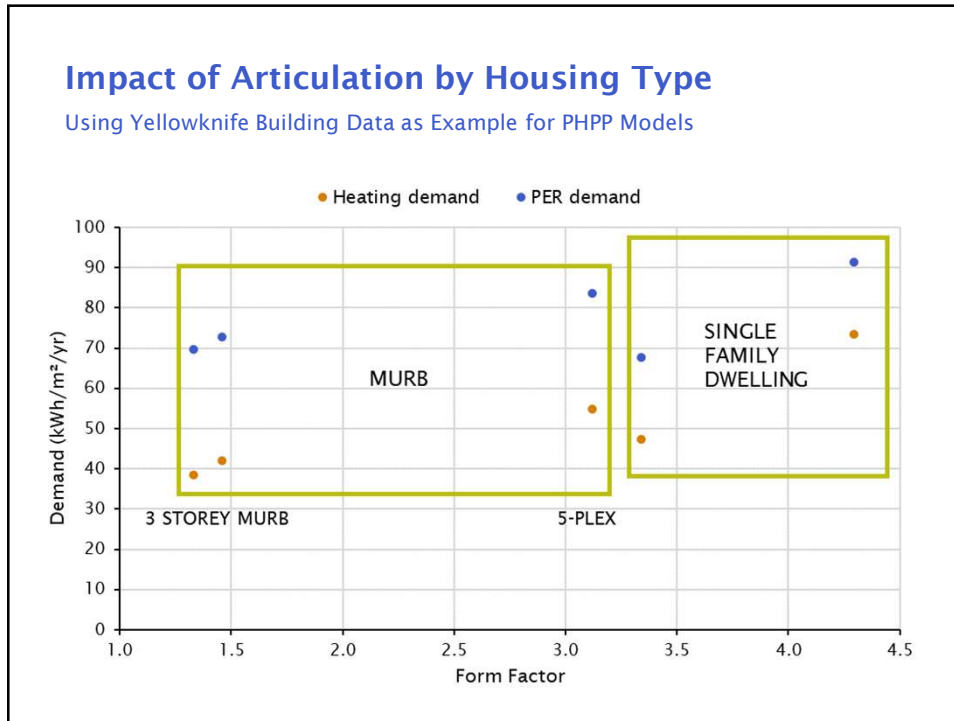


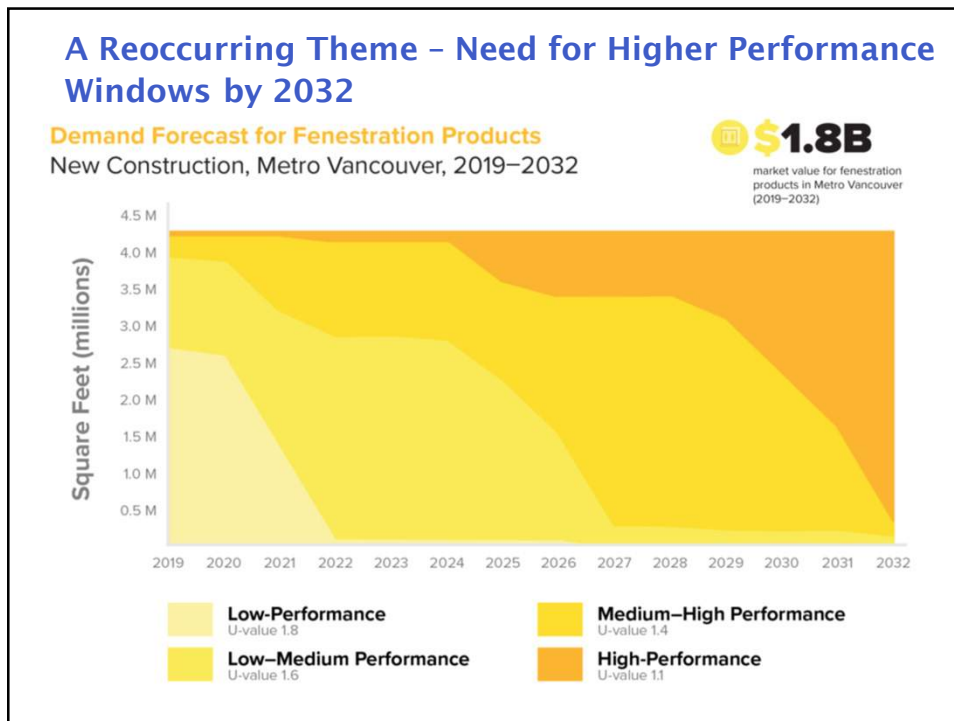
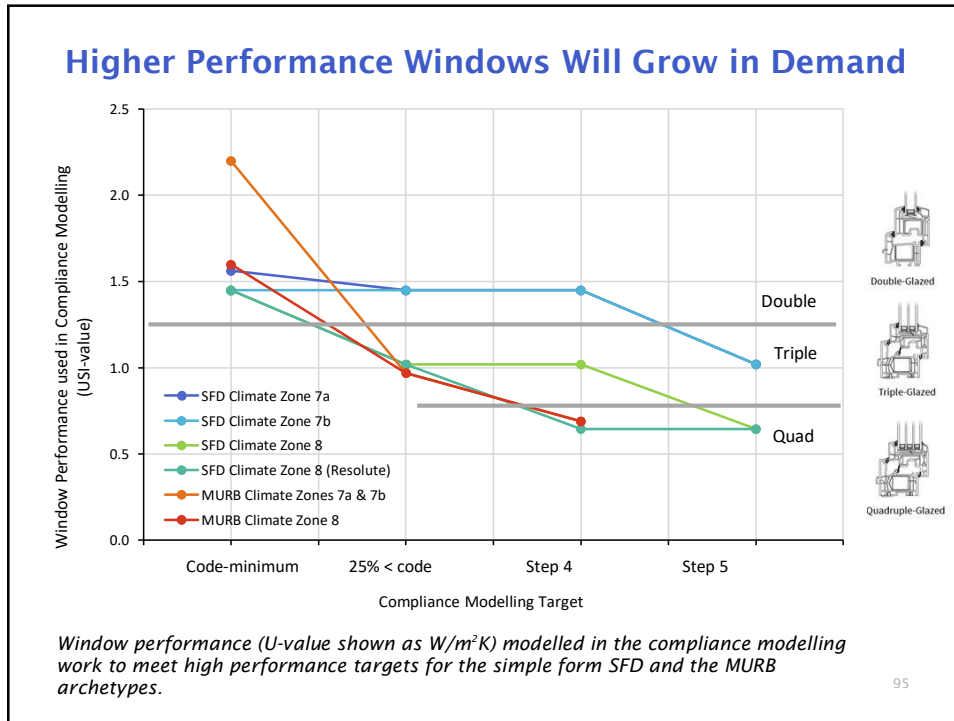
RDH BUILDING SCIENCE

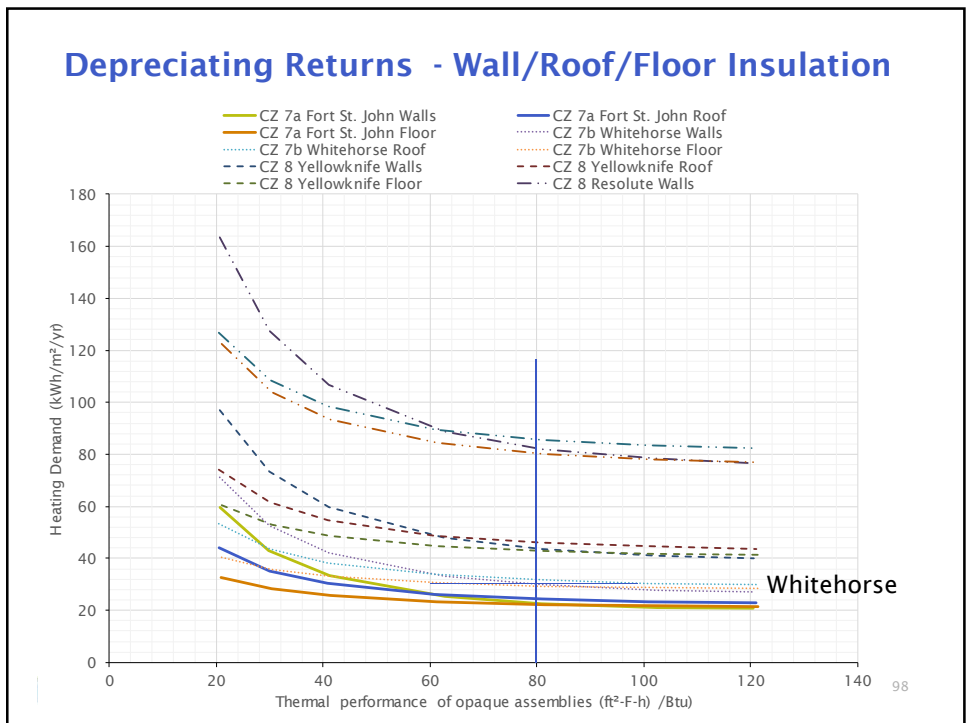
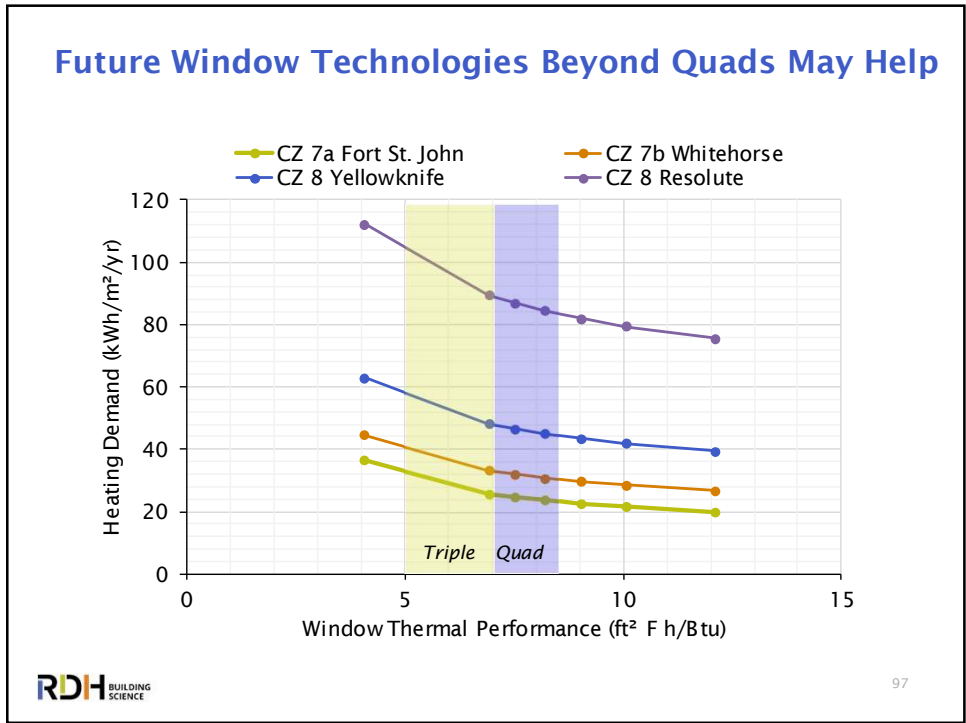
91

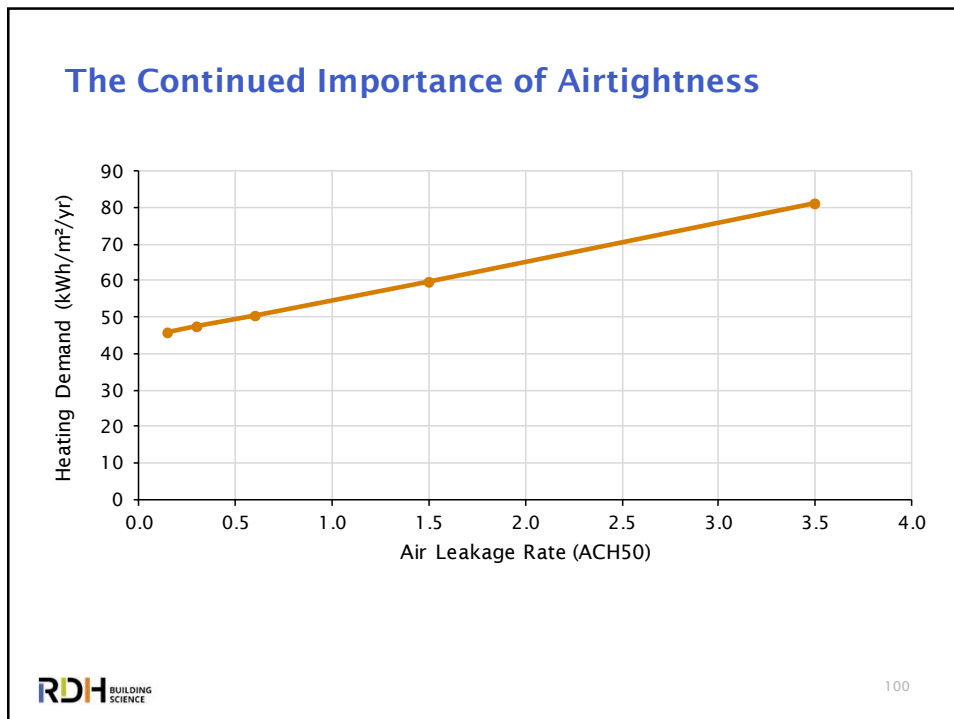
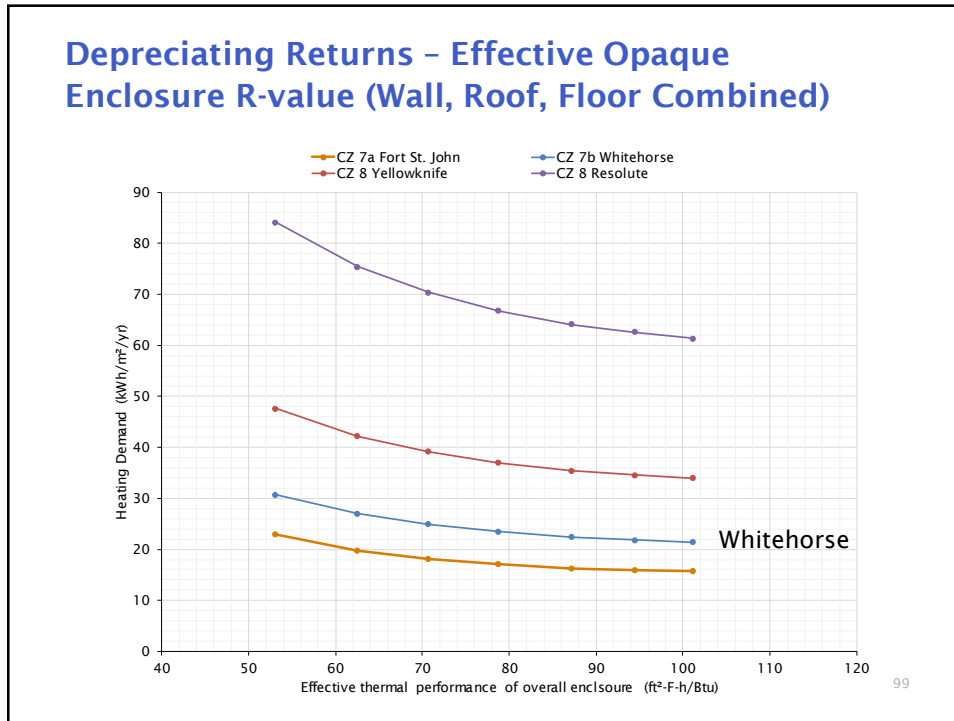
Impact of Articulation on Heating Demand



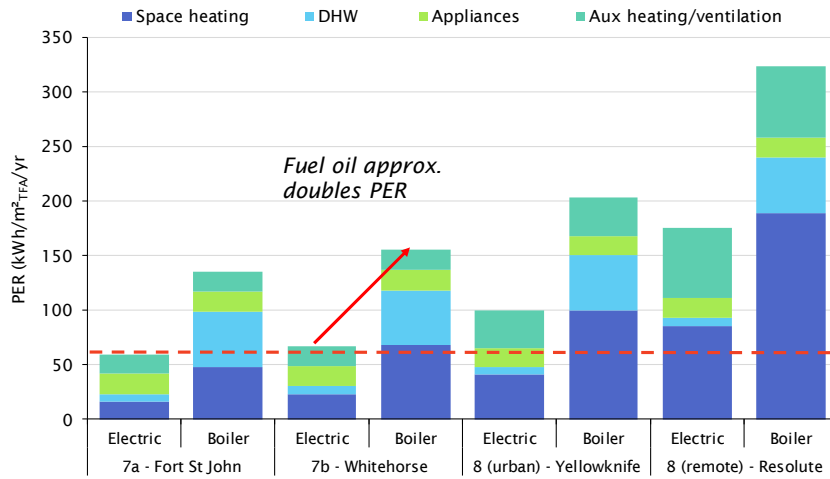






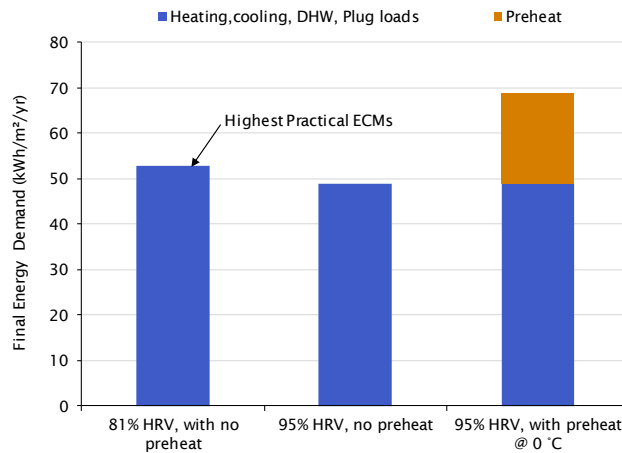


Need for Local Electrical Grid Reliability and Capacity

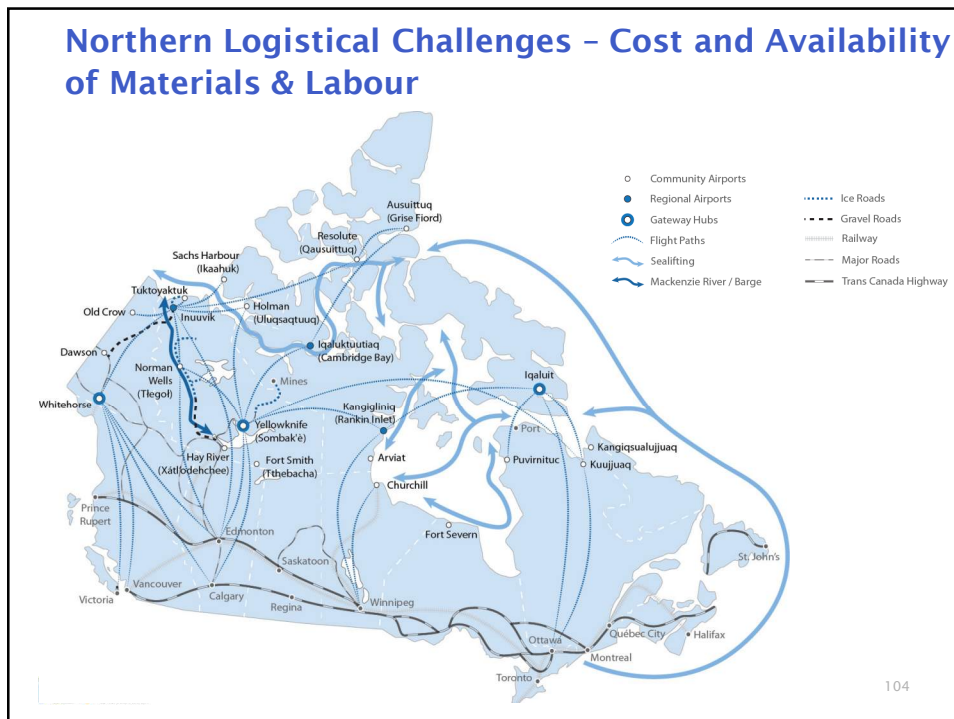
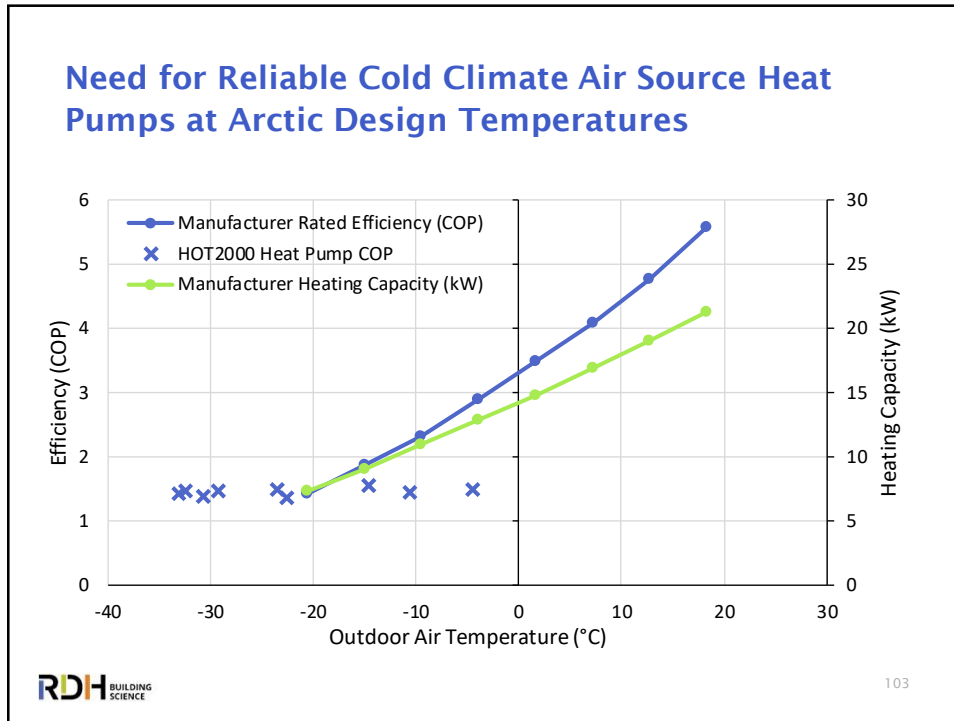


PHPP PER from modelling the simple form SFD with both electric (COPs ≥ 1.0) and fuel oil (93% efficient) systems.

Need for More Efficient HRVs without Need for Pre-Heat for Defrost



Comparison of different high performance HRV options. The 81% efficient dual core unit was used as the highest performing practical ventilation ECM instead of a 95% efficient HRV due to the additional preheat energy that would be required in the north (shown in orange for SFD in Yellowknife).



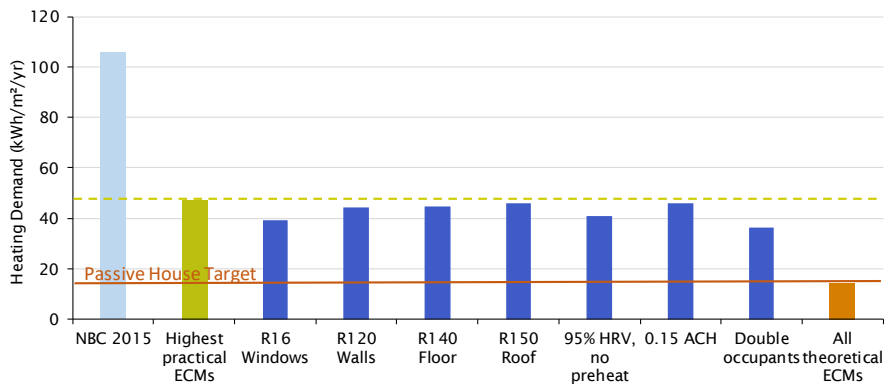
3 Pathways to Achieving the Highest Building Energy Performance Targets in the North

1. Technology - Use best of today within practical and cost effective means, future technology may be, but is not guaranteed to be the solution, plus we can't wait another 20 years
2. Minimum Energy Code Targets for Arctic need to be adjusted from Southern Canada. Passive House Practicality?
3. Think Bigger - Community Scale Net Zero Energy Ready



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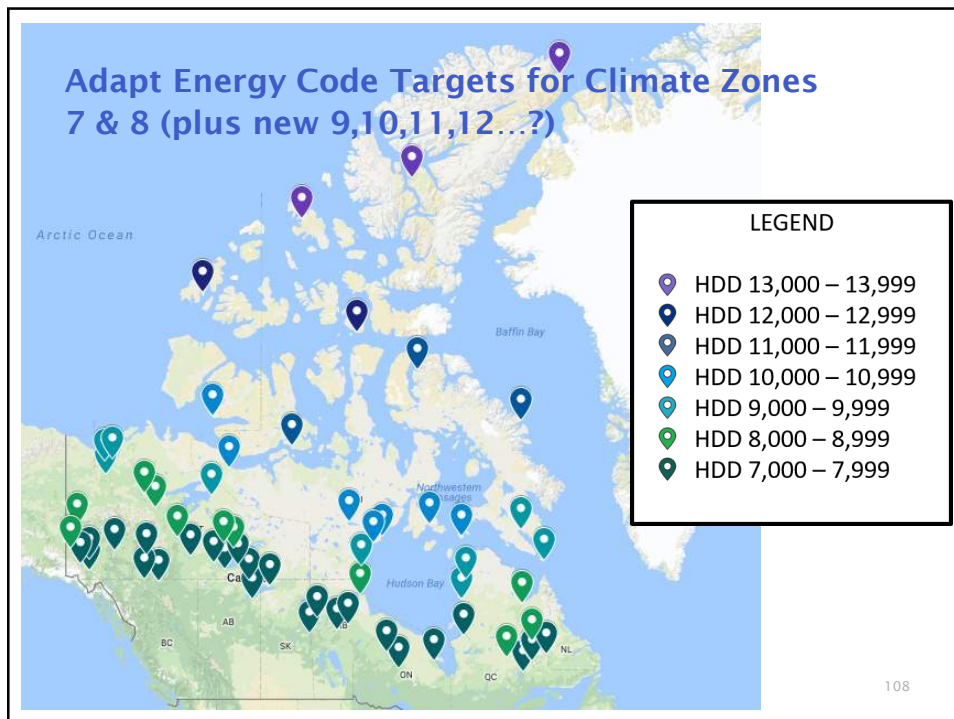
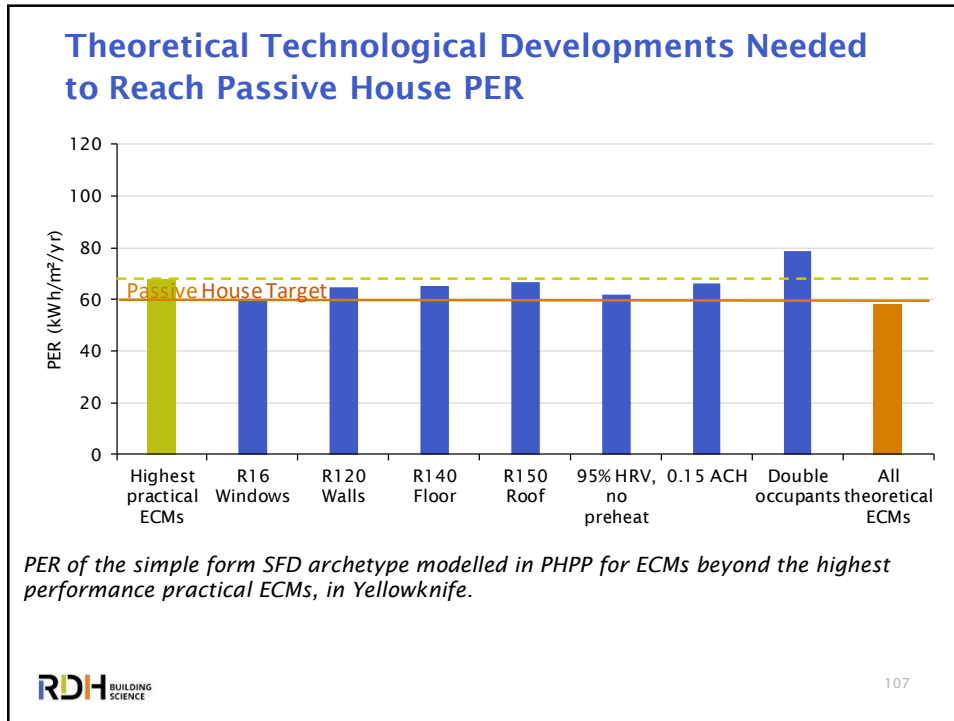
Theoretical Technological Developments Needed to Reach Passive House Heating Demand



Heating Demand of the simple form SFD archetype modelled in PHPP for ECMs beyond the highest performance practical ECMs, in Yellowknife. NBC 2015 baseline TEDI is shown for comparison (light blue), modelled in HOT2000.



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Net Zero Communities instead of Buildings

- May be more practical way of achieving net zero energy goals in remote regions, and already becoming a necessity to reduce reliance on fossil fuels and reduce GHGs & cost
- For buildings powered by community utility - would be reasonable to set a “near net zero” energy budget (i.e. Step 4/5 Levels?) factored by available generation capacity



Key Takeaways

- Literature Review
- Energy Modeling Tools
- Energy Compliance with Upper Steps & Passive House
- Costing SFDs and MURBs
- Challenges & Solutions



Discussion + Questions

FOR FURTHER INFORMATION PLEASE VISIT
→ www.rdh.com

OR CONTACT US AT
→ gfinch@rdh.com - 250-479-1110

The graphic features a dark background with abstract, glowing shapes in blue, green, and yellow. A vertical yellow line is on the left side. The RDH logo is at the bottom left, with 'RDH' in large letters and 'BUILDING SCIENCE' in smaller letters to its right.