

Low-Exergy Climate Adapted Buildings and Technologies

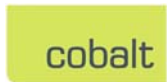
In Association with: **CEATI, BC Hydro, Manitoba Hydro, Hydro-Québec**

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A member of Integral Group

Overview

- Study Background & Objectives
- Energy Fundamentals
- Study Methodology
- Passive Design Principles
- Low-Exergy Building Design Approach
- Sample Study Results
- Conclusion

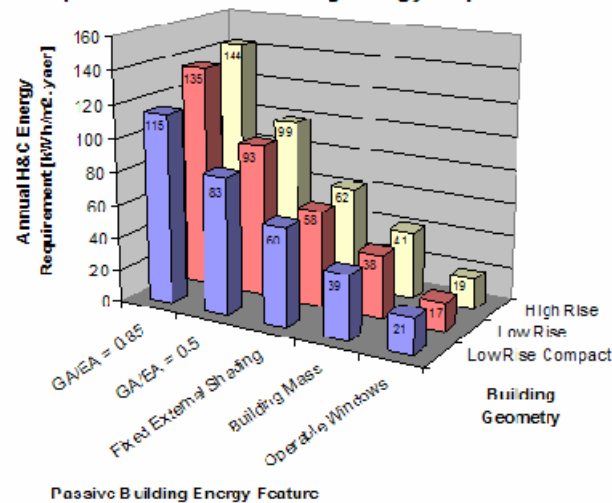
Study Background & Objectives

- Inspired by Vancouver's Passive Design Toolkit
- Need for clear and measurable energy performance targets/benchmarks

Passive Design Toolkit

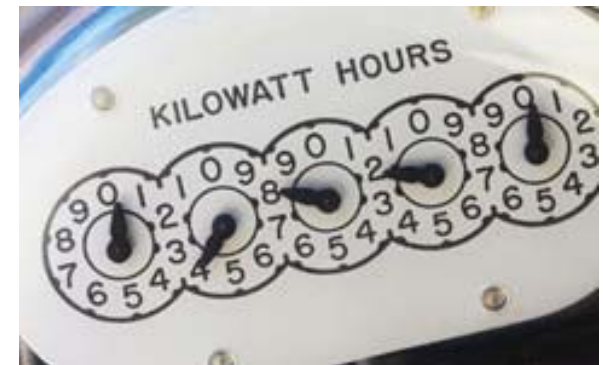


Example A SHRAE 90.1 Building Energy Requirements



Building Energy Standards

- North America - ASHRAE 90.1 (US), MNECB (Canada)
 - Energy performance is a moving target
 - Relative comparison to an unclear baseline
 - measured in non energy units
- European Union – “EPB Directive 2002/91/ES”
 - Provides clear & measurable target
 - Energy Intensity in (kWh/m². year)



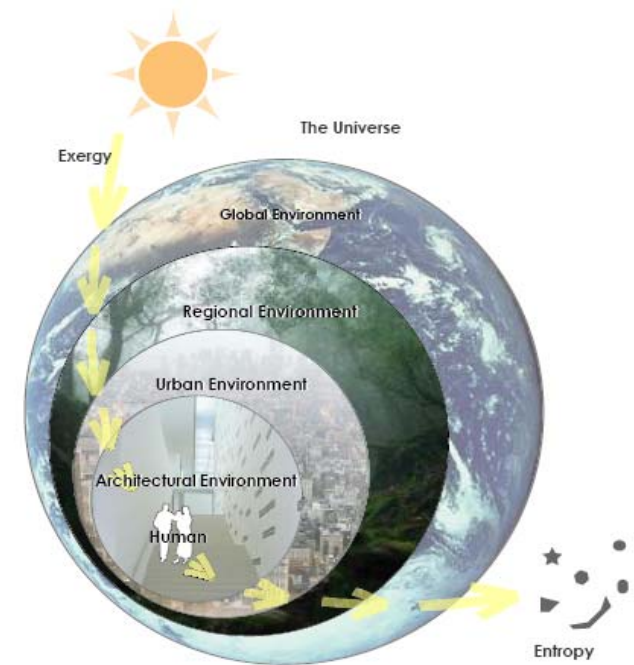
Energy Efficient Design Focus

- Energy quantity reduction “conservation”
- Do we really need to “conserve” energy?



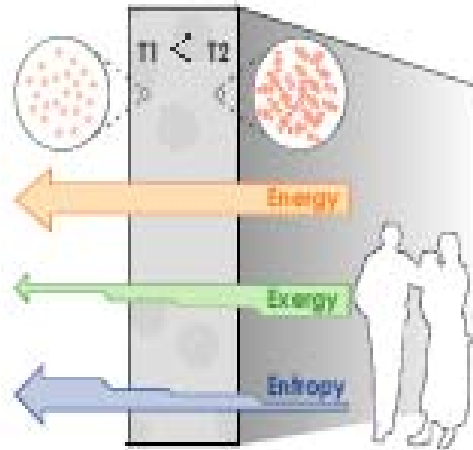
Energy Basics

- 1st Law of Thermodynamics
 - Energy cannot be created or destroyed
- There is no need to conserve energy
- What do we need to conserve?
 - **High quality Energy Sources**
 - **Fuels**

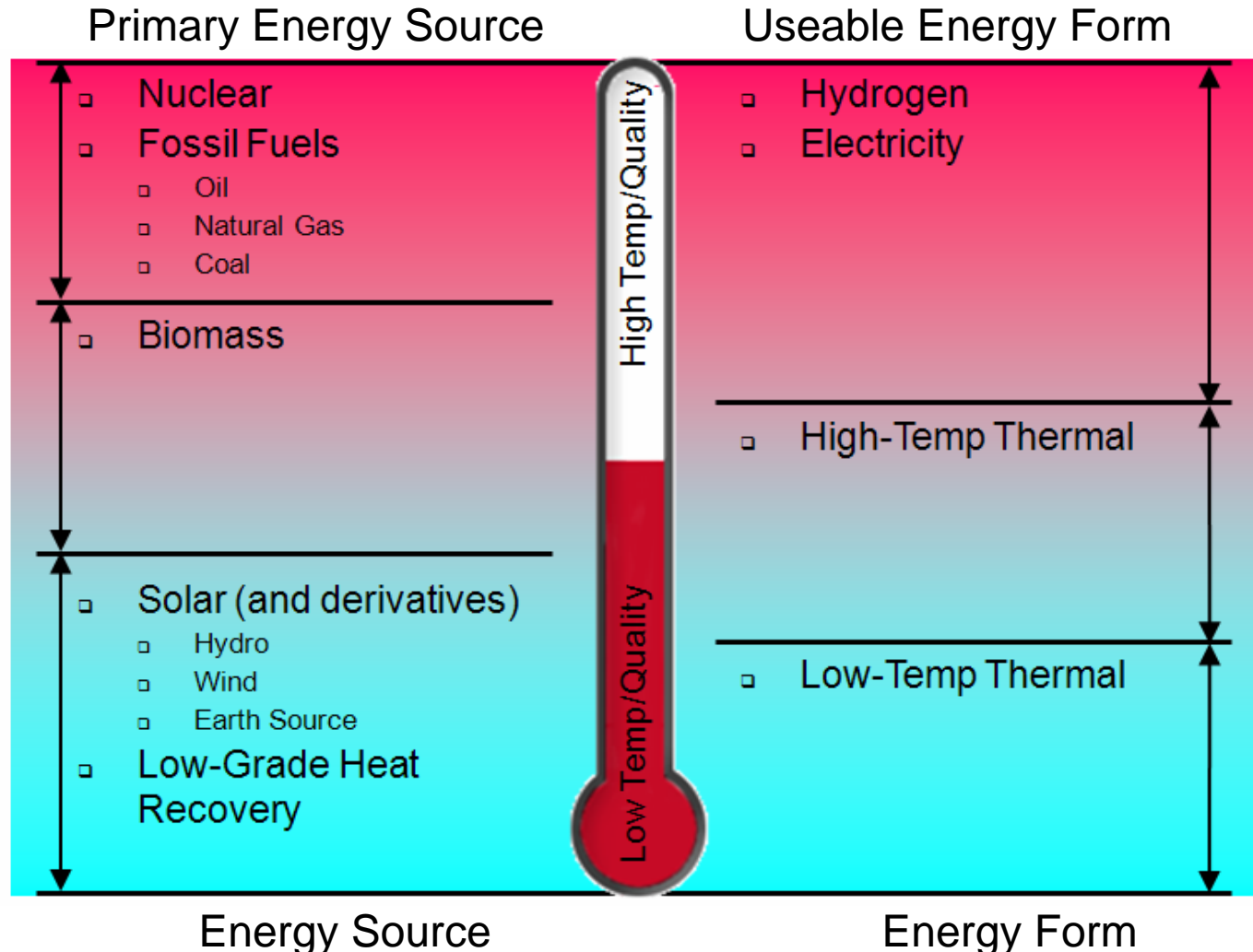


Energy – Exergy – Entropy

- Energy – the quantity stays constant
- Exergy – the quality of energy
- Entropy – cumulative degradation of energy quality



Exergy = Energy Quality



Why do we use Fossil Fuels?

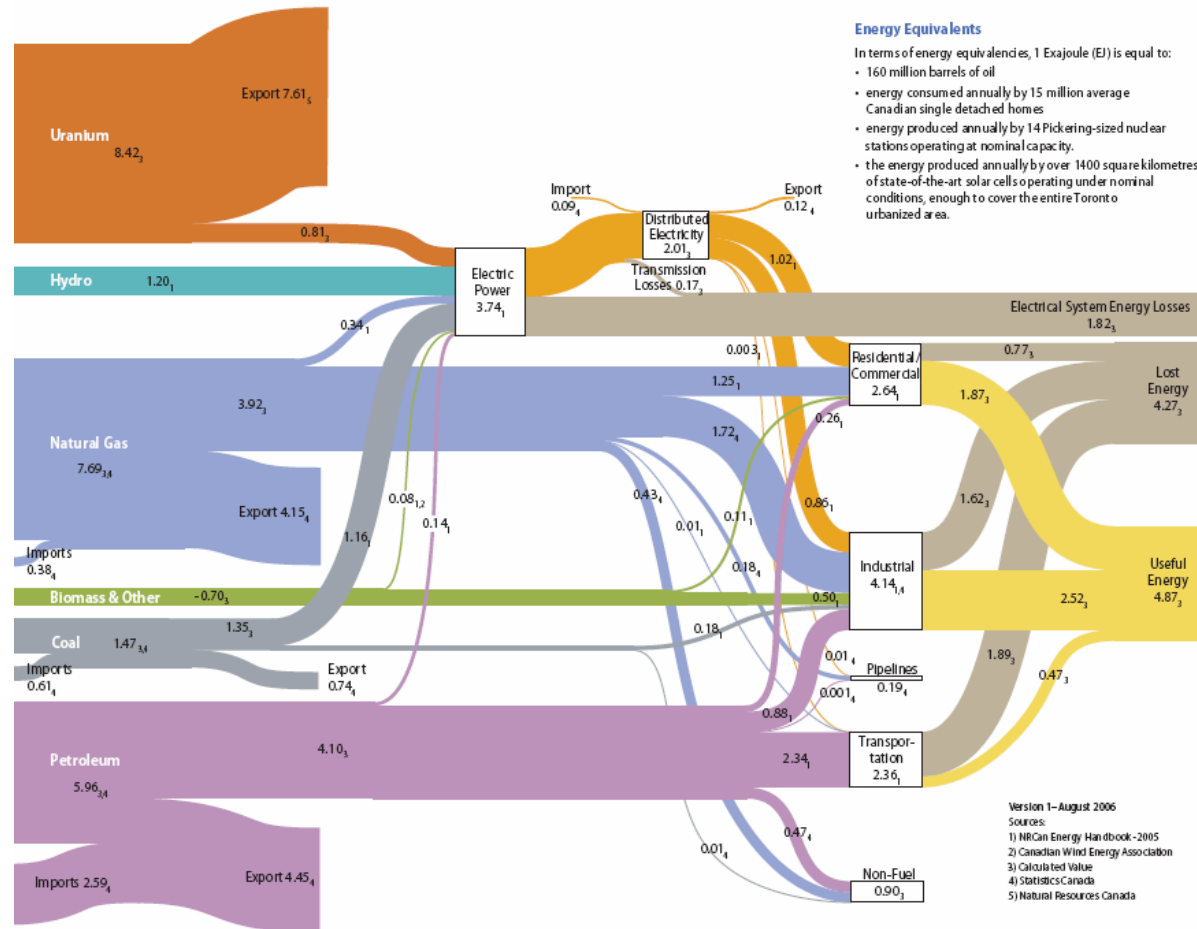
- Energy density – what counts:
 - Oil/gasoline - 9.0 kWh/l (13.5 kWh/kg)
 - Coal - 6.24 kWh/l (6.6 kWh/kg)
 - Biomass (wood) - 2.1 kWh/l (5.0 kWh/kg)
 - Propane gas* - 0.025 kWh/l (13.9 kWh/kg)
 - Natural gas* - 0.010 kWh/l (12.1 kWh/kg)
 - Hydrogen H₂*
(* at STP) - 0.002 kWh/l (39.0 kWh/kg)



Petroleum – the most energy dense fuel available on our planet !

Canadian Energy Utilization

- 72% of our primary energy resources are exported
- 70% of our energy needs are covered by fossil fuels
- 41% efficiency: overall primary energy input/ net energy output
- Net electricity output equals to 17% of our primary energy input



Energy Footprint of Buildings

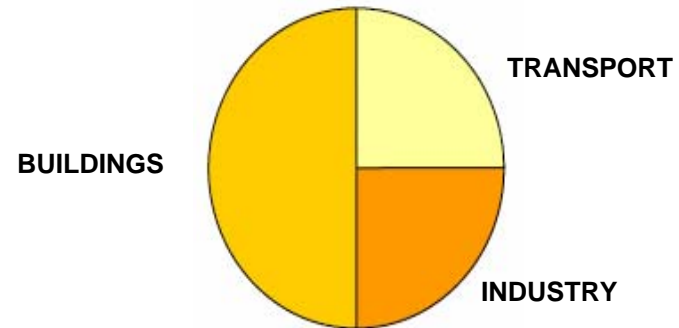
Energy Use in Buildings

- “..is the single greatest environmental impact of a building..”
- Electricity consumption in commercial buildings doubled between 1980-2000

Buildings Are Not Mobile!

- How can we minimize their dependence on fossil fuels and electricity?

Global Energy Use



Common Building Practice

- Cooling dominant buildings in a heating dominant climate
- Simultaneous heating and cooling
- Sealed glass buildings with no shading
- Air as dominant energy transfer medium - Forced-Air HVAC
- High system operating temperatures
- Reliance on high-grade energy: fossil fuels and electricity



Building Energy Use Benchmarks

- Why do we need them?
 - Clear performance target
 - Measurable
- Energy Use Intensity [kWh/m².year]
- Reference Building Types
- Reference Building Geometry
- End Energy Use Intensity
- Total Energy Use Intensity



Study Methodology

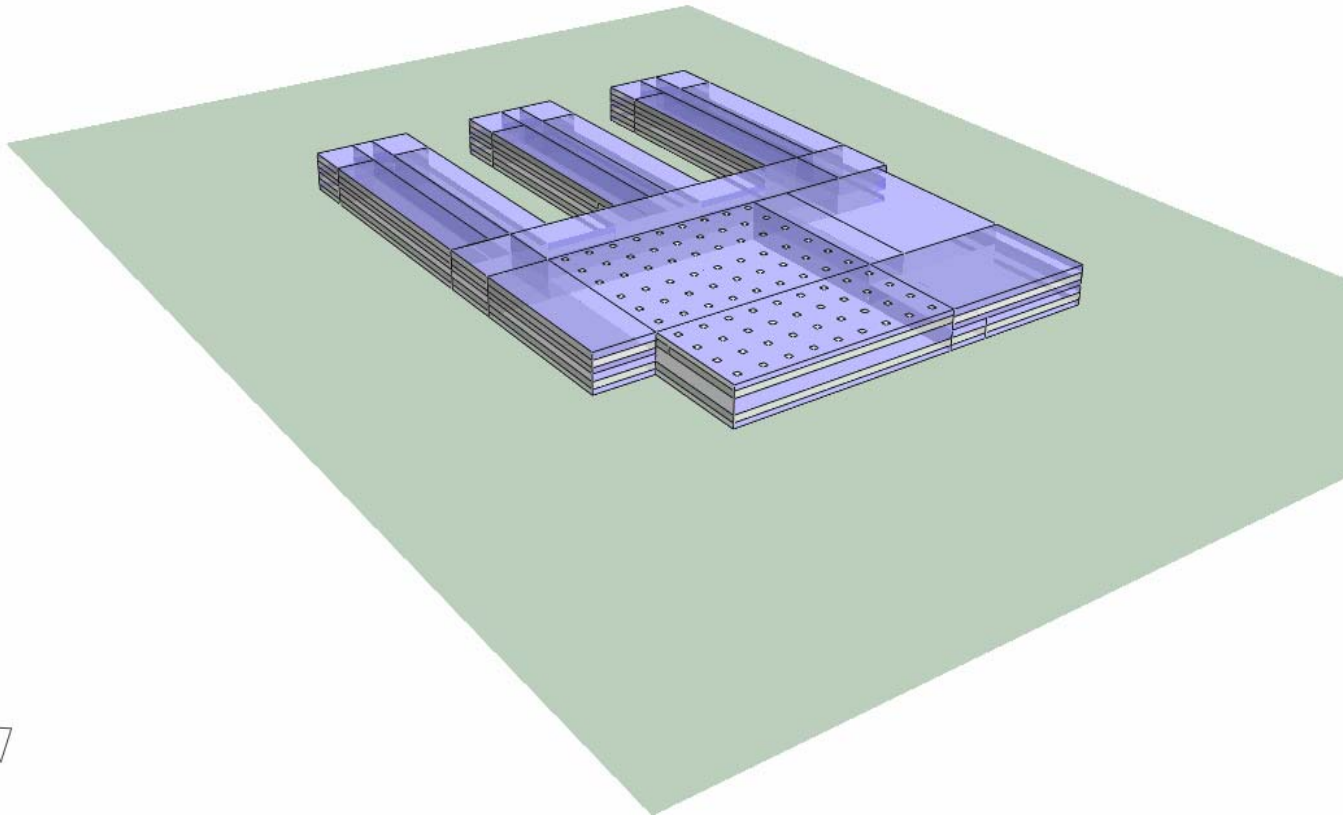
- Parametric Energy Modeling in IES (VE)
- Calibrated against:
 - ASHRAE 90.1 2007 Baseline performance
 - 4 US DOE Reference Building Types
- 2 Representative ASHRAE Climate Zones: #5&7
- 10 Passive Measures
- 7 Active Systems/Technologies
- In total: 88 models, 264 model iterations

Representative Building Types

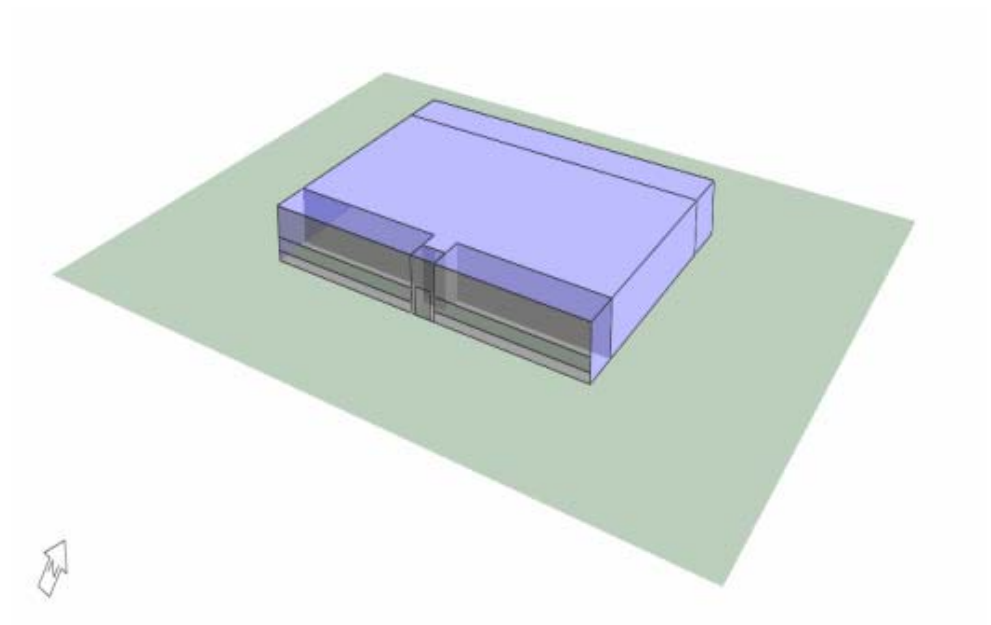
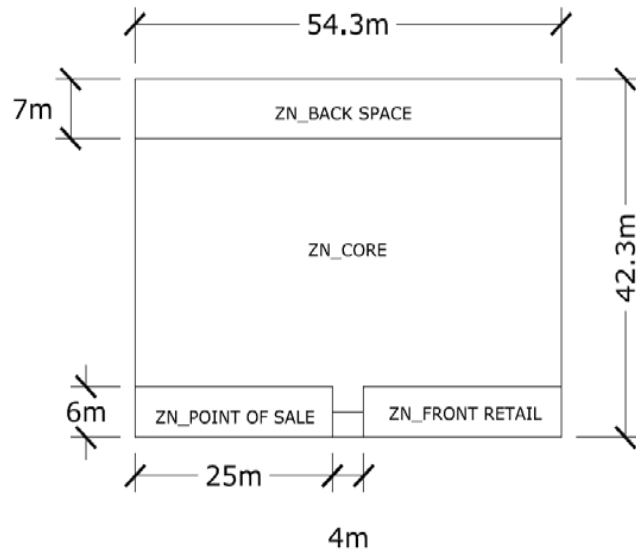
- US DOE Reference Buildings
- This Study – 4 Building Types:
 - Retail (stand alone “big box”)
 - Secondary School
 - Office (high-rise)
 - Residential (high-rise & Low-rise)



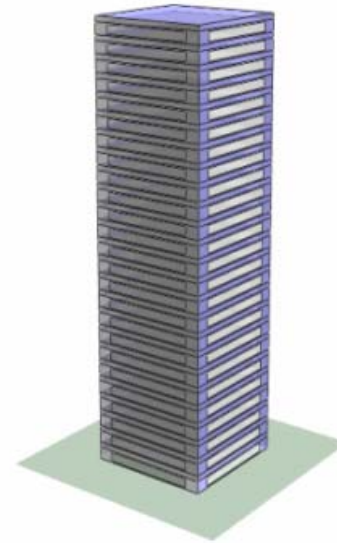
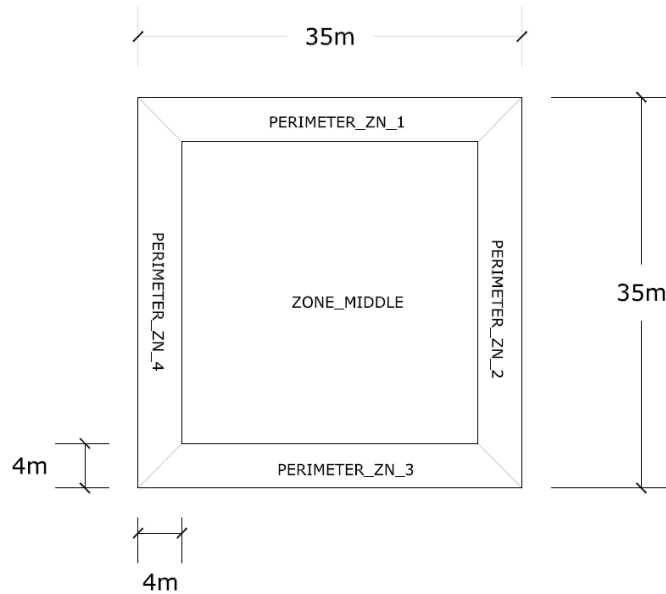
Secondary School



“Big-Box” Retail

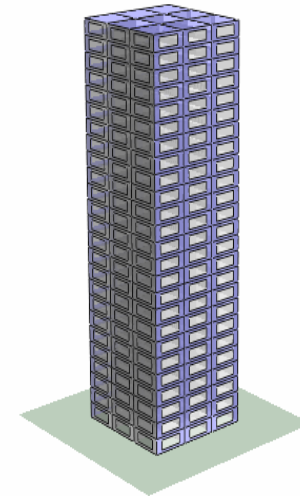
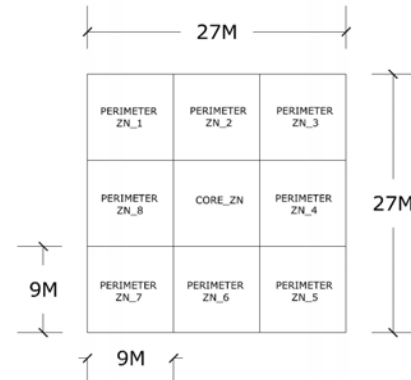
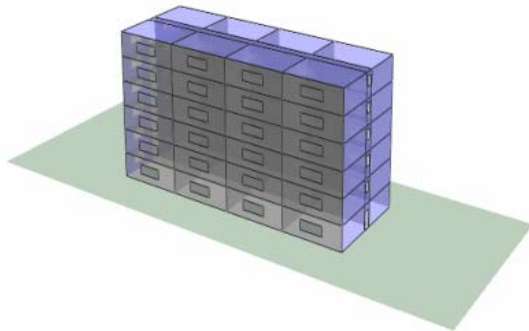
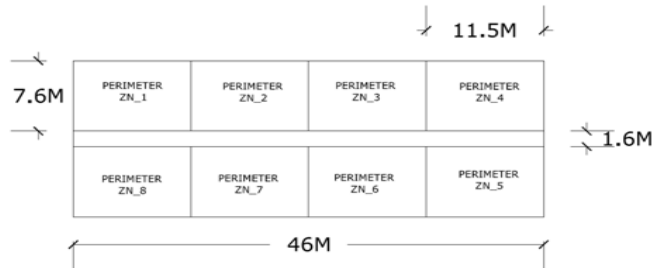


High- Rise Office

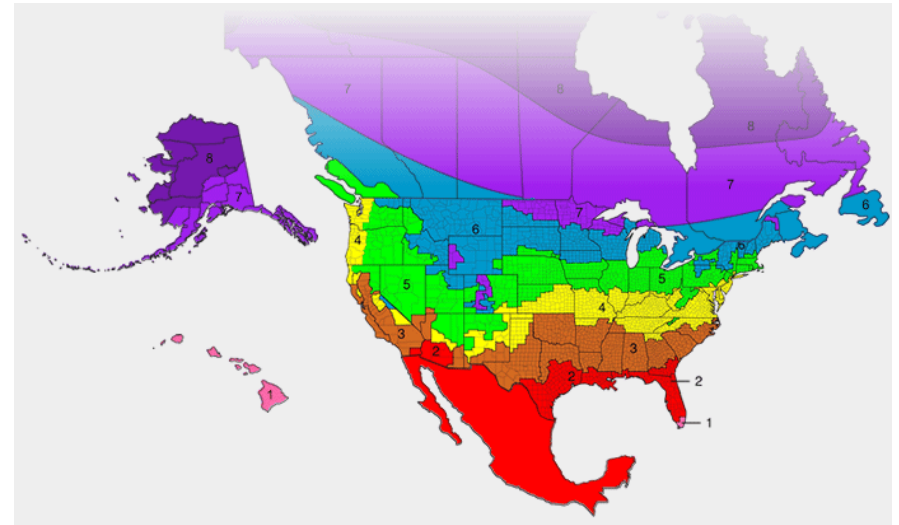


Residential: High & Low - Rise

- High-Rise : Climate Zone 5
- Low-Rise: Climate Zone 7



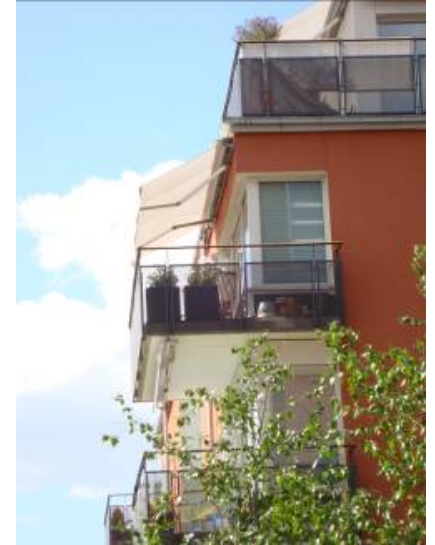
ASHRAE Climate Zones



- Defined by Heating Degree Days
- Modeling results are unique to each specific location
 - Climate Zone 5 – Vancouver, BC
 - Climate Zone 7 – Winnipeg, MB
- Limitations of ASHRAE Climate Categorization system

Analyzed Passive Measures

- High Performance Façades
 - Glazing & Opaque Wall
- Glazing areas
- Solar shading
- Thermal mass
- Infiltration
- Cooling by Natural Ventilation
- Buffer Space
- Daylighting



Analyzed Passive Measures

Revised Baseline Passive Measure		Climate Zone 7			
		Retail	Secondary School	Office	High-Rise Residential
Glazing Performance	U-value - 3.5 W/m ² .°C	-	-	-	-
	U-value - 0.8 W/m ² .°C	✓	✓	✓	-
Opaque Envelope	U-value - 0.5 W/m ² .°C	-	-	-	-
	U-value - 0.1 W/m ² .°C	✓	✓	✓	-
Roof Insulation	U-value - 0.15 W/m ² .°C	✓	✓	✓	-
Infiltration	0.1 ACH	✓	✓	✓	-
Thermal Mass	100mm Concrete	✓	✓	✓	-
Glazing Ratio	20%	-	✓	✓	-
	40%	-	-	-	-
	70%	-	-	-	-
Natural Ventilation	Openings equivalent to 5% of floor area	-	✓	-	-
Solar shading	Overhang depth = 300mm	-	-	-	-
	Overhang depth = 2400mm	-	-	-	-
Buffer Space	900mm deep exterior balcony	-	-	✓	-
Daylighting	Artificial lighting to control to 300 lux	-	✓	✓	-

Passive Design Principles

- Understand and Respect Local Climate!
- Passive protection from external environment
 - Building form
 - Optimized building envelope
- Passive retention of beneficial energy
 - Thermal mass
- Passive rejection of undesirable energy
 - Cooling by natural ventilation
- Passive capture of on-site renewable energy
 - Passive solar – “Low-Exergy” design
- Result: “Climate Adapted Design”



Analyzed Active Technologies

- DOAS ventilation with heat recovery
- Displacement ventilation
- Radiant slab heating & cooling
- Condensing boilers
- Water-to-water heat pump
- Photo-voltaics
- Solar thermal



Analyzed Active Technologies

Active Measure		ASHRAE 2007 Baseline Systems				Climate Zone 7			
		Retail	Secondary School	Office	Low-Rise Residential	Retail	Secondary School	Office	Low-Rise Residential
Space Heating/Cooling	Hydronic/radiant	-	-	-	✓	✓	✓	✓	✓
	Forced Air/Convection	✓	✓	-	-	-	-	-	-
	Mechanical Cooling	✓	✓	-	✓	✓	✓	✓	-
Technology	Standard Efficiency Boiler	-	✓	✓	-	-	-	-	-
	PTAC	-	-	✓	✓	-	-	-	-
	Packaged RTU	✓	✓	-	-	-	-	-	-
	Zoned VAV	-	✓	✓	-	-	-	-	-
	Condensing Boiler	-	-	-	-	✓	✓	✓	-
	Displacement Ventilation	-	-	-	-	-	✓	✓	-
	DOAS Ventilation Heat Recovery	-	-	-	-	✓	✓	✓	-
	Water to Water Heat Pump	-	-	-	-	✓	✓	✓	-
Photovoltaics	-	-	-	-	✓	✓	✓	-	
Solar Thermal	-	-	-	-	-	-	-	✓	
Energy Source	Conventional	Fossil	✓	✓	✓	✓	✓	✓	✓
		Grid Electricity	✓	✓	✓	✓	✓	✓	✓
	Renewable	Solar PV Elec.	-	-	-	-	✓	✓	-
		Solar Thermal	-	-	-	-	-	-	✓

Low-Exergy Building Design

- Minimize the building's energy demand by effective passive design and energy recovery
- Choose Building Systems with the lowest possible system operating temperature and low-grade energy
- Limit building's dependence on high-grade energy (Electricity and fossil fuels)
- Harness on-site renewable low-grade energy sources (Solar and its derivatives)



Sample Energy Modeling Results

		Building Type	ASHRAE 90.1 Baseline	Optimum Passive	Optimum Active
		kWh/m2.yr			
Climate Zone	5	Retail	224.8	161.2	100.7
		School	177.7	102.5	65.2
		Office	117.9	90.1	87.3
		High-rise Res.	119.4	55.0	46.4
	7	Retail	393.4	279.6	111.9
		School	297.9	191.0	78.7
		Office	182.8	123.0	92.2
		Low-rise Res.	215.8	100.8	86.6

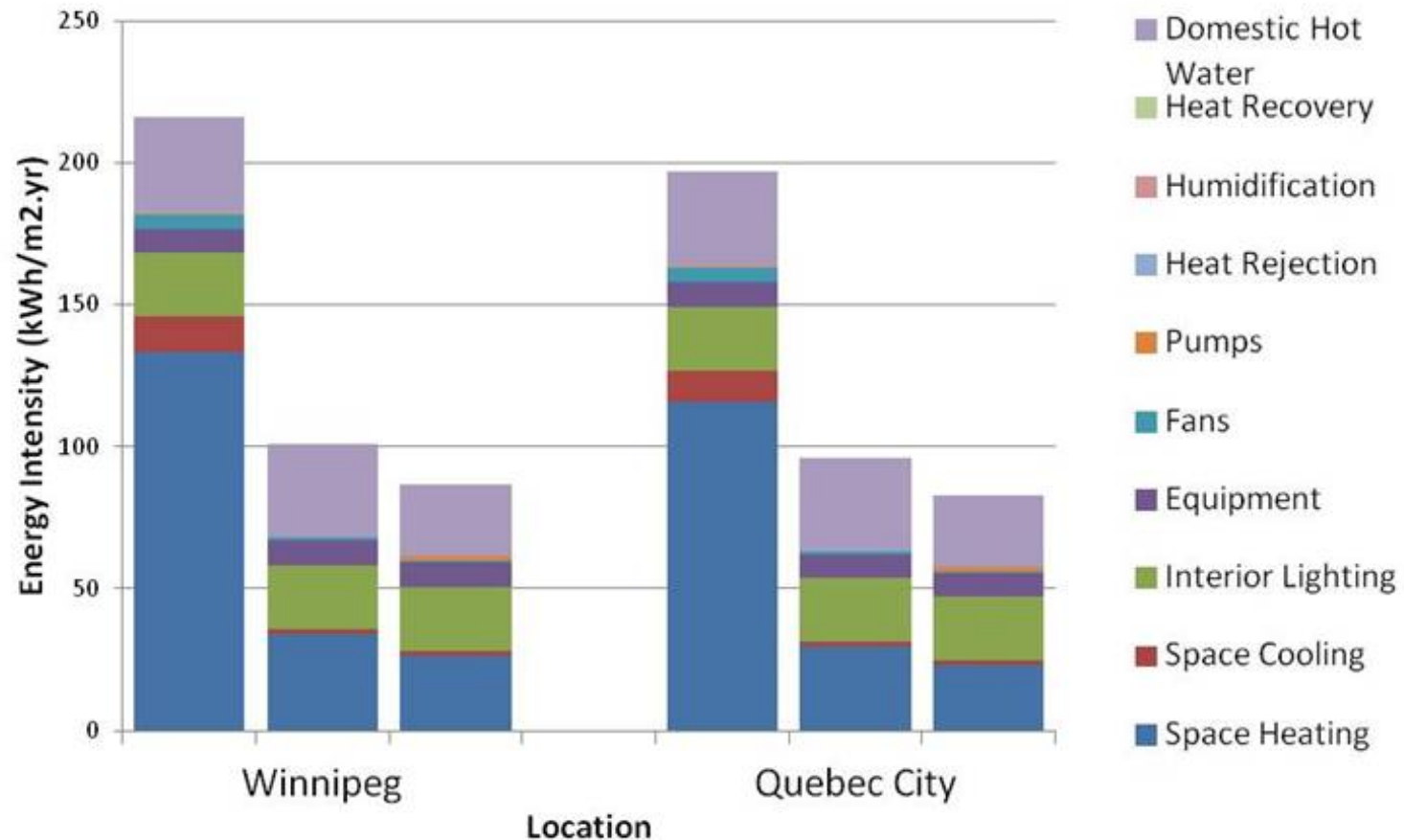
Extrapolation for Other Locations

- “Rough” Approximation Methodology
- Using Heating and Cooling Degree Day Ratios

		Winnipeg			Quebec City		
		HDD (18°C) = 6032			CDD (10°C) = 991		
		HDD (18°C) = 5249			CDD (10°C) = 873		
Energy End-Use	Baseline	Optimal Passive Design Baseline	Optimal Passive & Active System	Baseline	Optimal Passive Design Baseline	Optimal Passive & Active System	
	kWh/m ² .yr						
Space Heating	133.3	34.3	26.6	116.0	29.8	23.1	
Space Cooling	12.4	1.6	1.6	10.9	1.4	1.4	
Interior Lighting	22.5	22.5	22.5	22.5	22.5	22.5	
Equipment	8.5	8.5	8.5	8.5	8.5	8.5	
Fans	5.0	1.0	0.4	5.0	1.0	0.4	
Pumps	0.5	0.1	1.7	0.5	0.1	1.7	
Heat Rejection	0.8	0.1	0.1	0.8	0.1	0.1	
Humidification	-	-	-	-	-	-	
Heat Recovery	-	-	-	-	-	-	
Domestic Hot Water	32.8	32.8	25.2	32.8	32.8	25.2	
TOTAL	215.8	100.9	86.6	197.0	96.2	82.9	

Québec City Extrapolation

- Extrapolated Energy Use Intensity for Low-Rise Residential



Life Cycle Cost Evaluation

- Capital cost premiums estimated based on recent cost of similar projects
- Current utility rates for Electricity and Nat. gas
- Paybacks – greater than 10 years!!



Conclusions

- Low-Exergy Climate Adapted building design can significantly reduce building energy use
- Relatively “low” cost of energy in Canada
- Results in long payback >10 years
- Non-stringent energy code requirements
- Free-Market will NOT shift the building industry towards significant reduced energy use without:
 - Government Legislation
 - Industry Standards
 - Higher Energy Cost
 - Incentives (BC Hydro...)





Thank You!