Basic Building Science




House as a System

What is Building Science?

- *involves study of building materials*
- *includes the study of building components, building details and methods of construction*
- *consist of taking a detailed look at the "dynamic interaction between variables such as the impact of temperature, air, water and moisture"*
- *interaction of these various systems*
- *often referred to as "building physics or building dynamics"*

Goals

Upon completion of this webinar the participant will:

- *differentiate basic concepts of building science*
- *identify various factors that influence the "house as a system"*
- *recognize conditions that contribute to problems in residential construction*
- *understand the importance of air quality, ventilation and impact of combustion spillage*
- *be familiar with the importance of healthy housing concepts*

The House as a System

- concept sees the house as a total environment made up of the building envelope plus the contents
  - building envelope defines the separation of outdoor environment to the indoor space
  - contents are made up of the occupants and the mechanical systems.

House = Building Envelope + Occupants
Contents = Occupants + Mechanical Systems

These 3 elements: **building envelope, occupants and mechanical system** together with the outdoor climate and soil conditions and have a consequence on the house. These interplay with key characteristics of air, heat and moisture.

The House as a System

- component systems of a home are interrelated
- changing one part without consideration of the others can create a domino effect with negative outcomes
- change to one part of the system will affect other parts of the system
- became apparent when the building industry increased envelope tightness only to find decreased home performance in air quality and moisture control
- homes built tighter - indoor air quality decreased and moisture issues cropped up
- to counter such problems, moisture and water must be kept out of the structure, combustion appliances such as furnaces and water heaters properly ventilated, and fresh air provided through controlled, mechanical ventilation

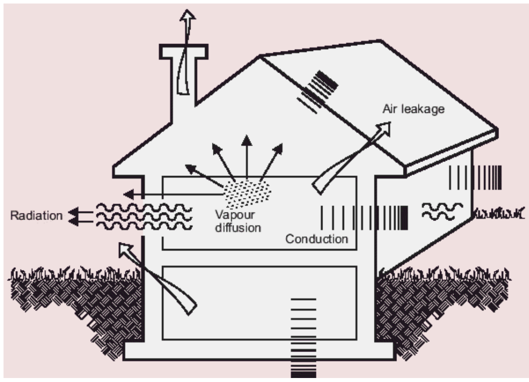
(HAAS) House as a System

- house much more than the 4 exterior walls and a roof
- interactive system: made up of many components, structure, building envelope, mechanical, and electrical
- each component impacts the performance of the entire system
- buildings perform in very predictable fashion
- these performance characteristics are based on a few simple principles of physics
  - *Moisture and air movement, dew-point temperature, pressures & heat flow*
- although solid design and building structure provides a good starting place for a healthy home, proper and ongoing maintenance is important for both interior and exterior components to function as designed

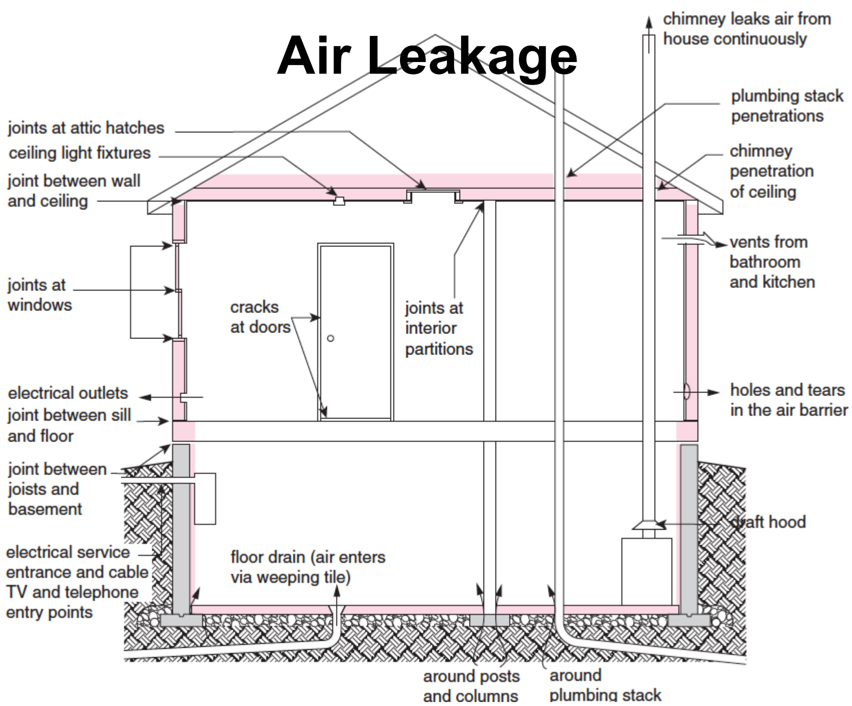
General Principles

The **main principles** that will help provide a better understand how a house performs are:

1. Moisture/air movement
2. Dew-point temperatures
3. Pressures
4. Heat flow



Air Leakage



1. Moisture Movement

Problems often related to liquid water or water vapour finding its way in or out of the building envelope. There are 5 mechanisms of moisture migration:

1. **Gravity** – downward flow of liquid water due to gravity.
   Example - condensation on windows collecting on the bottom sill.
2. **Capillary action** – upward movement of liquid water through narrow spaces.
   Example – water traveling up through porous masonry or tightly lapped siding.
3. **Pressure difference** – liquid water pushes through cracks in building elements due to pressure differential across the material.
   Example – water leaking in through cracks in a foundation wall.

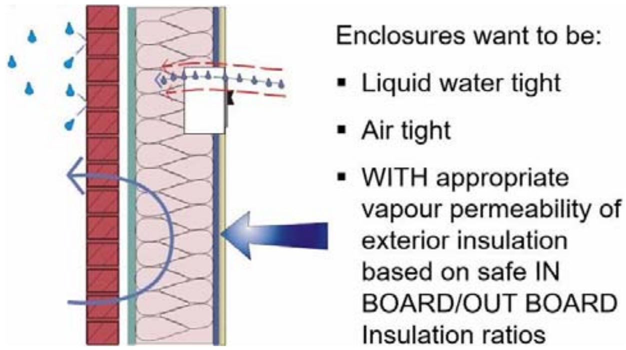
Moisture Movement

4. **Air transport** – water vapour carried by airflow.
   Example - warm, humid inside air exfiltrating through unintentional gaps in the building envelope.
5. **Vapour diffusion** – depending on the permeability of the building envelope, varying amounts of water vapour will diffuse through the material from the warm, humid inside air to the cooler, dryer outside air.
   Example: If it's cold outside, this means vapour diffuses from the warm air inside of the house to the colder outside of the house.

Remember that all of these can drive water into a wall assembly!

Weather Barrier

- protects the wall assembly from the effects of wind, rain, snow & sun
- must trap air and keep it still to be effective
- located toward the outside of the building envelope to prevent the circulation of outside air
- helps protect the envelope components from outside moisture sources



2. Dew-point Temperatures

- the temperature at which water vapour in the air becomes saturated and begins to condense as drops of water *(Example: 67F = 19.4C & 25F = -3.8C)*
- a function of temperature and relative humidity
- when the air at a particular temperature is at 100% relative humidity, it is said to be saturated

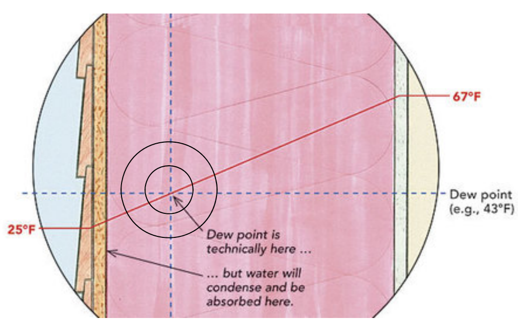
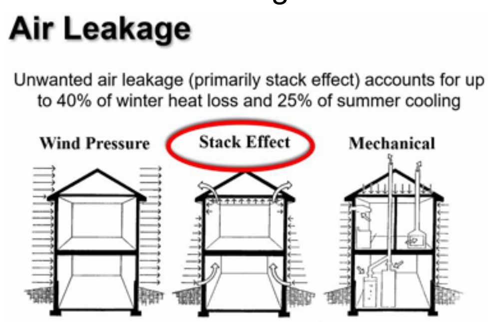


Image credit: Fine Homebuilding

3. Pressures

- air flows into or out of a structure due to pressure difference
- air flows from high pressure to low pressure
- heated air becomes less dense and rises
- **stack effect** is the positive pressure that forces air out of the envelope at the ceiling area and upper wall or upper floor levels and draws cooler air in through the lower portions of the building.



Pressures

- mechanical ventilation, such as a bathroom or kitchen exhaust fan creates a negative pressure, drawing outside air in through openings in the building envelope
- negative pressure can also cause flue gases to reverse and spill back (back-draft) into the basement or lower levels of the home with the potential for serious consequences

  Example: can cause carbon monoxide poisoning of the occupants.

Air Infiltration

- increasing insulation reduces the drying potential of an assembly
- walls “do not breathe” but they do need protection from water & moisture
- low permeability exterior insulation can be used as long as the in-board/out board insulation levels are appropriate
- limiting air infiltration reduces potential moisture damage inside walls
- predominant source of moisture in enclosures comes from air leakage, not vapour diffusion

What’s the difference?

Air vs. Vapour Barrier

Air Barrier (AB) Criteria

- Resistant to air flow
- Not necessarily impermeable to moisture flow
- Installed anywhere in building envelope assembly
- CONTINUOUS, by sealing all seams, edges, gaps, holes, etc.
- DURABLE during construction and for the expected life of building
- Rigid and strong enough to withstand air-pressure differences

Vapour Barrier (VB) Criteria

- Impermeable to moisture flow
- Not necessarily resistant to air flow
- Installed on the warm side of the insulation
- Must cover as much surface area as possible, NOT necessarily CONTINUOUS
- DURABLE during construction and for the expected life of building

4. Heat Flow Mechanisms

Heat flows through a house and also through the structure.

- It travels by conduction, convection and radiation.

Two important facts you should know about heat movement.

1. heat seeks a balance: applied to a home's air temperature, this means warm air always moves from a warm position to a colder one and vice versa; the greater the discrepancy, the faster the flow of heat.
2. heated air rises: unless it's stirred up, the air in a room tends to stratify; warm air collects near the ceiling, while cool air moves toward the floor.

Heat travels by:

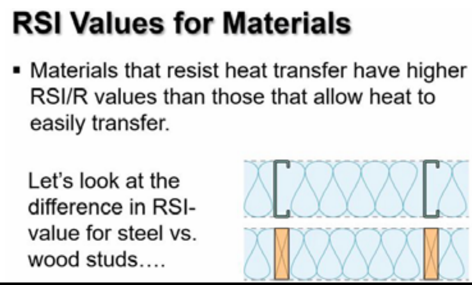
Conduction - transmission of heat from a warm body to a cooler body through direct contact between molecules. Conduction has little effect on actual heat loss.

Convection - transmission of heat through the movement of air from a warm surface to the surrounding air. Large temperature differentials and increased air motion induce more heat transmission by convection.

Radiation - transmission of electromagnetic waves of heat energy through the air from a warm surface to a cooler surface. Light colours reflect, while darker colours absorb heat. Poor conductors make good radiators. Radiant heat cannot go around corners and is not affected by air motion.

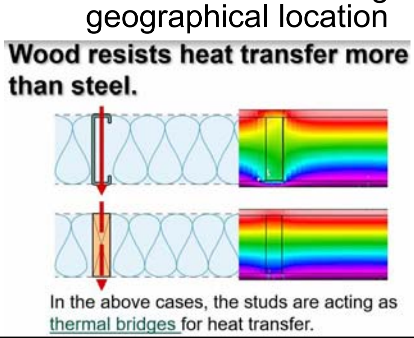
Heat Transfer

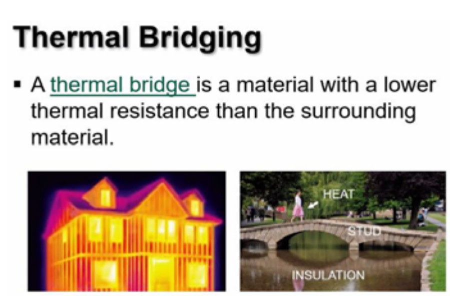
- heat moves through walls, windows, doors, and ceilings and also through the floor and basement of the structure
- insulation, sheathing and exterior finishes are used to control unwanted heat flow
- additionally, walls and other building components exposed to the sun often gain surface heat from direct exposure. This surface heating reduces the temperature difference across the component also the conductive heat loss



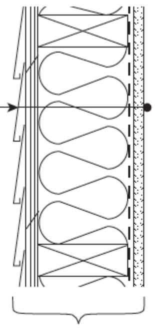
Insulation

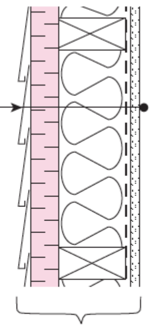
- insulation is the building component, which controls temperature directly, and indirectly affects the movement of moisture to and from building spaces
  - *example: insulation is rated according to its thermal resistance value, called the **RSI value** (or R-value in Imperial units), which measures a material's ability to resist heat flow*
- higher the RSI value, the better the material insulates
- minimum RSI insulation levels recommended for the retrofit of existing homes vary according to geographical location





Insulation





Thermal Resistance

RSI 3.52 (R20)	Nominal	RSI 3.43 (R19.4)
RSI 4.70 (R26.6)	Total nominal	RSI 4.48 (R25.4)
RSI 3.11 (R17.6)	Total effective[1]	RSI 3.40 (R19.2)

Measuring the transfer of heat

What about Air Flow Mechanisms?

- air flows into or out of a structure due to **temperature difference**
- air flows from higher pressure to lower pressure
- air also flows by forced air mechanical and some types of heating systems
- there is air movement into and out of a house through cracks and openings - referred to as **infiltration** and **exfiltration**
- above grade, moisture can dry to the outside or to the inside, depending on temperature & moisture conditions
- below grade moisture can only dry inward

Air Flow Mechanisms

- amount of air infiltration can be determined by air change method
- amount of **air changes per hour** a building experiences indicates its efficiency
- lower the number the better sealed the house is rated for efficiency
- building assemblies must be designed to resist the flow of air
- air leakage can contribute to heat loss and it can carry water vapour into wall cavities and lead to condensation

Air Requirements

Air requirements for a home may be categorized as follows:

- Ventilation air
- Combustion air
- Make-up air

Ventilation air can be provided either mechanically or naturally to provide fresh air for the occupants.

Combustion air can be provided mechanically or naturally to satisfy the requirements of combustion appliances.

Make-up air can be provided mechanically or naturally in order to enable the proper operation and control of negative house pressures.

Air Requirements – cont'd

- construction of tighter houses has often resulted in a higher interior humidity and air pressure differential
- these factors have combined to increase the accumulation of condensation moisture in framing and sheathing components
- creates serious concern about structural failure from wood decay

As homes become more airtight, they must have a ventilation system to provide adequate air exchange.

Indoor Air Quality

- best defined by describing what constitutes poor indoor air value
- house with sufficiently high concentrations of one or more pollutants that adversely affect the health or safety of the occupants has poor indoor air quality
- these pollutants can include excessive moisture, suspended particles in the air, gases given off by new furniture, and combustion gases spilling into the house
- some symptoms of poor indoor air quality may be obvious

  Example: mould growth on walls or a musty smell; others may be less obvious, such as radon gas or suspended particulates in the air

- conditions can often be contingent from health symptoms of the occupants or can be identified by specialized tests.

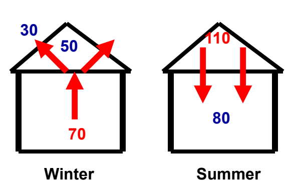
Indoor Air Quality

General strategies to correct IAQ problems include:

- Identifying sources, then removing or reducing the source, sealing or covering the source, or modifying the environment
- Improving ventilation to provide outside air to occupants and to dilute and/or exhaust pollutants
- Improving air filtration to clean air from outside and inside the building tests.

Climatic Factors

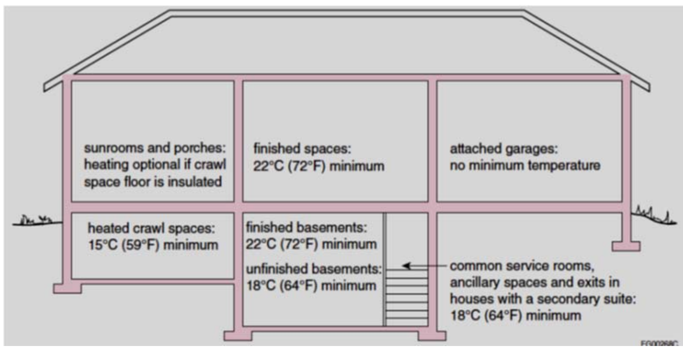
- most important effect of climate is its impact on our body perceived temperature
- air temperature and thermal comfort are affected by the sun, wind and precipitation
- air temperature impacts thermal comfort of the occupants. It’s generally too hot or too cold, and never seems to satisfy everybody all the time.



Temperature Degrees Fahrenheit

Indoor Design Temperatures

Buildings are required to maintain specific indoor design temperatures. In Canada the 2.5% design temperature is normally used as the basis to design heating systems for cold climates. This means statistically the measured outdoor temperature is lower than the design temperature about 2.5% of the time.



Air Temperatures

The air temperature is the most important climatic factor because of the relationship between both human comfort and energy consumption.

Compare the heating degree-days between Winnipeg Manitoba and Ajax Ontario (east of Toronto).

Winnipeg consumers will likely spend almost 50% more on energy heating their homes compared to a Toronto homeowner – unless appropriate steps are taken to reduce this factor.

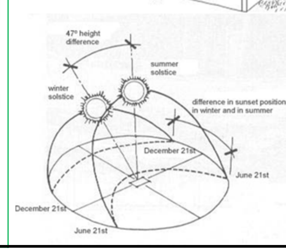
Let's take a look at the data on the next slide

Table C-2 (Continued)

Province and Location	Elev., m	Design Temperature January 2.5% °C	January 1% °C	July 2.5% Dry °C	July 2.5% Wet °C	Degree-Days Below 18°C	15 Min. Rain, mm	One Day Rain, mm	Ann. Tot. Ppn., mm	Ground Snow Load, kPa S_s	S_r	Hourly Wind Pressures 1/10 kPa	1/30 kPa	1/100 kPa	Seismic Data Z_a	Z_v	Zonal Velocity Ratio, v
Weyburn	575	-33	-35	32	22	5500	33	100	400	1.3	0.1	0.38	0.45	0.53	0	0	0.00
Yorkton	510	-34	-37	29	21	6150	23	90	440	1.6	0.1	0.32	0.37	0.44	0	0	0.00
Manitoba																	
Beausejour	245	-33	-35	28	23	5900	28	90	530	1.7	0.2	0.31	0.37	0.45	0	0	0.00
Boissevain	510	-32	-34	32	23	5700	33	110	510	2.0	0.2	0.44	0.52	0.63	0	0	0.00
Brandon	395	-33	-35	31	22	6000	38	100	460	1.9	0.2	0.37	0.45	0.54	0	0	0.00
Churchill	10	-39	-41	24	18	9200	8	60	410	2.6	0.2	0.48	0.59	0.72	0	0	0.00
Dauphin	295	-33	-35	30	22	6050	25	100	490	1.7	0.2	0.31	0.37	0.44	0	0	0.00
Flin Flon	300	-38	-40	27	20	6700	13	75	475	2.0	0.2	0.33	0.40	0.49	0	0	0.00
Gimli	220	-34	-36	29	23	6100	28	100	530	1.7	0.2	0.30	0.37	0.45	0	0	0.00
Island Lake	240	-36	-38	26	20	7100	13	80	550	2.4	0.2	0.33	0.40	0.49	0	0	0.00
Lac du Bonnet	260	-34	-36	28	23	6000	28	90	560	1.7	0.2	0.28	0.34	0.41	0	0	0.00
Lynn Lake	350	-40	-42	27	19	7900	8	70	490	2.2	0.2	0.33	0.40	0.48	0	0	0.00
Morden	300	-31	-33	31	23	5550	28	110	520	2.0	0.2	0.40	0.48	0.58	0	0	0.00
Neepawa	365	-32	-34	30	22	5900	33	100	470	2.0	0.2	0.33	0.40	0.49	0	0	0.00
Pine Falls	220	-34	-36	28	23	6100	25	80	420	1.7	0.2	0.29	0.35	0.43	0	0	0.00
Portage la Prairie	260	-31	-33	30	23	5800	36	110	525	1.9	0.2	0.36	0.43	0.51	0	0	0.00
Rivers	465	-34	-36	30	22	6000	33	100	460	1.9	0.2	0.36	0.43	0.51	0	0	0.00
Sandilands	365	-32	-34	29	23	5850	28	90	550	2.0	0.2	0.31	0.37	0.44	0	0	0.00
Selkirk	225	-33	-35	29	23	5900	28	100	500	1.7	0.2	0.33	0.39	0.47	0	0	0.00
Split Lake	175	-38	-40	27	19	8100	10	60	500	2.3	0.2	0.37	0.45	0.54	0	0	0.00
Steinbach	270	-33	-35	30	23	5800	28	85	500	1.8	0.2	0.31	0.37	0.44	0	0	0.00
Swan River	335	-36	-38	29	22	6200	20	85	500	1.8	0.2	0.30	0.35	0.42	0	0	0.00
The Pas	270	-36	-38	28	21	6750	15	75	450	1.9	0.2	0.33	0.40	0.49	0	0	0.00
Thompson	205	-42	-45	26	19	7850	10	70	540	2.2	0.2	0.37	0.45	0.54	0	0	0.00
Virden	435	-33	-35	30	22	5800	33	100	460	1.8	0.2	0.36	0.43	0.51	0	0	0.00
Winnipeg	235	-33	-35	30	23	5900	28	90	500	1.7	0.2	0.35	0.42	0.49	0	0	0.00
Ontario																	
Ailsa Craig	230	-17	-19	30	23	4000	25	85	960	2.0	0.4	0.40	0.50	0.62	0	0	0.00
Ajax	95	-20	-22	30	23	4000	23	85	825	0.9	0.4	0.43	0.52	0.64	1	1	0.05
Alexandria	80	-24	-26	30	23	4600	28	95	975	2.2	0.4	0.30	0.37	0.45	4	2	0.10
Alliston	220	-23	-25	29	23	4400	28	105	875	1.8	0.4	0.22	0.29	0.38	1	0	0.05
Almonte	120	-26	-28	30	23	4850	25	80	800	2.3	0.4	0.30	0.37	0.48	4	2	0.10
Armstrong	340	-39	-42	28	21	7050	23	90	725	2.5	0.4	0.21	0.25	0.29	0	0	0.00
Arnprior	85	-27	-29	30	23	4800	23	80	775	2.3	0.4	0.27	0.34	0.42	4	2	0.10
Atikokan	400	-34	-37	29	22	6100	25	95	760	2.2	0.3	0.21	0.25	0.29	0	0	0.00
Aurora	270	-21	-23	30	23	4300	28	100	800	1.8	0.4	0.30	0.39	0.50	1	0	0.05
Bancroft	365	-27	-29	29	22	4900	25	85	900	2.8	0.4	0.23	0.29	0.36	2	1	0.05
Barrie	245	-24	-26	29	22	4600	28	90	900	2.3	0.4	0.21	0.29	0.39	1	1	0.05
Barriefield	100	-22	-24	27	23	4350	23	105	950	1.9	0.4	0.35	0.43	0.52	2	1	0.05
Beaverton	240	-24	-26	30	22	4650	28	100	950	2.0	0.4	0.24	0.32	0.42	1	1	0.05
Belleville	90	-22	-24	29	23	4100	23	95	850	1.6	0.4	0.32	0.39	0.48	1	1	0.05
Belmont	260	-17	-19	30	23	4050	25	90	950	1.6	0.4	0.35	0.45	0.58	0	0	0.00
Big Trout Lake	215	-38	-40	25	20	7850	13	85	600	2.9	0.2	0.33	0.39	0.46	0	0	0.00
CFB Borden	225	-23	-25	29	22	4550	28	105	875	2.0	0.4	0.21	0.29	0.39	1	0	0.05
Bracebridge	310	-26	-28	29	22	4850	25	95	1050	2.8	0.4	0.26	0.32	0.39	1	1	0.05

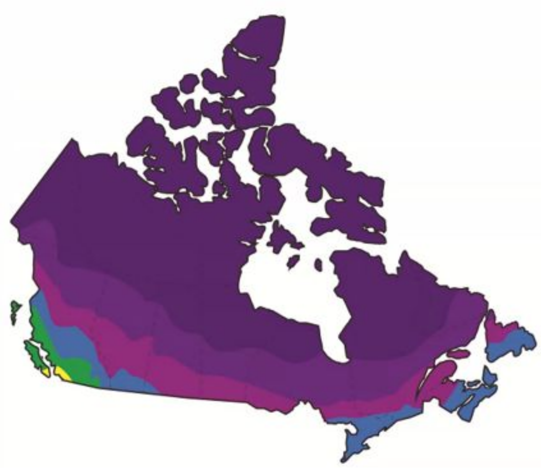
National Building Code of Canada 1995 C-13

Source: National Building Code of Canada



ASHRAE Climate Zones for NECB 2011

Where we live DOES matter!



Heating Degree Days below 18°C

- 8 - ≥ 7,000
- 7B - 6,000 < 6,999
- 7A - 5,000 < 5,999
- 6 - 4,000 < 4,999
- 5 - 3,000 < 3,999
- 4 - < 3000

Heating degree-days provides a means of comparing the temperature and heating requirements of similar buildings in different locations. Therefore the need for different insulation requirements in different geographical locations.

Healthy Housing

Based on research exploring the issues of environmental and economically sound design and development techniques.

Supported on 5 fundamental principles.

1. Occupant Health
2. Energy Efficiency
3. Resources Efficiency
4. Environmental Responsibility
5. Affordability

Air Quality

Other factors which influence indoor air quality are:

- site, weather,
- ventilation and infiltration,
- environmental control systems,
- durability of materials,
- structure contents, furnishings,
- structure maintenance, and deterioration of structure and contents,
- design and human factors.

Summary

Hopefully what have learned today? That building science may not be your expertise when it comes to diagnosing and considering the relationship of the house as a system, or as a home inspector.

There are a number of unseen conditions that are beyond the general recognition of a home inspection. But yet we know that a number of conditions related to building science are connected to conditions that we can encounter during a home inspection.

One thing people will want to ask is “if the home inspector suspects anything beyond the walls”.

Credits

- ACBOA - NECB Training
- Fine Home Building
- Illustrated Building Code Guide