Net Zero Energy Retrofit

Habitat Studio & Workshop Ltd.

Context

- Started with CMHC's EQuilibrium Housing initiative.
- 5100^0 C (9180^0 F) Heating Degree Day Climate
- -34^0 C Design Temperature

Riverdale NetZero

Parkland NetZero

Belgravia NetZero

Mill Creek NetZero

South Windsor Park NetZero

Thanks

- **Habitat Studio &Workshop Ltd.**
- **Howell-Mayhew Engineering**
- **Solnorth Engineering**
- **CMHC**
- Conergy Canada Ltd
- SESCI-NAC
- NAIT
- City of Edmonton
- Servus Credit Union
- Alberta Research Council
- Pembina Institute
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- Eco Ammo
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- **Dr Sam Wong**
- Green Alberta
- Relumen Engineering Ltd.
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- Hicklin Consulting
- Green Door Builders
- Ron Wickman Architect
- Shafraaz Kaba
- Philip Mees P.Eng.
- Tang Lee Architect
- Duxton Windows
- Mancap Ventures
- Climate Change Central
- **Bob Heath**
- **Dennis and Christy Cuckoo**
- **Aaron and Nicki Dublenko**

Retrofits of Existing Housing

- 85% of the housing stock we will be using in 2050 is already built
- The cost per kWh saved with energy retrofits is significantly higher than for new construction
- The hardest houses to fix will be those most recently built

Now House, Toronto

Achieve an annual energy cost of zero

1. Reduce electricity use by 59.8%
2. Reduce heat loss to achieve EGH rating of 84
3. Produce energy on site increasing EGH to 94
4. Use minimal new resources and produce minimal waste

Canada

EQuilibrium
HEALTHY HOUSING
FOR A HEALTHY ENVIRONMENT

CMHC SCHL

Net Zero Energy

- Produces all of its own energy for Heating, DHW, Lighting and Appliances on site over the course of a year.
- Next to impossible without aggressive conservation and good solar orientation.

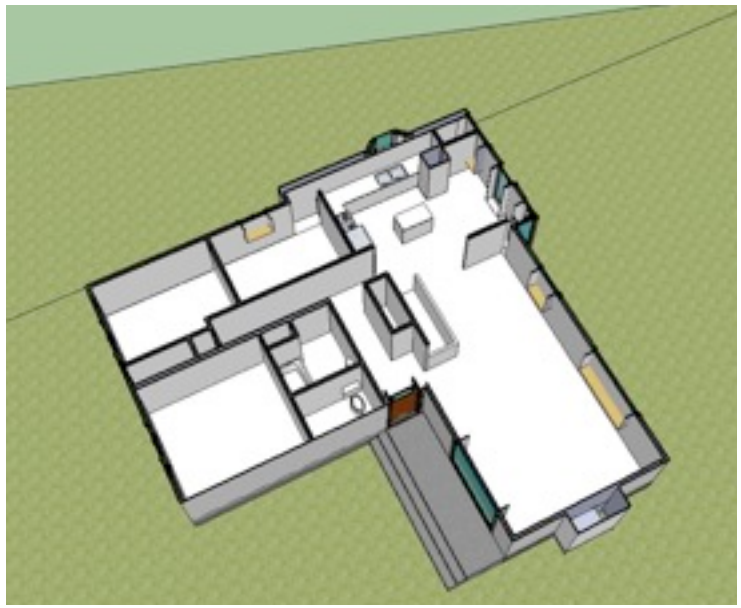
Starting Point

- 1960's 2x4 construction
- Recently renovated
- 1200 sq.. ft. bungalow with a finished basement

West Elevation

South Elevation

Site



Floor Plan

Existing Condition

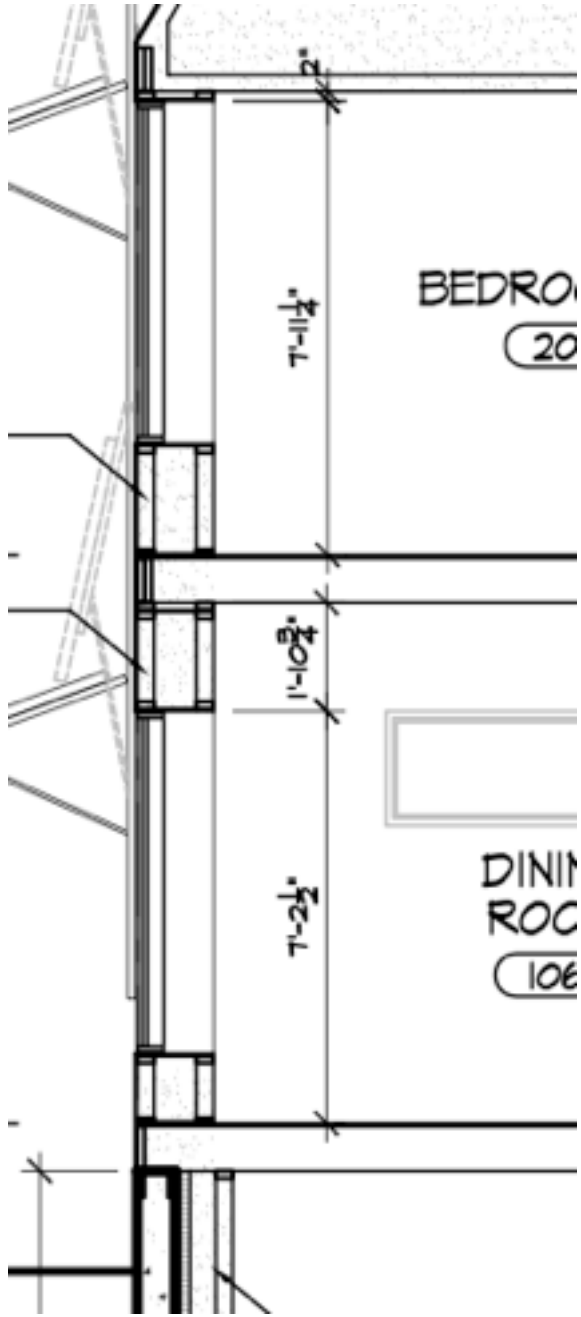
- 1230 Sq.ft. bungalow with a finished basement
- L shaped
- South exposure, no south windows
- Large trees

Objective

- Net Zero Annual Energy
- Add enough space to accommodate parents
- Minimize disruption to existing finishes

Modelling

- HOT2000
- Essential for cost control
- Model early
- Model in house if possible



Starting Energy Consumption

	Base Case	Belgravia
Net Space Heating Energy* - kWh/year	25743	3270
Lighting, Appliances, & Miscellaneous Electrical (L.A.M.E.) kWh/year	8760	3150
Domestic Hot Water (DHW) kWh/year	5317	3430
Total Annual Energy - kWh/year	39820	9850

* This has already been reduced to take into account useable solar gains and internal gains

All PV?

Reduce L.A.M.E. and Domestic Hot Water

	Original	Reduced L.A.M.E. & DHW	Belgravia
Net Space Heating - kWh/year	25743	28095	3270
Lighting ,Appliances, & Miscellaneous Electrical (L.A.M.E.) kWh/year	8760	3800	3150
Domestic Hot Water (DHW) kWh/year	5317	3700	3430
Total Annual Energy - kWh/year	39820	35595	9850

Electrical Load Reduction

- Energy Efficient Appliances
  - refrigerator
  - clothes washer
  - cooking
- Energy Efficient Lighting
  - compact fluorescents
  - LEDs
  - task lighting
  - day lighting
- Energy Efficient Motors
  - ventilation
  - heating
- Phantom Load Control
- Consumption Monitors

Domestic Hot Water Reduction

- Low Flow Showers and Faucet Aerators
- Efficient Appliances
- Aim for 150 litres of hot water per day or less
- Install a demand hot water tank or equivalent

Reduce Water Heating Energy

- Drain Water Heat Recovery - Configure plumbing for shower water collection
- Electric or Condensing Natural Gas - 90% + efficiency
- Demand Hot Water Tanks
- Insulate Hot Water Tanks

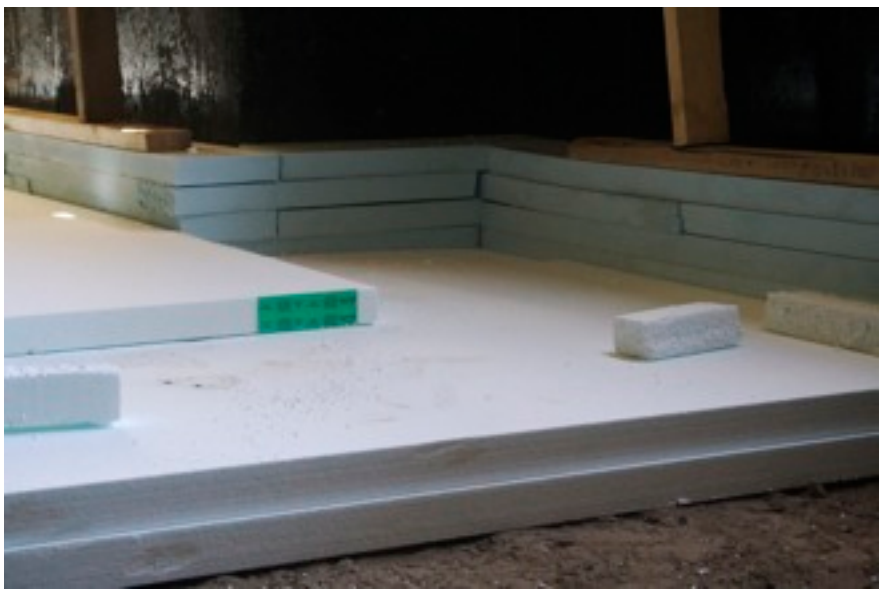
Cost per kWh/year of energy conservation measures

=

Cost per kWh/year of Energy collection

Envelope Modelling/Optimization

- Determine Current PV cost or benchmark energy price.
- Evaluate envelope upgrades with respect to cost per kWh/year
- Optimize envelope specifications
- Extra conservation cost can often be offset by simpler mechanical systems



Space Heat*- Where is it going?

	Original (kWh/year)	Belgravia (kWh/year)
Walls ~R10	11366	2283
Ventilation /Air leakage -assuming ~2.5ACH-50	8474	1989
Roof ~ R40	2044	636
Basement Walls ~R8 and Floor ~R 0. 5	9143	2494
Windows and Doors - Dual Low E Argon	6269	6549
Total Heating Energy Loss NIC Passive Solar and Internal Gains (kWh/year)	37296	13951

*These numbers represent gross space heat before accounting for passive solar and internal gains

Space Heat Upgrades*

Upgrade	Original (kWh/year)	Saving (kWh/year)	After Upgrade (kWh/year)	Belgravia (kWh/year)
Roof from R40 to R80	2044	977	1067	636
Walls from R40to R56	4037	488	3549	2283
Walls from R10 to R40	11366	7329	4037	2283
Basement Walls (R42) and Floor (R10)	9143	6193	2950	2494
Upgrade Windows and Doors	6269	1170	5099	6549
Air leakage from 2.5ACH** to .75 ACH	8474	2903	5571	1989
Total Heating Energy Loss NIC Passive Solar and Internal Gains (kWh/year)	37296	19060	18236	13951

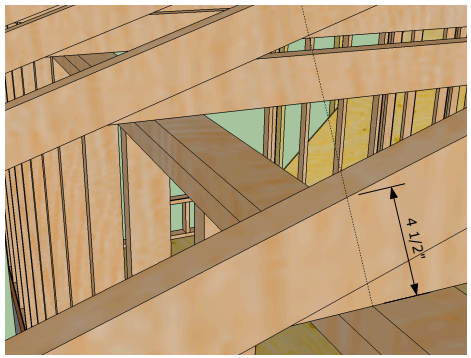
*These numbers represent gross space heat before accounting for passive solar and internal gains

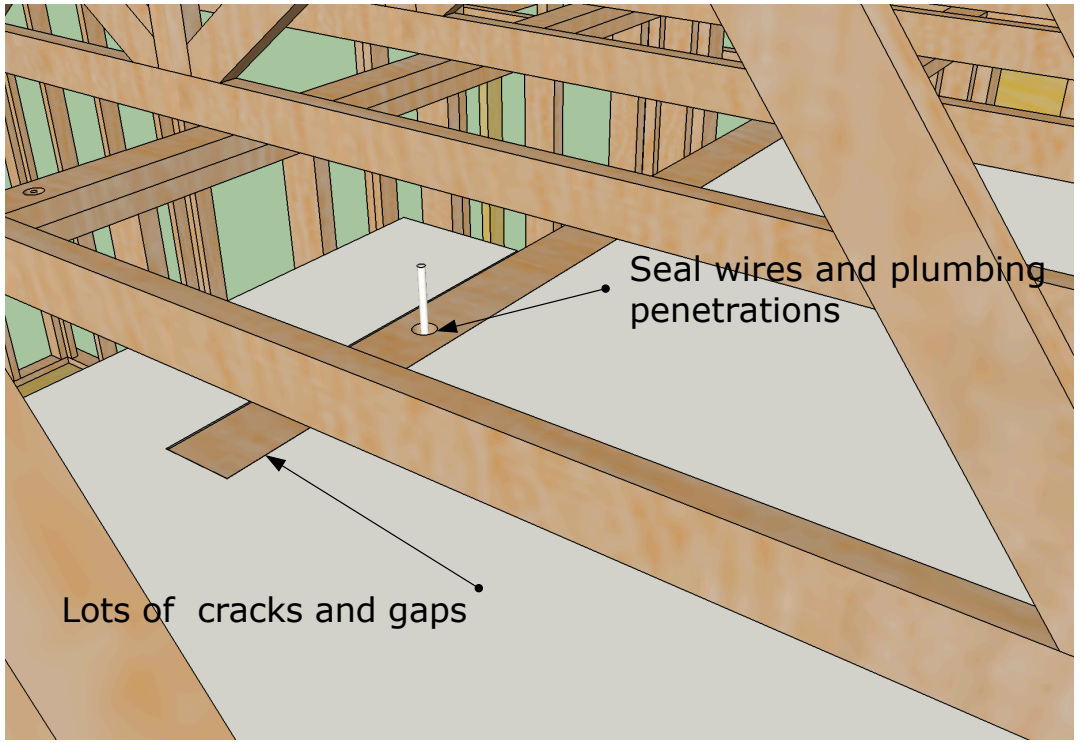
** ACH - Air changes per hour at -50 pascals

Roof/ Ceiling

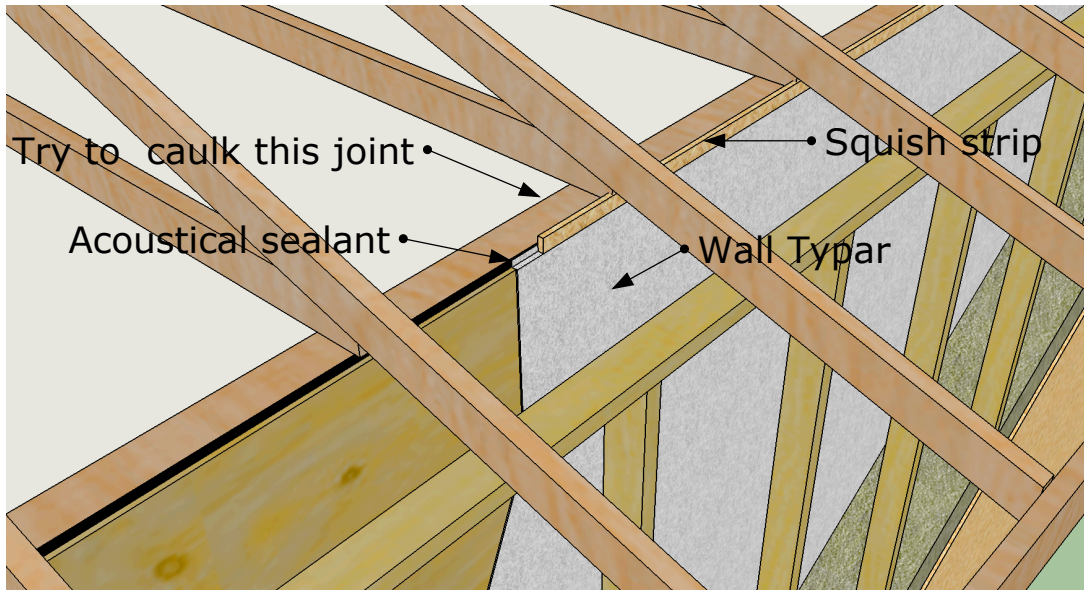
- Existing attic already has already R40
- Low heel trusses in existing attic
- HOT2000 predicted savings of 988kWh/year for R80
- 2 possible approaches
  - Add insulation and try to seal existing attic
  - Chainsaw retrofit

Work within the existing roof

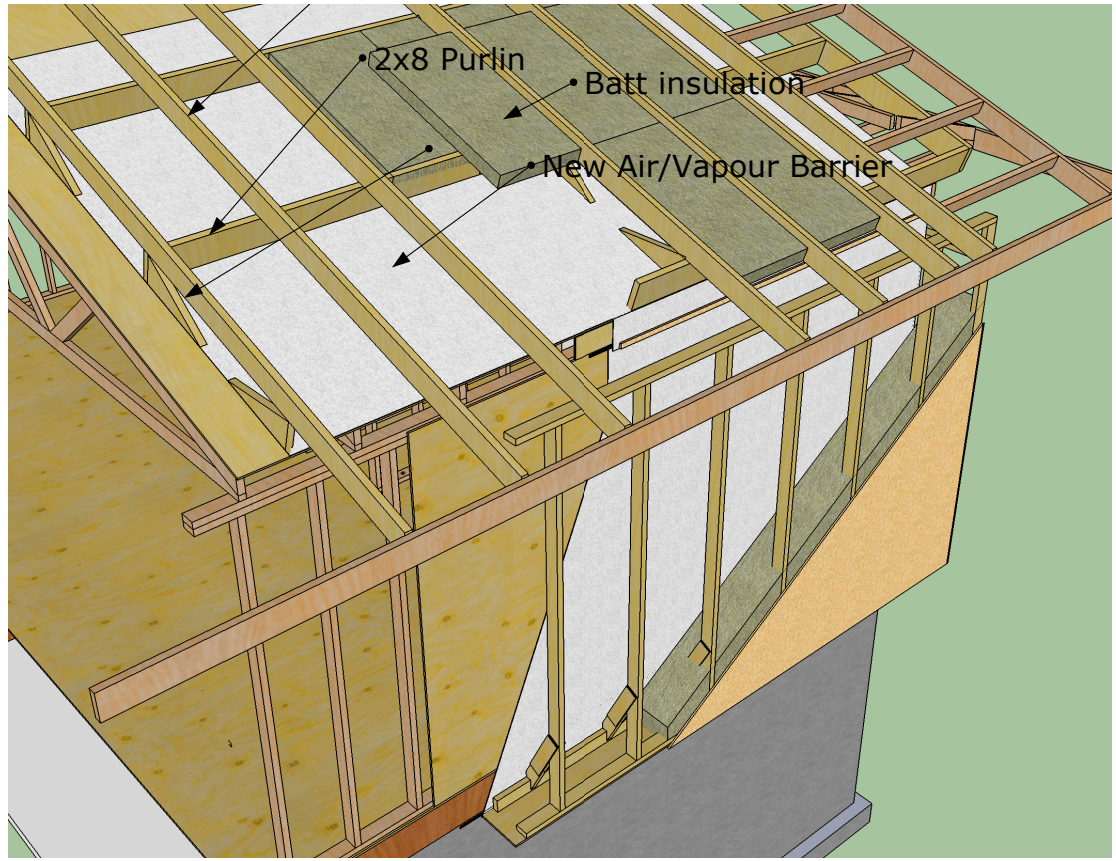




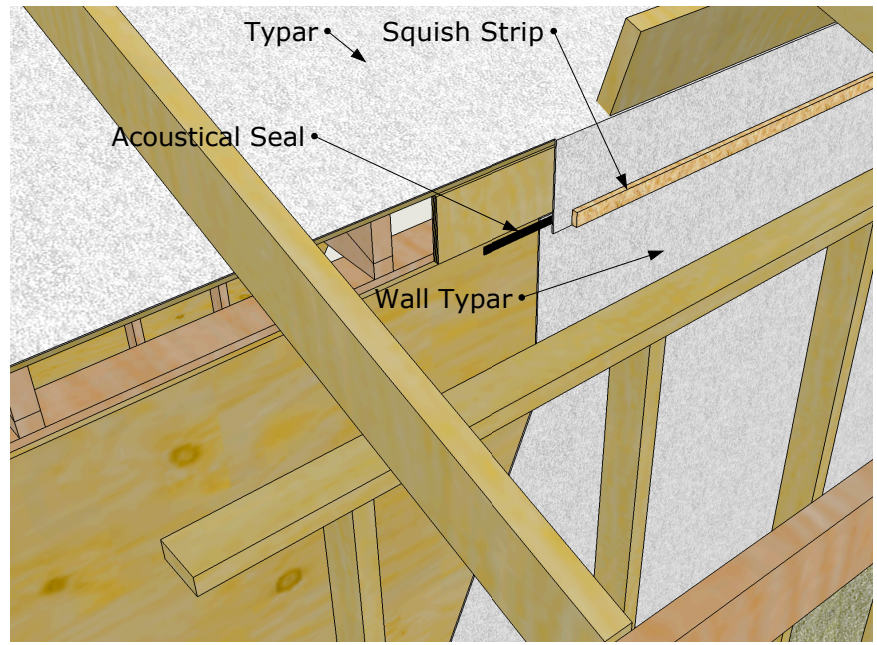
- Low truss or rafter heel limits insulation at the edge
- Hard to seal existing attic in the ceiling plane- need to move existing insulation
- Saves building a new roof overhang, soffit and fascia.
- Less expensive



Chainsaw retrofit



- Saw off the the existing overhang
- Wrap roof in new air/ vapour barrier and tie into new wall sheathing
- Build new roof cavity
- Roof could be configured to accommodate PV



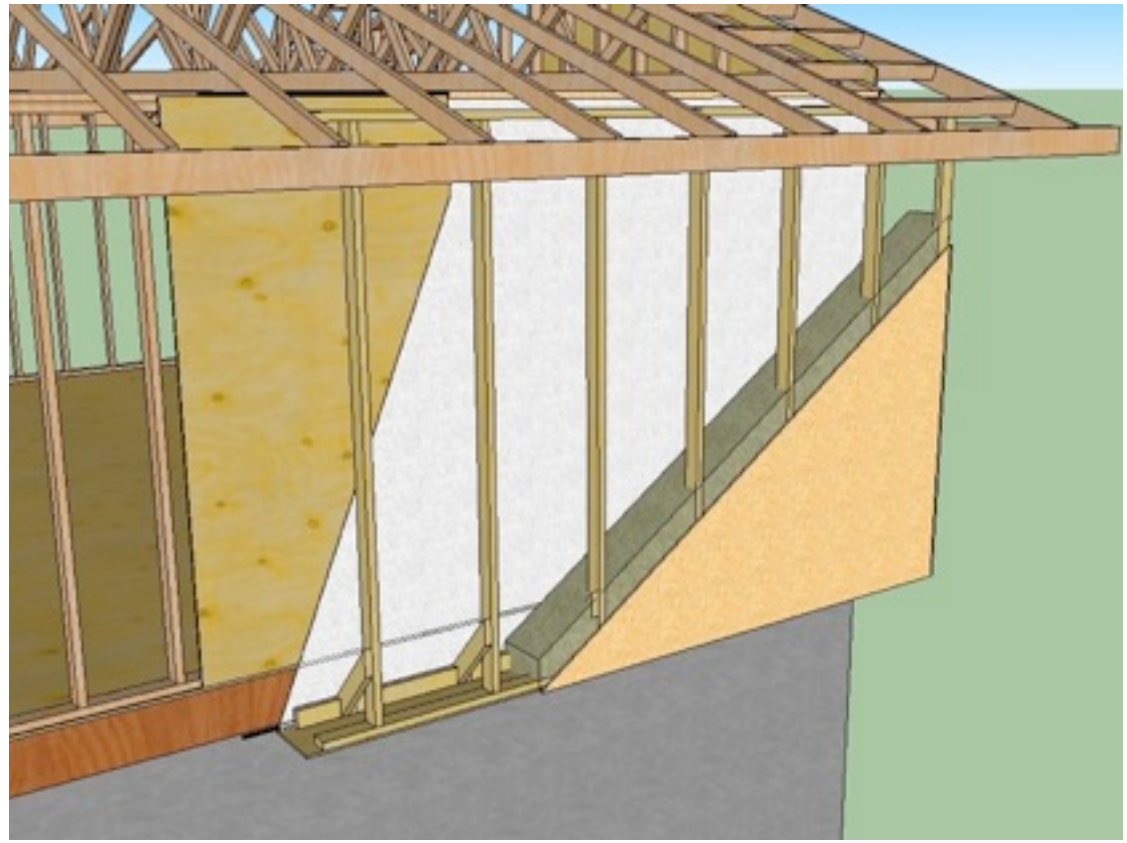
Chainsaw Retrofit- Roof Framing

Walls / Air Tightness 1

Existing Wall Framing

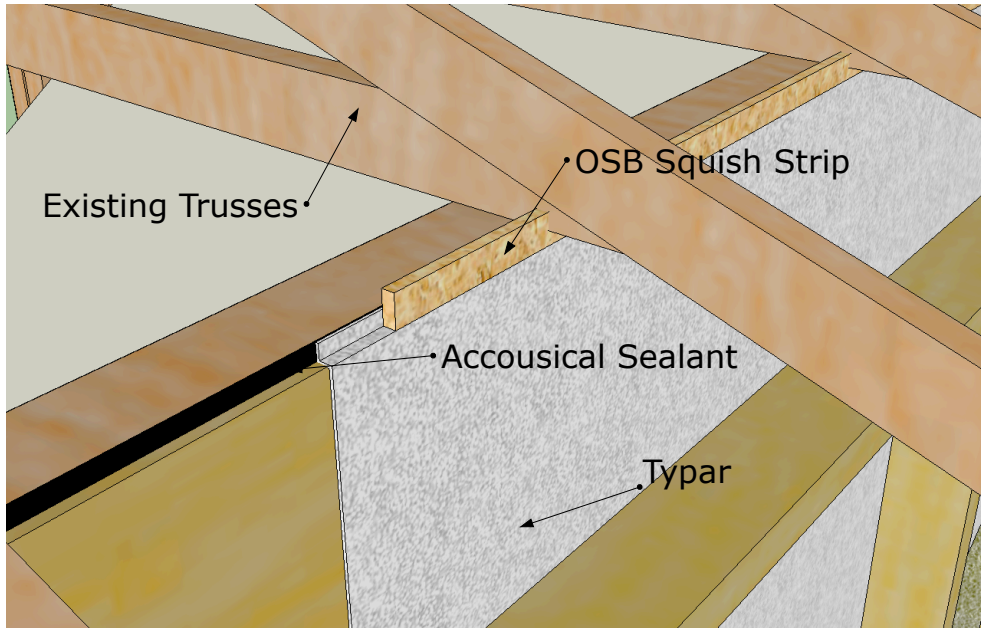
- Existing walls would likely have a system R value about R10 at best
- HOT2000 predicted savings for an upgrade to R40 would save 7300 kWh/ year- R56 would save 7800 kWh/year
- Getting air tightness from 2.5 ACH down to .75ACH would save 2900 kWh/year

Walls / Air Tightness 2

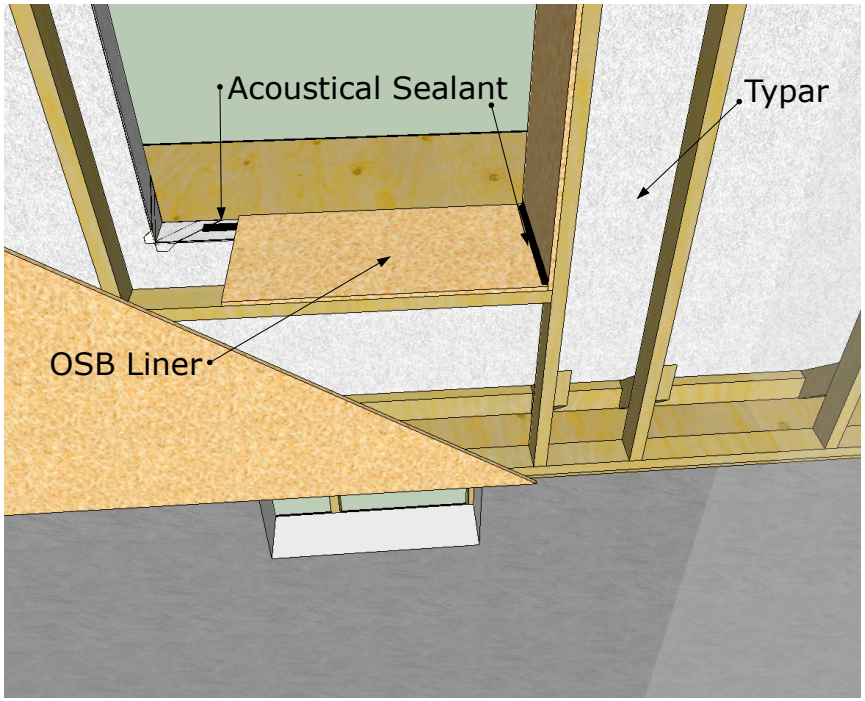


- Best to strip off existing wall finish
- Air/ Vapour Barrier and additional insulation should be done simultaneously
- Could also use Larsen trusses or I joists.

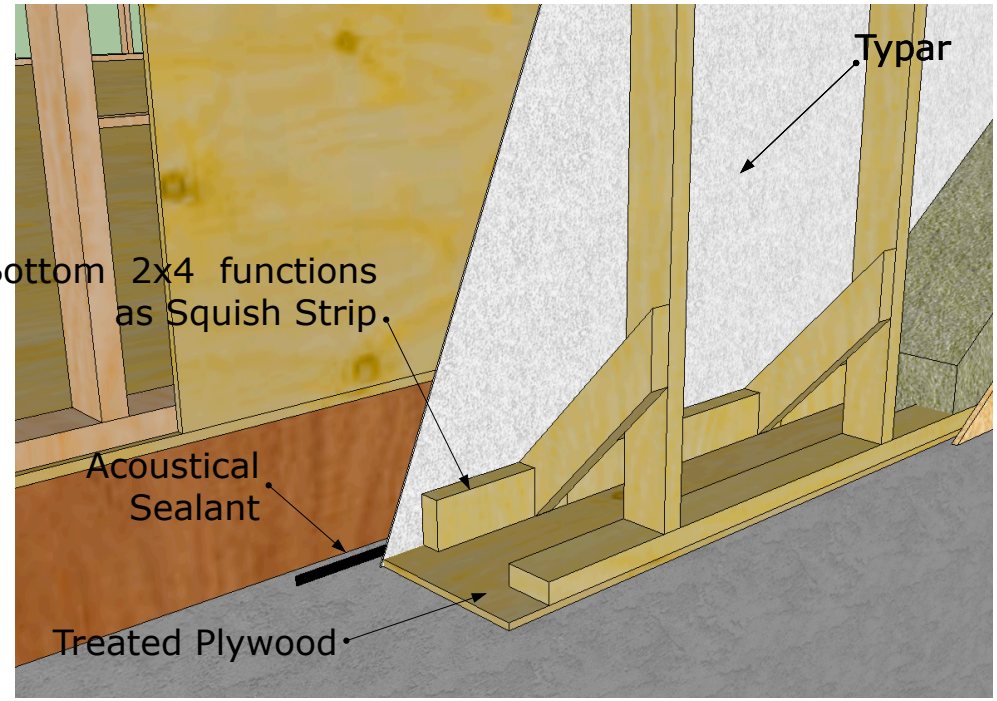
Wall Upgrade
Air Sealing details



Sealing New Air Barrier to Top Plate



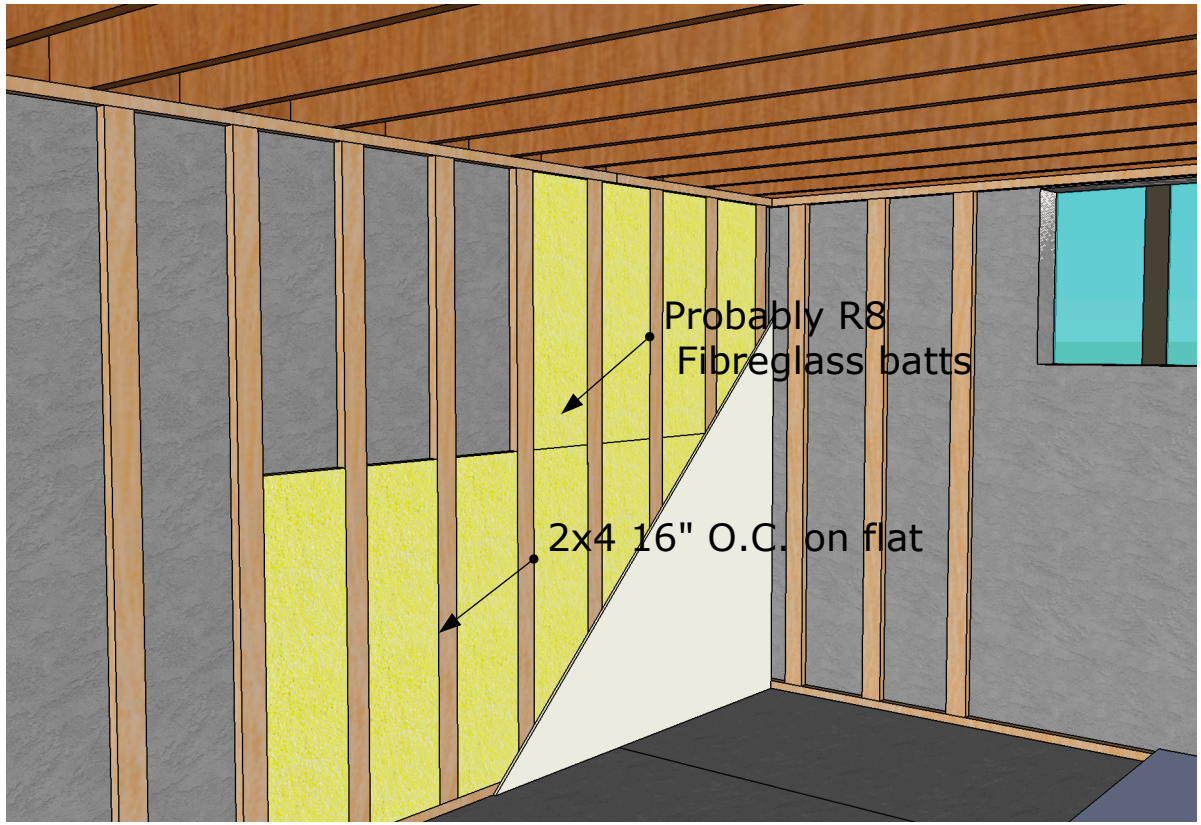
Sealing New Air Barrier at Window/ Door Openings



Sealing New Air Barrier to Concrete Wall

Saskatoon Chainsaw Retrofit

Basement Insulation



Existing Basement

- Upgrading the basement wall insulation to R40 and the basement floor insulation to R10 will save 6190 kWh/ year
- Can be done either inside or outside

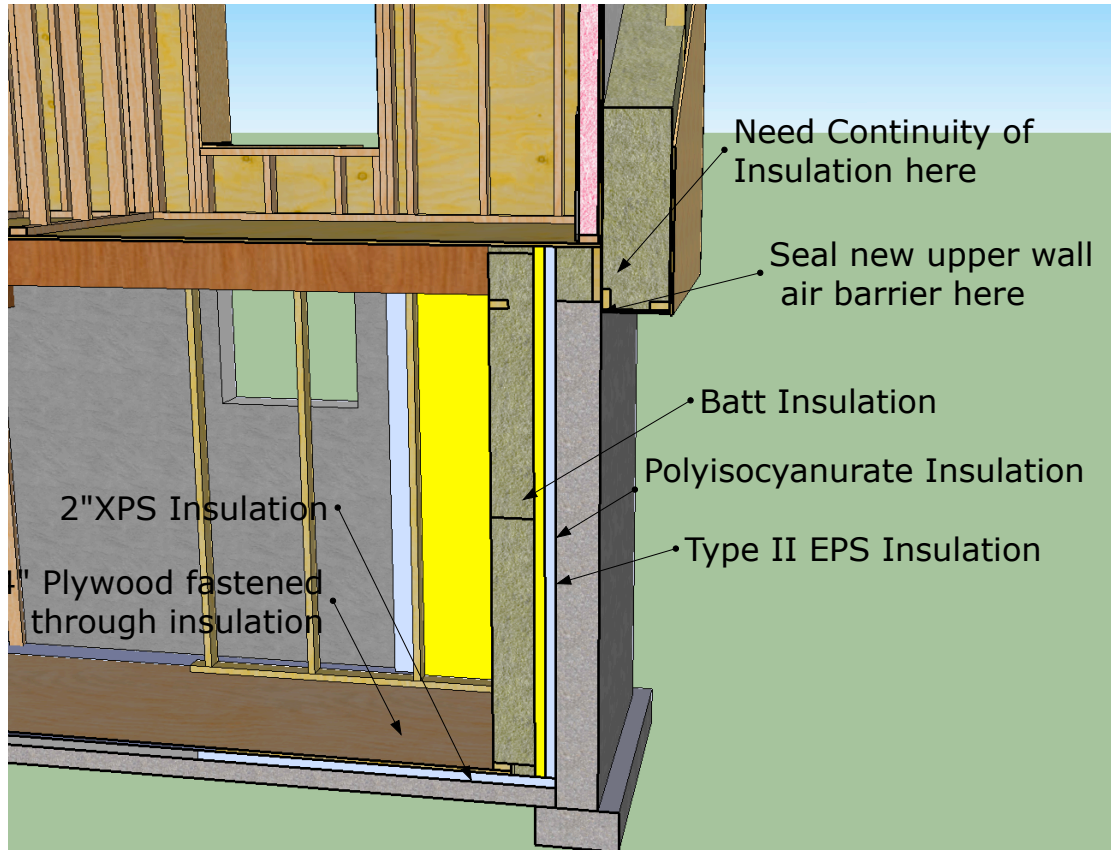
Basement Insulation- Inside

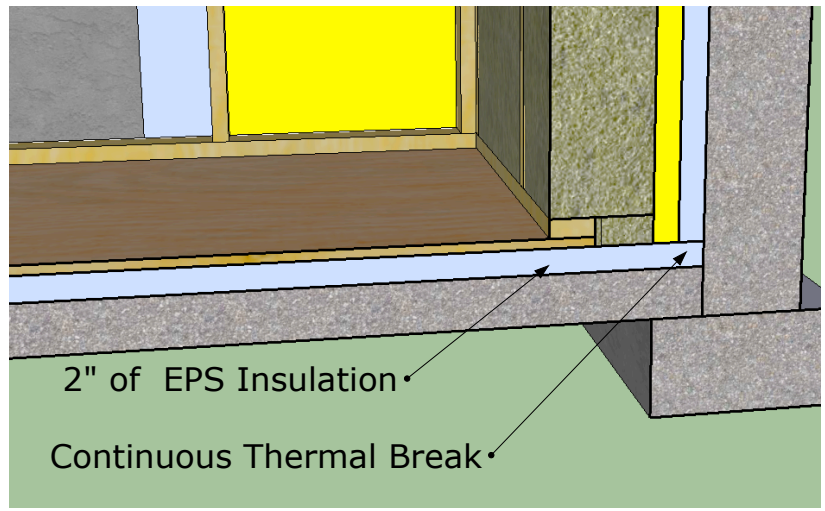
Advantages

- Possibility to control thermal bridging at footing. (This could be worth about 1400kWh/year)
- Faster, less costly in an unfinished basement.

Disadvantages

- Lost basement space
- Disruption of existing finishes





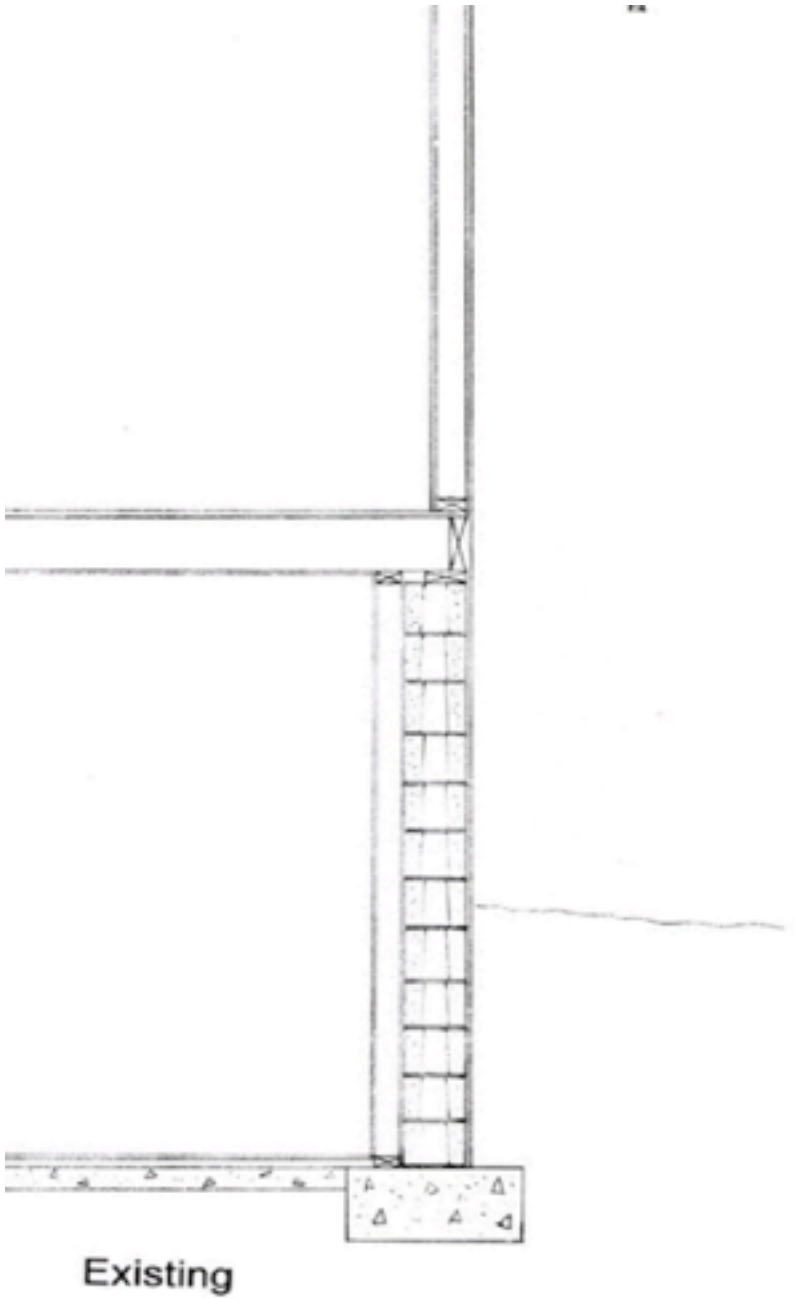
Basement Insulation- Outside

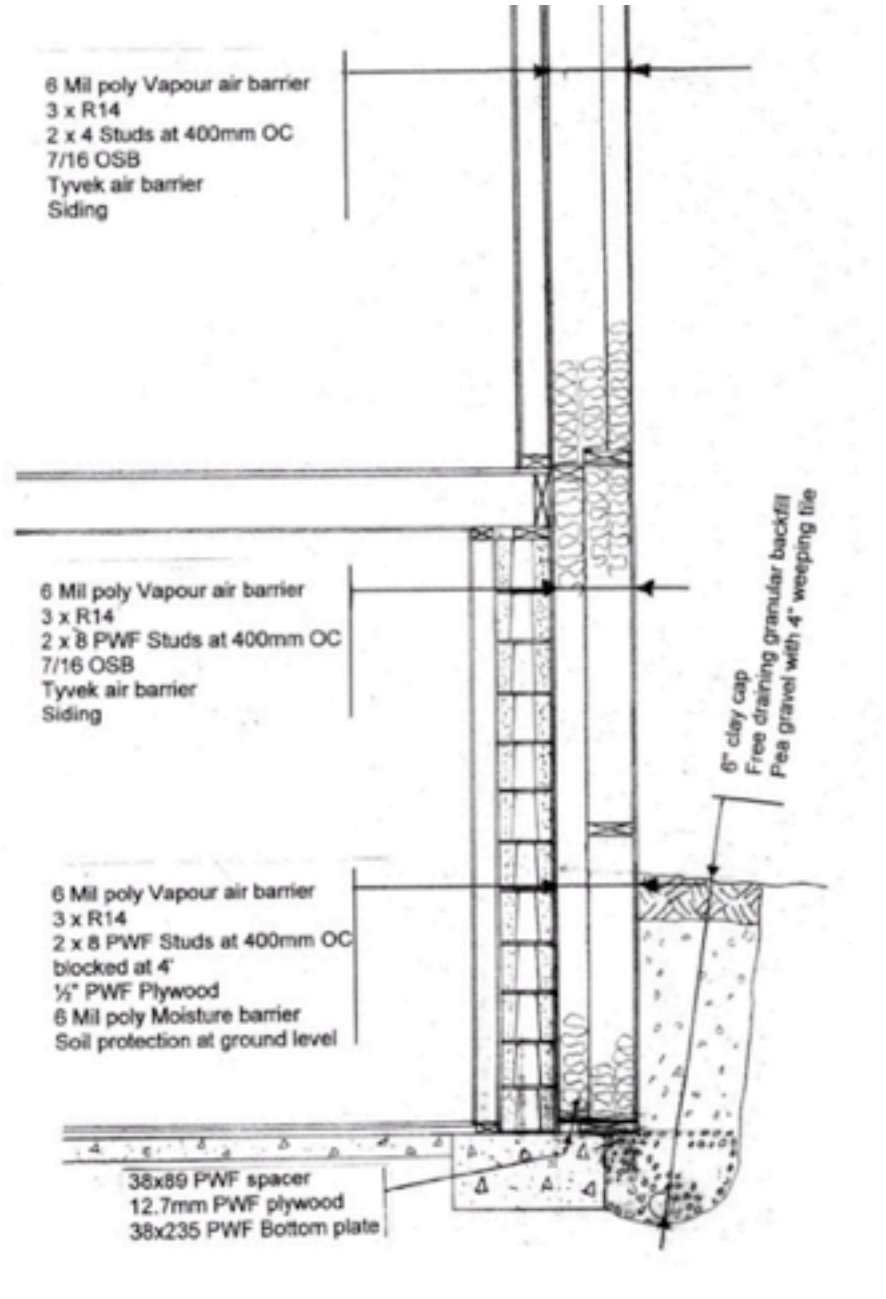
Advantages

- No disruption to existing finished basement
- Basement wall build out supports upper wall.
- Walls remain flush on outside
- Opportunity to repair, reinforce and waterproof old foundation

Disadvantages

- Major disruption to existing decks and landscaping
- No reduction in thermal bridging at footing
- Doesn't simultaneously provide for insulation of basement floor. Insulating the basement floor to R10 saves about 1500 kWh/year





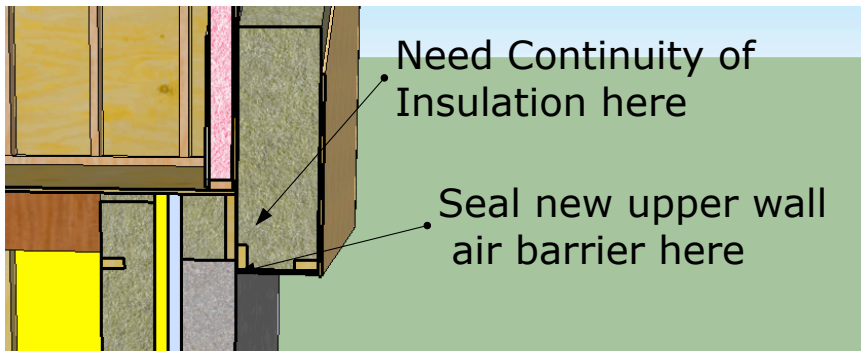
Slide courtesy of Harold Orr

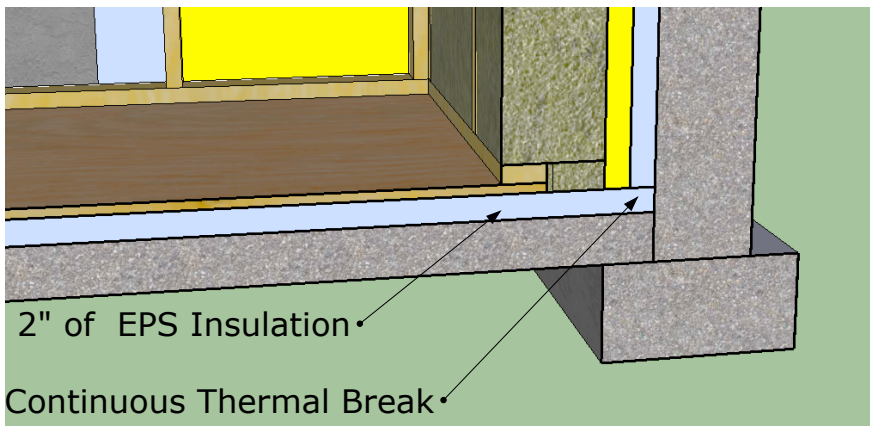
Basement Insulation- Outside

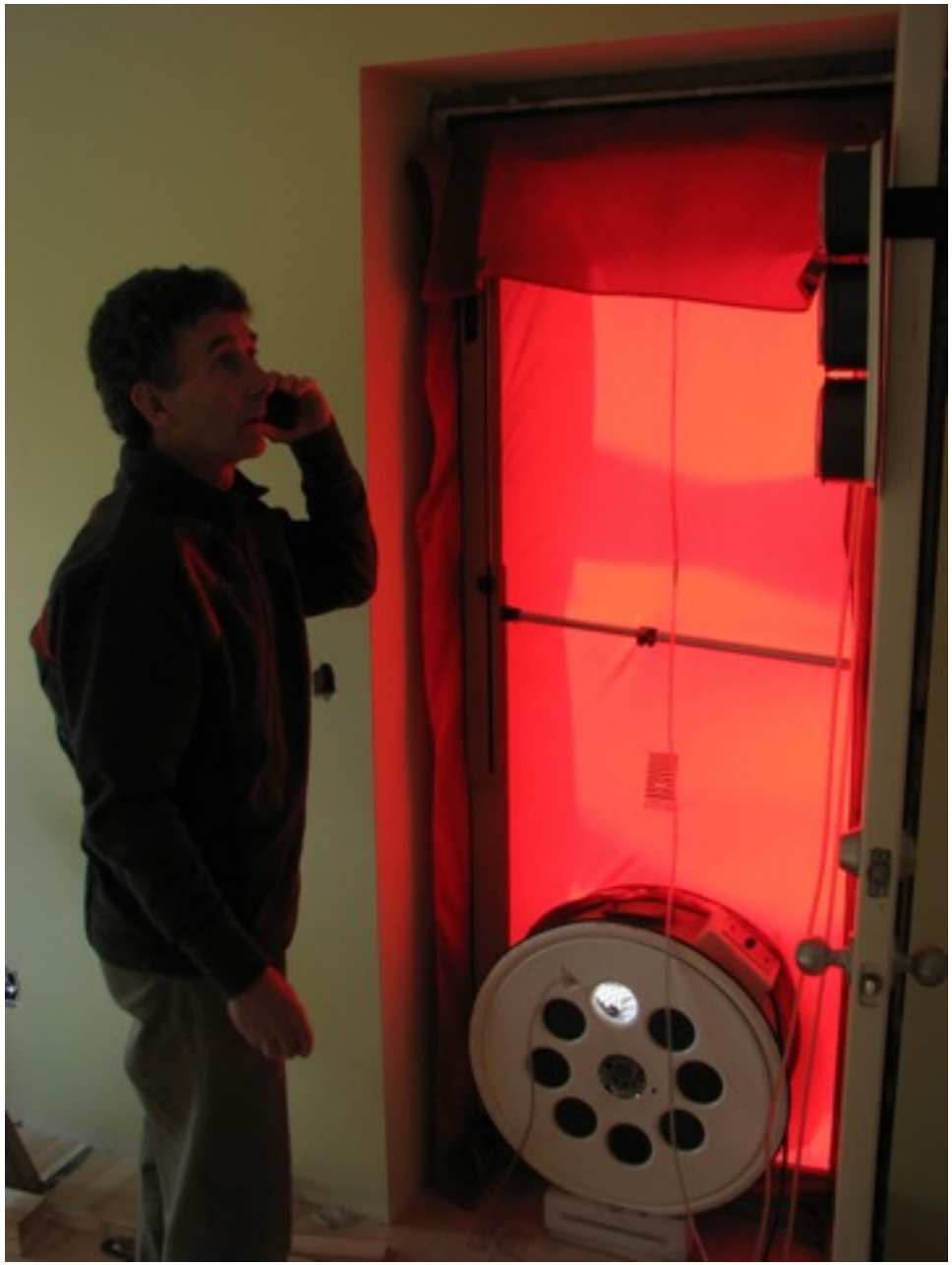
Wrap details

Thermal Bridging

- Lots of thermal bridging in older 2x4 framed walls
- Fireplace is a significant thermal bridge. It loses 1365 kWh/year from transmission alone. This done't include air leakage. Very likely losing more heat than than it produces







Air Testing

HRV s

- Locate unit as close as possible to intake and exhaust hoods
- Ductwork should be carefully designed and installed for most efficient air flow

- Select for highest heat recovery efficiency and lowest electrical use.
- Control module is important too

Windows

R 8.3 SHGC .57 (COG)

R 8.3, SHGC .37 (COG)

- Upgrading the existing windows in the house will save 1170 kWh/year. The saving are small because we already have double glazed windows with argon and a low E coating.
- Adding 2 unobstructed south facing windows will save 660 kWh/year.
- No additional thermal mass yet

- Minimize South U value
- Maximize South SHGC
- Minimize East, West and North U value
- Minimize frame and spacer losses.

Space Heat*-
after upgrades to existing envelope.

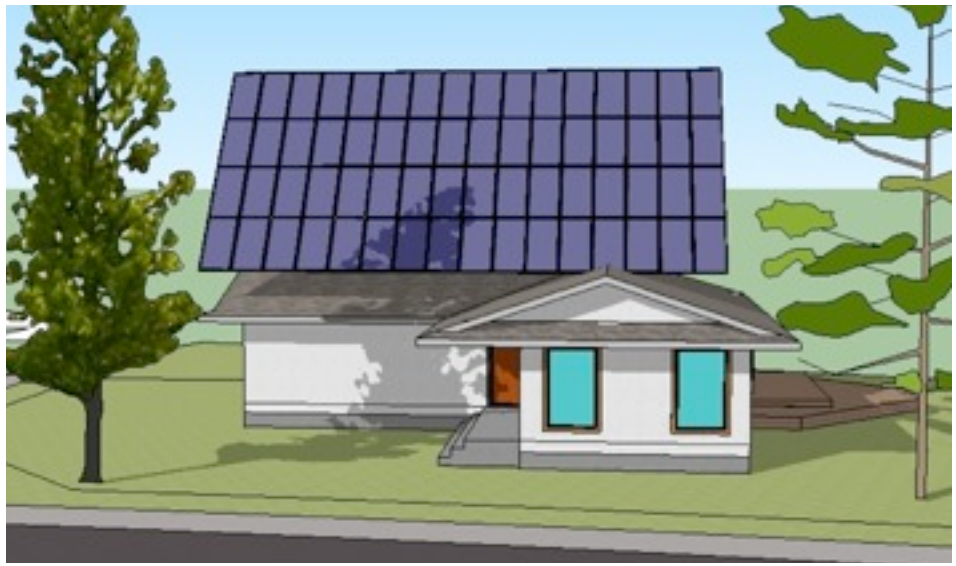
Upgrade	Original (kWh/year)	Retrofit w/o addition	Belgravia (kWh/year)
Walls ~R10 to R56	11366	3550	2283
Ventilation /Air leakage 2.5 ACH to .75 ACH and add HRV	8474	5570	1989
Roof R40 to R80	2044	1070	636
Basement Walls ~R8 and Floor ~R 0. 5	9143	2950	2494
Windows and Doors - Dual Low E Argon to Tri Low Argon w	6269	5100	6549
Total Heating Energy Loss NIC Passive Solar and Internal Gains (kWh/year)	37296	18240	13951

*These numbers represent gross space heat before accounting for passive solar and internal gains

Total Energy Needed from Renewables

	Upgraded Existing House	Original	Belgravia
Net Space Heating - kWh/year*	8860	28095	3270
Lighting ,Appliances, & Miscellaneous Electrical (L.A.M.E.) kWh/year	3800	3800	3150
Domestic Hot Water (DHW) kWh/ year	3700	3700	3430
Total Annual Energy - kWh/year	16360	35595	9850

*These numbers represent net space heat after accounting for passive solar and internal gains

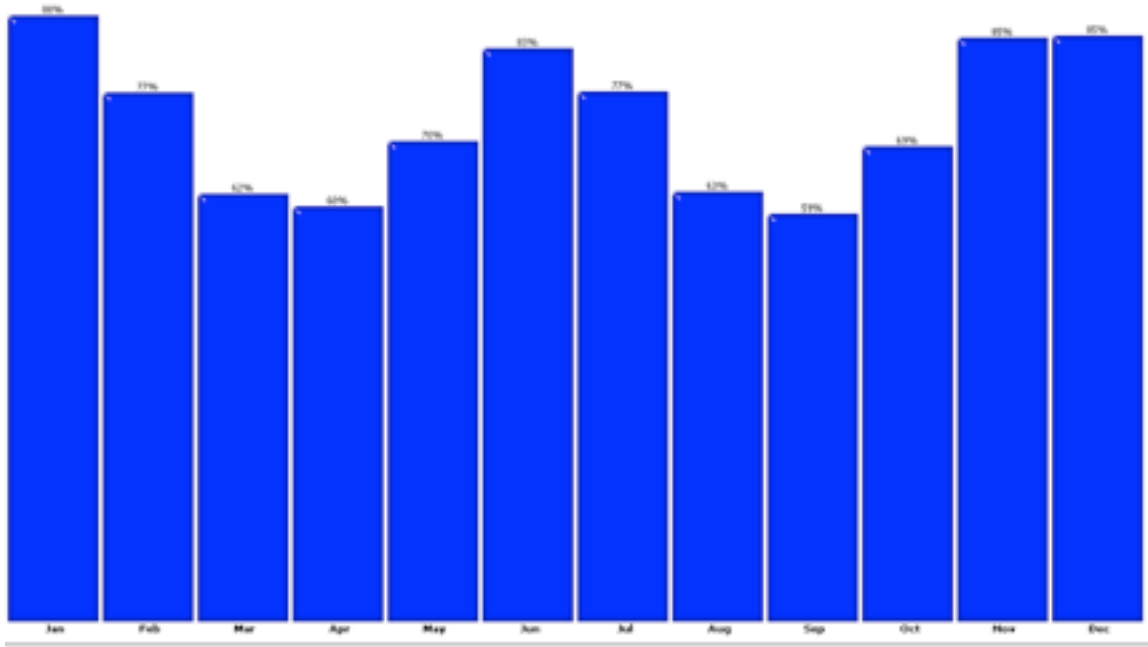


Renewable Energy Collection
(kWh/year)

	Upgraded house	Mill Creek	Belgravia	Parkland
Useable Passive Solar	3800	8,200	8,300	17470
Solar thermal	?	2500	0	0
Photo voltaic	?	8000	9900	21000
Total	?	18,700	18,200	38740

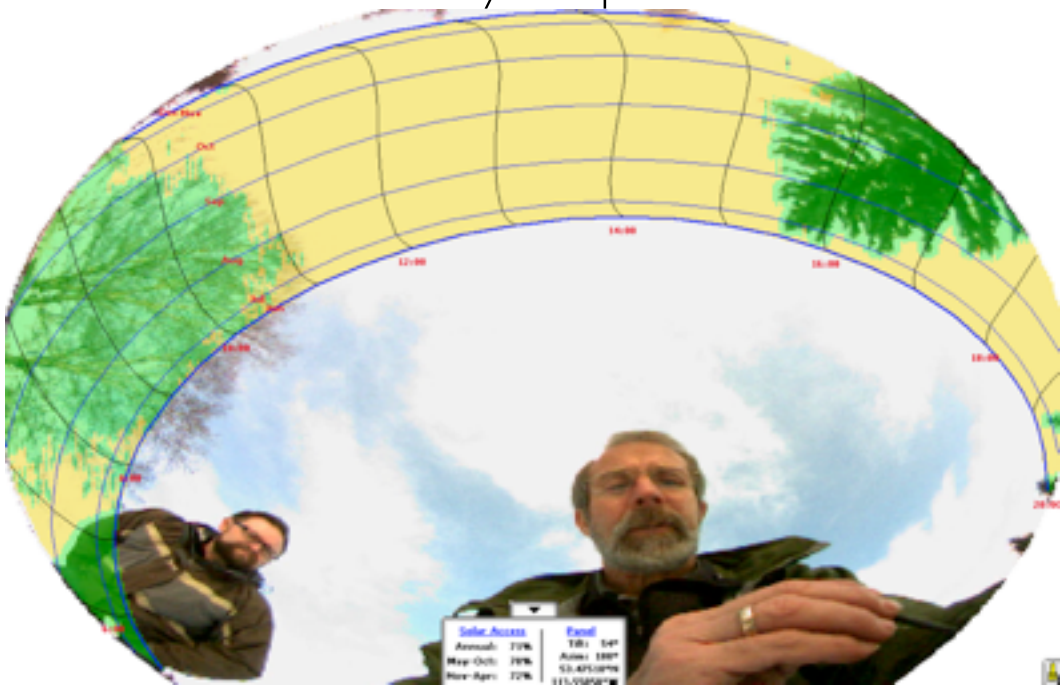
Mill Creek Passive Solar

- Maximum south window area
- Thermal Mass -64 mm concrete floor overlay
- Summer shading
- Over 50% of total annual space heat needs



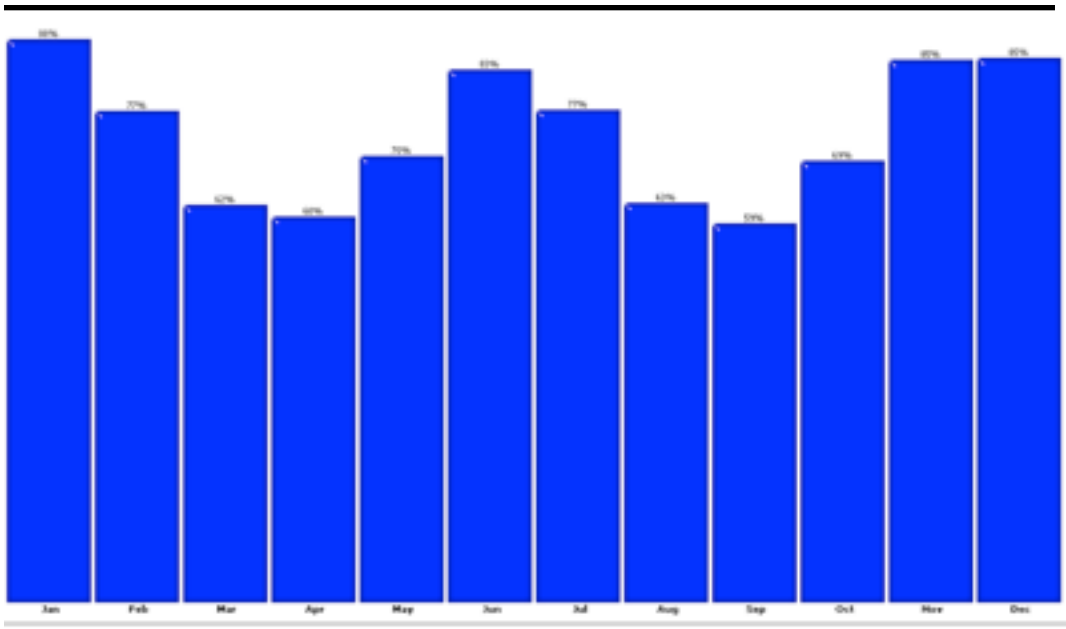
Suneye Report

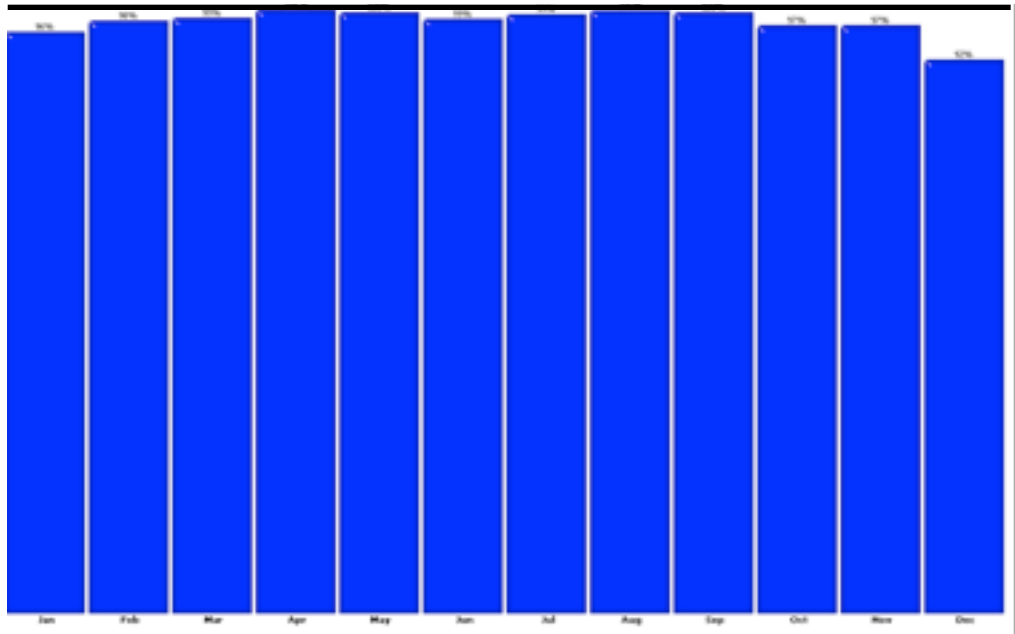
Looking South

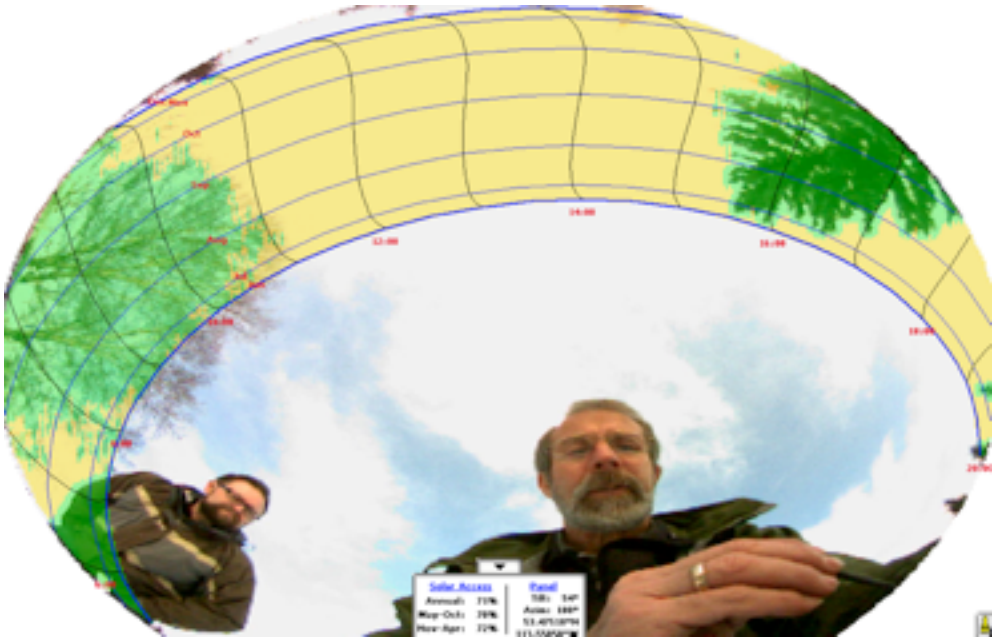


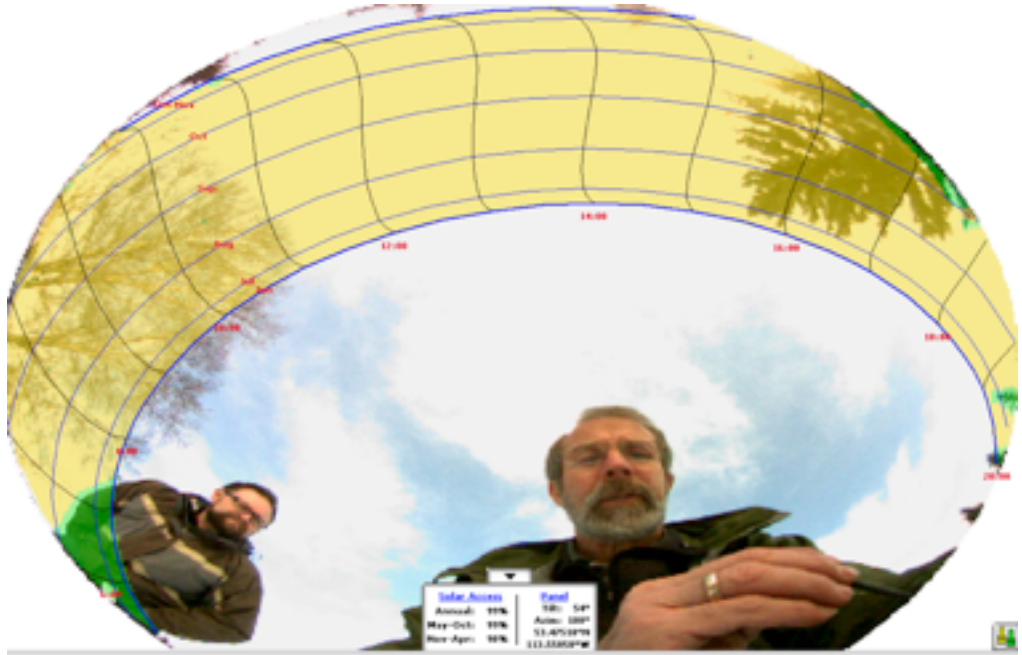
Sunshine I

South Side of Existing House





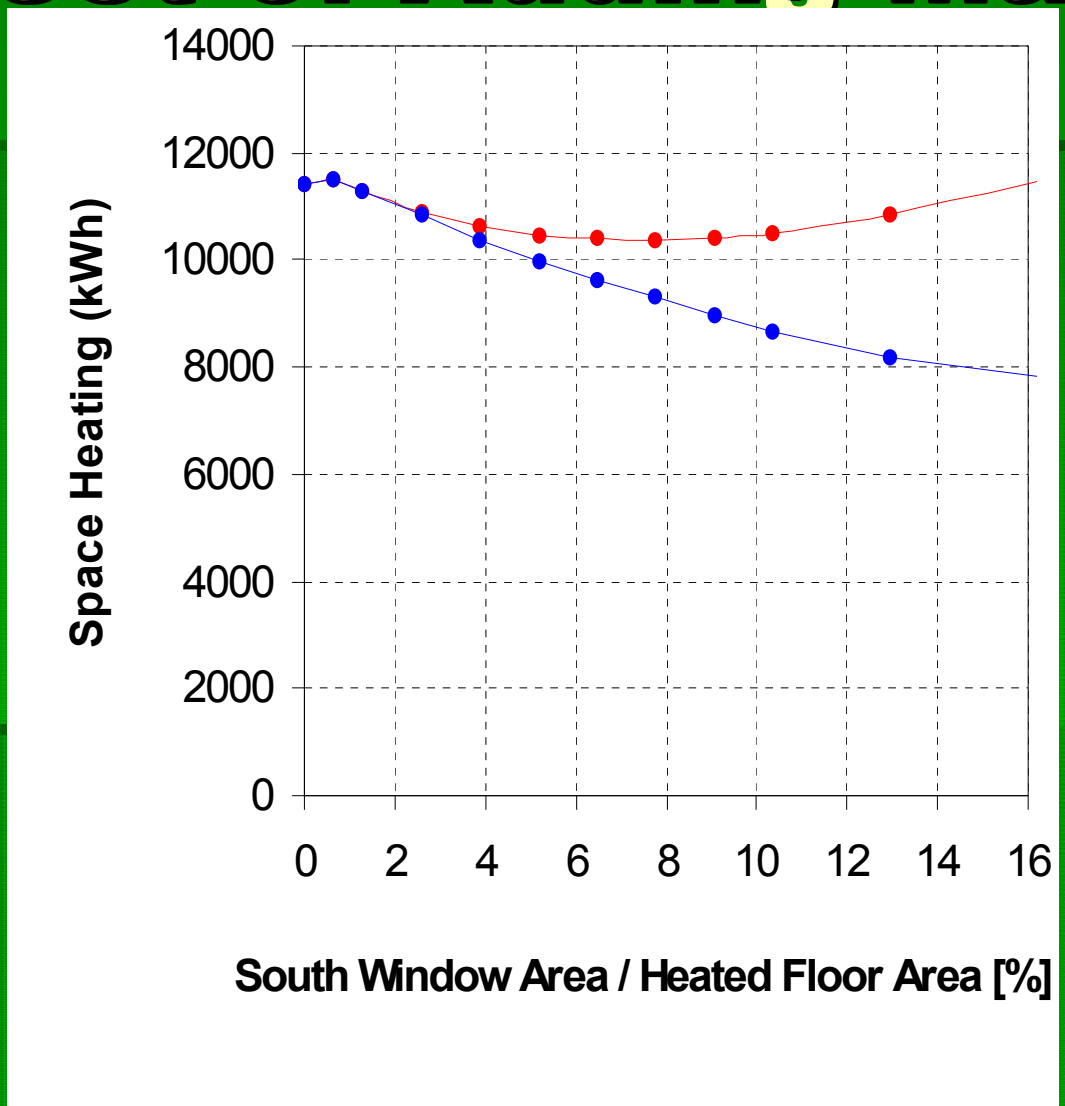




Before Chainsaw Retrofit #2

After Chainsaw Refrofit #2

Effect of Adding Mass



Upper Line
Light, wood frame, construction

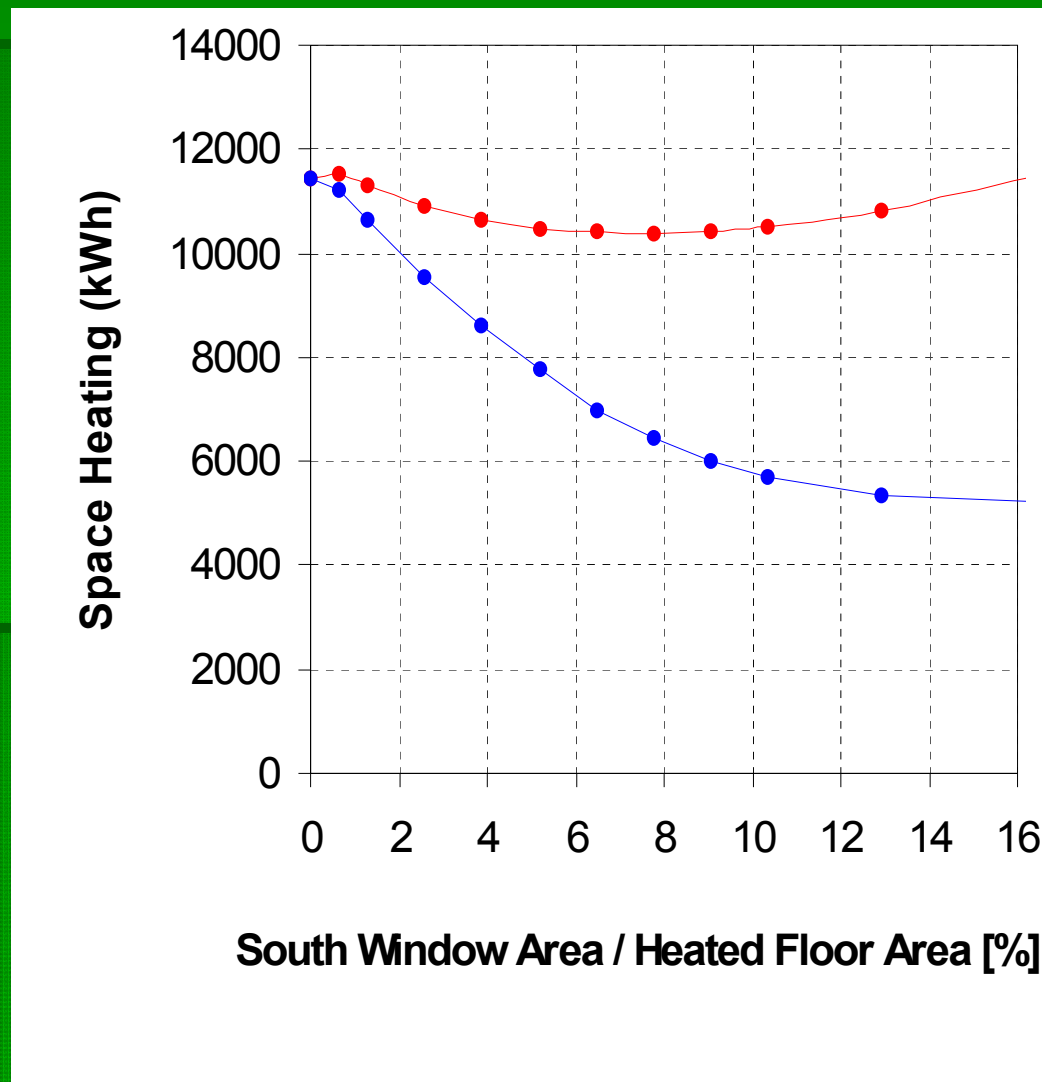
Triple paned, low-e, argon filled, windows

Lower Line

Same windows, change construction to very high thermal mass

Slide courtesy of Dr Rob Dumont

Higher Performance Windows & High Thermal Mass



Upper Line
Light, wood frame, construction

Triple paned, low-e, argon filled, windows

Lower Line

Change construction to very high thermal mass and install new windows

Slide courtesy of Dr Rob Dumont

Useful Volume and Area compared to Heat Loss Surface Area

	Original	Belgravia
Heat Loss Surface Area (Square metres)	461	436
Total Enclosed Volume (Cubic metres)	564	637
Heat Loss Surface Area to Enclosed Volume Ratio	0.82	0.68
Inside Floor Area NIC Basement (Sq. metres)*	113	150
Ratio of Heat Loss Surface Area to Floor Area	4.07	2.90

Two Scenarios

Plan A

- 500 sq. foot second story addition
- ground level solar green house

Plan A

Plan B

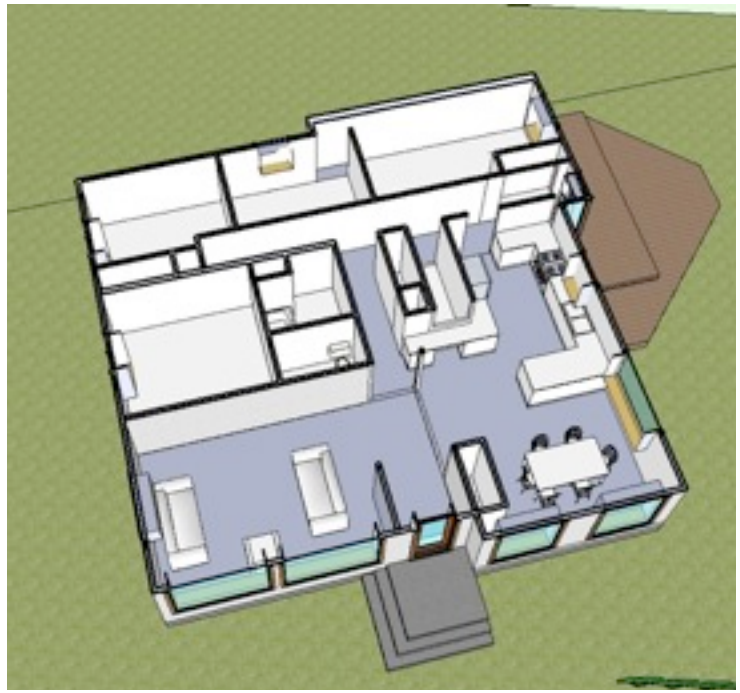
- 300 sq. foot main floor addition to fill in the 'L'
- Roof shaped to accommodate PV array

Plan B

Plan B

Pros

- Filling in the 'L' means very little extra heat loss
- Straighten out the front so one section of the building isn't shading another.
- opportunity to add mass on the main floor in the sun.
- New space is prime living space - in the sun
- Roof can accommodate PV
- More space with slightly less heat loss.



Cons

- Needs more work in the architecture department
- May not add as much space as required
- More disruption of existing space

Plan B: Changes to Net Space Heating* Needs

Upgrade	Marginal Benefit (kWh/year)	Remaining Space Heat (kWh/year)	Belgravia (kWh/year)
Add PlanB space with 2 more south windows	-122	8255	-
Add mass	-854	7401	-
Add more mass	-748	6653	-
Reduce overhang and add awning	-400	6253	-
Attic to R90	-102	6151	-
Total Heating Energy Loss (kWh/year)		6151	3270

*Net space heat after deducting useable passive solar gains and internal gains

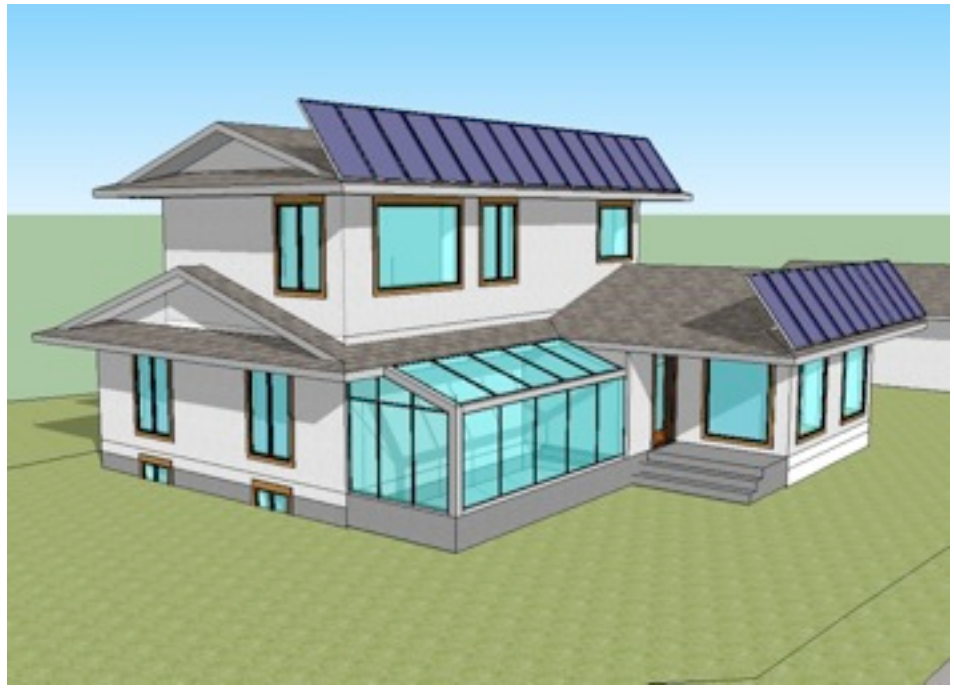
Plan A

Pros

- Aaron's first suggestion
- Private master suite upstairs
- Minimal disruption to existing space.
- Accommodates some on site food production

Cons

- More expensive
- Harder to incorporate thermal mass.
- Hard to control passive solar
- Potential for summer overheating
- Less room for PV

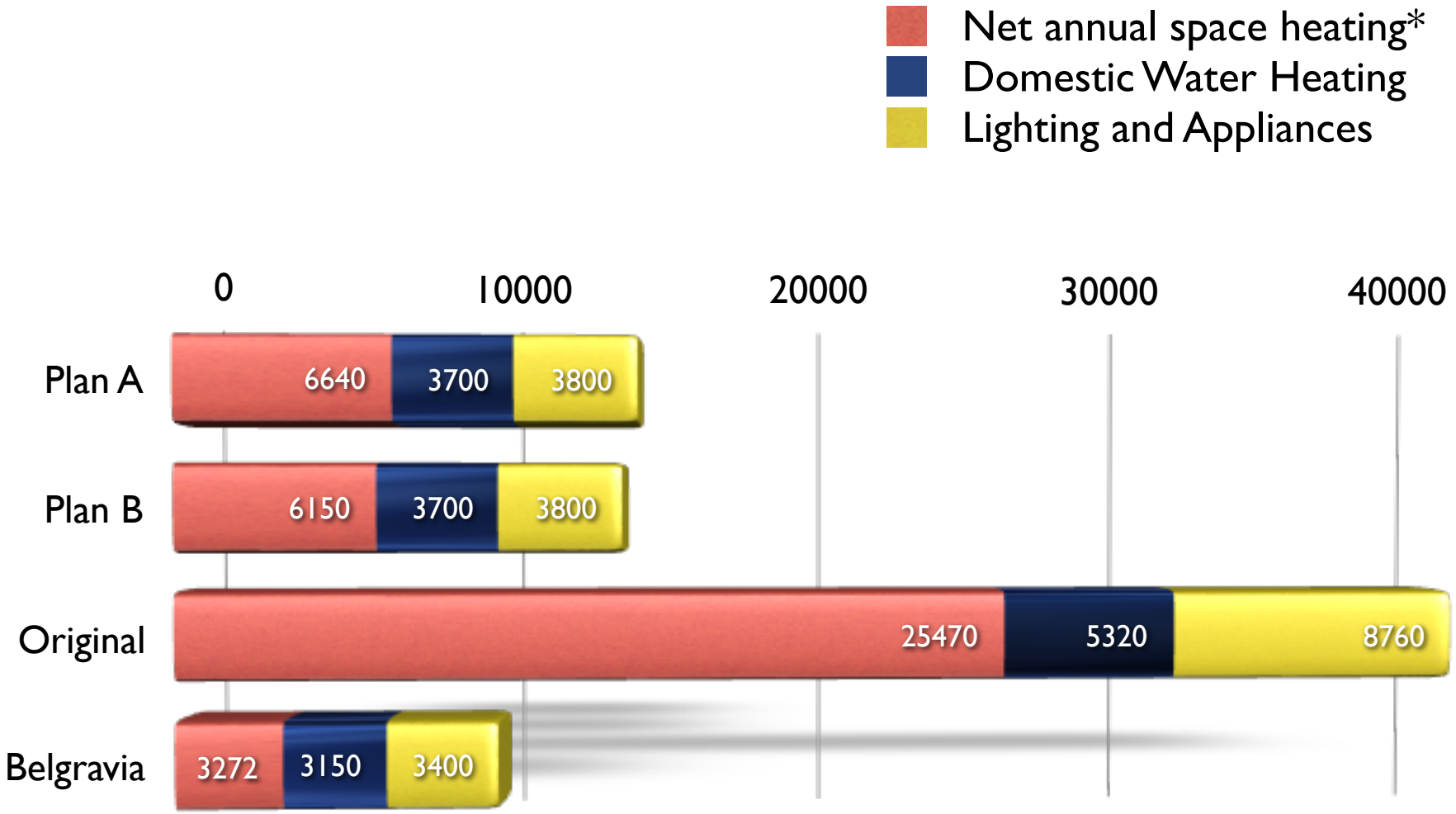


Plan A: Changes to Net Space Heating* Needs

Upgrade	Marginal Benefit (kWh/year)	Remaining Space Heat (kWh/year)	Plan B (kWh/year)	Belgravia (kWh/year)
Existing house with energy upgrades		8865		-
Add second storey with 3 south facing windows	532	9397		
Add mass	-1231	8698		
Add solar greenhouse	-1355	6644		
Total Heating Energy Loss (kWh/year)		6644	6151	3270

*Net space heat after deducting useable passive solar gains and internal gains

Total Annual Energy Use Summary(kWh/year)



*After including passive solar and internal gains

Total Energy Needed from Renewables

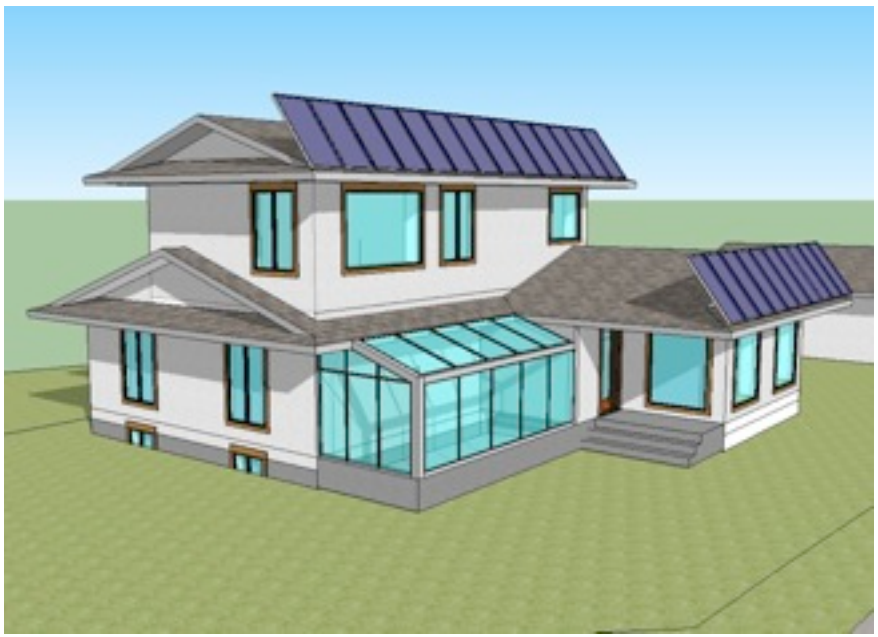
	Plan A	Plan B	Original	Belgravia
Net Space Heating - kWh/year	6640	6150	28095	3270
Lighting ,Appliances, & Miscellaneous Electrical (L.A.M.E.) kWh/year	3800	3800	3800	3150
Domestic Hot Water (DHW) kWh/ year	3700	3700	3700	3430
Total Annual Energy - kWh/year	14140	13650	35595	9850

Solar Thermal

- 2 Collector DWH systems make good sense
- Solar thermal space heating is still unproven in cold climates

PV Considerations

- Solar array is mounted at 53°tilt or steeper to :
  - Maximize annual electricity production
  - Minimize snow cover,
- Try to match roofing and module longevity
- Higher efficiency modules cost more per watt
- Cost is coming down quickly



Photovoltaic Systems

	Riverdale	Mill Creek	Belgravia	Plan B
Total Module Area (Sq. M)	33	35	45	64
Total Peak Capacity(watts)	5600	6080	7380	10965
Annual Output (kWh/year)	6300	8008	9761	13315
Rough Cost (w/o mark up)	~$37000	~$49000	~$48000	~$60000

Energy Profile (kWh/year)

	Riverdale	Mill Creek	Belgravia	Parkland	Plan A	Plan B
Total Annual Heating Energy*	2980	3720	3270	6720	6640	6150
Annual DHW	3100	3450	3150	4480	3700	3700
Annual L.A.M.E	3870	3360	3400	8760	3800	3800
Total Annual Consumption	9950	10520	9850	20210	14140	13650
Solar Thermal	4100	2500	0	0	0	0
Photovoltaic	6600	8000	9910	21000	6626	13350
Total Renewable Production	10500	10500	9910	21000	6626	13350
Net Zero?	-550	20	-60	-790	7514	300

*Net space heat after deducting useable passive solar gains and internal gains

Designing for Net Zero

New Construction

- Site assessment
- Preliminary design
- Model Energy Performance in Hot 2000*
- Optimize envelope
- Optimize passive solar
- Reduce DHW load
- Reduce lighting and appliances loads
- Examine / Model solar DHW
- Size PV to meet remaining total load
- Detailed architectural and system design

Retrofit/Renovation

- Model Energy Performance in Hot 2000*
- Reduce lighting and appliances loads
- Reduce DHW load
- Site assessment
- Optimize envelope
- Preliminary design
- Optimize passive solar
- Examine / Model solar DHW
- Size PV to meet remaining total load
- Detailed architectural and system design

riverdalenetzero.ca

greenedmonton.ca/MillCreekNetZeroHome

habitat-studio.com