Habitat Studio
& Workshop Ltd

Solnorth
Engineering Ltd

howell-mayhew
engineering, inc.

RiverdaleNetZeroHome

BARRHEAD
GREEN EXPO

2009 May 02

Gordon Howell, P.Eng.

howell-mayhew
engineering, inc.

Focus of Presentation

- Tell you about the house
- Show you:
  - What net zero energy means
  - How we achieved it
  - What we've learned
- Answer your questions

My Role…

- I am a solar system project developer
- I am not an equipment supplier
- I have no vested interest in any technology

- My interest is that you choose wisely
  - with your eyes wide open
  - based on the facts and whether it is right for you or not.

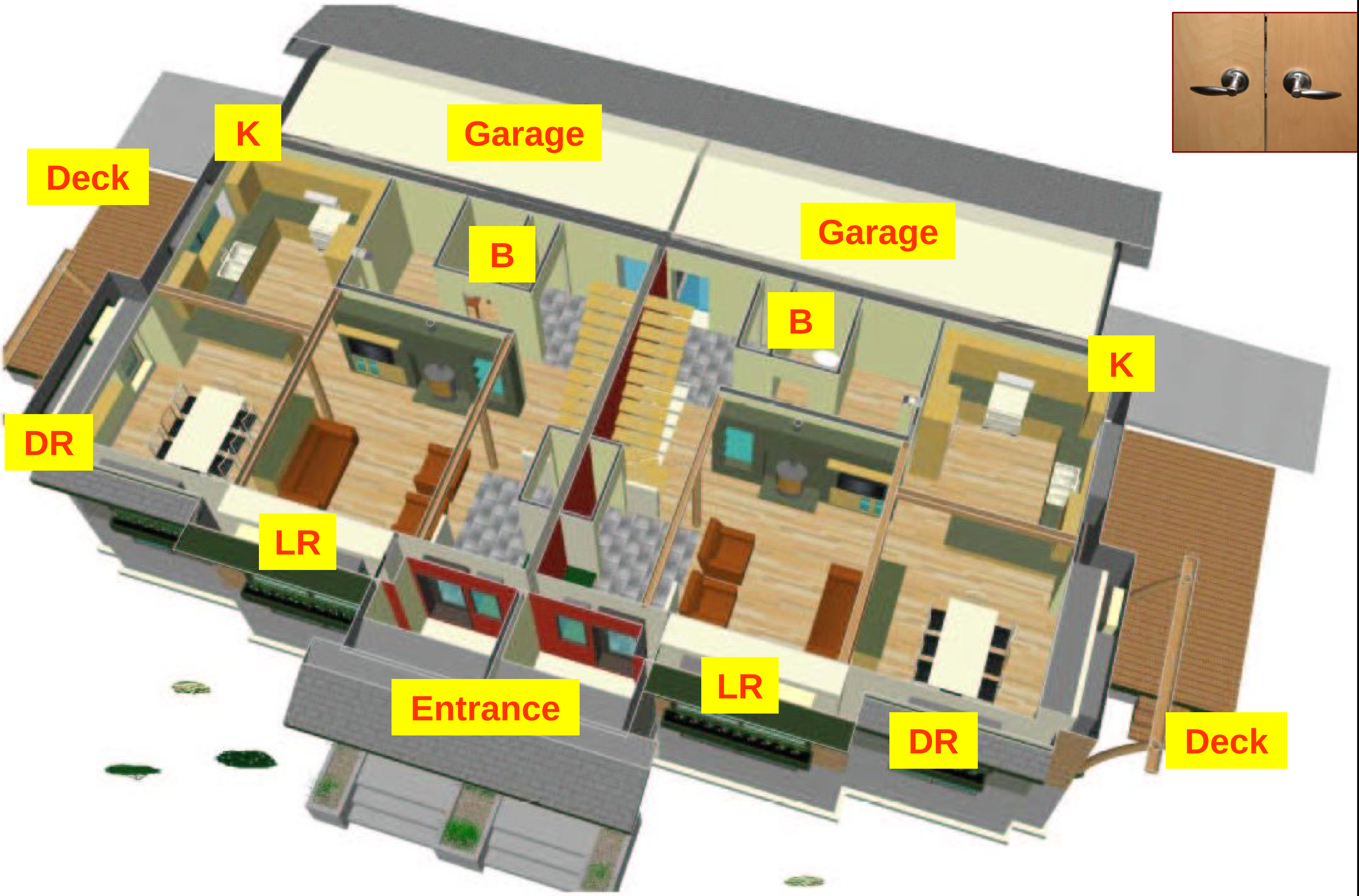
- We are open for questions, challenges…

Riverdale NetZero Energy Home – Edmonton

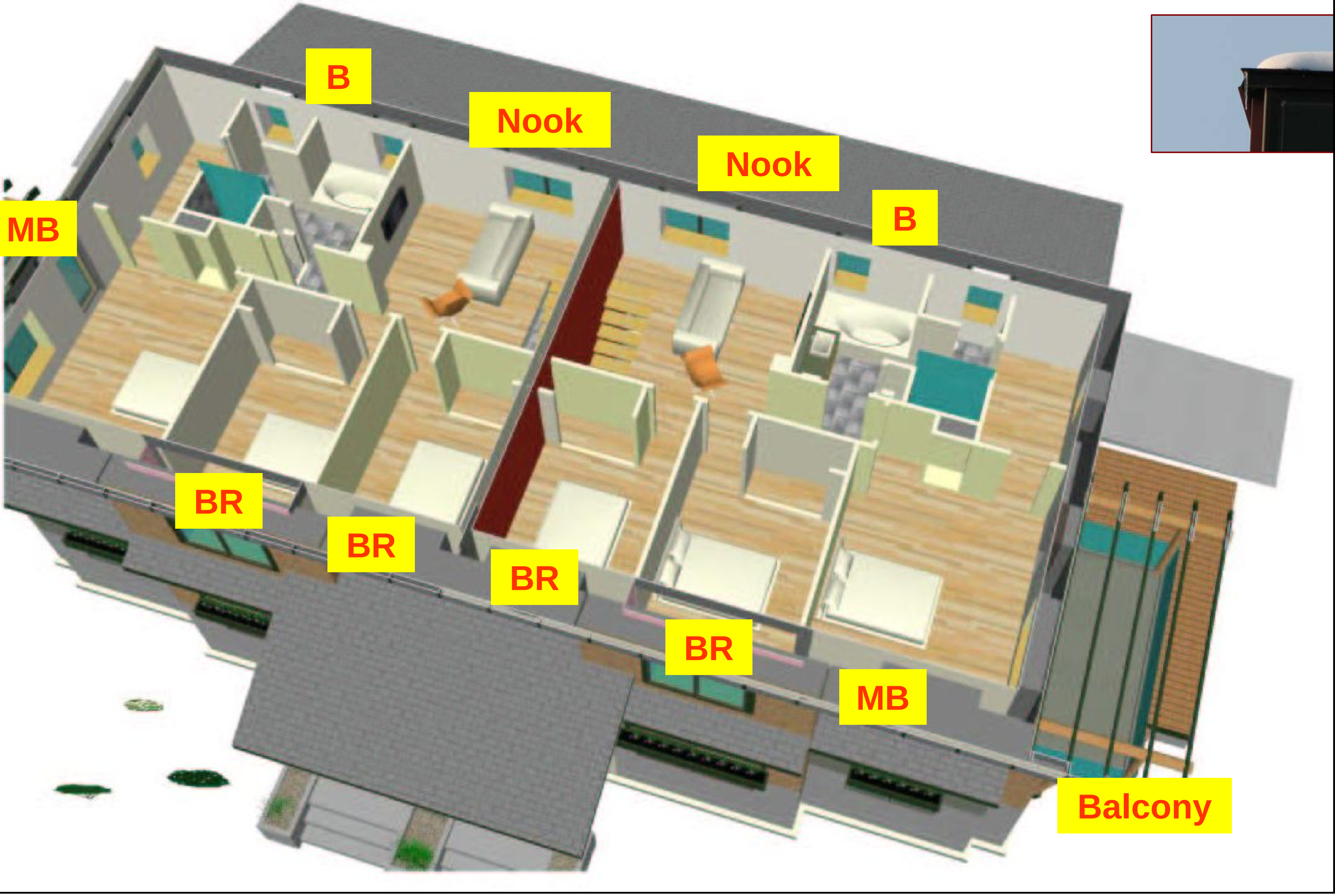
- duplex
- 1844 ft2 per side
- 2519 ft2 including basement
- 3 bedrooms

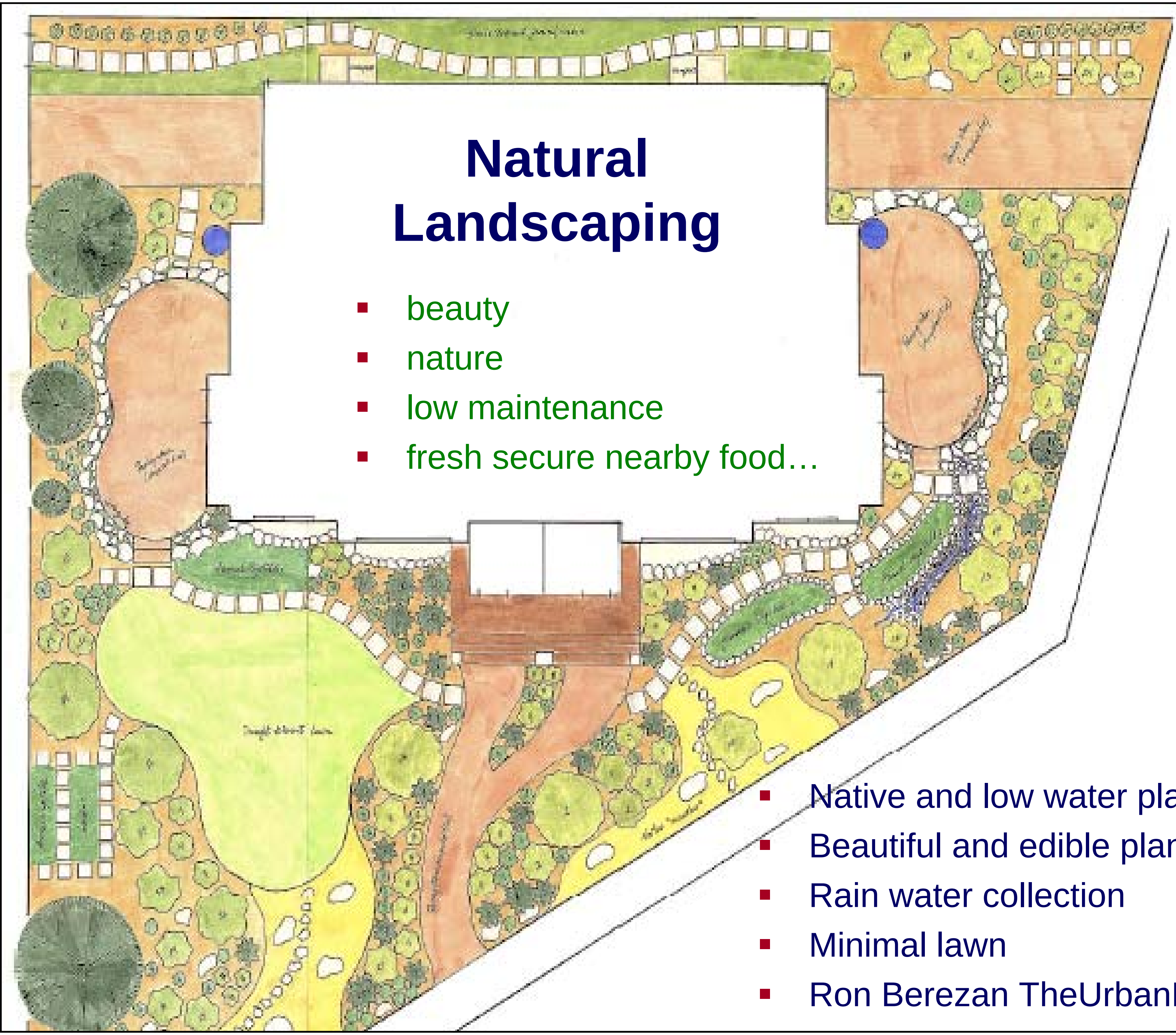
All numbers shown are for each side of the duplex.

Main Floor



Upper Floor





Natural Landscaping

- beauty
- nature
- low maintenance
- fresh secure nearby food…

- Native and low water plants
- Beautiful and edible plants
- Rain water collection
- Minimal lawn
- Ron Berezan TheUrbanFarmer.ca

Sustainable Materials, Air Quality

- Use materials that:
  - Had low manufactured energy
  - Are cleanly manufactured
  - Have low transportation energy
  - Are highly durable

  - Have high recycled content, are recyclable
    - Uses feature beams recycled from liquor store
    - Uses siding from the old house for finish exterior around the windows
    - Recycled floor from a gym
    - Recycled window and door moldings
  - Have low off-gassing of VOC's (volatile organic compounds)

Sustainable materials:
GreenAlberta.ca

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Riverdale NetZero Team – Proponents

- Peter Amerongen Habitat Studio and Workshop
  - designer, builder, developer
- Andy Smith, P.Eng. Solnorth Engineering
  - structural engineer, passive solar heating specialist
- Gordon Howell, P.Eng. Howell-Mayhew Engineering
  - electrical engineer, solar PV specialist
- Plus 45 additional team members…

Habitat Studio & Workshop Ltd

Solnorth Engineering Ltd

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Net Zero Energy Healthy Housing Competition

- Design-build competition (without being paid for it)
- 15 were selected:
  - New Brunswick – Moncton
  - Quebec – Montreal, Eastman, Hudson
  - Ontario – 2 in Toronto, 1 in Ottawa
  - Manitoba – Winnipeg
  - Saskatchewan – Prince Albert
  - Alberta – Edmonton, 2 in Red Deer, 1 in Calgary
  - British Columbia – Kamloops, Vancouver

- CMHC brand: “EQuilibrium Housing”

Canada

EQuilibrium

HEALTHY HOUSING FOR A HEALTHY ENVIRONMENT

MAISON SAINE POUR UN ENVIRONNEMENT SAIN

CMHC SCHL

Sustainable Housing Demonstration Project

Projet de démonstration de logement durable

CMHC's EQuilibrium Initiative

L'initiative EQuilibrium de la SCHL

www.cmhc.ca

www.schl.ca

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Elements of EQuilibrium Housing

- Health
  - Indoor air quality
    - Emissions
    - Thermal comfort
    - Moisture
    - Particle control
    - Ventilation
  - Daylighting
  - Noise control
  - Water quality
- Energy
  - Annual energy consumption
  - Renewable energy strategy
  - Peak electricity demand
  - Embodied energy strategy
- Resources
  - Sustainable materials
  - Durability
  - Material efficiency
  - Water conservation
  - Adaptability / flexibility
- Environment
  - Land use planning
  - Sediment and erosion control
  - Storm water management
  - Waste water management
  - Solid waste management
  - Air pollution emissions
- Affordability
  - Financing
  - Marketability

Canada

EQuilibrium
HEALTHY HOUSING
FOR A HEALTHY ENVIRONMENT

CMHC SCHL

Why is it called a Net Zero Energy Home?

- A home that generates all its heat and electricity on an annual basis.

- It still uses energy…
- but it gets all its energy from renewable sources (usually solar)

Net zero is just the dividing line between

– net deficit (when your house needs energy from the grid because it doesn't generate enough), and

– net surplus (when the environment is better off because your house exists).

The Design Challenge: Is it possible to achieve NZ energy?

(after all, it’s pretty cold and dark here in the winter…)

- An average house uses:
  - Around 6 times more heating fuel energy than electricity!
  - Biggest challenge is <u>not</u> in supplying household electricity…
  - Instead … it is in supplying home heating!

How do you plan for a net zero energy house?

- **<u>Minimise</u>**:

  the heating and electricity consumption of the house
  - The cheapest energy option,
    but it is boring…

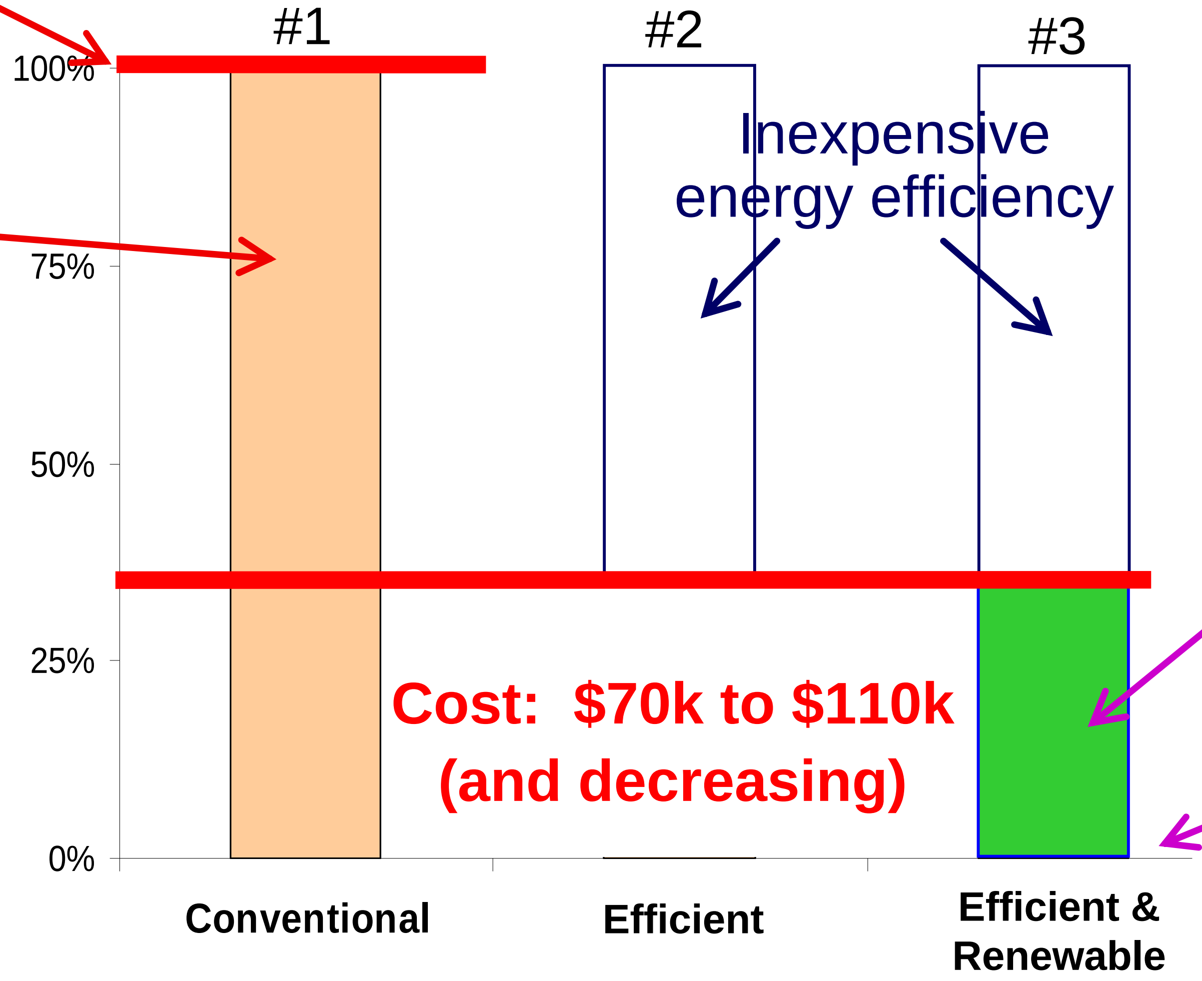
- **<u>Maximise</u>**:

  solar energy supply to the house for its heating and electricity
  - The most expensive energy option,
    but it is the most exciting…

Achieving Net Zero Energy

Purchased Energy

Conventional Energy



Inexpensive energy efficiency

More expensive renewable energy

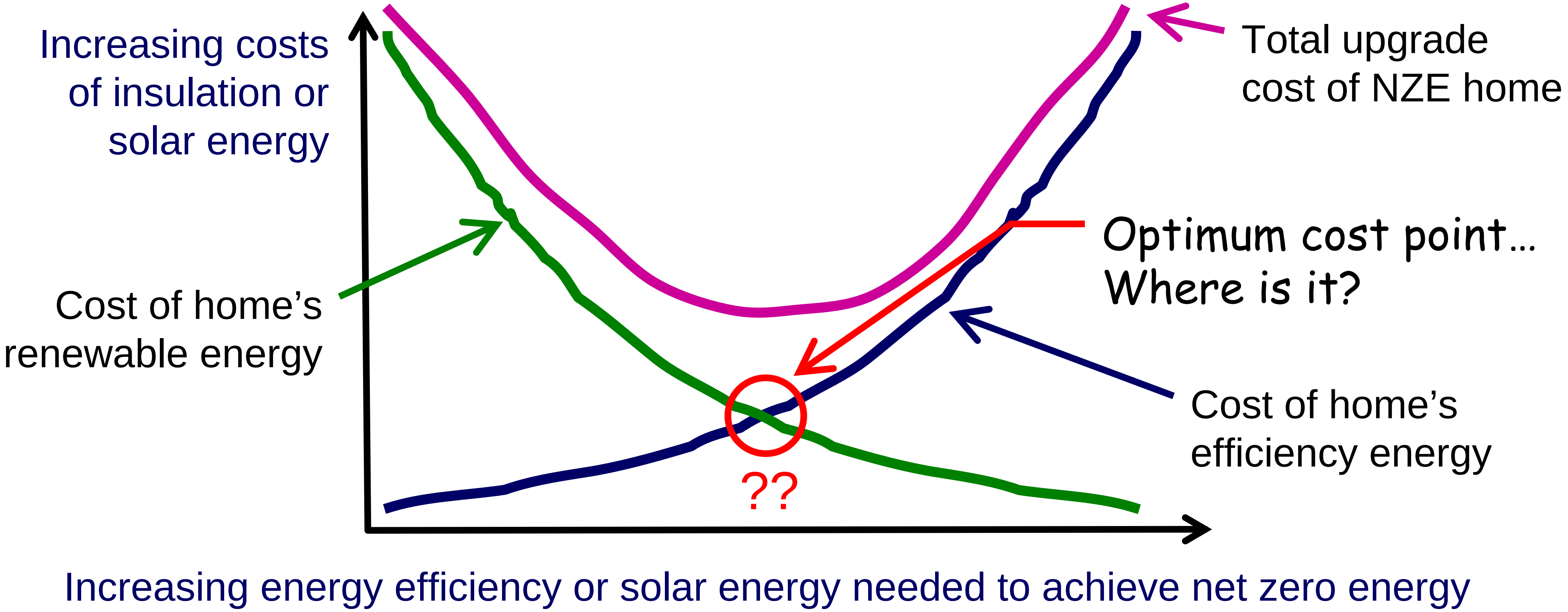
Cost: $70k to $110k (and decreasing)

Net zero energy home

Design Challenge

Where do we find the minimum construction cost to achieve net zero?

- We need large amounts of energy efficiency <u>and</u> large amounts of renewable energy



Increasing costs of insulation or solar energy

Total upgrade cost of NZE home

Optimum cost point… Where is it?

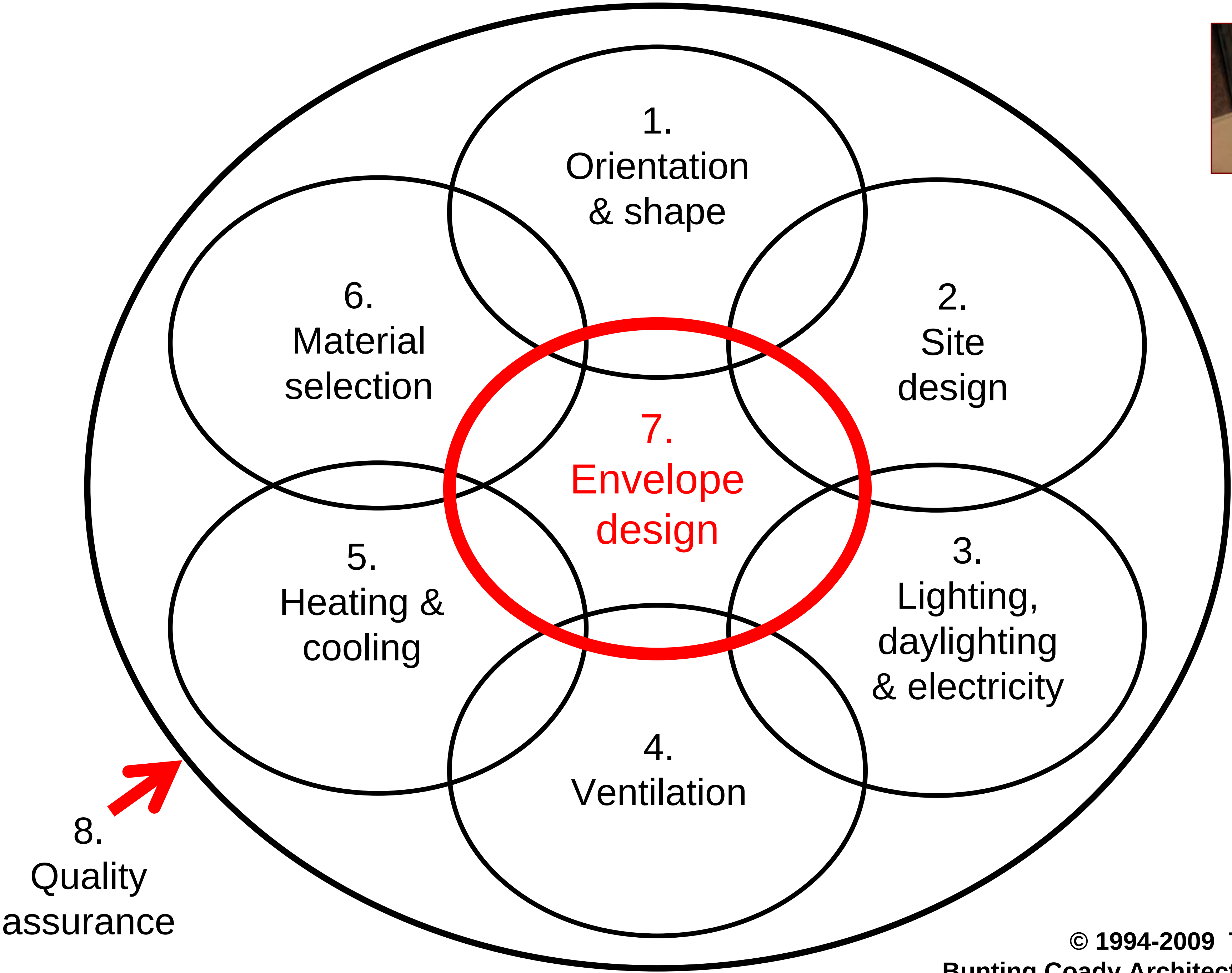
Cost of home's renewable energy

Cost of home's efficiency energy

??

Increasing energy efficiency or solar energy needed to achieve net zero energy

House Envelope Affects Everything Else



1.
Orientation
& shape

2.
Site
design

3.
Lighting,
daylighting
& electricity

4.
Ventilation

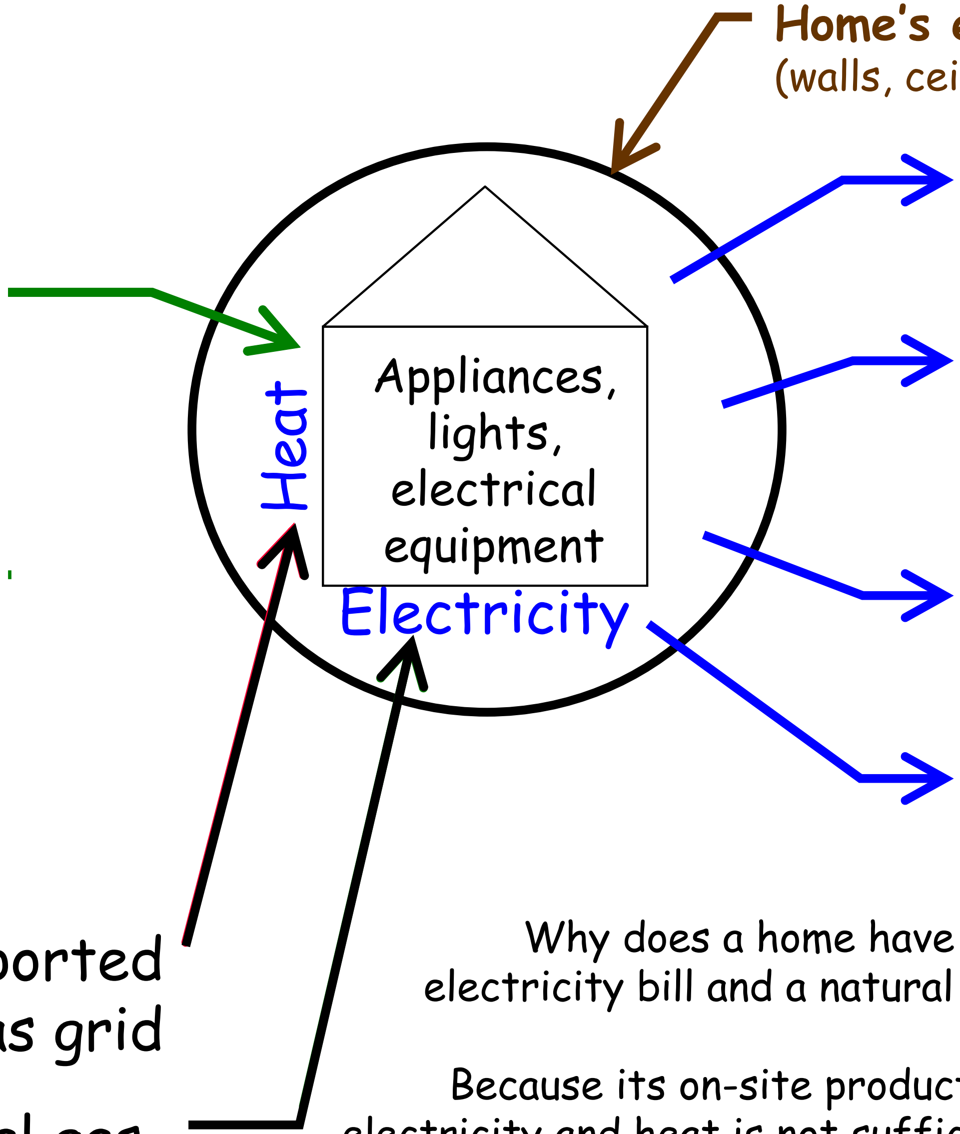
5.
Heating &
cooling

6.
Material
selection

7.
Envelope
design

8.
Quality
assurance

Energy Flows – Standard Home



Home's envelope
(walls, ceiling, floor, windows, doors)

Passive solar for space heating – all windows

Heat

Appliances, lights, electrical equipment

Electricity

Heat loss through envelope

Heat loss from ventilation air
(forced plus natural ventilation)

Heat loss from waste water

Electricity used outside the home

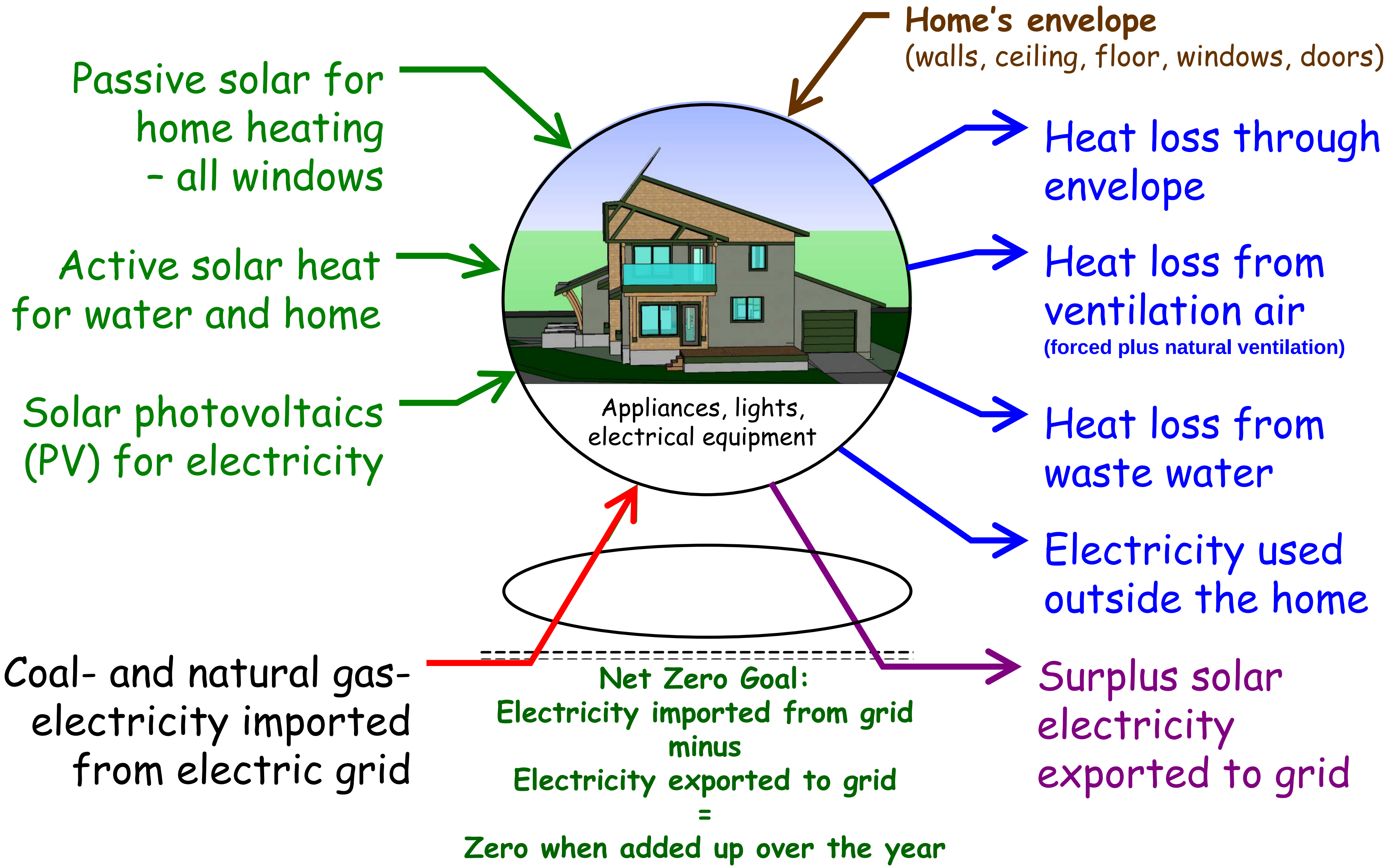
Natural gas imported from gas grid

Coal- and natural gas-electricity imported from electric grid

Why does a home have an electricity bill and a natural gas bill?

Because its on-site production of electricity and heat is not sufficient to meet its electrical and heating requirements and so it needs to import energy from the grids.

Energy Flows – Riverdale NetZero Home



Passive solar for home heating – all windows

Active solar heat for water and home

Solar photovoltaics (PV) for electricity

Coal- and natural gas-electricity imported from electric grid

Home's envelope
(walls, ceiling, floor, windows, doors)

Appliances, lights, electrical equipment

Heat loss through envelope

Heat loss from ventilation air
(forced plus natural ventilation)

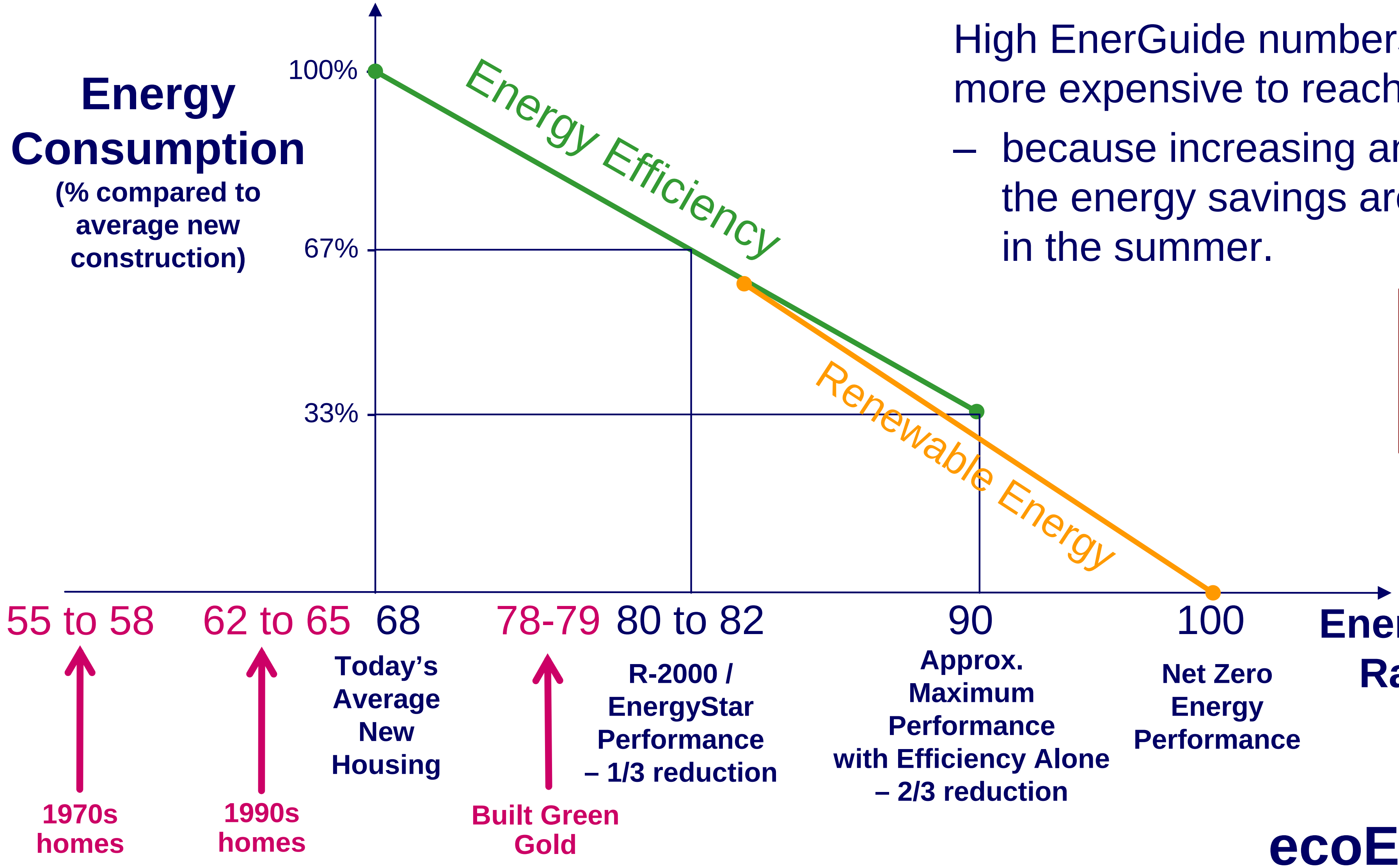
Heat loss from waste water

Electricity used outside the home

Surplus solar electricity exported to grid

Net Zero Goal:
Electricity imported from grid
minus
Electricity exported to grid
=
Zero when added up over the year

Efficiency & Renewables to Get to Net Zero



High EnerGuide numbers become more expensive to reach

– because increasing amounts of the energy savings are wasted in the summer.

ecoENERGY

The Journey to Net Zero Energy

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- cheapest to most expensive

- Electrical fixtures and appliances – electrical
- Water fixtures and appliances – water
- Building envelope – heating

Ultra-high efficiency <u>technologies</u>

- Passive solar space heating…???
- Active solar liquid for domestic water heating…???
- Active solar liquid for space heating…???
- Active solar air for space heating…???
- Heat pump: ground, air, water…???
- Solar photovoltaic heating: heated air, electricity…???

Heating <u>technologies</u>

- Solar photovoltaics…???
- Microwind…??? (probably not in urban settings)

Electricity <u>technologies</u>

#1. Domestic Electricity


Fridge

- Electricity consumption reduced by **50%** for an upgrade cost of **$1800 (est)**
  - Energy efficient appliances, ECM ventilation motors
  - Energy efficient lighting (compact fluorescent, LEDs)
  - Task lighting (halogen)
  - Daylighting
  - Phantom load control

- Annual savings: $550 (4600 kWh est., 4200 kg of emissions)
- Energy price: (simple) **1.6 ¢/kWh = $4.50 /GJ (25 years)**
- Return on Investment: (simple) 30% /year (= ~3 year payback)


Clothes dryer


Dishwasher


Light Emitting Diode (LED) lighting


CF lighting

#2. Domestic Water Heating

Drain water heat recovery

- Fuel consumption for water heating reduced **75%** for an upgrade cost of **$1750**
  - Water efficient shower heads, faucets, dishwasher, clothes washer
  - Drain water heat recovery

- Annual energy savings: 6200 kWh
  46,000 DHW litres
  1500 kg of emissions
  $260
- Energy price: (simple) **1.1 ¢/kWh = $3.10 /GJ (25 years)**
- Return on Investment: 15% /year

(plus additional savings in water volume too)

Shower heads and faucets

Dish washer

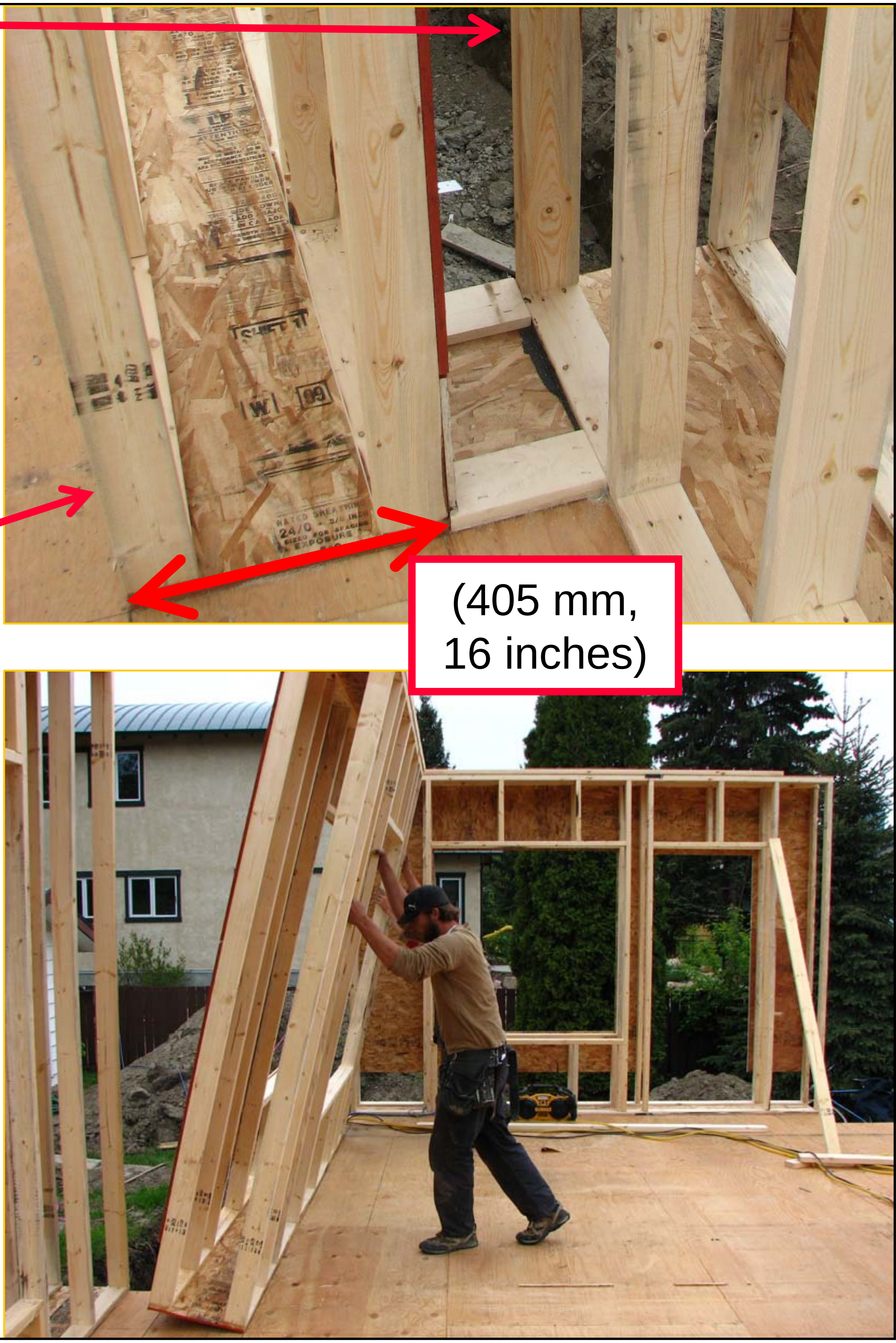
Clothes washer

#3. Energy Efficiency – the most important part

	Riverdale NZE	90s house	70s house
Wall construction:	double 2x4	single 2x6	single 2x4
Insulation:			
– ceiling:	R-100	R-28 to 34	R-12
– walls:	R-56	R-20	R-8
– basement walls:	R-54	R-8 (upper part)	nothing
– basement floor:	R-24	nothing	nothing
Windows:	3-glazed (S, E, W) 4-glazed (N) low-e, argon gas	2-glazed	2-glazed
Air leakage rate:	0.5 AC/hour	4 to 6 AC/hour	5 to 7 AC/hour
Ventilation system:	with heat recovery 80% efficient	none	none

Wall Construction and Insulation

- Double-stud 2x4
  - Easily able to be reproduced by home builders
  - 400 mm thick
- Cellufibre insulation
  - Recycled newspapers
  - Low embodied energy
  - Locally produced
  - Sequestered carbon
  - Not a hydrocarbon product
  - R-59 value for insulation alone
  - R-56 overall wall value (including thermal bridging)



Outside of wall

Inside of wall

(405 mm, 16 inches)

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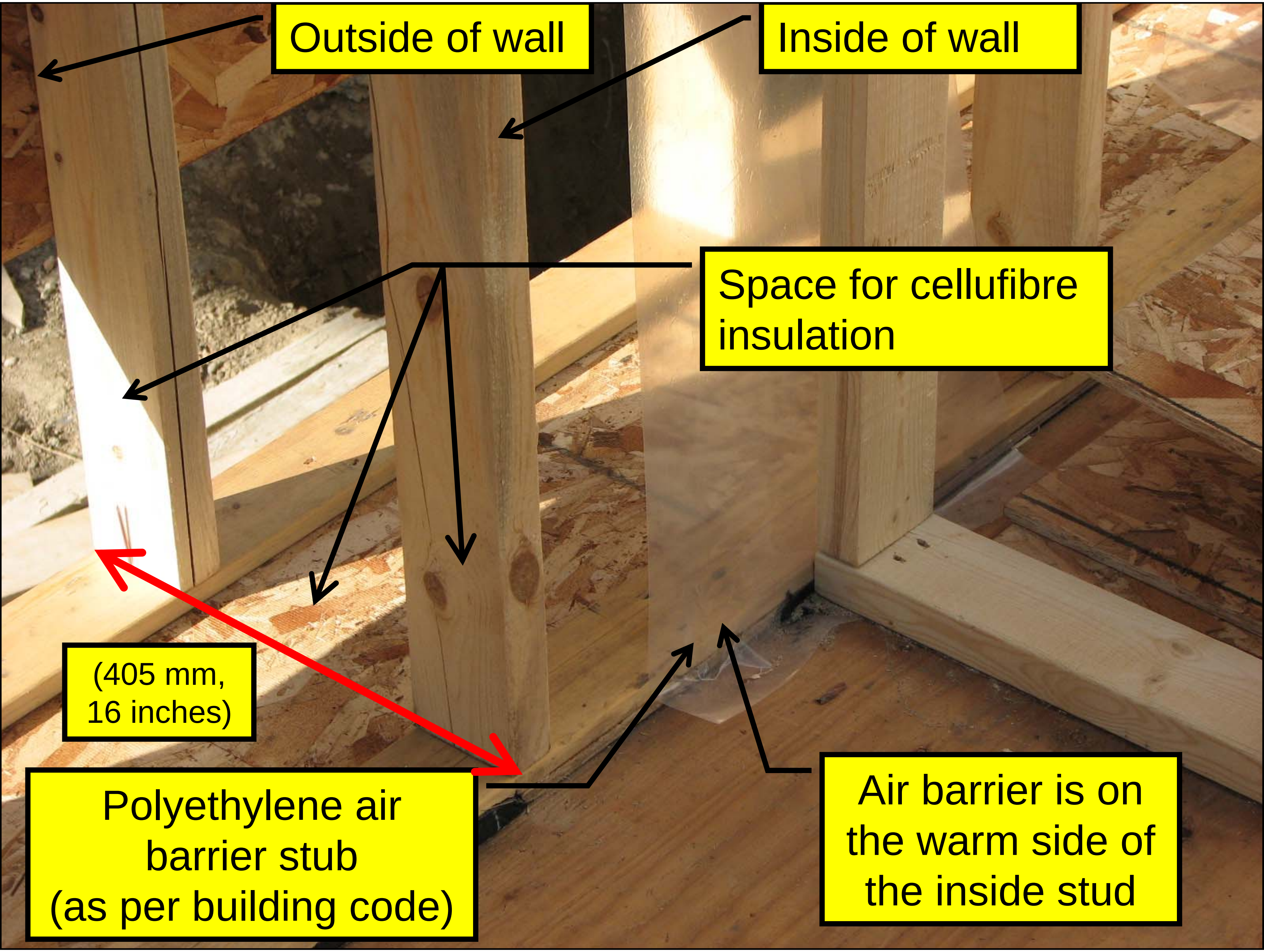


Outside of wall

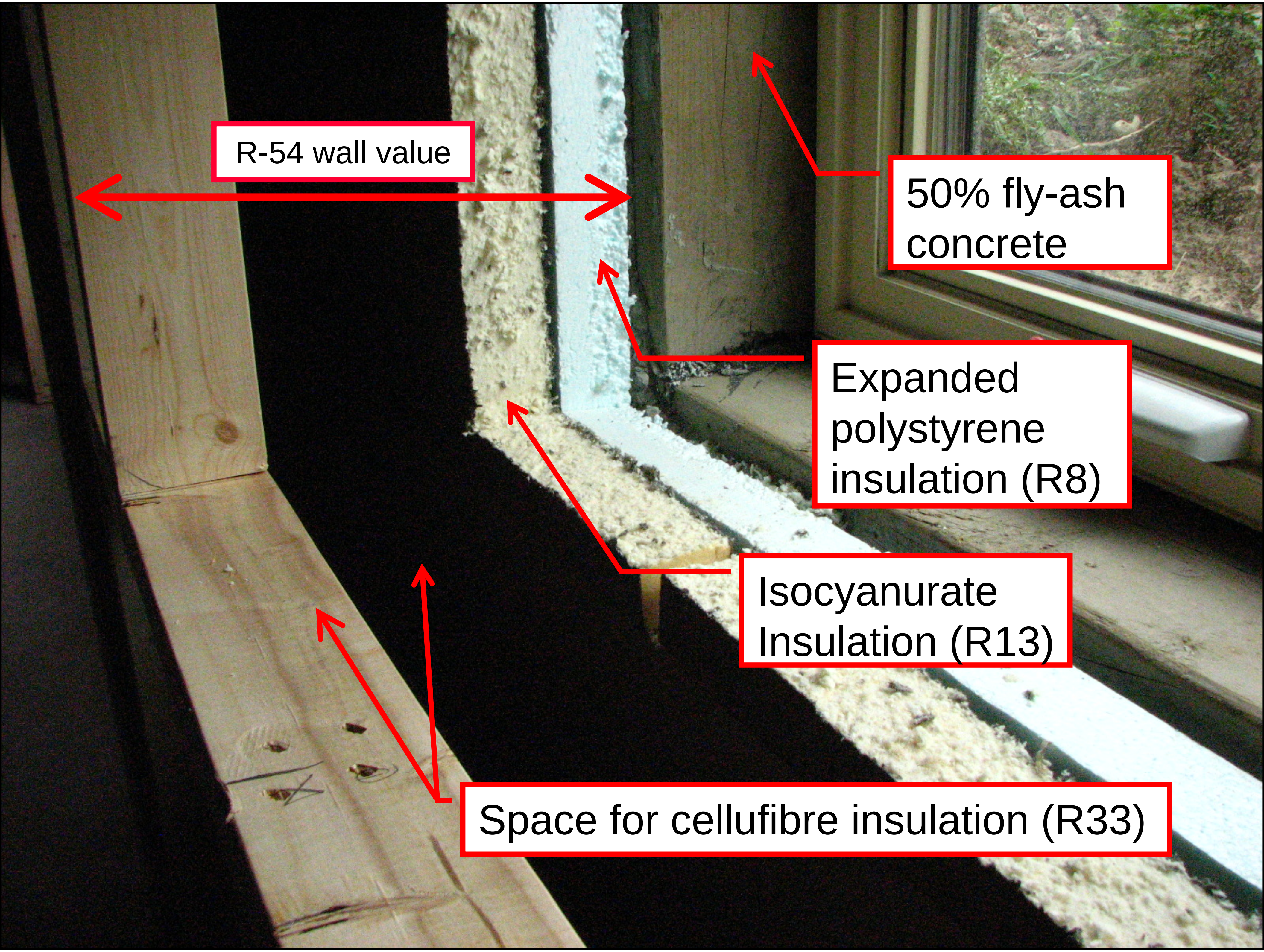
Inside of wall

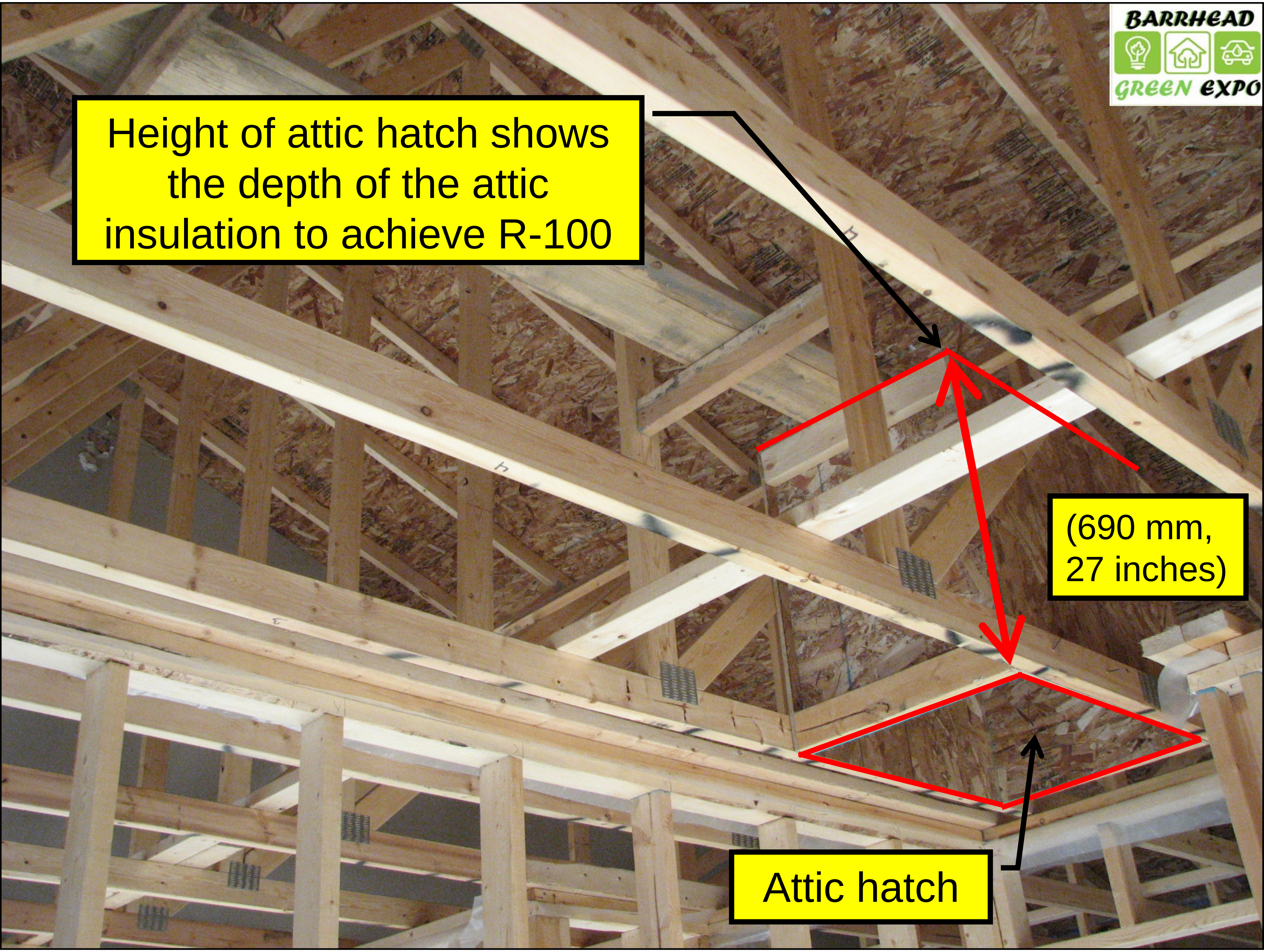
Space for cellufibre insulation

(405 mm, 16 inches)

Polyethylene air barrier stub (as per building code)

Air barrier is on the warm side of the inside stud


R-54 wall value
50% fly-ash concrete
Expanded polystyrene insulation (R8)
Isocyanurate Insulation (R13)
Space for cellufibre insulation (R33)

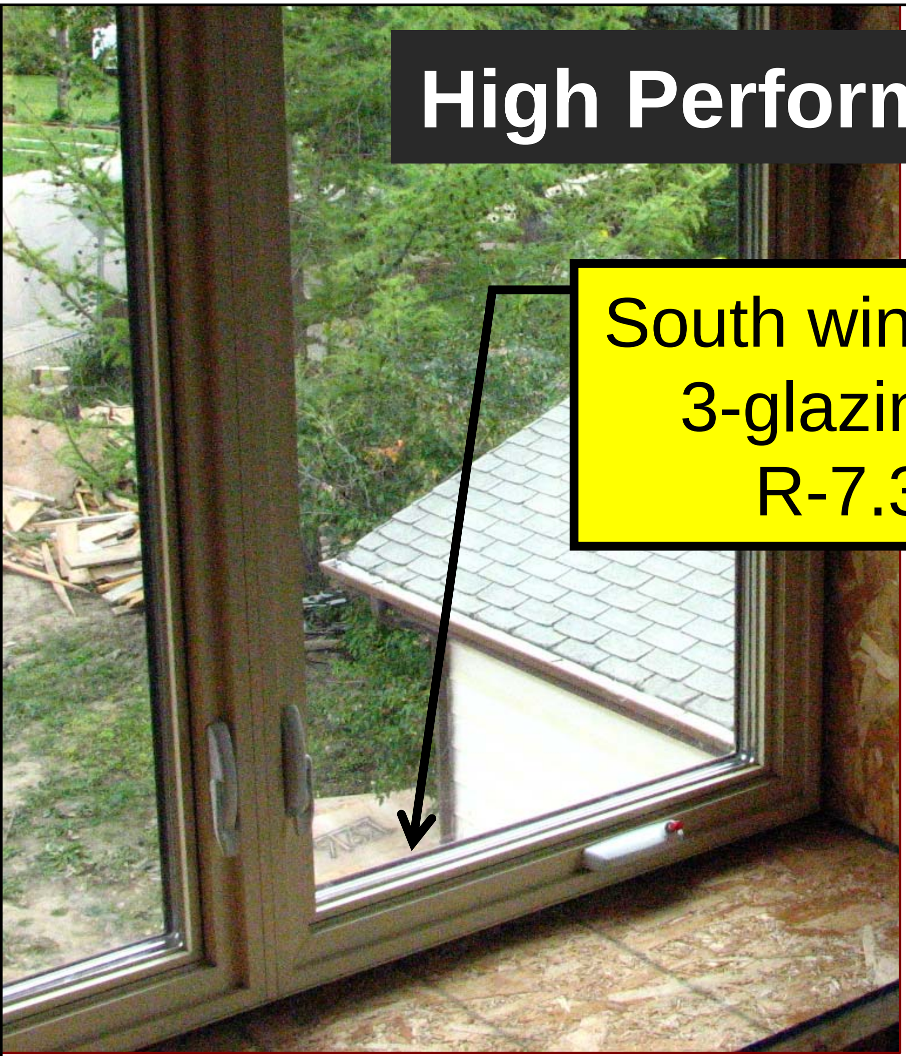


Height of attic hatch shows the depth of the attic insulation to achieve R-100

(690 mm, 27 inches)

Attic hatch

High Performance Windows



South windows
3-glazings
R-7.3

East/west windows
3-glazings
R-8.3

North windows
4-glazings
R-10

- Soft-coat low emissivity coatings
- Argon gas between the glazings
- “Warm edge” spacer
- Insulated fibreglas frames
- Manufactured by Duxton, Winnipeg

Results: Heat Loss at Winter Design Conditions

	Riverdale NZE	**90s house**	**70s house**
Floor area:	**1844 ft^2**	**1500 to 1800**	**1500 to 1800**
Heat loss at –32°C:	**6.6 kW** **(22,400 BTU/h)**	**20 to 26 kW** **(70,000 to 90,000)**	**29 to 35 kW** **(100,000 to 120,000)**
# of 4-slice toasters to heat the house at –32°C at night	**4** **(or 6 hair dryers)**	**12 to 15** **(18 to 22)**	**17 to 21** **(24 to 30)**
EnerGuide rating: (building envelope efficiency)	**86**	**62 to 65**	**55 to 58**

(Built Green Gold = 78, 79)

(R-2000 = 80 to 82)

#3. Building Envelope

- Fuel consumption for space heating reduced by **70%** for an upgrade cost of **$12,000**
- Annual savings: 25,000 kWh
  5900 kg of GHG reductions
  $1000
- Energy price: (over 50 years)
  (simple) **0.9 ¢/kWh = $2.60 /GJ**
- Return on Investment: 9% /year

Ceiling R-100 cellufibre

Double-stud 2x4 walls with R-56 cellufibre

Basement walls R-54

South windows
R-7.3
R-8.3

North windows
R-10

Air tight envelope
0.59 AC/h

Heat recovery ventilator
80% efficient

#4. Passive Solar Heating

- 16.9 m^2 of south glazing
  = 10% of floor area
- Provides daylight to further reduce electricity consumption
- 20,000 kg thermal mass
  - Feature wall
  - Concrete counter tops
  - Extra drywall
- Provides 40% of space heating
- EnerGuide rating: **93**
  (electricity efficiency, passive solar)

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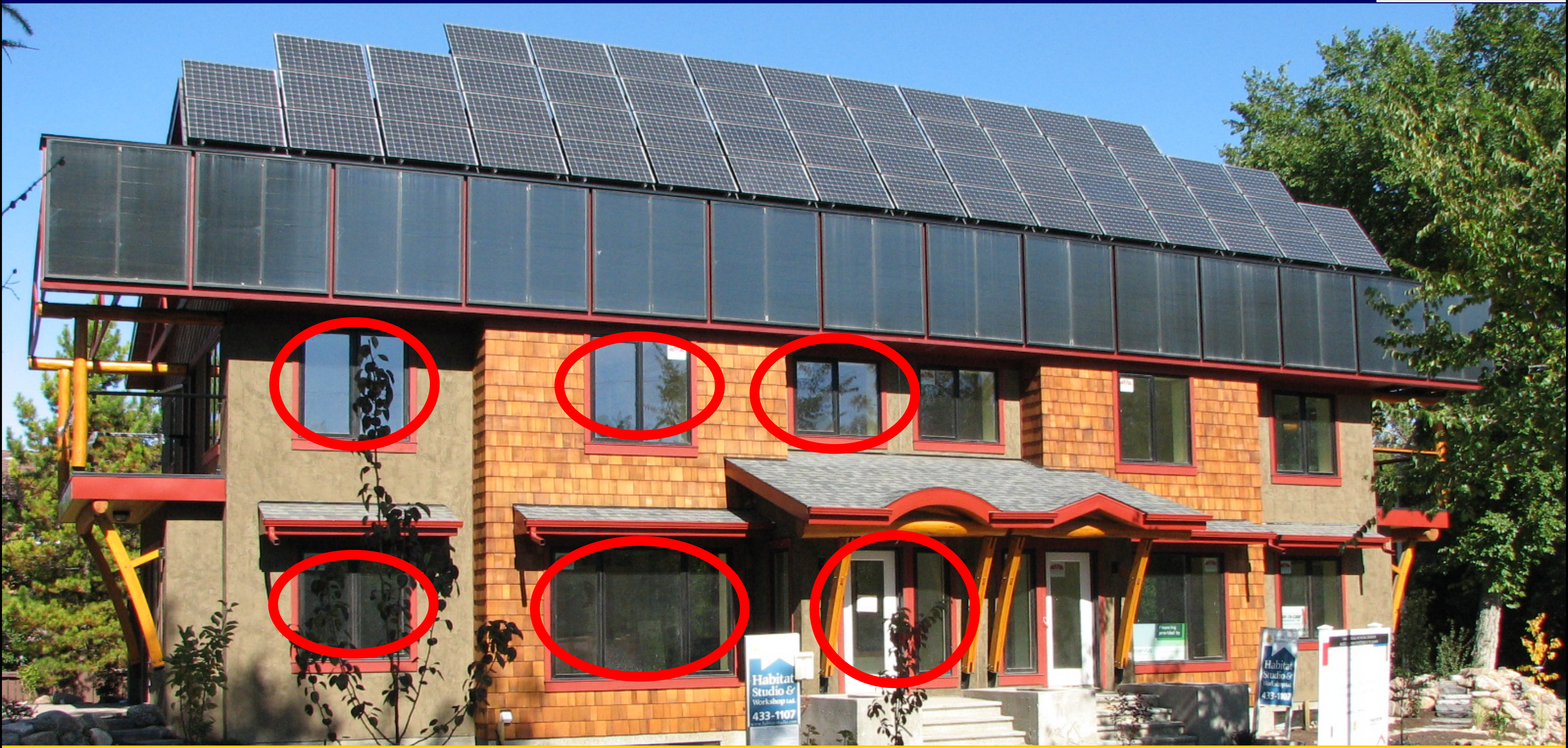
#4. Passive Solar Space Heating



Upgrade cost:	$2,400 for additional concrete mass
Annual value of passive solar heat:	4400 kWh est.
	1000 kg of GHG reductions
	$185

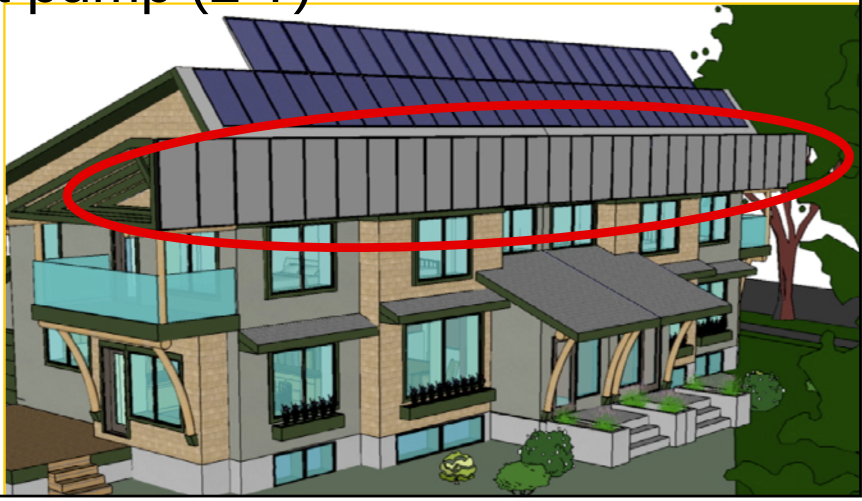
Economics are integrated with building envelope & not easy to determine (yet)

#5. Active Solar Thermal Space and Water Heating

- 7 Zen collectors (21 m^2) – high-efficiency flat-plate collectors
  – mounted on a vertical tilt
    – to maximise winter solar gain
    – to eliminate snow cover
    – to maximise reflected solar energy

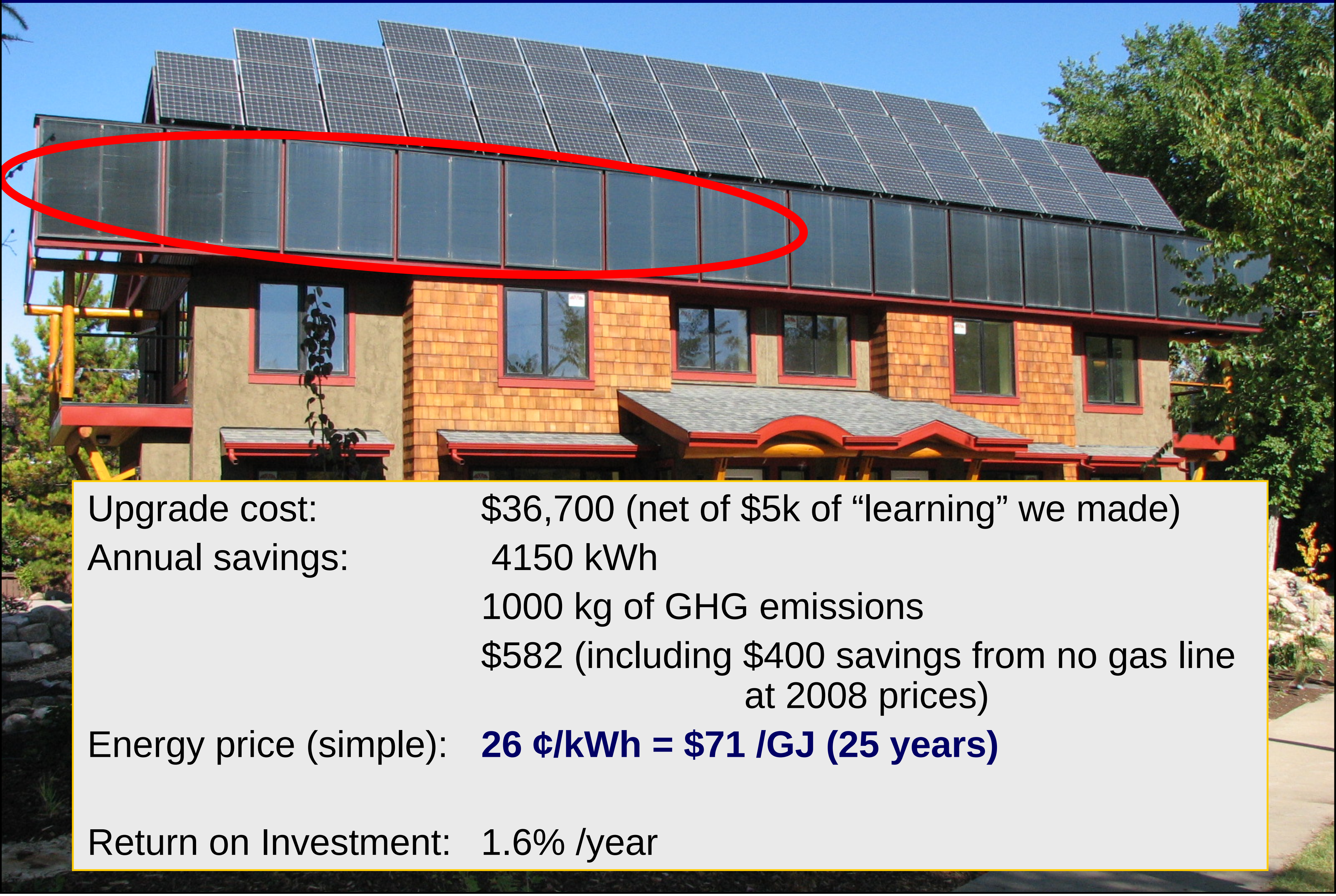
300 litres	– hot water storage	– water heating
+ 17 000 litres	– warm water storage in basement	– home heating

- Drainback system – water-based
  – does not use glycol
- May include a very small solar-assist heat pump (2 T)



- Provides 83% of domestic water heating and 21% of space heating
- EnerGuide rating: **96**

#5. Active Solar Thermal Space & Water Heating



Upgrade cost: $36,700 (net of $5k of “learning” we made)

Annual savings: 4150 kWh

1000 kg of GHG emissions

$582 (including $400 savings from no gas line at 2008 prices)

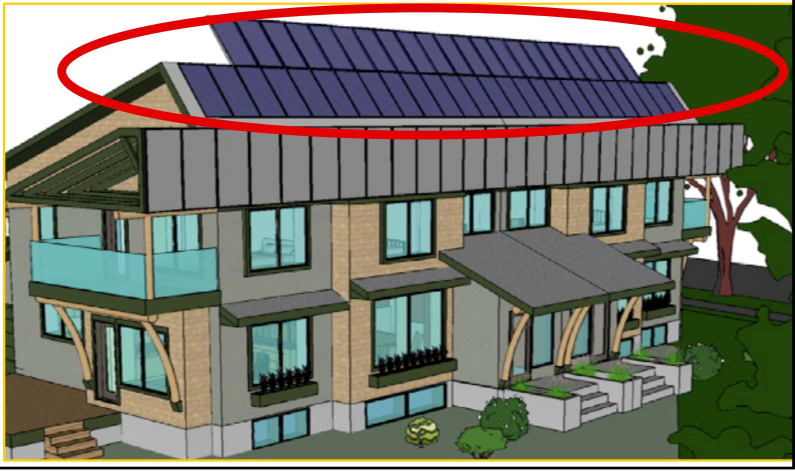
Energy price (simple): **26 ¢/kWh = $71 /GJ (25 years)**

Return on Investment: 1.6% /year

#6. Solar Electric Power System

called “photovoltaics” or PV

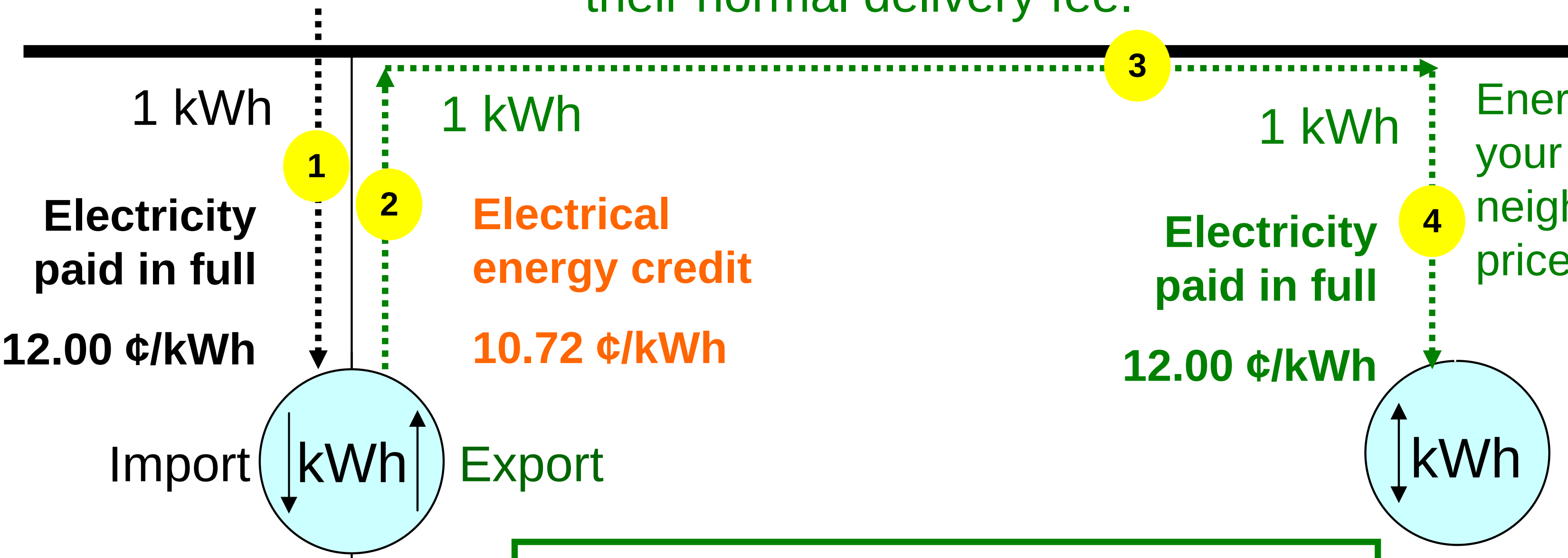
- 28 Sanyo high efficiency (17%) 200 W PV modules (Japan)
  - 33 m^2, 5600 W in bright sunshine
  - Solar array mounted at 53°tilt to minimise snow cover, and maximise annual electricity production
- SMA Sunny Boy 6000W grid-dependent inverter (Germany)
- No battery bank
- Exports to grid every day of the year (even cloudy days)
- Provides 6% of domestic water heating,
  11% of space heating and
  112% of electricity consumption
- EnerGuide rating: **100.4**
  (surplus of 620 kWh/year)



#6. Solar PV for Domestic & Deficit Heating Electricity

Upgrade cost:	~$54,000
Annual savings:	6600 kWh measured 6100 kg ~$800
Energy price (simple):	**27 ¢/kWh = $76 /GJ (30 years)**
Return on Investment:	1.5% /year

How does Alberta’s net billing work?



Energy Retailer,
Electricity Delivery
Company

Electricity is delivered to your neighbours by your local Electricity Delivery Company for their normal delivery fee.

Electricity
delivery wires

1 kWh

①

Electricity paid in full

12.00 ¢/kWh

1 kWh

②

Electrical energy credit

10.72 ¢/kWh

③

1 kWh

④

Electricity paid in full

12.00 ¢/kWh

Energy Retailer sells your energy to your neighbour for full retail price.

Bidirectional
kWh meter

Ordinary kWh
meter

PV system
owner

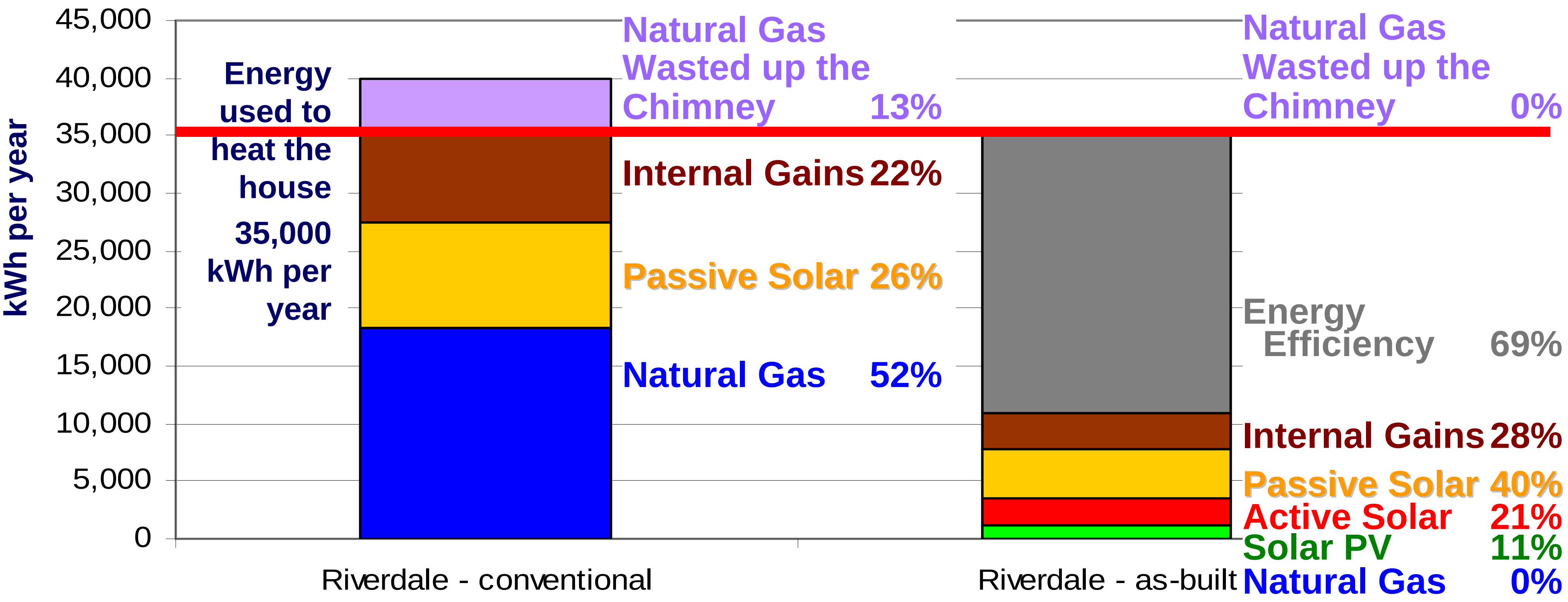
Net billing allows exported electricity to be valued at any price, such as:

- a **discounted** wholesale price,
- a price **equal** to the import price, or
- a **premium** feed-in (green) price.

Neighbour

1 kWh supplied, 1 kWh paid for

Source of Energy – Space Heating



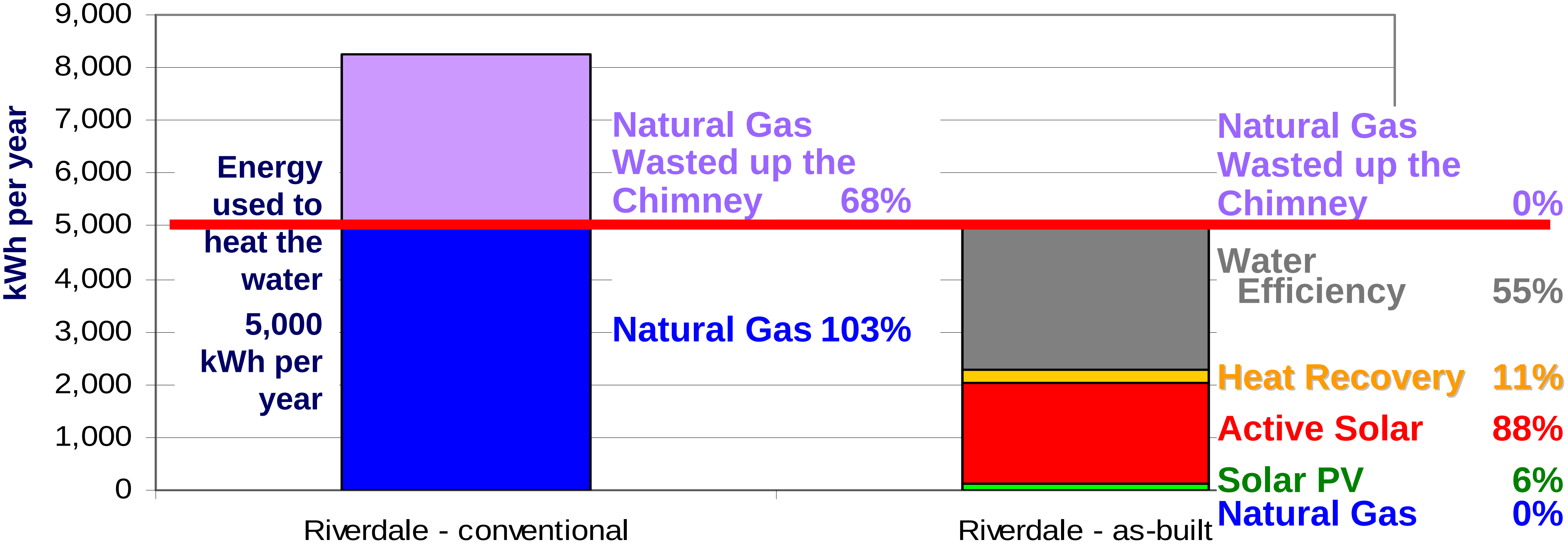
If RNZ were built with conventional construction

As-built:

of remaining 31% of energy requirements after efficiency improvements

13%	0%	🟪 Efficiency losses
0%	69%	⬛ Building envelope energy efficiency
22%	28%	🟫 Internal gains from DWH, people, electricity
26%	40%	🟨 Passive solar through south windows
0%	21%	🟥 Active solar thermal
0%	11%	🟩 Solar PV electricity
52%	0%	🟦 Natural gas

Source of Energy – Water Heating

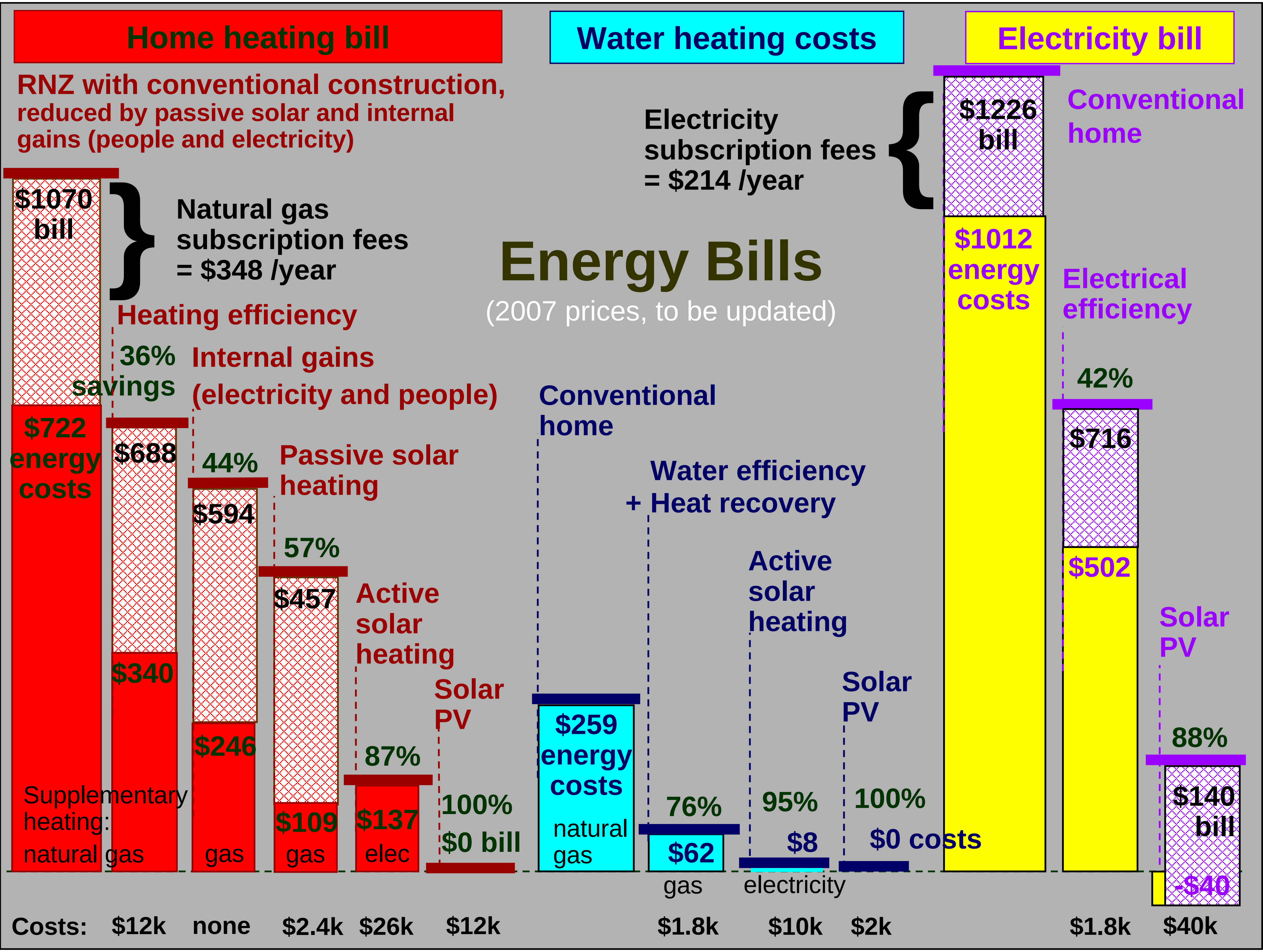


If RNZ were built with conventional construction

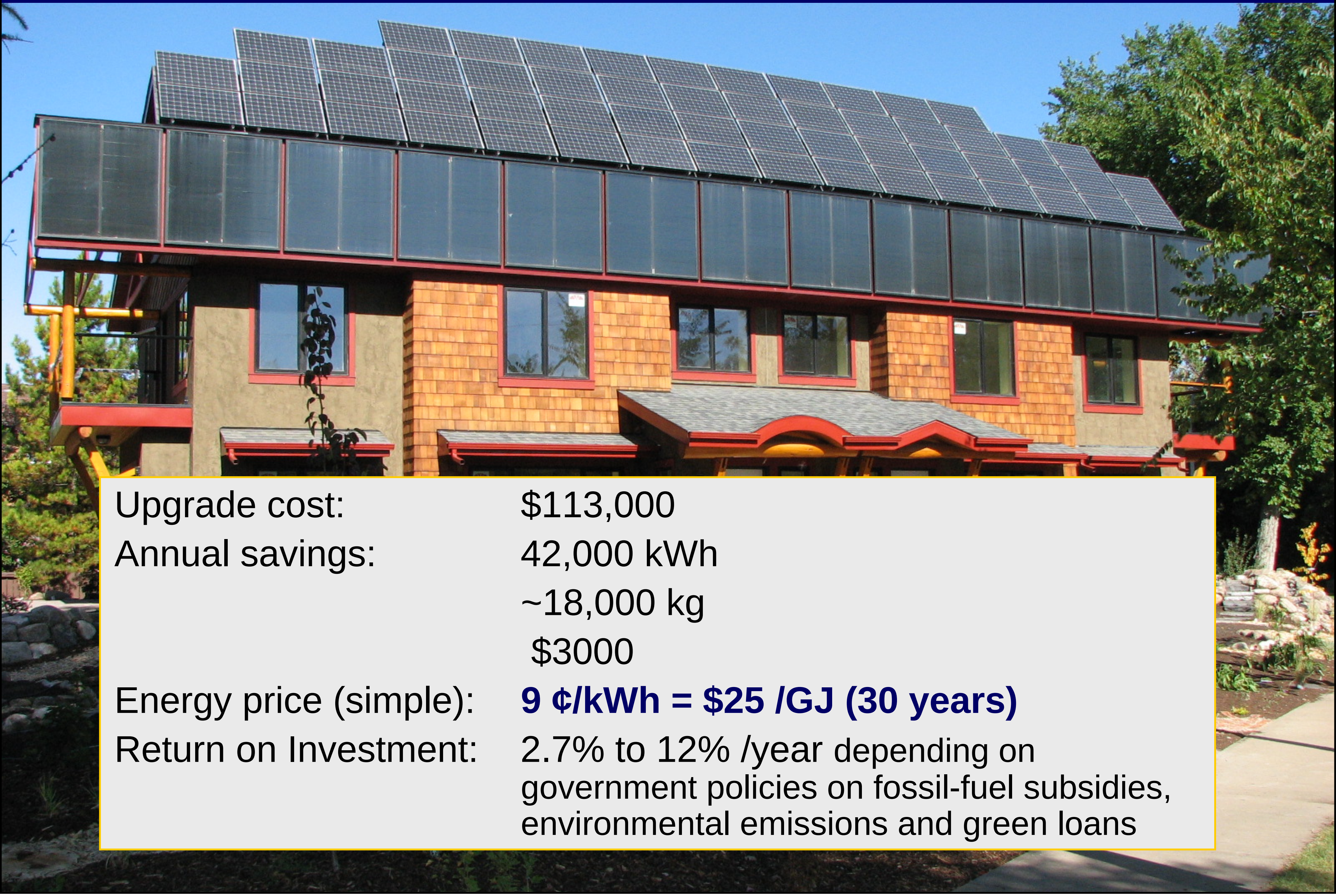
68%	**As-built:**	0%	🟪 Efficiency losses
0%		55%	⬛ Water efficiency
-3%	of remaining 45% of energy requirements after efficiency improvements	-6%	🟫 Internal losses to house
0%		11%	🟨 Heat recovery
0%		88%	🟥 Active solar thermal
0%		6%	🟩 Solar PV electricity
103%		0%	🟦 Natural gas

Energy Bills

(2007 prices, to be updated)



Economics of Combined Systems



Upgrade cost: $113,000

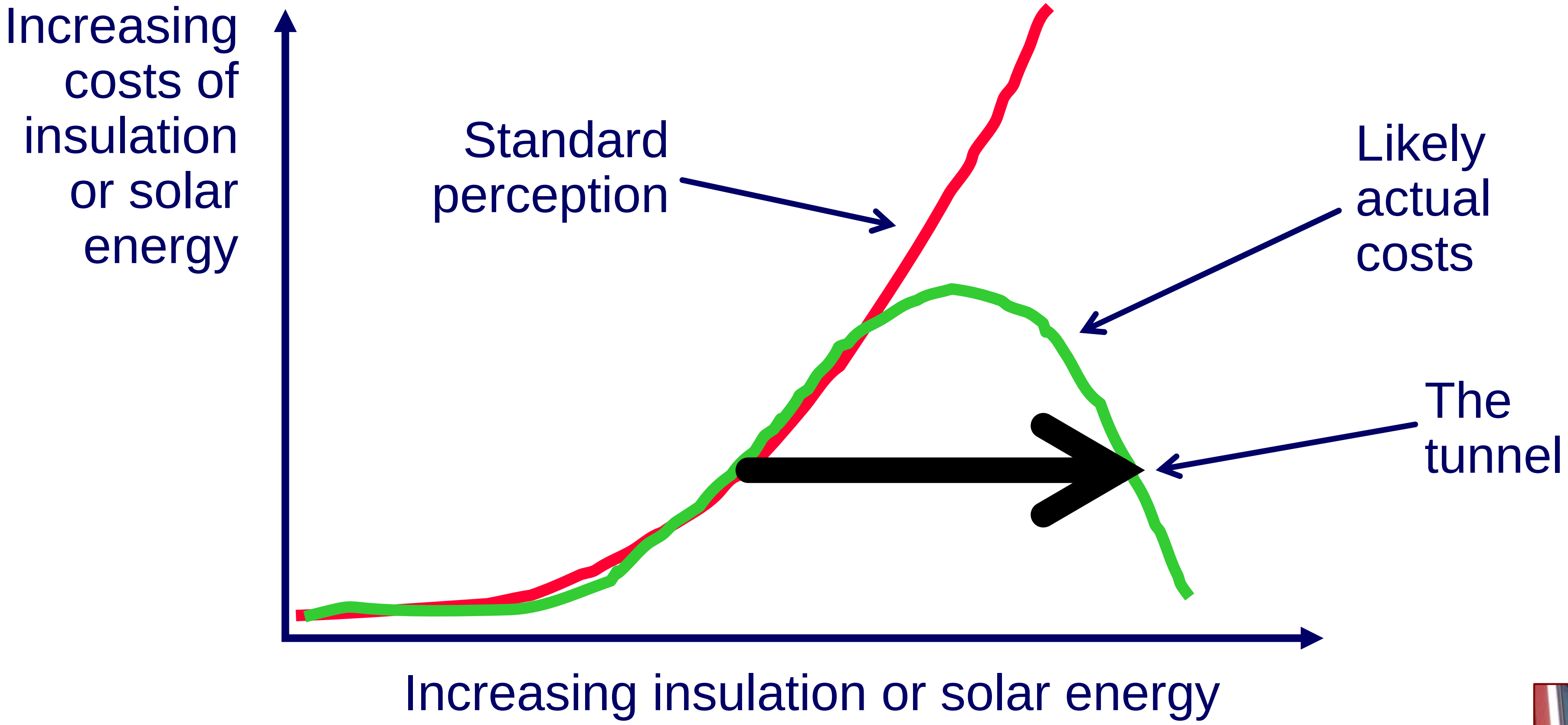
Annual savings: 42,000 kWh
~18,000 kg
$3000

Energy price (simple): **9 ¢/kWh = $25 /GJ (30 years)**

Return on Investment: 2.7% to 12% /year depending on government policies on fossil-fuel subsidies, environmental emissions and green loans

Economic Challenge – Tunnelling Through the Threshold…

- Diminishing returns… yes,
  but… there are cost reduction opportunities too…



Increasing costs of insulation or solar energy

Standard perception

Likely actual costs

The tunnel

Increasing insulation or solar energy

Concept courtesy of Amory Lovins

What have we learned so far?

1. Point-source heating works
   - No need for much of a heat distribution system!
2. Make the house “grey water ready”
   - To add in the future
3. Use more passive solar space heating
   - Make sure it is controlled well
4. Solar thermal space heating is much more complex than grid-connected solar PV.
5. Design, installation and controls for active solar space heating are quite complex.
6. Solar PV is very easy and flexible.
7. The price of energy from grid-connected solar PV is comparable to the price of energy from solar thermal <u>space heating</u>.

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Learned: Heating System…

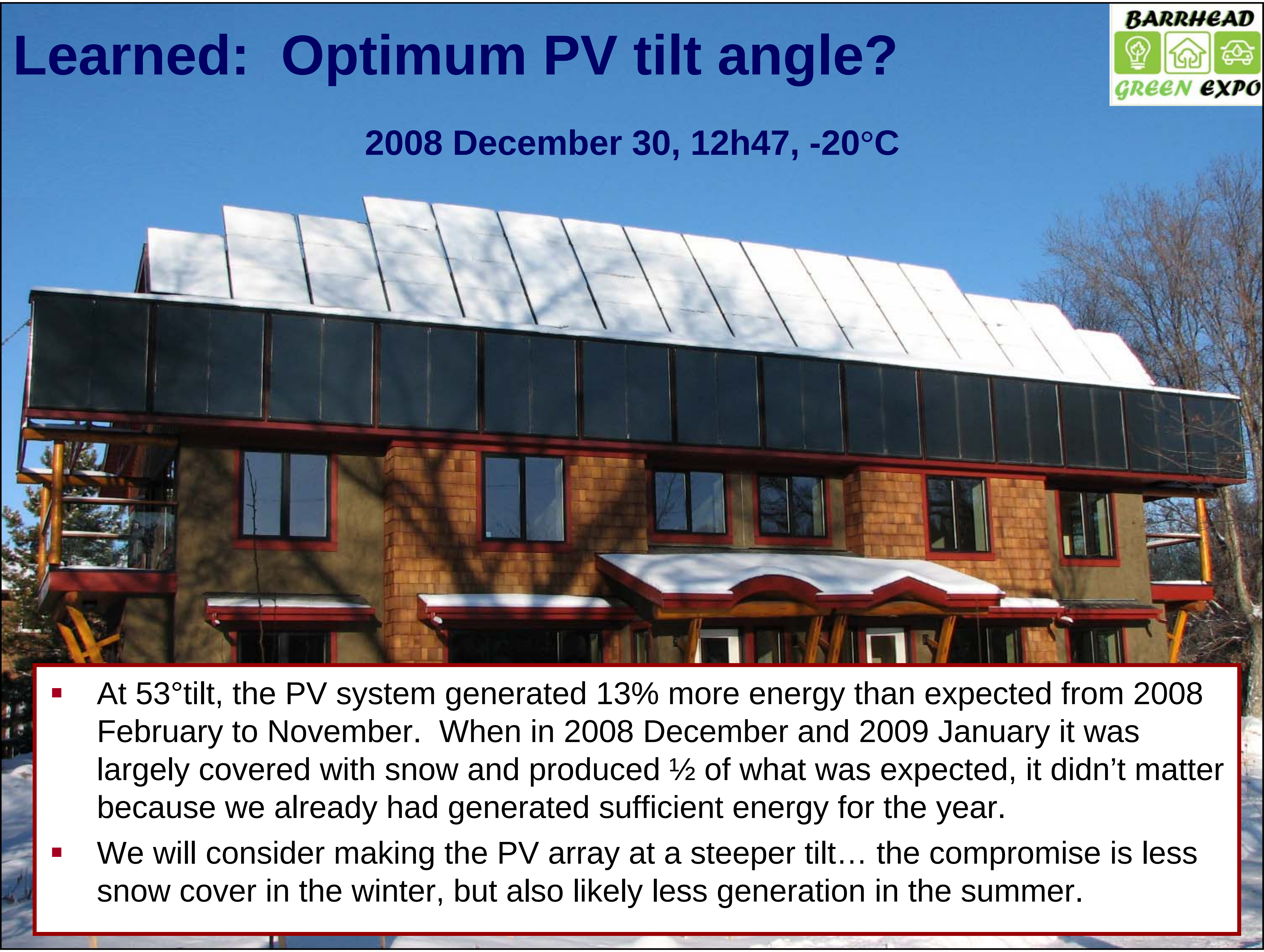
- Standard, forced air heating system
- No furnace, uses a fan coil connected to the solar heating system
- BUT we don’t (much) need to heat the rooms themselves… mostly all we need to do is heat the house!

Return air at outside of wall

Heat and air supply vents to centre of rooms

- Can do this because the walls and windows have such high R-values and so:
  - the walls and windows will be warmer; and
  - the rooms will need very small amounts of heat.

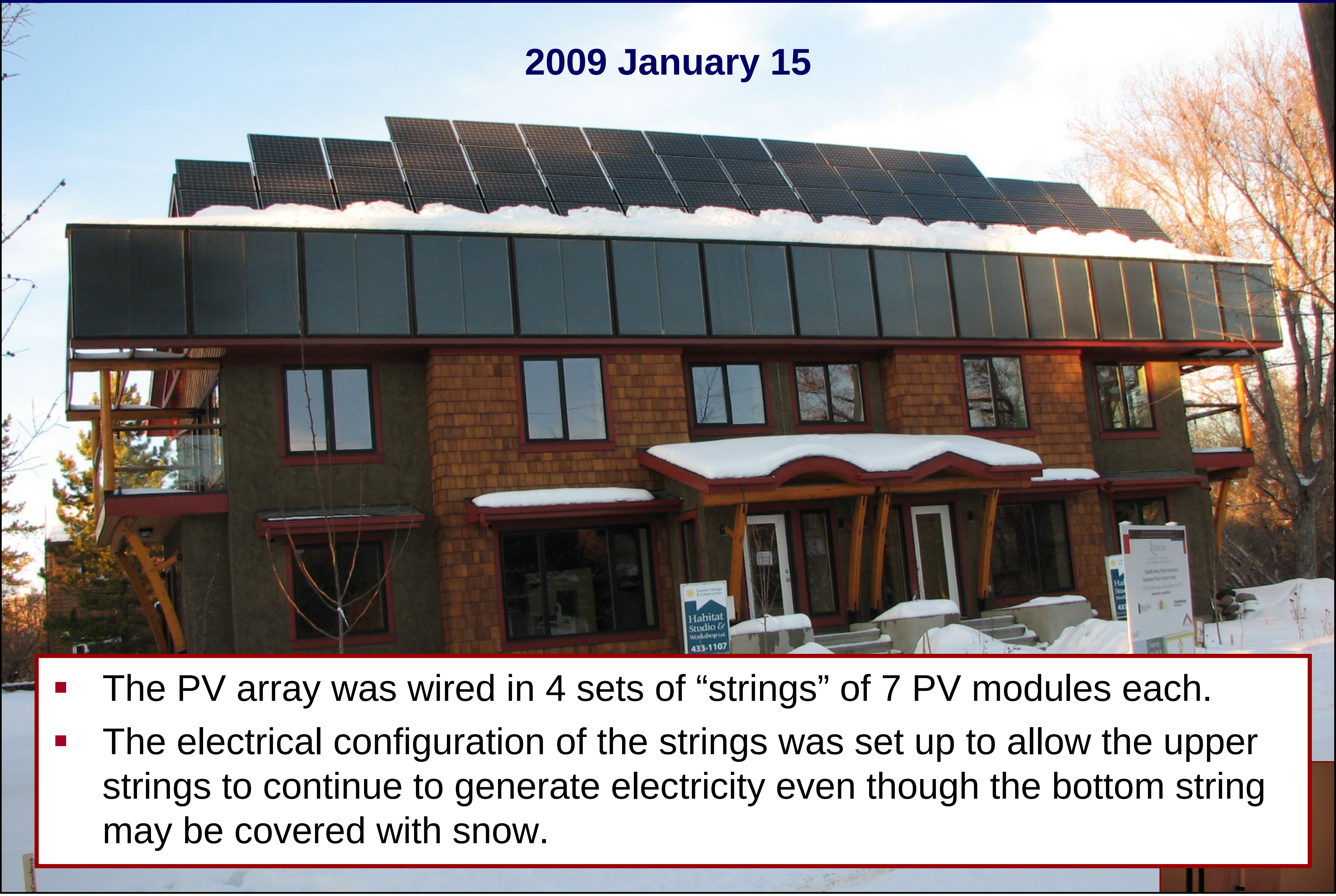
Learned: Optimum PV tilt angle?



2008 December 30, 12h47, -20°C

- At 53°tilt, the PV system generated 13% more energy than expected from 2008 February to November. When in 2008 December and 2009 January it was largely covered with snow and produced ½ of what was expected, it didn't matter because we already had generated sufficient energy for the year.
- We will consider making the PV array at a steeper tilt… the compromise is less snow cover in the winter, but also likely less generation in the summer.

Designed: PV Array Electrical Configuration



2009 January 15

- The PV array was wired in 4 sets of “strings” of 7 PV modules each.
- The electrical configuration of the strings was set up to allow the upper strings to continue to generate electricity even though the bottom string may be covered with snow.

Designed: Once in a while solar doesn't work

2008 November 20, 19:26

- Of course, when the big light in the sky turns off, the solar production systems don't work – passive solar, active solar and solar PV – so instead we draw electricity from the electric grid, and draw heat from the solar storage tanks.

Designed: How about Cooling?

- Our climate presents us with very small cooling requirements…
  - There are also 8 designs that keep the house cool.
- Passive cooling:
  - **Ultra-insulated walls** that keep out the heat energy caused by the solar radiation incident on the outside of the house,
  - **Ultra-insulated windows** that keep out the heat energy also,
  - **Overhangs** on the south windows to shade the windows from high summer sun angles,
  - Low **solar heat gain coefficient** (tinting) on east and west windows,
  - **Ventilation** through openable windows.
- Active cooling:
  - Circulating water through the **ground loops** under garage and next to foundation to provide a small amount of cooling to the fan coil,
  - Circulating water through the **solar thermal collectors** at night to provide cooled water to the fan coil,
  - Last resort: using the **solar-assist heat pump** to further chill the water from the ground loops.

What we did not use…

- Insulated Concrete Forms (ICF)
  - great technology and products,
  - more expensive than double-stud 2x4 wall,
  - does not give us the R-value we need,
  - very high embodied energy consumption and emissions uses in manufacturing.

- Structural Insulated Panels (SIPs)
  - great technology and products,
  - more expensive than double-stud 2x4 wall,
  - more difficult to air seal than double-stud 2x4 wall,
  - is a hydrocarbon product.

What we did not use…

- Radiant Floor Heating
  - very comfortable heat delivery system,
  - more expensive than low-speed forced air heating,
  - not necessary in a net zero energy house – don’t have to distribute much heat around the house;
  - do not see the advantage in a net zero energy house.

- Window Shutters (inside or outside)
  - technology not as well developed as we would like,
  - concerns with:
    - condensation, air sealing,
    - rattling in the wind, effective R-value,
    - cost, durability,
    - would they be used consistently.

What we did not use…

- Evacuated Tube Solar Collectors (ETC)
  - great technology and products,
  - more expensive than flat-plate collectors,
  - is performance as high as claimed?,
  - concerned about durability.

- Geothermal Heat Pump (GTHP)
  - great technology and products,
  - was a possibility for this house,
  - did consider it,
  - installed purchase costs and operating costs are a factor,
  - could be a good option if we did not have an active solar space heating system.

What we did not use…

- Heating zones
  - this heating system configuration works well
  - this is used in very energy in-efficient houses to reduce heating costs
  - this is not needed in an ultra-efficient house
- Night set-back thermostat
  - this is used in energy in-efficient houses to reduce heating costs
  - likely not enough energy could be saved in a net zero house to make this worthwhile

Why use expensive electricity instead of cheap natural gas?

- If we supplied our backup heat from natural gas,
  we would only be need 4.9 GJ worth of heat, which would mean
  we would need to burn 5.3 GJ of natural gas to get this heat.

- This would cost us:
  - $50 for the gas (= $44 to heat the house and $6 to heat the water)
  - plus $400 for the annual service charges (in 2008)
  - for a total of $450 per year.

- Natural gas:
  - cost is $450 for 4.9 GJ of heat = $91 /GJ
- Electricity:
  - cost is $165 for 4.9 GJ of heat at $33 /GJ

In this case,
electricity is less expensive than natural gas because of the large gas connection fees.

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Barriers and Opportunities

– where policies need to facilitate change instead of blocking change…

- **Value** the environment
- **Allow** full cost recovery of all electricity fed into the grid
- **Value** Canada’s solar industrial capacity
- **Mandate** full-cost accounting for all energy sources
- **Remove** fossil fuel subsidies
- **Require** fossil fuels to pay for their environmental damage
- **Provide** ultra-low interest green loans for renewable energy and energy efficiency projects

What can you do?
– Becoming Ready for NetZero in a New House

- Make your house as energy efficient and solar friendly <u>as possible</u>!

- House orientation
  - roof lines from SW to SE

- Amount of solar collection area
  - Area of south windows, roof
  - Roof tilt angle

- Landscaping
  - Well-placed trees, deciduous trees on the south

- Space from basement to attic
  - Conduit for electrical cables
  - "Chase" for 2 solar hot water pipes

What can you do?
– Energy Efficiency in an Existing House

- Make your house as energy efficient as possible!
- Get an energy audit done on your house – it is a roadmap of what can be done
  - See www.energyexperts.ca and www.atcoenergysense.com
- Replace your incandescent light bulbs
- Replace your ancient fridge
- Change out your standard efficiency furnace to a high efficiency one

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What can you do?
– Energy Efficiency in an Existing House

- Make your house as energy efficient as possible!

- ***Lots*** of energy information is available
  - “Keeping the Heat In” from CMHC
  - Energy Solutions Alberta (www.energysolutionsalberta.com)

- Sustainable Materials
  - See Green Alberta (www.greenalberta.ca)

- Landscaping
  - See The Urban Farmer (www.theurbanfarmer.ca)

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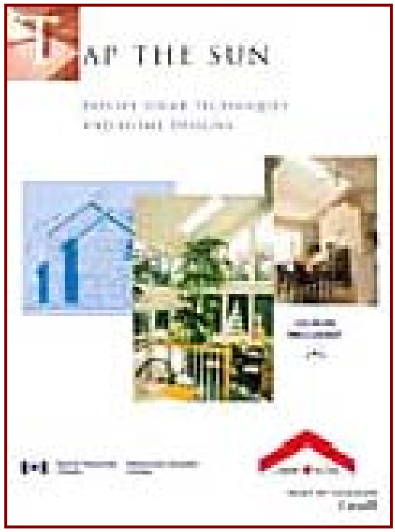
What can you do?
– Solar Energy in an Existing House

- There is a lot of research and information already available for you.
- Tap the Sun passive solar design book from CMHC (www.hme.ca/tapthesun)
- Canadian Solar Industries Association (www.cansia.ca)
- Eco-Solar Contacts and Services List for Alberta
  - download from www.hme.ca
  - lots of web sites on the internet



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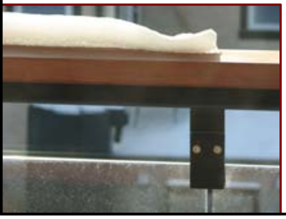
Want to Learn More?

- Riverdale NetZero presentations, workshops, tours
  - www.riverdalenetzero.ca
  - send us your e-mail address so we can keep in touch with you.
- Mill Creek NetZero energy house
  - www.greenedmonton.ca
- Solar Energy Society of Canada – Northern Alberta Ch
  - www.solaralberta.ca
  - courses in solar power, solar heating, off-grid
- Eco-Solar Home Tour – June 6, noon to
  - www.ecosolar.ca
  - last time to see the Riverdale net zero h
- Much more is coming soon…



We welcome any feedback, questions, suggestions, comments and challenges to anything we present.

…we hold the future in our hands

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Alberta Emerald Foundation

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