Transforming Housing

…The Path to Net Zero Energy Homes

Riverdale NZE

ARCH-243

Mechanical/Electrical Systems

SAIT

Calgary

2010 November 29

Belgravia NZE

Gordon Howell, P.Eng.

howell-mayhew engineering,inc.

Edmonton

Mill Creek NZE

Introduction…

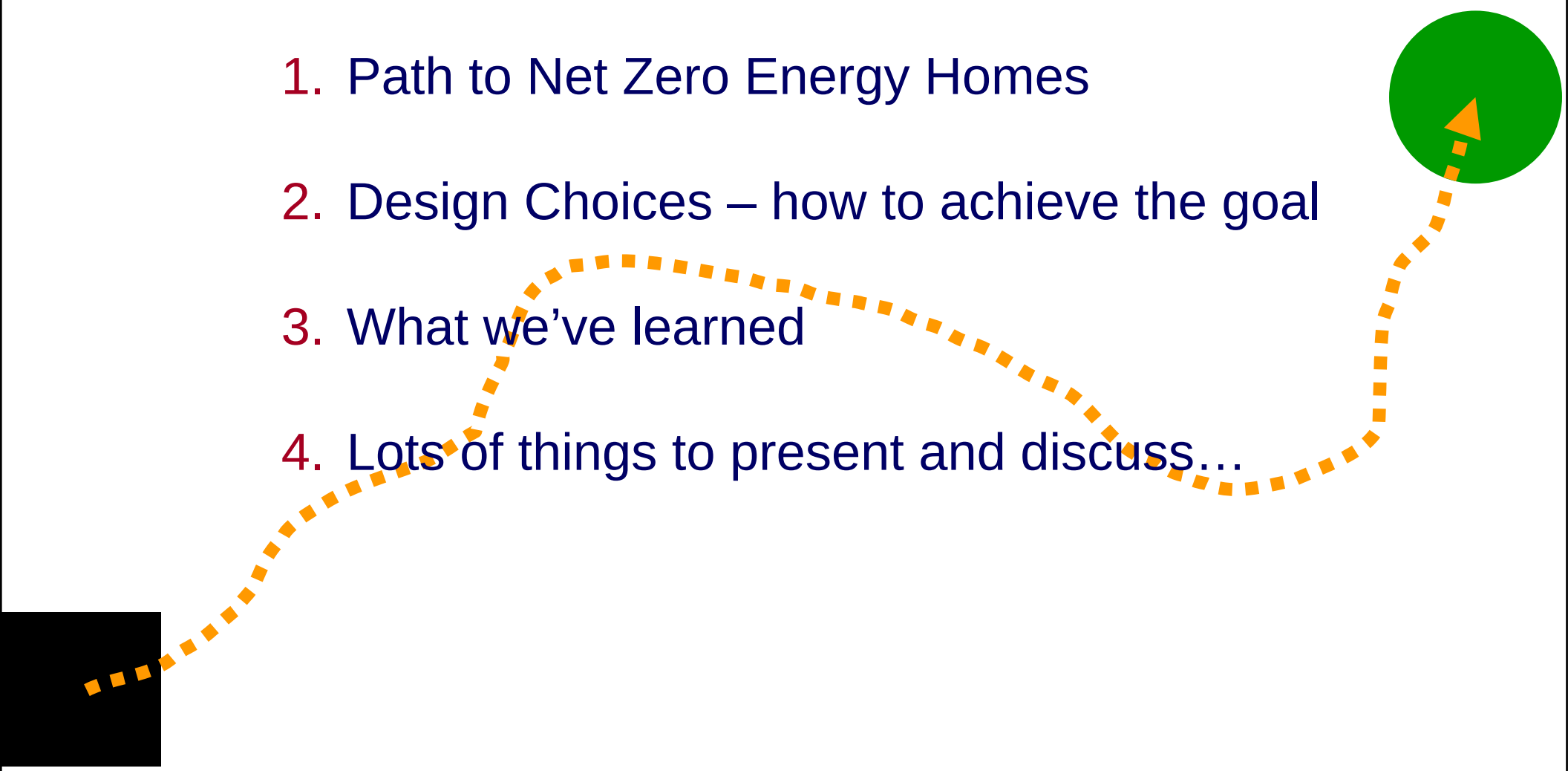
- Howell-Mayhew Engineering is a developer of solar electric (PV) system projects
- We also work with homebuilders who want to build net zero energy homes
  - Edmonton's first 5:

    Habitat Studio & Workshop Ltd
  - plus, under development:
    - Effect Homes
    - Rosecrest Homes
    - Kensington Master Builder
    - and others…

howell-mayhew engineering, inc.

Presentation Focus

1. Path to Net Zero Energy Homes
2. Design Choices – how to achieve the goal
3. What we've learned
4. Lots of things to present and discuss…



The Earth provides enough to satisfy every man's need,
…but not every man's greed.

Mohandas Karamchand Gandhi
(*Mahatma*)
India

Precedents

Saskatchewan Conservation House (1977)
Regina
76 kWh/m^2

Rob Dumont's House (1992)
Saskatoon
47 kWh/m^2

Factor 9 House (2007)
Regina
33 kWh/m^2

howell·mayhew engineering, inc.

Edmonton's Net Zero Energy Houses

- Riverdale

- 2 net zero houses completed
  - 6 under construction
    - 2 being planned
- 6 builders

- Mill Creek

Peter Amerongen

Habitat Studio & Workshop Ltd

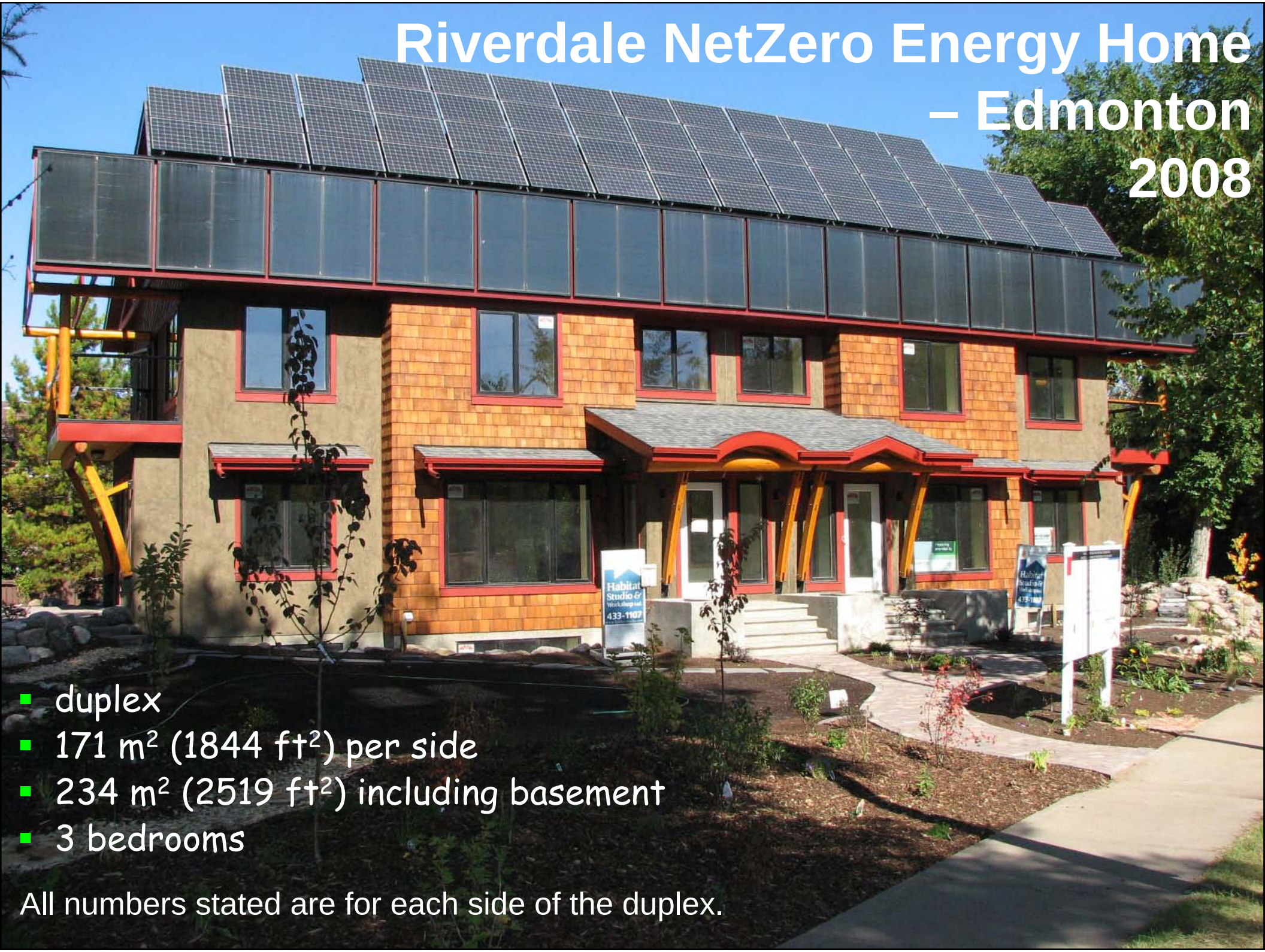
www.habitat-studio.com

- Parkland

- Belgravia

- South Windsor Park

Riverdale NetZero Energy Home – Edmonton 2008



- duplex
- 171 m^2 (1844 ft^2) per side
- 234 m^2 (2519 ft^2) including basement
- 3 bedrooms

All numbers stated are for each side of the duplex.

2008 December 30, 12h47, -20°C

Why is it called a Net Zero Energy House?

- **A house that generates all its own heat and electricity on an annual basis…**

- **Net zero energy is just the dividing line between**
  - **net deficit energy and** (where you need to purchase energy because your house doesn't generate sufficient of its own)
  - **net surplus energy** (where the house is a benefit to the environment because it is operating)

- **It had never been done before in Canada until CMHC developed their EQuilibrium Sustainable Housing Initiative.**

howell·mayhew engineering, inc.

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

Discussions of EQuilibrium Housing

- **Technology**
  - Products
  - Performance simulation
  - Design
  - Installation
  - Operation
  - Monitoring
- **Attributes of House**
  - Energy (house, food, transportation)
  - Indoor environment (air, water)
  - Outdoor environment (water, landscaping)
  - Sustainability, materials, recycling
  - Emissions (air, water, soil, land, waste)
  - Costs, economics
- **Technology Transfer**
  - Communication
  - Awareness
  - Education
  - Training
  - Demonstration
  - Marketing
- **Organisation of Society**
  - Policies and their goals and consequences
  - Infrastructure (energy, housing, transport)
  - Industrial capacity
  - Incentives, barriers and standards
  - Subsidies, green taxation
  - Removing competing subsidies

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

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

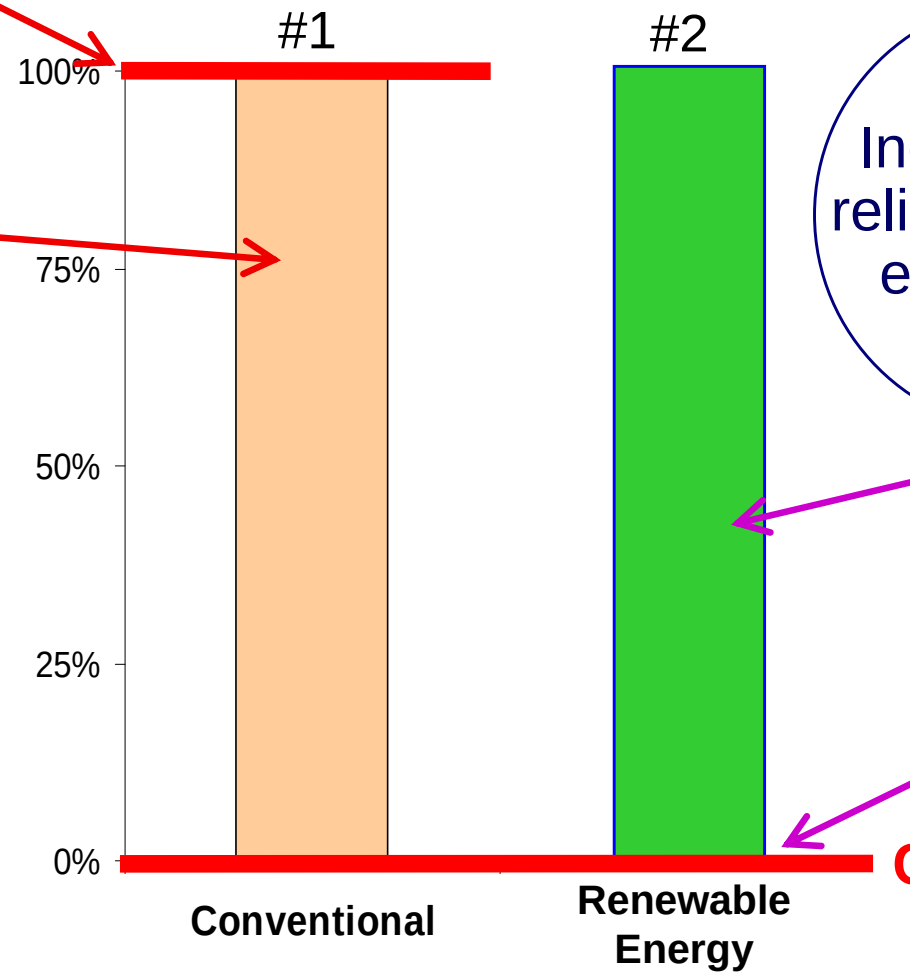
- In Edmonton, an average house uses:
  - Around 6 times more heating fuel energy than electricity!
  - Biggest challenge is <u>not</u> in supplying household electricity…
  - Instead … it is in supplying home heating!

howell·mayhew engineering, inc.

The most expensive way to achieve NZE…

Net Purchased Energy

Conventional Energy



Where is it?

Inexpensive, reliable energy efficiency…

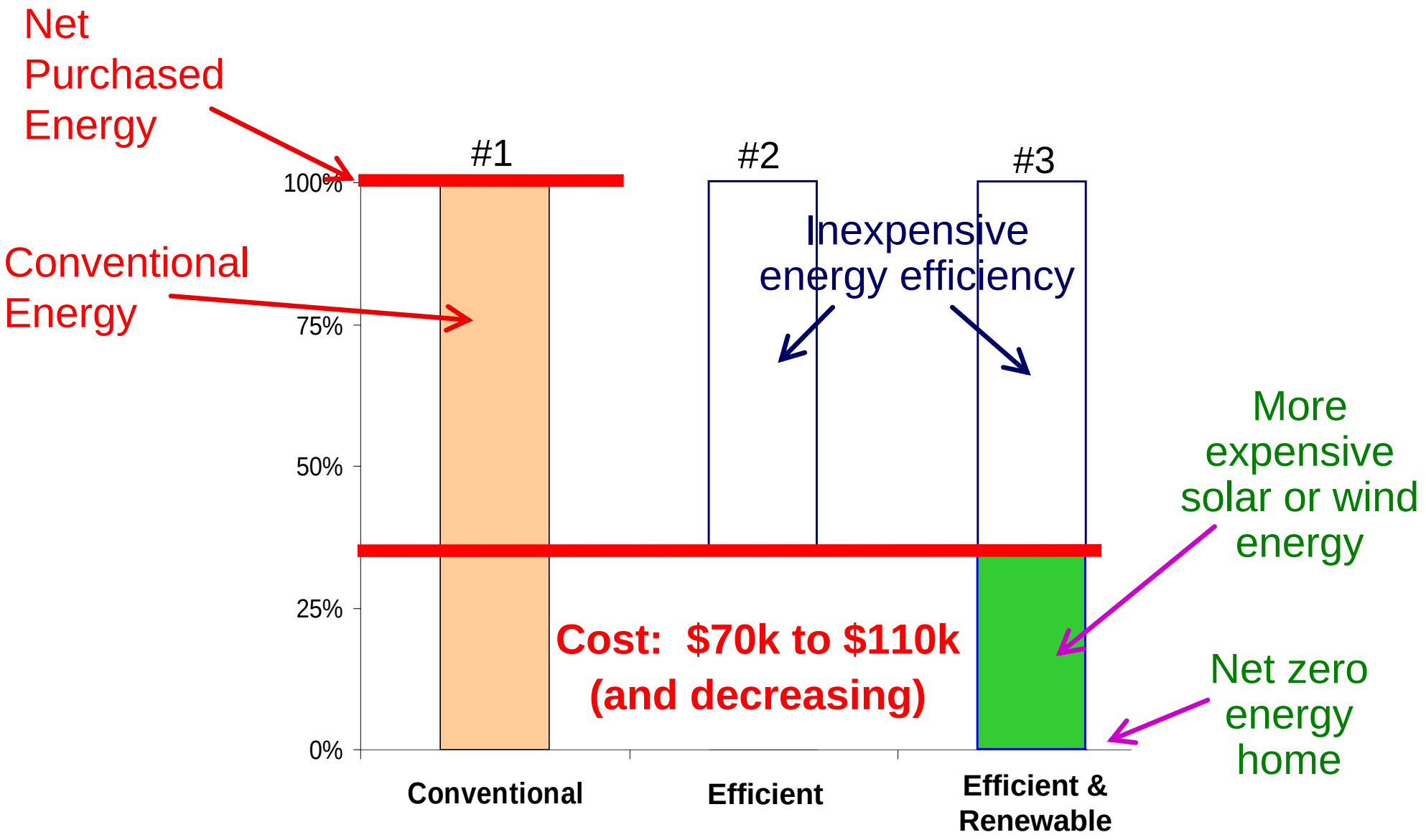
Add expensive solar or wind energy

Net zero energy home

Cost: $250k

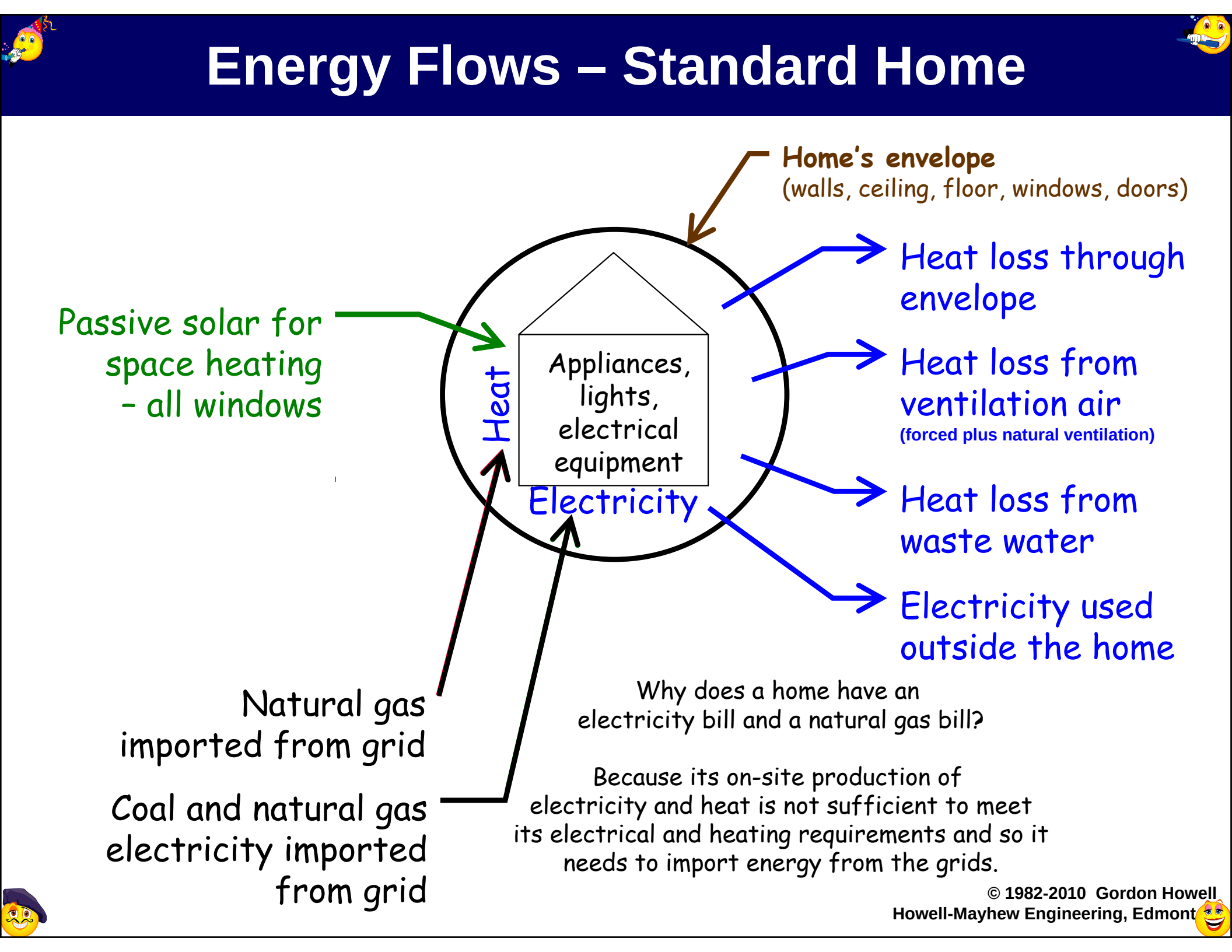
howell·mayhew engineering, inc.

The least expensive way to achieve NZE…



howell·mayhew engineering, inc.

Energy Flows – Standard Home



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 – Any NetZero Home

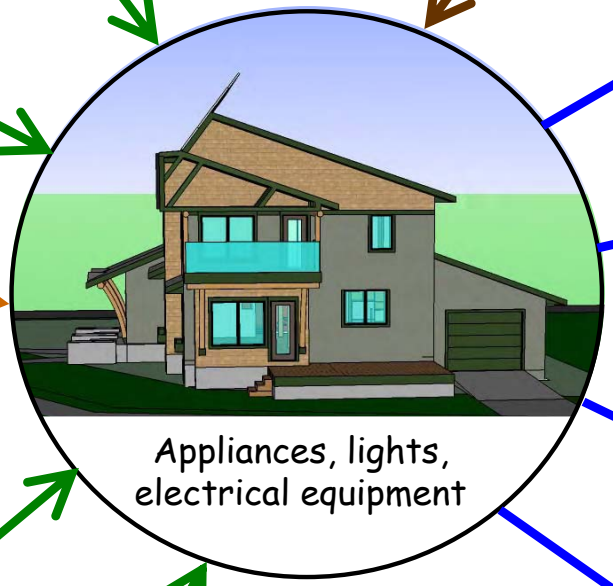
Passive solar for home heating – all windows

Active solar heat for water and space

Ground-, air- or water-source heat pump

Solar photovoltaics (PV) for electricity

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



Heat loss through envelope

Heat loss from ventilation air
(forced plus natural ventilation)

Heat loss from waste water

Electricity used outside the home

All electricity used inside the house goes to heat the house

==========

#3. The third key to a net zero energy house is to **maximise** and **control** the energy gains…

==========

#1. The first key to a net zero energy house is to **minimise** and **control** the electricity usage…

==========

#2. The second key to a net zero energy house is to **minimise** and **control** the house heat loss…

Energy Flows – Any NetZero Home

Passive solar for home heating – all windows

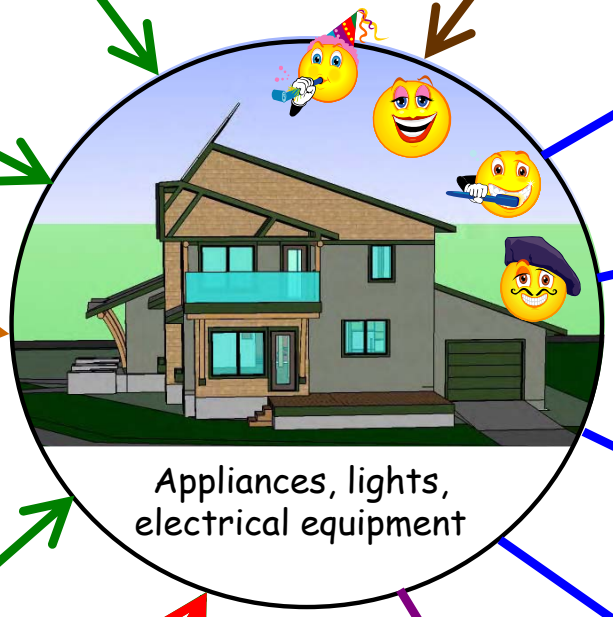
Active solar heat for water and space

Ground-, air- or water-source heat pump

Solar photovoltaics (PV) for electricity

Coal- and natural gas-electricity imported from electric grid

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



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

How do you plan for a net zero energy house?

- First and most important:
  - **Minimise** heat and electrical energy consumption
  - **Reduce** by ***65%*** through energy efficient and water efficient design, construction and appliances
  - This is the cheapest-cost option
  - Cost was $20,000 (net cost of $10,000 to the homeowner, because of Alberta's $10,000 incentive for EGH 86 homes)
- Second:
  - **Maximise and control** the contribution of solar energy
  - **Supply** ***35%*** balance of heat and electrical energy
  - Cost was $90,000 on first house ($50,000 on the next two)

howell·mayhew engineering,inc.

The Journey to Net Zero Energy

– cheapest to most expensive

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

} Ultra-high efficiency technologies

- 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…???
- Solar-electric heating: heated air, electricity…???

} Heating, cooling technologies

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

} Electricity technologies

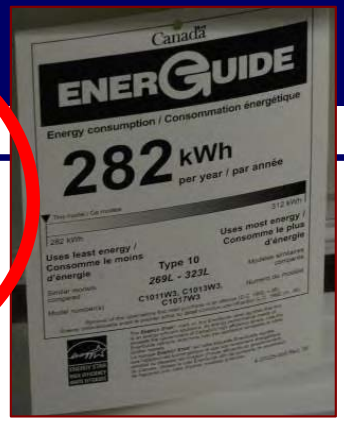
Next…

2. Design Choices

howell·mayhew engineering, inc.

#1. Domestic Electricity

- Electricity consumption reduced by **50%**
  - ❖ EnerGuide energy efficient appliances
  - ❖ ECM ventilation motors
  - ❖ Lighting
    - – compact fluorescent, LEDs,
    - – halogen task lighting
    - – daylighting
  - ❖ Phantom load control
- Domestic electricity consumption calculated to be 3800 kWh/year
  (compared to 6600 kWh/year for average household)



- LED lighting:
  Dining room
  Living room
  Master bedroom

CF lighting

Fridge

Clothes dryer

Dishwasher

#2. Domestic Water Heating

- Fuel consumption for water heating reduced **75%**
  - ❖ Water efficient shower heads, faucets
  - ❖ EnerGuide dishwasher, clothes washer
  - ❖ Shower drain water heat recovery (50% recovery)
- Hot water 105 litres per day
  (compared to 227 L/day average)
- Potable water modelled at
  330 litres per day

Drain water heat recovery

Shower heads and faucets

Dish washer

Clothes washer

#3. Building Envelope

- Fuel consumption for space heating reduced by **70%**
  - Ultra high insulation levels
  - High performance windows
  - Ultra low air leakage rate
  - High efficiency heat recovery ventilator
- Space heat consumption modelled at 10,800 kWh per year (39 GJ/year)
- Heat loss at -32°C = 6600 W, = 6 hair dryers

EG 86

Ceiling Usi-0.057 (R-100) cellufibre

Double-stud 2x4 walls with Usi-0.10 (R-56) cellufibre

Usi-0.105 (R-54)

Windows

Triple glazed

south: Usi-0.78 (R-7.3)

East/West: Usi-0.68 (R-8.3)

North windows

Quadruple glazed

Usi-0.57 (R-10)

Air tight envelope

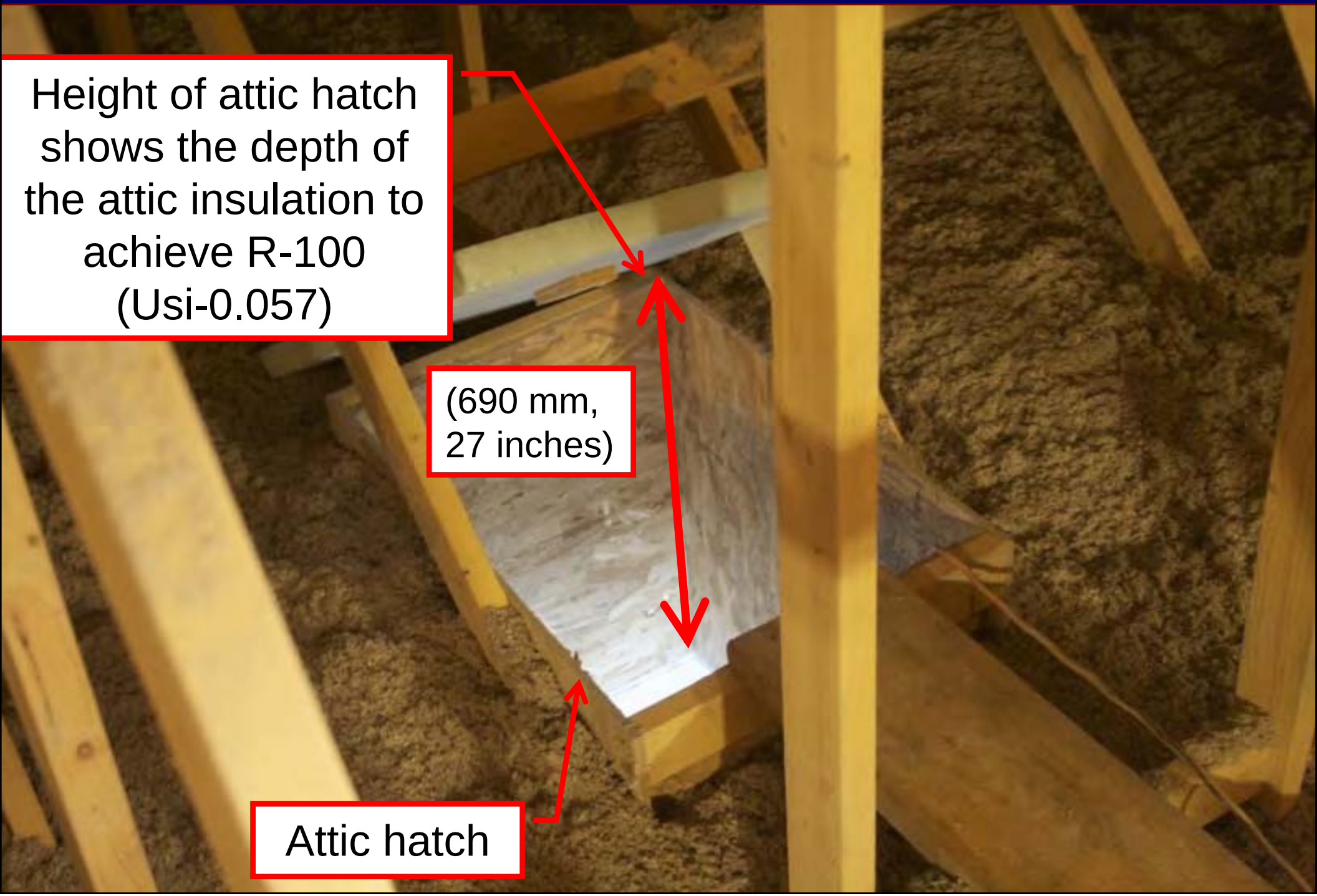
0.50 AC/h

Heat recovery ventilator

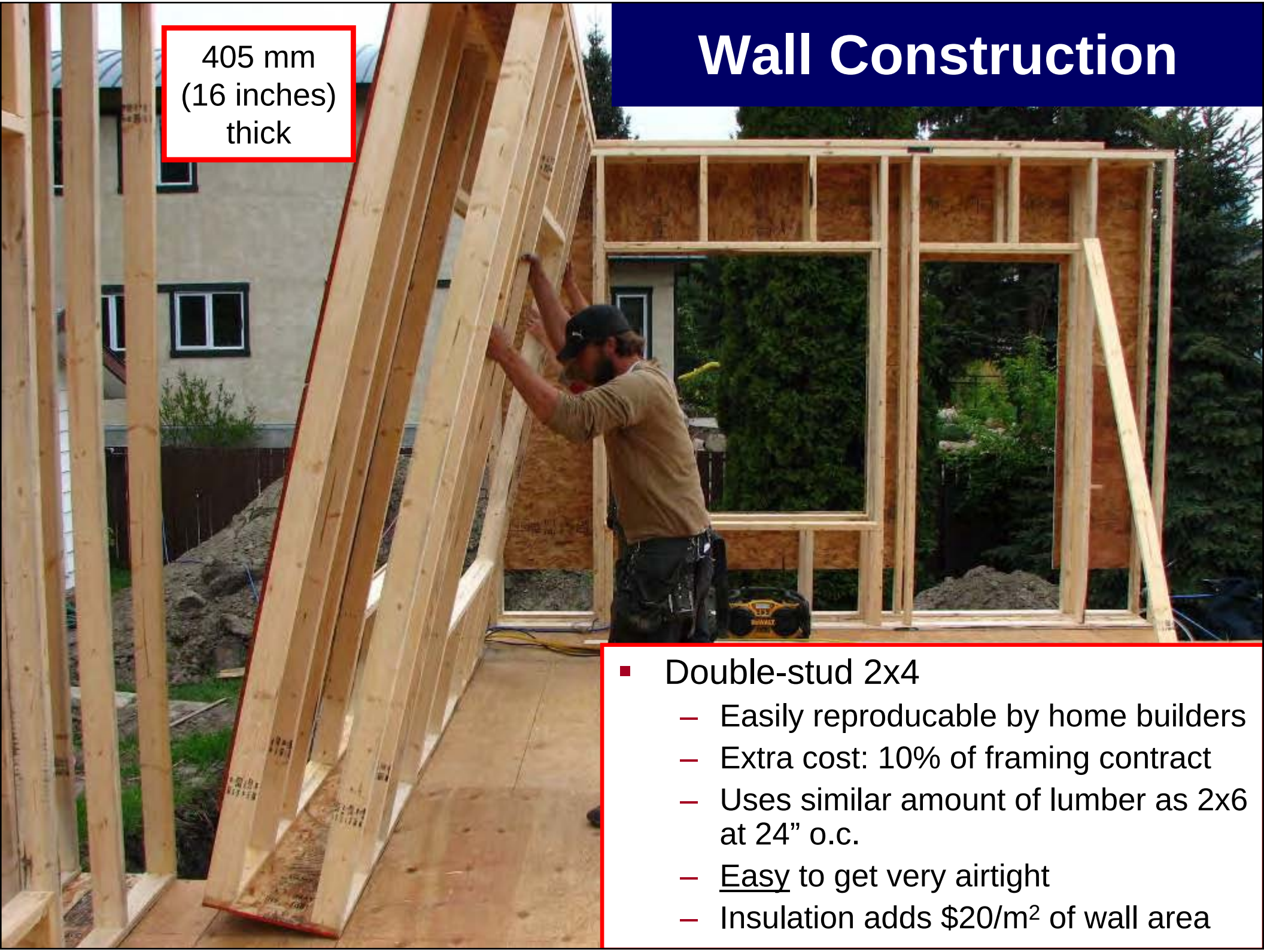
72% efficient

Ceiling Insulation

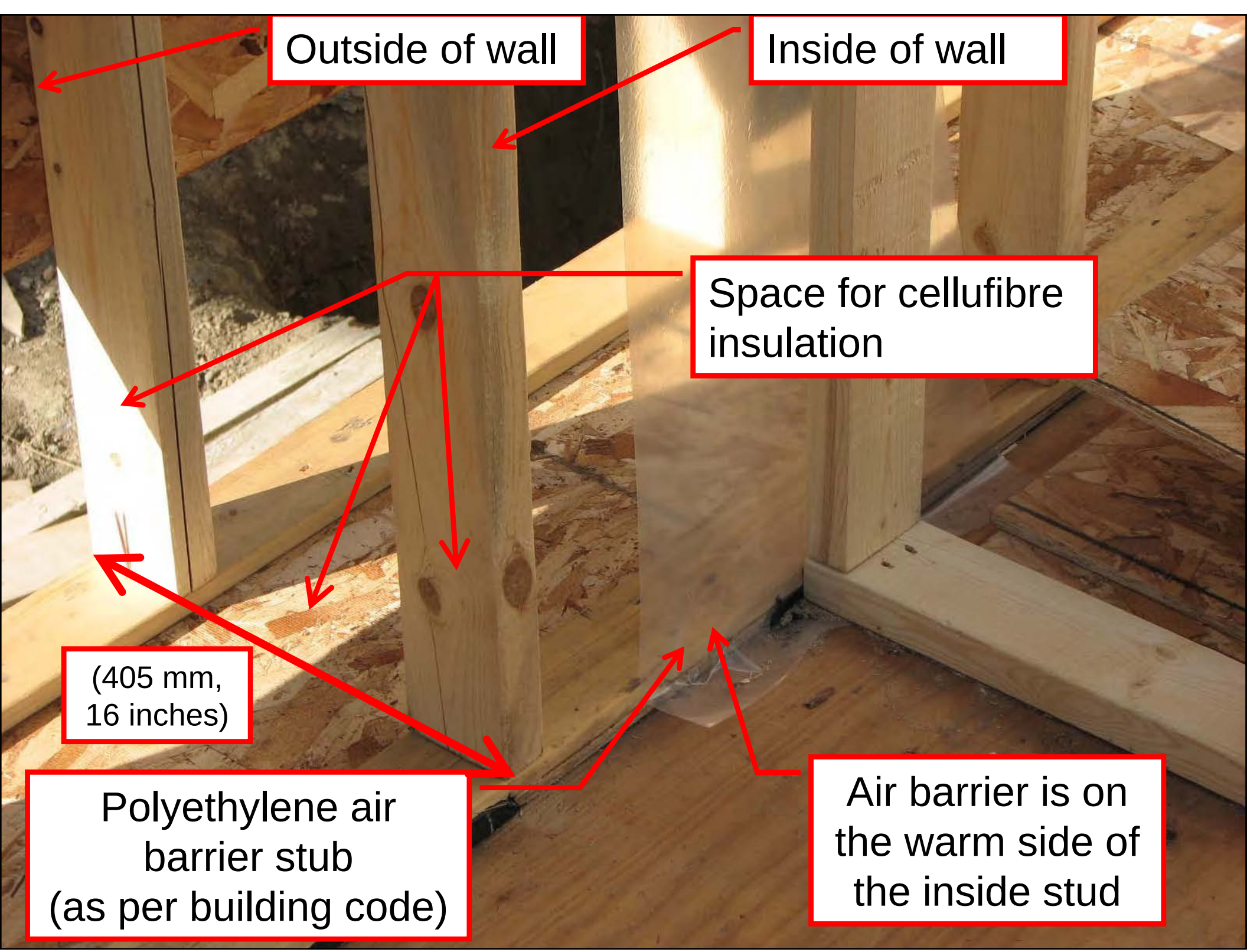
Ceiling Insulation



Wall Construction



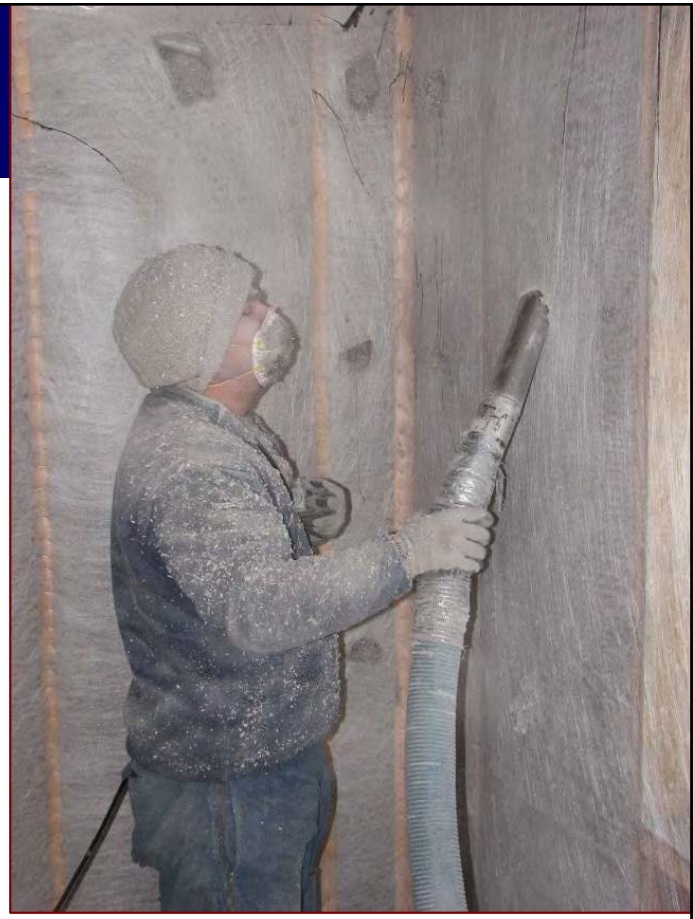
- Double-stud 2x4
  - Easily reproducable by home builders
  - Extra cost: 10% of framing contract
  - Uses similar amount of lumber as 2x6 at 24” o.c.
  - Easy to get very airtight
  - Insulation adds $20/m^2 of wall area


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

Cellulose Fibre Insulation

- Recycled newspapers
- Low embodied energy
- Locally produced
- Sequestered carbon
- Not a hydrocarbon product

- Walls: 400 mm (R-56)



Insulation itself is very airtight

Wall is covered with a fibre mesh to keep insulation intact during installation

Window Headers in Rim Joist Area

Achieving Ultra-Airtightness

Electrical poly-vapour hats and backers

- Not hard to do
  - Framers need to be very aware of this
  - No deviation from normal construction sequence.
  - Builder doing this for 20 years.
- Extremely effective performance
- Extremely cost-effective
- at -50 Pascals
  - Riverdale NetZero house: 0.50 AC/h
  - Mill Creek NetZero house: 0.36 AC/h

Rim joist air barrier wrap

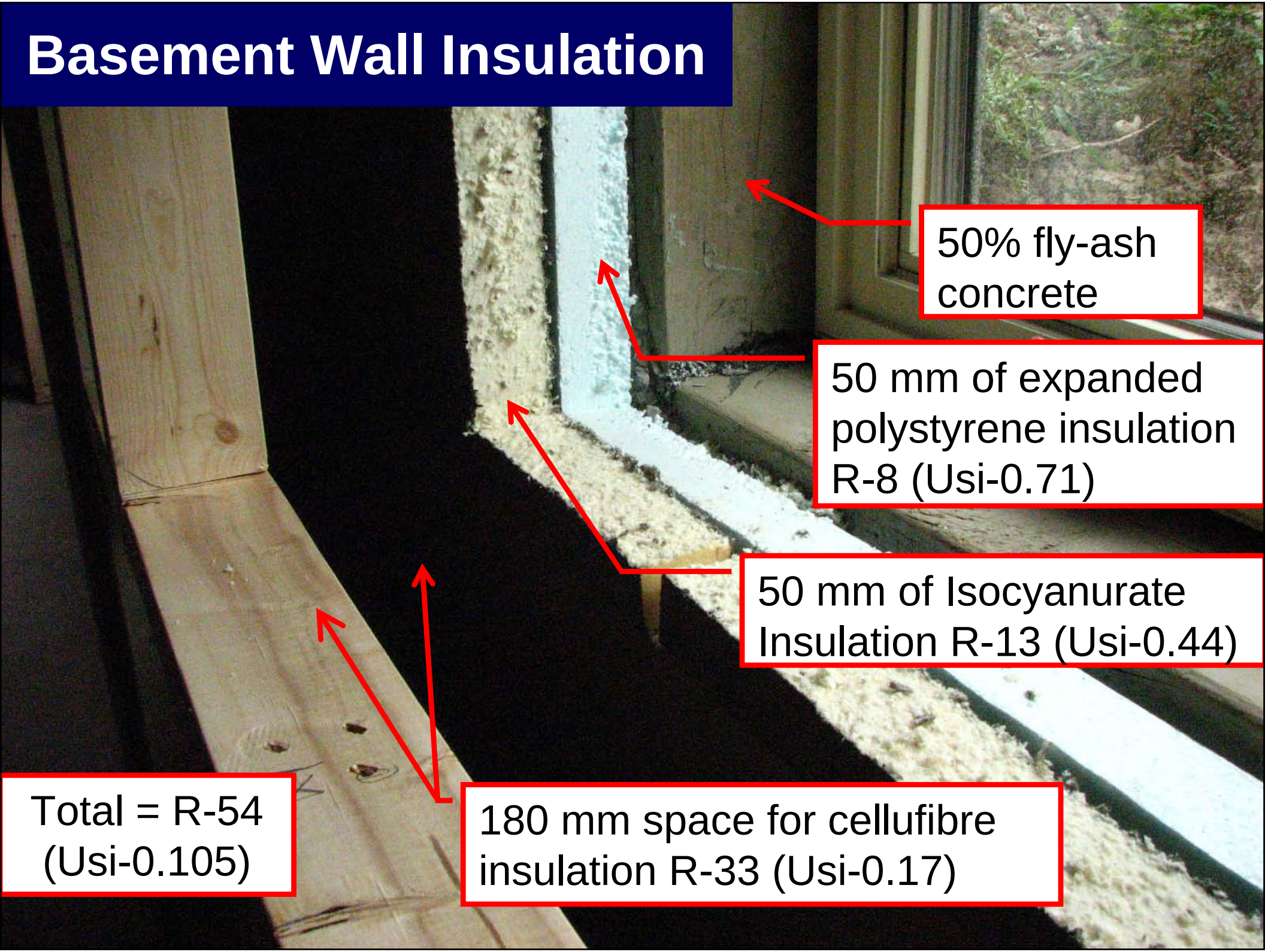
Spreader plate joints sealed

Windows foamed

All penetrations sealed

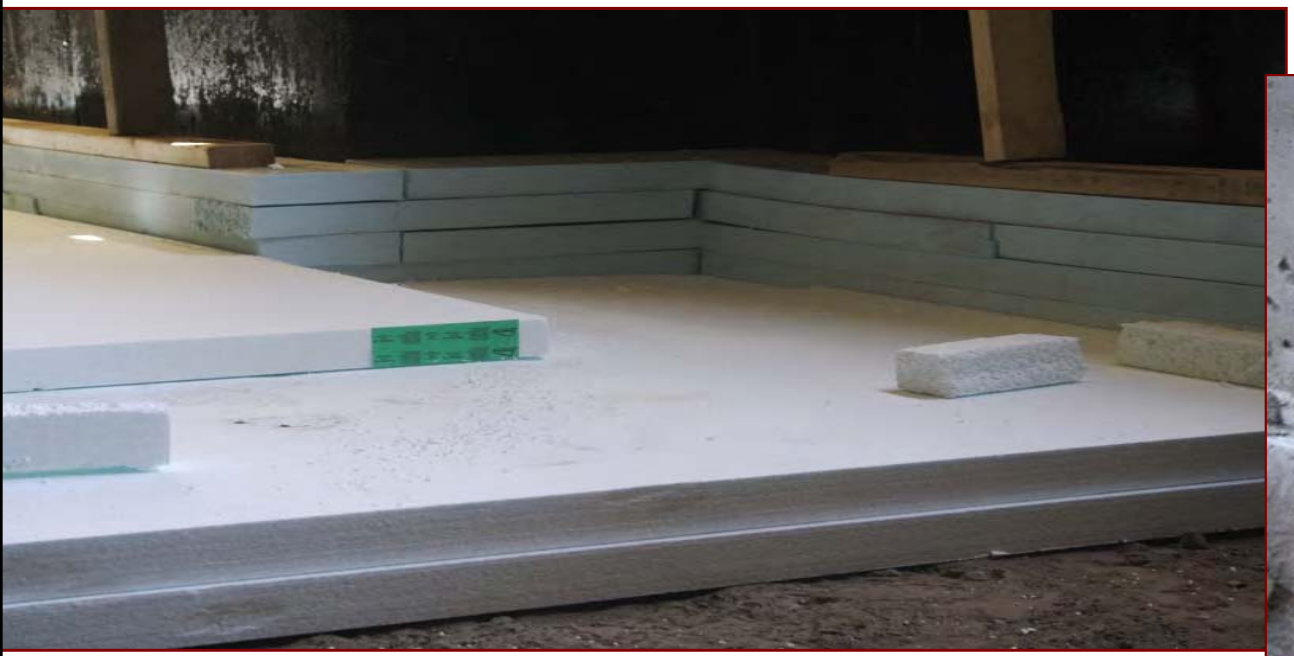
Rim joist vapour barrier

Basement Wall Insulation



Basement Floor Insulation

- Usi-0.237 underneath the concrete
- Extruded polystyrene



howell·mayhew engineering, inc.

High Performance Windows

South windows
3-glazings
R-7.3 (Usi-0.78)
SHGC 50%

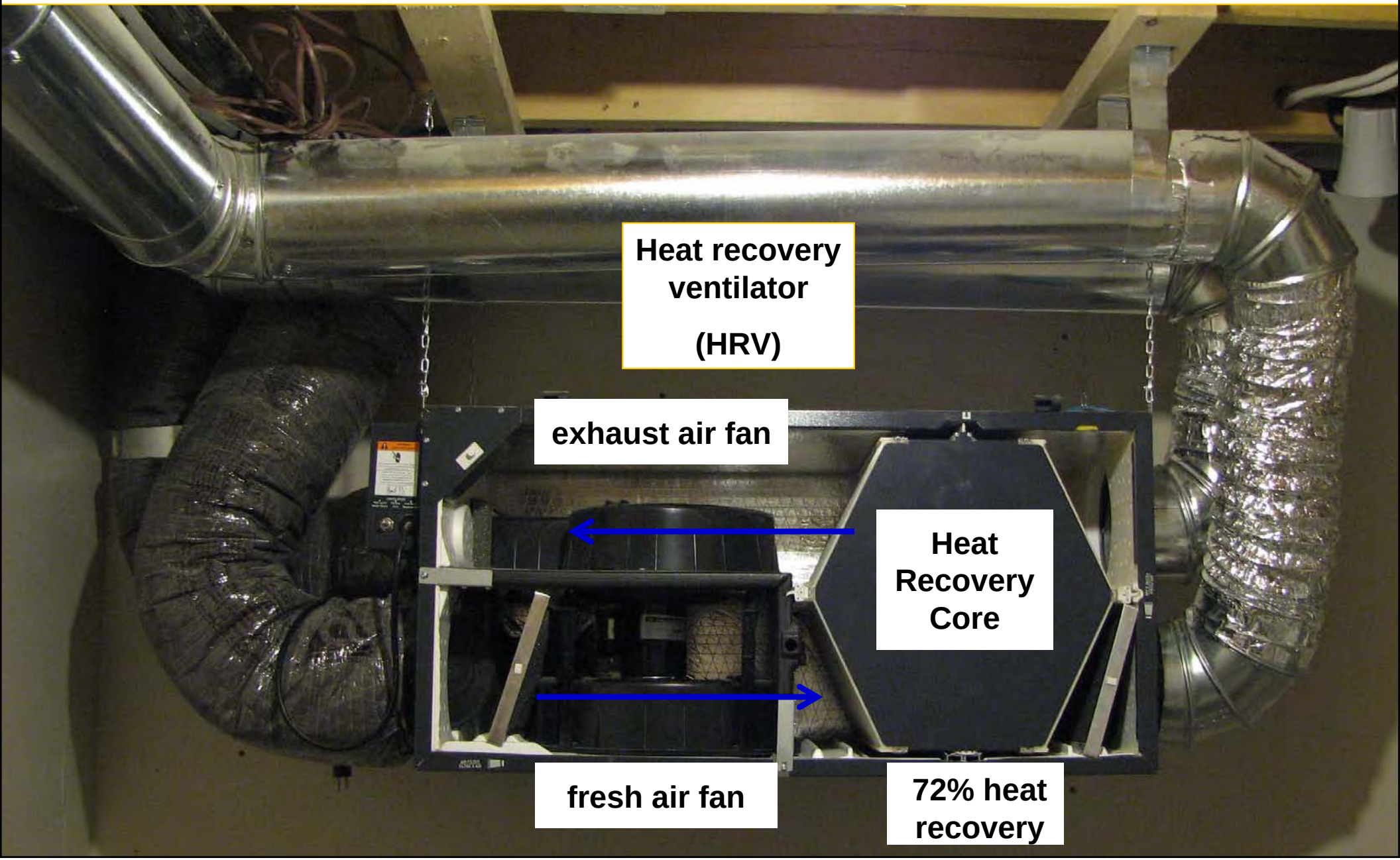
East/west windows
3-glazings
R-8.3 (Usi-0.68)
SHGC 37%

- Soft low emissivity coatings
- Argon gas between the glazings
- “Warm edge” glazing spacer
- Urethane insulated fibreglass frames
- Duxton Windows, Winnipeg

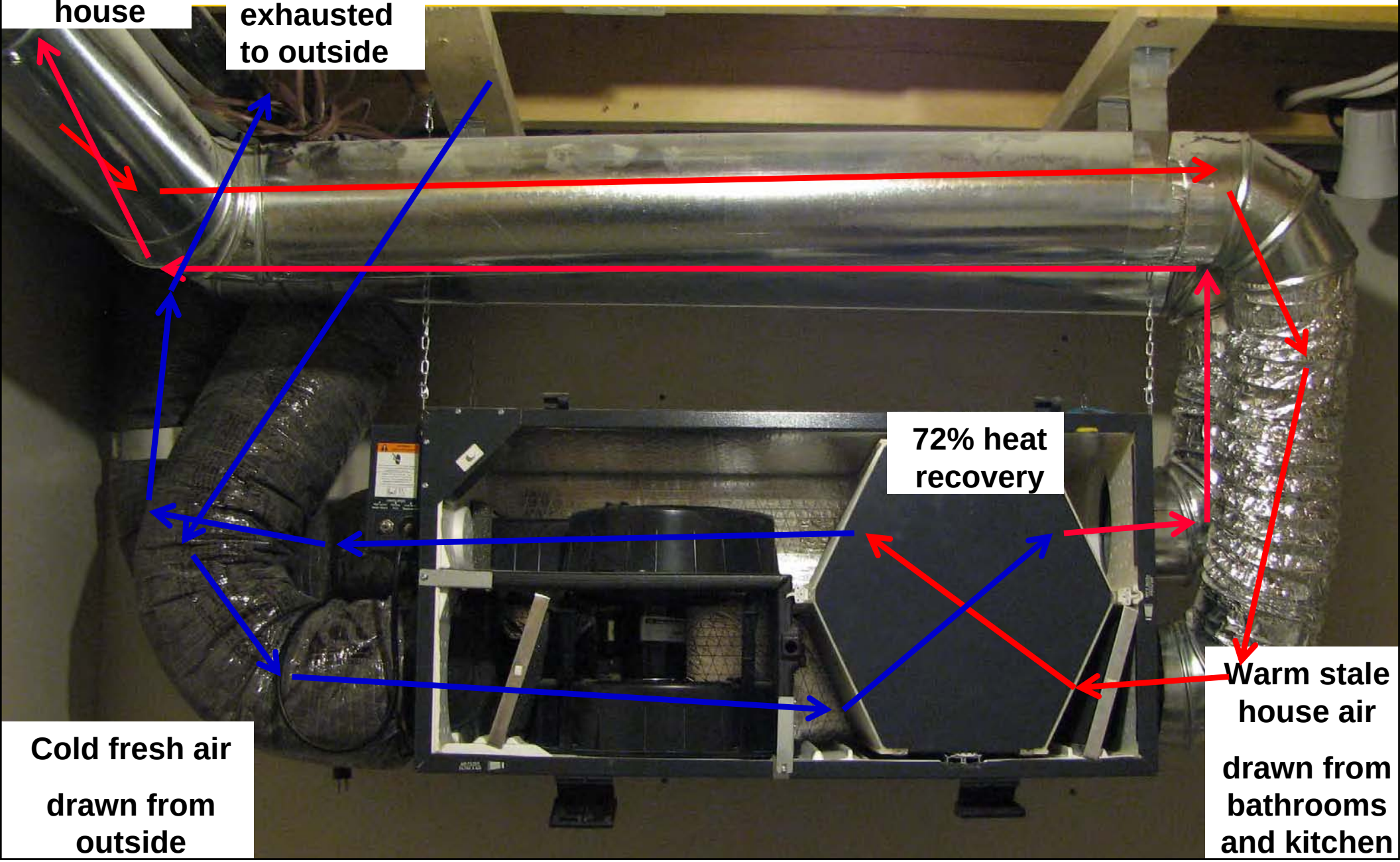
North windows
4-glazings
R-10 (Usi-0.57)

Mechanical Ventilation with Heat Recovery

Ventilation with Heat Recovery - Insides



HRV Operation



RNZ Heating System…

- Standard, forced air heating system
- Solar furnace: fan coil connected to the solar heating system
- BUT we don't specifically need to heat the rooms themselves… primarily all we need to do is heat the house!

- 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.

#4. Passive Solar Space Heating

All south windows: 17 m², 10% of floor area
Estimated production = 4400 kWh per year

Provides
~40% of space heating

#5. Active Solar Thermal Heating – Space & Water

Drainback collectors: 7, 21 m^2, vertical
DWH heat storage: 300 litres
Space heat storage: 17,000 litres
Heat distribution: fan-coil, forced-air
Supplemental: electric resistance
Estimated production = 4200 kWh per year

Provides
83% of domestic water heating,
21% of space heating

#6. Solar PV for electricity – domestic and heating

PV array: 28, 33 m², 5.6 kW, 53°tilt

Electricity storage: "on the grid"

Measured production = 6600 kWh per year

Provides
112% of electricity consumption,
6% of domestic water heating,
11% of space heating

Mill Creek NetZero Energy House

- Single-family house
- 241 m^2 (2300 ft^2)
- Not including area of finished basement with suite

howell·mayhew engineering, inc.

Passive Solar Space Heating

Maximise the south window area

South windows: 23 m^2, 11% of floor area

Passive solar heating: 8300 kWh per year

Add thermal mass: 64 mm concrete floor overlay

Summer shading is <u>really</u> important

Passive solar provides ~50% of annual space heating

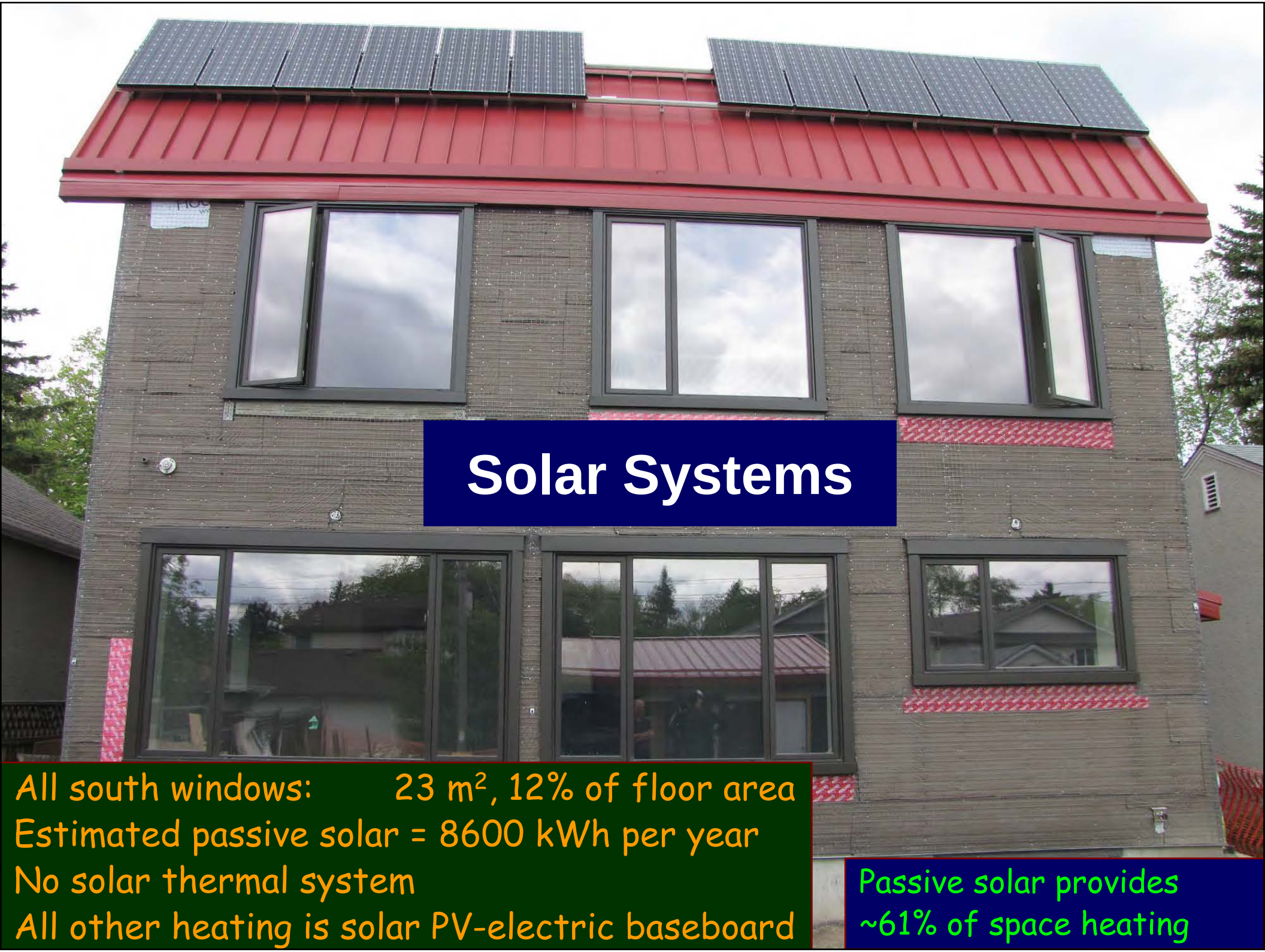
Simple solar domestic water heating system

All other heating is solar PV-electric: baseboard + electric water tank

Belgravia NetZero House

177 m² (1900 ft²)

(not including basement)



Solar Systems

All south windows: 23 m^2, 12% of floor area
Estimated passive solar = 8600 kWh per year
No solar thermal system
All other heating is solar PV-electric baseboard

Passive solar provides
~61% of space heating

Moveable Solar PV Awning

Fixed
PV array

PV
awning

Position
in August

Position
in December

Natural Landscaping

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

kiwi,
fiddleheads,
lots of berries,
apples,
herb garden,
mushroom stump

wetland,
waterfall

Edible forest

- Native and low water plants
- Beautiful and edible plants
- Rain water collection
- Minimal lawn

Designer: 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 database: GreenAlberta.ca

Next…

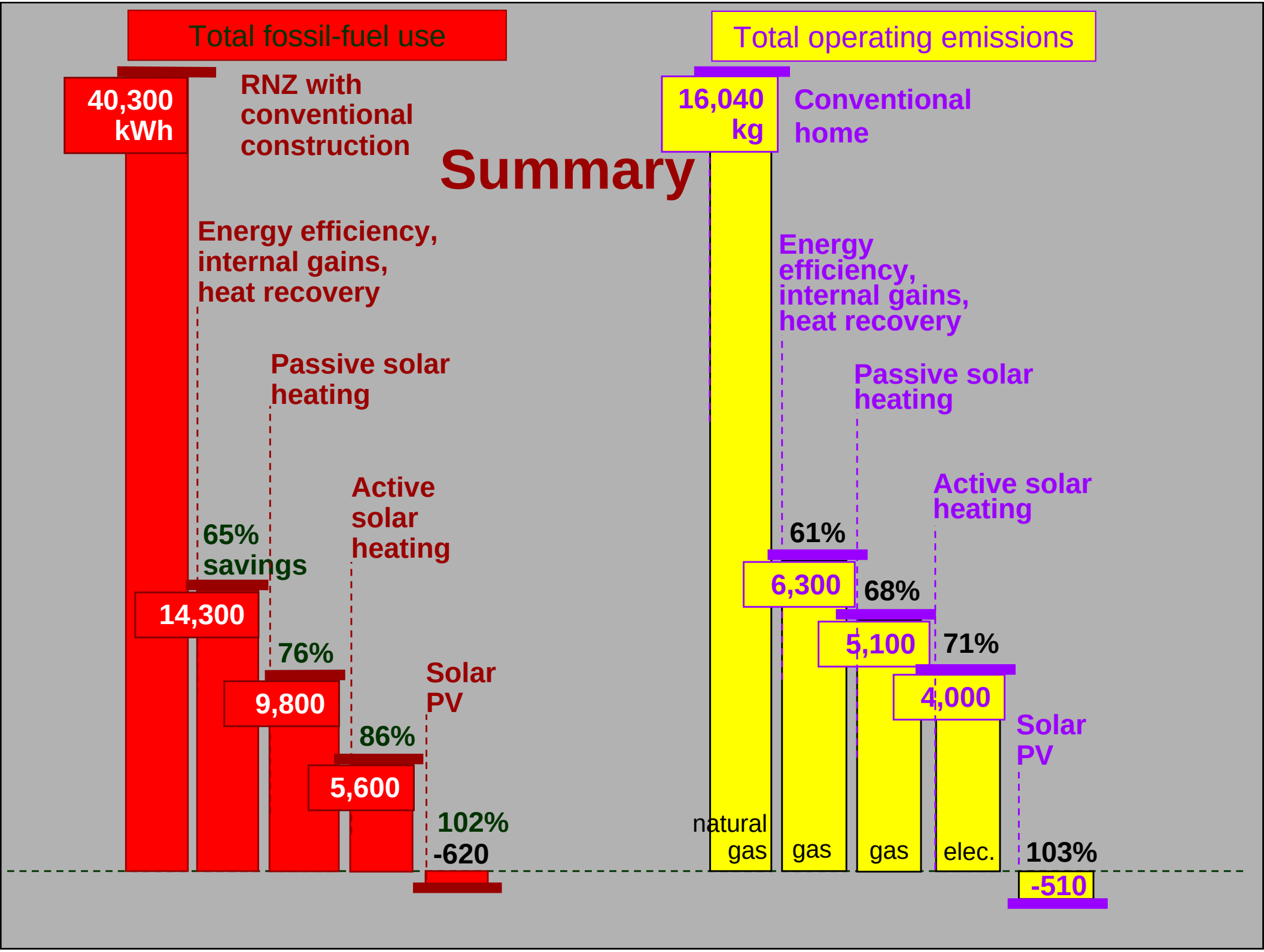
3. Expected Performance

howell·mayhew engineering, inc.

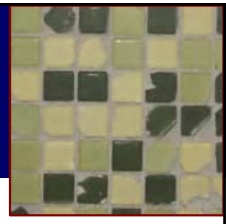
Once in a while solar doesn't work

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.


Total fossil-fuel use
Total operating emissions
Summary
40,300 kWh
RNZ with conventional construction
16,040 kg
Conventional home
Energy efficiency, internal gains, heat recovery
Passive solar heating
Active solar heating
Solar PV
65% savings
14,300
76%
9,800
86%
5,600
102%
-620
61%
6,300
68%
5,100
71%
4,000
103%
-510
natural gas
gas
gas
elec.

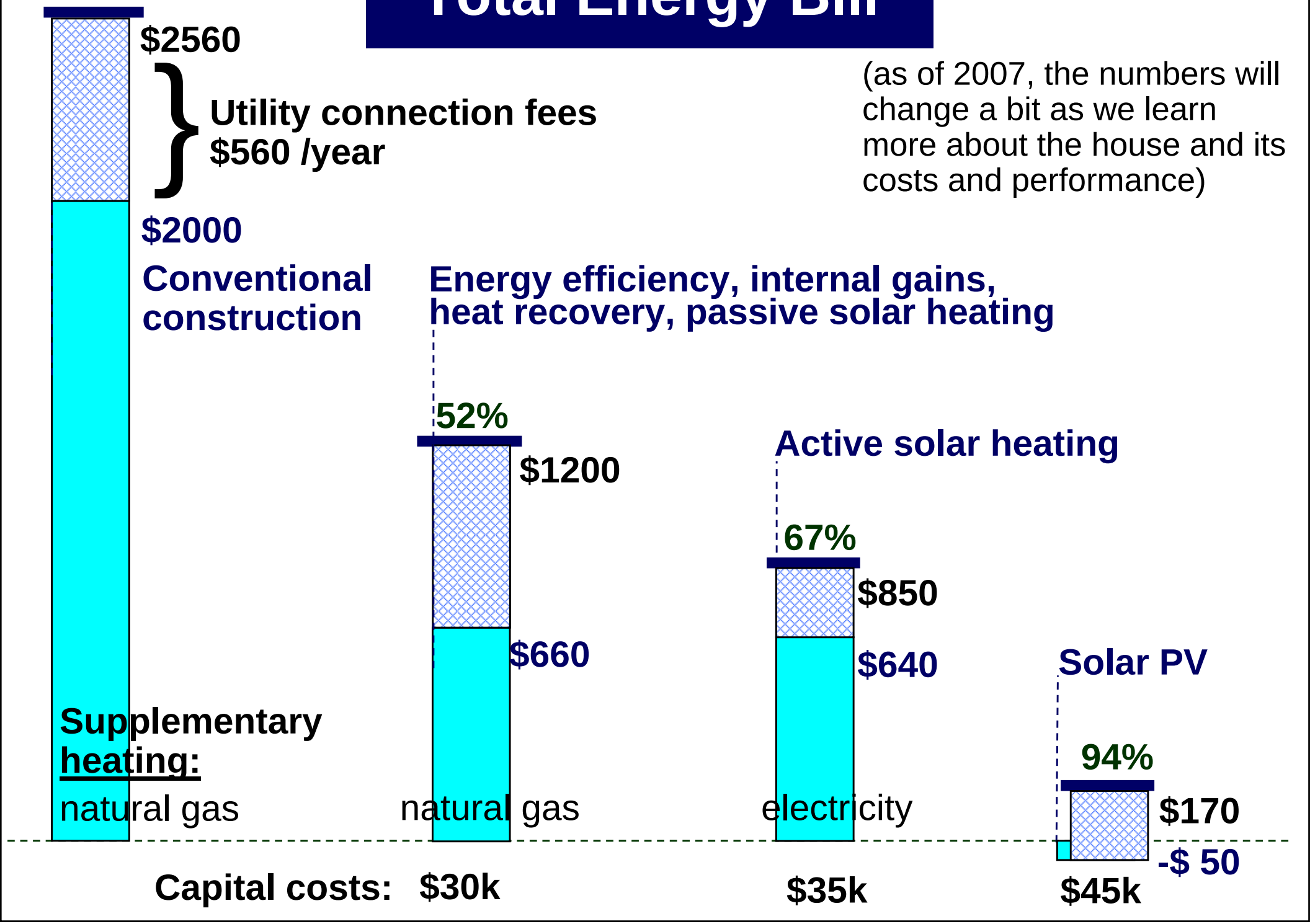
Next…



4. Costs and economics

howell·mayhew engineering, inc.

Total Energy Bill



(as of 2007, the numbers will change a bit as we learn more about the house and its costs and performance)

Results: Annual RNZ Home Energy Bills

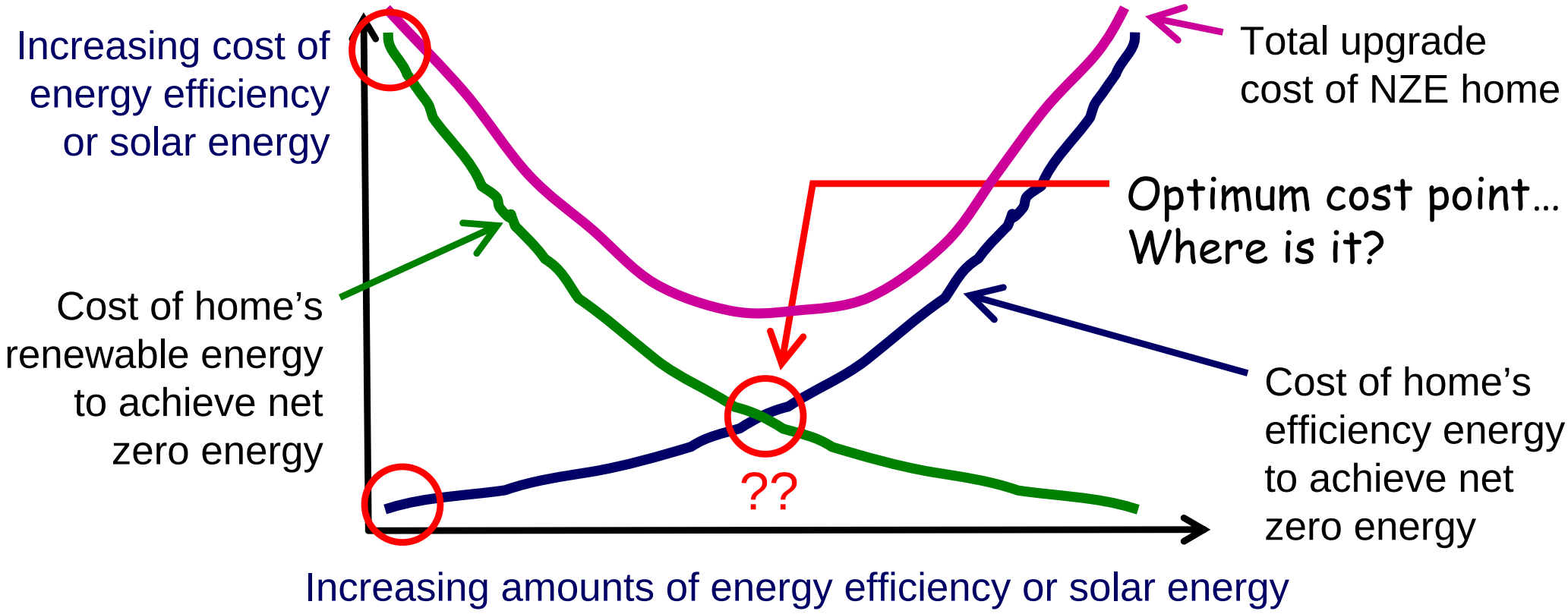
- Natural gas bill: $0 — no gas line needed, also saves $520 per year in connection fees (in 2010)
- Electricity costs: surplus ~$40 — ranging from $150 surplus to $100 deficit per year depending on homeowner electricity consumption choices
- plus standard electricity grid connection fees of $229 (in 2010)

howell·mayhew engineering, inc.

Design Challenge

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

- We need large amounts of energy efficiency and large amounts of solar energy



Decision Focus

Add energy efficiency measures until their cost per kWh/year

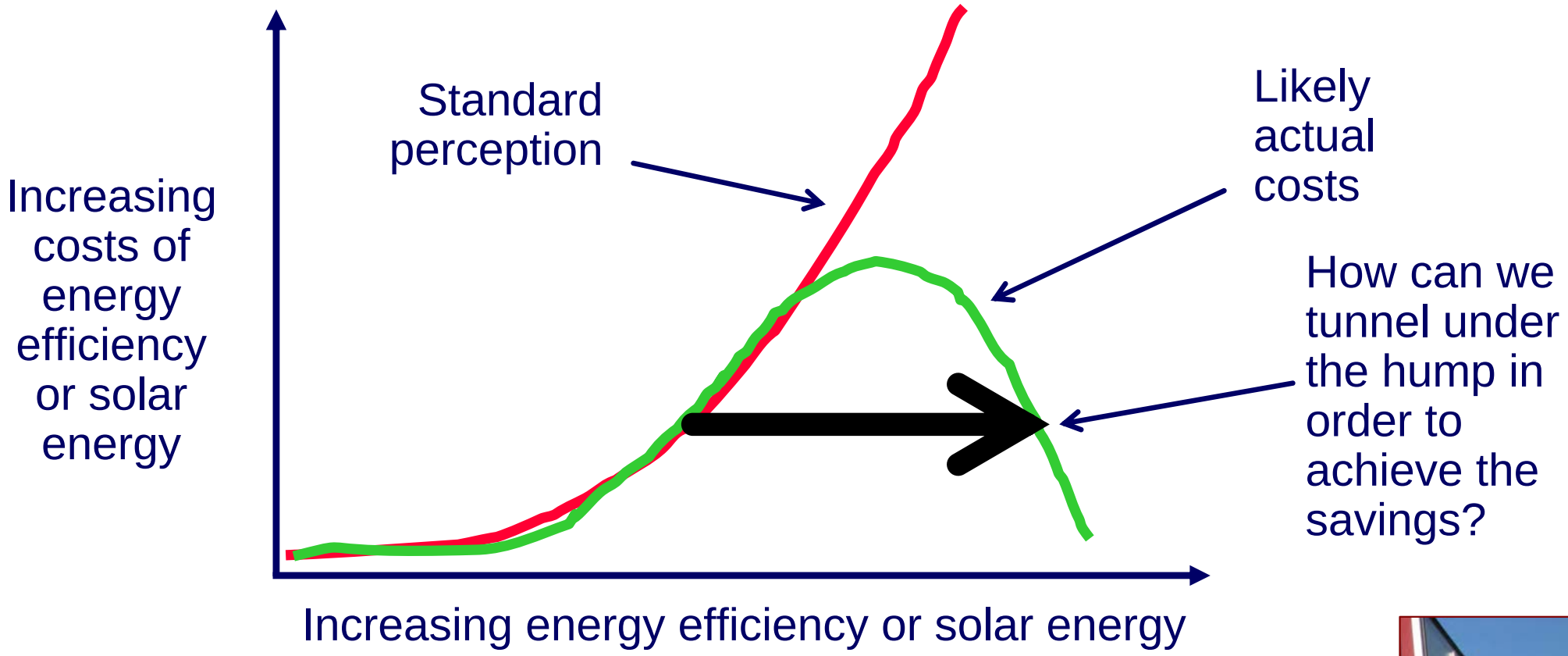
=

The cost per kWh/year of energy generation using solar PV

howell·mayhew engineering, inc.

Economic Challenge – "Tunnelling Through the Threshold"…

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



Concept courtesy of Amory Lovins

Riverdale NZE House Component Economics

	Upgrade Cost	Savings $/year	Energy price (simple analysis)		Return on investment
Electricity efficiency	**$1,800**	**$550**	**1.6 ¢/kWh**	**$4.50 /GJ**	**30% /year**
Water efficiency	**$1,750**	**$260**	**1.1**	**$3.10**	**15% /year**
Building envelope efficiency	**$12,000**	**$1000**	**0.9**	**$2.60**	**9% /year**
Passive solar space heating	**$2,400**	**$185**	▪ difficult to determine as a separate item…		…from the building envelope
Active solar space & water heating	**$36,700**	**$582**	**26**	**$71**	**1.6% /year**
Solar PV	**$54,000**	**~$700**	**27**	**$76**	**1.7% /year**
Overall house	**$109,000**	**~$3000**	**9**	**$25**	*** 2.7% to 12%**

plus 18,000 kg GHG savings

* depending on government policies on fossil-fuel subsidies, environmental emissions and green loans

Financial Challenges

- **House cost**
  - some $70k to $110k extra to build because of NZE features
- **Energy bill savings**
  - around $3000 per year (increasing every year)
- **Return on investment** (simple analysis)
  - Perceived to be 2.7% to 4.3% per year (23 to 37 year payback)
  - Not including mortage costs
  - But at 4% interest, this is $2800 to $4000 per year in loan payments
- **Government regulatory polices** regarding
  - Selling house electricity into the grid (participant costs, low value)
  - Lack of policies and value placed on the environmental sustainability
  - Subsides of fossil fuels (implicit and explicit)
    - Reduce the savings and benefits of energy efficiency and solar energy
  - Mortgage costs
    - Increase the operating costs for the house
  - Result in a **minus 4%** per year ROI (payback is never).

Policy Solutions

- **If government regulatory polices**
  - **Allowed** full cost recovery of all electricity fed into the grid (no fixed fees, provided equal import and export prices)
  - **Removed** fossil fuel subsides (such as natural gas rebates)
  - **Required** fossil fuels to pay for their environmental damage (air pollution and health care budgets)
  - **Provided** ultra-low interest green loans (< 1%)

- **Then…**
  - The energy operating cost of the house would be **zero**
  - The benefits of energy efficiency and solar energy would be **fully valued**
  - Would result in a **+5.2%** per year ROI (18 year payback).

- The changes to achieve this relate to how we want to **organise** ourselves, they are not technical.

Opportunity for “Net Zero Ready”…

- We are finding that “**net zero ready**” (ultra efficiency plus passive solar) is likely the cheapest-cost energy option for our new houses…
  - 73% energy reduction
  - 58% emission reduction
  - 54% utility bill reduction
  - yet only 4% of the costs of a new house…
- The infrastructure of “**net zero ready**” houses leaves homeowners and cities with a positive legacy instead of a future retrofit burden…

Next…

5. What we've learned...

howell·mayhew engineering, inc.

Design Challenges

- Amount of roof and wall ***space available***…

  is there enough unobstructed area available for all the
  - **solar-thermal liquid collectors**?
  - **solar-thermal air collectors**?
  - **solar PV modules**?

  and
  - **view windows**? (**which also provide passive solar heating**)

- ***Budget***
  - always a restriction
  - how can we make it **simpler** and **cheaper**?

howell·mayhew engineering, inc.

Design Guides…

- ***Keep it simple***
- ***Complexity*** of systems ***is a concern*** with their:
  - Design; Controls; Maintenance;
  - Modelling; Commissioning; Documentation; and
  - Installation; Operation; Homeowner training.
- ***Reduce # of House Energy Systems***:
  - Homeowners likely not familiar with most of the new energy systems in the house
  - Reduce the number of systems people have to deal with.
  - Need to look at all the heating options and decide whether they are really needed or not…

howell·mayhew engineering,inc.

Other Technologies …/1

- There are several strategies and technologies to get to the net zero energy goal…
- **Active solar air-thermal for space heating**
  - did not consider, didn't know much about it
- **Solar PV-thermal air for space heating**
  (recovery of heat by running air behind the back of a PV array)
  - were not aware of modelling software or case studies to give us confidence to try this

Other Technologies …/2

- **Heat pump**
  - **Ground-source (also called geothermal)**: did consider it but found it to be too expensive for the small additional amount of heating that we still needed. Could be good on a larger house or if we did not have solar thermal space heating. Complicates and increases the cost of the heating system, compared to electric baseboards.
  - **Air-source (like an air-conditioning system)**: did not consider because we perceived that it would not work in the winter in Edmonton. It could be worth re-evaluating.
  - **Water-source**: did not consider for an urban house
  - **Solar-source**: could be used. We are not certain of its performance.

Other Technologies …/3

- **Radiant Floor Heating**
  - did not consider,
  - more expensive than low-speed forced air heating,
  - do not see the advantage in a net zero energy house – don't have to distribute much heat around the house.

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

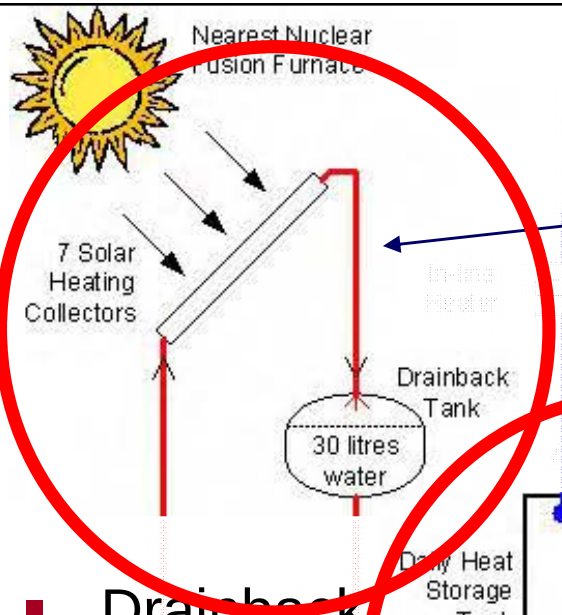
Other Technologies …/4

- **Evacuated Tube Solar Collectors** (ETC)
  - don't need the higher temperatures that it can provide,
  - more expensive than flat-plate collectors,
  - concern about performance claims,
  - concern about durability.

- **Heating zones**
  - not needed in an ultra-efficient house

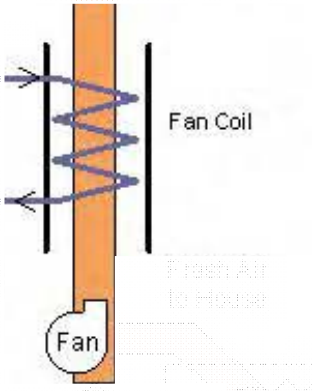
- **Night set-back thermostat**
  - likely not enough energy could be saved in a net zero house to make this worthwhile

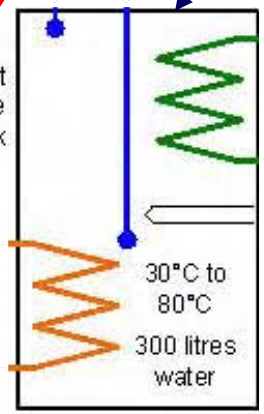
    (instead, we use a manual thermostat)



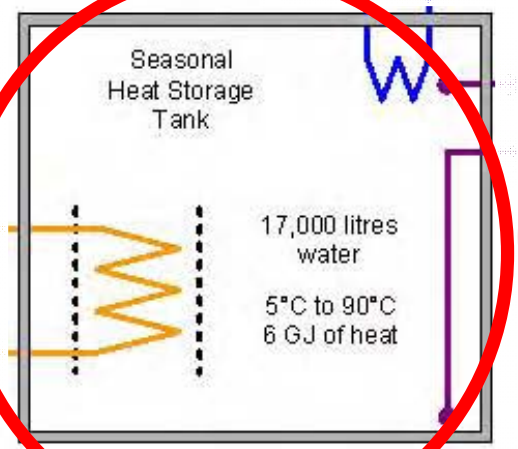
Major solar thermal components at RNZ

1. Solar collector array – 7 collectors
2. DWH tank – 300 litres
3. Space heating tank – 17,000 litres
4. Fan coil



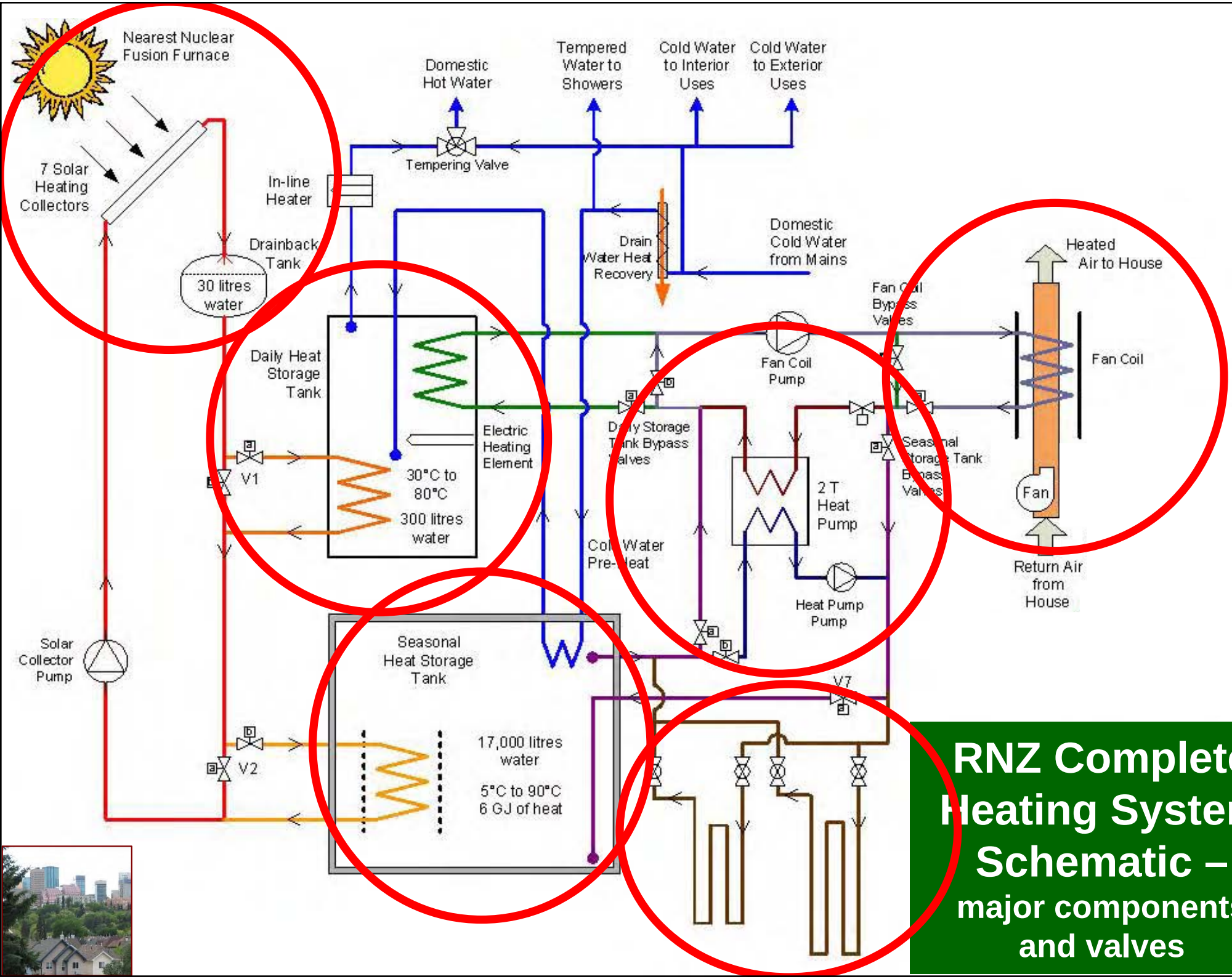


- Drainback tank in bedroom



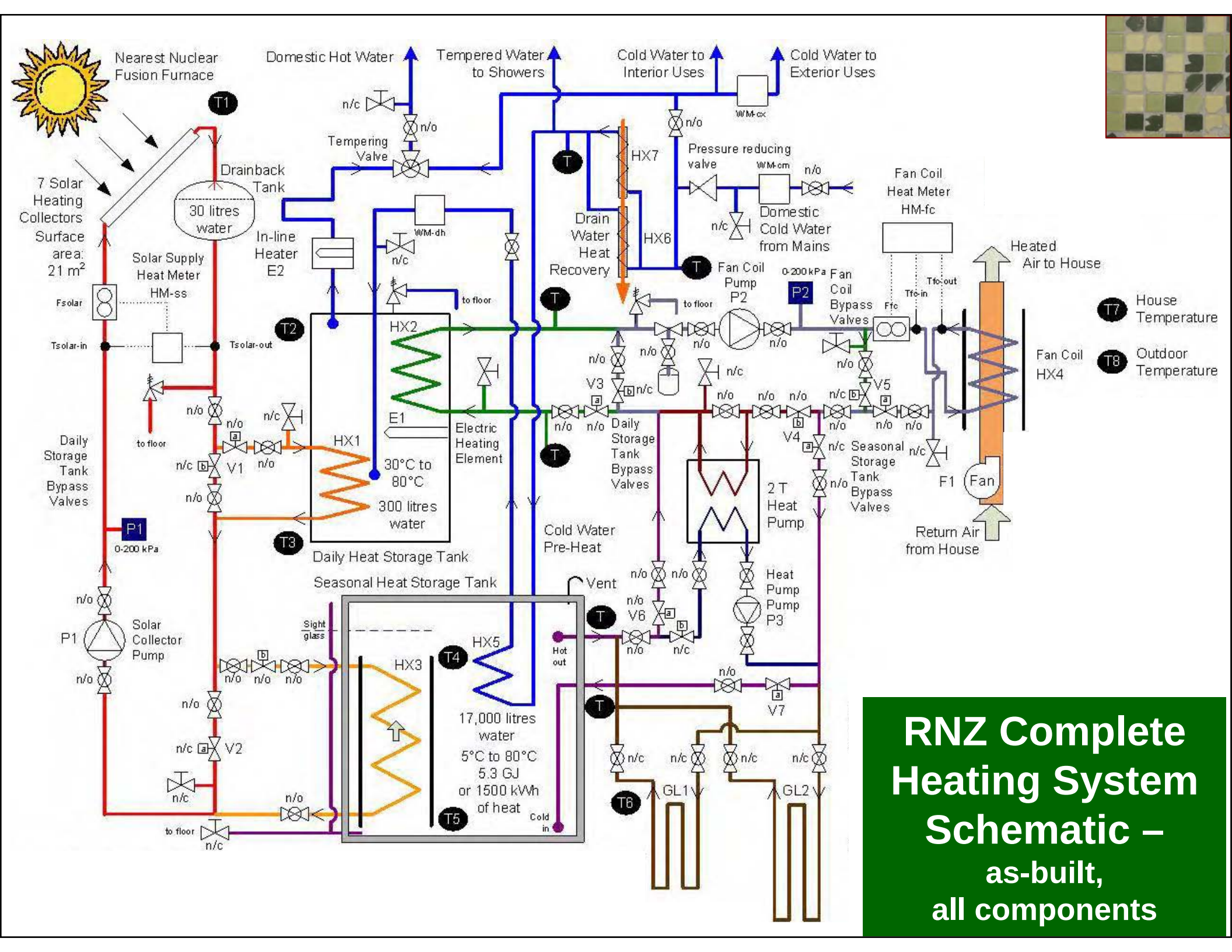
- Heat exchangers in large tank

- Fan coil



RNZ Complete Heating System Schematic –

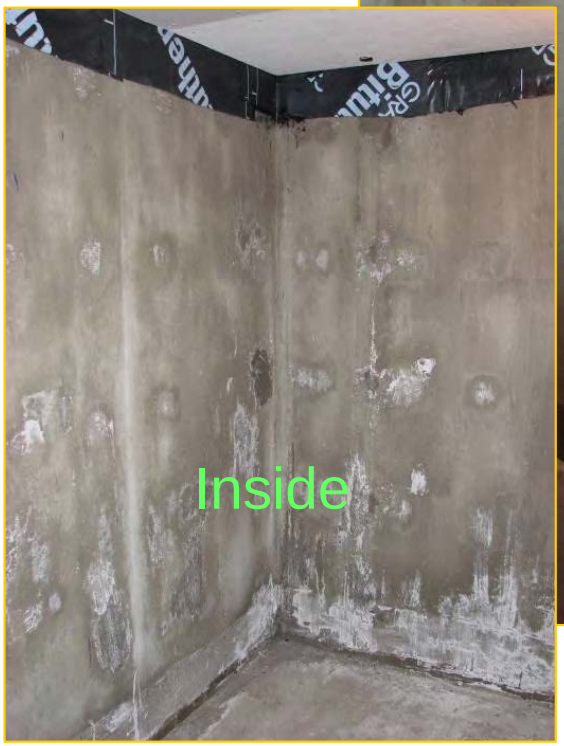
major components and valves



RNZ Complete Heating System Schematic –

as-built, all components

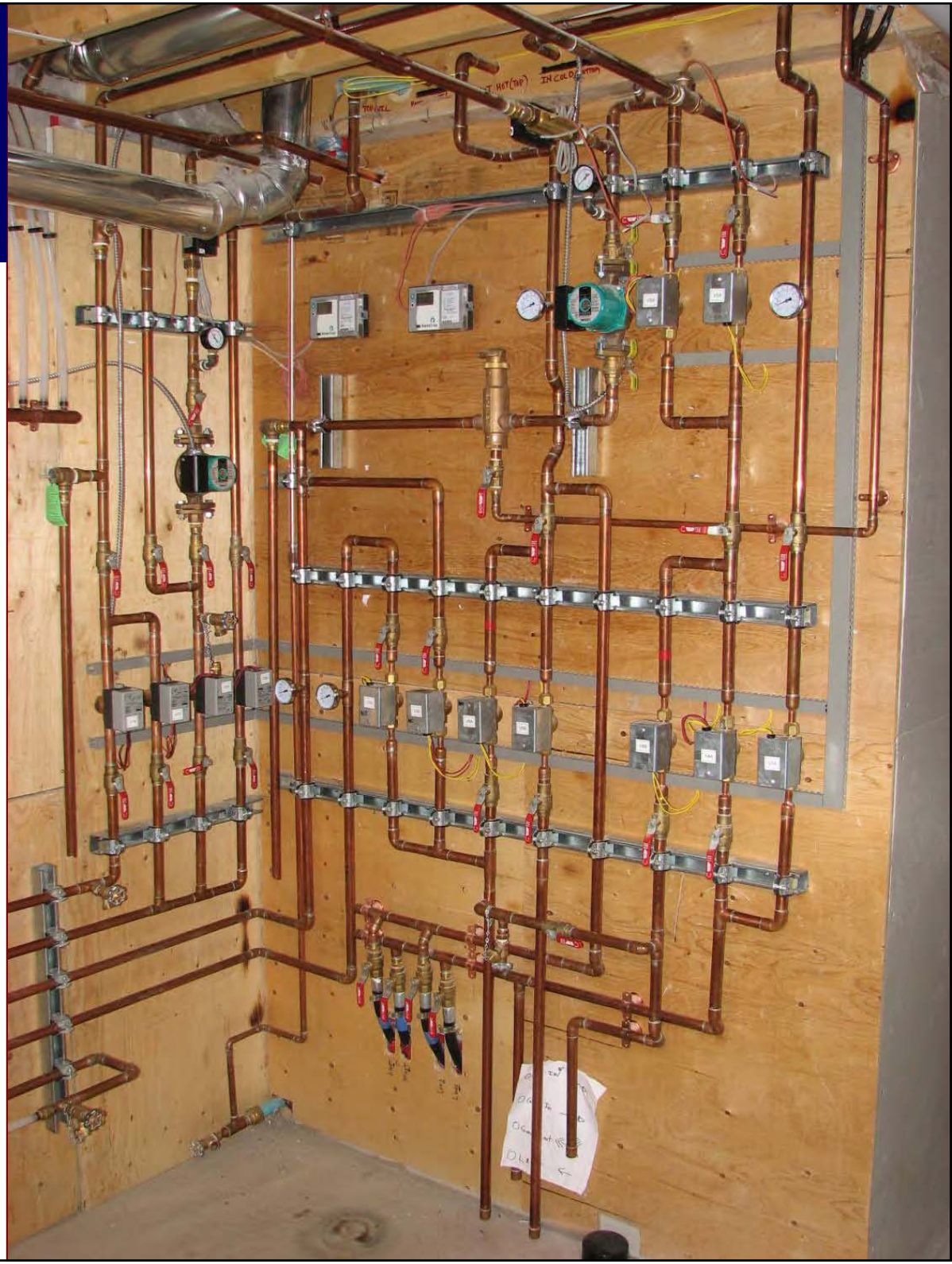
17,000 Litre Solar Storage Tank



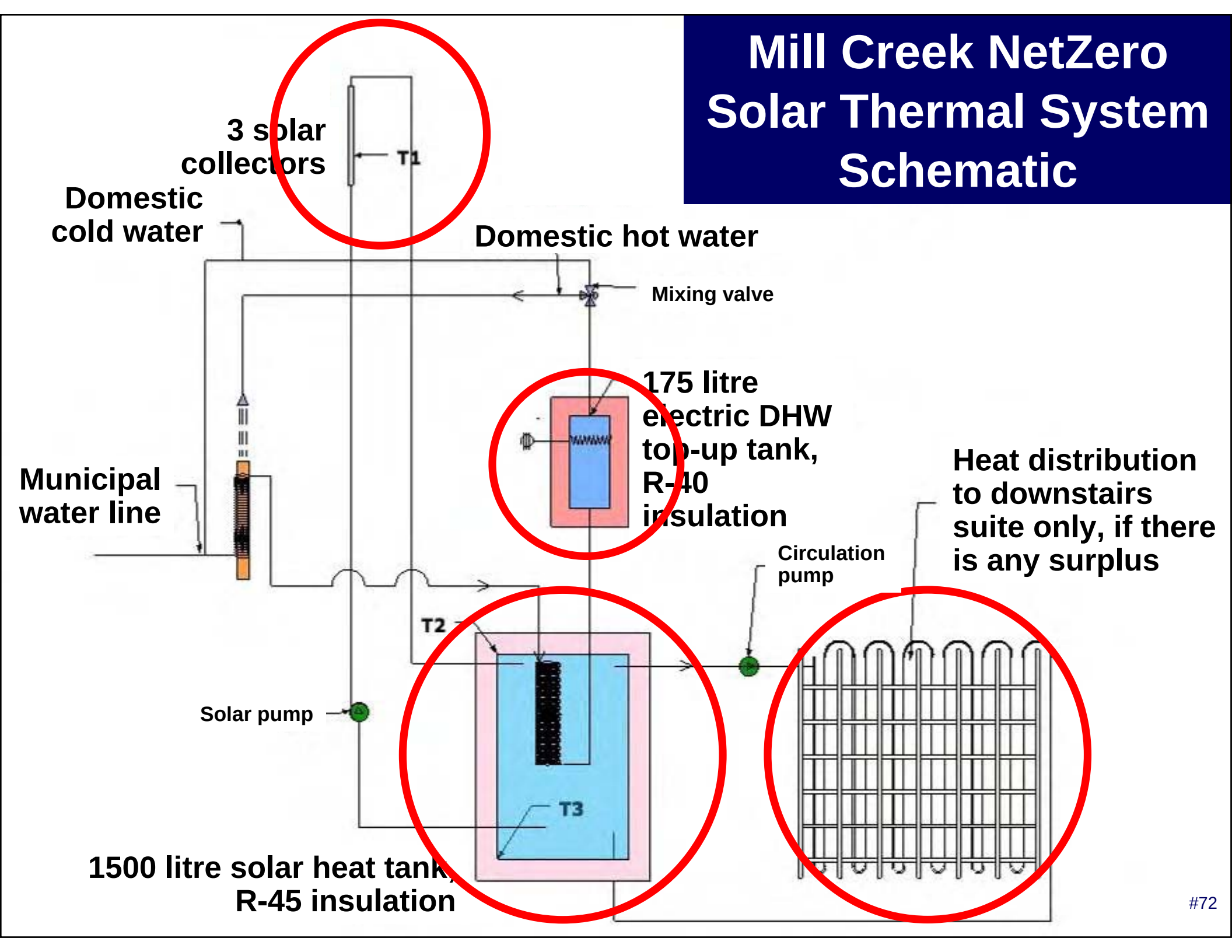
Tank, showing partial R50 insulation
(on walls and ceiling, R20 under floor)

Utility Room Solar Plumbing Layout - RNZ

- When completed, the piping will be insulated, colour-coded and have direction arrows.
- Complex to
  - design, model,
  - install, commission,
  - control,
  - describe, document, and train
- Takes up floor space for:
  - space heating tank
  - domestic water tank
  - fan coil
- Unknown maintenance
  - Can have air locks in piping
  - Risk of valve and tank leaks



Mill Creek NetZero Solar Thermal System Schematic



Belgravia NetZero Solar Thermal System Schematic

There is none….

howell·mayhew engineering, inc.

Nearest Nuclear Fusion Furnace

28 Solar PV Modules

Surface area: 33 m²

Grid-Dependent DC-AC Inverter

468 mm x 613 mm x 242 mm

Pac 5178 W

Vpv 393 V

Inverter integral DC and AC disconnects

D1

Pull-out safety switch at meter

D2

To the grid

M2

bi-directional cumulative house revenue meter

D4

Main House Breaker

Main House Breaker Panel

D3

40 A two-pole breaker

M1

PV system energy production meter

Operating voltage: 250 to 450 VDC

Operating current: 0 to 14.4 A

Operating voltage: 240 VAC

Operating current: 0 to 29 A

RNZ Solar PV system – single-line diagram

Electrical Room Solar Inverter Layout

- Simple to design, model, install, control, describe, document and train
- Compact
  - only takes up wall space
- Quiet
  - inverter relays click every 5 minutes at the start and end of each day
- No maintenance, essentially

howell·mayhew engineering, inc.

Summary

1. Energy efficiency is the first choice.

2. Solar PV is next.

3. Get ready for cheap solar PV.
   Make buildings “PV-ready”.

4. Housing that is “net zero energy ready”
   (which means ultra efficiency minus solar PV)
   is likely the cheapest cost option in a house
   right now.

Net Zero Energy Housing

… can we really afford anything less?

Download this presentation and others from

www.hme.ca /presentations

www.greenedmonton.ca

www.riverdalenetzero.ca

www.solaralberta.ca

www.ecosolar.ca

Calvert Island north of Vancouver Island

Alberta Emerald Foundation

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

Gordon Howell, P.Eng.
Howell-Mayhew Engineering
Edmonton
Phone: +1 780 484 0476
E-mail: ghowell@hme.ca

Photo credits: Gordon Howell and several others