On the Road to Net Zero Energy Homes

Rob Dumont, Ph.D.
robdumont@hotmail.com
Based on a talk given at

University of Nairobi
Dept. of Architecture and Building Science
May, 2009

Why should we be interested in Net Zero Energy Homes?

- 1. Global warming
- 2. Global warming
- 3. Global warming

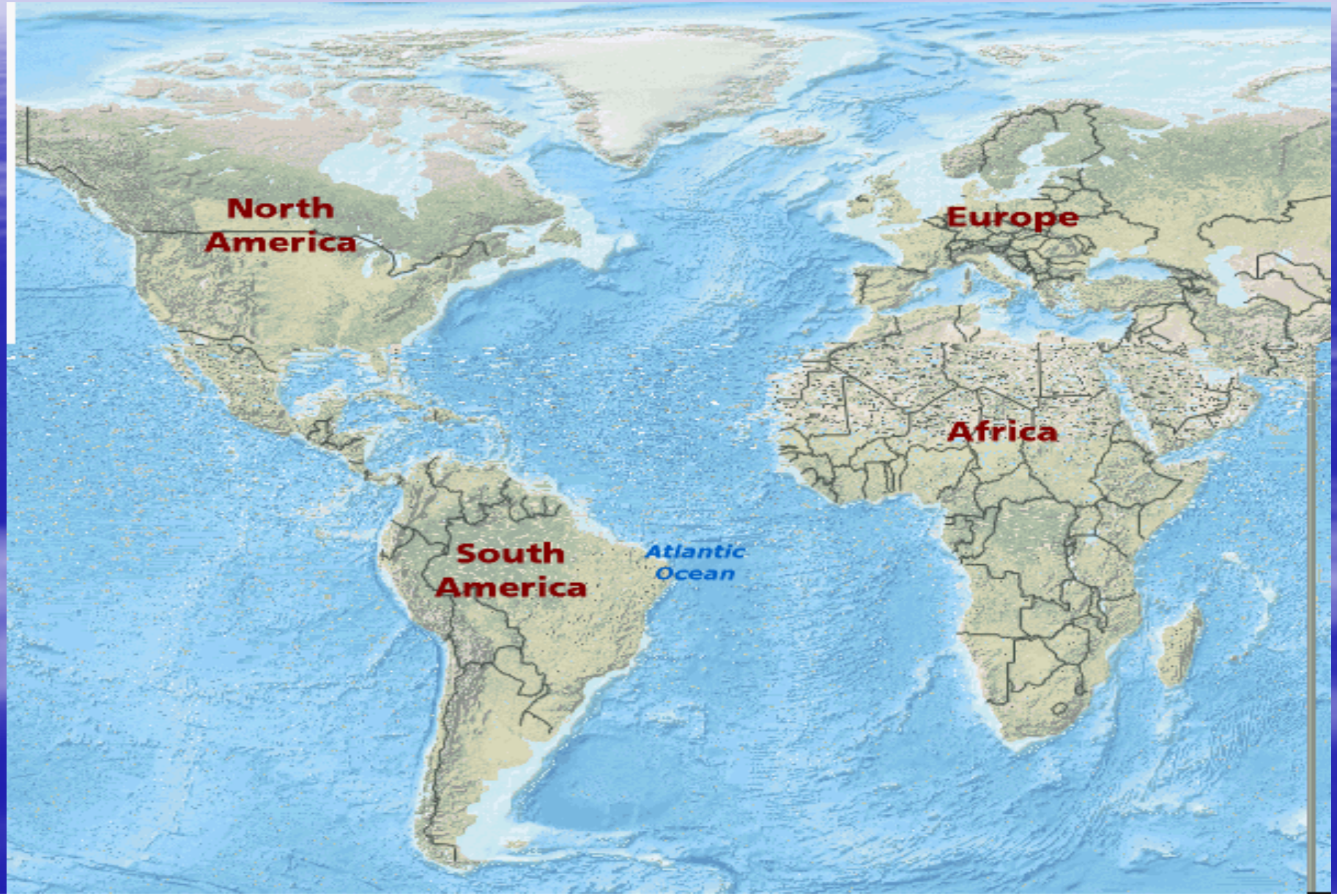
Other reasons

- By 2016, all new houses in the United Kingdom will have to be carbon neutral or net zero energy
- The American Institute of Architects AIA has called for all new buildings to be carbon neutral by 2030
- Saskatchewan currently may have the highest carbon footprint of any jurisdiction in the world (72 tonnes of carbon dioxide per capita per year) [the world average is about 7 tonnes per capita per year]

Audience Question

- How many homes in Nairobi are solar heated?

Saskatoon, Saskatchewan


North America
Europe
Africa
South America
Atlantic Ocean

Comparison of Climates (data from www.retscreen.ca)

	Nairobi	**Saskatoon, Saskatchewan**
Annual Average Temperature (ºC)	18.9	2.0
Annual Solar Radiation on a Horizontal Surface (GJ/m2)	7.8	5.1
Altitude (meters)	1600	500

- Nairobi is considerably warmer and considerably sunnier than Saskatoon

Comparison of Climates (data from www.retscreen.ca)

In Saskatoon, there is usually snow on the ground for 5 months of the year.

	Nairobi	**Saskatoon, Saskatchewan**
Outdoor Design Temperature for Heating Systems (ºC)	+11.0	-35.0

February 2005, Saskatoon

More than the sidewalks had to be shovelled that day. (Normally the snow will blow or melt off.)

Comparison of Climates (data from www.retscreen.ca)

	Nairobi	**Saskatoon, Saskatchewan**
Outdoor Design Temperature for Cooling Systems (ºC)	+28.1	+35.0

Question

- *Is there a more ideal climate in the world than Nairobi?*
- Nairobi is very sunny, not too warm and not too cold, gets adequate rainfall, is not too humid, and it never snows. A well-designed building in this climate needs neither space heating nor space cooling. Extremely few places in the world can make that claim.
- *Design with Climate* by Victor Olgyay has an excellent discussion about architectural design and climate around the world.

- Olgyay's Four Bioclimatic Zones

- Temperate
- Cool
- Hot Humid
- Hot Dry

- Kenya has all 4 zones!

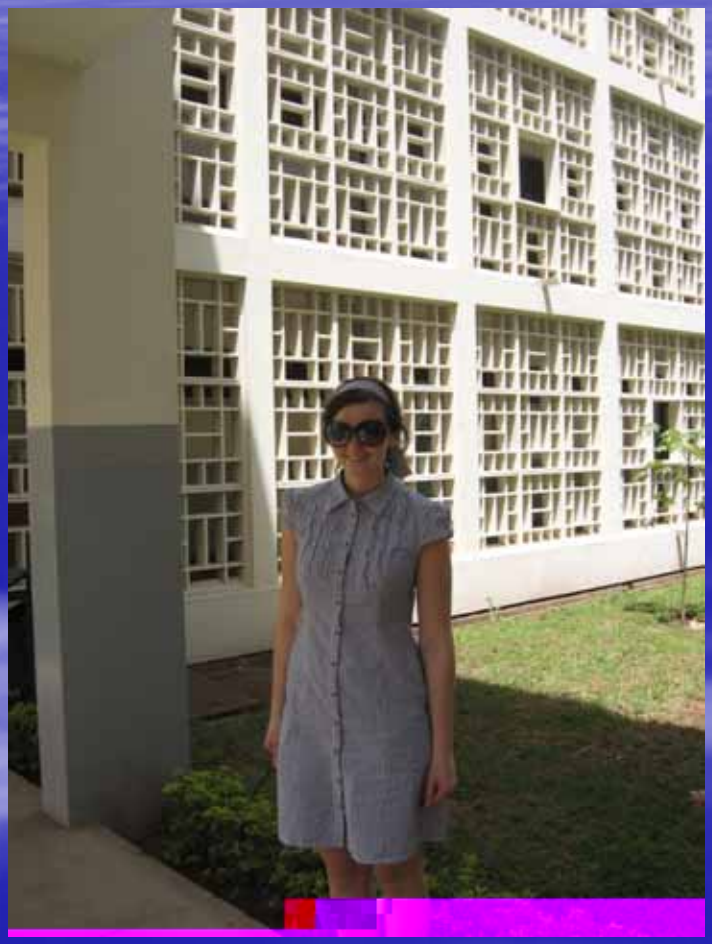
Energy Needs for Buildings

- Space heating
- Space cooling
- Domestic Hot Water
- Cooking
- LAME (Lighting, Appliances, and Miscellaneous Electricity)

Energy Needs for Well-designed Buildings in Nairobi

- Space heating X
- Space cooling X
- Domestic Hot Water
- Cooking
- LAME (Lighting, Appliances, and Miscellaneous Electricity)

Exterior lattice used on Nairobi Kenya Polytechnic Classroom Building as a sunscreen



Exterior Window Shading
University of Nairobi

Curtain Wall in a Hot, Sunny Climate = Big Cooling Loads
(in a country with frequent power outages)

Some examples of cold-climate low energy houses

- 1977 Saskatchewan Conservation House
  Regina, Saskatchewan, Canada

Note: Active Solar System Vacuum Tube Collectors on South Side, and insulating shutters on south windows

Rule of Thumb for Solar Collectors

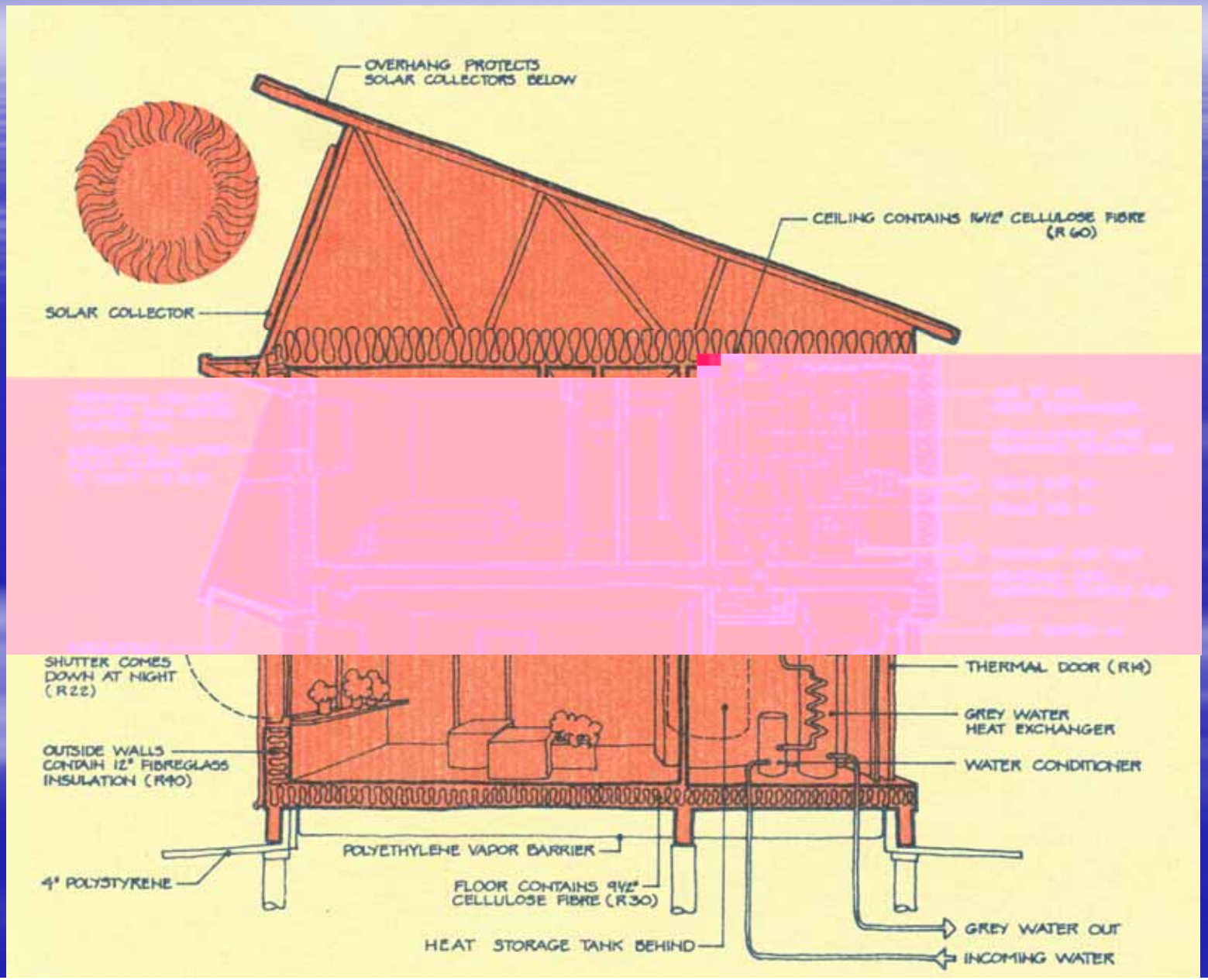
- A good rule of thumb is that solar collectors should face toward the equator.
- The tilt angle from the horizontal should be equal to the latitude angle plus or minus about 20 degrees.
- In Saskatchewan, the latitude angle of the major cities is about 50 degrees.
- In Saskatchewan we often tilt solar collectors at about 70 degrees to favour solar collection in the winter and to help keep snow off the collectors.

Comparison of Annual Solar Radiation

- **Saskatoon:**
- Horizontal Surface 5.1 GJ/m^2
- South facing surface
- tilted at 70 degrees to the horizontal 6.5 GJ/m^2

- **Nairobi Horizontal** 7.8 GJ/m^2

Saskatchewan Conservation House



Lessons Learned

- 1. Passive features worked very well.
- On sunny days the space heating was mostly covered by passive solar gain from the modest south windows, which were double glazed with exterior insulating shutters.
- 2. Much more work was needed to reduce domestic hot water loads and electricity usage (LAME)
- 3. Active solar system was too complicated.

Dumont Residence, Saskatoon, 1992

Features

- 1. “The best insulated house in the world” (at the time it was built in 1992)
- Attic insulation (600 mm of cellulose fibre-- R80)
- Wall insulation (400 mm of blown cellulose—R60)
- Basement wall insulation (400 mm—R60)
- Basement floor insulation (235 mm—R35)
- Approximately 8 tonnes of cellulose insulation used in the house

- 2. High performance windows
- Triple glazed with two low e coatings, two argon gas fills, non-metallic spacer bars, wood frames and casement design
- 3. Well-sealed building envelope (0.47 air changes per hour at 50 pascals)
- 3. Passive direct gain solar system (11.6 square metres of south window)
- 4. 15.6 square meters of active solar glycol based solar collectors with a 3000 litre water based heat storage tank.

- 5. High effectiveness (85%) air to air heat exchanger with low energy use brushless direct current motors.
- 6. Relatively energy efficient appliances
- 7. Compact fluorescent lighting
- 8. Relatively low water use appliances and exterior landscaping
- 9. Detached garage with roof sloped to accept photovoltaic panels at a later date
- 10. Low embodied energy through use of wood products (roof, siding, finish flooring, preserved wood foundation, cellulose insulation [8 tonnes])

Lessons Learned

- 1. Insulation and passive features worked well.
- 2. A greater passive solar contribution could be achieved with somewhat larger south facing windows and newer windows with better low e coatings and gas fills.
- 3. More energy efficient appliances would be helpful.

Factor 9 Home --2007

- Saskatchewan home designed to use 90% less energy and 50% less water than the average Saskatchewan home

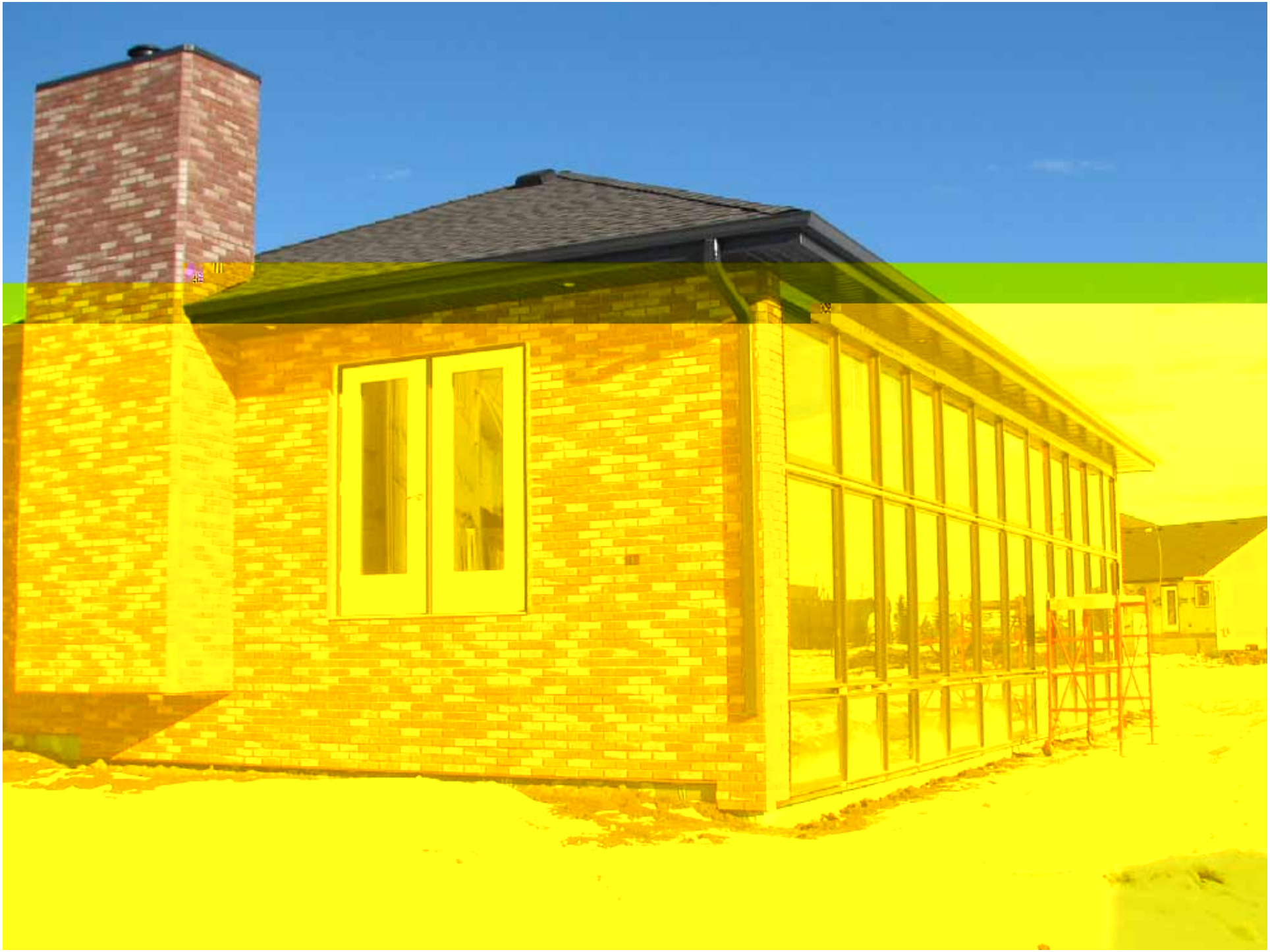
Factor 9 Home:

- Conventional appearance, high performance

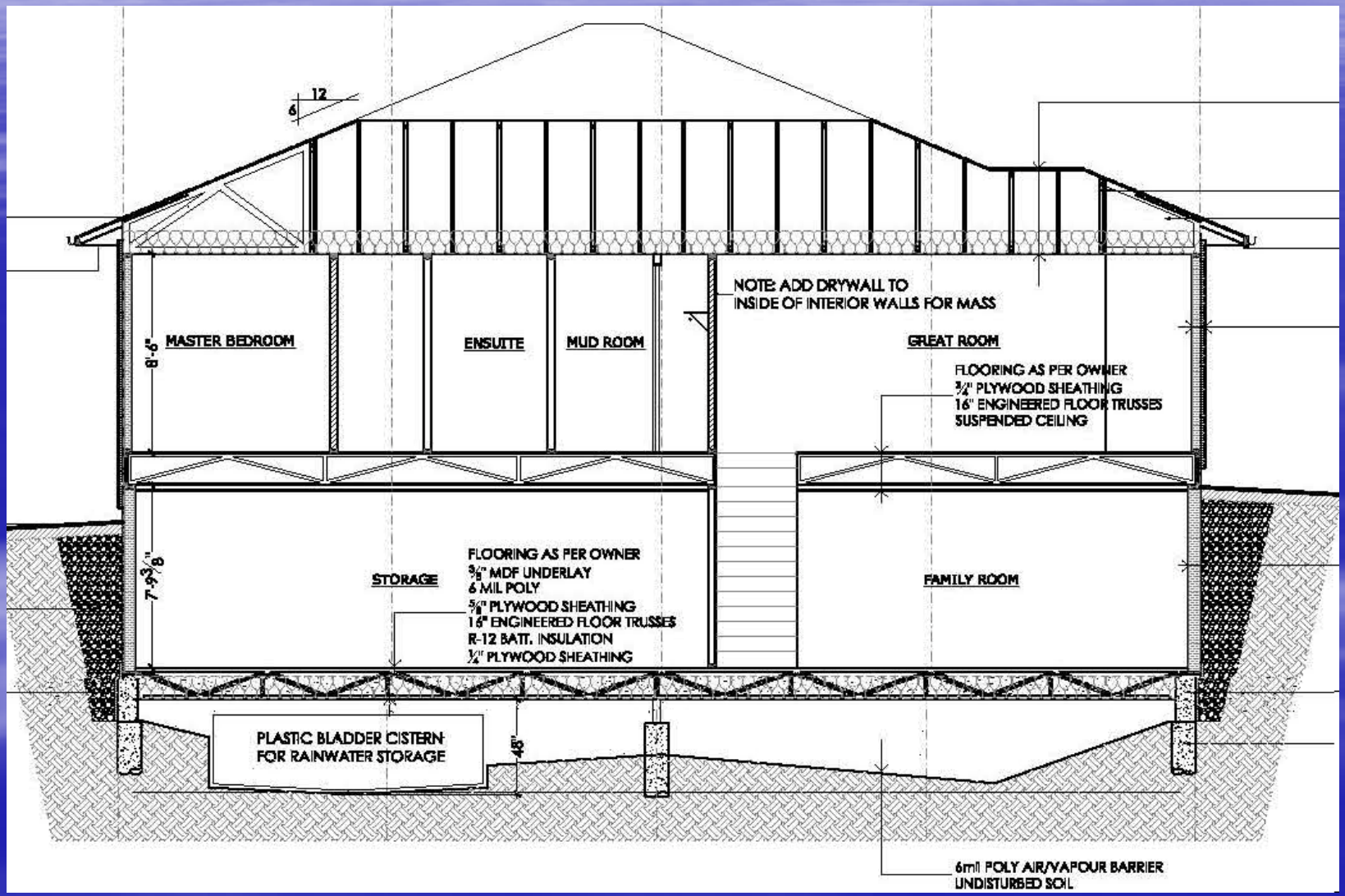
Why Factor 9?

- This is the number that is needed for global sustainability.
- Future world population growth: Factor 1.5
- Future world consumption growth per person: Factor 3
- Future reduction needed in world GHG production: 2
- 1.5 x 3 x 2 = **9**

Active Solar Thermal Panels are in a horizontal band at the mid-height of the south wall



Cross Section Showing Water Storage Tanks in the Crawl Space



Thermal Resistance Values for the Factor 9 Home

- Attic – R80 (RSI 14)
- Walls – R34.5 (RSI 6.1)
- Basement Walls – R50 (RSI 8.8)
- Basement Floor – R11.4 (RSI 2)

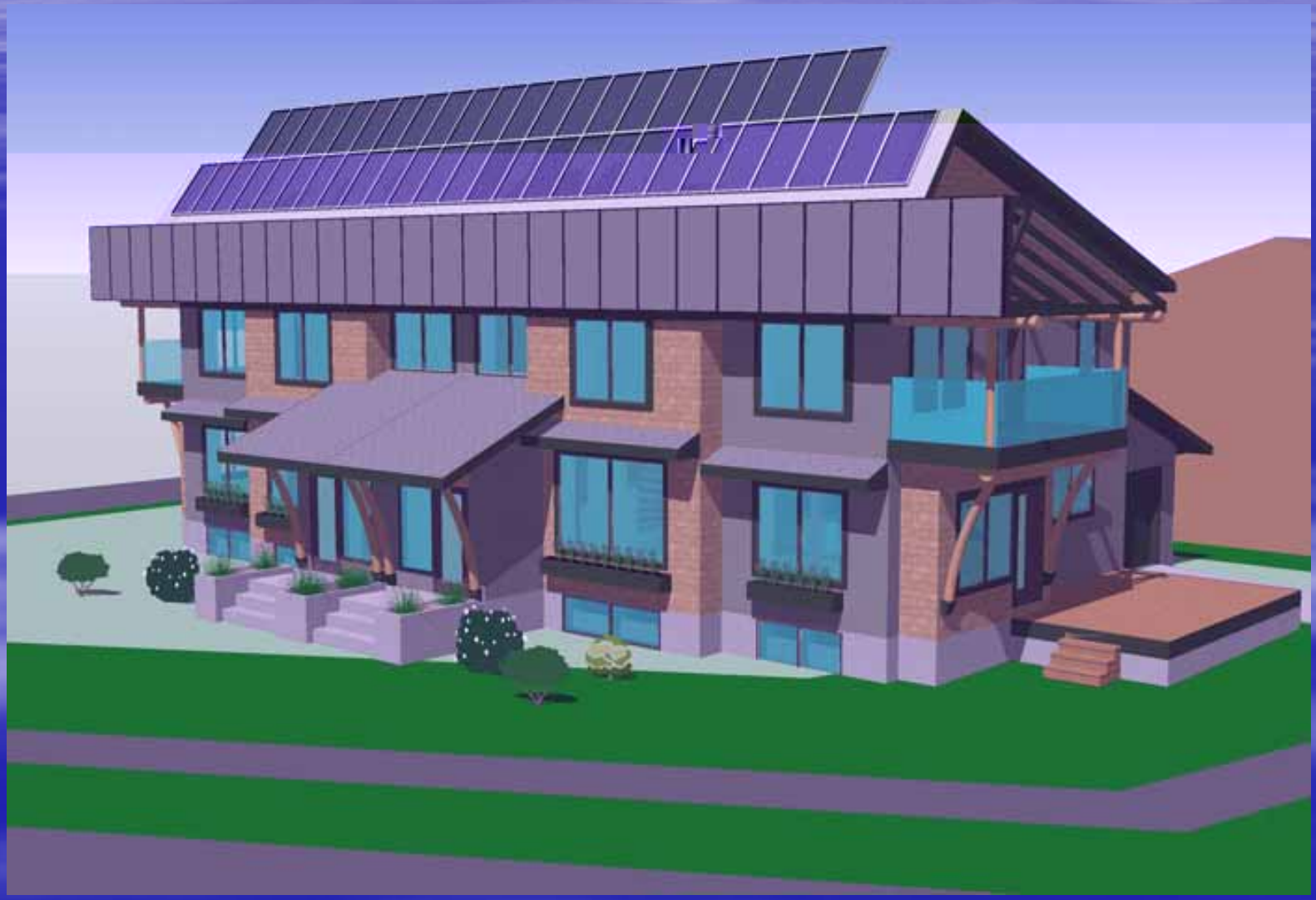
Sustainable Energy Features

- Passive solar space heating through south windows
- Active solar space and water heating through south vertical solar heating panels (21 sq.m.) with 2400 litre heat storage tank
- Orientation of the roof to the south so that photovoltaic panels can be placed as the cost comes down
- Extraction of cooling from the 15 ft (4.5 metre) deep pilings under the house

Other energy efficiency measures

- Energy Star White Appliances
- Compact Fluorescent Lamps
- Drain Water Heat Exchanger
- Air to air heat exchanger with brushless DC motors
- The Energy Detective™ whole house electricity monitoring device
- Fan coil with oversized heating/cooling coil and brushless DC fan motor

Riverdale Net Zero Duplex
Edmonton, Alberta, 2007-2008



Energy Efficiency & Renewable Energy Features

- Attic R 100 (RSI 17.6)
- Walls R 56 (RSI 9.9)
- Basement Floor R24 (RSI 4.2)
- Triple (S) and Quadruple (N,E,W) glazed windows with low e and argon gas

- Passive solar space heating
- Active solar space and water heating
- Photovoltaic system for electricity generation

Other energy efficiency measures

- Energy Star Appliances
- Compact Fluorescent Lamps
- Drain Water Heat Exchanger
- Air to air heat exchanger with high effectiveness
- Whole house electricity monitoring device

Riverdale Net Zero Home: October 2008

Projected Net Annual Energy Consumption:

- Zero

- Grid connected photovoltaic system will generate enough energy in a year to compensate for all the purchased energy used by the house. No natural gas or other fossil fuels are used on site.

Interesting Web Site

- Next page shows “live” summary of the output of the 6.2 kilowatt peak photovoltaic system for the day of September 2, 2009

- Available at www.riverdalenetzero.ca

VIEW | Simple | Detail

As of: 8:25 PM Sep 02, 2009

System Size: 5.6 kW DC

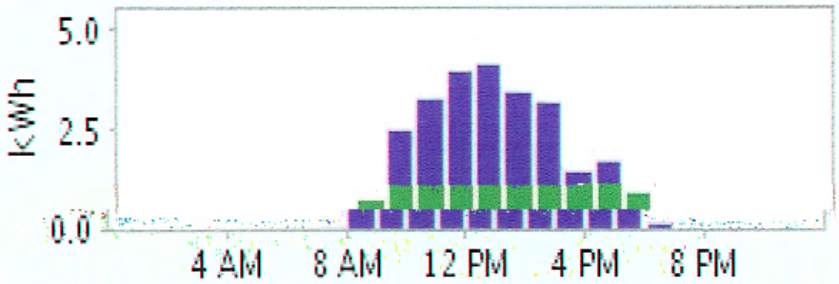
Generating 0 W

Local Weather

Historical

Today | Week | Month | Year | Lifetime

Generated 26.2 kWh



Greenhouse Gases Avoided

Since Installation Feb 19, 2008

Equivalent to:

The energy to operate a TV for 79,814 hours.

The pollution an average passenger car emits over 419 days.

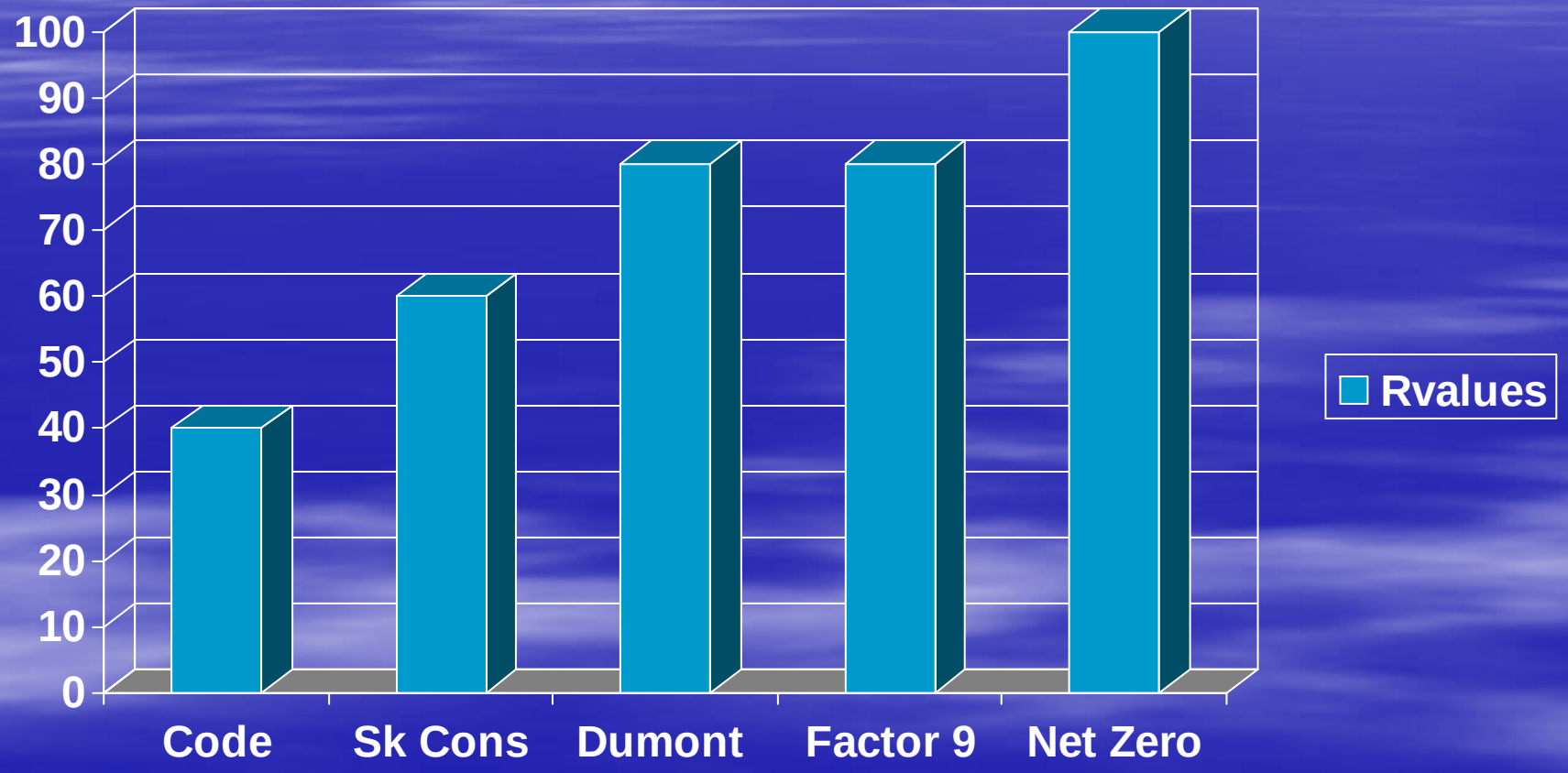
CO_2 11,484 kg

Powered by Fat Spaniel TECHNOLOGIES

Measured Energy Performance of the Demonstration Houses

	Purchased Annual Energy (kWh/m^2)
Saskatchewan Conservation House (1977)	76 (24,100 Btu/ft^2)
Dumont Residence (1992)	47 (14,900 Btu/ft^2)
Factor 9 Home (2007)	33 (9,500 Btu/ft^2)
Riverdale Net Zero (2009) **Sold and occupied in 2009**	**0 (projected)** (0 Btu/ft^2)

Attic Insulation Levels (English Units)



Approximate Incremental Construction Cost for Energy Efficiency and Renewable Energy Features

	Approximate Incremental Cost (excl. land) & Net Annual Purchased Energy Performance	
Dumont Residence (1992)	7%	(14,900 Btu/ft^2)
Factor 9 Home (2007)	12%	(9,500 Btu/ft^2)
Riverdale Net Zero (2009)	**35%** (Estimated incremental cost of about $110k, mostly for PV and active solar systems)	(0 Btu/ft^2)

Mill Creek House, Edmonton
Net Zero Design

- Address: 9805 84th Ave
- Very high energy conservation levels
- Simplified mechanical design emphasizing more passive solar
- Lower incremental cost

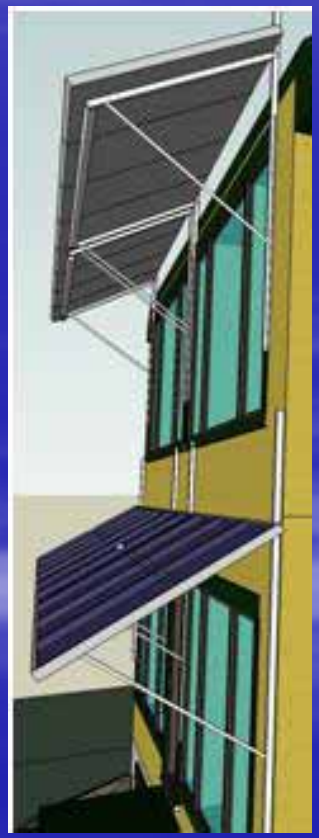
View from Southeast in July with the solar awnings in the low position (Sketchup drawing) (Note how the solar shading is accurately generated by Sketchup)

View from Southeast in December with photovoltaic panels up

North side of Mill Creek House

South side

Integrated Design of South Awning and Photovoltaic Panels which are tiltable.



Mill Creek House

R60 walls, added thermal mass, high SHGF windows, "oversized" south windows

Incremental Cost for Energy Features at the Mill Creek House

- $65 k vs about $110 k for the Riverdale Net Zero House

- **Why are costs so dramatically reduced even though houses are roughly the same size?**
- A. Greater use of passive systems (more high performance South glass)
- B. More thermal mass (primarily concrete floor topping)
- C. Size of active solar thermal system was reduced
- D. Cost of photovoltaic panels has dropped about 40% in the last year.

More Information on recent demonstration houses

- Factor 9 Home
- www.factor9.ca

- Riverdale Net Zero Home

  www.riverdalenetzero.ca

Mill Creek House

http://greenedmonton.ca/mcnzh-solar-awning-part-01

Answer to the Question:
How many homes in Nairobi are solar heated?

- They all are. All homes in Nairobi are already about 99%% solar heated

- (The temperature in Nairobi would be
  -273 ^{o}C if the sun were not there)

  All that Nairobi's space heating systems have to do is raise the temperature of homes an average of about 3 ^{o}C.

Free Computer Programs for Estimating Performance of Renewable Energy Systems

- www.RETSCREEN.ca
- Modules to estimate annual performance of
- Domestic Hot Water Systems
- Solar Swimming Pool Systems
- Passive Solar Heating Systems
- Solar Photovoltaic Systems
- Wind Energy Systems

RETScreen® Solar Resource - Solar Air Heating Project

Site Latitude and Collector Orientation	Estimate
Nearest location for weather data	Nairobi/Dagoretti
Latitude of project location for weather data	°N
[illegible]	0.
[illegible]	20.

Monthly Inputs

hly age ature	Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Mont aver temper
)				(°C
0	January	1.00	6.45	18.
8	February	1.00	6.55	18.
4	March	1.00	6.19	19.
2	April	1.00	5.25	19.
8	May	1.00	4.64	17.
3	June	1.00	4.19	16.
6	July	1.00	3.59	15.
9	August	1.00	3.93	15.
3	September	1.00	5.28	17.
5	October	1.00	5.61	18.
4	November	1.00	5.31	18.
1	December	1.00	6.13	18.

ual			Ann
2	Solar radiation (horizontal)	MWh/m²	1.9
2	Solar radiation (tilted surface)	MWh/m²	1.9
8	Average temperature	°C	17.

Kenya Weather Data available in RETSCREEN

- Garissa
- Kitale
- Lodwar
- Mandera
- Mombasa
- Nairobi
- Voi

Some Conclusions

- 1. Net Zero Energy Homes have now been built in Canada and the U.S.A.
- 2. The technology has been proven.
- 3. Costs of photovoltaic panels are declining.
- 4. The world will not be sustainable without sustainable buildings, because buildings consume so much energy both in their construction and in their ongoing energy use.

Acknowledgement of Sponsors

- Office of Energy Conservation, Government of Saskatchewan
- Communities of Tomorrow, Saskatchewan
- Saskatchewan Research Council
- Natural Resources Canada
- Canada Mortgage and Housing Corporation

- *Their participation is gratefully acknowledged*