Passive Solar Heating and Thermal Mass

Rob Dumont
robdumont@hotmail.com
2010

Quick Facts about the Sun

- 1. It supplies the earth continuously with about 10,000 times as much energy as is supplied by all the fossil fuels that we currently consume.
- 2. All our homes in Saskatoon are already mostly heated by the sun. (If the sun were not there, the temperature outside would be -273 ^{o}C)

Three Uses of the Sun:
1. Passive Solar Heat thru windows
2. Photovoltaic Panels on south roof
3. Solar Thermal Panels (vertical)

What is direct gain passive solar heating?

- The use of common building components such as south facing windows and thermal storage in the home's ceilings, walls and floors to capture useful space heating.

Big Questions:

- 1. How energy conserving is the home?
- 2. How big is the home?
- 3. How is the home situated?
- 4. What building materials are used?

- 5. What type of windows will be used?
- 6. How much thermal mass inside the home will be used?

- **1. How energy conserving should the house be?**
- Saskatoon has an average annual outdoor temperature of +2 ^{o}C (36 ^{o}F)
- [Less than 1% of the world's population live in as bracing a climate.]
- Suggested ***minimum*** insulation values for this climate:
- Attic R60 Walls R40 Bsmt Floor R15
- Well sealed air/vapour barrier: 0.5 air changes per hour at 50 pascals
- Heat recovery ventilator with an effectiveness of 0.8 or higher
- Energy Efficient LAME (Lights, Appliances and Miscellaneous electricity users)
- Allocate space for solar water heater and solar photovoltaic panels

- 2. How big should the house be?
- Small is beautiful. A smaller house requires less energy. Use creative floor layouts to keep the house smaller.

- **3. How is the home situated?**
- Orient the home along an east-west axis so that the main windows can face south and the east and west windows are minimized.

- **4. What building materials should be used?**
- As much as possible, use local building materials. Wood based products have a low embodied energy, and also remove carbon dioxide from the earth's atmosphere.
- For thermal mass, concrete, brick and stone, and occasionally water have been used.

- **5. What type of windows should be used?**
- **On the south side, use windows with a high solar heat gain factor (greater than 0.55) and moderate R value.**
- **On the east, west, and north sides, use windows with a high R value and a lower solar heat gain factor.**

Example: VerEco Home

- **South Windows**:

  Solar Heat Gain Factor of 0.57
- R value 5.88 Center of glass

- **East, West and North Windows**:
- Solar heat gain factor of 0.31
- R value of 8.06 Center of glass

Passive Solar even works on a cloudy day

- 6. How much thermal mass inside the home will be used?
- A. If the ratio of the south window area to the floor area is less than about 6%, no additional thermal mass is needed because there is enough heat storage in the house wood materials and gypsum board already.

Dumont House, Saskatoon

- South Window to Floor Area ratio equal to 5.5%

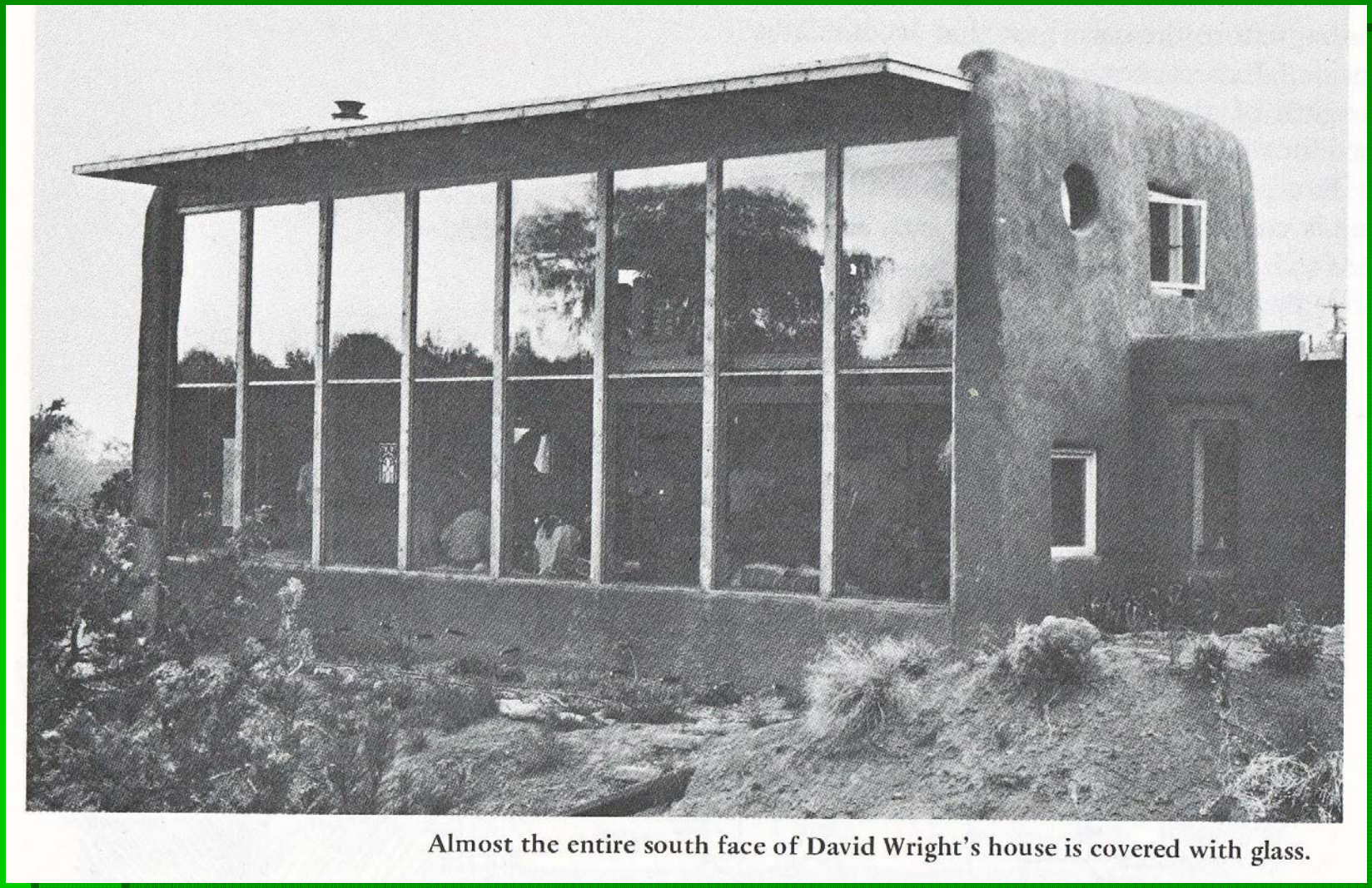
Dumont Residence, Saskatoon, 1992
South window to floor area ratio = 5.5%

Almost no overheating; only extra thermal mass is scrap gypsum board in the interior walls. Note shading of upper windows in summer by roof overhang

Dumont Residence, Winter

Note the lower sun angle and absence of shading on the windows

Too much glass:-- Not recommended.
Roughly 30% ratio of south glass to floor area
David Wright House in Santa Fe, New Mexico, 1974



Almost the entire south face of David Wright's house is covered with glass.

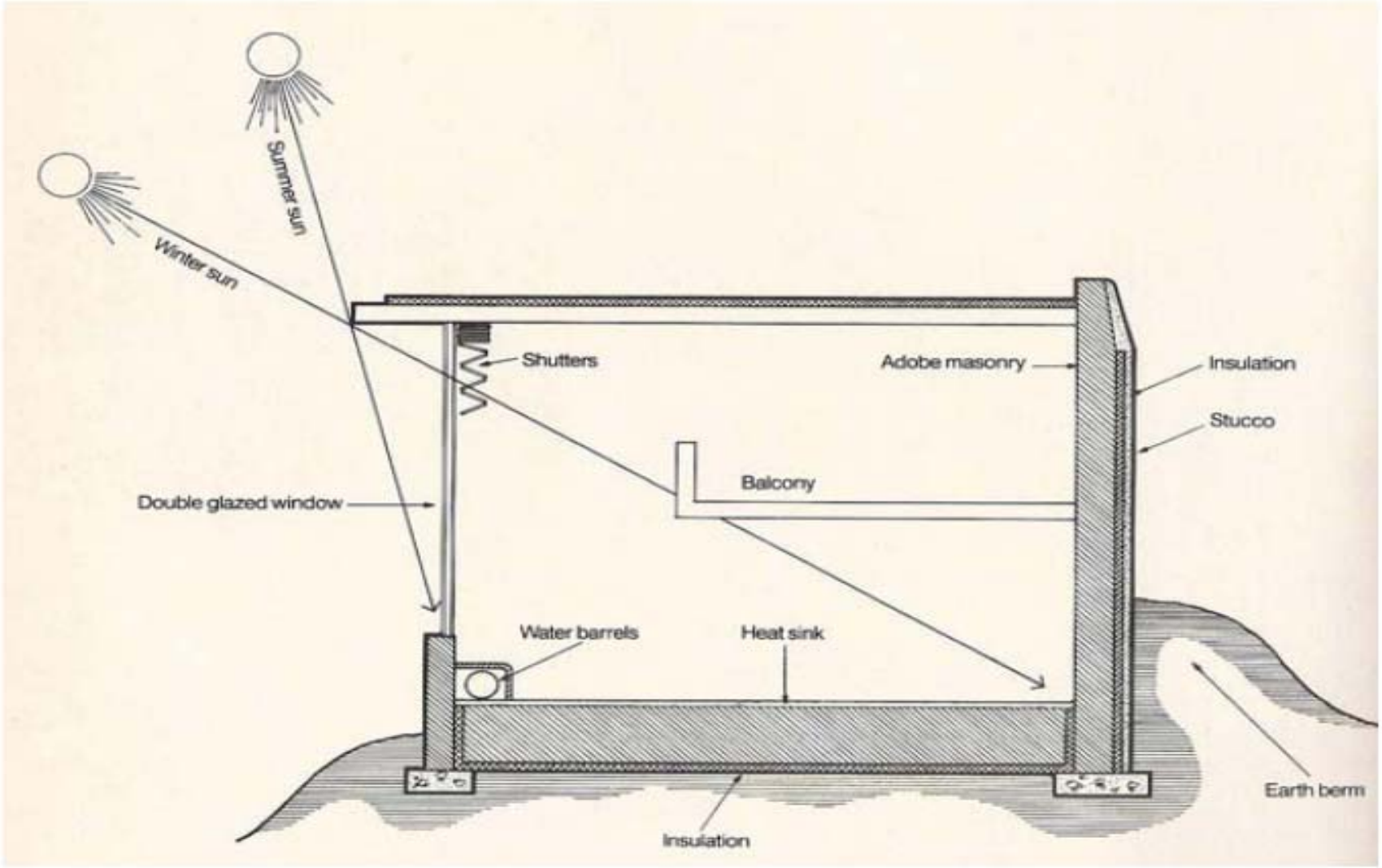
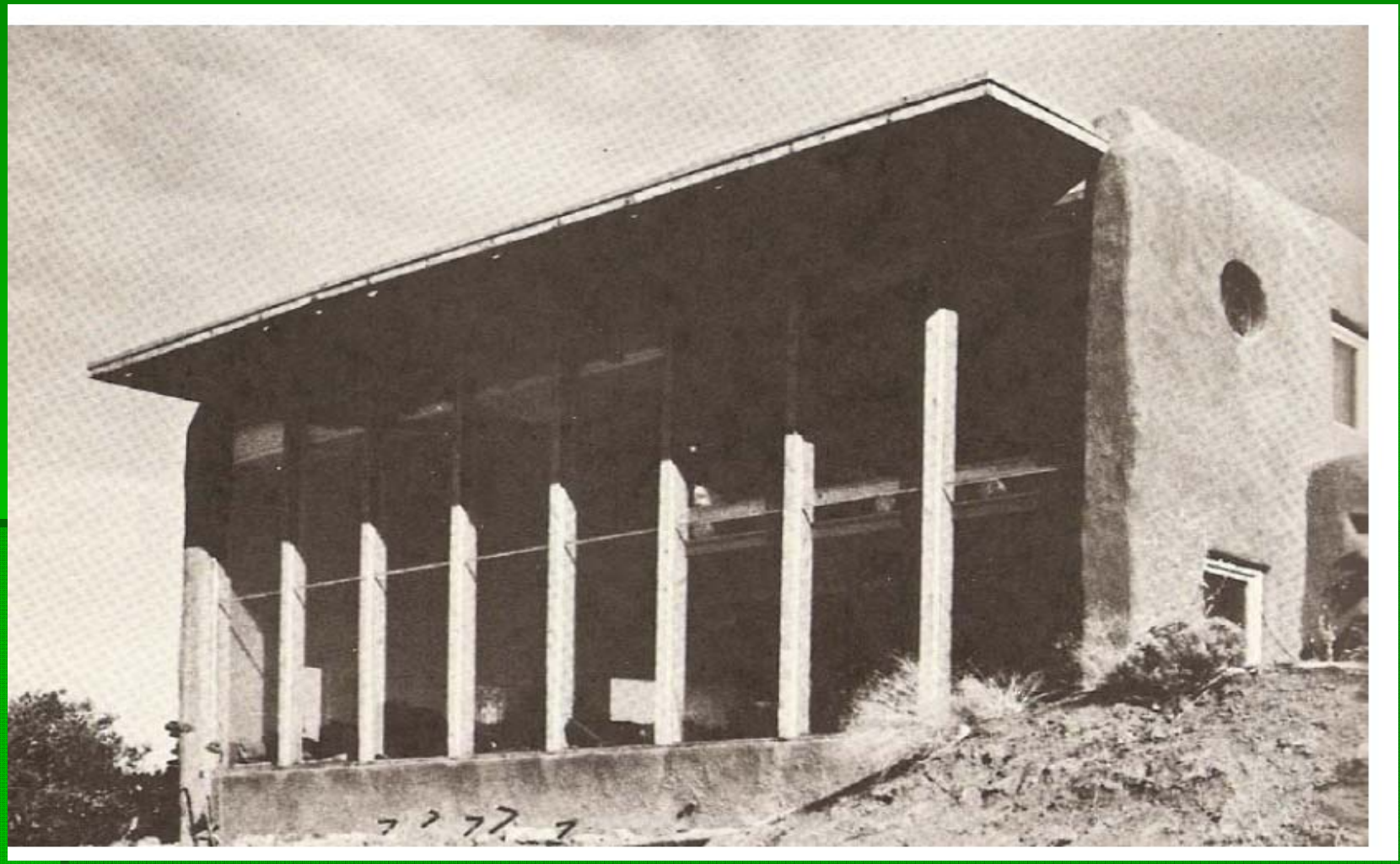


Figure 2. Cross Section of the David Wright Mass and Glass House

Use of overhang on south windows



Problems with too much glass:

- 1. Severe overheating, particularly in the spring and fall, and also in the summer. The Santa Fe house shown on the previous slide would swing 20 degrees F (11 degrees C) on a sunny day in ***January*** even though the house had a lot of thermal mass.
- 2. Windows are quite costly compared with walls.

- 6. How much thermal mass inside the home should be used?
- A. If the ratio of the south window area to the floor area is greater than about 6% additional thermal mass should be added. Inexpensive thermal mass can be scrap gypsum board placed inside the interior stud walls. Other thermal mass options are concrete floors, scrap gypsum placed in the floor cavities. (Be careful about additional structural loads.)

Direct Gain Heating

- *Use direct solar radiation to provide thermal comfort*
- *Use only building components, the windows, walls, floors, and ceilings, for solar collection and storage.*
- **Concerns:**

  Daytime overheating and overnight heat loss

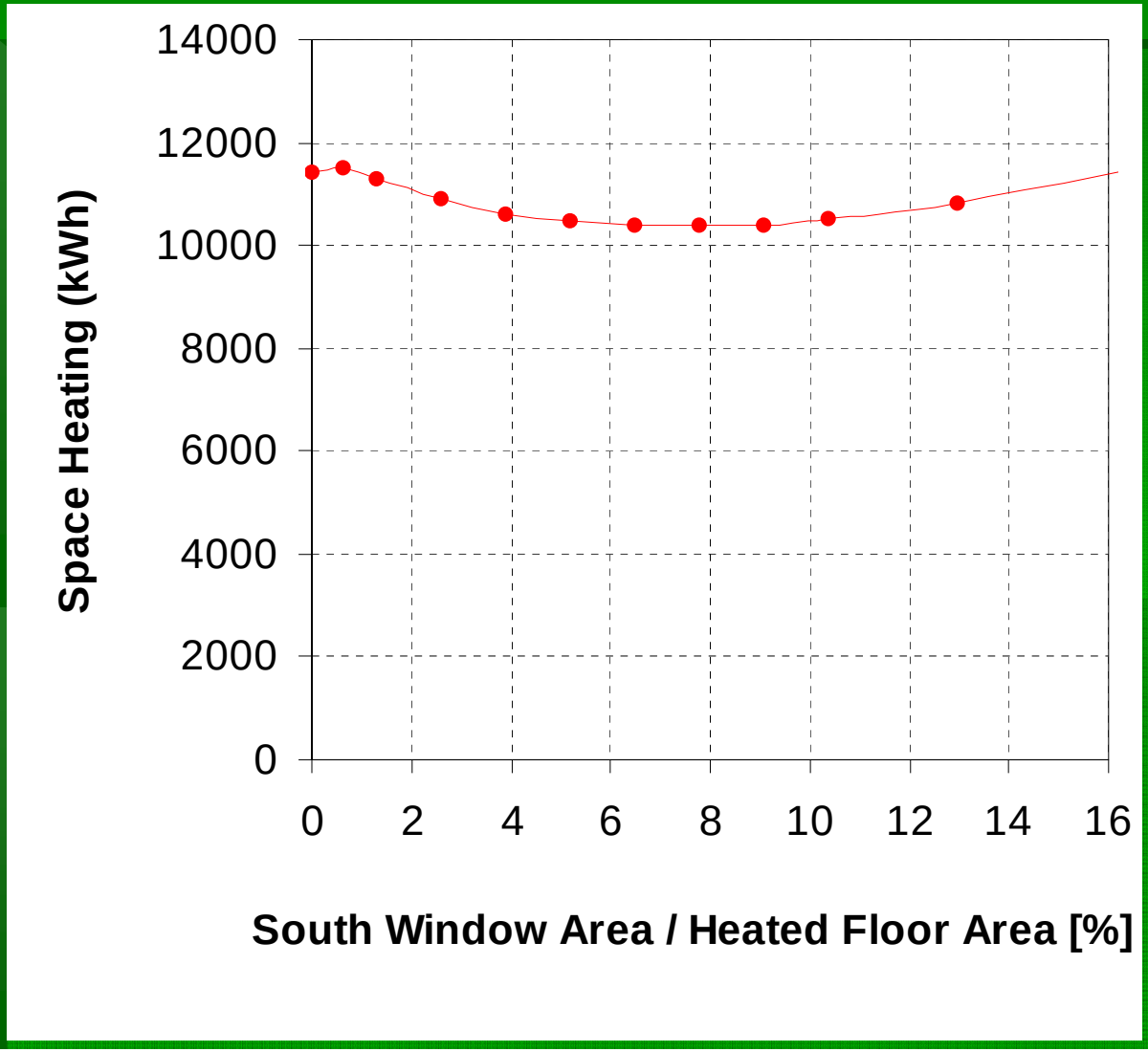
Window Design

- *For a given heat loss, what combination of*
- *south window area, south window type,*
- *interior thermal mass, and exterior*
- *shading will give optimum building*
- *performance?*

Design Guidelines

1. *Windows should be concentrated as far as possible on the south facing wall*
2. *6 to 8 %, percentage of south window area compared to heated floor area suggested in the past*
3. *South window area can be increased if the house has additional thermal storage*
4. *Summer overheating must be addressed*

Dumont Residence - Saskatoon

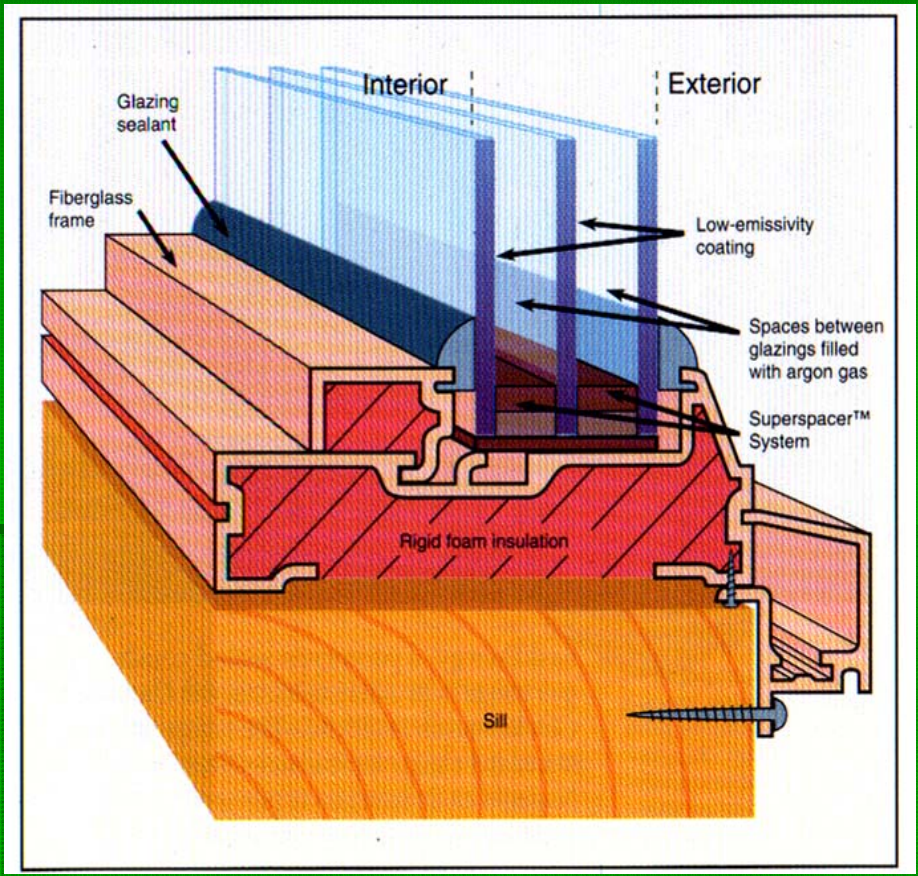


Upper Line

Light, wood frame, construction

Triple paned, low-e, argon filled, windows

High Performance Windows



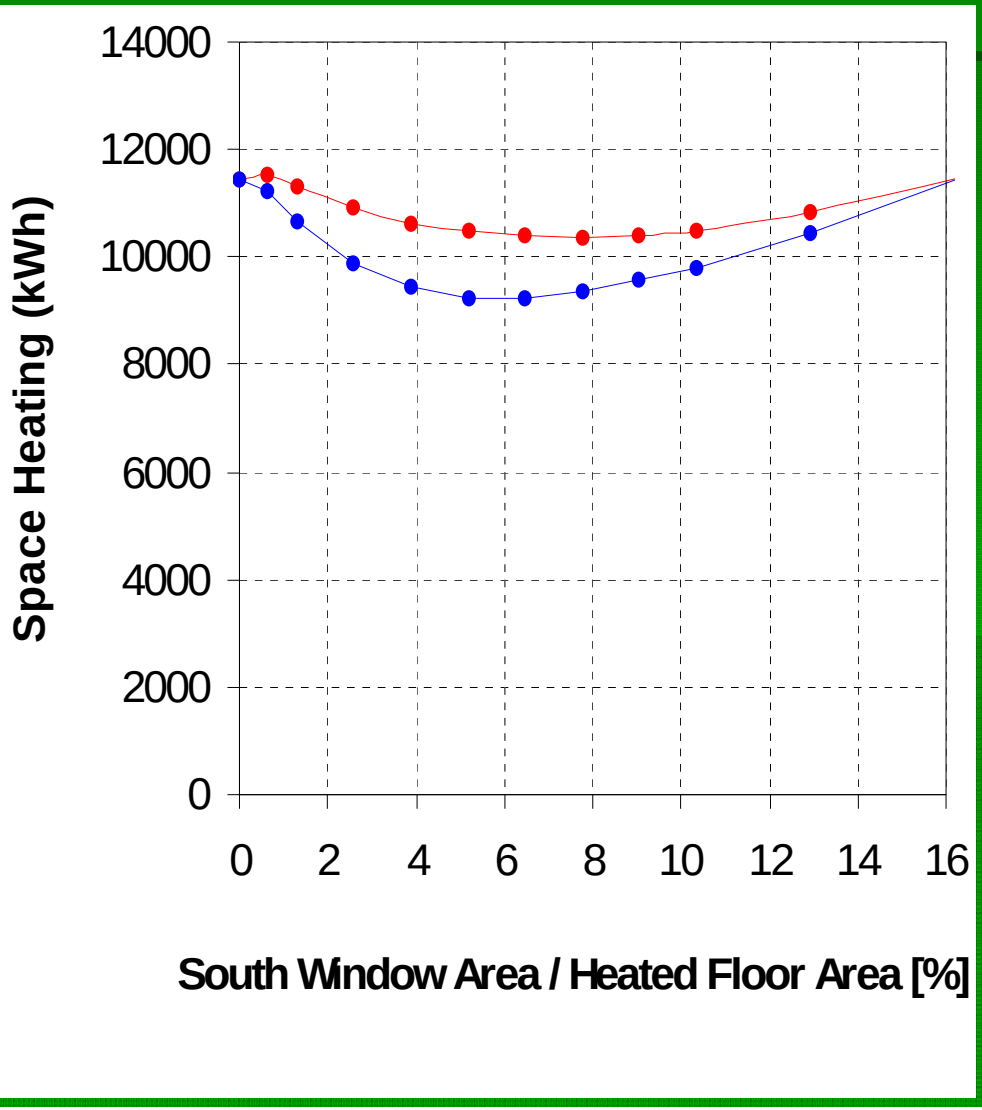
1.2 m x 1.2 m

Low e, triple paned, argon filled, 12 mm spacing

SHGC 0.59

R 5.9

Dumont House with and without better Windows



Upper Line

Light, wood frame, construction

Triple paned, low-e, argon filled, windows

Lower Line

Replace current windows with better windows.

Dumont Residence, Saskatoon, 1992

South window to floor area ratio = 5.5%

Almost no overheating; only extra thermal mass is scrap gypsum board in the interior walls. Note shading of upper windows in summer by roof overhang

Thermal Storage / Mass

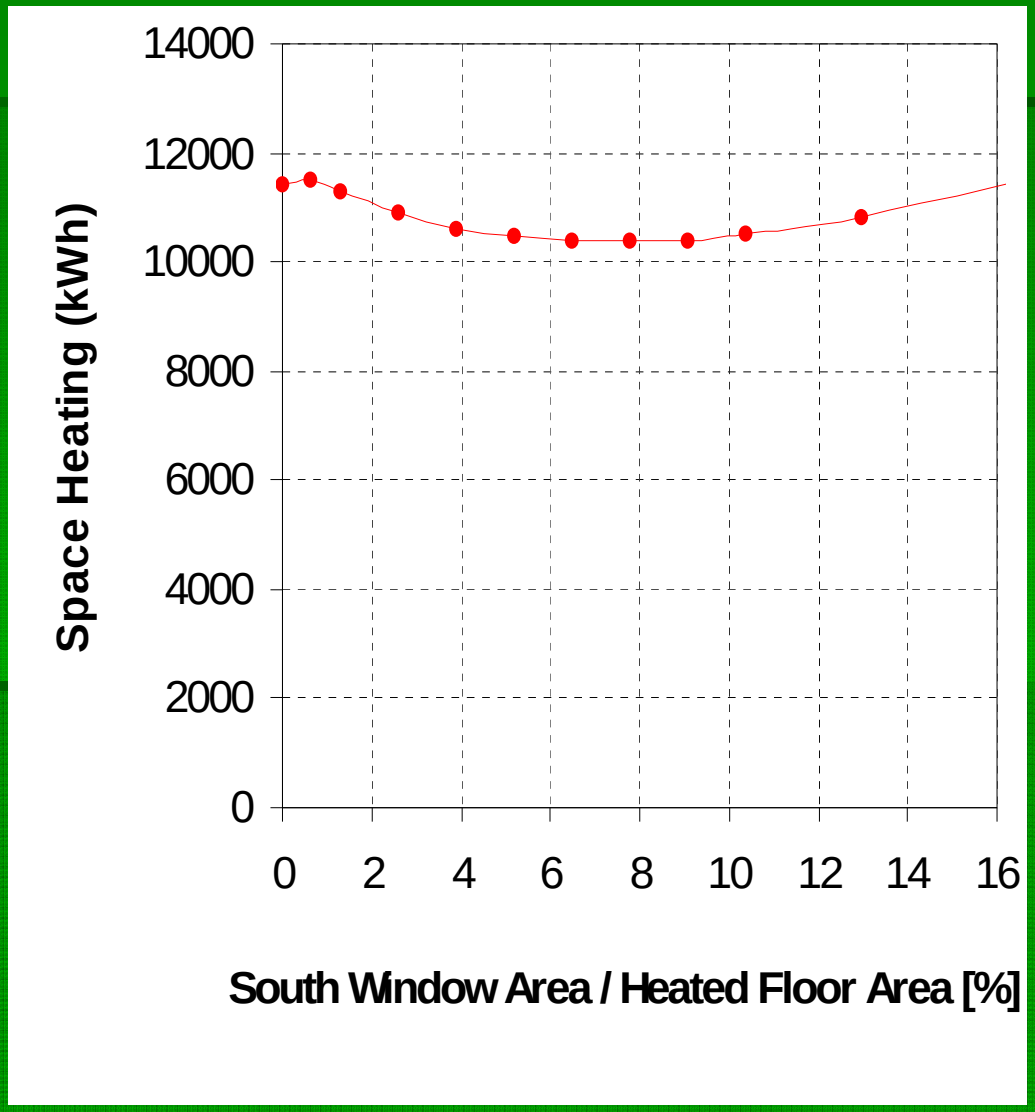
- *The building's ability to **store** internal and solar heat gains*
- *Greatly depends on the interior construction of the building*

Thermal Mass – Options

- **Hot 2000 Computer Building Simulation**

Description	Thermal Capacity MJ/Km^2 (floor area)
Standard frame construction, 12.7 mm (0.5 in) gyproc walls and ceilings, carpet over wooden floors	0.060
As above, but 50.8 mm(2 in) gyproc walls and 25.4 mm (1 in) gyproc ceiling	0.153
Interior wall finish 101.6 mm (4 in) brick, 12.7 mm (0.5 in) gyproc ceiling over wooden floor	0.415
Very heavy commercial office building, 304.8 mm (12 in) concrete floor	0.810

Dumont House - As Built

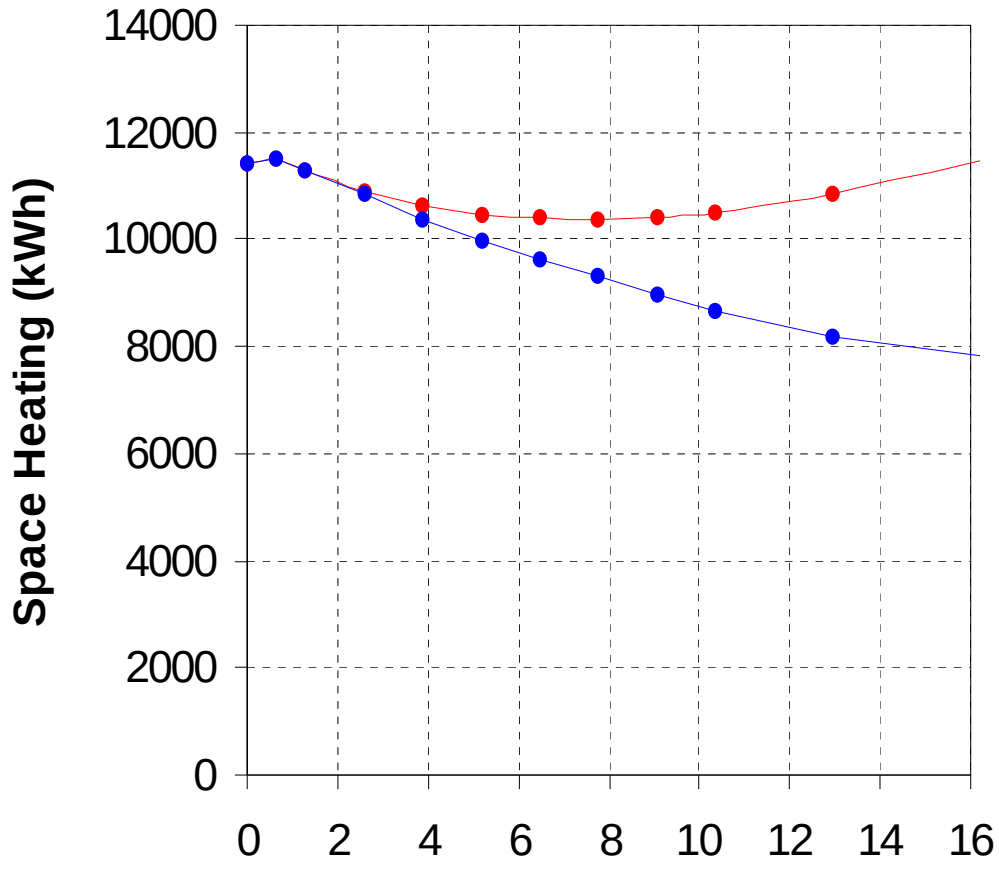


Upper Line

Light, wood frame, construction

Triple paned, low-e, argon filled, windows

Effect of Adding Mass



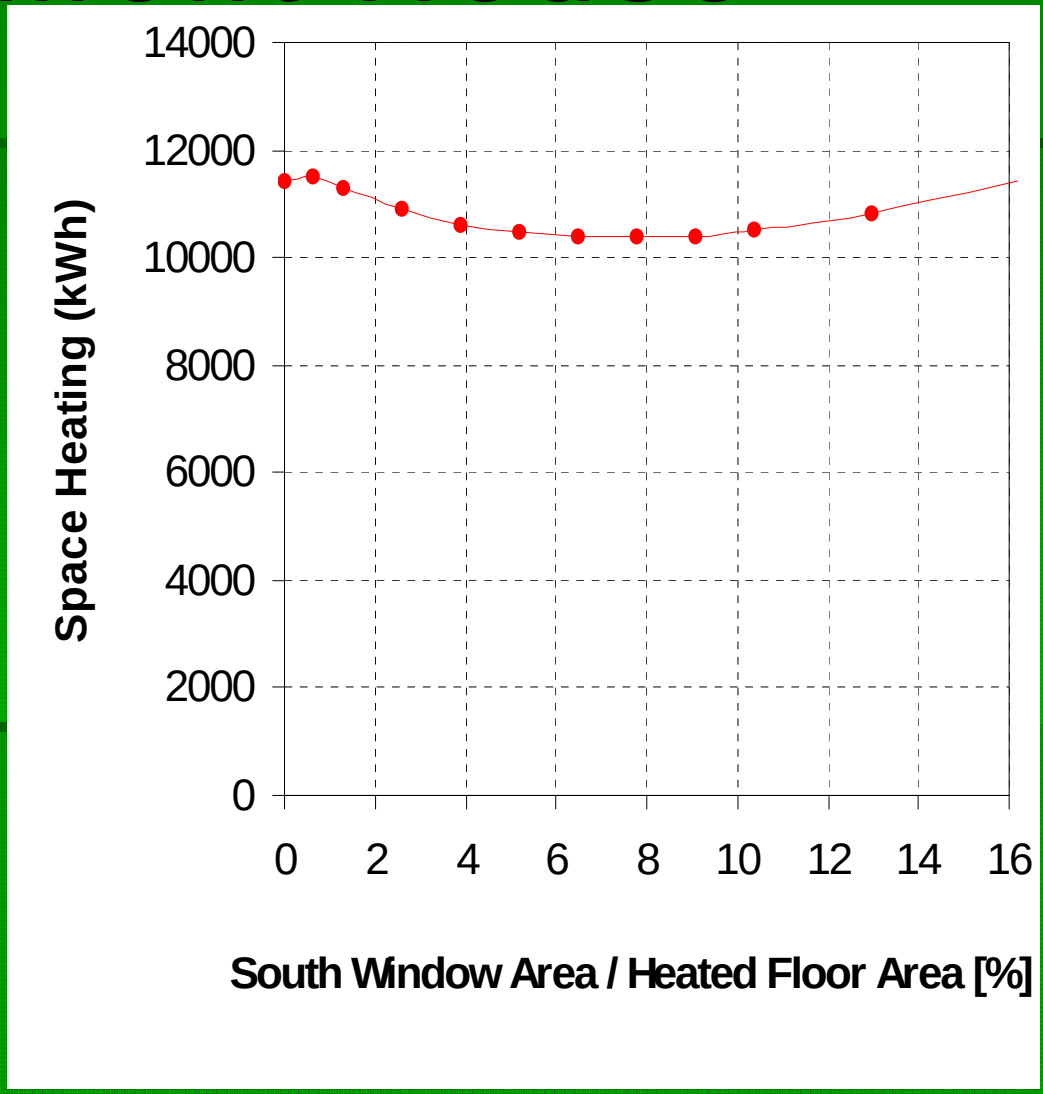
Upper Line
Light, wood frame, construction

Triple paned, low-e, argon filled, windows

Lower Line

Same windows, change construction to very high thermal mass

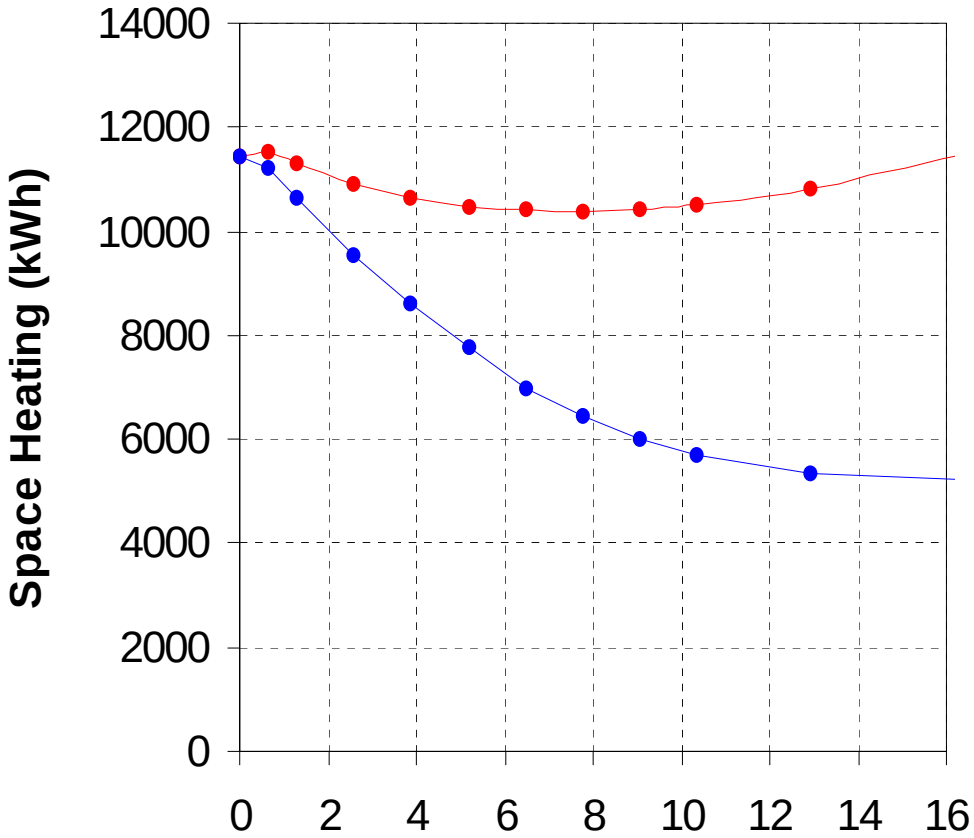
Dumont House



Upper Line
Light, wood frame, construction

Triple paned, low-e, argon filled, windowa

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

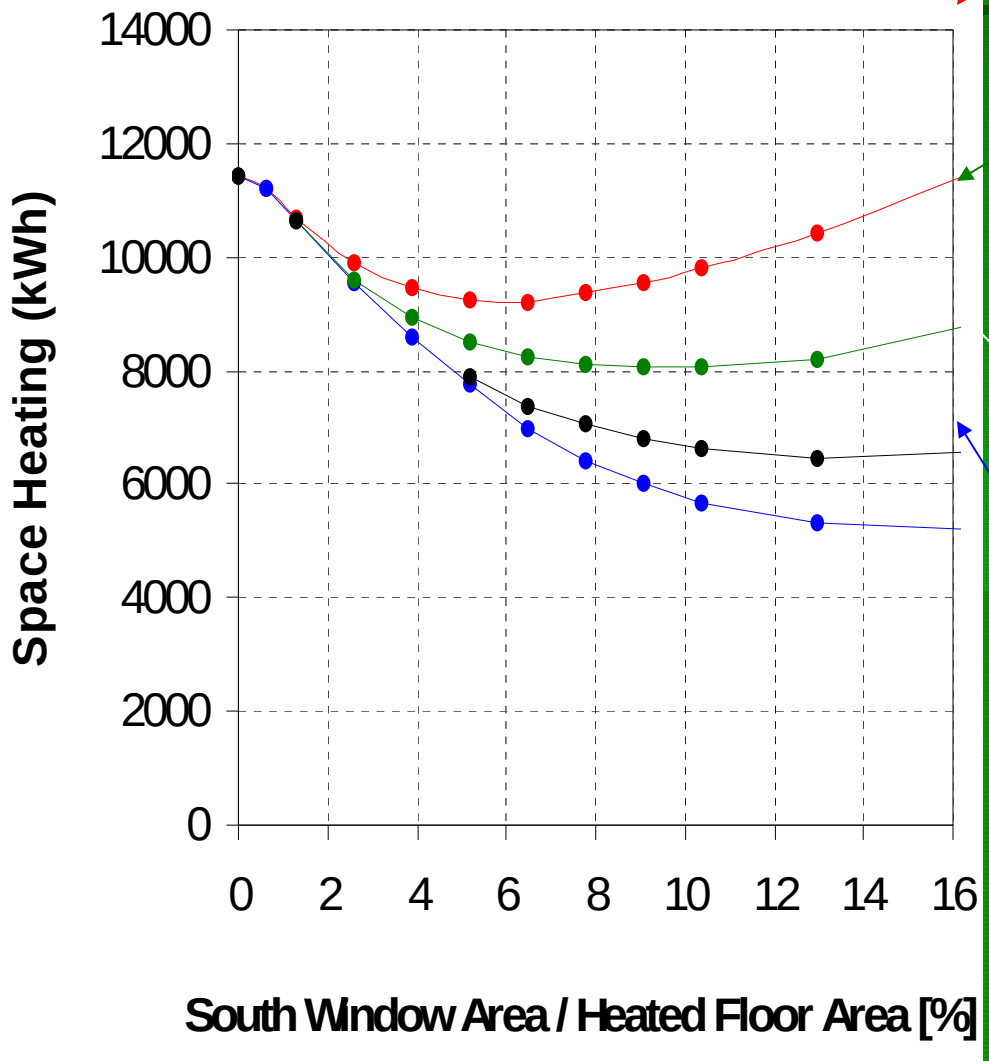
Thermal Mass Ideas

1. Large interior masonry wall
2. Concrete floor
3. Thicker gypsum
4. Thick walls, filled with scrap gypsum
5. Thick walls, filled with scrap steel
6. Thick walls, filled with water

Mass Comparison

Description	Thermal Capacity MJ/Km^2
Very heavy office building, 30 cm (12 in) concrete floor	*0.810*
0.5 inch gypsum walls	0.072
1.5 inch concrete floor	0.057
2 inch gypsum walls	0.232
2 inch gypsum walls, filled with scrap gypsum	0.413
2 inch gypsum walls, filled with scrap steel	0.774
2 inch gypsum walls, filled with water	0.809
2 inch gypsum walls, 1.5 inch concrete floor, half filled with scrap gypsum	0.380

High Performance Windows– *Vary Mass*



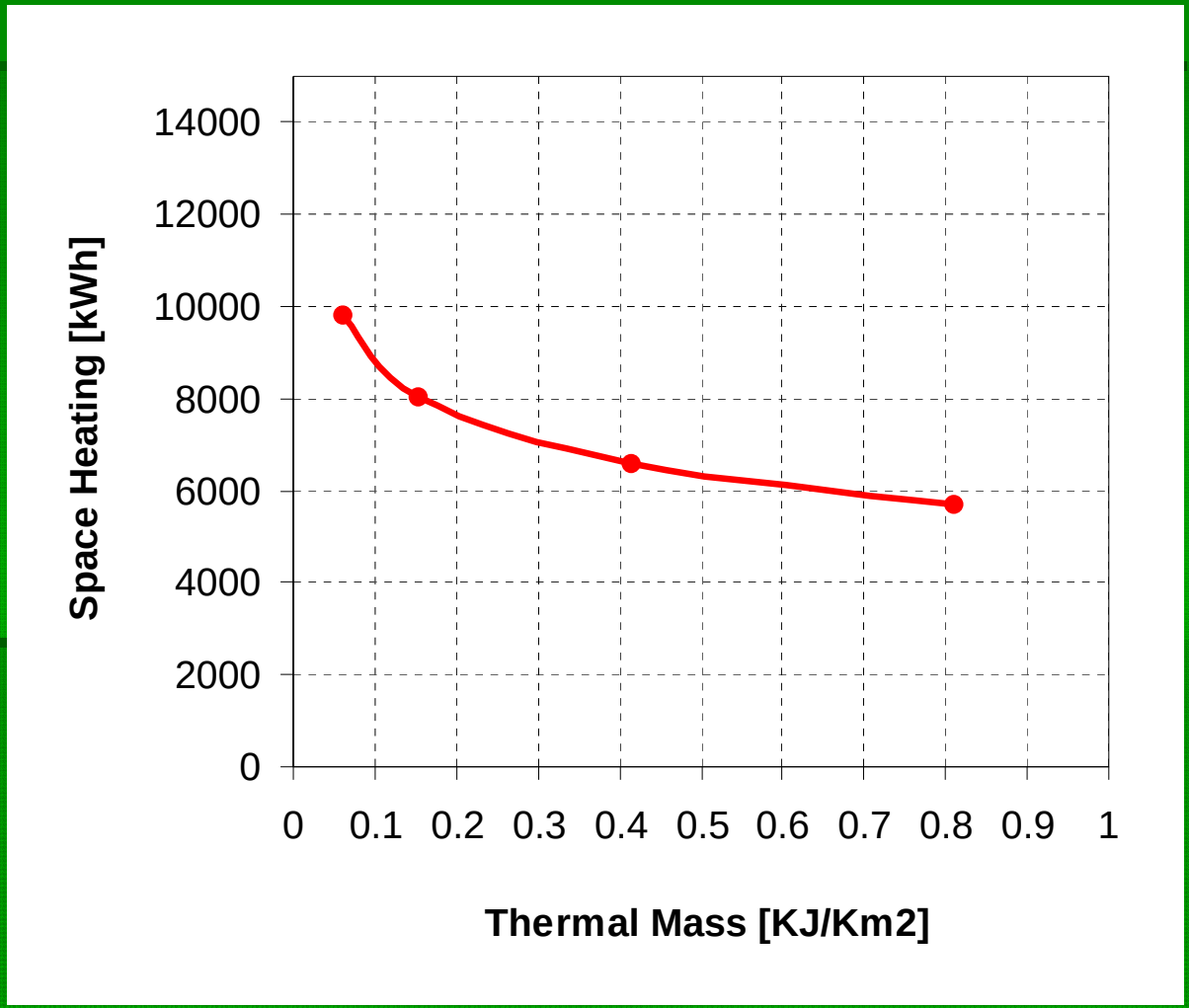
Light (wood frame) construction (0.060 MJ/Km²)

Medium (thick walls) costruction (0.153 MJ/Km²)

Heavy (masonry) construction (0.415 MJ/Km²)

Very heavy (concrete) construction (0.810 MJ/Km²)

10% Ratio – High Performance Windows



Case Study of High Glass, High Mass, Passive Solar Prairie House

- Thanks to Conrad Nobert and Rachel Amores
- 220 sq.m. single family home on a 10m wide lot
- On track for LEED Platinum Certification

http://greenedmonton.ca/MillCreekNetZeroHome

Mill Creek House, Edmonton, 2009

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

Mill Creek House

- ***Very Energy Conserving House***
- R90 attic insulation
- R56 wall insulation
- R24 basement floor insulation
- High Performance Windows (Triple, low-e, argon filled, tuned to orientation)
- Heat Recovery Ventilator

- South Window to floor area ratio: 10.7%
- Added Thermal Mass: 2.5 inch thick concrete topping on wood floors
- Added Weight: 20,700 kilogrammes
- Annual Usable Passive Solar Heating: 50%

Passive Solar Comparison

	Riverdale	Mill Creek	Belgravia	Typical Home
Gross Annual Heating Energy (kWh/year)	11,200	16,400	15,400	~45,000
Useable Solar Gains Fraction	38%	50%	55%	~10-15%
South Glazing Fraction	10.0%	10.7%	12.8%	~5%
Additional Mass (kg)	7000	20700	18600	N/A

Conclusions

- *Start with a very energy conserving design, orient for solar use*
- *Concentrate windows on the south wall*
- *Use best windows available*
- *Use inexpensive thermal mass*
- *Consider effect of overheating*

Acknowledgments:

- VerEco Homes, Ronn Lepage
- Habitat Studio, Peter Amerongen
- Carroll Homes, John Carroll
- Conrad Norbert, Mill Creek House
- Dan Hagan, New Mexico State Gov.