Design Brief

Elephly House, Mono Mills, Ontario

This design brief outlines the passive and low-energy systems incorporated into a large residence to be built in Mono, Ontario. Document prepared for SNRG 310 – Low Energy Building Systems.

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Executive Summary

This Design Brief is for a structure to be built in Mono, Ontario. The owner presented our design team with concept sketches by which we were to implement passive design elements and low-energy systems. Our challenge was to create systems around the owners design, rather than design a building according to system requirements. The following is a brief summary of our recommendations.

Building shape and orientation was selected as east-west to maximize potential solar heat gains and daylighting. The room layouts were selected on occupancy rates and heating requirements during different periods of the day. Windows were chosen based on utility, U-value, solar heat-gain potential and environmental friendliness. Window coating needs varied with location, thus care was taken in the selection process.

Daylighting was a central feature of this structure due to the inclusion of an interior courtyard. Copious amounts of windows allow complete lighting of each zone. Care was taken to prevent overexposure to direct solar radiation through adequate shading.

Walls and roof elements were chosen on a basis of structural requirements, health and environmental benefits, and aesthetic appeal. Structurally Insulated Rammed Earth (SIREwall) was selected for the exterior walls; Structurally Insulated Panels (SIPs) were chosen for the roof assembly with a Green Roof system mounted on top of that. These assemblies provide superior thermal performance and greatly reduce heating/cooling loads while simultaneously aiding in storm-water management and noise reduction.

Passive heating and cooling elements were incorporated into this design. The numerous window placements allow passive solar heating during the winter months. Overhangs, shading from deciduous trees and an insulated-curtain system prevent overheating in the summer. The high thermal and hygric mass properties of rammed earth construction allow heat and moisture storage in the walls, enabling a stable indoor environmental quality. Earth tubes feeding a basement inlet work with a solar chimney on the second floor to create stack ventilation. A louvre system allows control of airflow through the chimney.

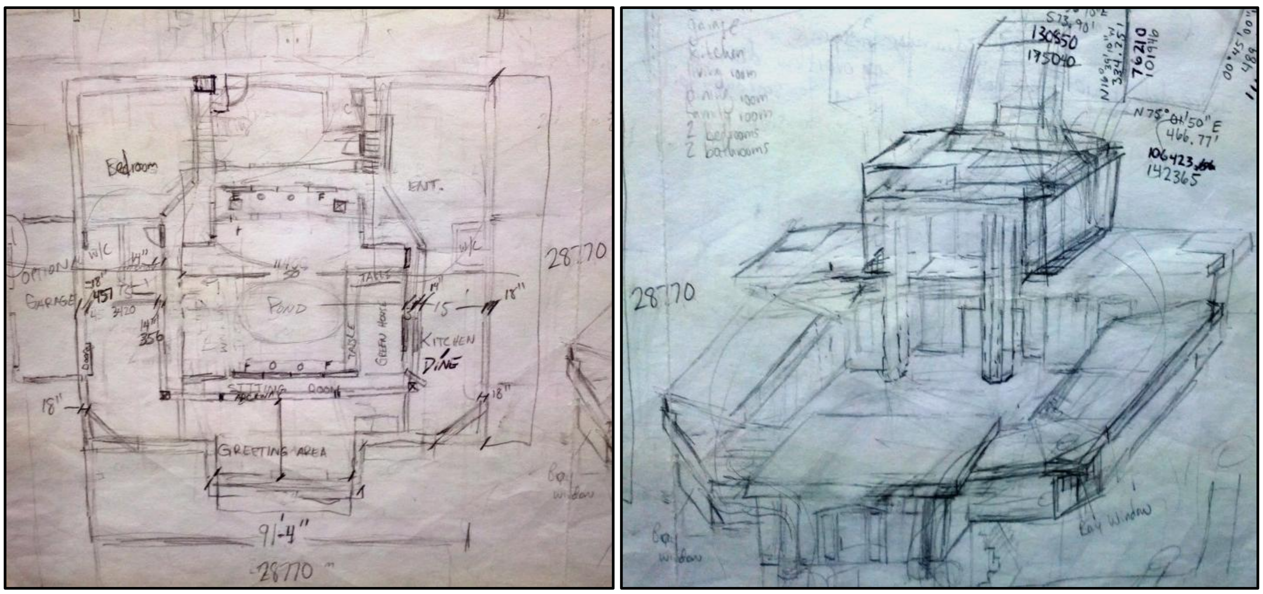
In addition to the above systems, a rooftop solar thermal system was implemented to offset heating and domestic hot water loads.

Finally, an energy model was completed using Hot2000. Verification of low-energy and passive design was possible from the house report generated from this software.

Introduction

Location: Mono, Ontario
Design Specifications: Owner’s Design Request – Rammed Earth Structure
Desired Floor Area: 750 m^2
Occupancy: 3 adults, 3 children
Shape: Box, Cube
Adjustment: Interior Courtyard
Orientation: East-West
Requests: Basement, kitchen, living room, dining room, family room, 2 bedrooms, 2 bathrooms
Goal: Passive design, low-energy intensity

Concept Sketches



Building Shape and Orientation

The shape of this structure presented both advantages and disadvantages. Normally a cubic shape allows for a low surface area to volume ratio (SA:V), however the interior courtyard acts to further increase structural surface area, and thus exposure to the elements.

Advantages: views, ample day-lighting in all zones, natural ventilation in all zones, aesthetic appeal.
Disadvantages: Large exterior surface area, potential heat losses/gains

With the shape of the building pre-selected, orientation was chosen with a preference for solar heat gains. The front of the house was placed facing south where the majority of solar gains are possible. Additionally, exterior wall exposure on the east and west sides will provide further solar gain and lighting potential.

It must be noted that overexposure to solar heat gains is often a result of this orientation in the summer months. To mitigate these effects, adequate shading from trees and window overhangs will be utilized. Please refer to Figure 1 in Section 6: *Passive Heating and Cooling* for a visual aid.

Floorplan and Room Layouts

Requirements: Kitchen, 3 bedrooms (one master), 3 bathrooms (1 ensuite in master BR), sitting room, games room, entertainment room, office, basement (utility room)

Floor Plan

The large workable area for this structure allowed a high degree of freedom in design for floor plans and room layouts. With the building shape consisting of enclosed space ringing an outdoor-interior zone (courtyard), a design was selected that allows free air flow around the ring.

Benefits of this design include:

- Excellent lighting and views in all zones
- Compatible with passive heating/cooling systems
- Open space atmosphere
- Highlights interior courtyard space

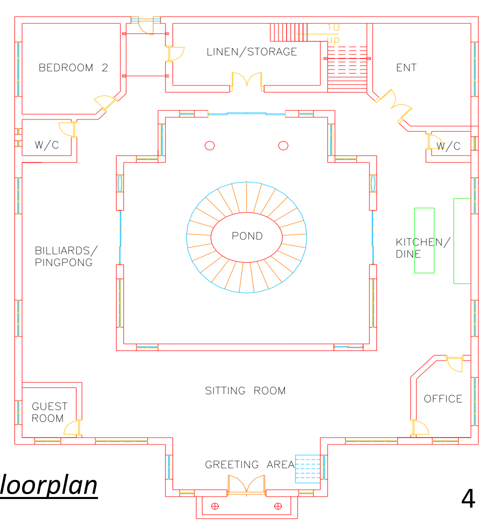
Room Layout

Rooms were kept to the outside of the structure allowing a continuous loop running adjacent to the interior walls. The intent was to allow for airflow from the basement fresh-air intake to funnel up to the main floor and out through the solar chimney. The following is a brief summary of our reasoning for room layouts.

Kitchen: Capture morning solar heat/daylighting
Entertainment Room: Northeast corner, avoid excessive heat gains because of electronics.
Linen: Back of the house, avoiding heat gains, doubles as storage area.
Games Room: West side, open area. Evening views and lighting.
Sitting Room: Combined with main entrance for entertaining guests
Bedrooms:

Master: Second floor, rear of building. Passive solar gains and views. Bird's-eye view of building providing utility with aesthetic appeal.
Bedroom 2: Northwest corner, evening daylighting
Bedroom 3: Guestroom. Close to entrance and games room area. Non-restrictive for airflow.

Office: Near Kitchen; early morning solar and daylighting gains.
Bathrooms: One on each side of structure for easy access. Full bath- rooms located in master bedroom and in west side W/C.



CAD Floorplan

Windows

Frame Type: Fiberglass
Glazing: Double or triple pane, argon filled cavities
Coatings: Low-E – hard or soft coating
Brand: Inline Fiberglass[1]
Models used: Awning 325 Series; Strip Window 400 Series
Product Features:

Awning 325:

Keeps rain out while letting fresh air in
Folding roto-handles allow blinds to pass unobstructed
Material strength and frame/sash design allow creation of large operable units

Strip 400:

100mm (4") frame, available in multiple configurations
Strong, low-conductive material creates superior thermal characteristics
High-performance glazing options

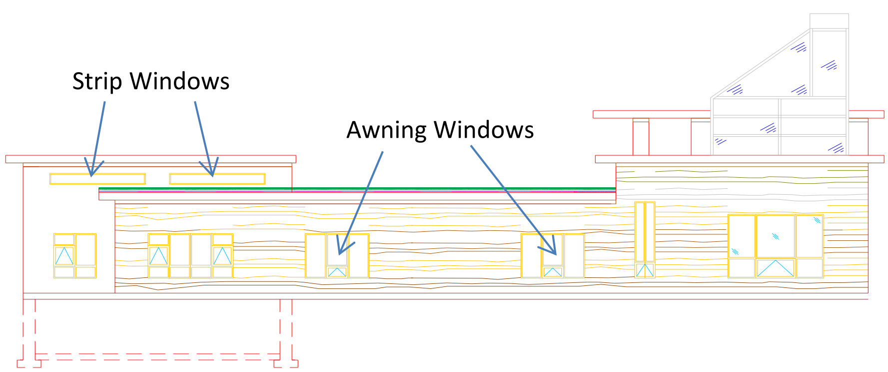
Location

Window locations were chosen to maximize utilization of solar resources, which provide passive heating and day-lighting. Access to view was also a design criteria, therefore the structure has plentiful window space; the window-to-wall ratio is 1:3.

Operation

The Awning 325 Series are the primary window units used throughout the structure. Operable windows are able to provide natural ventilation in the structure during shoulder seasons and are a main feature of our passive design. Occupants will have the ability to open and close windows according to specific needs. Cross-ventilation can be achieved by opening windows at opposite ends of the building. The courtyard area will provide a unique through-point for airflows. Strip windows are fixed and used primarily for day-lighting and heat gains. Please refer to *Appendix 1 and 2* for window details.

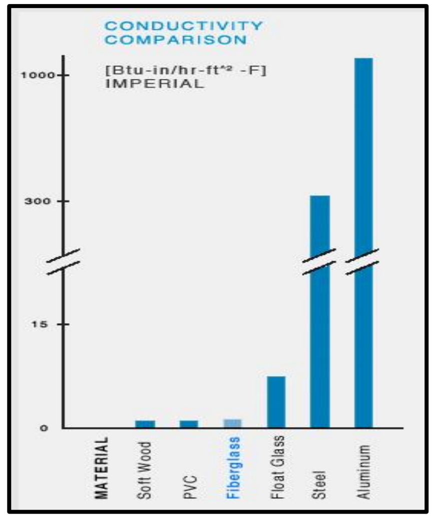
East Elevation Windows



[1] Inline Fiberglass website, www.inlinefiberglass.com

Frames

Fiberglass (FG) window frames were chosen for the structure to achieve the lowest thermal conductance possible. The chart to the right shows conductivity comparisons with some common frame materials. Fiberglass frames are able to provide a high degree of thermal resistivity which will reduce overall heat loss.



Fiberglass frames also have superior strength and durability. The 325 Series can resist up to 4875 Pa in wind loads, making it 8 times stronger than PVC. Additionally, FG frames contain the lowest embodied energy when compared to other common window frames while providing the longest life expectancy. This makes FG frames by far the most sustainable choice for window selection.

Glazing

Glazing was selected on a basis of energy efficiency rating, solar heat gain coefficient and U-value. Windows on the east, south and west exterior elevations will be dual-paned and fitted with a low-e/hard coat on the inside pane, this will prevent heat from escaping while allowing gains from the outside. This configuration will allow high amounts of solar radiation through to charge the rammed-earth walls. Solar gains will be collected during winter months, with overhang and deciduous tree shading providing protection from unwanted heat gains in the summer.

Windows on the interior (courtyard) east and west elevations will be triple-paned (where applicable) with a low U-value. Courtyard glazing for the east and west elevations is meant primarily for views and diffuse daylighting, thus glass with low U-values were selected. Strip windows were chosen primarily for solar gains and placed at higher elevations; glazing with higher SHGC was permitted for these applications, as overhang shading would protect unwanted heat gains in the summer months. Please refer to *Appendix _: Window Performance Sheets*.

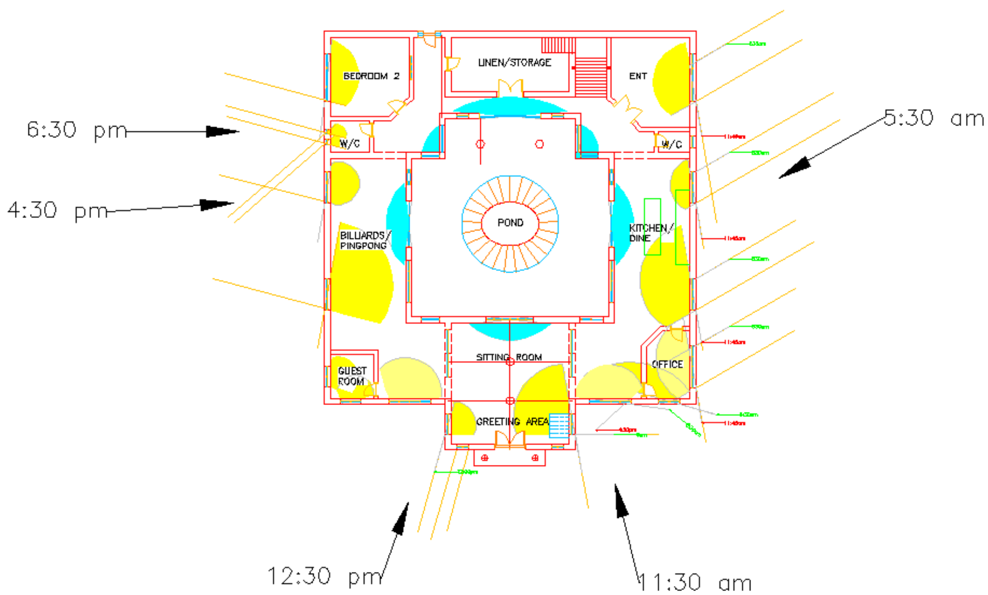
Daylighting

The house was designed in order to take advantage and control natural sun-light using building orientation, window orientation, window type, and shading devices. Allowing natural sun-light into the building gives many benefits, including:

- Offsets lighting loads during the day
- Brings in a good quality light into the space
- Optimizes passive heating
- Provides views

The buildings orientation and windows help to optimize day lighting. The orientation of the building designed along the east-west axis. This allows the building to have daylight supplied to areas of high occupancy, such as, the kitchen, living room and office. The abundance of windows supplies a great amount of day light. The high strip windows allow day light to penetrate deeper into the house during the winter when the sun path is at a lower elevation angle. The courtyard windows allow diffuse light to penetrate the building. The deciduous trees would not be a shading issue during the winter when we want solar heat gain.

Simulated Light Infilatration in July

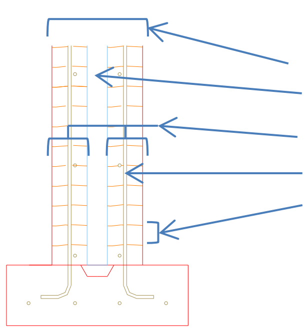


The building features overhangs and curtains on the interior side of the windows as a mitigation strategy for excessive day-lighting. During the summer over heating can occur because of the amount of windows throughout the building. All the windows on the west, east, and south elevations will have overhangs to block direct sunlight from the sun's summer elevation angle. Furthermore, deciduous trees and curtains will help control unwanted direct sunlight. Please see *Appendix 6: Mono Sunpath* for sun angles.

Wall Assembly

Wall Materials – Structurally Insulated Rammed Earth (SIREwall)

Rammed Earth Cross Section:



- 457mm (18") exterior wall thickness
- 100mm (4") high-density XPS – RSI .0352/mm
- 178mm (7") rammed earth on either side of XPS
- 19mm (¾") rebar run horizontally and vertically at 600mm (24") O.C.
- 100mm (4") layers of earth, manually tamped

Advantages

Structurally-Insulated Rammed-Earth, has been selected for the exterior walls because of its numerous health and ecofriendly qualities, as well as its sound structural fundamentals. Advantages of SIREWALLs over traditional concrete and timber construction include:

- Low-energy, low carbon building method
- Locally sourced materials
- Flexibility in plan form
- Strength and wall thickness
- No noxious chemicals
- Impervious to mold formation
- Excellent thermal and hygric (moisture absorbing) mass

Downside

Rammed earth construction offers a wide range of benefits as we have seen, but the technology does come with some downsides that need to be considered. These are:

- Requires certified SIREWALL project manager
- 10-15% increased capital costs over traditional methods
- Rammed Earth Construction not covered in Ontario Building Code
- Wall thickness limits overall usable area
- Not a "do-it-yourself" type of project

Sirewall VS. Competitors

	ICF	SIP	SIREWALL
Wall Thickness (typical)	11"	6.5"	18"
Interior living Space	Thicker walls reduce living space unless exterior dimensions enlarged (zoning and cost permitting)	Up to 180 sq. ft. extra living space	Thicker walls reduce living space
R-Value (typical)	R22 (up to 50% energy savings over traditional wood framing)	R29 (over 50% energy savings compared to traditional wood framing	R29 or above (over 50% energy savings compared to traditional wood framing
Building Envelope	Walls and foundations only	Entire envelope (walls, foundations, floors, roofs)	Walls, foundations
Construction Speed	Typically requires ICF installers with follow-up by concrete pourers, framers, carpenters, etc.	Installed quickly by a single crew. Door and window framing easy on site.	Typically requires rammed earth installers. Labourious mixing and pouring process.
Interior Finishing	Mounting heavy items may require drilling through concrete centre	Hanging and mounting is easy anywhere, even with heavy items	No finishing required. Hanging and mounting easy.
Structural Strength	Said to withstand hurricanes, earthquakes	SIP homes have withstood tornadoes, earthquakes in Kobe, Japan and Northridge, California, as well as Hurricane Andrew	SIREWALLs are built to withstand earthquakes and offer resistance to tornadoes.
Indoor Air Quality	Traditional standard	Less moisture in basements	Highest quality due to non-toxic materials and breathability
Aesthetics	Straight walls	Straight walls	Sandstone-like finish, sculpting possible. Earthy feel.

Building Materials	Different insulation, same concrete. Chemically treated materials present.	Concrete eliminated, foam and OSB board replacement. Chemically treated materials present.	Free of chemicals. Locally obtained.
Carbon Footprint	Big	Big	Small

Material Selection

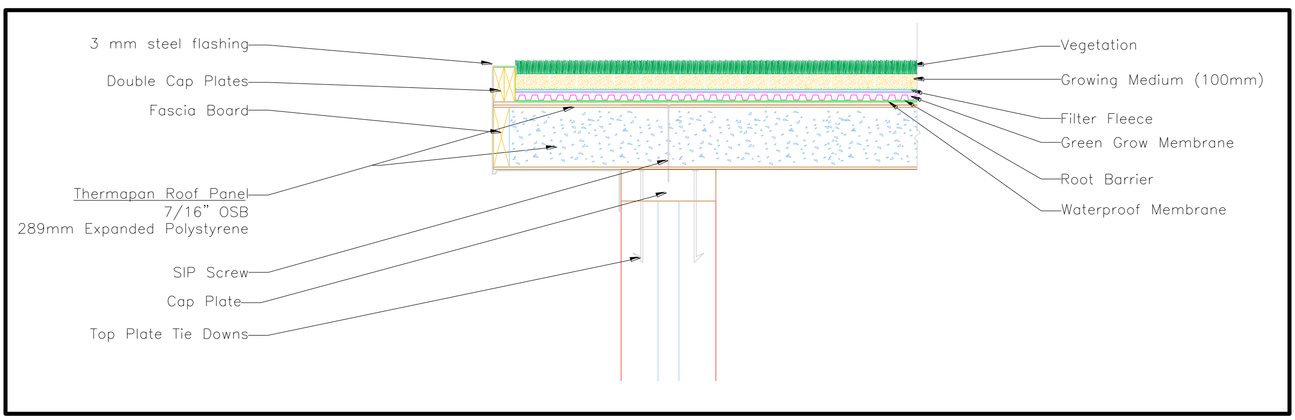
After analyzing the data on structurally insulated rammed earth and comparing it to other new forms of high efficiency building envelope options, Rammed Earth stood above the rest. The advantages of SIREWALL construction in terms of energy efficiency, health, environmental concerns and structural integrity fit into our definition of sustainable design while the earthy and natural feel of rammed earth has aesthetic appeal. Please refer to *Appendix 3: Wall Assembly* for another cross section.

Roof Assembly

Type: Flat Roof, Thermapan SIP
Addition: Green roof, Eco-Roof

Considerations: Solar thermal system placement

Roof Section



Roof Materials

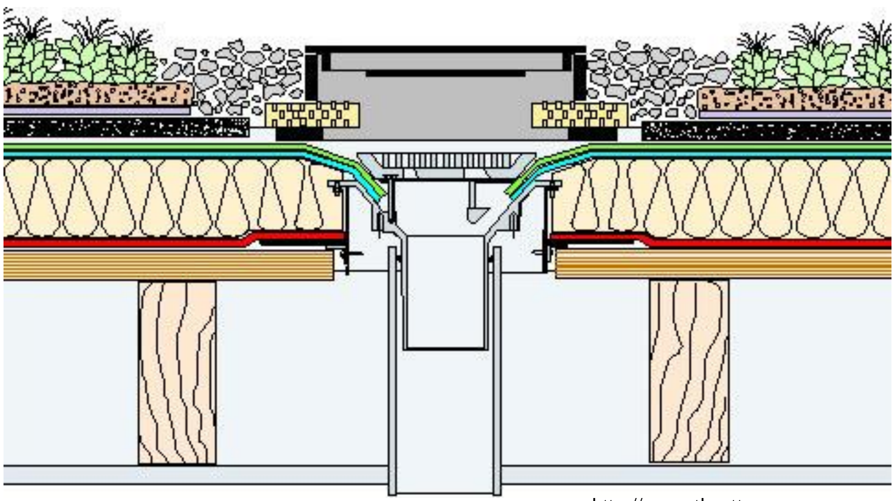
A SIP was selected for the main component of the roof assembly because of its structural, insulating, and air tight properties. High-density EPS packed within two oriented strand board pieces coupled with lumber splines provide structural support that enables spans of up to 4.8 meters and loads of up to 125lbs/ft^2. Closed-cell expanded polystyrene also provides exceptional insulation by reducing convection loops that are common in open-cell batt insulation. Additionally, it provides an effective water and air barrier that enables a mold-free, airtight indoor environmental quality.

Green Roof

Due to the large roof area a Green Roof was selected to lie on top of the flat roof. The roof will be populated with drought resistant plants that are suited to northern climates, which will not require much maintenance throughout the year. Fully saturated, the green roof will create a 25 lbs/ft^2 load. The benefits of a green roof include:

- Stormwater management
- Energy efficiency in buildings (prevents temperature swings and heat transfer through roof)
- Creates a more ecologically and sustainable environment
- Noise reduction
- Aesthetic appeal

A drainage system needs to be installed for green roofs and would look something similar to the diagram below.

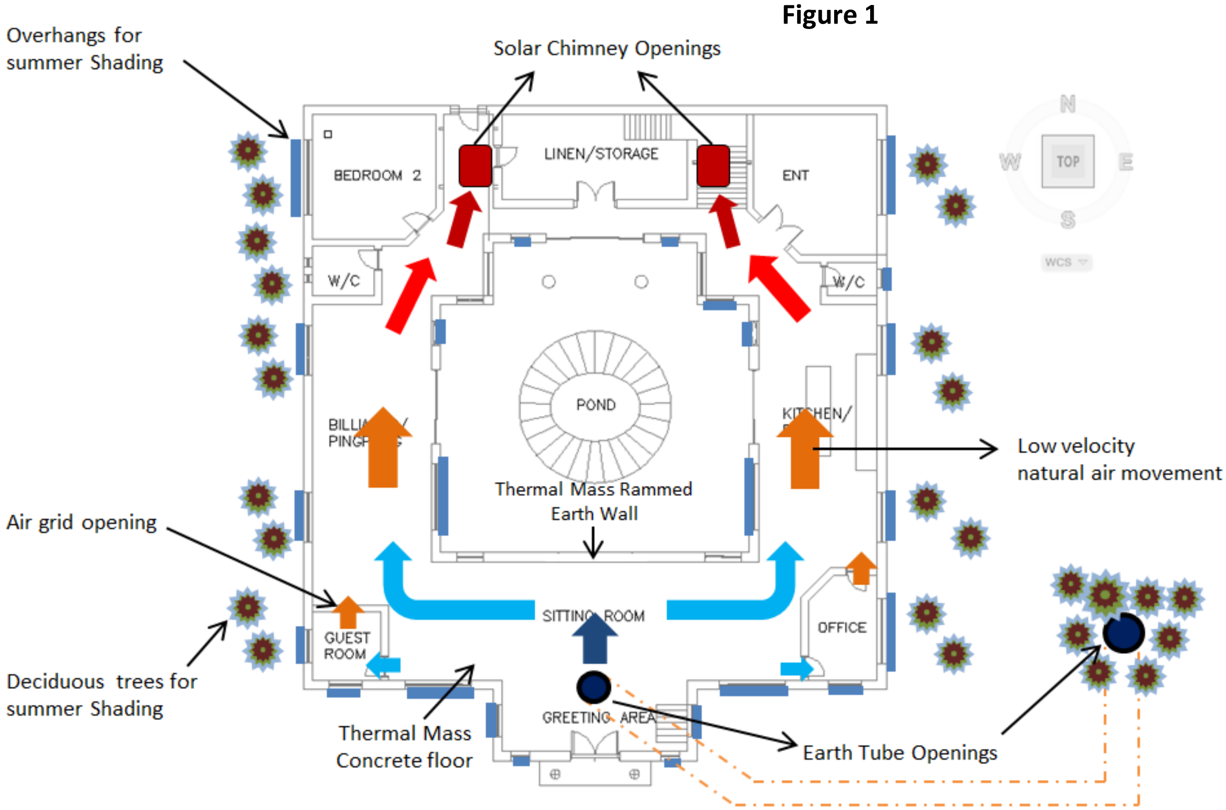


http://www.theotternursery.com

Additionally, green roof placement needs to be carefully selected with a consideration for solar-thermal system needs. There does not need to be competition between the two for roof space, but correct placement of roof vegetation will facilitate ease of installation for the solar thermal panels. Please see *Appendix 5: Green Roof* for further details.

Passive Heating and Cooling Systems

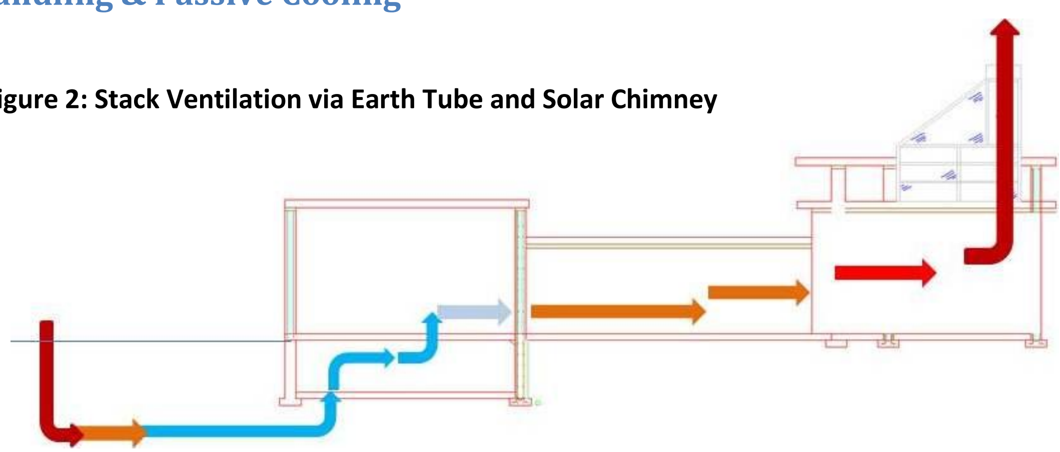
Figure 1



Our design focuses on passive heating and cooling; in addition, our high efficiency HVAC System supports our passive design in worst case scenarios. Use of thermal mass, natural air circulation, earth tubes, solar chimney, operable windows and highly insulated/airtight envelope are some of the main characteristics of our passive design.

Air Handling & Passive Cooling

Figure 2: Stack Ventilation via Earth Tube and Solar Chimney



Our building layout and large corridors enable a low velocity natural air movement. These air corridors are the main air distribution channels of our design which distributes fresh air from earth tube into the whole house. We use an earth tube to pre-condition the fresh outside air. The earth tubes function as earth-to-air heat exchangers; therefore, they make use of relatively constant temperatures of the ground[2].

The earth tube inlet is located next to a small outdoor botanical garden which filters and treats the outside air naturally. Furthermore, the botanical garden provides desired seasonal fragrances such as lavender and oleaster to the occupants through the earth tube. Consequently, earth tube contributes to IAQ and IEQ at the same time. We selected 610mm (24”) HDPE (High Density Poly Ethylene) pipes for earth tube in order to maintain incoming air quality[3]. Condensation is a disadvantage with earth tubes in summer months. We sloped our tube to drain the condensed water, at the lowest point, in the basement. Please see *Appendix 7: Earth Tubes* for pipe specifications.

The air corridors continue to the second floor; consequently, this creates a stack effect. In addition, we will be using a solar chimney to intensify this stack effect. Earth tube opening and solar chimney is located at opposite elevations; therefore, difference in air pressure will pull the air from one side the building to other side naturally. This air movement will create a cooling effect in summer months. Even though, in winter months solar chimney will be deactivated, exhausting stale air will be continuing at the same elevation.

The solar chimney was designed to maintain the 1.5 air changes per hour (ACH) that a low-energy house demands. In order to avoid widely differing airflow rates during times of fluctuating outdoor temperature, it was necessary to add louver control to the chimney outlet. The louver would be included in the building automation system controls and would monitor flow rate according to household needs. Additionally, the chimney has the ability to greatly increase the ACH if needed, which could be useful in times when IAQ is poor. Please refer to *Appendix 8: Stack Effect Calculations.*

A copious amount of operable windows will enable occupants to take advantage of free cooling during the shoulder months. Appropriate size window overhang shadings as well as deciduous trees will prevent summer overheating.

Passive Heating

Our design accommodates numerous windows both on the exterior and in the courtyard of the building. This feature creates a large amount of solar heat gain potential as well as an overheating risk. Therefore, we are planning to store excessive heat into thermal mass, which are our rammed earth walls and concrete floors. The stored heat will be realized during the night; therefore, our heating load will be less night time. Hot2000 annual space heating report4 results confirms our design selection. According to this report our passive heating design created 55% heating demand reduction.

Annual Gross Space Heating Load (Hot 2000) with Curtains	
380325	MJ
Auxilary Energy Required	
172170	MJ
Demand reduction from passive heating design	
55	%

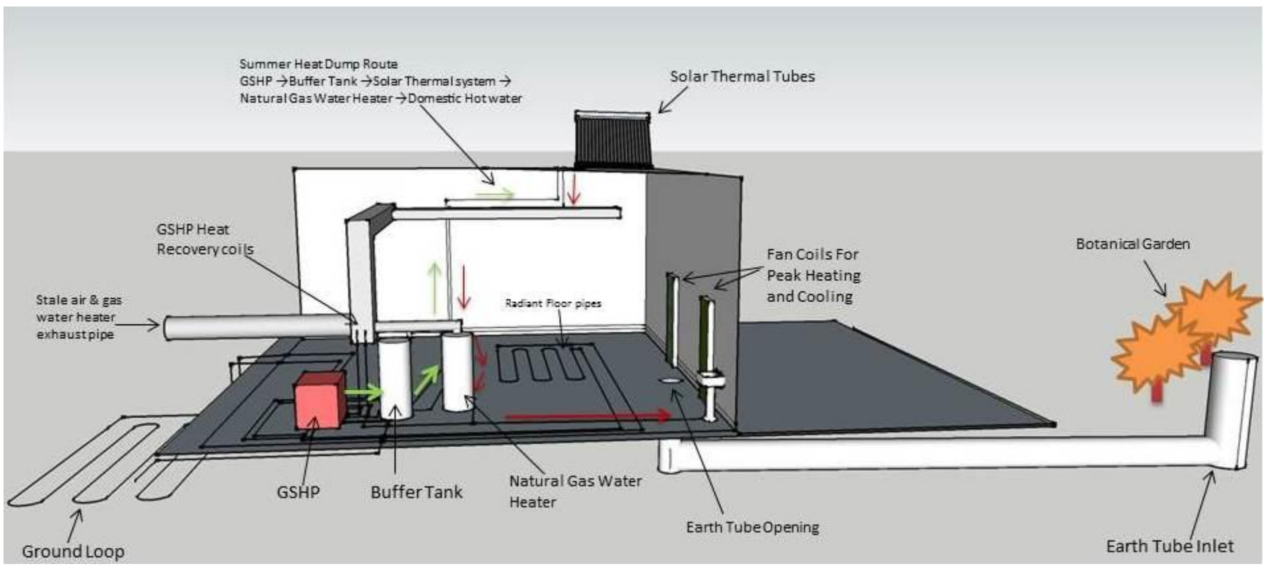
[2] http://www.cmhc.ca/odpub/pdf/67558.pdf
[3] http://www.performancepipe.com/en-us/ww/Pages/AdditionalInformation.aspx
[4] Please refer to the attached Hot 2000 Report file for details

Our design includes an Insulated Curtain System[5] to reduce heat losses from windows. We compered our heating demand with and without these curtains with Hot 2000. According report results insulated curtains created 15% heating demand reduction compared to base load.

Annual Gross Space Heating Load (Hot 2000) without Curtains	
447072	MJ
Annual Gross Space Heating Load (Hot 2000) with Curtains	
380325	MJ
Demand reduction from Curtains	
15	%

Ground Coupled, Hybrid (Natural Gas & Solar thermal), Heat Recovery

Reversible Heat Pump Technology



Even though our passive heating and cooling design reduces mechanical heating and cooling, we need some sort of mechanical HVAC system to be ready for extreme weather conditions and worst case scenarios. Consequently, our HVAC system design aimed for:

- Making use of free and recovered heating and cooling
- Reducing overall system size
- Reduction on purchased energy use

In order to achieve these goals we designed a Ground Coupled, Hybrid (Natural Gas & Solar thermal), Heat Recovery and Reversible Pump Technology. Conventional systems are less expensive compared to our choice. The reasons why we did not select a conventional HVAC system are:

- Conventional systems are not good at making use of free heating and cooling
- Increased overall system size
- Increase on purchased energy use and GHG emissions

[5] Warm Window® Insulated Shade System, http://www.solar-components.com/quilts.htm

All our system components are interconnected and the system is focused on making use of free and recovered energy. Therefore, our system set up appears highly complex. However, knowing every component's main and by-products makes system design simpler. Below we explained how the all system components are related to each other:

For the Heating Mode:

- Roof mounted solar thermal system[6] assists GSHP and provides free domestic hot water
- Heat Recovery from the stale air & gas water heater exhaust pipes to increase GSHP[7] efficiency
- Hydronic radiant floor heating system to distribute the heat efficiently
- Ground Coupled GSHP for an efficient heating and cooling
- Hybrid mode: An efficient natural gas water heater[8] assists GSHP at extreme cold conditions
- Air source : Earth Tube pre-conditions/warms the fresh outside air
- Air handling: Fan coil fans support the natural air convection when needed
- A high efficient exhaust fan exhaust the stale air to outside

For the Cooling Mode

- Reversible Heat Pump Technology[5] for both heating and cooling
- Dual Mode Cooling (Radiant floor cooling & Fan coils)
- Radiant floor cooling for base cooling. Water temperature is kept above dew point temperature of the slab to prevent condensation.
- Radiant floor cooling for Thermal Mass storage during the night. Less expensive energy during the night, more efficient cooling for the following day.
- Decorative and effective fan coils[9] for dehumidification and peak cooling
- GSHP's Hot Water Generator Mode for dumping house heat into domestic hot water
- Interconnected loop: Dump heat from GSHP →Buffer Tank →Solar Thermal system → Natural Gas Water Heater→ Domestic hot water
- Air source : Earth Tube pre-conditions/cools the fresh outside air
- Air handling: Fan coil fans support the natural air convection when needed

Pros & Cons

Pros

- Free cooling & heating
- Maximized Heat recovery
- Maximized IAQ

Cons

- Complicated system installation
- Complicated system operation
- Initial Cost

Even though our system is complicated and more expensive, it is a good investment for a long term energy efficient HVAC system. The system provides maximized and efficient IAQ and low impact on the environment. A professional team is required for overall installation. An optional automated monitoring

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[6] Solar thermal system, http://184.106.137.17/userfiles_us/SS-1.4-8--AP30C.pdf
[7] GSHP, http://www.nextenergy.ca/pdf/TMW-IOM.pdf
[8] Natural Gas Water Heater, http://products.geappliances.com/ApplProducts/Dispatcher?REQUEST=SpecPage&Sku=GG50T06PVT
[9] Greenor® fan coil, http://www.cinier.us/articles/Cinier-Greenor-US-EN-2012.pdf

and control system would guarantee system efficiency. Please refer to *Appendix 9: Heat Pump* for specifications.

Solar Thermal System

We included 16 evacuated solar tube collectors into our design. This system is capable of heating 605 litre of water to 65 c°, daily10. 60 % of this system covers daily hot water demand. 40 % excess capacity (304 MJ/yr) supports GSHP to reduce the total heating load.

RETScreen Outcomes	
Hot water use - estimated (Daily)	360 Lt
System size (Daily)	605 Lt
Excess hot water - estimated (Daily)	40 %

Annual Total Natural Gas offset from Solar Thermal	
711	m³
Annual Excess Natural Gas offset from Solar Thermal	
288	m³
287926	Btu
304	MJ
Space Heating Demand reduction from Solar Thermal Sytem\yr	
304	MJ

Energy Modeling and Related Calculation Limitations

Hot2000 software does not allow any inputs for the solar thermal water heating systems. We had to model our solar thermal system through RETScreen. Therefore, we had to interpret the results to each other by converting the energy values. After our calculations and comparisons we found that solar thermal system's contribution to the space heating seems less than 1 %. We believe the contribution of the solar thermal system to the space heating should be higher; different more sophisticated software would give more accurate numbers.

[10] Please refer to the attached RETScreen file for details.

Solar Thermal Calculations

Annual Gross Space Heating Load (Hot 2000)		
380325	MJ	
360478496	Btu	→

Minimum System Size	
41151	Btu/h →

Our GSHP System Size	
97000	Btu/h

RETScreen Outcomes		
Hot water use - estimated (Daily)	360	Lt
System size (Daily)	605	Lt
Excess hot water - estimated (Daily)	40	%

Annual Total Natural Gas offset from Solar Thermal	
711	m^3
Annual Excess Natural Gas offset from Solar Thermal	
288	m^3
287926	Btu
304	MJ
Space Heating Demand reduction from Solar Thermal Sytem\yr	
304	MJ

Annual Gross Space Heating Load (Hot 2000)	
380325	MJ
Auxilary Energy Required	
172170	MJ
Demand reduction from passive heating design	
45	%

Annual Gross Space Heating Load (Hot 2000) without Curtains	
447072	MJ
Annual Gross Space Heating Load (Hot 2000) with Curtains	
380325	MJ
Demand reduction from Curtains	
15	%

Conversion Factors	
Hours in Year	8760
MJ/Btu	0.001055056

Hot2000 Energy Model

A Hot2000 energy model created using the parameters of our building. The heating and cooling results were mentioned earlier in the report and will not be expanded upon here. However, it is worth noting that our overall annual energy consumption was calculated to be 36,168 kWh. The annual space and DHW energy consumption numbers are considered as accurate, though the appliance loads, which are mostly lighting loads, were outside the parameters of our design criteria. The following is an excerpt from the report; full details are included in the *Hot2000 pdf* included with this report.

ENERGY CONSUMPTION SUMMARY REPORT

Estimated Annual Space Heating Energy Consumption		= 53563.55 MJ	= 14878.77 kWh
Ventilator Electrical Consumption: Heating Hours		= 0.00 MJ	= 0.00 kWh
Estimated Annual DHW Heating Energy Consumption		= 21345.24 MJ	= 5929.23 kWh
ESTIMATED ANNUAL SPACE + DHW ENERGY CONSUMPTION		= 74908.80 MJ	= 20808.00 kWh
Estimated Greenhouse Gas Emissions	17.046 tonnes/year		

ESTIMATED ANNUAL FUEL CONSUMPTION SUMMARY

Fuel	Space Heating	Space Cooling	DHW Heating	Appliance	Total
Natural Gas (m3)	0.00	0.00	572.89	85.31	658.20
Electricity (kWh)	14878.76	3561.67	0.00	10725.03	29165.46

Even with the lighting calculations from the House Report included, we have achieved an energy intensity of around 130 GJ per year. This may not be an astounding number on its own, as average energy intensities for Canadian households in 2009 was 106.1 GJ/household.[11] However, when we look at the intensity per unit area we achieved some impressive results. The Canadian average was 0.79 GJ/m2 while our building achieved 0.17GJ/m^2. These results speak to the efficiencies that are possible with technologies that are currently on the market.

[11] Energy Efficiency Trends in Canada, 1990- 2009. http://oee.rncan.gc.ca/publications/statistics/trends11/appendix-1.cfm?graph=23&attr=0