

HUMBER COLLEGE SUSTAINABLE RESIDENCE CONCEPTUAL DESIGN & FEASIBILITY STUDY

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Executive Summary

Humber has identified sustainability as one of its six values: “We preserve our collective future by embracing the social, ecological and economic impact of our decisions.”¹ In mandating this core strategy, Humber has embedded an integrated planning and resource allocation model that commits to development and operations that emphasize social justice, ecological preservation and economic viability. It is with this in mind that the design of this **sustainable, affordable, replicable and low impact** residence was developed. In recognizing the need for further infrastructure that supports on-campus living, a conceptualized model was designed that balances a self-sustaining, community-style living accommodation with a progressive educational platform.

This report focuses on the core design concepts for the project: a **desirable, passive and feasible** concept. It is paramount to the success of this residence that it be appealing to the students, college and other post-secondary institutions. It is apparent to our team that the current residence conditions are not desirable for students, as many find alternative accommodations as the year progresses. The design of this residence embodies a community-style living scenario that promotes active, social involvement and we believe this will draw the attention of students. Developing on-campus living that takes advantage of **poorly used property** and showcases the schools drive to improve campus sustainability is an attractive opportunity for improving its **reputation and marketability**. As well, other post-secondary institutes can look to this **showcase building as a model** for practical and sustainable campus living solutions.

Stringent passive building standards can be achieved in this building. The design phase allowed us to orient and shape the building for optimal solar and wind benefits. Placing windows and thermal massing in strategic locations, the building will be able to gain a significant source of heating from solar energy during the winter. During the summer months, a combination of high performance windows, natural ventilation and solar shading will prevent the building from overheating. In addition to the envelope, **all passive building requirements were considered and achieved** to ensure a reduction in the size of the mechanical systems and a diminished burden on the city systems. Minimizing thermal-bridging and maximizing heat recovery and air tightness was of paramount importance in achieving this.

¹ <http://www.humber.ca/sustainability/about-sustainability-humber>

Although passive building standards optimize the energy performance of the building, we felt it was important to incorporate **further sustainable strategies** to showcase the advantages of these building practices. Passive building requirements for airtightness, heat recovery and passive design were achieved and enhanced by incorporating innovative sustainable technologies that worked to further improve energy and water management. Further to this, we felt it was of equal importance to heighten the social and community aspects of the building. We believe incorporating green spaces, naturally illuminated study spaces, and educational laboratories will enhance the residence’s appeal.

Ease of replication was paramount to the design of this building as well. The building was designed to maximize existing property uses, as most school properties are surrounded by concrete parking lots. Therefore, it is intended for **build above existing parking lots** to enhance the **multi-functionality** of the college space. When excavation and construction is complete the building will sit atop an **enclosed parking area** that will continue to draw revenue for the college, while making use of prime property space. The parking lot design is integral to the building’s replicability. Other post-secondary colleges and universities looking to expand their on-campus living can easily replicate this building on an existing parking structure. Further to this, all building systems and materials are readily available in the marketplace and the existing building design can be modeled with relative ease.

In our design, we made use of retired shipment containers for the structural frame of our building. By upcycling these containers, we were able to cut the construction cost significantly, by 76%.

Total Fee Cost (\$)	3,835,810.01
Total Proposed Building Cost (\$)	8,513,627.09
Total Base Building Cost (\$)	35,885,336.00
Cost Reduction	76%

Finally, energy and water optimized building systems and components were carefully interwoven to ensure a cohesive design that actively embodied the concept of sustainable building design. This report will detail the design process and will provide justification for the technologies and materials selected. Many measures were investigated, with the most feasible and attractive options being integrated; sizing, costing and payback have been addressed in this report.

Scope

The development of an on-campus sustainable residence conceptualized as a means to meet the demand for on-site **self-sustaining living** using an energy-conscious and community minded business model.

As it stands, Humber College does not have the infrastructure to support the demand of first year students requiring on campus living; a waiting list formulates each year, forcing a significant number of students to seek alternative means of living. As the population of students at Humber College continues to expand, it will become exceedingly necessary to explore options for residence development. We have identified this shortcoming as an opportunity for the school to develop a campus community focused on sustainable and functional living.

Building Design

Our building design is intended to be low cost and low impact; regional materials will be repurposed and designed to optimize the use of passive strategies. The result is intended to yield energy efficient and smart buildings that appeal to students and present an attractive opportunity for the school to reduce building consumption and costs. Ontario currently has a surplus of shipping containers and we intend to upcycle them for our building design.

Community Garden/Agricultural Centre

An agricultural centre will serve as a means for local food production; residents will be able to gain hands-on experience growing and harvesting produce that will be used on-site. Further, we believe that an agricultural centre provides an opportunity to connect resident occupants to one another as well as to their campus community. Volunteering time to nurture the green house and surrounding gardens will provide students with the opportunity to take pride in their work and community. Further, there is potential for an energy exchange; in return for green house work students will receive some of the harvest. As well, on-site organic waste recycling systems will enable us to utilize the waste on campus as enriched fertilizer for food production.

Educational Platform - Living Lab

There is risk involved in developing a residence that potentially requires a greater amount of facilities staff and maintenance and operation. This risk will be mitigated by incorporating the site as a living lab for Humber College programs. College programs including Sustainable Energy and Building Technology, the Horticultural Technician Apprenticeship, etc. will be able to use this facility as an educational tool. Incorporating the building facility operations into the curriculum for relevant programs, such as Sustainable Energy and Building technology and HVAC, will provide students with the opportunity to gain a practical understanding of building automated systems and passive design strategies. Our intention is to build the framework for students to develop innovative ideas of their own for the facility operations and agricultural production.
























The living lab will not only benefit the students it will also provide necessary operating services for the school.

Showcase

The development of a sustainable campus residence would be the first of its kind in the Greater Toronto Area. This facility would serve as a showcase for Humber College; an innovative and forward-thinking development project for the school. This innovative concept will attract more students and if successful, will have other post-secondary schools looking to develop similar business models. This will improve Humber's reputation and inadvertently increase the school's marketability.

Project Schedule

A project schedule was formulated to detail the various milestones determined; the project was completed on schedule and all milestones were achieved.

	<input type="checkbox"/> Capstone - Sustainable Campus Residence	76 days	Fri 1/10/14	Fri 4/25/14
	- Planning	71 days	Fri 1/17/14	Fri 4/25/14
	Define Scope	6 days	Fri 1/17/14	Fri 1/24/14
	Contact Humber Residence Facilities Manager	6 days	Fri 1/17/14	Fri 1/24/14
	Interview Humber Residence Facilities Manager	6 days	Mon 1/27/14	Mon 2/3/14
	Interview Black Creek Farm Operations Manager	1 day	Tue 2/4/14	Tue 2/4/14
	Redefine scope using new information	4 days	Mon 1/27/14	Thu 1/30/14
	Develop business plan/model	56 days	Fri 2/7/14	Fri 4/25/14
	- Executing	50 days	Mon 1/20/14	Fri 3/28/14
	Build replica model	5 days	Mon 1/20/14	Fri 1/24/14
	Research building materials	10 days	Mon 1/27/14	Fri 2/7/14
	Determine appropriate technologies/strategies to utilize	10 days	Mon 1/27/14	Fri 2/7/14
	Conceptualize building design	10 days	Mon 2/10/14	Fri 2/21/14
	Produce design phase 1 (DP1)	6 days	Sat 2/8/14	Fri 2/14/14
	Energy Model DP1	21 days	Sun 2/2/14	Fri 2/28/14
	Review shortcomings	6 days	Mon 3/3/14	Mon 3/10/14
	Evaluate and change any design parameters as necessary	6 days	Tue 3/11/14	Tue 3/18/14
	Finalize DP1	11 days	Wed 3/19/14	Wed 4/2/14
	Closing	21 days	Sat 3/29/14	Fri 4/25/14
	Finalize business plan/model	16 days	Sat 3/29/14	Fri 4/18/14
	Develop presentation/design panel materials	16 days	Sat 3/29/14	Fri 4/18/14
	Report Submitted	1 day	Fri 4/18/14	Fri 4/18/14
	Present to SNRG 600	1 day	Fri 4/25/14	Fri 4/25/14

Design Process

An informational interview was conducted with Humber College North Campus' residence manager to identify the existing and desired amenities. Using the information provided we established a set of design parameters to optimize passive and sustainable building strategies. A plethora of energy conservation measures were scrutinized and a select number were implemented into the design based on the following factors:

A Desirable Concept

As mentioned above, Humber College's Residence Manager emphasized specific amenities and desired building attributes. Referencing these design parameters we have developed a campus residence that is attractive to the students, college and other post-secondary institutes.

Student Desirability

A student living on campus expects to be provided with a comfortable, safe space that provides all of the amenities required for a student lifestyle. Amenities, such as study and social spaces, food and beverage options, facilities for physical activity, and basic living requirements are traditional residence expectations. The residence we have designed will reach beyond these expectations, providing students with amenities that promote healthy, energy conscious living focused on social engagement and community connection. The student selection should therefore be streamlined based on academic and personal interest in energy, sustainability, HVAC, horticulture, and social studies.

Upon interviewing the residence manager of the Humber College North Campus it became apparent that open student space was lacking in the existing residences. Considering this shortcoming, we have conceptualized a design that provides students with open study/work spaces that take advantage of natural daylight for improved productivity. It is expected that these spaces will provide students with a space to focus on their personal academics, but also to engage with other like-minded individuals. To further this space as an educational platform, we have incorporated a living lab. This lab will be focused on building automation systems and associated sustainable technologies, as well as horticultural related studies. This will be attractive for students in related programs, but will also provide students that simply have an interest in energy management and self-sustained lifestyles to gain exposure to their consumption.

We believe the most desirable attribute of the residence will be the green, open spaces that encourage social engagement and community living. The greenhouse and surrounding green space are intended to provide a space that occupants can take pride in. The opportunity to volunteer time and work to optimize the green house operability and output will provide students with a self-sustaining lifestyle. The success of this space is dependent on their effort as a group and it is our hope that this will bring a sense of community to the residence occupants. Engaging with students from different educational backgrounds will be abundant and this will enrich their personal and educational experiences at school.

College Desirability

As we have learned from the Humber College residence manager, current infrastructure does not support the demand of first year students initially requiring on-campus living. While we have learned that the number of residence occupants dwindle as the year progresses, we believe that our design will be an attractive living scenario for students. This student desirability will help to improve occupancy levels and enhance the college's demand for on-campus living. At the same time, the college will be able to provide accommodation that will consume less energy thereby reducing consumption costs incurred by the school.

This building is also an attractive venture for the college as it maximizes the use of existing school property. The structure is designed for build above an existing parking lot to reduce the need to procure more land and to provide multi-functional use for that space. While the parking area will have to undergo excavation to ensure the building is structurally sound, the ground level of the building will serve as an enclosed parking lot. This will minimize revenue losses from parking fees and will enhance will existing property.

This innovative design concept is one that has not been achieved in Ontario. If implemented successfully it can become a showcase that highlights the advanced and forward-thinking vision of the college. This will effectually increase the marketability of the post-secondary school, further facilitating the potential for growth and industry recognition. The greater the recognition the greater the potential for attracting new students and staff.

Other Post-Secondary School Desirability

Designing a residence that is successful in showcasing a self-sustaining, low impact lifestyle opens up the potential for a new market. This residence would be the first of its kind in this province and would be designed with the intention for

easy replication. Thus, if the development has an impact on the building industry and gains positive market attention it will become a model for sustainable residence design. Other post-secondary schools interested in expanding their residence capacity will desire the replicability of a low impact building that operates at optimal efficiency and can be incorporated by building on any existing parking lot. It must also be noted that additional floors can easily be added if desired, as shipping containers are structurally sound and easily stacked.

A Passive Concept

This residence design meets passive design standards in order to effectively mitigate energy use and associated costs. Each passive building requirement was assessed and considered when designing the residence. The following details the requirements outlined by the Passivhaus Institute and how these requirements were implemented and/or verified.

Passive Solar Design

Passive building standards encourage the balance of solar and internal heat gains with overheating protection. This balance will be achieved in the residence in the following ways:

- South facing entrance with triple glazed windows enclose main atrium space.
 - Passivhaus certified windows sourced
 - Winter sun penetrates atrium through triple glazed windows (high SHGC)
 - Thermal mass flooring stores heat for evening release
 - Summer solar gains for atrium prevented with window film that reflects unwanted radiation
 - Balances reflection and necessary daylighting
- South facing balconies enclosed with double glazed curtain wall systems serving as sunrooms that provide a thermal buffer zone.
- North facing side of building has minimal window openings
- Solar PV panels (BIPV) on roof of sunrooms will be dual purpose
 - Solar energy collection and shading
- Thermally-insulated window shades for suites – superior shading capabilities with insulation value of R-5

Super-Insulated Envelope

The following table breaks down the high performance building envelope materials that will collectively yield an effective R-value of 72. To meet passive building standards a building's heat transfer coefficient must be greater than or equal to 0.15 W/m²K or R-37. Based on this, the building envelope of the residence well exceeds these requirements.

	Material	Thickne ss (inch)	U Value W/m- °K	U Value (Btu/h)/ft ² °F	R Value ft ² °F/(Btu/h)	R-Value (per inch) ft ² °F/(Btu/h)	Total R Value ft ² °F/(Btu/h)
Shell No thermal bridge	Stucco	0.5	0.6918	3.922506	0.1274695 31	0.12	0.06
	Polystyrene	8	0.0346	0.196182	40.778460 82	5	40
	Polyisocyanurete	2	0.0202	0.114534	17.462063 67	8	16
	Steel Corrugation	0.5	44.969 6	254.977632	0.0019609 56	0.033	0.0165
	SMARTWALL	4.25					16
	Total	15.25					72.0765

Thermal Bridge-Free Design

In order to successfully design and construct a passive building it must be free of any thermal bridging wherever walls, floors and roofs meet and where windows and doors are installed. In order to accomplish this it is recommended that insulation be installed at all interconnections. The first floor of the residence will be Insulated Concrete Forms (ICFs). These hollow foam panels, which are made of highly insulated polystyrene and filled with poured concrete, are stacked like building blocks to form the walls of the substructure. This material creates a wall system that offers continuous, superior insulation that is said to minimize infiltration and heat loss.

The superstructure of the building will consist of shipping containers covered with continuous interior smartwall insulation that will be coupled with exterior polystyrene for added value. Smartwall technology consists of a prefabricated wall system that is proven to increase the thermal efficiency and air tightness of the building envelope.² Coupled with the exterior polystyrene this wall system eliminates any thermal bridging. All flooring on the main floor (level 2) is insulated. This can be seen in the adjacent section view, where the flooring connected to the ICFs on the parking level is continuously wrapped in polystyrene eliminating the potential for thermal bridging.

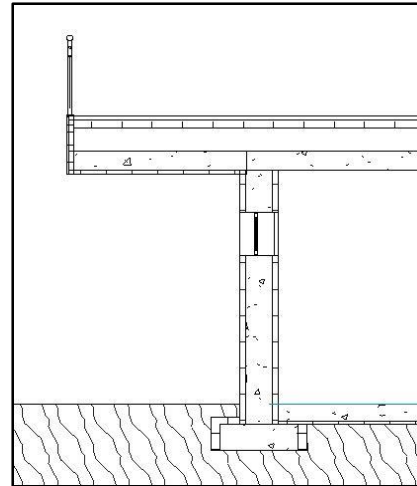


Figure 1: Minimized thermal bridging

Further to this, the windows will sit atop an anchor to ensure that there is no direct contact between the window framing and the shipping containers. In doing so, the potential for thermal bridging will be minimized. Figure 2 is an illustration of how the Passive House Institute achieved a thermal bridge-free design. Figure 3 illustrates how this will be achieved for the residence.

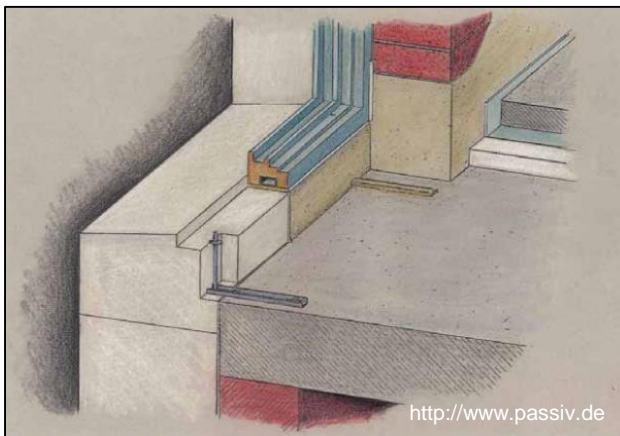


Figure 2: Passivhaus thermal bridge-free window connection

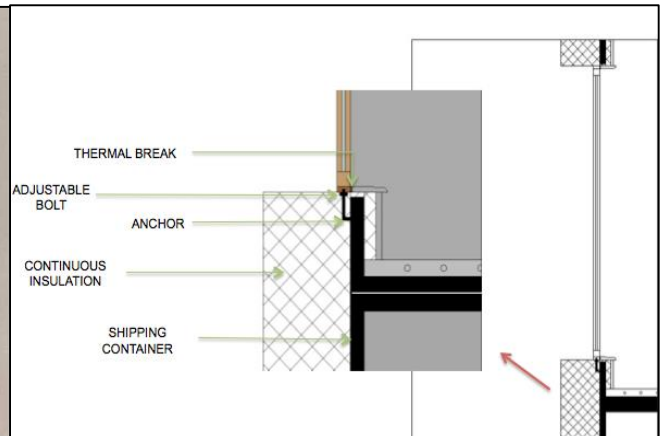


Figure 3: Passivhaus thermal bridge-free window connection applied

Shared enclosed balconies were incorporated for occupant use. While balconies are often major obstacles in battling thermal bridging, the ones incorporated in the residence are not traditional. This design simply takes advantage of the tiered building design, which allows unused roof space to be used by occupants. The

² <http://pacific-homes.com/smart-wall-technology>

existing roof/balcony space can be accessed via suite doors and does not include the addition of any floor or wall interconnections.

High R Windows

Passive design standards indicate that triple glazing windows with two low-e coatings, argon gas fill and insulated spacers should yield an acceptable U-value of at least 0.8 W/m²K (R-7) with a solar heat gain coefficient of minimum 0.62. Windows have been sourced to meet these requirements and will be procured for installation on the residence. The Northwin Vision windows are high performance windows that have been certified by the Passive House Institute³. The following is a breakdown of the windows thermal performance:



Figure 4: Triple glazing

U Glazing	U_g [W/(m²K)]	0.66	0.60	0.54
U Window	U_w [W/(m²K)]	0.72	0.67	0.63

Airtightness

Ensuring a minimum tested airtightness level of 0.6 air changes per hour (ACH) at 50 Pascal is integral for meeting passive building requirements. The residence will uphold this condition by integrating the following measures:

- Double sided tape and super metal sealant glue used to adhere insulation to shipping containers.
 - Safeguards from any leaks that occur due to punctures in insulation.
- Exterior polystyrene provides continuous insulation.
- Caulking for corners.

³ http://northwin.com/wp-content/uploads/2013/01/zd_northwin_vision_en.pdf

Ventilation Heat Recovery

The final requirement for meeting passive building standards is the recovery of a minimum of 75% of the heat intended to be exhausted. This will be accomplished in the residence by installing a heat pipe system at the top of the solar chimney. We were not able to use traditional air-to-air heat recovery ventilators for our building due to the implementation of earth tubes. Instead we are making use of heat pipe technology to harvest waste heat for our building design. Heat pipes are simple and efficient heat recovery products that do not require any mechanical power. They work based on evaporating and condensing cycle principles, which can be seen in Figure 5.⁴

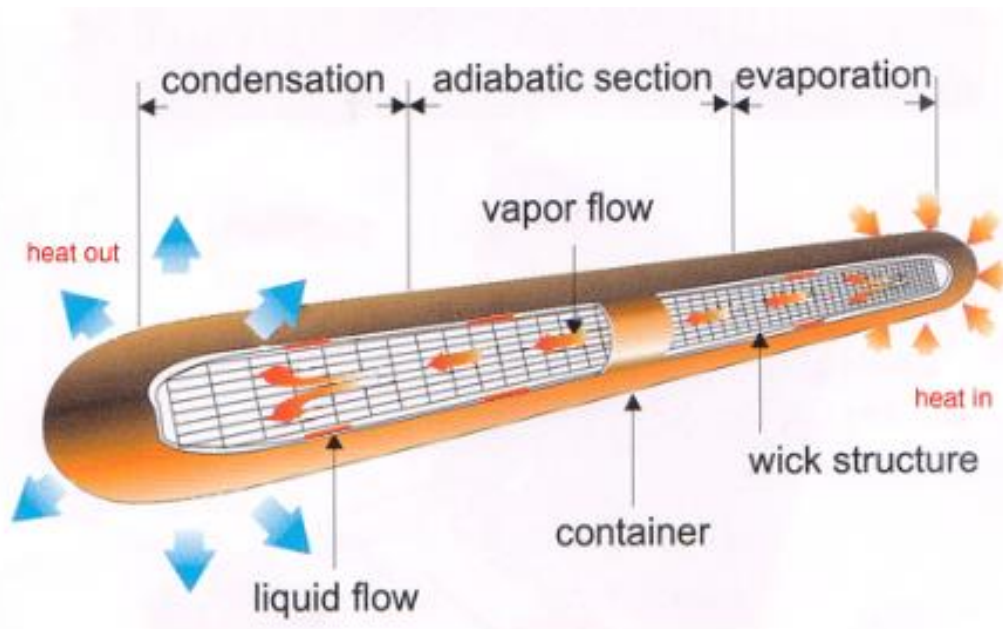


Figure 5: Schematic of heat pipe technology

There are air-to-air and air-to-water heat pipe heat recovery applications. Heat pipes are commonly used within the evacuated solar collector tubes to collect and increase the heat harvested from the sunlight to heat domestic hot water. Figure 65 illustrates the use of heat pipe technology coupled with evacuated solar collector tubes.

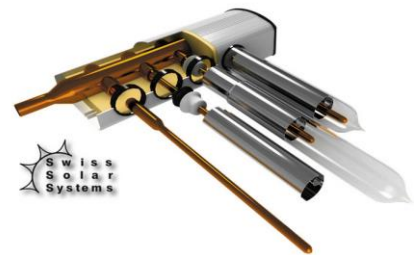


Figure 6: SHW tube incorporating heat pipe

⁴ Schematic of a heat pipe: http://www.thermoguide.co.il/Heat_pipes.html

⁵ Solar Heat Pipe Application: <http://www.swissolarsystems.com/index.php/archives/331>

We are using an air-to-water heat recovery heat pipe system to harvest waste heat from exhaust air at the top of the solar chimney, which was also designed as a heat box using external glazing. The system selected and its application within the residence design can be seen in Figures 7⁶ and 8 below.

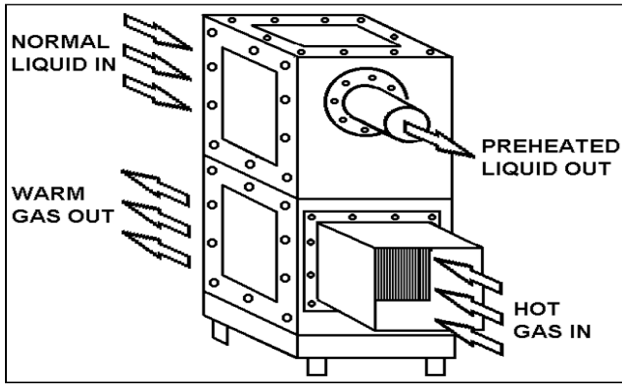


Figure 7: Air-to-water heat recovery heat pipe

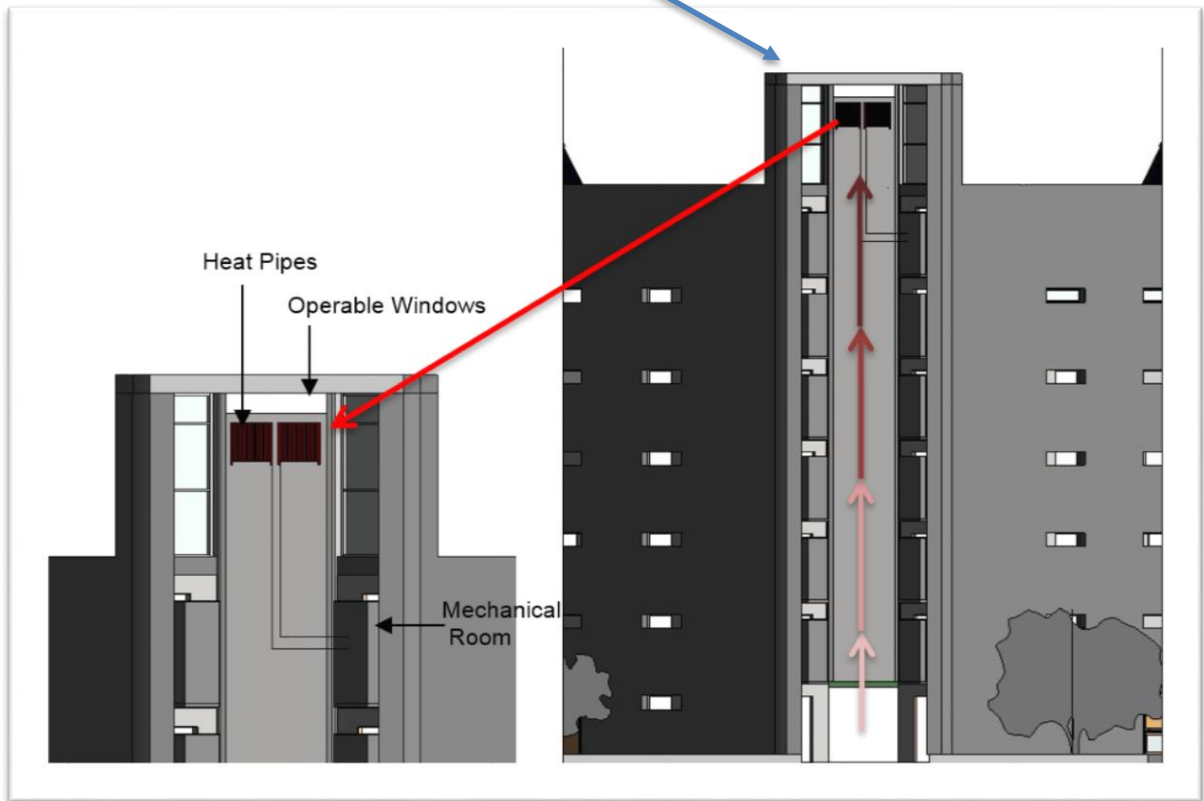


Figure 8: Air-to-water heat recovery heat pipe application

⁶ Hot Gas to Liquid Heat Pipe Heat Exchangers: http://www.manorenterprises.com/product_heat_pipe.html

A Practical & Feasible Concept

While passive standards result in high building performance, we intended to incorporate materials and equipment that would work to further reduce energy consumption and improve water conservation. An on-site green house and open green space will require extensive irrigation, emphasizing the importance of water optimization on site. Easy to implement sustainable measures, often known as “low hanging fruit”, have also been identified and implemented to contribute to the overall energy reduction of a typical residence. The heating and cooling of the building was also a critical consideration, as HVAC systems are often the most significant energy burden in a building. Many alternatives to typical heating and cooling systems were analyzed with extensive focus on renewable energy options. Below will justify the systems selected for energy and water reduction opportunities.

Shipping Containers

Conceptualizing a building constructed of shipping containers was a viable option for a myriad of reasons. The initial attraction was the ability to up cycle a construction material that would effectively eliminate the need for conventional structural materials, such as brick, steel, cement and wood. Canada is a heavy importer of goods that require freight containers for shipment. The cost to return these containers is often not economical for companies, which has resulted in a surplus of abandoned freights. Further to this, a shipping containers life span for intended use is approximately 20 years. Although it is no longer useful for shipping purposes after this time, they are said to have an infinite life span when stationary.⁷ The recycling of these containers reduces the embodied energy of the residence and supports a **cradle-to-cradle** model. They are durable, structurally sound, easily stacked, locally sourced and extremely economical. Based on market research a price range was determined for 20’ Standard, 40’ Standard and 40’ High Cube containers. The pricing details can be found below:

SIZE (ft)	PRICE RANGE (\$)
20' Standard	2,200-2,700
40' Standard	2,700-3,600
40' High Cube	3,100-3,700

Containers will be used for the entire building structure; a breakdown of the number of containers required for each level and cost can be found below. It should be noted that an assumption was made about the bulk pricing of the

⁷ <http://www.greenhomebuilding.com/articles/containers.htm>

shipping containers. A price of \$2500 for 40' High Cube containers was assumed.

Shipping Containers - 40'		
Floor	# of Containers	Cost
Level 1	88	\$220,000.00
Level 2	26	\$65,000.00
Level 3	22	\$55,000.00
Level 4	18	\$45,000.00
Level 5	14	\$35,000.00
Level 6	10	\$25,000.00
Level 7	4	\$10,000.00
Tower	2	\$5,000.00
Total	184	\$460,000.00

The cost of the shipping containers is insignificant compared to the cost to procure and implement traditional building materials. Using the containers mitigates the requirement for concrete and steel structures, as well as roughly 50% of the interior walls. As a result of this, the overall building cost is astronomically lower than a traditional building's cost.

Earth Tubes

Earth tubes are a passive technology that works to reduce the heating and cooling required for the building. Using the earth as a heat sink, the tubes draw fresh outdoor air in and pre-condition it using the constant ground temperature. This pre-conditioned outdoor air is directed to the mechanical systems and effectually reduces the work the systems need to do to treat the air to the desired set-point. This results in a reduced burden on the HVAC system and therefore reduces energy consumption and related costs. As well, they will allow for the use of 100% fresh air during shoulder months further eliminating the use of the mechanical systems.

For this application, the earth tubes will be coupled with a Ground Source Heat Pump. A High Density Polyethylene (HDPE) pipe will be sourced as it is an "inert plastic with none of the health concerns of PVC" piping.⁸ The piping has the following specifications:

- 3 pipes laid 71" (1.8m) apart
- Diameter of 12"

⁸ http://www.homeintheearth.com/tech_notes/earth-tubes/earth-tube-design-for-earth-sheltered-homes/#hdpe-pipe

- Length of 95' or 29m (majority of heat transfer occurs in first 100 ft (30 m) of tube)
- Length of the building is 129 ft (39.2 m) leaving room for any intake or openings required.
- Buried 10 ft (3 m) below ground level to ensure pipes below frost line.

In order to maximize the rate of heat transfer, it is ideal to flow the air at a low velocity through the earth tubes to provide adequate lag time for the heat transfer to occur. As well, the earth tubes must be angled to eliminate condensation and should therefore be equipped with a condensate trap.

Solar Chimney

A solar chimney is very effective when coupled with earth tubes. The height of the solar chimney results in an air pressure differential between the ground and ceiling of the building. The lower pressures near the top of the building help pull air upward. The earth tubes, which pre-treat the incoming fresh air, aid in creating a larger pressure differential that works to create a vacuum effect. During the summer, this vacuum pulls the hot air out of the solar chimney while pulling the cooled air into the space from the earth tubes. Similarly, during the winter the pressure differential causes the stale air to be pulled to the top of the solar chimney and heat from the stale air will be harvested via heat pipes before exhausting the stale air.

Using the following calculation from the 1997 ASHRAE Fundamentals handbook and a stack effect calculator, we determined a stack effect of 5,384 CFM:

$$Q = 60 * Cd * A * \text{sqrt}(2 * g * (Hn - Hb) * ((Ti - To) / Ti))$$

where

Q = Flow rate (CFM)

Cd = 0.65 (for unobstructed openings)

A = opening area (ft²)

Ti = indoor temp (°F)

To = outdoor temp (°F)

Hn = height of "neutral pressure point" (for simple systems, assume 1/2 way between top and bottom openings)

Hb = height of bottom opening

g = gravity

Area:	<input type="text" value="16"/>	square feet.
Height difference:	<input type="text" value="39.7"/>	feet.
Indoor Temperature:	<input type="text" value="70"/>	F.
Outdoor Temperature:	<input type="text" value="86"/>	F
Flow Rate:	<input type="text" value="5384"/>	CFM.

http://chuck-wright.com/calculators/stack_effect.html

The solar chimney opening was determined based on the number of operable windows at the top of the inlet. There are 2 windows at 0.98m² each operated by the building automation system that determines ventilation needs within the building. The pre-treated fresh air from the earth tubes will be pulled via natural suction and the supply fan ducting system. The supply fan ducting system will be placed in the parking garage. The ducting system will run through the corridors on each floor with channels into every room, forcing fresh air into the rooms. Return air will exit rooms through a door/wall grill where it will enter the corridor and be pulled, via the solar chimney vacuum effect, towards the atrium opening.

Ground Source Heat Pump (GSHP)

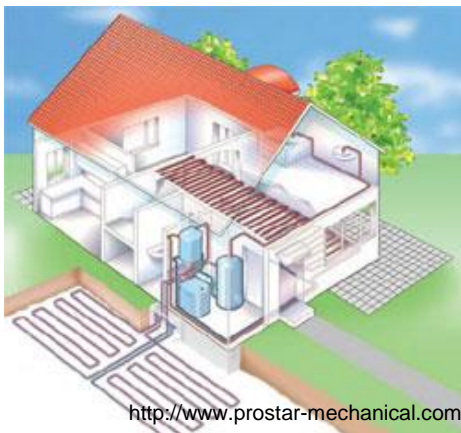


Figure 7: GSHP coupled with radiant flooring

A vertical ground source heat pump is proposed due to the limitation on space for this particular project; another location may be able to implement a horizontal application to reduce capital costs. The GSHP will use the constant temperature of the earth as a source of heat in the winter and as a heat sink for heat removed from the home in the summer. The liquid running through the pipes in the vertical loop acts as a heat absorber in the winter. In this case, the GSHP will be coupled with radiant heating. The heat pump for the radiant heating system will absorb the pre-heated liquid from the primary loop (GSHP) increasing its temperature before it is directed into the secondary loop (radiant heating loop). During the summer it performs the reverse action as the liquid in the radiant loop absorbs the heat from the indoor air. The heat pump then absorbs the heat from the secondary loop and dumps it into the primary loop (GSHP) where it is transferred to the earth. Utilizing the earth's constant temperature to reduce the burden on the

pre-heated liquid from the primary loop (GSHP) increasing its temperature before it is directed into the secondary loop (radiant heating loop). During the summer it performs the reverse action as the liquid in the radiant loop absorbs the heat from the indoor air. The heat pump then absorbs the heat from the secondary loop and dumps it into the primary loop (GSHP) where it is transferred to the earth. Utilizing the earth's constant temperature to reduce the burden on the

mechanical system of the building will result in lower energy consumption and related costs. There is the potential for excess waste heat in the summer season, some of which can be used to pre-heat the incoming city water required for other residences on campus.

The feasibility of integrating a hybrid vertical ground source heat pump was investigated and based on RETScreen outputs, a total of 59% of energy expended for heating and cooling can be offset. Although the analysis indicates a simple payback of approximately 50 years the initial capital investment for installation is minimal at \$21,250. RSMMeans Green Costing Data values the installation of a 25 Tons geothermal system at approximately \$220,000. Due to the passive building components the system size required for this building is significantly lower than a standard system. Therefore, we believe these factors justify the viability of this system installation. Below are the results of the analysis:

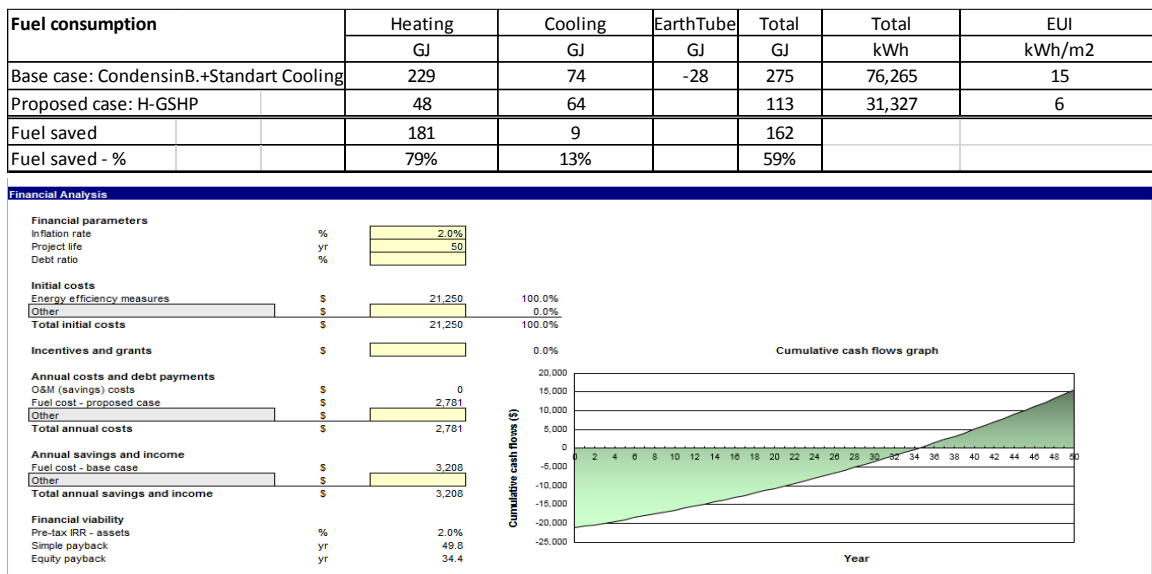


Figure 8: RETScreen output for GSHP

Using a combined heat and power system was considered for heating and cooling; however, when analyzed in RETScreen it was determined that it would not be feasible. RETScreen indicated that the simple payback for this system would be approximately 161 years and it is for this reason that we recommend the vertical hybrid GSHP system. The RETScreen outputs can be examined below:

Total Power capacity	kW	18.8
Minimum capacity	%	0.27
Electricity delivered to load	MWh	0
Electricity exported to grid	MWh	25.31
Manufacturer	Ecopower	
Model	4.7kW	
Heat rate	Btu/kWh	13829
Heat recovery efficiency	%	0.6
Fuel required	GJ/h	0.274
Heating capacity	kW	34.436

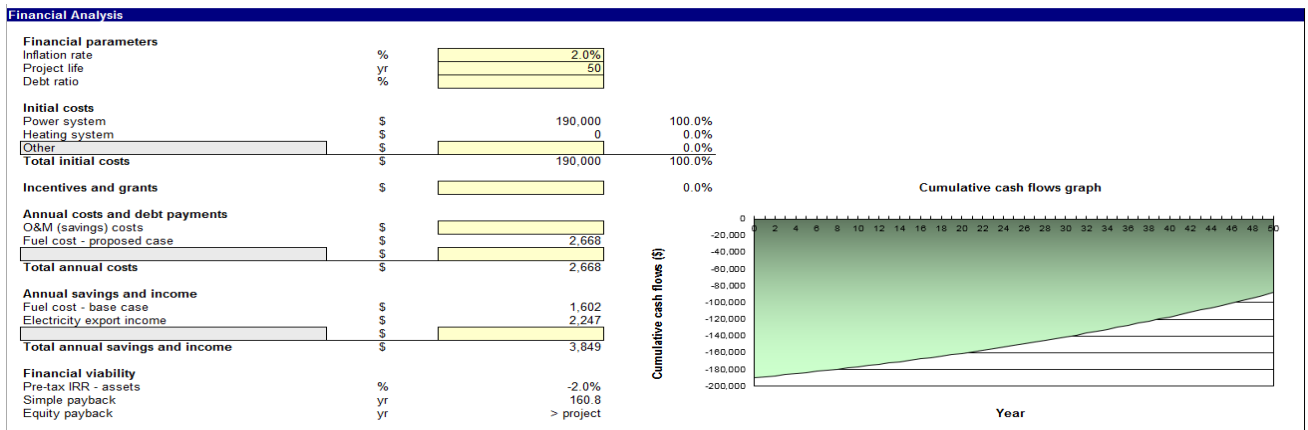


Figure 9: RETScreen output for CHP

Further examination of the RETScreen data can be found in Appendix A: RETScreen Analysis

Radiant Heating/Cooling

Radiant heating and cooling is a low energy system that exchanges heat with the floor slab placed above it through convection and radiation. By circulating heated or chilled water through a network of pipes installed in the floors, this system will distribute energy in a uniform and efficient manner. It works to improve overall energy efficiency and effectively improve overall thermal comfort.

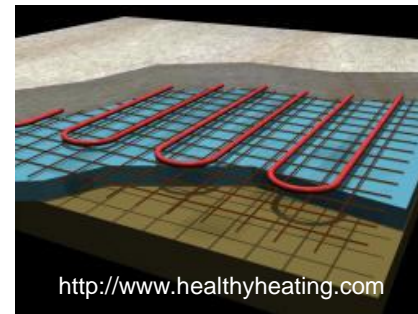


Figure 10: Radiant Heating Components

Building Automation System

One of the key items featured in the design of this residence is a building automation system (BAS). The implementation of a BAS system is intended for monitoring and controlling mechanical, ventilation, humidity control, lighting, and

water systems. The BAS will be located in the living lab and is intended for use as an educational tool. Students whose studies focus on energy management, as well as those with a keen personal interest, will have the opportunity to gain practical experience monitoring and controlling various systems in the building. This system can be incorporated into the curriculum, providing students with a technical application on energy management and faculty with an opportunity to provide a tangible skillset. Just as important, by incorporating this system into the curriculum of various programs the school can mitigate the need for additional staff. The following are the systems suggested for monitoring:

Ventilation

Air changes require monitoring to ensure ventilation rates are acceptable based on many variables including occupant and activity level. As well, the BAS will operate the windows all around the building as well as the windows located at the top of the solar chimney. During the summer season when the earth tubes and solar chimney are working to draw warm air out of the space, the BAS will monitor the building flow rates and determine the extent to which the windows must open.

HVAC

The automation system is also intended to optimize energy use within the building. Sensors and controls within the building will provide feedback about the building's heating/cooling levels to the system. Based on specified set-points, the BAS will work to correct whatever errors the system is producing, modulating those errors until the controlled variable has reached its set-point. Thermal comfort and air quality levels are essential in any building and this system works to optimize these, while constantly improving the performance of the mechanical systems.

It must be noted that the BAS will also monitor condensation levels of the radiant cooling system. In monitoring these levels the system is limiting the amount of chilled water supplied to the radiant system, preventing the water temperature from going over its dew point.

Lighting Controls

Photosensor lighting will be incorporated into the atrium, cafeteria and recreational room lighting plans. Occupancy sensors will be used in all corridors and stairwells. Both will be controlled by the BAS system, which will work to

monitor these lighting systems to take advantage of daylighting techniques and to eliminate any discrepancies.

Water Conservation

Stats Canada Annual Precipitation in Toronto (m)	0.793 ⁹
Total Building & Footprint Area (m ²)	2481.8
Annual Potential for Stormwater Capture (m ³)	1968

With an opportunity to capture almost 2000m³ of stormwater on-site, we immediately recognized an opportunity to conserve water. Various water conservation best practices were assessed and several are encouraged for implementation in the building. Rainwater collected from the roof and surrounding grounds will be filtered and stored for irrigation, as the needs of the green house and surrounding green space will be quite significant. Storage Cisterns will be located in the conditioned parking garage and in the penthouse. The parking garage cisterns will collect the majority of the stormwater and will pump it gradually up to the penthouse cisterns for daily usage.

Grey water from lavatories and showers will be recycled and used for flushing ultra low flow water closets. One recycling system can serve 12 occupants; therefore, we will require approximately 2 per floor. Low flow washroom and kitchen faucets will be implemented, along with water recycling showers. These showers provide 3 litres of potable water that is captured, filtered, heat pasteurized, and reused all under 30 seconds. No water is shared between users and it is said to reduce shower water and electricity consumption by approximately 70%.¹⁰ Finally, the site will be landscaped with native plant species and extensive green roofing.

⁹ <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/phys08a-eng.htm>

¹⁰ <http://www.recyclingshower.com.au>

Building Integrated Solar Photovoltaics (PV)



Solar photovoltaics have been incorporated to reduce the need for mechanical cooling. The PV panels are integrated into the sunroom/balcony on the south facing side of the building. Below are the details of the panel specification and output:

Type	mono-Si	
Manufacturer	Canadian Solar	
Model	mono-Si - CS6P-245M - ClearPower	
Total Power capacity	31.36	kW
Efficiency	0.1523	%
Nominal operating cell temperature	45	°C
Temperature coefficient	0.004	% / °C
Total Solar collector area	205.9093894	m ²
Installation Cost*	3	\$/Watt
# of Units	128	
Azimuth Angle	135 & 225	°
Slop	7	°

The PV panels will be critical in providing shading during the summer months. In order to optimize the shading effect, while blocking the summer sun a precise positioning and angle had to be determined; using a PV panel as the overhang required an extensive investigation into the appropriate dimensions for the systems. The following is the solar shading analysis performed to determine optimal positioning:

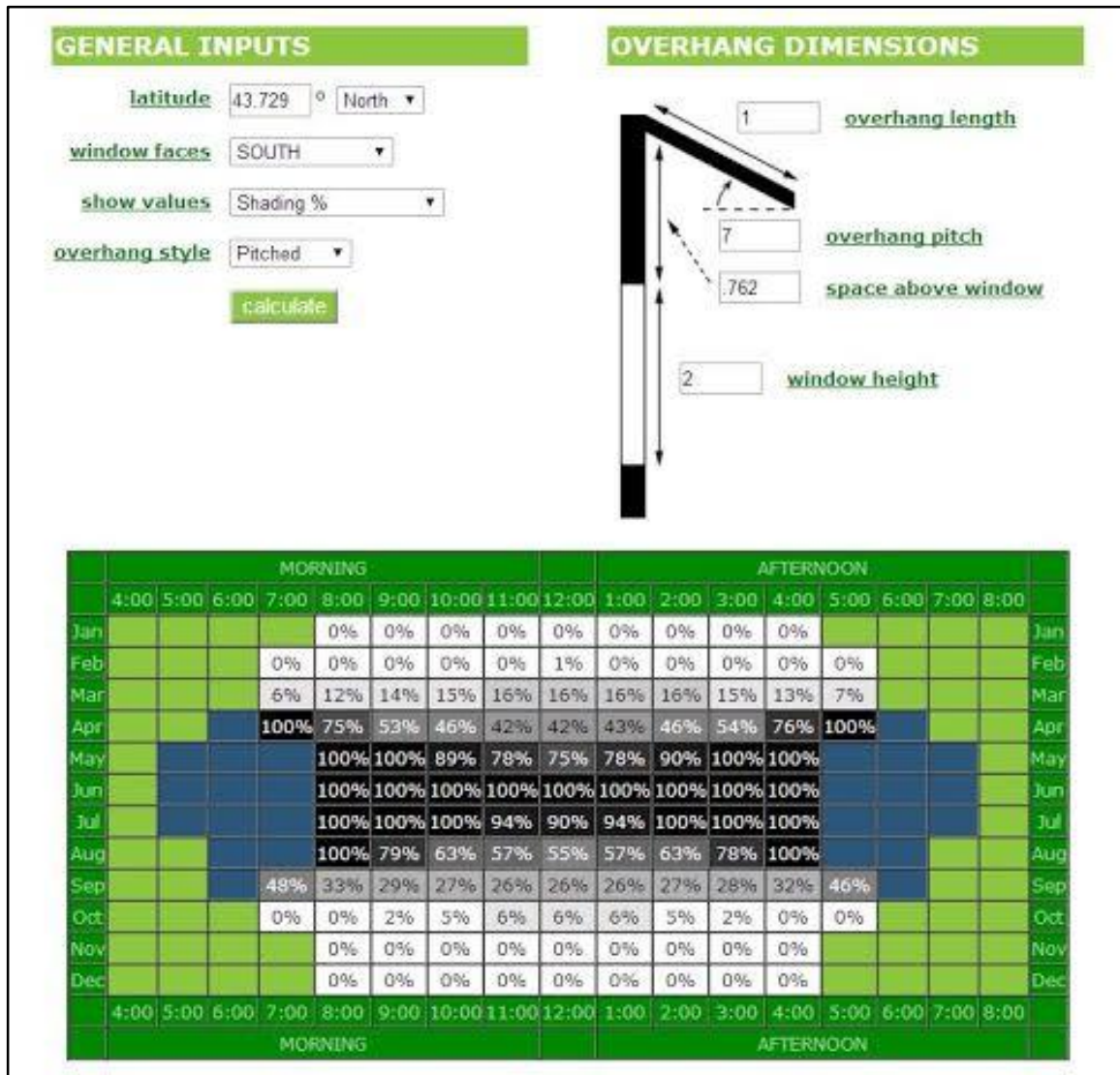


Figure 11: Solar shade analysis
http://www.susdesign.com/overhang_annual/index.php

A RETScreen analysis was performed to assess the viability of implementing these solar panels. These panels will offset non-renewable energy consumption reducing the burden placed on the grid. They will also be intentionally placed on the roof of the south facing sunrooms to act as shading during the summer months. Based on an initial cost of \$94,080 sourced from the PV panel

manufacturer, the panels have a simple payback of 8.2 years and will produce an excess of 33 MWh annually. This electricity can be exported to the grid, or can be used in another building on campus. This short payback scenario indicates that the implementation of the solar PV panels is feasible for this project.

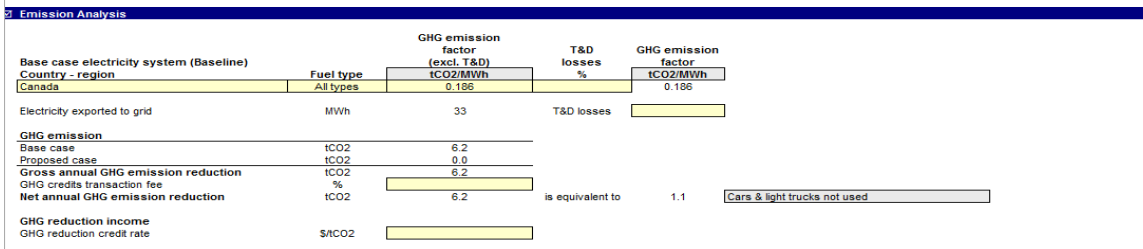
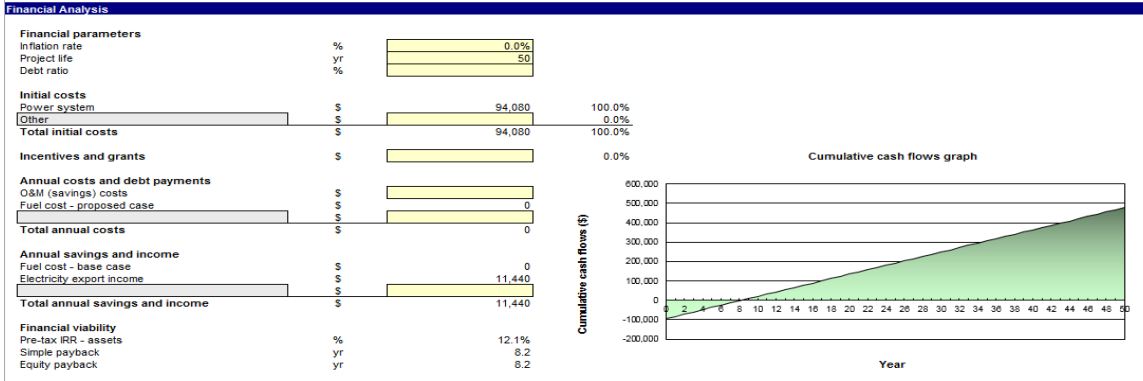


Figure 12: RETScreen Analysis for Solar PV

The results can be further analyzed in Appendix A: RETScreen Analysis

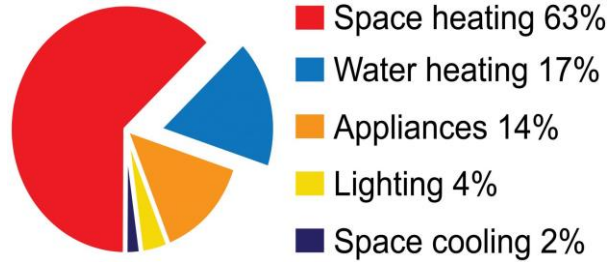
Lighting

LED Lighting will be suggested because they are energy efficient, durable and have an exceptionally long operational lifetime expectation.

Solar Hot Water

According to the Natural Resource Canada chart below, average residential water heating accounts for approximately 17% of annual energy use. It is our intention to minimize this heating requirement by installing solar hot water heaters on the rooftop of the residence. The sun heats the absorber plate and this heat is then transferred to a glycol mixture that transfers the solar energy to the solar storage tank located in the mechanical penthouse. The system is estimated to offset 46% of the annual heating load for the building.

Residential energy use in Canada by activity, 2010



The following SHW collectors were sourced to perform a RETScreen analysis.

Type	Evacuated	
Manufacturer	Solargenix Energy	
Model	Winston Series CPC WS0503	
Gross area per solar collector	2.239	m ²
Aperture area per solar collector	2.091	m ²
Fr (tau alpha) coefficient	0.6	
Fr UL coefficient	5.679	(W/m ²)/°C
Temperature coefficient for Fr UL	0	(W/m ²)/°C ²
Solar collector area	76.126	m ²
Capacity	49.7658	kW
Number of collectors	34	
Installation Cost Per Unit*	\$5,500.00	
Total Installation Cost	\$187,000.00	

The results of this analysis indicate that the installation of solar hot water collectors is not feasible. However, the collectors would offset a significant percentage of the building's annual heating load. Although these systems may not be attractive at the present time, we believe that future rising energy costs may make this an attractive and viable option. The results can be assessed below:

Resource assessment

Solar tracking mode	:	Fixed
Slope	:	40.1
Azimuth	:	180.0

Show data

	Daily solar radiation - horizontal		Daily solar radiation - tilted		
	Month	kWh/m ² /d	Month	kWh/m ² /d	
January	1.68	0.77	January	1.68	0.77
February	2.28	1.07	February	2.28	1.07
March	3.60	1.60	March	3.60	1.60
April	4.90	3.05	April	4.90	3.05
May	5.36	3.99	May	5.36	3.99
June	5.82	4.68	June	5.82	4.68
July	6.18	4.67	July	6.18	4.67
August	5.28	3.56	August	5.28	3.56
September	3.90	2.06	September	3.90	2.06
October	2.50	1.06	October	2.50	1.06
November	1.28	0.71	November	1.28	0.71
December	1.18	0.61	December	1.18	0.61
Annual	3.67	2.33	Annual	3.67	2.33
Annual solar radiation - horizontal	MWh/m ²	1.34	Annual solar radiation - tilted	MWh/m ²	0.85

Heating system

Project verification

		Base case	Proposed case	
Heated floor area for building	m ²	4,969	4,969	
Heating load for building	W/m ²	6	3	
Domestic hot water heating base demand	%	0%	0%	
Total heating	MWh	63	34	46%

Heating system

		Natural gas - m ³	Natural gas - m ³	
Fuel type		89%	89%	
Seasonal efficiency				
Fuel consumption - annual	m ³	6,749.2	3,631.6	m ³
Fuel rate	\$/m ³	0.228	0.228	\$/m ³
Fuel cost	\$	1,539	828	

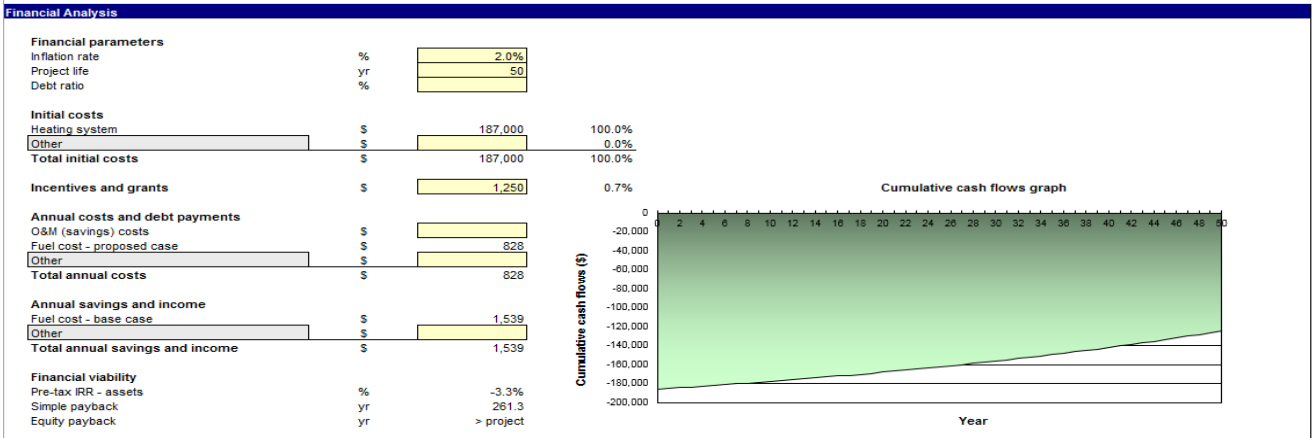


Figure 13: RETScreen Analysis for Solar Hot Water

These results can be further analyzed in Appendix A: RETScreen Analysis.

A Cost Effective Concept

A cost analysis was performed to confirm the feasibility of developing a low impact building opposed to a traditional build. RSMeans costing data and manufacturer pricing was used to determine the total cost of the proposed structural, mechanical, electrical, and sustainable systems. The overall proposed building cost was compared against RSMeans costing for a 4-8-story campus dormitory. The table below showcases the final costs and the resulting reduction for the proposed building case.

Total	4,677,817.08
Contractor Fees:	
General Requirements	10%
Overhead	5%
Profit	10%
Architect Fees:	7%
Contingencies	50%
Total Fees	82%
Total Fee Cost (\$)	3,835,810.01
Total Proposed Building Cost (\$)	8,513,627.09
Total Base Building Cost (\$)	35,885,336.00
Cost Reduction	76%

It must be noted that contingencies were included to account for any building costs that may have been unaccounted for.

A detailed material and cost breakdown can be found in Appendix B:
Construction Assembly Costing

Conclusion

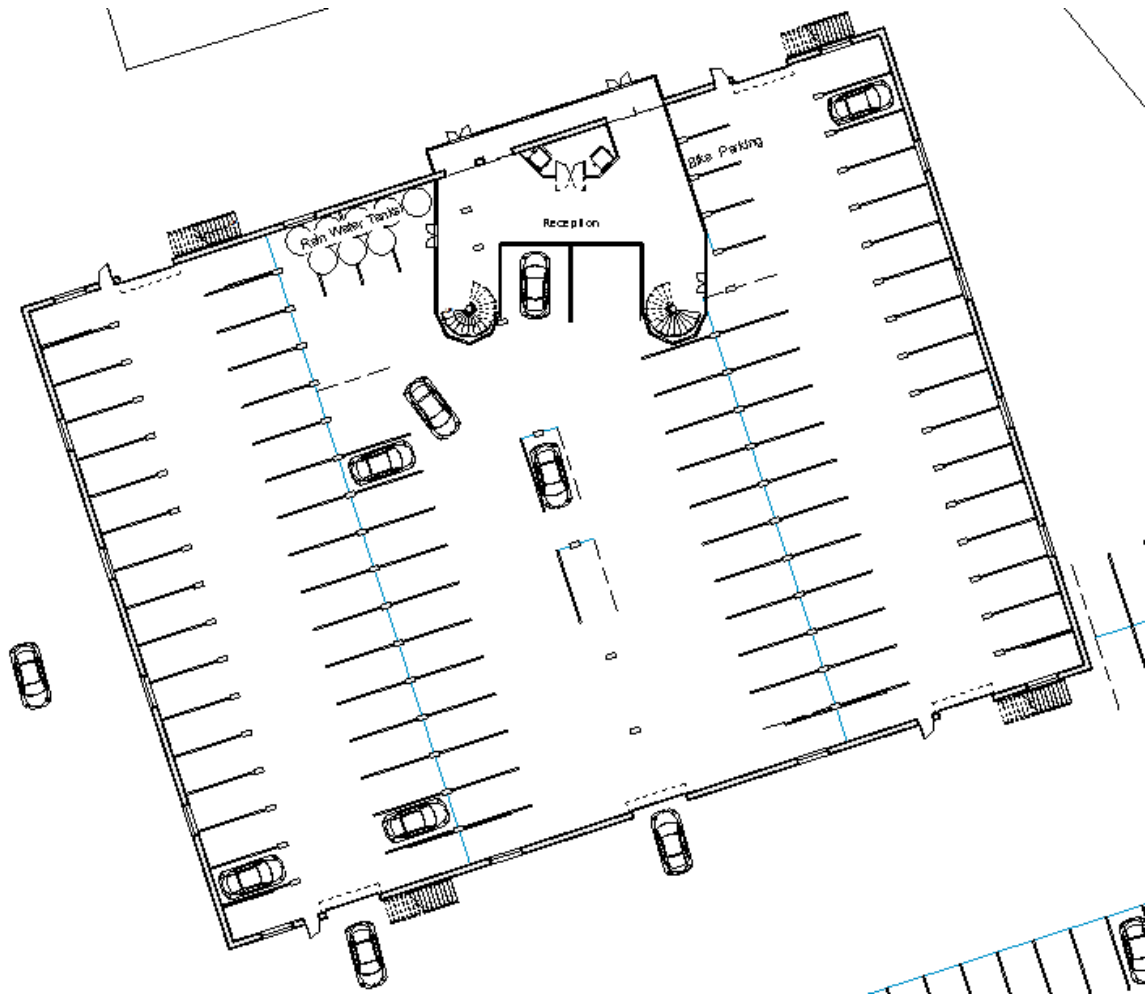
As Humber College continues to strengthen its sustainability strategy, the importance of energy and water management will become increasingly apparent. As the college continues to expand the need for on-campus living accommodations will become necessary. With present interest in reducing reliance on municipal electricity and natural gas distributors, we have developed an opportunity to help achieve this by designing a residence with core focuses on energy management and community living. This residence will further solidify the school's mandate for embracing sustainability and focusing on social justice, environmental preservation and economic viability. It will not only reduce the school's reliability on municipal energy distributors, but will also showcase an innovative, progressive drive to reduce the schools environmental impact. The opportunity to be at the forefront of on-campus sustainable building innovation is present. **With great risk comes great reward and this project presents an opportunity to be the change.**

Appendix List

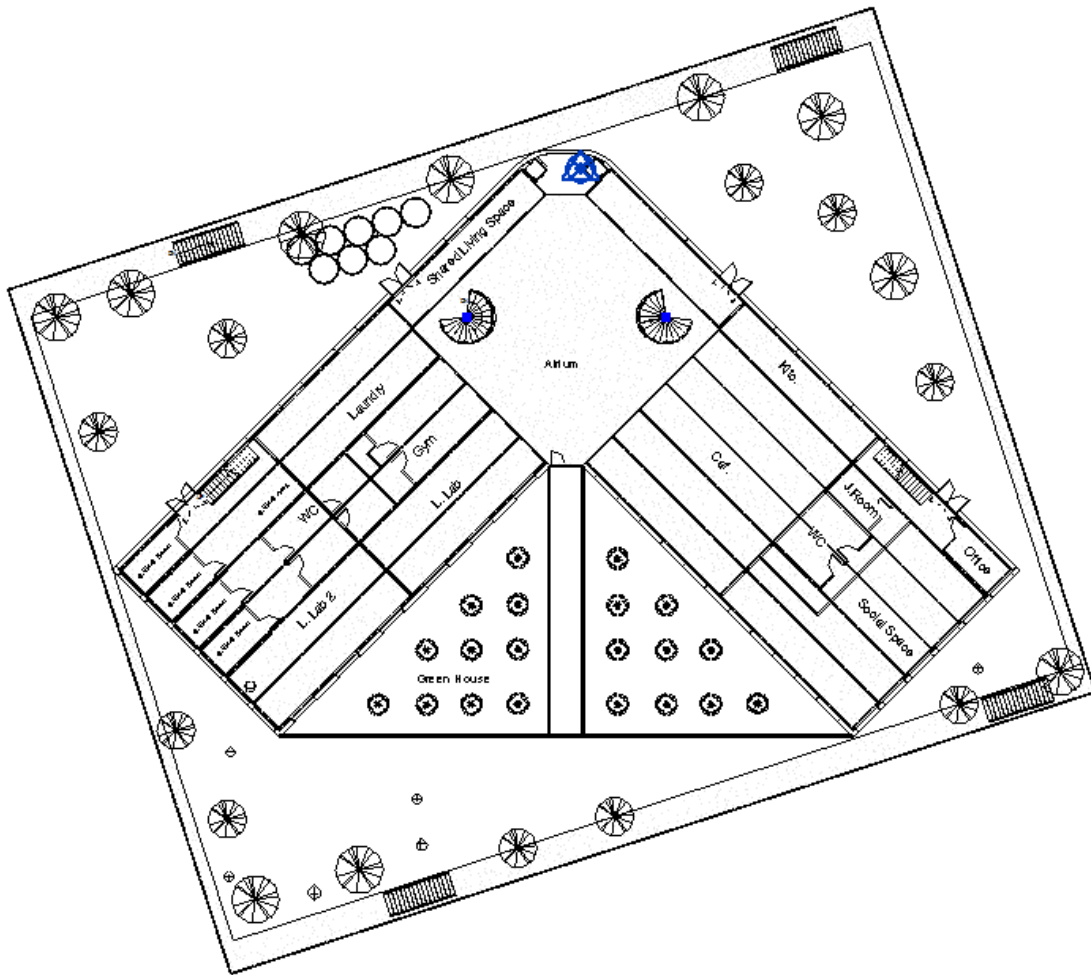
- Appendix A: RETScreen Analysis
- Appendix B: Construction Assembly Costing
- Appendix C: Floor Plans
- Appendix D: Revit Model

APPENDIX C Floor Plans

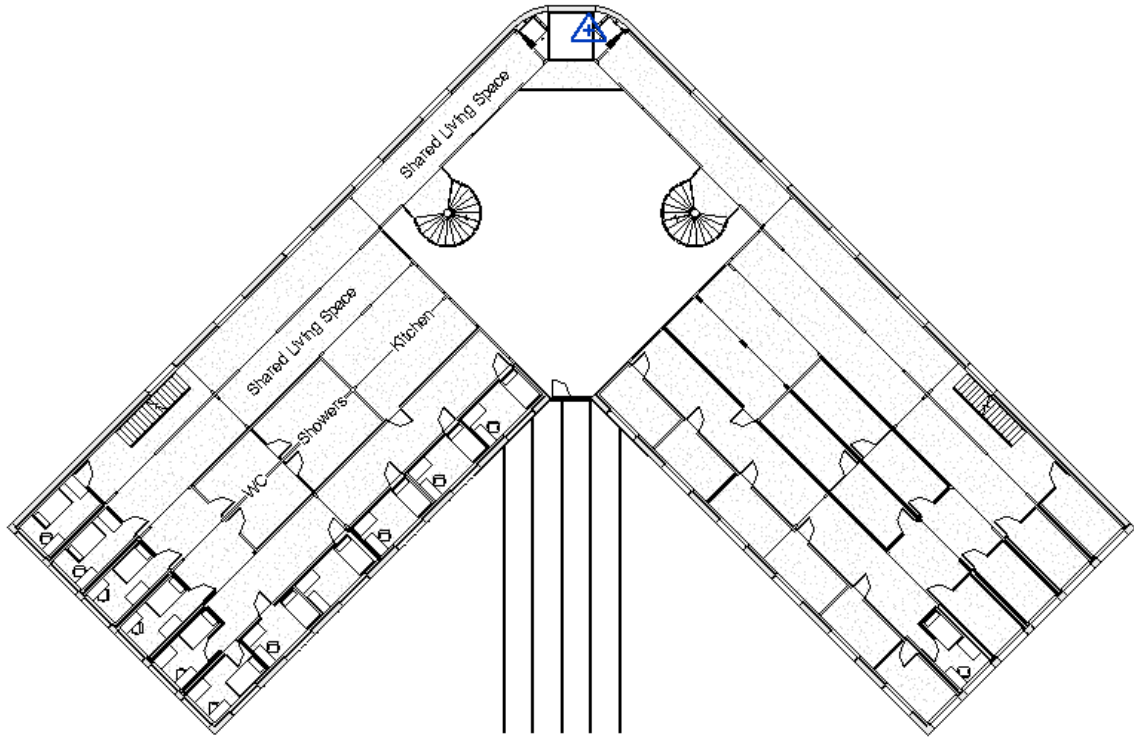
Parking



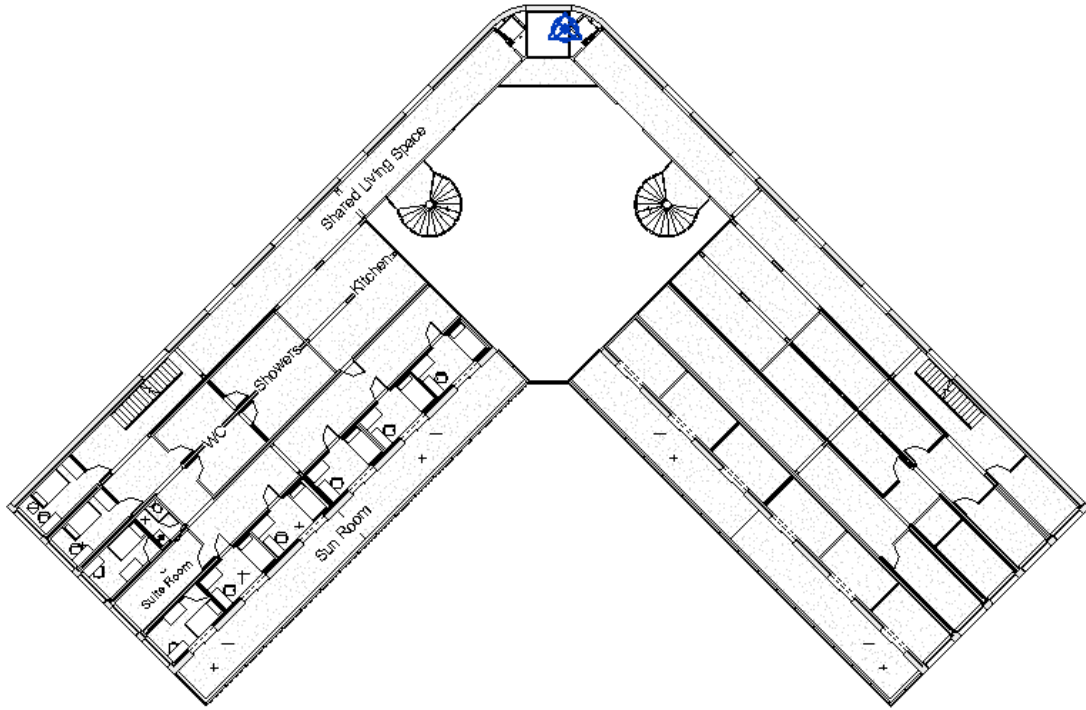
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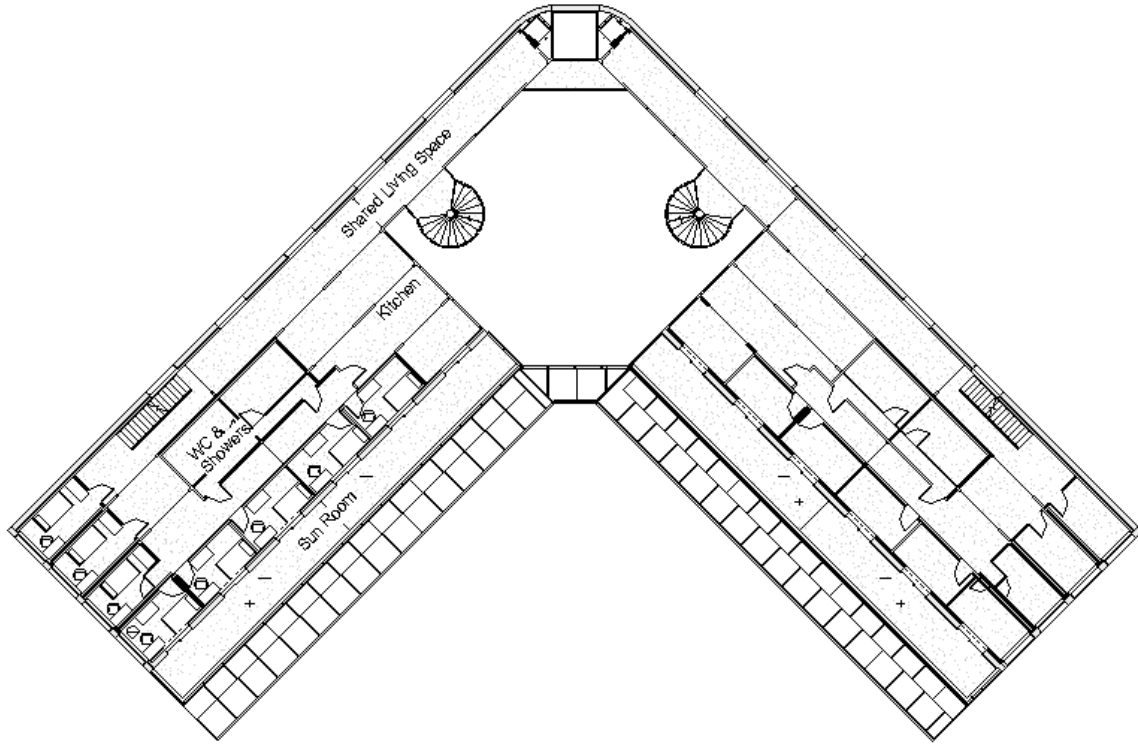
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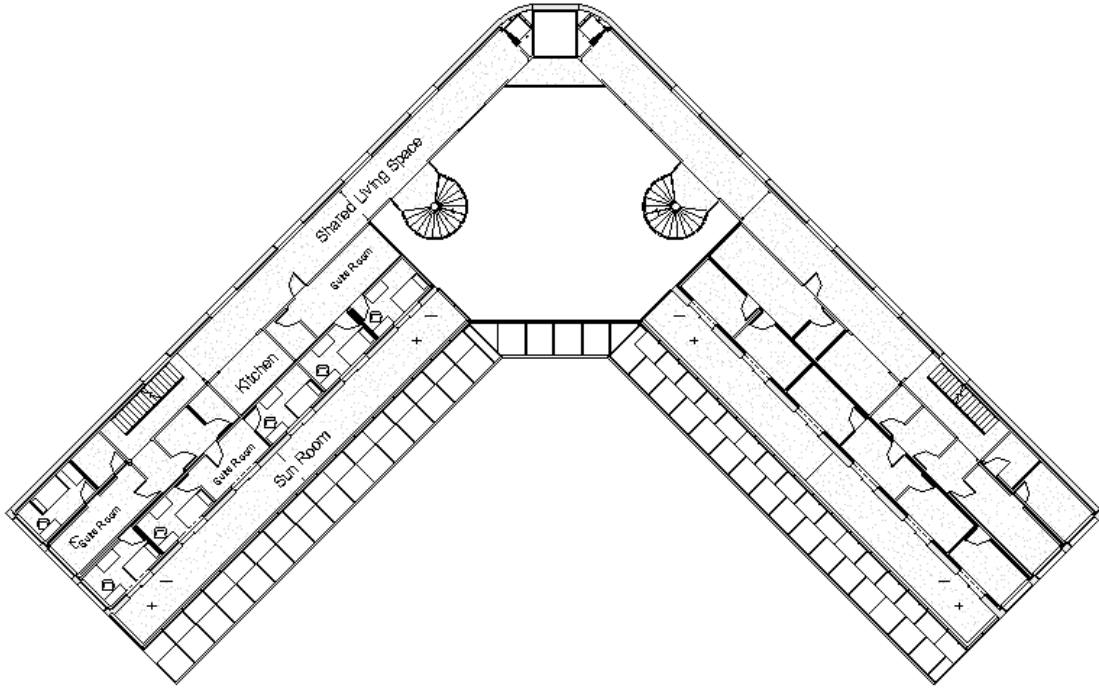
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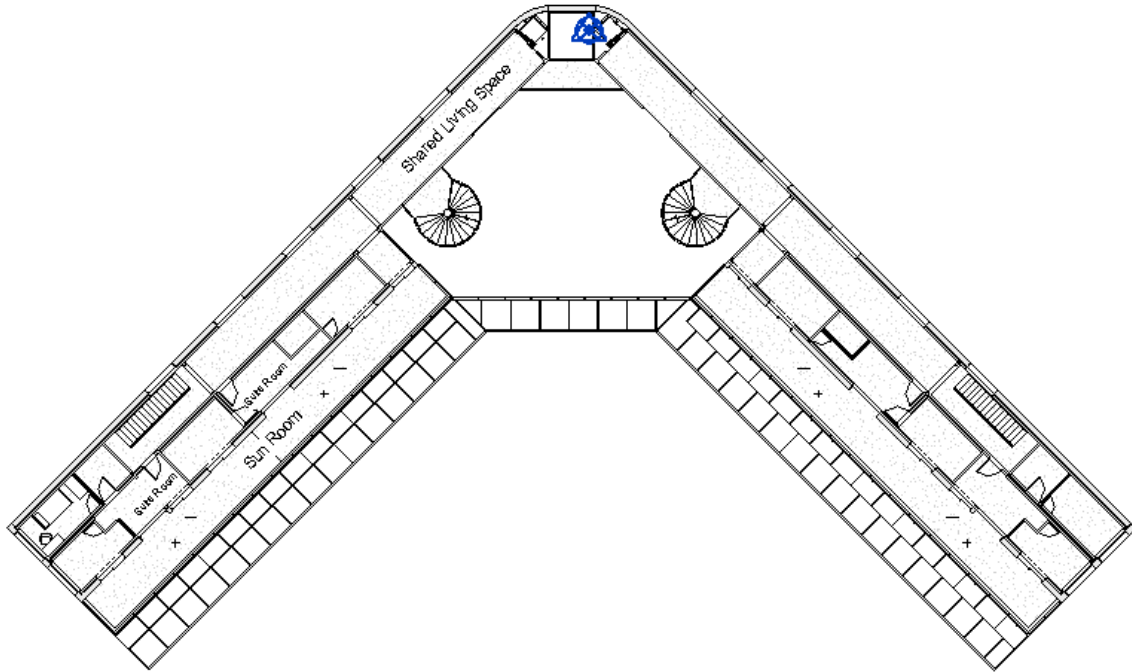
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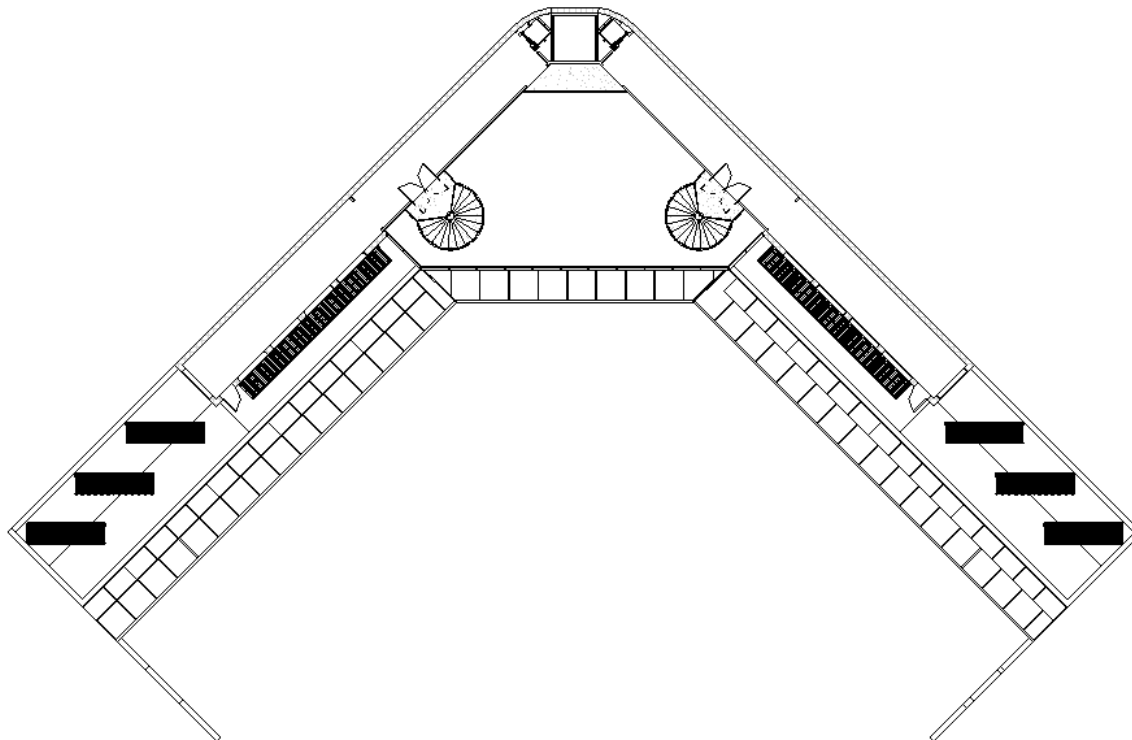
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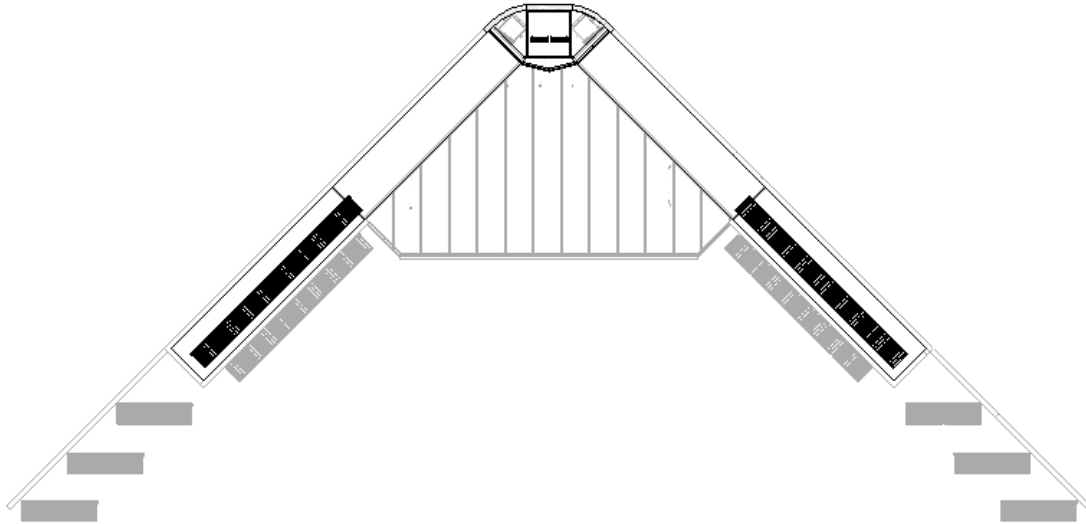
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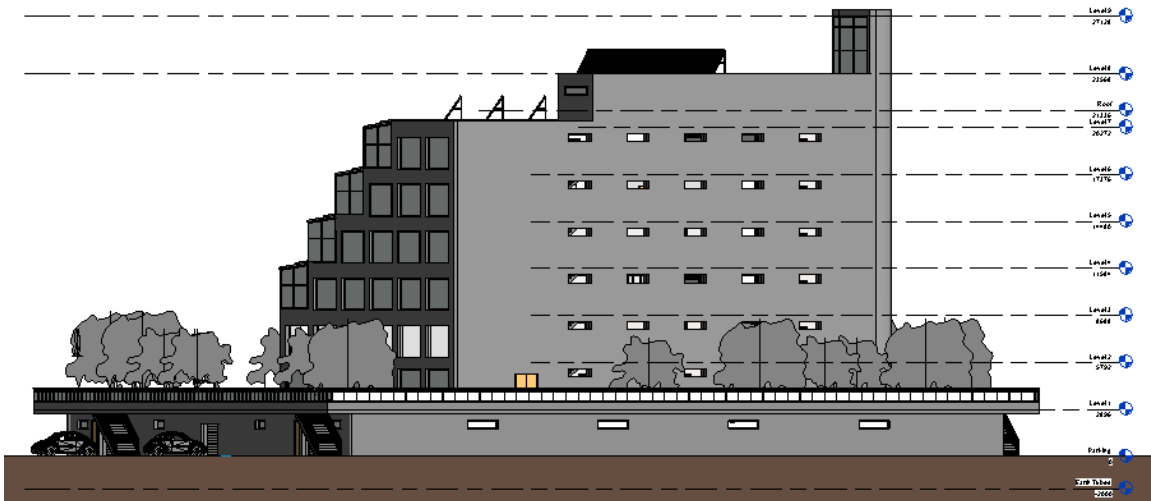
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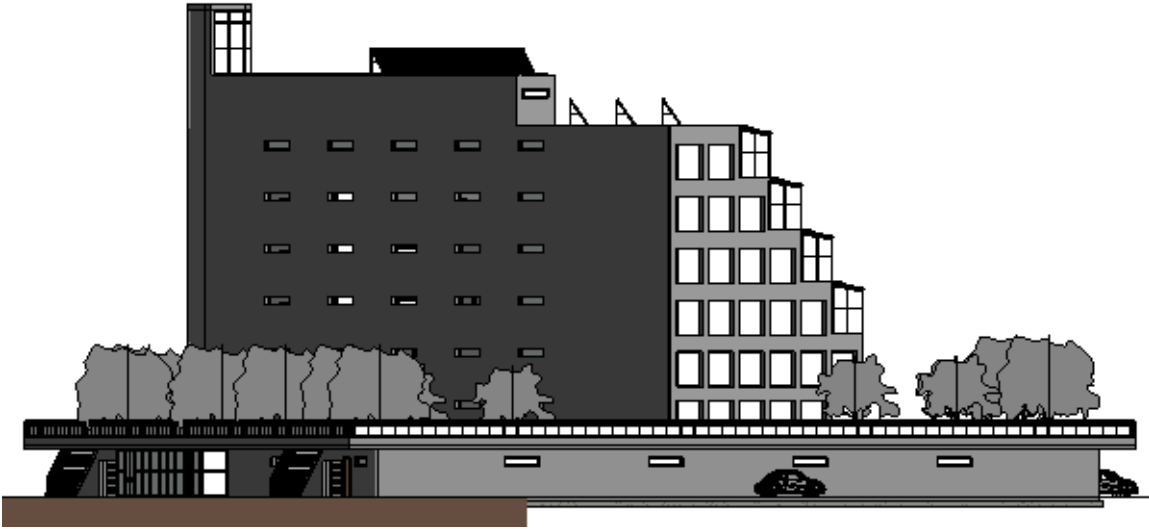
Roof



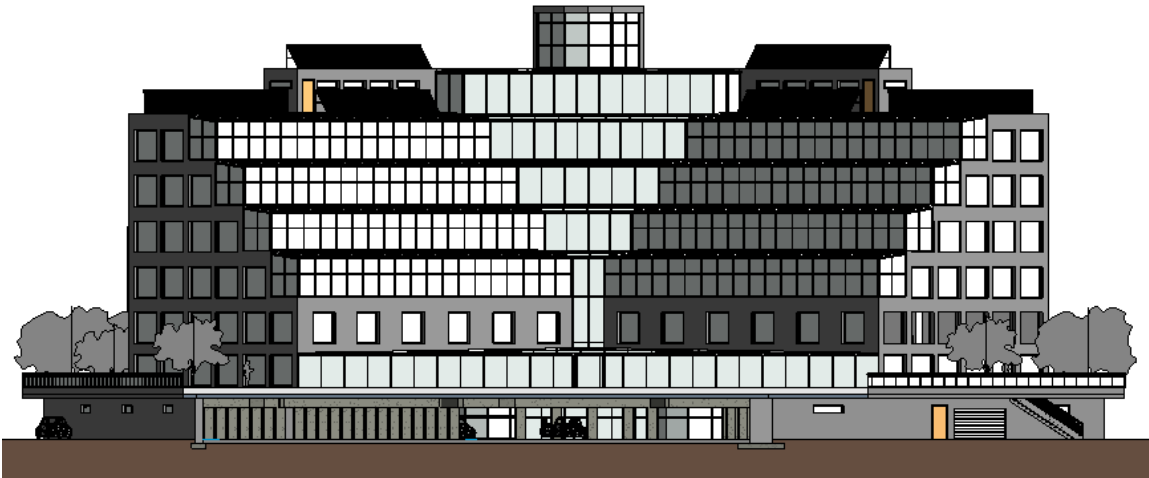
East Elevation



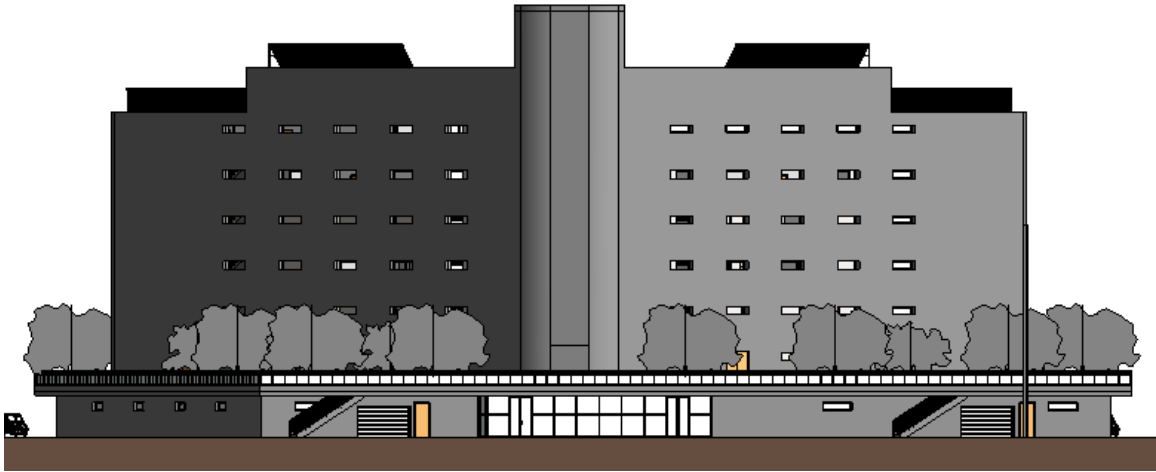
West Elevation



South Elevation



North Elevation



Site

