Design of an Affordable Wooden Tiny House

by

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Abstract

Wooden tiny houses have captured the imagination of alternative housing enthusiasts with their dollhouse facade, sustainable strategies, and quality craftsmanship. Although wooden tiny houses still baffle many people, it is a growing and potential industry that benefits many fields, such as removable hotels and public reading houses. This thesis report first presents a comprehensive literature review of some studies addressing tiny houses. Then, it discusses introducing and classifying wooden tiny houses, their design and construction, and their applications. Finally, this report describes some commonly adopted approaches to making an environmentally friendly and affordable wooden tiny house.

Keywords: Tiny house, wood structure, construction design, cost analysis, LCA analysis, affordability.

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Finally, I want to thank my parents Xialin Wang and Xianhong Zhou, for their unconditional support and assistance.

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Area Family Median Income	(AFMI)
Area Median Income	(AMI)
Accessory Dwelling Unit	(ADU)
Blanket Insulation	(BATT)
Cubic Feet	(CF)
Downward Stairs	(DN)
Dryer and Washer	(D/W)
Entrance	(EN)
Existing Level	(EL)
Footing	(FTG)
Greenhouse gas	(GHG)
Heat Recovery Ventilator	(HRV)
Insulating Performance	(U value)
Leadership in Energy and Environmental Design	(LEED)
Life Cycle Assessment	(LCA)
Linear Feet	(LF)
National Building Code of Canada	(NBCC)
Off Center	(o.c)

Oriented Strand Board	(OSB)
Recreational Vehicles	(R.V)
Relative Strength Index	(RSI)
Thermal Resistance	(R-value)
Square Feet	(SF)
Spruce Pine Fir	(SPF)
Tiny Houses on Wheels	(THOW)
United States of America	(USA)
World War 1	(WW1)
World War 2	(WW2)

1. Introduction

1.1 Definition and Types of Wooden Tiny House

The definition of what would constitute a tiny house varies widely from source to source. There are certain agreed-upon characteristics that all the sources have in common. For example, a tiny house is a small dwelling which is often built upon a mobile foundation, such as a trailer base located in a temporary location. Usually, these characteristics for a tiny house are defined as a dwelling unit container with less than 430 ft^2 (40 m^2) of interior space. This definition can encompass the majority of the agreed-upon sizing of a tiny house (Kilman, 2016). A common popular size is around 200 ft^2 (18 m^2), which is about the size of an average university dorm room. A typical tiny house on wheels is usually less than 8 by 20 ft (2.4 by 6.1m), with livable space totalling up to 120 ft^2 (11 m^2). The reasons for this choice in size are that it would exempt from needing a building permit and facilitate the ability to tow the tiny house (Boothe Sr, 2017). Although the choice in size does exempt it from needing a building permit, it does come with some restrictions, as many of the tiny houses conflicts with zoning regulations and building code requirements. These factors make the building of tiny house communities strife with nimbyism from the residents of the communities surrounding them (Zhang *et al.*, 2022).

Although the size factor is an important consideration for the definition of a tiny house, whether the tiny house has any type of mobility is also one of the determining factors in the classification of the tiny house. A summary of the typology of the tiny house defined by Sharer's report is shown in Tables 1 and 2, which can be used to classify the two major groups of tiny houses. The two major groups of tiny houses are mobile and permanent, each of which can be classified into three groups in terms of their mobility and their purpose. For example, semi-mobile tiny houses or semi-permanent tiny houses, where the main encapsulated idea of the mobile type, would constitute a house that can be used in a place for a few months and then later moved to another location. Each of these categories has its own unique characteristics and classifications.

Type 1 is a tiny mobile house. The category is divided into iconic tiny houses on trailers, semi-permanent tiny houses, and fully mobile dwellings. The semi-permanent tiny house relies on towing machines to settle at a specific location (Shearer, 2018). Compared with the other two, it stays the longest in one location. Differing from tiny houses on a trailer which car hauls the tiny house, fully mobile dwellings including Recreational Vehicles (RVs), boats, and tents, can move without means of transportation. It is highly mobile. In some countries, people do not see RVs as tiny houses.

Type 2 is a tiny permanent house. The category includes purpose-built tiny houses/cottages, converted non-residential buildings and tiny house apartments in tiny house villages (Shearer, 2018). Purpose-built tiny houses and tiny houses in a tiny house village are fully legal. Purpose-built tiny houses are usually built in private rural/rural residential areas for individual purposes. Tiny house villages usually get support from the government as an exploration of a sustainable lifestyle or be invested by hotel enterprises as a selling point to be close to nature. Converted non-residential buildings are sometimes illegal since it is hard to meet some basic building codes.

Table 1 Type 1. Mobile Tiny House (Shearer, 2018)

Type 1. Mobile			
Typology	1a	1b	1c
Brief description	− Iconic tiny house on a trailer − Mobile, on a trailer.	− Relocatable tiny house, moved to the site, then fixed or semi-permanent. − Prefab, cabin, shipping container, “tiny house,” mine hut, kit home, etc.	− Fully mobile dwellings (Caravans, boats, buses, trucks, tents, tepees) − Highly mobile and often temporary structures
Size	< max dimensions allowable (around 20 m^2 or <3.5 Tonnes (EU))	< max dimensions allowable (around 20 m^2 or <3.5 Tonnes (EU))	Very small (smaller than 1a and 1b)
Ownership and costs	− Owner/friends/family built. − House fully owned, trailer and vehicle that are possibly financed.	− Owner/friends/family build purchased second-hand or as a kit. − Cost (likely to be greater than 1a). − House often fully owned, land owned, mortgaged, or rented.	− Not generally built from scratch, purchased new/used or repurposed (e.g., bus/truck) − Cost, varies wildly (<$1,000–$100,000+) − Environmental ethos as per the tiny house movement
Legal	Legal as a “caravan” or RV varies depending on the location	Legal as primary/secondary/ancillary dwelling on own or rented land	Legal to park in designated areas, such as caravan parks, free camping, and state forests; if on other (friends/family)
Location	Moves from construction sites	Moved infrequently (<6 months is the	

	to permanent or semi-permanent sites in urban or rural land, free campsites, friends/family land, caravan parks	general minimum lease time)	property, time permitted depends on the council.
Environmental and community focus	Have a strong environmental focus and be often off-grid. Can have a community focus	No specific environmental or community focus (other than the individual)	Often a strong community focus. Environmental sustainability is not a prime motive; it depends on the individual.
Figure source: https://image.baidu.com			

Table 2 Type 2. Permanent Tiny House (Shearer, 2018)

Type 2. Permanent (non-mobile)			
Typology	2a	2b	2c
Brief description	Purpose-built tiny house/cottage	Converted non-residential building (shed, garage, barn)	Tiny house village (apartment complex/cottage/townhouse in intentional or co-housing community).
Size	Generally, under 50 m^2	Under 70 m^2	Generally, the individual's private space is small (mostly under 40 m^2), with shared facilities (i.e.,

			kitchen, garden, tools)
Function and Location	− Semi/detached, usually built by a registered builder or owner, friends, and family. − Generally, in a rural/rural residential area	− Can be a temporary dwelling but is not usually moved. − Detached or semi-detached (attached to a larger property) − Located in all areas, from suburban to rural	− Designs vary widely and may include “alternate” dwellings such as converted railway carriages and yurts. − Located from city centers to rural and regional areas.
Ownership and cost	Cost (varies widely, likely $50 k plus, depending on construction material, builders)	Cost: Mostly relatively inexpensive <$20,000.	− Cost is variable and depends on tenure and location. − Either rented or owned or subject to alternate tenures such as tenants in common or social housing
Legal	Fully legal (subject to council restrictions, such as on potable water and sewage) on own land.	Legal, but councils differ widely regarding these dwellings and the length of permitted residence.	Fully legal in many countries.
Environmental and community focus	No particular environmental or community focus (other than the individual)	No particular environmental or community focus (other than the individual)	Frequently have a strong fundamental ecological and/or social philosophy and rules.

Figure source: https://image.baidu.com			

1.2 History of Tiny Houses

The concept of small homes is not new to the public. Table 3 shows the evolution of tiny and small house living.

Table 3 Evolution of Tiny and Small House Living (Evans, 2017)

Tiny/small house term	*Concept*
Vernacular small home	Historically, small homes that took local building materials and traditions into account are common. Examples include the frontier log cabin, bungalow, cottage, and camp. In Canada, vernacular small homes appeared between the 17th and 18th centuries as colonial immigrants moved into Canada. In the late medieval mixed used houses using vernacular architecture were common with the peasants. The closest thing to a modern historical house in Canada using vernacular architecture would be the Acadian houses in New Brunswick pre-expulsion (1755), as their houses were framed houses, mentioned by Pierre Boucher in 1663 (Edwards, 2018)

Accessory dwelling unit (ADU)	An ADU is a smaller housing unit on the same property as a main or primary dwelling. ADUs traditionally served such purposes as housing for servants, elderly parents, and newlyweds. Sometimes termed alley or granny flats, ADUs are experiencing a resurgence in popularity. The popularity of ADU in Canada skyrocketed because of the economic crisis of 1929 and lost its popularity during the 1950s to 1960s because of the prosperous economic situation (Arpent, 2018). ADUs experienced a resurgence in popularity in 1970 and 1990 as the economic stagnation and fears of the uncertain economic environment. Most slave housing between the 1800s-1900s would also classify as an ADU, but they would also count as vernacular small houses, as they followed vernacular architecture (Dumas et al., 2017).
Prefabricated small home kits	To address a post-WWI affordable housing shortage, companies such as Sears and Roebuck sold popular small home mail-order home kits, which included all necessary building materials and could be easily delivered via train. The Sears Catalog was the most popular for selling home kits; they sold over 70000 from 1908 to 1940 (Rare Historical Photos, 2023). They experienced a short-lived resurgence between

	1950 to 1960, as they were used as a solution to the housing crisis after WWII. (Built Prefabs, 2023)
Mobile home	Shortly after the advent of the automobile, the mobile home emerged. Mass-produced and easy to deliver, the mobile home offered an affordable housing solution to poorer classes. The first examples of mobile homes are credited to the Roma(ni) people, often known as Gypsies, of the 1500s, known for their nomadic culture and lifestyle. These homes were drawn by horses. In the United States, the first mobile homes were built in the 1870s; the first to be drawn by automobiles appeared in 1926 and were called 'trailer coaches' (Bellis, 2019).
Manufactured home	The term "manufactured housing" replaced the "mobile home" when federal regulations enacted manufacturing standards for such homes in 1976. However, the terms are still used interchangeably to describe this type of smaller home, which frequently faces community opposition.

Counterculture living	In the 1960s and 70s, countercultural living arrangements grew in popularity and promoted values such as communal living and environmental stewardship. Precursors of today’s tiny house designs arose during this era, such as buses converted into dwellings, small geodesic domes, and hay bale homes.
Tiny House	The tiny house movement arose during the early 2000s to address a variety of concerns: such as quality-of-life factors, environmental concerns, and rising debt. Though no formal definition exists, many advocates contend that a tiny home is 430 ft^2 or smaller.
Tiny houses on wheels (THOW)	THOWs offer both downsized and mobile living and have become associated with the tiny house movement itself. However, THOW dwellers are often at a loss for where to put such structures due to current zoning and land use laws.

Tiny houses develop with different policies at different times. There are several driving forces behind the growing tiny house movement. Among them are increased environmental concerns, a growing dissatisfaction with excessive materialism, a greater cultural awareness of the American cycle of debt, and a desire to use small structures as a practical means of housing the poor and homeless (Gauer, 2004; Anson, 2014; Heben, 2014).

Historical examples of vernacular small home designs include the frontier log cabin, bungalow, cottage, shotgun house and camp (Comstock, 2007; Walker, 2013). Also, in the past, tiny houses were used to house servants, elderly parents, and newlyweds. After World War I (WWI), the Architect's Small House Bureau was established in 1919 to assist returning veterans with homeownership (Hunter, 1999). This organization provided architectural plans for small homes (approximately 800 ~ 1,000 ft^2 (74 ~ 93m^2)) suitable for small lots (30 to 50 feet (9 ~ 15m) wide) at a nominal fee to potential homebuilders (Hunter, 1999). Affordable housing packages became common when the industrial assembly line swept across the nation as a popular means of production. Mobile homes emerged as automobile and assembly line production grew in popularity. With the enactment of federal regulation about creating manufacturing standards for such homes in 1976, the term "mobile home" was replaced with "manufactured housing" (Evans, 2017). With the change in people's thinking, the rise of counterculture, and the enactment of zoning codes, tiny house dwelling has emerged largely as a counterculture movement. Because of its emphasis on alternative lifestyles, the tiny house movement can be loosely linked to the various alternative communities that arose in the 1960s and 1970s for similar reasons. (Evans, 2017).

Though today's tiny house movement may lack the communal element typical to many of these prior alternative communities, it shares the desire to achieve simplified, meaningful lifestyles that put people, relationships, and value systems first.

Nowadays, a solution was proposed to use tiny homes for mobile housing for busy travellers (Shahani, 2015), temporary housing and guest homes (Hunter, 2015; Robinson, 2016), housing for the homeless (Priesnitz, 2014; Johnson, 2016), and as a general solution for housing in urban areas that host large populations in limited space (Priesnitz, 2014; Maghribi *et al.*, 2015).

People are still searching for alternative living arrangements that allow for the pursuit of meaningful and holistic lives in a system many perceive as oppressive. Some people view tiny house living as a potential way to achieve such a countercultural lifestyle (Evans, 2017).

1.3 The Potential of Tiny House

Tiny houses conceptualize the city in diverse ways.

- Tiny houses are affordable and can reduce economic burden compared to traditional houses. The issue of increasing land prices exists in almost every country around the world, including developed countries (such as European countries and the USA). Tiny houses occupy less space and could be an affordable method to help solve the growing housing shortage. Also, living in a tiny house consume less electricity, water, telecommunications, heating, cooling, cooking, and transportation. Under these conditions, monthly housing expenditure can be reduced.
- In the study from Harvard, it is estimated that 30% of Americans are cost-burdened by their housing situation, using more than 30% of their income on housing. Tiny

houses can offer a more affordable place to stay for the affected members of low-income households. (Zhang *et al*., 2022)

- Tiny houses have a smaller environmental footprint. The residential construction sector consumes 40% of the world's total resources and subsidizes more than a third of global greenhouse gas emissions. The promotion of 'efficient houses' as a response to these threats seems plausible (Carvalho, 2019). Since a tiny house is small, it needs less material to manufacture, which in turn means lower emissions associated with transportation. Figure 1 compares GHG emissions associated with tiny and traditional houses, showing the lower environmental impact of the former.

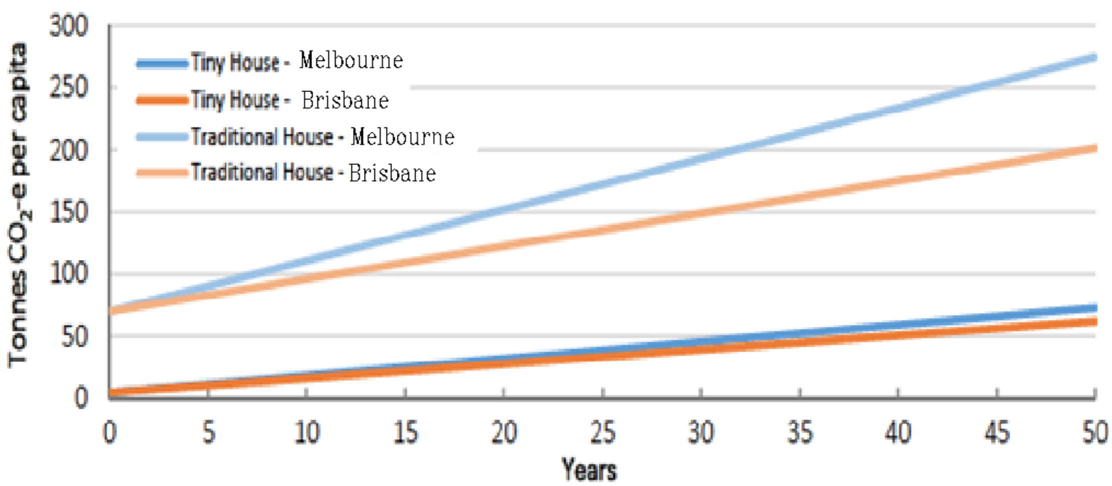


Figure 1 Life Cycle GHG Emissions of Tiny Houses and Traditional Houses in Melbourne and Brisbane (Source: Crawford et al., 2020)

- Tiny houses can alter the owner's mindset. People who live in tiny houses tend to accept the ideas of minimization of consumption, adoption of sustainable living strategies, and emphasis on strong, local relationships over time (Kilman, 2016). Because of the limited space, people purchase only what they definitely need, thereby reducing impulse consumption. It can cut the excess expenditure on useless or site-occupied furnishings and reduce the chance of impulse consumption. Moreover, for mobile tiny homes and tiny homes off, grid resources such as water and power tend to be scarcer in tiny houses, discouraging waste. This new lifestyle would also contribute to environmental protection.

- Tiny houses strengthen the relationship between people and the community. Living in a house with few resources, people tend to focus on neighbours' mutual help and use communal facilities to the maximum. People living in tiny houses would go to the library, bathhouse, and gym more often than those in traditional houses.

1.4 Objective and Scope of Work

The objective of this thesis report was:

1) Creating a comprehensive cost analysis of building a wooden tiny house designed.
2) Reviewing the concepts and philosophy of tiny houses and their impacts on the everyday lives of the citizens and communities.
3) Assessing the environmental impacts of constructing a wooden tiny house.

4) Exploring regulatory and legal considerations to leverage on the building of the wooden tiny house to mitigate some of the cost via tax/grant benefits.
5) Reviewing the architectural calculations and general design of the proposed wooden tiny house that conforms to or exceeds the requirements stipulated in the building codes.

The scope of work is as follows:

1) Design of the wooden tiny house
2) Estimation of the cost of construction.
3) Material selection. The materials for constructing the tiny house were selected based on affordability, sustainability, durability, and environmental impacts.
4) Life cycle analysis report. The report was created to evaluate the cradle-to-grave environmental impact of the tiny house.

1.5 Organization of Thesis Report

This thesis was structured to present a comprehensive exploration of the design of a proposed wooden tiny house, which contains five chapters. Chapter 1 provides a background on what qualifies as a tiny house and the different categories of tiny houses. Furthermore, it also covers the history of tiny houses and their potential significance in our society.

Chapter 2 illustrates the design of the wooden tiny house, covering the design concepts and philosophy, the exterior and the interior of the house, the selection of the materials for constructing the house and the reasoning behind the choice, the structural design and construction of the tiny house, the basic structural calculations, and the life cycle assessment of the house.

Chapter 3 discusses the project management, materials, and pricing of the tiny house to be constructed and the energy savings using solar panels.

Chapter 4 is an overall discussion regarding the use of proposed tiny houses and similar studies done by others.

Chapter 5 includes the general conclusions and future work of the wooden tiny house designed in this thesis report.

2. Design of a Wooden Tiny House

2.1 Subtractive Design Concept for Tiny House

Anggreani and Herlily (2021) proposed the concept of subtractive design of a tiny house, which includes the following basic principles:

1. Utilization of Vertical Space

The aim is to maximize the use of vertical spaces by turning anything above 2 meters into storage, as if not utilized, it would have become dead space. This way, dead space is reduced and can be functionally used.

2. Order and Organization of Everything

For a tiny house resident, everything has a designated storage place; following the proposed subtractive design of "a place for everything and everything in its place" helps avoid the house's overcrowding with items. Since the house has a tiny footprint, a tiny house easily becomes overcrowded; there must be a strong justification for acquiring additional items.

3. Multi-functional Items

To maximize the use of space that an item may occupy, the item should be able to serve multiple functions.

4. Frequently Used Items should be Easily Accessible.

Items that are infrequently used could be stored in relatively inaccessible places. However, for items that are used daily, common sense would suggest that they should be much more accessible than items that are rarely used. To facilitate the search for a specific item, arranging the items based on their frequency of use is recommended.

5. Purposeful Built-ins

Tiny houses benefit significantly from the use of built-ins since they reduce the use of space while still providing essential facilities such as tables, sofas, chairs, and beds. The use of built-ins is not only to create hidden furniture but can also be used to store hobby items, such as fishing equipment, guitars, and bikes, further adding to their practicality.

6. Less Meaning More

Items can be used as tools to support daily life instead of being impediments if the "less is more" approach is followed. The less is more approach focuses on reducing, organizing, and arranging the items inside the house to allow the few items that the tiny house has to be used effectively instead of becoming a burden on the homeowner.

2.2 Design of a Tiny House

Based on the above subtractive design concepts, the design of a wooden tiny house is proposed in this thesis report, Figure 2. The main goals are for this house to be environmentally friendly, aesthetically pleasing, and affordable. To achieve these, some green techniques were implemented in this proposed wooden tiny house with an aim to save energy for the house and to use local materials to reduce CO_2 emissions and other pollution during transportation. The philosophy of the design was to have a greener wooden tiny house and make this type of house more affordable, which could change the whole community and spread the idea of having a green lifestyle. Afterward, a life cycle assessment (LCA) of the tiny house was made in Section 2.2.3.

Figure 2 Rendering for the Wooden Tiny House.

2.2.1 Exterior Design

Figure 3 Exterior outlook of the building

Figure 3 shows the exterior of a wooden tiny house located in Fredericton, New Brunswick, Canada. The climate in New Brunswick tends to be continental, though tempered by proximity to the ocean. It has a long winter, 6 months or more, every year. The minimum metal roof slope to make sure the snow does not accumulate above the roof is 3/12 (NBCC, 2015). The roof plan is shown in Figure 4. The roof consists of two parts. The largest part is split into two counter-placed angles. The side to the front foyer of the house places a funnel around the roof shingle for rainwater harvesting, and it mitigates the collection of snow load on the roof during winter. The back side of the roof is at a more reflex angle to avoid snow accumulation on the roof. A gutter system is only installed in the front of the roof above the entrance. There will be a gutter water catcher by the end of the post.

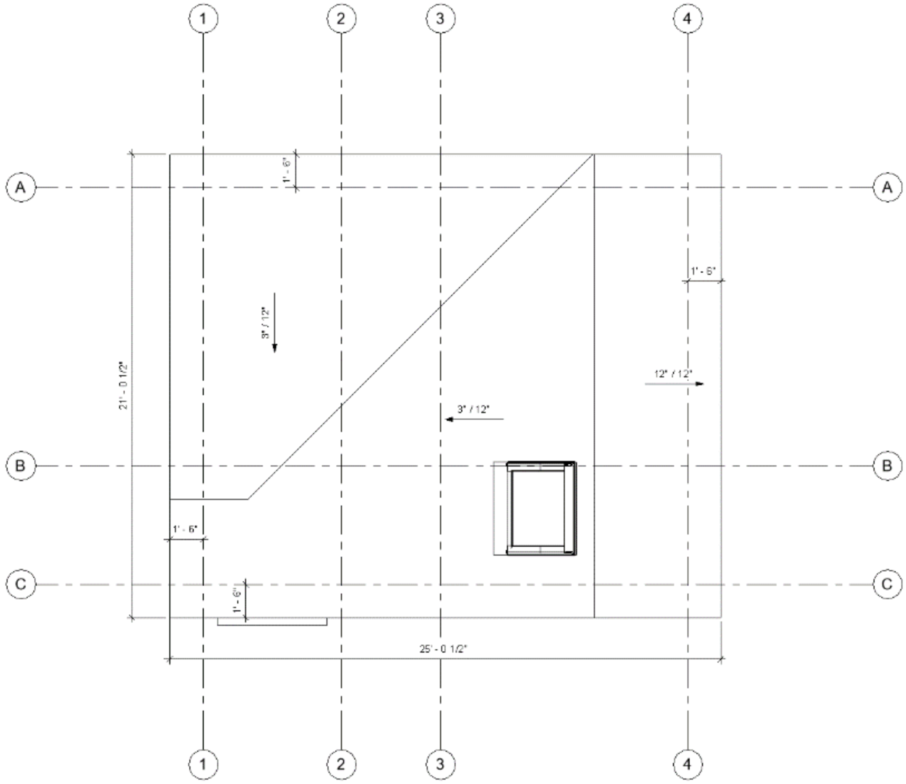


Figure 4 Roof Plan

Also, there is a skylight window on the front part of the roof above the bedroom to have a wider view, provide a sense of comfort and relief, and make the tiny size feel less oppressively small.

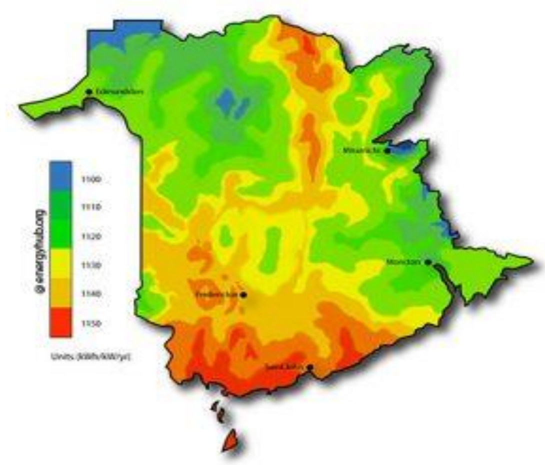
The other part of the roof is covered by solar panels, which can provide electricity for the whole house.

The solar panels used in this building will be ones that can be bought in New Brunswick Fredericton; the solar panel is the Longi Solar LR4-72HPH-450M - 450w, at a cost of

$349 and is rated for 450w while having a size of 209.40 × 103.80 × 3.50 cm (about 1.38 in), which is 23.40 ft^2. With the backside roof and the roof over the living room as space for solar panels, the proposed wooden tiny house has a total area of 347.48 ft^2; using 327.6 ft^2 of the roof with 14 panels; this solar panel array can produce around 600kWh/monthly. In Fredericton, there are 3.7 hours per day that provide peak hours for the solar panels (Omni Calculator), according to 14 panels of 450w each above, which makes the system 6.3 kW. Table 4 shows Solar Potential in New Brunswick. According to New Brunswick solar potential map table 8 and EnergyHub.org, the Fredericton region should produce around 1147kWh/kW/year, which means this system can produce 7226.1 kWh per year, which means a monthly average of 602.175 kWh/monthly. For a rough estimate of the average kWh usage of the tiny home, according to eenergyrates.ca, the average 950 ft^2 apartment in Canada uses up to 467kWh (EnerGenie, 2018). It can be concluded that the 364 ft^2 tiny home would use less than 467kWh monthly, as it has a smaller footprint than a 950 ft^2 apartment.

But with this assumption, the proposed tiny home, at maximum would use 467kWh monthly, and the system would overproduce 135kWh monthly. Using the Net Metering policy of NB power, the credit afforded should cover any higher uses of power during the colder months. The Net Metering policy allows the tiny house owner to sell all the energy produced to NB Power via their smart meter. The energy that the tiny house uses is deducted from the total that it produces. The over-produced energy will earn credits for the tiny house owner (NB Power, 2023). The excess energy will be sold to NB Power, which simultaneously tracks the energy output into the system. Therefore, there is no need for an energy capture device like a battery system. The net metering policy offers between $0.2 to $0.3 credit per excess wattage, which means the system with an estimated 135kWh excess production would offer between $27 to $40.50 of monthly credits, and the credits reset every March (SaveEnergyNB, 2023). The total cost of this system, without including labour or tax, will be $4,886.

Table 4 Solar Potential in New Brunswick (Natural Resources Canada, 2023)



Month	kWh/kW
January	78
February	96
March	113
April	105
May	109
June	111
July	112
August	113
September	103
October	83
November	60
December	60
Annual Total	**1142**

2.2.2 Interior Design

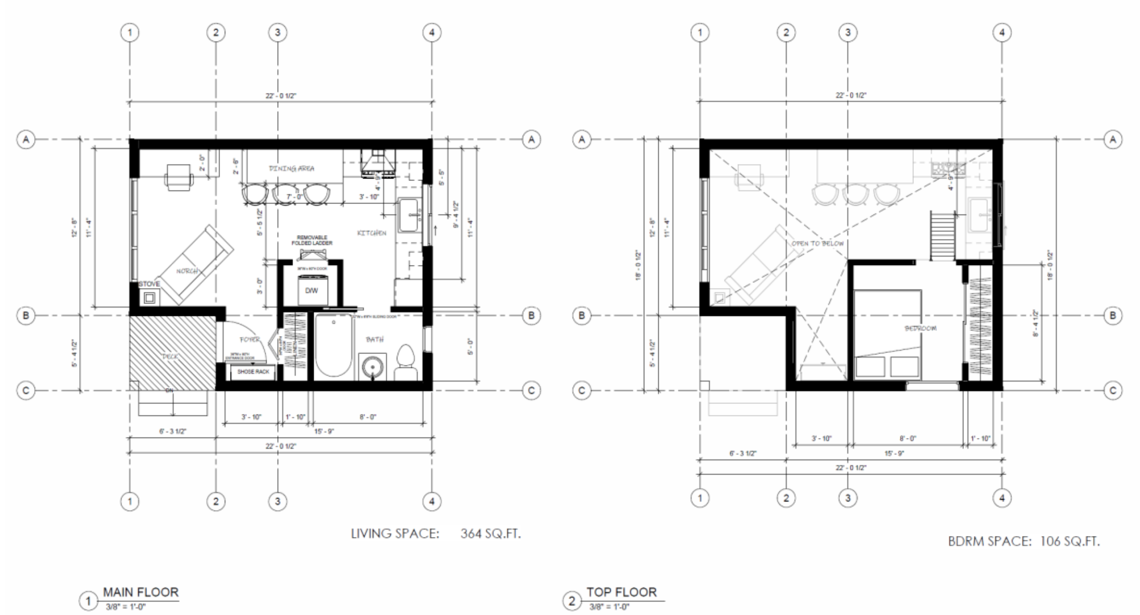


Figure 5 Floor Plan

Figure 5. shows the floor plans of the wooden tiny house. The total area is 364 ft² (33.8 m^2). It is a house for 1 or 2 people to live in. It is more like a mini version of a traditional house plan design. The ceiling height is around 8’ (2.44 m) for the main floor and extends 6’3” (1.905 m) for a bedroom above. The walls of the laundry room and the cabinet above the fridge give the bedroom support. There is a removable and foldable ladder attached to the floor joist of the loft bedroom entrance for accessing the bedroom. The ladder is usually folded and moved in front of the laundry room to save space. There is an optional office table at the notch near the dining area to enlarge the living room’s space according to people’s preferences. Window walls with transom windows in the front of the house provide a view of beautiful scenery. All roofs are cathedral roofs to make the limited headroom necessitated by the loft seem less oppressive.

2.2.3 Material Choice

Materials were chosen in terms of their sustainability, cost, and minimal maintenance. For example, floorings are made of maple hardwood produced by J.D. Irving Limited, a local wood products manufacturer. The siding is from Mitten Building product, their board and batten vinyl siding; it was selected for its minimal maintenance and low cost. Many materials were locally sourced or from local brands. The gypsum panels for the bathroom are CGC mould though sheetrock, as it is resistant to water required to give the bathroom walls a relatively long life and low maintenance, and it is made from 100% recycled materials. The windows are made from Thermopane glass, allowing the wooden tiny house to be more energy friendly and lowering the total cost of energy consumption. The roofing goes for aluminum roof panels for their minimal maintenance and sustainability, as aluminum is 100% recyclable and is made from a minimum of 30% recycled materials. The subfloor chosen is OSB polyethylene subfloor air plus, which allows the concrete underneath to breathe, reducing the chances of damage to the floor and building from moisture and mould (Home Depot, 2023).

2.2.4 Structural Design

Conventional framing, the industry standard for framing residential construction, typically consists of 2×4 (38 x 89mm) or 2×6 (38 x 140mm) wood framing spaced 16 inches (406mm) on center, double top plates, three-stud corners, multiple jack studs, double or triple headers, cripple studs, and other members that are often redundant (Canadian Wood Council, 2021). This wooden tiny house uses the traditional 16-inch spacing for studs based on the National Building Code of Canada (NBCC, 2015). This wooden tiny house also uses the advanced framing insulated two studs required by NBCC 2015 Note A-9.36.2.4 (NBCC, 2015).

2.2.4.1 Wood Framing

Figure 6 shows the whole wood framing for the wooden tiny house. Figures 7 to 10 illustrate the structure of the roof, edge of the wall, wall, and floor.

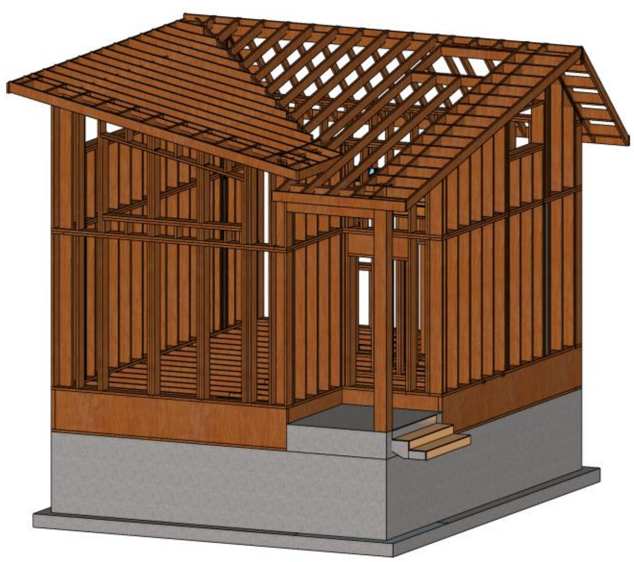


Figure 6 Wood Framing for Wooden Tiny House

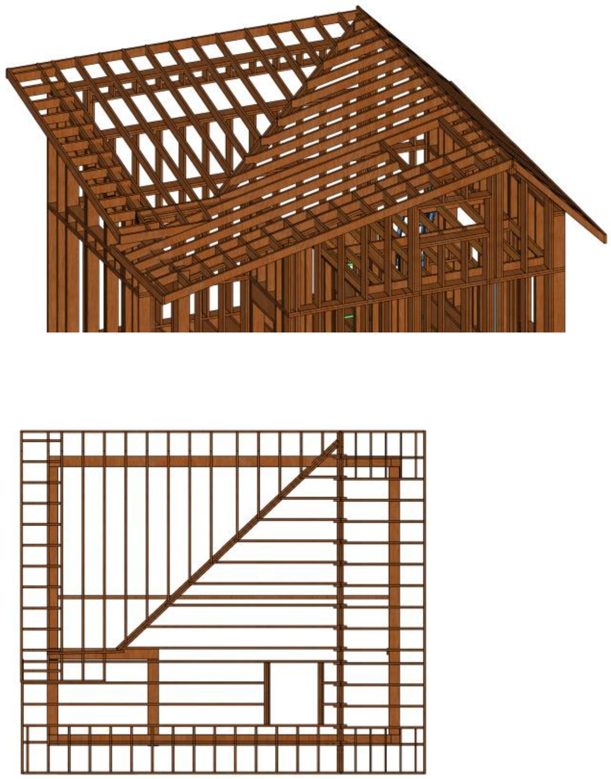


Figure 7 Roof Structure for Wooden Tiny House

Figure 7 shows the roof structure. All roofs are 1’6” overhang, using 16”-spacing wood studs vertically around for better support.

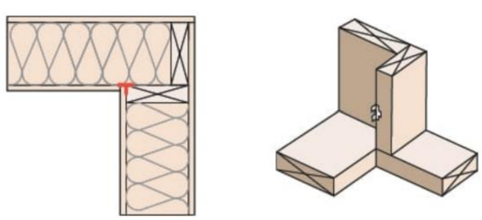


Figure 8 Edge of the Wall (source from CWC 2021)

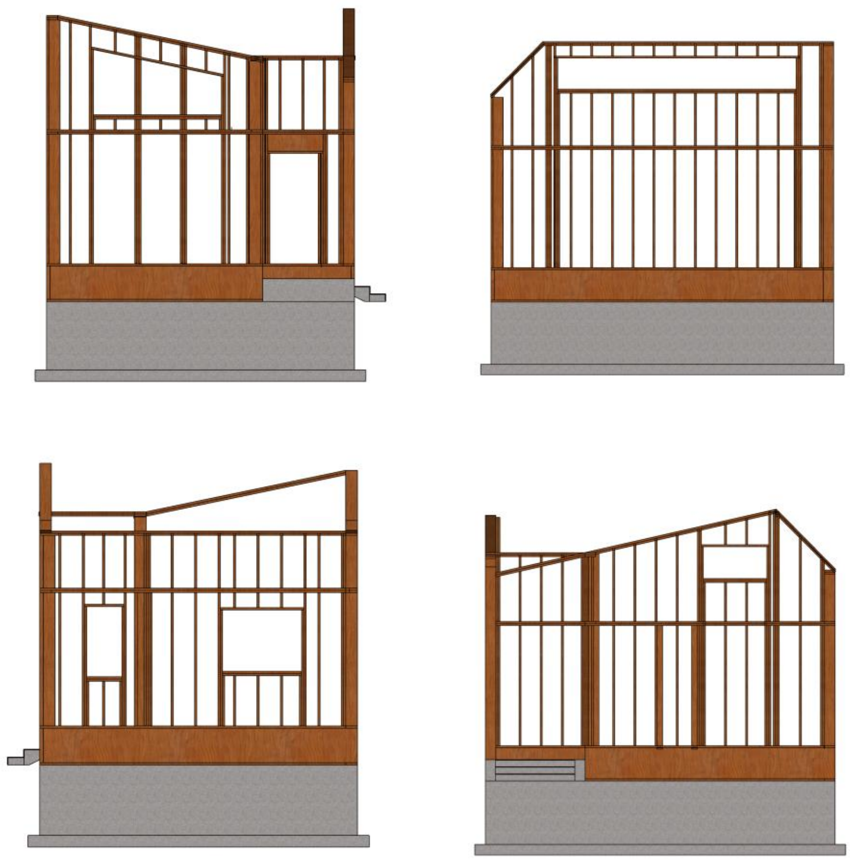


Figure 9 Four Sides of the Wall.

Figure 9 shows the wood frame on all sides of the wall. Window and door framing follows the Canada Wood Council and NBCC 2015 design. Except for that, the front look shows how to support the large window with wood studs.

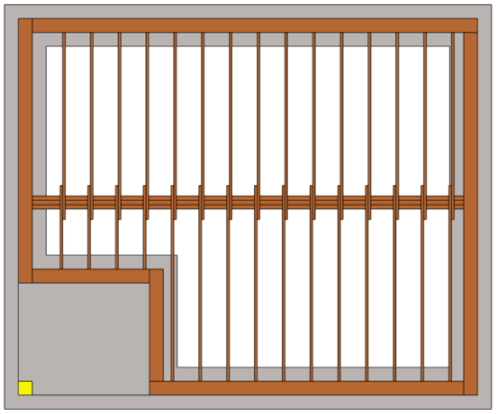


Figure 10 Floor Joist for Wooden Tiny House

Figure 10 shows the floor joist for the wooden tiny house. A beam is under the wood joist to support the joist.

2.2.4.2 Section Design

Figure 11 shows the section of the house on which side has a loft. More details of the foundation plan are shown in Appendix 2

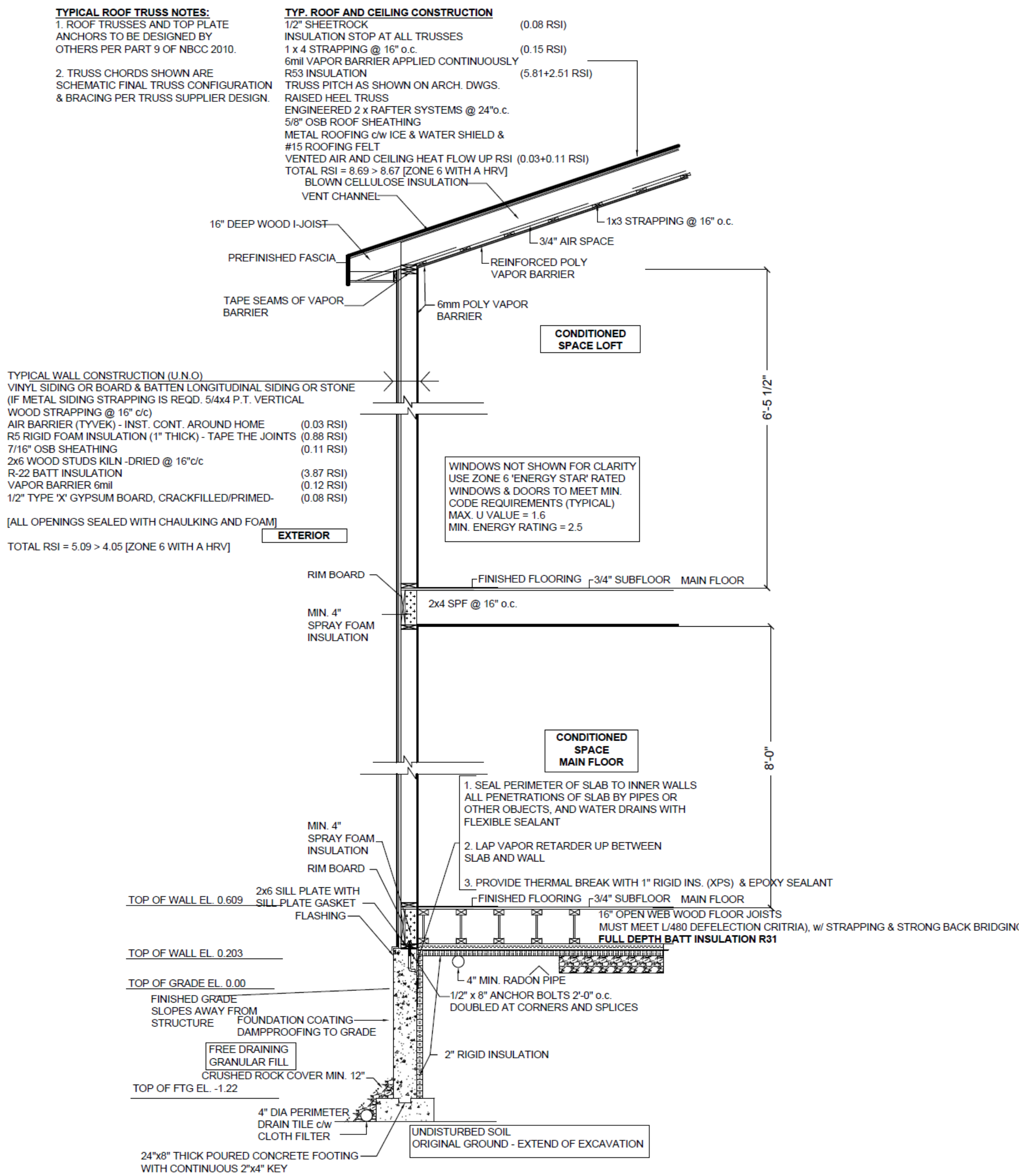


Figure 11 Section of the Wooden Tiny House under Loft (adopted from Noory Engineering Inc, 2023)

2.2.4.3 Engineering Calculations of the Sizes of Beam and Columns for Entrance

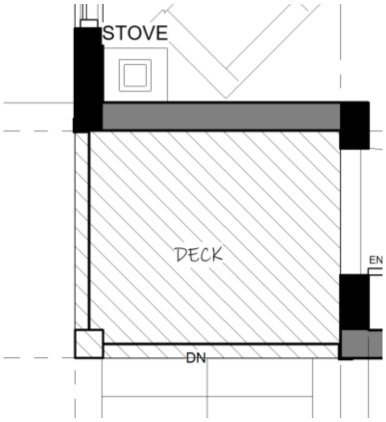


Figure 12 Entrance

Check the entrance beam size:

Snow load calculation: S = Is[Ss(CbCwCsCa)+Sr]   (NBCC, 2015)

Eq. 1

Where,

S: This represents the total snow load on the structure, represented in units of force as kilopascals per square foot.

Is: this represents the importance factor, which considers the consequences of failure for the structure, in which 1.0 is the standard importance level.

Ss: this represents the ground snow load.

Cb: this represents the shape coefficient that accounts for the shape of the roof.

Cs: this represents the importance of the snow load factor.

Ca: This represents the altitude coefficients since the snow load tends to increase with higher altitudes.

Sr: this represents any additional or special snow load that might be present.

Entering the data used in this design in Eq. (1):

S = 1.0[3.1(0.55 x 1.0 x 1 x 1.0) +0.6] = 2.31kPa

S= 2.31kPa

For the span calculations:

Span for each support = total span length/number of supports

Span for each support =1.92m/2 = 0.96m

For the calculation of snow load on the beam

Snow load on the bean = snow load (S) x span for each support

S = 2.31 kN/m x 0.96m

S= 2.21 kN/m

For the calculation of the dead load on the beam:

Dead load D = Coefficient x span for each support

Dead load: D = 0.75 x 0.96 = 0.72kN/m

The information about snow load is from the Jabacus website. According to the Office Design Software WoodWorks Sizers (CWC 2022), the size of beams above the entrance stairs is 2 by 4, S-P-F, Grade No.1 / No.2

The unfactored Snow load = 2.14

The unfactored Dead load = 0.75

From Sizers, 2 by 4, Grade No. 1 / No. 2, S-P-F, are used for the beam in the front door to support the roof.

2.2.5 LCA of the Wooden Tiny House

LCA is the abbreviation for Life Cycle Assessment. The goal of LCA is to systematically analyze the potential environmental impacts of a product or service during its entire life cycle (ISO 14040:2006, 2006). It is called the cradle-to-grave LCA (Sphera, 2020). To measure the potential impact on the environment in the LCA, both the upstream and downstream processes will be considered, including the production of the raw materials, the conversion of the raw materials into auxiliary materials and operating materials, the distribution of the materials, the use of the materials, and the end of life of the materials. The life cycle impact assessment LCA takes into account all the inputs such as inputs such as ores, land use, and water, and all the output like carbon dioxide and nitrogen oxide emissions into the air, water, and soil.

LCA has 15 impact categories: climate change, ozone depletion, acidification, eutrophication of freshwater, eutrophication of marine water, terrestrial eutrophication, photochemical ozone formation (Smog formation), depletion of abiotic resources in the form of minerals and metals, depletions of abiotic resources in form of fossil fuel, human toxicity, eco-toxicity, water use, land use, ionizing radiation, and particulate matter emissions (Ecochain, 2023). Although there are a total of 15 impact categories, the five (5) key environmental impacts in a given LCA report are the global warming potential, acidification potential, eutrophication potential, ozone depletion, and smog formation (Gu *et al*., 2022) , which are defined below:

The global warming potential is the indicator of the potential global warming due to the emissions of GHG into the air (Ecochain, 2023), which is measured by kg CO2 eq, Acidification potential is an indicator of the potential acidification of the soil and water due to the release of sulphur oxide, which is measured by kg SO2 eq. Eutrophication potential is the indicator of the potential enrichment of the ecosystem with nutritional elements due to nitrogen containing compounds, which is measured by kg N eq. Ozone depletion is the indicator of emissions to the air that can cause depletion of the Ozone layer in the stratosphere, which is measured by kg CFC-11 eq. Smog formation is the indicator for emissions of gasses that creates photochemical ozone (smog) in the atmosphere (Ecochain, 2023), which is measured in kg O3 eq.

Tools approved by Leadership in Energy and Environmental Design (LEED) for LCA analysis break down into two distinct categories. One of them is the Design Team LCA tools that people like architects and engineers use, and the other is LCA Practitioner tools used by LCA practitioners focused on product LCA. For example, LCA practitioners will focus on the LCA of a product like a bicycle, while an LCA design team will only do building LCA. The LCA practitioner tools can also be used for whole building LCA, but they are less intuitive and require more user training. The popular design team LCA tools are Athena Impact Estimator for Building, LCADesign, Envest2, and Tally (Splitstream, 2022). The popular LCA practitioner tools are Thinkstep GaBi and SimaPro. The only LEED-approved LCA tools for the whole building LCA are Athena Impact Estimator for Buildings, Thinkstep GaBi, and SimaPro (Splitstream, 2022). LEED is one of the top authorities in green building certification globally, which has been developed by the U.S. Green Building Council (United States Green Building Council, 2018). Since Athena Impact Estimator for Building is a focused LCA design team tool that is approved by LEED and therefore allows for the creation of cradle-to-grave and beyond LCA based on the bill of materials used in building construction, this paper will use Athena Impact Estimator for Building as the tool of choice for all LCA assessments.

2.2.5.2 Materials and Methods

Athena Impact Estimator for Building was used to examine the environmental impacts of the wooden tiny house. The building LCA was conducted following the ISO 14040 and ISO 14044 standards since the Athena Impact Estimator for Building was developed based on the LCA methodology standards of ISO 14040 and ISO 14044. Athena Impact Estimator for Building uses both its own database and the US Life Cycle Inventory Database. (Athena Sustainable Materials Institute, 2022).

2.2.5.3 System Boundary

Building Assessment Information	Building Lifecycle Information	Product Stage	A1	Raw material supply
			A2	Transport
			A3	Manufacturing
		Construction Process stage	A4	Transport
			A5	Construction-installation process
		Use stage	B1	Use
			B2	Maintenance
			B3	Repair
			B4	Replacement
			B5	Refurbishment
			B6	Operational energy use
			B7	Operational water use
		End-of-life stage	C1	De-construction demolition
			C2	Transport
			C3	Waste processing
			C4	Disposal
	Supplement information beyond the building life cycle		D	Benefits and loads beyond the system boundary

Figure 13 Life Cycle Assessment System Boundary Stages

The system boundary for this building LCA report includes the product stage A1 to A3, the construction stage A4 and A5, the use stage B2, B4 and B6, the end-of-life stages C1 to C4, and included in some of the tables the outside of the system boundary of beyond building life stage D. Below are all the LCA stages; the bold stages are the ones not used as they are not calculated by Athena Impact Estimator for Building.

The life cycle for LCA analysis is broken down into 3 primary stages called gates, then subdivided into 5 secondary stages, and each stage is further divided into sub-categories (Table 5)

Table 5 LCA Stages in Detail

A	Product Stage: the product stage includes the production of the building materials and the extraction of the raw materials; the two gates in A are extraction to Manufacturing.	A1. Raw Materials Extraction: In this stage, the raw materials needed for the building are extracted.
		A2. Transport: In this stage, the raw materials are transported to the factories.
		A3. Manufacturing: In this stage, the raw materials are transformed, if necessary, into the auxiliary or operating materials needed.
	Construction Stage: the construction stage includes the transportation of the materials to the construction site and the construction of the building.	A4. Transport: In this stage, the raw materials are transported to the construction site.
		A5. Construction and Installation: The construction process starts in this stage, and the materials are installed/constructed into the planned building.
B	Use Stage: in this stage, the building is used for its planned lifetime and	**B1. Use: In this stage; the LCA is taken from the period that the building is utilized for the building's estimated lifetime**

	includes the Lifecycle assessments of all the repairs and maintenance the building will require during its planned lifetime.	B2. Maintenance: This stage encompasses all the regular activities performed on the upkeeping of the building during its lifetime.
		B3. Repair: This stage encompasses all the repairs done to the building during its lifetime.
		B4. Replacement: In this stage, it would involve substituting building materials or systems that met their end of life during the lifetime of the building.
		B5. Refurbishment: This stage would include renovating and upgrading parts based on functionality, aesthetics, or efficiency during the use phase.
		B6. Operational Energy Use: In this stage, it would be the total energy the building uses during its lifetime.
		B7. Operational Water Use: In this stage, it would be the total water the building uses during its lifetime.

C	End of Life: in this stage, the building is demolished and dismantled; in this stage, it also includes the disposal of these building materials and the processing of the waste materials.	C1. Demolition: This stage involves the dismantling and demotion of the building.
		C2. Transport: This stage involves moving the materials from the demolition site to the waste processing site.
		C3. Waste Processing: This stage involves processing the waste caused by the demolition of the building.
		C4. Disposal: This stage involves the disposal of the waste from the waste processing facility of the building materials.

D	Beyond Building Life: This stage is outside of the standard Cradle to grave LCA; it is called the beyond system boundary assessment and focuses on the ability of the building to be reused or recycled into other materials.	D. Reuse: This stage focuses on the component or the building being able to be repurposed into a new construction project rather than disposing of all the materials. D. Recovery: This stage focuses on the recovery of the valuable materials of the building. D. Recycling: This stage focuses on reprocessing the building materials into transforming them into new materials. D. Exported Energy: This stage refers to the energy generated through the building via renewable sources, or the energy produced with the materials recovered from the building itself.

2.2.5.4 Assumptions

Due to the limitations of the data and the data collection, there are a few assumptions that were made in this thesis report to simplify the LCA calculations as follows:

1. Since Athena Impact Estimator for Building has only a few listed locations selectable around the Canadian Atlantic region, this paper uses the closest city to Fredericton that Athena Impact Estimator for Building has, which is Halifax, Nova Scotia.

2. The life expectancy of the wooden tiny house is 60 years, based on the average building LCA lifespan given by Gran (2016). Therefore, the use phase and occupational energy consumption are calculated using that.
3. The operating energy usage during the use phase is set at zero, based on the use of solar panels and the expectation that energy production will meet or exceed energy use. The estimated energy use is based on the average use of a 950 ft² apartment in Canada (EnerGenie, 2018).
4. The calculation did not include the fasteners, nails, and staples required for the construction.
5. Since Athena Impact Estimator for Building does not have 20MPA concrete in their database, 25MPA was chosen and will give a close enough estimation for the LCA.

2.2.5.5 Bill of Materials

Table 6 Bill of Materials LCA

Material	Unit	Total Quantity	Mass Value	Mass Unit
1/2” Fire-Rated Type X Gypsum Board	m²	155.4770	1.2718	Tonnes
1/2” Moisture Resistant Gypsum Board	m²	13.7338	0.1237	Tonnes

Concrete Benchmark CAN 25 MPa	m^3	12.3500	28.7684	Tonnes
FG LF Open Blow R13-20	m^2 (25mm)	154.7192	0.0289	Tonnes
Large Dimension Softwood Lumber, kiln-dried	m^3	115.8943	49.0384	Tonnes
Metal Roof Cladding - Residential (30 Ga.)	m^2	54.2077	0.1918	Tonnes
Oriented Strand Board	m^2 (9mm)	190.2268	1.1106	Tonnes
Small Dimension Softwood Lumber, kiln-dried	m^3	250.7736	106.1098	Tonnes
Vinyl Siding	m^2	176.6549	0.4063	Tonnes

Table 6 covers materials used in Athena Building Impact Estimator to determine the input into the LCA system.

2.2.5.6 LCA Analysis

Table 7 Stage A Detailed LCA Measurements

		PRODUCT (A1 to A3)			**CONSTRUCTION PROCESS (A4 & A5)**		
LCA Measures	**Unit**	Manufacturing	Transport	**Total**	Construction-Installation Process	Transport	**Total**
Global Warming Potential	kg CO_2 eq	1.02E+04	6.90E+03	**1.71E+04**	5.96E+02	1.07E+04	**1.13E+04**
Acidification Potential	kg SO_2 eq	8.86E+01	6.65E+01	**1.55E+02**	5.83E+00	1.58E+02	**1.64E+02**
HH Particulate	kg PM2.5 eq	3.55E+01	3.68E+00	**3.92E+01**	2.41E+00	5.06E+00	**7.47E+00**

Eutrophication Potential	kg N eq	2.35E+01	4.13E+00	**2.76E+01**	1.61E+00	9.77E+00	**1.14E+01**
Ozone Depletion Potential	kg CFC-11 eq	1.16E-04	2.41E-07	**1.16E-04**	7.52E-06	4.28E-07	**7.95E-06**
Smog Potential	kg O3 eq	1.64E+03	2.10E+03	**3.73E+03**	1.07E+02	5.17E+03	**5.28E+03**
Total Primary Energy	MJ	5.79E+05	1.01E+05	**6.79E+05**	3.94E+04	1.46E+05	**1.86E+05**
Non-Renewable Energy	MJ	1.23E+05	1.01E+05	**2.23E+05**	7.44E+03	1.46E+05	**1.54E+05**
Fossil Fuel Consumption	MJ	1.17E+05	1.00E+05	**2.18E+05**	7.31E+03	1.46E+05	**1.53E+05**

Table 7 summarizes the environmental impacts of stage A of the LCA report, which covers the production of the materials and construction of the wooden tiny house. The transportation covers the estimated distance from the Athena impact building estimator's American database and ISO 140400 and ISO 24032, using the distance to the closest city in the database (Halifax).

Table 8 Stage A Detailed LCA Measurements

		USE (B2, B4 & B6)			
LCA Measures	**Unit**	Replacement Manufacturing	Replacement Transport	Operational Energy Use Total	**Total**
Global Warming Potential	kg CO2 eq	2.25E+02	2.92E+01	0.00E+00	**2.55E+02**
Acidification Potential	kg SO2 eq	3.31E+00	3.20E-01	0.00E+00	**3.63E+00**

HH Particulate	kg PM2.5 eq	3.09E-01	1.64E-02	0.00E+00	**3.26E-01**
Eutrophication Potential	kg N eq	6.90E-02	1.98E-02	0.00E+00	**8.88E-02**
Ozone Depletion Potential	kg CFC-11 eq	9.89E-06	1.15E-09	0.00E+00	**9.89E-06**
Smog Potential	kg O3 eq	9.39E+00	1.02E+01	0.00E+00	**1.95E+01**
Total Primary Energy	MJ	5.44E+03	4.23E+02	0.00E+00	**5.86E+03**
Non-Renewable Energy	MJ	5.44E+03	4.23E+02	0.00E+00	**5.86E+03**
Fossil Fuel Consumption	MJ	5.44E+03	4.23E+02	0.00E+00	**5.86E+03**

Table 8 summarizes the Use stage environmental impact of the wooden tiny house during its planned 60-year lifespan. Operational Energy use is measured by Athena, but since the operational energy comes from within the building's solar panel system, it does not require energy from any outside primary energy sources. This section is crucial since it is used to offset the total calculated from A to

C and A to D, causing A to D to have a negative global warming potential, as it does not require any fossil fuel or non-renewable energy sources.

Table 9 Detailed LCA Measures in Stage C

		END OF LIFE (C1 to C4)		
LCA Measures	**Unit**	Deconstruction, Demolition, Disposal & Waste Processing	Transport	**Total**
Global Warming Potential	kg CO2 eq	4.62E+03	1.04E+03	**5.67E+03**
Acidification Potential	kg SO2 eq	6.61E+01	1.00E+01	**7.62E+01**
HH Particulate	kg PM2.5 eq	1.64E+00	5.56E-01	**2.20E+00**
Eutrophication Potential	kg N eq	4.13E+00	6.24E-01	**4.75E+00**

Ozone Depletion Potential	kg CFC-11 eq	2.02E-07	3.65E-08	**2.38E-07**
Smog Potential	kg O3 eq	2.20E+03	3.17E+02	**2.51E+03**
Total Primary Energy	MJ	6.89E+04	1.52E+04	**8.41E+04**
Non-Renewable Energy	MJ	6.88E+04	1.52E+04	**8.41E+04**
Fossil Fuel Consumption	MJ	6.87E+04	1.52E+04	**8.39E+04**

Table 9 summarises the end-of-life environmental impact of the wooden tiny house, from the demolition of the wooden tiny house to the disposal of the waste materials.

Table 10 Detailed LCA Measures in Stage D

		BEYOND BUILDING LIFE (D)		
LCA Measures	**Unit**	BBL Material	BBL Transport	**Total**
Global Warming Potential	kg CO2 eq	-1.23E+05	0.00E+00	**-1.23E+05**
Acidification Potential	kg SO2 eq	-5.46E-01	0.00E+00	**-5.46E-01**
HH Particulate	kg PM2.5 eq	-2.39E-01	0.00E+00	**-2.39E-01**
Eutrophication Potential	kg N eq	-2.80E-02	0.00E+00	**-2.80E-02**
Ozone Depletion Potential	kg CFC-11 eq	0.00E+00	0.00E+00	**0.00E+00**
Smog Potential	kg O3 eq	-5.52E+00	0.00E+00	**-5.52E+00**

Total Primary Energy	MJ	-1.09E+03	0.00E+00	**-1.09E+03**
Non-Renewable Energy	MJ	-1.09E+03	0.00E+00	**-1.09E+03**
Fossil Fuel Consumption	MJ	-2.19E+03	0.00E+00	**-2.19E+03**

Table 10 summarizes the out-of-system stage D, which calculates the total reductions to stages A to C of each impact category, as it follows the principles of recycling and reuse of material and transitioning the materials to auxiliary or raw materials, giving a net reduction in the total system. Since the materials used are sustainable materials that can be reused on other buildings, the total of A to D will be negative, as other systems can employ the materials to reduce another LCA system's total impact categories.

Table 11 A-C and A-D LCA Total Effect

		TOTAL EFFECTS	
LCA Measures	**Unit**	**A to C**	**A to D**
Global Warming Potential	kg CO2 eq	**3.44E+04**	**-8.83E+04**
Acidification Potential	kg SO2 eq	**3.99E+02**	**3.98E+02**
HH Particulate	kg PM2.5 eq	**4.92E+01**	**4.90E+01**
Eutrophication Potential	kg N eq	**4.39E+01**	**4.38E+01**
Ozone Depletion Potential	kg CFC-11 eq	**1.34E-04**	**1.34E-04**
Smog Potential	kg O3 eq	**1.16E+04**	**1.15E+04**
Total Primary Energy	MJ	**9.55E+05**	**9.54E+05**
Non-Renewable Energy	MJ	**4.67E+05**	**4.66E+05**

Fossil Fuel Consumption	MJ	**4.61E+05**	**4.59E+05**

The sole purpose of Table 11 is to summarize the total environmental effect of the wooden tiny house from the cradle to the grave (A to C), and the total reduction of the environmental impact within the LCA system can be calculated using an outside-of-boundary system of A to D, as the materials are reused on other buildings or projects.

The Use phase operational energy use total is 0 since the proposed building uses solar panels to offset the yearly kWh that would have come from an energy supplier if the proposed building did not have solar panels. The total effect of global warming from A to C is 3.44E+04 KgCO2; since the materials can be recycled and recovered in phase D, the total effect of global warming is reduced to a negative -8.83E+04 KgCO2.

Table 12 Cradle-to-Gate (A to C) LCA Measure Report

Summary Measure	**Unit**	**Total Effects** **Cradle to Grave A to C**
Global warming potential	kg CO2 eq	3.44E+04
Stratospheric ozone depletion	kg CFC-11 eq	1.34E-04
Acidification of land and water	kg SO2 eq	3.99E+02
Eutrophication	kg N eq	4.39E+01
Tropospheric ozone formation	kg O3 eq	1.16E+04
Depletion of non-renewable energy resources	MJ	4.67E+05

Table 12 includes the required LEED LCA measurements for Cradle to Grave analysis, as other systems have different standards. And does not include the out-of-system boundary of ISO 14040 Beyond building assessment. Table 12 can be viewed as a simplified version of Table 11. The LEED table includes A to C, as it is cradle to grave, while D is outside of the system boundary. Following ISO 21930, this allows materials used in the system that have their emissions accounted for, if it is used in another system because of D, it would be counted as an emission reduction into the second building. This also explains why A to C a positive number is, while A to D will be a negative number for carbon emission (Woodworks, 2021).

Table 13 Energy Consumption Life Cycle Inventory Results Table by Life Cycle Stage A

		PRODUCT (A1 to A3)			**CONSTRUCTION PROCESS (A4 & A5)**		
Energy Source	**Unit**	Manufacturing	Transport	**Total**	Construction-Installation Process	Transport	**Total**
Hydro	MJ	7.74E+02	4.24E+01	**8.16E+02**	3.93E+01	6.12E+01	**1.01E+02**
Non-Hydro Renewable	MJ	1.49E+03	0.00E+00	**1.49E+03**	7.45E+01	0.00E+00	**7.45E+01**
Coal	MJ	1.58E+04	6.18E+02	**1.64E+04**	4.68E+02	8.94E+02	**1.36E+03**
Diesel	MJ	4.76E+04	9.18E+04	**1.39E+05**	3.29E+03	1.35E+05	**1.39E+05**
Feedstock	MJ	3.41E+03	0.00E+00	**3.41E+03**	3.41E+02	0.00E+00	**3.41E+02**

Gasoline	MJ	2.53E+03	0.00E+00	**2.53E+03**	1.77E+02	0.00E+00	**1.77E+02**
Heavy Fuel Oil	MJ	1.28E+04	4.13E+03	**1.69E+04**	6.36E+02	4.36E+03	**5.00E+03**
LPG	MJ	1.19E+03	9.25E+01	**1.28E+03**	9.34E+01	1.34E+02	**2.27E+02**
Natural Gas	MJ	3.40E+04	3.78E+03	**3.77E+04**	2.30E+03	5.46E+03	**7.76E+03**
Nuclear	MJ	5.28E+03	1.57E+02	**5.43E+03**	1.34E+02	2.37E+02	**3.71E+02**
Wood	MJ	4.54E+05	0.00E+00	**4.54E+05**	3.18E+04	0.00E+00	**3.18E+04**
Renewable Energy	MJ	4.56E+05	4.24E+01	**4.56E+05**	3.19E+04	6.12E+01	**3.20E+04**
Primary Energy	MJ	5.75E+05	1.01E+05	**6.76E+05**	3.91E+04	1.46E+05	**1.86E+05**
Non-Renewable Energy	MJ	1.19E+05	1.01E+05	**2.20E+05**	7.10E+03	1.46E+05	**1.53E+05**

Fossil Fuel	MJ	1.14E+05	1.00E+05	**2.14E+05**	6.97E+03	1.46E+05	**1.53E+05**

Tables 13 to 17 present the total energy use estimation for each stage; these are automatically measured based on the available ECO database used by Athena.

Table 14 Energy Consumption Life Cycle Inventory Results Table by Life Cycle Stage B

		USE (B2, B4 & B6)			
Energy Source	**Unit**	Replacement Manufacturing	Replacement Transport	Operational Energy Use Total	**Total**
Hydro	MJ	8.92E-01	1.75E-01	0.00E+00	**1.07E+00**
Non-Hydro Renewable	MJ	0.00E+00	0.00E+00	0.00E+00	**0.00E+00**

Coal	MJ	7.08E+01	2.55E+00	0.00E+00	**7.33E+01**
Diesel	MJ	5.00E+01	3.87E+02	0.00E+00	**4.37E+02**
Feedstock	MJ	2.68E+03	0.00E+00	0.00E+00	**2.68E+03**
Gasoline	MJ	0.00E+00	0.00E+00	0.00E+00	**0.00E+00**
Heavy Fuel Oil	MJ	1.60E+02	1.74E+01	0.00E+00	**1.77E+02**
LPG	MJ	1.15E+00	3.82E-01	0.00E+00	**1.53E+00**
Natural Gas	MJ	2.48E+03	1.56E+01	0.00E+00	**2.49E+03**
Nuclear	MJ	1.45E+00	6.44E-01	0.00E+00	**2.10E+00**
Wood	MJ	0.00E+00	0.00E+00	0.00E+00	**0.00E+00**
Renewable Energy	MJ	8.92E-01	1.75E-01	0.00E+00	**1.07E+00**

Primary Energy	MJ	2.76E+03	4.23E+02	0.00E+00	**3.19E+03**
Non-Renewable Energy	MJ	2.76E+03	4.23E+02	0.00E+00	**3.19E+03**
Fossil Fuel	MJ	2.76E+03	4.23E+02	0.00E+00	**3.18E+03**

Table 14 also covers the building's operational energy based on the estimated requirement for a Canadian 950 ft2 house; the tiny house produces 603kWph monthly and has lower square footage than the Canadian data for a house of this size. It should be safe to assume that this house produces more than it will ever need in energy, and during the months that it might not produce as much, it would still be at a negative value as it feeds power into the NB power grid. Therefore, 0 Operational energy use is based on the calculations in section 3.1 and is also used by Athena Building Impact Estimator to estimate better the out-of-system boundary of stage D, which further explains the negative values.

Table 15 Energy Consumption Life Cycle Inventory Results Table by Life Cycle Stage C

		END OF LIFE (C1 to C4)		
Energy Source	**Unit**	Deconstruction, Demolition, Disposal & Waste Processing	Transport	**Total**
Hydro	MJ	2.91E+01	6.42E+00	**3.55E+01**
Non-Hydro Renewable	MJ	0.00E+00	0.00E+00	**0.00E+00**
Coal	MJ	4.25E+02	9.36E+01	**5.19E+02**
Diesel	MJ	6.43E+04	1.39E+04	**7.82E+04**
Feedstock	MJ	0.00E+00	0.00E+00	**0.00E+00**

Gasoline	MJ	6.07E+00	0.00E+00	**6.07E+00**
Heavy Fuel Oil	MJ	1.41E+03	6.13E+02	**2.02E+03**
LPG	MJ	6.33E+01	1.40E+01	**7.73E+01**
Natural Gas	MJ	2.59E+03	5.72E+02	**3.16E+03**
Nuclear	MJ	1.07E+02	2.38E+01	**1.31E+02**
Wood	MJ	0.00E+00	0.00E+00	**0.00E+00**
Renewable Energy	MJ	2.91E+01	6.42E+00	**3.55E+01**
Primary Energy	MJ	6.89E+04	1.52E+04	**8.41E+04**
Non-Renewable Energy	MJ	6.88E+04	1.52E+04	**8.41E+04**
Fossil Fuel	MJ	6.87E+04	1.52E+04	**8.39E+04**

Table 16 Energy Consumption Life Cycle Inventory Results Table by Life Cycle Stage D

		BEYOND BUILDING LIFE (D)	
Energy Source	**Unit**	BBL Material	**Total**
Hydro	MJ	0.00E+00	**0.00E+00**
Non-Hydro Renewable	MJ	0.00E+00	**0.00E+00**
Coal	MJ	-2.76E+03	**-2.76E+03**
Diesel	MJ	0.00E+00	**0.00E+00**
Feedstock	MJ	0.00E+00	**0.00E+00**
Gasoline	MJ	0.00E+00	**0.00E+00**

Heavy Fuel Oil	MJ	1.02E+02	**1.02E+02**
LPG	MJ	0.00E+00	**0.00E+00**
Natural Gas	MJ	4.68E+02	**4.68E+02**
Nuclear	MJ	1.10E+03	**1.10E+03**
Wood	MJ	0.00E+00	**0.00E+00**
Renewable Energy	MJ	0.00E+00	**0.00E+00**
Primary Energy	MJ	-1.09E+03	**-1.09E+03**
Non-Renewable Energy	MJ	-1.09E+03	**-1.09E+03**
Fossil Fuel	MJ	-2.19E+03	**-2.19E+03**

Table 17 Energy Consumption Life Cycle Inventory Results Table by Life Cycle Stage A-C and A-D Totals

		TOTAL EFFECTS	
Energy Source	**Unit**	**A to C**	**A to D**
Hydro	MJ	**9.53E+02**	**9.53E+02**
Non-Hydro Renewable	MJ	**1.57E+03**	**1.57E+03**
Coal	MJ	**1.84E+04**	**1.56E+04**
Diesel	MJ	**3.57E+05**	**3.57E+05**
Feedstock	MJ	**6.42E+03**	**6.42E+03**
Gasoline	MJ	**2.71E+03**	**2.71E+03**
Heavy Fuel Oil	MJ	**2.41E+04**	**2.42E+04**
LPG	MJ	**1.59E+03**	**1.59E+03**

Natural Gas	MJ	**5.12E+04**	**5.16E+04**
Nuclear	MJ	**5.94E+03**	**7.04E+03**
Wood	MJ	**4.86E+05**	**4.86E+05**
Renewable Energy	MJ	**4.88E+05**	**4.88E+05**
Primary Energy	MJ	**9.49E+05**	**9.48E+05**
Non-Renewable Energy	MJ	**4.60E+05**	**4.59E+05**
Fossil Fuel	MJ	**4.55E+05**	**4.52E+05**

Tables 13 to 17 list the energy consumption of each phase and estimate where the energy was taken from based on the location data of Halifax, Nova Scotia, Canada, given to Athena Impact Estimator for Building Sustainable Materials Institute Impact Estimator; for a more accurate result, the closest available city to the proposed building was chosen. Table 17 shows that the total difference between

A to C and A to D here are mostly the same; as it is in stage D, no energy is used as much outside of converting some of the recycled materials into other auxiliary or raw material.

3. Project Management for the Proposed Wooden Tiny House

3.1. Materials and Pricing for the Proposed Wooden Tiny House

Table 18 Material List

Material	Volume /Space		Price per	Source	Price tax and labour excluded
Concrete	415.37 CF		20 MPA $187 per Cubic Meter	Canada building materials	$2,244.00
Wood studs	2 x 4 (roof and interior walls)	1,151LF	2inx4inx12ft $7.18 each	Fredericton Kent South	$689.28
	2 x 6 (exterior walls)	1,798LF	2inx6inx12ft $13.78 each	Fredericton Kent South	$2,067.00

	2 x 10 (floor joist) 410LF	2inx10inx12ft $26.98 each	Fredericton Kent South	$944.30
Gypsum board	Type C drywall 1,521.4SF (interior walls and ceiling)	12’x4’x1/2” type c $49.49	Fredericton Kent South	$1,583.68
	Mould though 134.39SF (bathroom wall and ceiling)	½”x4’x12’ $49.19	Fredericton Kent South	$147.57
OSB	1,008.37 SF (outer wall)	7/16”x4’x8’ $15.95	Home Depot Fredericton	$510.00
	577.71SF (roof)	5/8”x4’x8’ $29.98	Home Depot Fredericton	$569.62
	364 SF (Subfloor)	23.25”x23.25”x3/4” $7.98	Home Depot Fredericton	$758.10
Siding	1,008.37 SF	4” vinyl siding from Mitten price according	Fredericton Kent South	$216.86

	14 Boxes	to a local retail location, $15.49 per Box		
Glass	158.66 SF	Windows 2 x 4: $80 2.4 x 5: $300 4.5 x 3.5: $600 3 x 15: $1,500 7.5 x 7: $2,199 3.7 x 7.5: $449	Fredericton Kent South	$5,128.00
Door		Exterior: $420 Interior: 3 x $210	Fredericton Kent South	$1,050.00

Insulation	Vapor Barrier	1,586.08SF	$74.97 per 1,000SF	Home Depot Fredericton	$149.94
	House Wrap	1,586.08SF	900SF $123	Fredericton Kent South	$246.00
	R22 fibreglass insulation	1,586.08SF	15x47x5.5 49SF for 2x6 exterior wall $74.20	Home Depot Fredericton	$2,448.60
Metal Roof	577.71SF		$14 per SF Aluminum	Canadian Metal Roofing	$8,092.00
Flooring	364SF		2-1/4inch Maple 20 ft² box $29.52	Fredericton Kent South	$560.88
Solar Panel	327.6SF	14 Panels	450W $349 each	Parie Sun Solar	$4,886.00
Total Cost					$32,291.83

3.2 Living Cost in New Brunswick Affordable House Model.

The cost of living in New Brunswick is relatively high compared to the rest of the country. The Canadian Living Wage Framework defines a living wage. It is the hourly rate that a household needs to meet its basic needs in a 35-hour work week, which includes employment income, government transfers, and government taxes (Human Development Council, 2022). The liveable wage in Fredericton New Brunswick in 2022 is $23.45 (Human Development Council, 2022) an hour compared to the $17.72 an hour required by a larger city like Montreal Quebec (MTLBLOG, 2023). In Fredericton with a sample of a family of 4, where both parents work 35 hours at the liveable wage, they would use 25% of their income on housing (Human Development Council, 2022). In a Harvard study, the cost burden is classified as spending more than 30% of your income on housing Zhang *et al*., 2022).

The Area Median family income (AMFI) is the median income of a family in a region, while Area Median Income (AMI) is the median income of an individual person in that region. The AMFI of New Brunswick is $70,000, while the AMI is $38,900 for individuals. For the individual to be non-cost burdened for housing taking the AMI into account, they must spend less than $972 monthly on housing, while the average single-bedroom apartment in Fredericton is $1250 monthly, and a 2-bedroom apartment is $1550 monthly (Zumper, 2023). This makes the average rental non-including the other costs of housing take 38.56% to 47.81% of the AMI, which means the average individual in New Brunswick is cost-burdened because of housing. 26.2% of New Brunswickers rent to meet their housing needs, while 73% own their house, while half of New Brunswickers have a mortgage (Point2Homes 2023).

The median list price of a single-family house in Fredericton is $449,900 (Ojo home, 2023); prices of tiny houses tend to be much lower. Table 19 shows the lower cost of a tiny home compared to the median listing price of a single-family house in Fredericton.

Table 19 Tiny Home and Mini Home Cost Comparison

Company	Location	Tiny House Name	Price $	ft^2
Kent Housing	Fredericton NB	Bayfield	190,000	960
Kent Housing	Fredericton NB	Robin	200,000	912
Mike Roy Carpentry	Oromocto NB	Eastern Pine 42	189,900	550
Mike Roy Carpentry	Oromocto NB	Eastern Pine 34OG	139,000	340
Rockbox Structures	Nisku AB	Half Johnson	80,000	220
Balance Container Homes	Oakville ON	GS320	130,000	320
Sunshine Tiny Homes	Port Mellon BC	Pacific Retreat	146,000	352
Tree Hugger Tiny Homes	Lacombe AB	Cascade	149,999	317

Teacup Tiny Homes	Lethbridge AB	Bianca	140,000	528
Teacup Tiny Homes	Lethbridge AB	Arlowe	130,000	480
Teacup Tiny Homes	Lethbridge AB	Florence	120,000	360

The above table does not include the land cost, but land in Fredericton tends to be around $19,000 (Zillow, 2023), meaning the average cost of a tiny home will still be below the cost of buying. The proposed wooden tiny house is much more affordable than the local tiny houses prices, as the proposed wooden tiny house is $32,291.83, while most similar-sized tiny houses tend to be $100,000-$120,000 more. The design of the proposed tiny house uses wood instead of steel for the framing which allows the house cost to be 43.5% lower than a nearly identical steel house (US Department of Housing and Urban Development 2022). Furthermore, the choice of wood makes the house not only more affordable but also more eco-friendly.

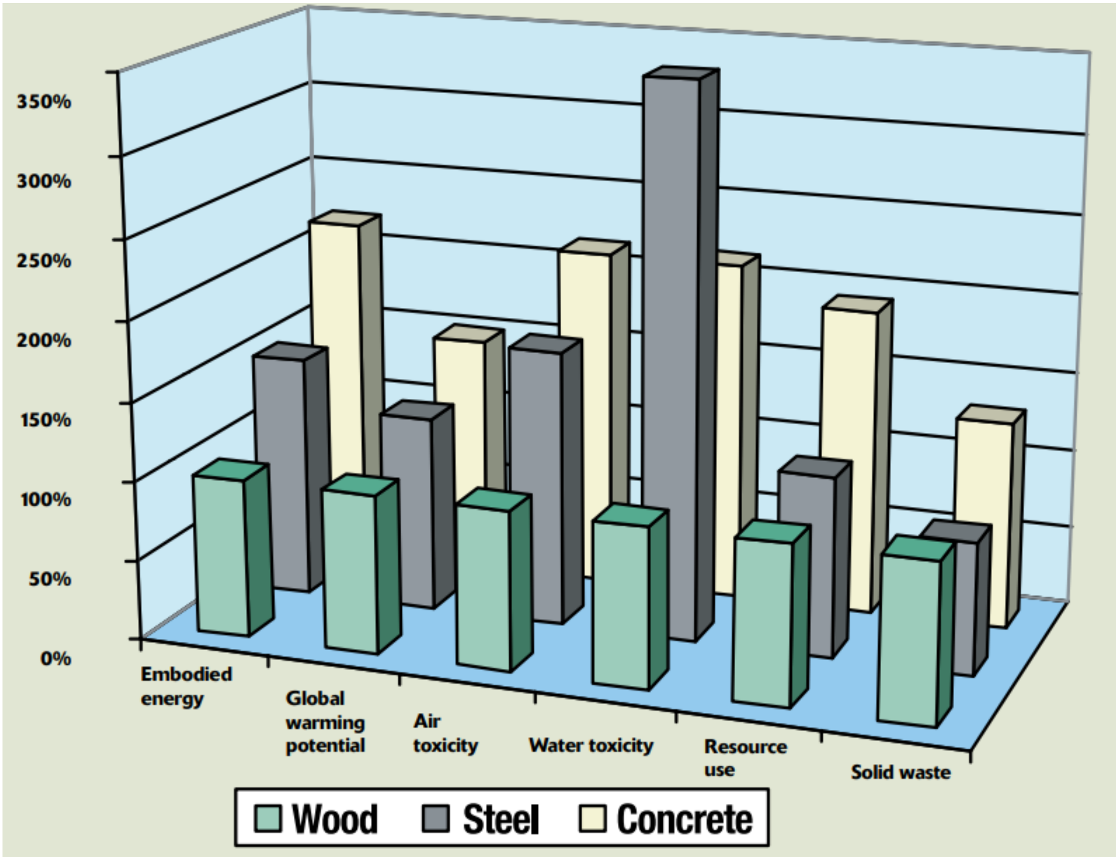


Figure 14 Wood vs Steel vs Concrete LCA (CWC Building NO.4, 2019)

The Embodied Energy of a wooden house is 53% and 120% less than its metal and concrete counterparts, respectively. The global warming potential of a wooden house is 23% and 50% less than its metal and concrete counterparts, respectively. The air toxicity index of a wooden house is 74% and 115% less than its metal and concrete counterparts, respectively. The water Toxicity index of a wooden house is 247% and 114% less than its metal and concrete counterparts. The Weighted Resourced use of a wooden house is 14% and 94% less than its Metal and Concrete counterparts, respectively. The only metric that metal beats wooden houses in a LEED LCA assessment is in Solid Waste Generation, as the metal in the ATHENA LEED database uses recyclable metals over the commonly used high-priced materials that are not commonly recycled (CWC Building NO.4, 2019). All assessments of these comparisons of materials assume that the wood and metal of the roof are completely recyclable; hence the actual wooden house assessment should be even lower than the assessment estimated in Figure 14.

Earlier in this section, it is mentioned how many are cost-burdened by renting apartments based on the AMI and the AMFI. The building of this proposed wooden tiny house under an insured loan would give the owner a housing cost of only 4.63% of the AMI and 2.57% of the AMFI. The total monthly housing cost is $150.25; the housing cost is calculated based on the home price of $32,291.83, a downpayment of 20% of $6458.37, a loan amortization period of 25 years, an interest rate of 5% (WOWA, 2023), the property tax of 1.1233% in Fredericton (GNB, 2023), and home insurance of $781 yearly (Ratehub, 2023). The total monthly housing cost does not include the utilities or the price of the land. A loan amortization period of 25 years and a 20% downpayment were chosen as it is required to have an insurable mortgage (Canada, 2022)

3.3. Energy Savings of the Wooden Tiny House

In the previous section, it was discussed how to reduce the cost of energy for the house using solar panels. Other ways to reduce energy use and cost for the tiny home include proper insulation, Energy Star windows, and weather stripping; each will reduce temperature loss. Having Energy Star-rated appliances and using a dual heat pump would also increase energy efficiency and reduce the energy costs of the house. These typical home upgrades tend to be more expensive initially but will pay off in the long term. To offset the initial cost of these upgrades, there are many government programs in New Brunswick and Canada that both offer federal and provincial grants to homeowners to upgrade or build energy-efficient houses. These grants can cover the cost of the solar panels and part of the cost of building the tiny home. From the provincial side, building an energy-efficient tiny house can offer grants of $6,000 or $10,000 under the New Home Energy Saving Program (SaveEnergyNb, 2022). On the federal side, they could receive up to $5,000 for upgrades under the Canada greener home grant (Natural Resources Canada, 2023). If the owner of the tiny house makes less than a combined income of $70,000, they would also be eligible to get upgrades to their home free of charge under the enhanced energy saving program (NB Power). The federal Canada Greener Home Initiative also offers interest-free loans up to $40,000 with a repayment term of 10 years (Natural Resources Canada, 2023). The provincial utility, NB Power, also offers a total home energy saving program (THESP), providing a rebate of $0.20 to $0.30 per watt produced by the solar system, as mentioned in 2.2.1 (NB Power, 2023). Furthermore, when the owner participates in the total home program, they can save up to 25% on their mortgage insurance premiums (NB Power, 2022).

3.4 Discussion

The primary objective of this report was to create an affordable wooden tiny house that is both economically and ecologically friendly while meeting the required building codes. It would qualify for incentives like the Canadian Greener Building and New Brunswick's New Home Energy Saving Program.

Sections 2.5 and 3.1 provided evidence that the materials used in the construction of the wooden tiny house were both affordable and sustainable. The use of sustainable materials makes it possible to recycle most of the building materials at the end of the house's life, as shown in Stage D beyond the building life in section 2.5. Additionally, the incorporation of the solar panel array enabled the tiny house to become a net positive energy producer, achieving self-sustainability for its electrical needs and significantly reducing its overall environmental impact. These objectives were to create an exemplary framework for building economically feasible eco-friendly housing solutions using wooden tiny houses.

Three uses for the wooden tiny house apart from simple residence are proposed. The first is for social programs for the homeless population, the second is as an adjunct hotel or Airbnb property, and the third is as an off-grid cabin.

This proposed wooden tiny house can be used to help with the homeless housing difficulties. Homeless people are categorized under these four circumstances:

1) individuals and families who do not have adequate nighttime residence or a place fit for human habitation.
2) those who may imminently lose their place of habitation,
3) unaccompanied youth,
4) individuals and families who are fleeing life-threatening situations such as violence or sexual assault (U.S. Department of Housing and Urban Development 2015b).

Service providers offer different methods of housing assistance for homeless individuals and families on both a short-term and long-term basis. These can be concluded as emergency shelters, transitional housing, permanent supportive housing, permanent affordable housing, and rapid rehousing (Furst, 2017). Table 20 is the description of 3 common housing methods.

Table 20 The Description of Different Methods of Housing Assistance (Furst, 2017)

Name	Description
Permanent supportive housing	a long-term housing option that enables persons with disabilities, mental illness, or chronic substance abuse to live as tenants in the community with access to supportive services.

Transitional housing	an interim place where people usually reside for up to 2 years before moving on to a more independent living.
Emergency shelters	provide the first point of entry for people who are immediately homeless and need a temporary place to stay while searching for more permanent housing.

Nowadays, emergency shelters and transitional housing are gradually abandoned for prohibitive cost, complicated application procedures and long waits. Permanent supportive housing and rapid rehousing are becoming increasingly popular. Local governments can also use tiny houses as a form of permanent or temporary supportive housing.

In some cities like Fredericton, communities and governments have taken it upon themselves to build and invest in tiny house villages as a cost-effective and quick way to provide housing for homeless people and families (Government of New Brunswick, 2022). For example, in Fredericton, by early in 2023, there were 45 tiny houses built in the 12 Neighbours Community, where many of the homeless went from living outside to being housed and employed within a year of the project beginning. Two of this group have already moved out into apartments, and others have gotten off social assistance but have chosen to stay in the community (CBC, 2023). The previously homeless that participate in the program are welcome to stay however long they wish in the tiny houses assigned to them whether or not they gain the financial ability to move elsewhere. Compared with the design, for interior layout, the proposed wooden tiny house from this paper has a larger kitchen, more living space, a bigger washroom, and French windows; it is thus more suitable and pleasant for long-term habitation. It is closer to a small version of a typical house, while the tiny house in the 12 Neighbours Community is closer to a transition shelter. In this way, the tiny house in the 12 Neighbours Community focuses more on how to help homeless people to reconnect to society; just as they said, ‘housing is just the beginning.’ (CBC, 2023) The tiny house for the 12 Neighbours community has a room for a bed, as in Figure 15 shown, without a ladder or non-standard stairs, and is thus more suitable for people with leg issues. Also, they prefabricated the house in a factory and then transported it to a specific area. Prefabrication offers considerable benefits in terms of construction duration, quality, and cost. Weather conditions, lack of skilled workers, shortage of materials, and limited access to roads that create roadblocks in construction that do not limit work in factories, which can operate regardless of the weather or extreme conditions (Koones, 2014). Both designs adopt solar panels to save electricity (Figure 16).

Figure 15 Bedroom for a Tiny House in 12 Neighbours Community (screen from the video: https://www.facebook.com/12Neighbours/videos/690537572586146)

Figure 16 12 Neighbours Community (screenshot from the video: https://www.facebook.com/12Neighbours/videos/691175219057289)

This tiny home can also be used among popular hotels as detached cabins to provide more privacy and autonomy. Moreover, tiny houses can be rented through services such as Airbnb, where zoning and permits allow. Airbnb also, in their term of services, explains that the owner of the property will need to follow the city zoning and administrative codes by registering, getting a permit, or obtaining the required license before they can list their property onto Airbnb service for short-term and long-term bookings (Airbnb, 2023).

The tiny home can be built as a second property also for camping, as the tiny house has a roof designed for water collection as well as a solar panel array; therefore, they require only a power storage system (e.g., battery pack) to be thoroughly equipped for off-grid camping. A septic system would be required for longer-term use.

4. Concluding Remarks and Future Work

4.1 Concluding Remarks.

In conclusion, wooden tiny houses have lots of advantages.

First, compared with an average size house, they are the epitome of ecological thinking, prioritizing sustainability and efficiency in their design. Their tiny footprint allows them to utilize less land, resulting in a reduced environmental impact. Also, they require less energy for heating and cooling, giving them a lower overall carbon footprint. Another advantage of the wooden tiny house's tiny size is that it translates into using fewer materials for construction and maintenance than the average house, lowering their ecological impact and lowering the total cost of owning such a house.

Secondly, constructing a tiny house out of wood instead of metal or concrete has several benefits. Building with wood over steel allows the building to be 43.5% cheaper. In every key environmental impact assessment mentioned in 2.2.5, the wooden house has a much lower environmental impact than similar buildings made of metal and concrete; for example, the global warming potential is 23% to 50% lower in wooden buildings than metal or concrete, respectively.

Thirdly, this proposed wooden tiny house focuses on sustainability principles, implementing locally harvested materials, incorporating solar panels, and utilizing energy-saving appliances and windows, incorporating a rainwater collector; all of these design choices allow this wooden tiny house to be even more eco-friendly and semi-self-sufficient with possible upgrades to be entirely self-sufficient.

Finally, the affordability of tiny houses provides several additional benefits. Without including the possible tax benefits and grants, the proposed tiny home has a total estimated cost of $32,291.83. This low cost and low land footprint can serve as a benchmark for building a wooden tiny house that can serve multiple uses, including a temporary home for people experiencing homelessness.

4.2 Recommendations for Future Work

Admittedly, this model also has some limitations. The layout of a tiny house means those living together will have relatively little privacy. Also, the use of a ladder to access a bed loft is inconvenient for those with disabilities, the elderly, and children. Healthy young and middle-aged groups may benefit more from living in this type of tiny house.

For LCA, the closest city to Fredericton that Athena Building Impact Estimate has is Halifax, Nova Scotia, Canada. For further study, the environmental impact data collected from New Brunswick could be used to get a more accurate result. Although both Halifax and Fredericton belong to Atlantic provinces, the weather conditions vary a lot. Halifax is a port city of the Atlantic Ocean, while Fredericton is in the middle of the province, about 100km away from the Ocean. For example, the Saint John River in Fredericton is primary fresh water while Halifax has more salty sea water. Therefore, the houses will face different erosion from Ocean wind and salty water.

Moreover, one uncontrollable factor is the continuous evolution of the market for construction materials, land, and labour costs. Depending on the needs of the market, the supply and demand would change the costs of materials, land, and labour. Also, the cost varies in different areas. It is hard to give an accurate and reliable estimate for all the analysis. The time and area, from which data is collected, need to be taken into account as a reference for future cost analysis.

Additionally, for future work, prefabrication could be considered in the design to lower the cost and increase the quality of tiny houses. Prefabrication can benefit in terms of construction duration, quality, and cost. Wood materials left in the wet condition (i.e., moisture content is over 30% or so), can easily rot and decay in their services. Furthermore, lack of labours or professionals would affect the efficiency and the quality of building a tiny house. These situations often happen during typical on-site construction but could be avoided easily by application of prefabrication technology.

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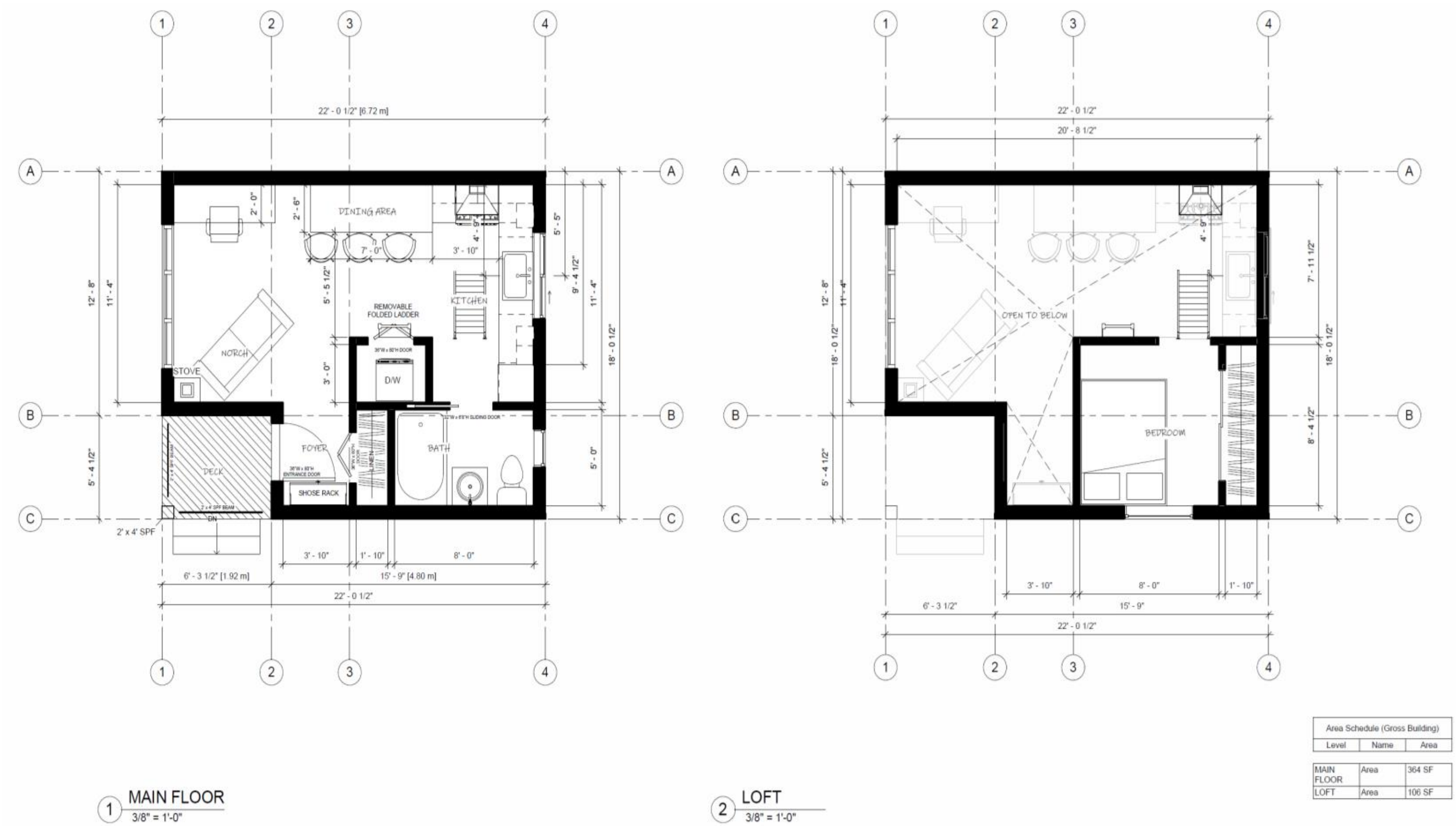
Appendixes

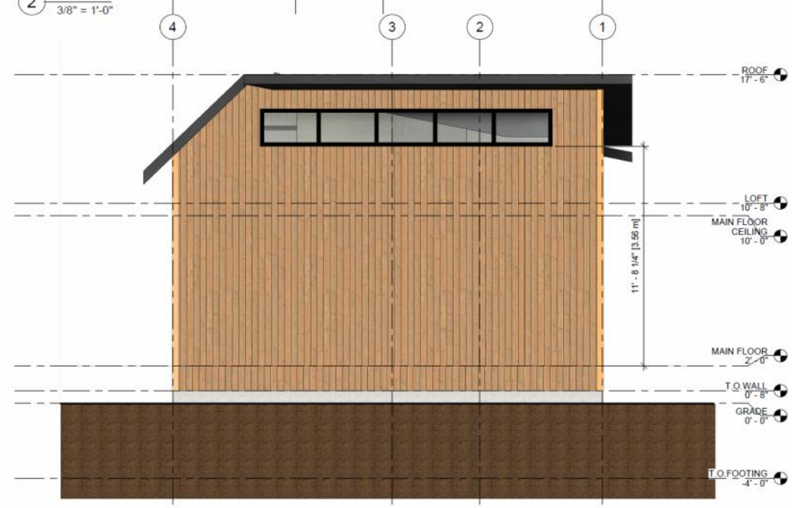
Appendix 1 Tiny house floor plan



1 South
3/8" = 1'-0"

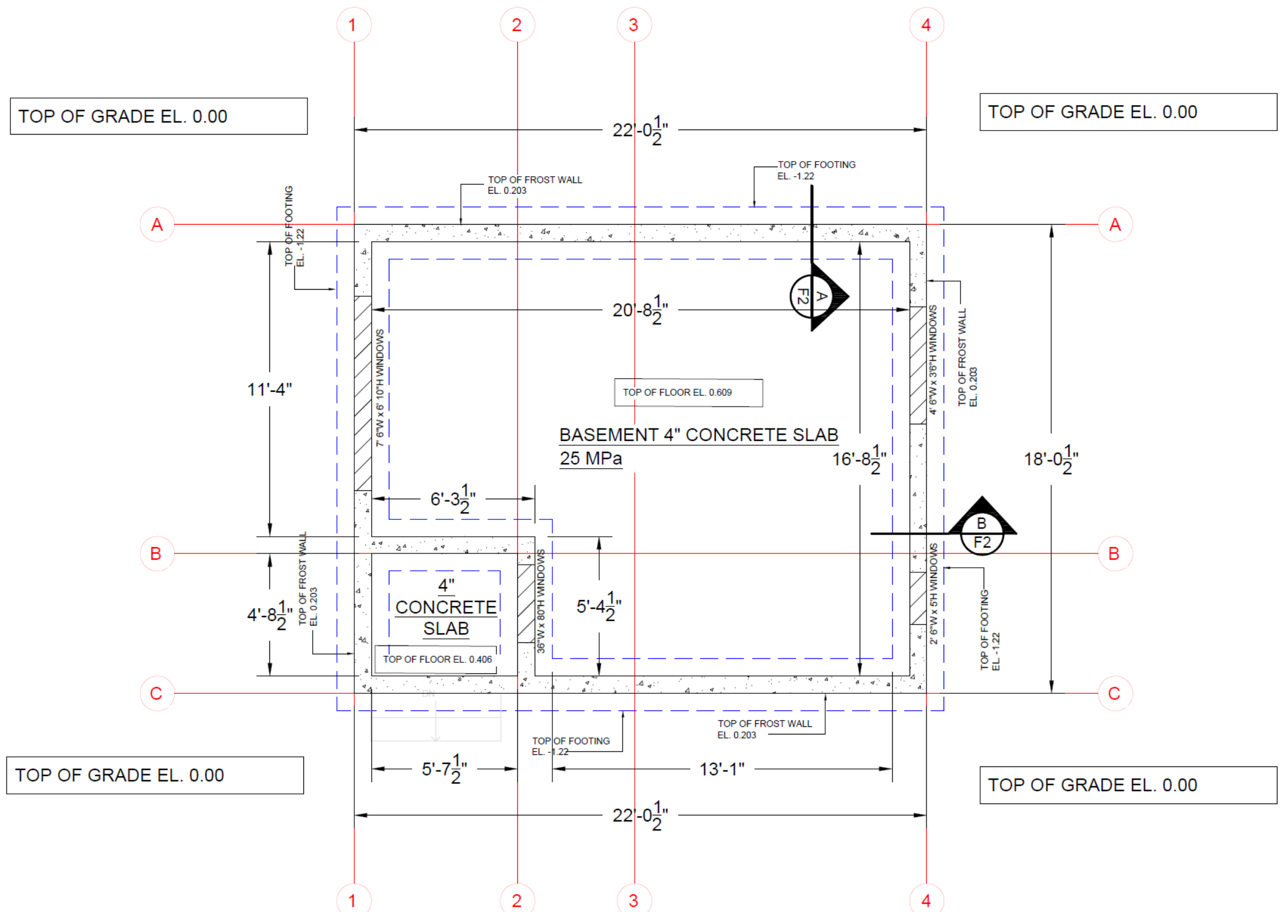
2 East
3/8" = 1'-0"

3 North
3/8" = 1'-0"



4 West
3/8" = 1'-0"

Appendix 2 Tiny House Foundation Plan



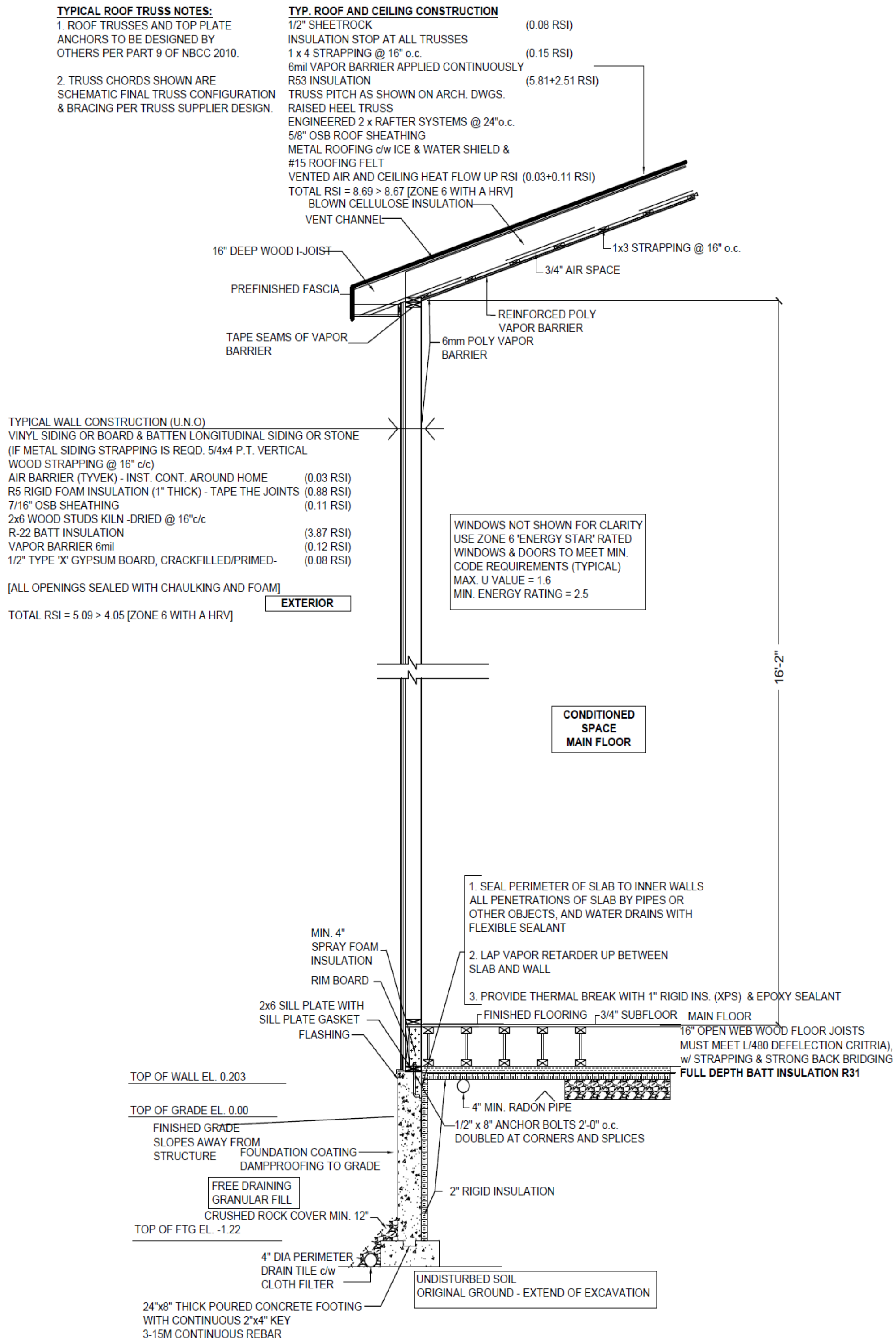
GENERAL NOTES AND SPECS

1. CONSTRUCTION TO MEET PART 9 OF NBCC .2010 ALL FOOTING, FOUNDATION AND DRAINAGE WORK SHALL CONFIRM TO NBCC 9.14 & 15. CONSTRUCTION BY ALL TRADES TO MEET OR EXCEED NATIONAL BUILDING CODE, PLUMBING CODE AND ELECTRICAL CODE.
2. REINFORCED CONCRETE MATERIALS, METHODS OF CONSTRUCTION AND WORKMANSHIP TO CSA A23.1-.14, "CONCRETE MATERIALS AND METODS OF CONSTRUCTION" UNLESS NOTED OTHERWISE. CONCRETE DESIGN IN ACCORDANCE WITH CSA A23.03-.14, DESIGN OF CONCRETE STRUCTURES, AND NBCC 2010.
3. REINFORCING TO BE DEFORMED REBAR CONFORMING TO CSA STANDARD G ,30.18GRADE 400. REBAR LAP SPLICES TO BE CLASS 'B'
4. CONCRETE CLEAR COVER: -TYPICAL (U.N.O.) = 2" -CAST AGAINST IN-SITU SOIL = 3"
5. CONCRETE STRENGTH AT 28 DAYS (MINIMUM): - SLAB: 35MPa - FOOTINGS, FOUNDATION WALLS: 25MPa
6. EXCAVATION TO BE APPROVED BY A QUALIFIED GEOTECHNICAL ENGINEER PRIOR TO FORMWORK CONSTRUCTION. DO NOT BUILD ON DISTURBED SOIL. BACKFILL ONLY AFTER FIRST FLOOR FRAMING CONNECTED TO WALLS.
7. FOUNDATION DESIGN AND FOOTING SIZES BASED ON ASSUMED ALLOWABLE SOIL BEARING PRESSURE OF 3000 PSF (150 kPa)
8. SEAL PERIMETER OF SLAB TO INNER WALLS, ALL PENETRATIONS OF SLAB BY PIPES OR OTHER OBJECTS, AND WATER DRAINS WITH FLEXIBLE SEALANT.
9. FLOOR JOISTS, SPACINGS, HANGERS, BRIDGING/STRUTTING DESIGN BY OTHERS. LVL BEAMS, COLUMNS, CONNECTIONS, TRUSSES TO BE DESIGNED BY THEIR SUPPLIER (s). FLOOR JOIST SUPPORTS/BEARING TO BE AS SHOWN ON DRAWING. ALL WOOD CONSTRUCTION SHALL CONFORM TO CAN/CSA O86.1-14. ALL STUDS, SHEATHING, TRUSS IS SPF SPECIES. FRAMING / BLOCKING GRADE: SPF NO. 2 OR BETTER. ENSURE MATERIALS ARE SEASONED TO A MAXIMUM MOISTURE CONTENT OF 19%.
10. LVL TO BE OF MINIMUM GRADE2600: f1.9-E AND EQUAL TO MICROLLAM LVL BY TRUS-JOIST MACMILLAN.
11. OSB STRONG AXIS AT RIGHT ANGLES TO JOISTS. END JOINTS PARALLEL TO JOISTS MUST BE STAGGERED. TONGUE & GROOVE EDGE JOINTS - CASE 1.
12. BRACE ALL BEAMS AND LINTELS ON BOTH SIDES WITH OSB FLOORING OR PERPENDICAULAR JOIST FRAMING TIED TO BEAM.
13. REFER TO TABLE 9.23.3.4& 9.23.23.5 & NBCC 2010 FOR NAILING.
14. NO OPENING PERMITTED IN LOAD BEARING WALLS UNLESS APPROVED BY THE ENGINEER PRIOR TO CONSTRUCTION.

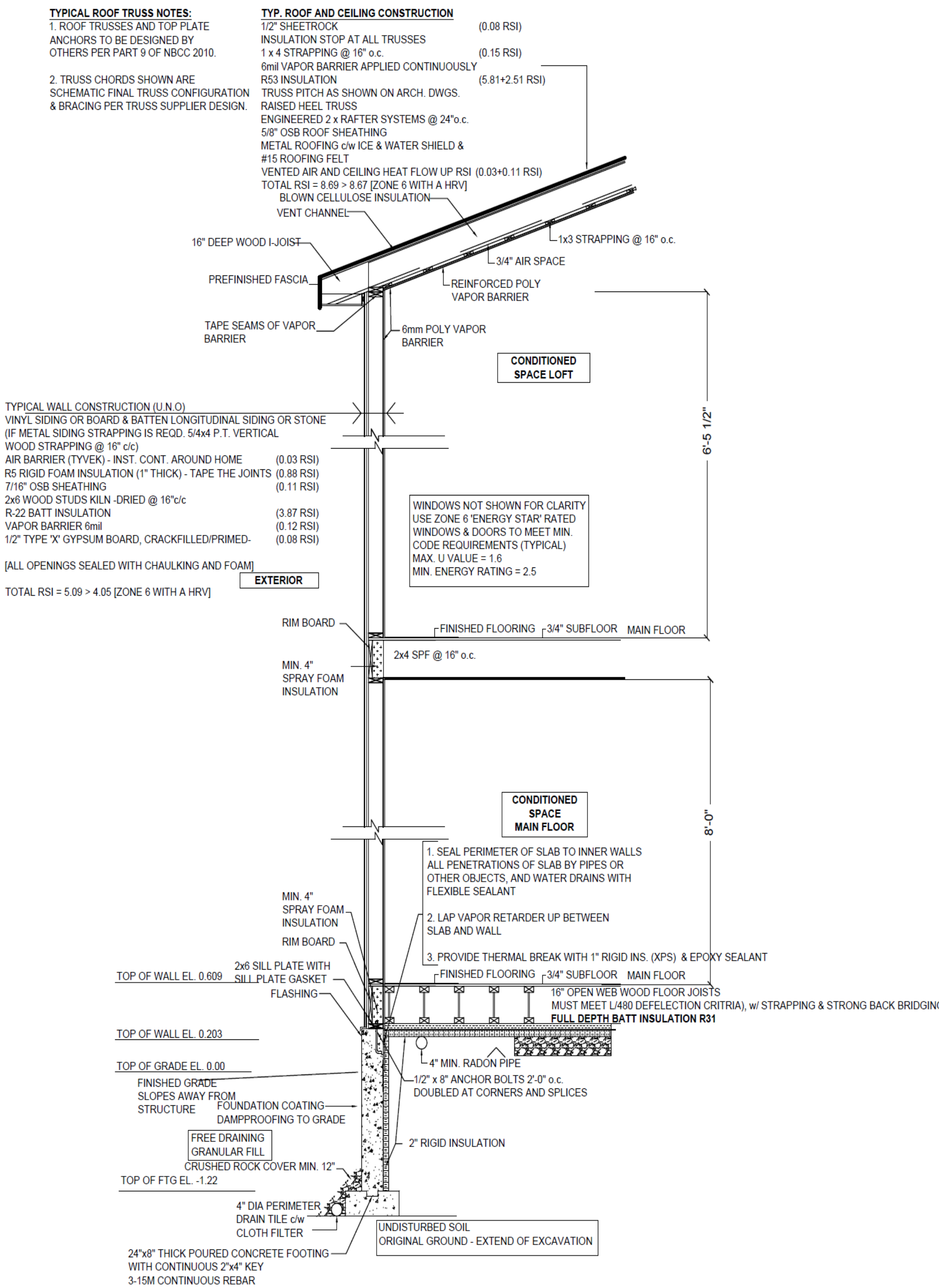
15. REFER TO ARCHITECTURAL DRAWINGS FOR WINDOW/DOOR OPENING SIZES AND PARTITION LOCATIONS.
16. CONFIRM ALL DIMENSIONS PRIOR TO CONSTRUCTION. REPORT ALL DISCREPENCIES TO ENGINEER. ITS CONTRACTOR RESPONSIBILITY TO ENSURE ALL SPECIFIED PRODUCTS SHOWN ON DRAWINGS MUST MEET MANUFACTURERS REQUIRED INSTALLATION.
17. NON-LOAD BEARING WALLS / PARTITION WALLS PARALLEL TO JOISTS SHALL BE SUPPORTED BY JOISTS BENEATH THE WALL OR ON BLOCKING BETWEEN JOISTS.
18. ALL WALL FRAMING EXTERIOR AND INTERIOR LOAD BEARING WALLS TO BE 2x 6AT 16" ON CENTER.
19. FLOOR LOADS ARE CALCULATED @ 36 PSF DEAD LOAD AND 40 PSF LIVE LOAD (MIN.). FLOOR SYSTEM COMPONENTS SELF WEIGHT SHALL BE ADDED SEPARATELY. DEFLECTION IS LIMITED TO L/480
FOR QUALITY CONTROL.
- RIM BOARD SHALL BE STRUCTURAL SOLID BLOCKING FOR NAILING PURPOSES.
20. COLUMNS MUST HAVE A BLOCKING MATCHING MAX. WIDTH/DEPTH OF COLUMN/WALL BETWEEN FLOOR JOISTS. DOUBLE JOISTS UNDER PARTITION WALLS (SEE ARCH. DWGS FOR LOCATIONS)
21. OSB SHEATHING GRADE AND THICKNESS:
- FLOORS: CSA O325 CONSTRUCTION SHEATHING 1F24, 19mm

(3/4") THICK
- EXTERIOR WALLS: CSA O325 CONSTRUCTION SHEATHING 1R24/2F16, 11.1mm (7/16") THICK (U.N.O.).
22. FLOOR (19mm OSB) SHEATHING NAILING (U.N.O.)
- 63.5mm (2 1/2") LONG MIN., 3.66mm DIA MIN., CWN NAILS @ 150mm (6") c/c ALONG PANEL EDGES AND @ 300mm (12") c/c ALONG INTERIOR SUPPORTS.
- FRAMING AT ADJOINING PANEL EDGES ARE 64mm (2 1/2") WIDE MIN.
23. WALL SHEATHING NAILING (U.N.O)
- 63.5mm (2 1/2") CWN NAILS @ 150mm (6") c/c ALONG PANEL EDGES AND @ 300mm (12") c/c ALONG PANEL INTERIOR SUPPORTS. ALL UNSUPPORTED PANEL EDGES SHALL BE SUPPORTED BY BLOCKING AND NAILED AS SPECIFIED ABOVE.

Section A


TYPICAL ROOF TRUSS NOTES:
1. ROOF TRUSSES AND TOP PLATE ANCHORS TO BE DESIGNED BY OTHERS PER PART 9 OF NBCC 2010.
2. TRUSS CHORDS SHOWN ARE SCHEMATIC FINAL TRUSS CONFIGURATION & BRACING PER TRUSS SUPPLIER DESIGN.
TYP. ROOF AND CEILING CONSTRUCTION
1/2" SHEETROCK (0.08 RSI)
INSULATION STOP AT ALL TRUSSES
1 x 4 STRAPPING @ 16" o.c. (0.15 RSI)
6mil VAPOR BARRIER APPLIED CONTINUOUSLY
R53 INSULATION (5.81+2.51 RSI)
TRUSS PITCH AS SHOWN ON ARCH. DWGS.
RAISED HEEL TRUSS
ENGINEERED 2 x RAFTER SYSTEMS @ 24"o.c.
5/8" OSB ROOF SHEATHING
METAL ROOFING c/w ICE & WATER SHIELD & #15 ROOFING FELT
VENTED AIR AND CEILING HEAT FLOW UP RSI (0.03+0.11 RSI)
TOTAL RSI = 8.69 > 8.67 [ZONE 6 WITH A HRV]
BLOWN CELLULOSE INSULATION
VENT CHANNEL
16" DEEP WOOD I-JOIST
1x3 STRAPPING @ 16" o.c.
3/4" AIR SPACE
PREFINISHED FASCIA
REINFORCED POLY VAPOR BARRIER
TAPE SEAMS OF VAPOR BARRIER
6mm POLY VAPOR BARRIER
TYPICAL WALL CONSTRUCTION (U.N.O)
VINYL SIDING OR BOARD & BATTEN LONGITUDINAL SIDING OR STONE
(IF METAL SIDING STRAPPING IS REQD. 5/4x4 P.T. VERTICAL WOOD STRAPPING @ 16" c/c)
AIR BARRIER (TYVEK) - INST. CONT. AROUND HOME (0.03 RSI)
R5 RIGID FOAM INSULATION (1" THICK) - TAPE THE JOINTS (0.88 RSI)
7/16" OSB SHEATHING (0.11 RSI)
2x6 WOOD STUDS KILN -DRIED @ 16"c/c
R-22 BATT INSULATION (3.87 RSI)
VAPOR BARRIER 6mil (0.12 RSI)
1/2" TYPE 'X' GYPSUM BOARD, CRACKFILLED/PRIMED- (0.08 RSI)
[ALL OPENINGS SEALED WITH CHAULKING AND FOAM]
EXTERIOR
TOTAL RSI = 5.09 > 4.05 [ZONE 6 WITH A HRV]
WINDOWS NOT SHOWN FOR CLARITY
USE ZONE 6 'ENERGY STAR' RATED WINDOWS & DOORS TO MEET MIN. CODE REQUIREMENTS (TYPICAL)
MAX. U VALUE = 1.6
MIN. ENERGY RATING = 2.5
16'-2"
CONDITIONED SPACE MAIN FLOOR
1. SEAL PERIMETER OF SLAB TO INNER WALLS ALL PENETRATIONS OF SLAB BY PIPES OR OTHER OBJECTS, AND WATER DRAINS WITH FLEXIBLE SEALANT
2. LAP VAPOR RETARDER UP BETWEEN SLAB AND WALL
3. PROVIDE THERMAL BREAK WITH 1" RIGID INS. (XPS) & EPOXY SEALANT
MIN. 4" SPRAY FOAM INSULATION
RIM BOARD
2x6 SILL PLATE WITH SILL PLATE GASKET
FLASHING
FINISHED FLOORING
3/4" SUBFLOOR
MAIN FLOOR
16" OPEN WEB WOOD FLOOR JOISTS MUST MEET L/480 DEFELECTION CRITRIA), w/ STRAPPING & STRONG BACK BRIDGING
FULL DEPTH BATT INSULATION R31
TOP OF WALL EL. 0.203
TOP OF GRADE EL. 0.00
FINISHED GRADE SLOPES AWAY FROM STRUCTURE
4" MIN. RADON PIPE
1/2" x 8" ANCHOR BOLTS 2'-0" o.c. DOUBLED AT CORNERS AND SPLICES
FOUNDATION COATING DAMPPROOFING TO GRADE
FREE DRAINING GRANULAR FILL
2" RIGID INSULATION
CRUSHED ROCK COVER MIN. 12"
TOP OF FTG EL. -1.22
4" DIA PERIMETER DRAIN TILE c/w CLOTH FILTER
UNDISTURBED SOIL
ORIGINAL GROUND - EXTEND OF EXCAVATION
24"x8" THICK POURED CONCRETE FOOTING WITH CONTINUOUS 2"x4" KEY
3-15M CONTINUOUS REBAR

Section B



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PREFINISHED FASCIA
REINFORCED POLY VAPOR BARRIER
TAPE SEAMS OF VAPOR BARRIER
6mm POLY VAPOR BARRIER
CONDITIONED SPACE LOFT
6'-5 1/2"
TYPICAL WALL CONSTRUCTION (U.N.O)
VINYL SIDING OR BOARD & BATTEN LONGITUDINAL SIDING OR STONE
(IF METAL SIDING STRAPPING IS REQD. 5/4x4 P.T. VERTICAL WOOD STRAPPING @ 16" c/c)
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FINISHED FLOORING
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MAIN FLOOR
2x4 SPF @ 16" o.c.
MIN. 4" SPRAY FOAM INSULATION
CONDITIONED SPACE MAIN FLOOR
8'-0"
1. SEAL PERIMETER OF SLAB TO INNER WALLS ALL PENETRATIONS OF SLAB BY PIPES OR OTHER OBJECTS, AND WATER DRAINS WITH FLEXIBLE SEALANT
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