

# **Unearthing the importance of Earthships**

**ARCC 1202A**

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## Introduction

### What are Earthships?



Figure 1: Euro Global Earthship. (Earthship Biotecture).



Figure 2: Waybee Global Model Earthship. (Earthship Biotecture).



Figure 3: Domingo Earthship. (Earthship Biotecture).



Figure 4: Lone Tree Global Earthship. (Earthship Biotecture).

Earthships are off-the-grid, self-sustaining houses designed with various innovative features that allow residents to survive completely by their own means, at least when it comes to utilities.<sup>1</sup>

They are a relatively new building type, surfacing on the market only in the last 50 years. They are often promoted and advertised as the most eco-friendly way to live, and they target the younger, more eco-conscious generations. This project has the end-goal of helping residents explore a different lifestyle; one that is significantly better for the environment.

Commissioning the construction of one of these houses can be expensive depending on the region where it is built and so the green advertisement and sustainable features target the upper middle class as well as the richer percent of

homeowners. Earthships are relatively built for \$220-\$275 per square foot<sup>1</sup> which is considered expensive in Taos, New Mexico, the area where they were first created and the region which has the highest concentration of Earthships in the world. In regions with higher priced housing markets, a 2000 sq-foot Earthship at the price of \$550,000 is a good deal.

And while each building is unique, there are general consistent factors that allow these 'green' houses to be considered Earthships. They are all built mainly of recycled and upcycled materials such as "earth-packed tires, aluminum cans, glass bottles, cement, adobe, [...] stucco,"<sup>2</sup> (the Spruce) concrete and wood. The houses have built-in facilities for utility collection and production. Rain and snowfall is accumulated, and the water is reused multiple times to make the most of each drop. Solar and wind energy is also harnessed to power Earthships. The heating and cooling of these buildings is not a concern either, as the sun and earth provide thermal heat for the structure, bypassing the need for fossil fuels. What's more, liquid waste is processed through built-in treatment and distribution facilities to allow for safe disposal.<sup>1</sup> Many Earthships also have gardens or greenhouses incorporated as well, so that residents can grow their own food.

The effectiveness, and cost effectiveness of these projects may not justify their creation. This report will explore Earthships as a general theme before delving deeper into two examples to truly understand this type of structure, how it works and whether in the end, it's 'all worth it.'

## Origins

The first Earthship was designed by Mike Reynolds in the 1970s. The energy crisis of the 70s,<sup>3</sup> caused by the sudden drop in the supply of petroleum and oil, led to an increased output of Earthships as people started looking for ways that more sustainable energy sources could be incorporated into everyday life. Since then, the buzz around Earthships just continued to grow especially with the boom of social media and the current increased access to information through the internet. Apps like Instagram and TikTok have also helped pique curiosity and increase interest. Today Earthships can be found all around the globe. There are currently over 3000 recorded Earthships worldwide. The majority of these structures can be found in the United States.<sup>4</sup>

Reynolds' firm, Earthship Biotecture, is the world's leader in Earthship architecture. Not only does the company produce these houses but they also teach

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<sup>1</sup> [Earthship Homes: Cost, Characteristics, Pros and Cons - Parade: Entertainment, Recipes, Health, Life, Holidays](#)

<sup>2</sup> [What Is an Earthship? \(thespruce.com\)](#)

<sup>3</sup> [1970s Energy Crisis - Causes, Effects, OAPC \(history.com\)](#)

<sup>4</sup> [What Is an Earthship? \(thespruce.com\)](#)

and assist families in the design and production of their own Earthships. The company focuses on ensuring all Earthships have six fundamental features: interior food production, solar photovoltaic energy production, water collection, thermal mass heating/cooling, upcycled building materials, and on-site sewage treatment.<sup>5</sup>



Figure 5: Earthship Biotecture company logo. (Michael Reynolds).

Thanks to the flexibility in terms of location because these houses are off-the-grid, construction of an Earthship is not tied to proximity to power lines as most other residential houses are. Often, Earthships must be built in more rural areas because zoning laws and building codes prevent the structures from being constructed near residential neighbourhoods. Climate also plays a key role in selecting a site for an Earthship. Due to the fact that these houses rely entirely on thermal heating from the sun and the Earth, cold Northern climates or other climates that receive too much shade cover are not suitable for Earthships.<sup>6</sup> Similarly, regions with too much rainfall can lead to flooding in an Earthship.

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<sup>5</sup> [Earthship Biotecture - Off Grid Sustainable Green Buildings - Earthship Biotecture](#)

<sup>6</sup> [Earthship Homes: Cost, Characteristics, Pros and Cons - Parade: Entertainment, Recipes, Health, Life, Holidays](#)



## Structural System of Earthships

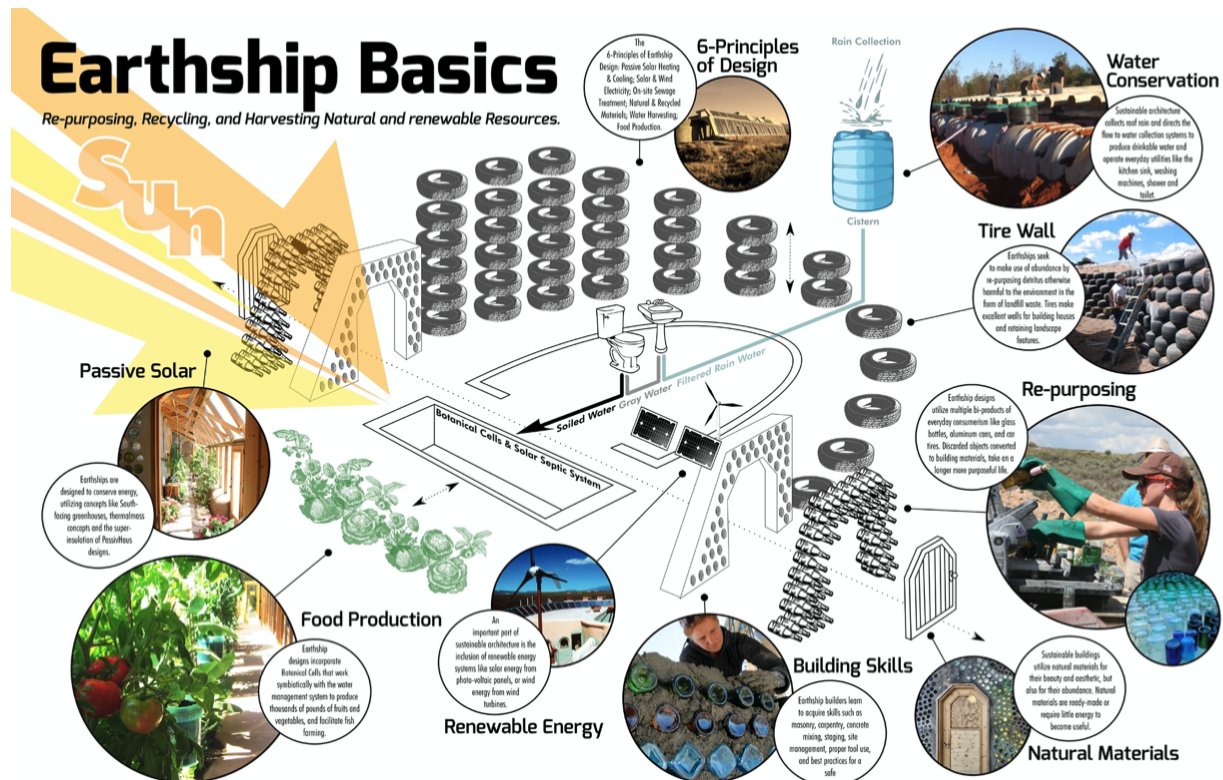


Figure 6: Earthship Biotechnology's diagram of general Earthship elements. (Earthship Biotechnology. "Earthship Design Principles.")

## The Six Core Principles

Earthships are passive solar houses designed to be self-sufficient and sustainable. They utilize the Earth's natural resources and climate to create a completely off-the-grid, or partially off-the-grid home. The overall structure of an Earthship is comprised of six core principles:

### ★ Thermal/Solar Heating and Cooling

The Earthship design exploits the sun's energy to heat and cool the home, using thermal mass to store heat during the day and release it at night (Pangea Builders).

### ★ Water Harvesting

Earthships use a combination of greywater recycling and rainwater/snow harvesting to obtain water that the building will utilize and circulate four times without polluting underground water aquifers (Earthship Biotechnology).

### ★ *Wastewater Treatment*

Earthships use composting toilets and greywater systems to treat and recycle waste on-site, reducing the environmental impacts of the home. The recycled sewage and treatment cells are also used for food growth (Earthship Biotecture).

### ★ *Food Production*

Earthships often incorporate greywater interior greenhouses and hydroponics to grow fresh produce for the residents (Earthship Biotecture).

### ★ *Solar and Wind Electricity*

Earthships typically incorporate renewable energy systems such as solar panels and wind turbines to produce electricity to function off-the-grid. Other forms of generating electricity also include Micro-Hydro, Geo-Thermal, and Biodiesel (Pangea Builders).

### ★ *Natural and Recycled Materials*

Earthships are built using sustainable, natural, local, and recycled materials, such as earth-filled tires, bottles, cans, and adobe, which help to reduce waste and create a low-carbon footprint (Pangea Builders).

## General Construction

### Choosing a Site

According to Thomas E. Griepentrog (Professional Engineer. T.E.C. D.C.), proper site drainage is crucial for maintaining the stability of tire walls, especially when using earth cliffs. Both surface and subsurface drainage must be managed to keep the foundation area dry throughout the building's lifespan, and no standing water should be present within 50 feet of the building. Landscaping around the building must be planned to divert all surface water runoff. It's also necessary to check for underground springs on or near the site.

### Tire walls

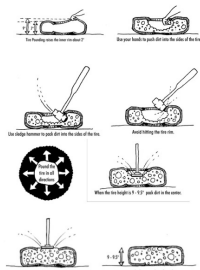


Figure 7:  
Pangea Builders.  
Tires rammed  
with Earth.

The central load bearing walls are about two feet four inches wide and are built using reused tires (their diameter matches the wall's width) packed with dirt (figure 7). The tires are then arranged in a staggered pattern (figure 8), in a similar way to adobe blocks, concrete blocks, and bricks are stacked (DeLapp). Mud plaster (made up of sand, straw and adobe mix) is then applied to the interior surfaces and used to fill in the empty spaces between the tires (Griepentrog).



Figure 8: Pangea Builders.

A wall is constructed to enable drainage near the rear at a height between seven to ten feet. The weight at the bottom of the wall is at most 3,600 pounds, and due to the narrow width of the wall, the pressure on the soil is approximately 1,550 pounds per square foot. According to Keneth DeLapp (P.E. Structural Engineer), the low soil pressure under the wall eliminates the need for a wide concrete footing, as it should not result in significant settlement.

Griepentrog explains how lateral bracing, which provides resistance against sliding and overturning, can be added to a free-standing wall. This bracing can be both horizontal and vertical. It is also transferable through the wall via tire-to-tire friction that occurs because of overlapping tiers of tires. This frictional force increases the wall's strength because any failure within would require overcoming the frictional forces along each plane of movement.

If tire walls stand without support, they can resist up to 36 pounds per cubic foot of fluid pressure. However, they should not be subjected to any lateral pressure until a U-shaped configuration or battered tire wall secures them at the closed ends and the wall returns at the open ends. After adding these reinforcements and installing the roof, the tire walls can endure lateral earth pressures as high as 128 pcf (Griepentrog).

### **Roof Attachment**

A standard roof is built with wooden Vegas with an approximate length of 16 feet (DeLapp). The roof attachments are crucial for the lateral bracing to stabilize the tire walls. Anchor bolts are used to tie the tires to concrete grade beams, securing a strong connection. The anchor bolts should be at least 7 inches long and surrounded by 3 inches of concrete on all sides in the concrete cavity carved into the top row of tires. The cavity should also extend at least 2 inches beyond the inside lip of the tires, and the anchor bolts from the grade beam to the sill plate should comply with the requirements of the Uniform Building Code for conventional construction (Griepentrog).

### **Battered Wall**

In Earthships, a sloping wall called a battered wall is crucial for providing stability and strength to the building, according to Griepentrog. Its purpose is to resist external forces and pressure acting on the wall. The battered wall is usually placed at the end of the tire walls in an Earthship to support the roof and distribute its weight evenly. The angled design of the battered wall reduces the lateral forces acting on the structure, making it more resilient to natural disasters like earthquakes and high winds (Griepentrog).

To provide a few examples of how these structural concepts are implemented in Earthships, the Kinney Earthship and the UNITY Earthship are two well-known examples of Earthships that showcase the versatility of this sustainable building design.

## Kinney Earthship



Exterior facade of the Kinney family Earthship. (David Dodge, Green Energy Futures).

The first exemplary Earthship that will be highlighted is the Kinney Earthship in Alberta, Canada.<sup>7</sup> This Earthship was the first of its kind in Alberta and was built by the Kinney family with the help of Mike Reynolds of Earthship Biotecture and volunteers from the Earthship Biotecture Academy. Duncan Kinney writes in a blog describing his and his father's experience building their family Earthship, "People want greener, cleaner, more energy efficient housing and they're educating themselves about it."



Kinney Earthship's entryway that doubles as a greenhouse to grow produce all year-round. (Christina Ryan, Calgary Herald).

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<sup>7</sup> 82. [How we built our own Earthship, a radically sustainable, off-grid home on the prairie - Green Energy Futures](#)



The Earthship has an indoor greenhouse that doubles as an entry walkway, creating a dynamic living atmosphere while at the same time making the most of every square foot of space.

The house is oriented south for maximum sunlight and was built into an artificial hill with a long, back retaining wall running the length of the building. The front face has a wall of large glass windows, allowing as much sunlight as possible to enter the building.

The project generated a lot of buzz; news crews from multiple outlets and hundreds of common folks visited the site to behold and ask questions about the structure and how it functioned entirely autonomously. The Kinney Earthship is a 1,800-square-foot house with three bedrooms (Kingbeil). The construction took about five weeks.

The Kinney Earthship is also a prime example of the common structural elements of a typical Earthship. It is a self-sufficient, off-the-grid home that utilizes passive solar heating and cooling, rainwater harvesting, and greywater recycling systems. The structural system of the Kinney Earthship is based on sustainable principles with its use of natural and recycled materials such as earth-filled tires, glass bottles, and aluminum cans (Klingbeil). The home is designed to be aesthetically pleasing and functional, emphasizing energy efficiency and sustainability.



Photo by Duncan Kinney,  
Green Energy Futures

The Kinney Earthship utilizes recycled materials such as tires and bottles to create a sturdy and sustainable home. The central load-bearing walls consist of reused tires packed full of dirt and stacked to the desired height, providing thermal mass to regulate the temperature inside the home. The walls are fully encased in mortar, allowing the building to retain heat and remain at comfortable temperatures even through the frigid Canadian winters (Kingbeil). The interior walls are composed of “aluminum cans sandwiched into a honeycomb matrix of concrete” (Kinney). The roof is supported by wooden vigas, which span the 16-foot distance between the two tire walls (see Figure 9).

These vigas are attached to the tire walls and are covered with a layer of insulation and a waterproof membrane to protect the home from the elements. The Kinney Earthship also incorporates a greenhouse on the south-facing side of the building, helping regulate the indoor temperature and providing a source of fresh produce (Dodge).



Earthships are self-sustaining homes constructed from as much locally-sourced, reclaimed material as possible.



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This is a detailed architectural floor plan of a house, showing various rooms and their dimensions. The plan includes a large living area with a fireplace, a dining area, a kitchen, and a breakfast room. There are three bedrooms, a bathroom, and a laundry room. The plan also shows a large deck, a pool, and a hot tub. The overall dimensions of the house are 84'-6" wide by 102'-3" deep. The plan is oriented with the front of the house at the top.

Key features and dimensions include:

- Overall Dimensions:** 84'-6" wide by 102'-3" deep.
- Rooms and Dimensions:**
  - Living Room: 13'-6" x 10'-2"
  - Dining Room: 10'-2" x 10'-4"
  - Kitchen: 10'-2" x 10'-4"
  - Breakfast Room: 10'-2" x 10'-4"
  - Bedroom 1: 11'-0" x 11'-0"
  - Bedroom 2: 11'-0" x 11'-0"
  - Bedroom 3: 11'-0" x 11'-0"
  - Bathroom: 5'-0" x 7'-0"
  - Laundry Room: 5'-0" x 7'-0"
- Other Features:**
  - Deck: 10'-0" x 10'-0"
  - Pool: 10'-0" x 10'-0"
  - Hot Tub: 5'-0" x 7'-0"
  - 1700 gal cistern
  - 10" x 40'-0" culvert for cooling tube
  - 2" rigid insulation
  - granite covered roof
  - (top) velux operable Egress

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## UNITY Earthship



The UNITY Earthship in New Mexico is another excellent example of how Earthships utilize sustainable building techniques to create a self-sustaining living space. Its unique structural systems and concepts showcase the potential for eco-friendly, off-the-grid living. The building incorporates passive solar heating and cooling, rainwater harvesting, and solar electricity, making it a net-zero energy structure (Earthship Biotecture - "We Build Earthships"). Furthermore, the use of recycled materials, including tires and glass bottles, is a testament to the versatility and sustainability of Earthship construction.

UNITY Earthship, World Ecologies.

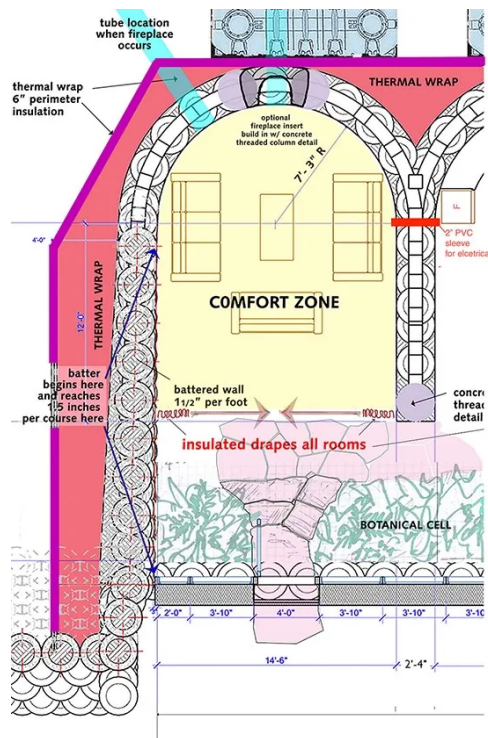


Figure 11: Enlarged capture of UNITY floor plan to show structural elements. (World Ecologies)

Earthship Biotecture, the company responsible for the design and construction of the UNITY Earthship, introduced early design concepts that incorporated multiple U-shaped living spaces (Figure 12), in contrast to the Global model's use of one large U shape. This creative design approach resulted in a more adaptable and roomy living area (Earthship Biotecture - "The Unity Earthship"). Similar to the Kinney Earthship, UNITY's interior walls are built with tires packed with rammed earth and then encased in plaster. In addition, a thermal wrap is installed to help the structure sustain an even temperature. What UNITY does differently is how it utilizes glass bottles in interior and exterior walls as ornamentation that plays with light (similar to glass windows - Figure 13). The Unity Earthship has its cisterns buried on the north side. These cisterns can hold up to 3000 gallons of water (Figure 14).

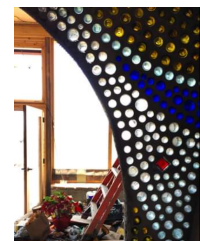


Figure 13:  
Design by  
@earthship on  
Facebook



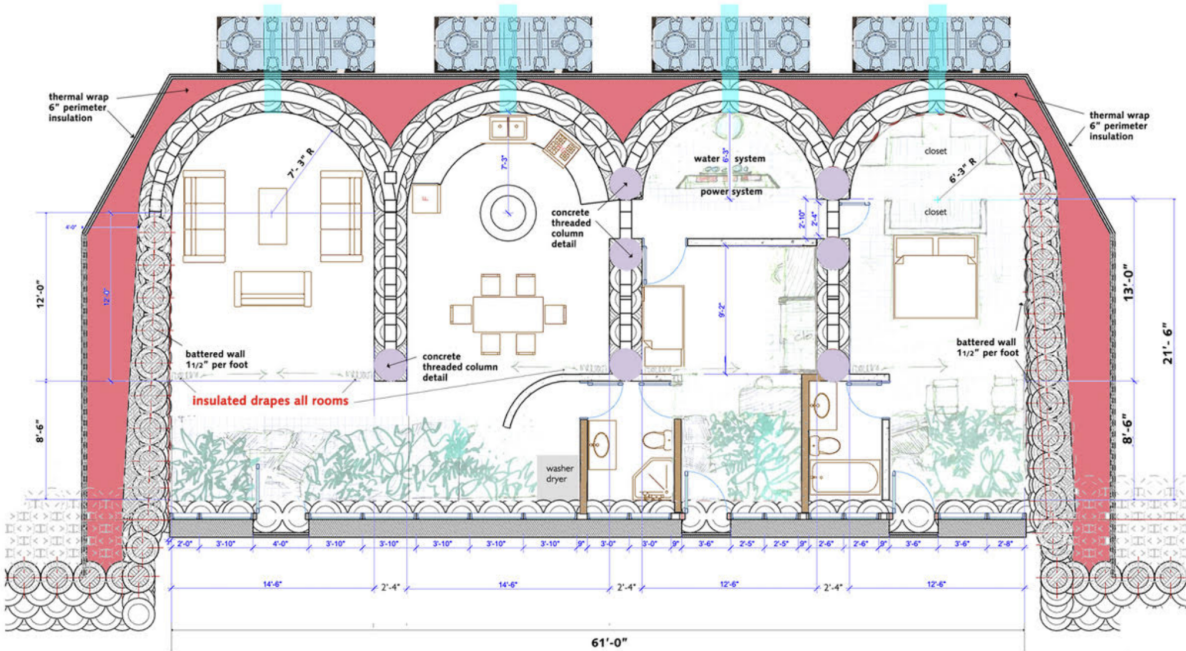


Figure 12: UNITY floor plan showing living spaces layout and interior structure. (World Ecologies)

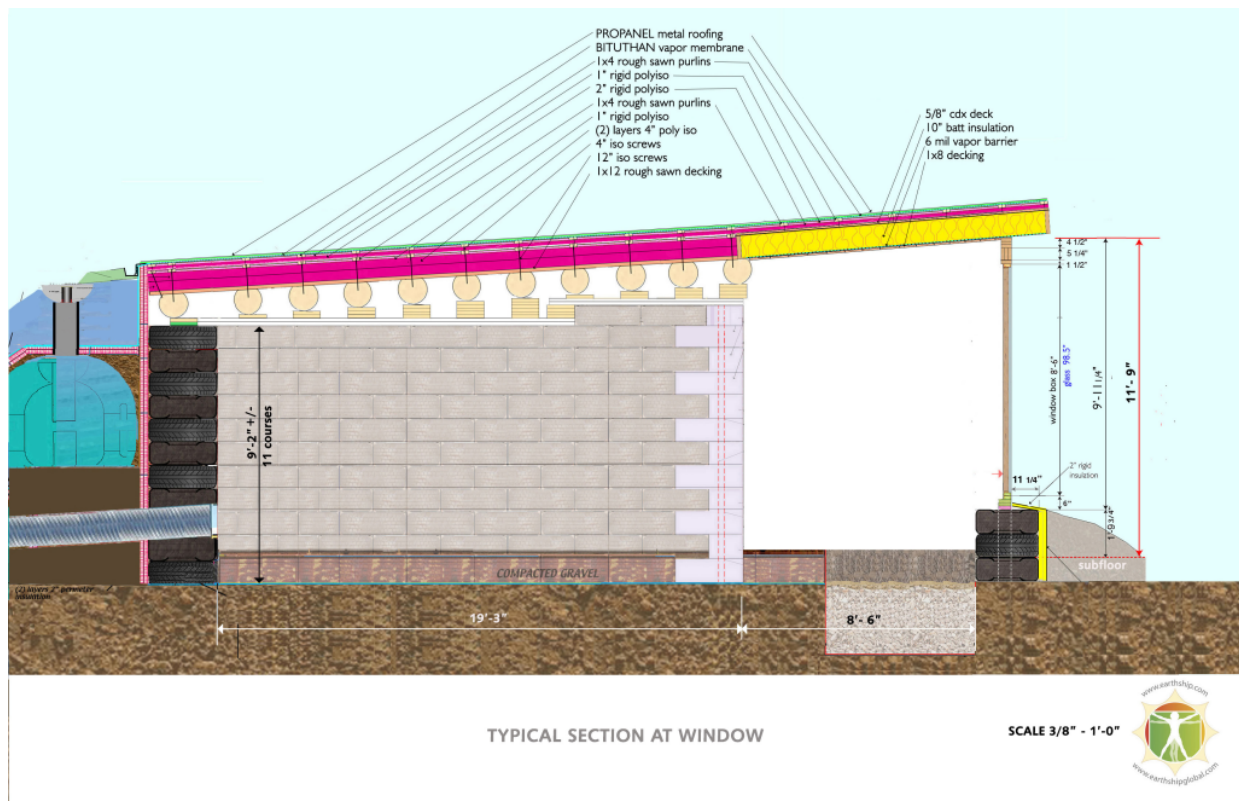


Figure 14: UNITY section drawing showing placement of cisterns and other structural elements. (World Ecologies)

## Conclusion

### Earthships and Architecture

Earthships are a form of sustainable and self-sufficient housing that incorporates various architectural features and principles. These buildings are designed to minimize their impact on the environment while providing comfortable and affordable living spaces for their occupants.

Earthships typically feature several sustainable design elements, including passive solar heating and cooling systems, water harvesting and recycling systems, and the use of natural recycled materials in construction. They are often built using earth-filled tires or other natural materials and may incorporate features like green roofs, indoor gardens, and natural ventilation systems.

Earthships represent a unique and innovative approach to architecture that emphasizes sustainability, self-sufficiency, and a deep connection to the natural world. As such, they have gained a following among environmentalists, homesteaders, and others interested in sustainable living practices.

The structure and design of Earthships are closely tied together, as the buildings are designed to be self-sufficient and sustainable; the structure is an integral part of achieving these goals.

Earthships are typically designed with the *six principles* (page. 6) in mind. The structure of the building is therefore designed to support these principles and to work in harmony with the natural environment.

The walls of an Earthship are commonly made from earth-filled tires or other natural materials, which provide excellent thermal mass and help to regulate the temperature inside the building. This design of the walls correlates with the sustainable principles of the house and the overall aesthetic and functionality of the space.

Similarly, the design of the roof and the placement of windows and skylights are also closely tied to the goals of the building, as they are designed to maximize natural light and ventilation while minimizing energy use. The overall design is thus a reflection of the sustainable principles that underlie the Earthship concept, and the structure is an integral part of achieving these goals.

## Limitations of Earthships

The practice of architecture is slowly progressing forwards and becoming much more sustainable. It is likely that they will continue to be developed, expanding their reach until they become more of a standard home construction design. However, as they stand currently, there are a few limitations preventing Earthships from reaching their full potential.

Earthships require a substantial financial investment before a homeowner can start reaping any rewards. Yes, utility costs are not a major concern later on, but since these houses are not the standard in residential design, they require specialized skilled labour, which can be expensive. Hiring a regular construction crew will not be appropriate for this. Most prospective homeowners go directly to the source and hire Earthship Biotecture to design and build their Earthship. While Earthship Biotecture does rely heavily on volunteers for manual labour, the cost of their help can be expensive.

The construction of Earthships can be expensive in New Mexico, where they are most common. The housing market in New Mexico prices the average residential house significantly lower than the housing market in Canada. However, building an Earthship in rural areas of Canada at \$550,000 USD for a 2,000 sq-foot house is affordable.

That being said, unless a prospective owner has that kind of cash on hand, it is quite hard to finance a project like this. Mortgaging Earthships proves to be quite difficult because this type of house is still relatively new. Most banks do not have comparable models to determine the value of such a home. Most banks will not be able to take on the risk and so if a homeowner cannot buy an Earthship outright, they often cannot afford to buy an Earthship at all.

Another issue that Earthship builders come across is the difficulties in choosing a site with a prime location. Due to zoning laws, Earthships cannot be built in neighbourhoods or suburbs. They typically end up being built in significantly more rural areas. This can be inconvenient for the average homebuyer who greatly prioritizes location. This means that access to grocery stores, schools, workplaces and even city attractions is reduced. Meeting up with friends and family is not as simple in an Earthship as it is in a suburb. This is why the people that typically find themselves building Earthships are older: seniors considering retiring or downsizing who can afford to move away from the hustle and bustle of urban city life without the responsibilities of young kids or workplace goals to consider.

When considering a location, climatic conditions also play a role in determining whether a site is suitable for the construction of an Earthship. Since these houses rely on thermal heating from the ground, going too far up north is not an option. A great amount of sunlight is necessary, so regions with frequent or

constant cloud cover are also out of consideration. Areas that receive high amounts of precipitation could also cause major concerns because too much rainfall can result in the house flooding.

Another factor that limits the consideration of an Earthship is the construction period of the project. This might not be the house for an impatient prospective homeowner because Earthships require twice as long to build than the typical residential house.

## The Future for Earthships

While all the limitations listed above do currently exist, moving forward and improving the design of these buildings is possible to make them a standard residential house design. In the long run, Earthships are beneficial for everyone to move towards sustainable energy resources by moving away from fossil fuels which will improve the state of our environment. As Earthships become more of a common practice and more people are made aware of them, zoning laws and bank financing will likely become much more receptive to accommodating them. Regarding more specific regional location concerns, with the further development of Earthships and their internal structural design, they can be improved upon to withstand and deal with harsh weather conditions.



An example of these latest developments already underway is the construction of the Florida Earthship. This Earthship addresses the common occurrence of hurricanes that can damage or completely destroy Florida residences, by being built to withstand high winds. It is, as the website claims, “hurricane resistant.”<sup>8</sup>

Figure 15: Florida Hurricane Resistant Earthship. (Pangea Builders).

In the future, Earthships can be expected to continue to adapt and to possibly become one of the best sustainable residential house types.

There are several other potential future directions for Earthships, such as expanding their use in urban environments. As sustainable building practices become more widely adopted, there may be increased interest in Earthships as a viable housing option. Additionally, advancements in technology and materials may lead to further improvements in the design and construction of Earthships, making them even more efficient and cost-effective.

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<sup>8</sup> [Florida Earthship - Pangea Design | Build \(pangeabuilders.com\)](https://pangeabuilders.com/build)



Illustrating how Earthships may eventually integrate into an urban environment, the company Earthship has introduced a new concept called Urban Sky Autonomy (Figure 16).

"This building sits on a tower, of any height, on any urban site in the world. It independently addresses the six major issues that every city in the world must address in order to provide for the people. These issues are: 1) comfort control; 2) water; 3) liquid waste; 4) energy; 5) solid waste; 6) food. We are leaning toward relief for struggling conventional infra structures in dense population sectors the world over." (Earthship - World Ecologies. See more details on the figure 16 source provided below.)

Figure 16: Urban Sky concept design by Earthship.

As the global community continues to focus on reducing its carbon footprint and addressing climate change, Earthships may play an increasingly important role in providing sustainable, off-the-grid housing solutions.



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