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# The Earthship: A Holistic and Sustainable Housing Model

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**Abstract**

Escalating climate change brought about by carbon emissions and dwindling finite resources demand urgent sustainable housing alternatives, especially for the worst offenders: single-family homes in developed nations. There are several net-zero energy home models in existence, but the Earthship is the only home model specifically designed to autonomously fulfill the four basic human needs of water, food, energy, and climate control. Earthship homes are versatile, fairly affordable, and can be used in any climate or geography, scalable, and use recycled material in the construction. The Earthship's innovative and holistic design principles offer a viable and compelling solution for the environmental damage being caused by conventional modern single-family housing, creating a more sustainable future for all.

*Keywords: climate change, sustainable housing, Earthship, net-zero energy homes, recycled materials*

## I. Introduction

Throughout all times, people have looked to the sky, seeking inspiration in a humble attempt to understand the unfathomable Universe. But unlike the endless vastness of space, the resources of our fragile planet are not infinite. One reason for this is the growing demand for energy for more than 8 billion people. In the 1970s, the seemingly impossible became reality when space stations were launched that were able to provide for human needs using revolutionary new self-sufficiency technologies such as solar energy and limited recycling of air and water, allowing the crews of these stations to live on board for weeks or even months (Curreri). But what if people could design homes on Earth that would meet their needs as autonomously as space stations? Unlike real spaceships, where regular food supplies are indispensable, on Earth such a level of independence is quite realistic. This future-oriented thinking is precisely what American architect Michael Reynolds has pursued since the early 1970s, culminating in what is possibly the most sustainable and comprehensive green building design in existence: the Earthship.

Scientists widely agree that manmade greenhouse gas emissions, primarily caused by burning fossil fuels for energy, are the underlying cause of global warming (Intergovernmental Panel on Climate Change). The global average annual carbon emissions per capita are about 4 tons, but in some countries this figure is much higher. For example, in Qatar it is 34 tons (International Energy Agency, "Qatar"), and in the USA it is 14 tons (International Energy Agency, "USA"). But even in countries like Kenya and Cameroon, where per capita emissions are relatively low (less than 0.4 tons on average), their contribution to global $CO_2$ levels is still significant due to the size of the population (International Energy Agency "Kenya", "Cameroon"). The Intergovernmental Panel on Climate Change warns that people need to urgently reduce these emissions to avoid catastrophic warming and destruction of our habitat. (Intergovernmental Panel on Climate Change).

Unfortunately, since international agreements such as the 2015 Paris Agreement and national regulatory measures have failed to reduce emissions to the required levels, it is more important than ever that people reduce their own environmental footprint (Maizland and Fong). We cannot ignore the fact that modern housing is a major source of greenhouse gas (GHG) emissions. In the EU in 2022, it accounted for 34% of energy-related emissions, which are partly related to the direct use of fossil fuels such as oil and gas in boilers for heating buildings, as well as the production of electricity and heat for their needs (European Environment Agency).

In order to achieve the most effective overall reduction in emissions, the worst household offenders should focus on reducing their own emissions. Reynolds realized this, created and continuously improved upon a revolutionary type of off-grid home that, in Reynolds' words, "takes care of people" (Earthship Biotecture "We Build Earthships"). The goal of the Earthships is to autonomously provide for the four primary needs of modern humans - water, food, climate control, and energy efficiently and sustainably, in addition to reducing environmental harm from construction. It also does this while simultaneously providing a very sturdy structure that can withstand hurricanes and earthquakes (Earthship Biotecture "We Build Earthships.").

## II. The Construction Process

The construction of a standard modern house in a developed country is accompanied by significant greenhouse gas emissions due to both the materials used and the methods of construction. Also, depending on the area and materials chosen, emissions for a modern home are estimated from 32 tons up to 78 tons (Massachusetts Institute of Technology). The use of cement is especially problematic, as the production of cement alone accounts for 7% of global carbon emissions (Massachusetts Institute of Technology). But even renewable materials like wood can have quite a significant carbon footprint if they are chamber dried or treated chemically. For example, the production of chamber dried hardwood in the southeastern United States generates emissions of 209 kg of CO2 per cubic meter (Heidari et al.).

In addition to the materials themselves, the construction process often involves the use of diesel machinery such as bulldozers and cranes, which introduces additional direct emissions of fossil fuels on construction sites (Weigert et al.). In contrast, Earthships minimize the need for heavy machinery: an excavator can be used to dig an excavation, but most of the work is done manually, which reduces emissions from diesel fuels (Earthship Biotecture "Building with Natural"). Earthships also use a completely different construction logic. They are built partially buried in the ground in order to use the insulating and temperature regulating ability of the soil they are built on. Standard Earthship projects involve walls made of used car tires, densely packed with earth and stacked like bricks covered with adobe or plaster. This technology creates walls with a huge thermal mass, allowing the building itself to accumulate and release heat like a battery. According to Earthship Biotecture, designs typically use at least 50% recycled, reused, or natural materials (Earthship Biotecture "Building with Natural"). This principle is followed in almost all Earthship projects to reduce the carbon footprint and encourage reuse of materials. Tires are especially important in this case, because more than 3 billion of them are produced annually and about 800 million are thrown away, and since they are not biodegradable, including them in construction becomes an innovative solution to the problem of their disposal (U.S. Environmental Protection Agency "Where Rubber Meets the Road"). Though the construction time is longer than in ordinary houses and takes from several months to a year, depending on the size, climate and the ratio of professional and volunteer labor (Earthship Eco Homes). Sizes can range from small mini-Earthships of 50 m2 to spacious multi-room houses of over 300 m2. Such buildings have already been built in more than 20 countries, from hot deserts to cold northern regions. In very cold climates, wood-burning stoves are sometimes additionally used for comfort (Dodge and Thompson). Their cost also varies, but on average, Earthships are comparable in price per square foot to conventional houses in North America from $300 to $400

per ft2 (for example, about $500,000 per 150 m2) for standard sizes, but they can be cheaper when self-built (Earthship Biotecture “We Build Earthships.”).

## III. Water

Throughout history, water, as the most basic human need, has been one of the reasons for both the rise and fall of many civilizations. Undoubtedly, the purification, storage, use, distribution and treatment of water is the foundation of any sustainable home. In this regard, global water use, storage and distribution account for approximately 10% of global emissions (“Global Water Industry”). Earthship solves this problem by implementing autonomous water supply systems suitable for almost any climate, while they can be connected to a well or municipal water supply system if necessary. In Earthship, a drainage system collects rainwater from the roof and directs it to a storage tank. The pump and filter are used to purify and supply water inside the house, where it is distributed through taps and showers, and later it can be used for drinking, cooking and bathing (Earthship Biotecture “Catch Water”). Heating is provided by a solar water heater, which provides residents with convenient access to hot water. The waste water after bathing, or the so-called gray water, enters the greenhouse, where it is used for watering plants. The excess is then sent to the toilets for flushing. After flushing, the "gray water" enters the septic tank, where the solid waste is decomposed by anaerobic bacteria, and the liquid is discharged into the outdoor garden. Such an innovative closed-loop system serves as a comprehensive solution for water supply (Earthship Biotecture “Catch Water”), however, certain difficulties still remain under extreme conditions. Such difficulties may arise in cold climates with prolonged frosts, where systems need to be insulated or buried below the freezing level to prevent pipes from freezing (Penn State Extension). Water collection can be supplemented with wells or the use of meltwater. In arid regions where precipitation is rare or seasonal, cisterns must have increased volume to collect rare rains, and during periods of drought houses are often integrated with wells or municipal networks. These limitations do not make the Earthship system unviable, but they require careful regional adaptation and hybrid solutions.

## IV. Food Production

The agrifood system is now one of the largest and fastest-growing sources of emissions. In 2022, it generated around 16 gigatons of $CO_2$ which is roughly 30% of global totals and 10% higher than it was in 2000 (Food and Agriculture Organization of the United Nations). Agriculture also takes up nearly half of the planet’s habitable land and uses around 70% of global freshwater, highlighting why local and efficient production is so crucial (Ritchie et al.).

The Earthship model inherently includes food production in the building itself. With its south-facing double-glazed greenhouse, it is planted with crops known for their high yields and rapid growth: herbs, tomatoes, peppers, cucumbers, beets, which are chosen because of their high productivity in protected indoor beds (Earthship Biotecture “Food Production.”). As it was described earlier, the greenhouse is integrated into the water cycle of the house to maximize efficient water use, the indoor plants are watered with gray water, while black water is used to water the outdoor plants (Earthship Biotecture “Waste Water Treatment”). Unfortunately, in some countries there are regulations that interfere with such a system, as it was originally in the case of the Ironbank Earthship in Australia. However, with increasing awareness of the benefits of gray water reuse, laws may be revised to allow for such innovative models, as happened with the Ironbank Earthship project (“Welcome to Earthship Ironbank.”).

But how much food can be grown in this greenhouse, for whom and in what area? In practice, Earthship greenhouses are linear "solar spaces", which in family models usually have from 20 to 60 m2 of planting area (Freney et al.). Using conservative indicators of protected agriculture, this translates into 100-300 kg of harvest per year, which is enough to cover a significant portion of fresh vegetables and herbs for 2-3 people, although the main products (grains, oils, animal

products) still come from outside. Field reports and interviews with practitioners estimate the total contribution to family nutrition at 25-50% of the needs, with the variation depending on diet, climate, and time spent gardening (Aspinwall).
Energy

Our world depends heavily on the convenience and comfort that electricity brings us, but there is a problem that lies not even in electricity itself, but in how it is produced. In 2024, almost 59% of the world's electricity was still generated from fossil fuels: coal—34.4%, gas—22%, oil—2.8%, while low-carbon sources reached 40.9% (U.S. Energy Information Administration). For example, housing remains an important source of emissions in the United States.

According to the EIA data for 2024, $CO_2$ emissions from the residential sector have decreased slightly, but when electricity production for residential buildings is taken into account, residential buildings still account for a significant proportion of final energy consumption.

Earthship solves this problem by operating autonomously, outside the common power grid. First, houses reduce demand through structural solutions such as cladding and thermal mass, and then cover the remaining demand with solar panels placed on roofs and batteries. All the electricity received is distributed using charge controllers and inverters (the panels generate DC, and household appliances are powered by AC), and the batteries ensure operation during periods when there is no sun (Earthship Biotecture “Off-Grid Electricity Systems”). Interruptions due to night, winter, or bad weather are also taken into account when designing. The National Renewable Energy Laboratory (NREL) recommends calculating battery life for 1-3 days of average consumption, or more, in regions with frequent cloudy periods and selecting the architecture of the system according to these features (National Renewable Energy Laboratory). As for practice, residents combine energy storage, postponing the operation of energy-intensive appliances at a time when the sun is in abundance, and make seasonal adjustments to the tilt of the panels, if necessary, sometimes add a backup generator for rare long-term outages. Component reliability and service life remains an important area of engineering research in the context of scaling solar panel systems and their storage (Friedman et al.). When power grids switch to low-carbon sources, emissions from electricity decrease. But the climate outcome is determined not by electricity itself, but by how much consumption corresponds to clean energy sources.

## V. Climate Control

In certain climates managing heat is becoming the primary comfort and safety challenge as the climate warms and heatwaves intensify. Globally, residential heating and cooling represent approximately 6% of total emissions; however, in the United States, an average of 42% of a typical house’s energy use is for heating and cooling systems (U.S. Environmental Protection Agency “Sources of Greenhouse Gas Emissions”).

The Earthship’s ingenious design allows for a comfortable temperature to be maintained year-round in almost every climate by utilizing nature optimally. The windows face the sun. The sun’s heat is absorbed by the walls and floors due to the packed earth tire construction, which has thermal mass that stores heat like a battery and releases it when indoor temperatures drop. To stay cool in hot weather, Earthships use cooling tubes to circulate air cooled by the insulated cool thermal mass. Earth tubes remove water from the air. Extensive research finds that additional heating or cooling is almost never needed over the long term in temperate climates (Freney). By harnessing and working with, rather than against, nature, Earthships can provide comfortable temperatures all year in almost every climate, rather than relying on energy and causing emissions (Earthship Biotecture “Thermal Mass”). In climates with extreme cold, however, a backup heating source such as a wood stove is likely needed to maintain a very comfortable temperature (Dodge and Thompson). When a wood stove is used, it’s important to keep the environmental and health trade-offs in mind. Wood smoke releases fine

particulates, black carbon, carbon monoxide and volatile organic compounds, all of which can harm heart and lung health. Modern certified stoves are cleaner, but they still emit more pollution than gas or electric heating, making public health agencies in the U.S. and Europe tighten their standards. The best practice is to burn dry, seasoned wood in an EPA certified stove (U.S. Environmental Protection Agency "Burn wise:").

## VI. Conclusion

With over 3,000 Earthships built across 20 countries on almost every type of geography and climate from the wet highlands of Scotland and Japan, to the deserts of Mexico, to the tropics of Haiti, to Canada, Africa, Australia, China, and beyond. The Earthship has proven its incredible versatility and global impact potential. The satisfaction of Earthship residents was evaluated in a doctoral thesis by M. Freney in 2014. His research found that residents of Earthships reported a high level of comfort and satisfaction, and at meeting its lofty goals. The Earthship should garner more widespread attention to enable more people to take personal responsibility and drastically reduce their own housing emissions, thereby allowing Earth's citizens to collectively reduce the devastating impact of greenhouse emissions and resource depletion and create a more sustainable future.

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