

FEASIBILITY OF EARTHSHIPS AS SUSTAINABLE HOMES IN BROOKINGS
COUNTY, SOUTH DAKOTA.

BY

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THESIS ACCEPTANCE PAGE

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This thesis is approved as a creditable and independent investigation by a candidate for the master's degree and is acceptable for meeting the thesis requirements for this degree.

Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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This thesis is dedicated to my family, those forever engraved in my heart.

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ABBREVIATIONS

EF	Ecological Footprint
EIA	Energy Information Administration
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
IEA	International Energy Agency
IRB	Institutional Review Board
JCHS	Joint Center for Housing Studies
MSW	Municipal Solid Waste
QR	Quick Response
SDGs	Sustainable Development Goals
SDSU	South Dakota State University
UN-DESA	United Nations Department of Economic and Social Affairs
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Program
UNICEF	United Nations International Children's Emergency Fund
USEPA	United States Environmental Protection Agency
WTA	Willingness to Accept
WTP	Willingness to Pay
WTTC	World Travel & Tourism Council

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ABSTRACT

FEASIBILITY OF EARTHSHIPS AS SUSTAINABLE HOMES IN
BROOKINGS COUNTY, SOUTH DAKOTA.

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Addressing the issue of housing deficit while providing affordable and sustainable homes is a significant problem in the United States today. This has prompted architects to design homes with less adverse environmental impacts despite their affordability, hence the birth of sustainable housing. Earthships are sustainable homes built from recycled materials, utilize solar or wind energy, and function as self-sufficient units. The study's main aim is to assess residents' perceptions of earthships and their willingness to adopt earthships in Brookings County, South Dakota. The research employs online surveys to garner data from residents, and data are analyzed using mixed methods. Results indicate that the most significant benefit perceived was the use of renewable energy resources, while the most significant barrier was the county's extreme cold temperatures. Factors affecting willingness to adopt earthships include age, homeownership, view of sustainability, annual gross income, and years of residency. The adoption of earthships in Brookings County will go a long way to contribute to the sustainable lifestyle of the community and release pressure on the County's natural resources.

Keywords: earthships, sustainable homes, perceptions, willingness to adopt, Brookings County

CHAPTER ONE

1.0 INTRODUCTION

1.1. Background to the Study

The sustainable use of natural resources and the preservation of the environment continue to face severe challenges because of population expansion. This is primarily due to excessive resource exploitation, intensified agriculture, urbanization, and land fragmentation, leading to a decline in the quality and quantity of these resources (Maja & Ayano, 2021). According to the United Nations (2023), the global population will increase by around 2 billion over the next three decades, rising from 8 billion to 9.7 billion by 2050 and perhaps reaching a peak of over 10.4 billion in the mid-2080s. With this could arise more issues of food insecurity, shortage of homes, pollution, and increase in energy consumption. We must address these issues through responsible resource management and conservation efforts to ensure the continued availability of our natural resources for future generations.

Sustainable development can play a crucial role in addressing the challenges associated with population growth. The Brundtland Commission Report of 1987 provides the most prevalent definition of sustainable development as "development that meets the needs of the present without jeopardizing future generations' ability to meet their own needs. The National Environmental Policy Act of 1969 committed the United States of America to sustainability by declaring it a national policy "that will encourage productive

and enjoyable harmony between man and his environment; to promote efforts that will prevent or eliminate damage to the environment and biosphere and stimulate man's health and welfare; to enrich understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality” (Congress, 1982). Sustainable development in housing, also known as sustainable housing, aims to achieve the maximum economic, social, and environmental benefits, with success measured by observable variables (Adabre et al., 2021). These observable variables, among others, are essential tools for assessing progress, identifying gaps, and formulating strategies for achieving sustainable development goals at various scales, from local to global (Kwatra et al., 2020).

Organizations like United Nations, Environmental Protection Agency, and the Global footprint network have developed observable variables. Some examples of these variables include carbon emissions, forest cover, water usage, and ecological footprint. The Global Footprint Network in 2008 defined environmental footprint as a measure to determine the human’s impact on the environment concerning the consumption of natural resources. Ecological footprints are calculated based on the consumption and waste produced per country and the Earth's ability to create new resources and absorb waste (Parris & Kates, 2003). The estimated ecological footprint of the United States is 8.1 global hectares per person, with a biocapacity of 3.1 persons. This leaves a deficit of 4.7 global hectares per person in biocapacity, meaning the demand for the country’s resources outweighs what its ecosystems can generate (The Global Footprint Network, 2018). Building with local natural materials reduces the ecological footprint by

decreasing carbon emissions from transportation, preserving biodiversity, supporting sustainable resource management, fostering cultural and community connection, and improving indoor air quality (Wuni et al., 2019). This can create more sustainable and environmentally friendly buildings that harmonize with their surroundings and contribute to a more resilient and sustainable future.

Infrastructural development is seen as a significant contributor to the depletion of natural resources, especially regarding the raw materials used in construction (Razzaq et al., 2022). According to Abraham Maslow's hierarchy of needs, shelter is an essential and basic physiological need. Access to affordable and decent housing is considered a fundamental prerequisite for maintaining a good standard of living, as proffered by the Universal Declaration of Human Rights of 1948 and the International Covenant on Economic, Social, and Cultural Rights of 1966 (UN-Habitat, 2018). A complex relationship exists between increasing population and housing demand, such that a growing population may increase the demand for houses. The demand and access to housing, amongst other factors, are heavily constrained by an increasing population, which may widen the housing deficit (Marshall & Onyekachi, 2014; Mulder, 2006).

The key to addressing the population-housing deficit dilemma differs from providing more housing units by perpetuating current methods. Instead, a concerted effort should be made to ensure sustainable housing units. People are also responsible for making lifestyle choices and promoting sustainable development (Mathew, 2021). Thus, humans must learn to incorporate the habit of living in sustainable homes and adopting

sustainable behaviors into their lifestyle, as the combination of these two factors will ensure the continual availability of resources on Earth (Booth et al., 2021). Various factors, including affordability, energy efficiency, community integration, and the environment in which the building is located, account for the provision of sustainable homes (Mulliner & Maliene, 2011).

Architects in recent years have designed sustainable and alternative homes that utilize renewable energy, such as solar panels, renewable building materials for construction, and more environmentally friendly practices (Erbil, 2018). Examples of such alternative homes are Earthships, known for their ‘off-grid nature,’ and thereby act as independent entities, surviving on renewable energy and adopting sustainable practices such as making use of solid recycled materials in their construction and collection of rainwater for domestic purposes (Sporer, 2018). Specific benefits of earthships include waste reduction, energy efficiency, and water conservation. Earthships offer a holistic approach to alternative housing that can contribute to sustainable development (Colby & Whitley, 2022).

Earthships have been constructed in most states of the United States, and over the last decade, the Earthship Movement has spread to and taken root in several countries outside the United States (Harkness, 2009). Some of the countries in Europe are Scotland, Spain, Belgium, and the Netherlands (Kuil, 2012); in Africa, Sierra Leone, Malawi, and South Africa (Nabahe, 2017); and in Asia, Nepal, India, Indonesia, and the Philippines (Booth et al., 2021). Although earthships have gained recognition in many parts of the

United States and other countries since the construction of the first one in the 1970s (Ekvall, 2019), many residents in other states have limited knowledge of them as alternative homes. South Dakota is one such state, as there is no record of earthships built there. This research thus assesses how feasible the adoption of earthships in Brookings County would be, taking into consideration residents' perceptions of the benefits and barriers of earthships, the factors that will influence their willingness to accept and adopt such buildings, and in so doing, creating the awareness of the importance of earthships on the environment. The study employs Slovin's formula to estimate the number of respondents that would be a representative fraction of Brookings County.

1.2. Problem Statement

The United States is one of the many countries plagued with a widening housing deficit (Kefler, 2021; Schwartz, 2021). The dilemma of bridging the housing deficit while ensuring and maintaining natural and ecological integrity is a significant challenge that still needs to be addressed (Smets & Van Lindert, 2016). Human settlement is a predominant land use type that is an essential source of CO₂ emissions and other greenhouse gasses (USEPA, 2020; Schwartz, 2021). Residential heating, cooling, and electrical consumption alone accounted for 20 percent of all greenhouse gas emissions in the United States in 2018 (USEPA, 2020). Housing also accounts for a significant portion of the greenhouse gases generated by transportation, which comprised 36 percent of total emissions in 2018 (Schwartz, 2021; U.S. Environmental Protection Agency, 2020).

The United States has over 100 million housing units, but most of these structures must be constructed sustainably when considering the negative impacts of buildings on the environment (Turcotte & Geiser, 2010). More and more people are becoming aware of their carbon footprint, but incorporating new technologies into their lifestyles to promote sustainability has yet to be widely known (Mathew, 2021). Misconceptions, limited exposure, and a lack of available information about the benefits and feasibility of alternative housing contribute to negative perceptions and hesitation toward embracing these options.

The world generates 2.01 billion tons of municipal solid garbage annually, with at least 33 percent of that waste needing to be managed environmentally safely (World

Bank, 2023). Brookings County has a record of 4766 tons of garbage, 846 tons of recycled materials, and 1267 tons of yard waste collected in 2021 (Brookings City Council, 2021). The quantity of solid waste produced annually can be channeled into earthship construction, hence the need for this research in the county.

1.3. Justification of the Study

The main aim of this study is to assess how feasible the adoption of earthships is in Brookings County, South Dakota. The need exists to find out how willing residents in the county are to adopt new strategies that can promote sustainability. This study will contribute to ways of achieving sustainability in our communities. Architects and builders in the county will be made aware of new building techniques that are more environmentally friendly. The thesis document will be shared with the Sustainability Council, the City Planner, and the Brookings Regional Builders Association.

Building sustainable housing of any form is challenged by affordability. Housing affordability is a significant issue that affects not only individual households but also the more excellent economy and environment, with consequences for employment, health, and sustainability (Mulliner & Maliene, 2011). The Earthship concept is one approach to overcoming structural difficulties to SDG 11 (... make cities and human settlements inclusive, safe, resilient, and sustainable by 2030) while also creating chances to improve people's livelihoods and well-being. Organizations such as City Councils and the Environmental Protection Agency (EPA) can evaluate policies on buildings to include more sustainable methods. This research will draw the attention of residents in the county

and other stakeholders interested in sustainability to establish projects on the construction of earthships in Brookings County.

With climate change challenges facing the world, alternatives like Earthships are a viable option for reducing carbon emissions and minimizing the effects of human activity on the environment (Samardzioska, 2019). Earthships' structural stability of earthships and ability to operate off the grid can make them vital in providing shelter and support in an emergency or natural disaster. Understanding Earthship engineering better could help improve disaster-resistant infrastructure (Colby & Whitley, 2022).

Many factors influence people's preferences and willingness to adopt sustainable and eco-friendly technologies. These militating challenges could be economic, socio-cultural, or biophysical (Tran et al., 2020). This study explains the prevailing sociocultural and biophysical factors in South Dakota that could influence people's willingness to adopt earthships as sustainable housing units. Understanding the knowledge gaps and factors impacting awareness is crucial in developing educational campaigns and strategies to promote accurate information and dispel misconceptions. The scarcity of evidence-based data on the perceptions and earthships adoption behavior necessitates this study.

The research asks the following questions to address the research gaps in the literature concerning the driving forces behind the successful adoption of earthships in communities.

1.4. Research Questions and Objectives

- What are the residents' perceptions of earthships?
- Are residents willing to adopt earthships?
- What are the factors influencing residents' willingness to adopt earthships?

The purpose of this research is to assess how feasible the adoption of earthships in Brookings County would be, considering people's perceptions, laws governing such housing in the state, and the awareness of the importance of earthships on the environment. To answer the research questions above, the study specifically seeks to:

- Assess residents' perceived benefits of earthships.
- Assess residents' perceived barriers to building earthships.
- Identify factors influencing the willingness of residents to adopt earthships.

Chapter 1 has provided a comprehensive overview of earthships and their potential as a sustainable housing solution. As we move into Chapter 2, we will delve deeper into the specific design elements and construction techniques that make earthships unique. Subsequent chapters will address data collection methods and present the study results.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1. Introduction

This chapter investigates the works of various authors who have done scholarly work on earthships. It consists of research concerning the relationship between housing and sustainability, the origin of earthships and their significance to sustainability, perceptions of earthships, willingness to adopt earthships, benefits and barriers of earthships, and criticisms of earthships.

2.2. The Relationship between Housing and Sustainability

Housing is an essential element of life that impacts many aspects of socioeconomic standing, including education, crime, health, and employment (Edwards & Turrent, 2002). It is also critical to consider achieving many of the United Nations' (UN) Sustainable Development Goals (Moore & Doyon, 2018). These objectives include providing everyone with affordable, dependable, sustainable, and modern energy, making cities and human settlements more inclusive, safe, resilient, and sustainable, and assuring sustainable consumption and production patterns (Desa, 2016). The term sustainability in housing is not limited to energy efficiency and the fight against climate change; it also refers to the economic, social, and environmental sustainability of individuals in houses, families, and communities (Bergman et al., 2007).

The need for inexpensive and excellent housing was emphasized when the US Congress declared in the preamble to the 1949 Housing Act that it would ensure "a decent home in a suitable living environment for every American family." (Schwartz, 2021). In recent years, Earthships have been at the center of sustainable development goals (SDG). SDG 11 seeks to "... make cities and human settlements inclusive, safe, resilient, and sustainable by 2030" (UN-DESA, 2022).

According to UN-Habitat, an estimated 1.2 billion people live in substandard housing. By 2030, that figure is expected to rise to at least 3 billion, implying that over 40 percent of the world's population would require access to appropriate and acceptable housing. To meet this growing demand, at least 96,000 new affordable and accessible housing units must be provided daily (UN-Habitat, 2022). Similarly, it is estimated that about 100 million people worldwide are homeless, and one in four people live in conditions considered deleterious, precarious, and harmful to their health, safety, and prosperity (UN-Habitat, 2022).

The United States (US) Energy Information Administration (2018) estimated that households in the US account for 55 percent of all energy used globally. Additional studies indicate that 20 percent out of the 55 percent of energy consumption of US homes was attributed to greenhouse gas release (Goldstein et al., 2020). Thus, building techniques must evolve to reduce contributions to greenhouse gas emissions hence the rationale behind sustainable housing (Seyfang, 2010).

In the UK, the energy consumed in residential, commercial, and industrial building construction and operation represents an estimated 50 percent of all greenhouse gas emissions (Jowsey, 2012). Therefore, addressing the sustainable housing deficit is essential in addressing the issues of climate change and its attendant impacts. According to the International Energy Agency (2013), as reported by Ekvall (2019), the housing industry is the world's most fantastic final energy consumer and the highest contributor to CO₂ emissions (Ekvall, 2019; IEA, 2013). It consumes the rawest materials (Pacheco-Torgal & Jalali, 2012) and generates up to 40 percent of all solid trash in developed countries (Ekvall, 2019).

It is currently projected that at least 100 million low and middle-income persons in the United Nations Economic Commission for Europe (UNECE) region (including the United States) are overburdened by housing costs, spending more than 40 percent of their disposable income on housing. Affordable housing is essential to the right to adequate housing and lodging, although it is sometimes a burden for vulnerable populations. (UNECE, 2021). Covid-19 made these inequalities more vivid when most people were advised to “stay at home” or “work from home,” reiterating the need to address the housing deficit and provide decent and affordable accommodation for all (UNECE, 2021).

Sustainable housing should include natural building materials obtained from natural resources and the earth itself (Turcotte & Geiser, 2010), mechanisms that utilize sunlight to moderate temperatures within buildings (Seyfang, 2009), cause less harm to

the environment (Edwards & Turrent, 2002). Other examples include using local and non-toxic substances in housing construction (Erbil, 2018). The importance of sustainable housing has been emphasized over the past two decades. The people taking part in its actualization are architects, policymakers, green building rating agencies, developers, and town and city councils (Khan et al., 2020). One of the ways sustainable housing can affect the regime is through the socio-technical contexts of mainstream construction adopting the various concepts and methods of sustainable housing (Seyfang, 2010).

2.3. Perceptions of Sustainable Housing

Perceptions are subjective points of view and entail an individual's sensory experience of the world (Démuth, 2013). According to Efron (1969), perceptions are an individual's primary form of cognitive contact with the world around him. He posits that understanding the complexities of people's perceptions of different subjects helps to develop conceptual knowledge. He further advances that "... the study of perception has always had a unique significance for philosophy and science" (Efron, 1969).

McDonald (2011) defines perception as a personal manifestation of how one views the world and is dependent on many sociocultural elements and factors. Markus and Kitayama (1991) argue that varied socio-cultural backgrounds have significantly different perceptions of self and others. Wang et al. (2019), Darko et al. (2018), Chan et al. (2017), Nguyen et al. (2017), and Koebel et al. (2015) are amongst a plethora of empirical and descriptive studies aimed at illustrating the perceptions, challenges, and

barriers to sustainable housing adoption and diffusion under different economic contexts and perspectives.

According to Tran et al. (2020), research has found that the adoption of sustainable housing technology such as earthships is influenced by three major factors, namely, technological factors (e.g., perceived environmental, economic, social benefits, relative advantages, technical complexity, perceived ease of use, etc.), potential adopters' organizational factor (e.g., corporate resources, competencies, resistance to change, leadership, etc.), and external environmental factor (e.g., availability of reliable, sustainable housing technology, information asymmetry, legal regulations, technical codes, external subsidies, etc.) (Tran et al., 2020).

Earthships are perceived as a breakthrough towards addressing climate change and reducing greenhouse gas emissions (Booth et al., 2021; Ekvall, 2019; Samardzioska et al., 2019; Freney, 2009). However, Mudombi (2011) argues that the adoption of climate change risk-reducing strategies are influenced by factors such as economic resources, technology development and dissemination, information and skills, infrastructure, land tenure, gender and equity, governance structure, sociocultural perspectives, environmental and health issues, extension services and incentives, and conflicts among different interest groups among others (Mudombi, 2011).

Researchers have proffered many theories and conceptual frameworks underpinning people's behavior and adoption of sustainable housing alternatives. These theoretical underpinnings help broaden our understanding of how different factors (e.g.,

Technological, economic, sociocultural, political, etc.) influence people's adoption behavior (Tran et al., 2020). Among these theories are the theory of planned behavior (Fishbein et al., 1980; Wang et al., 2018), the idea of reasoned action (TRA) (Abu-Elsamen et al., 2019), the diffusion of innovation theory (DOI) (Wang et al., 2019), the theory of resource-based view (Barney, 1991; Grant, 1991), and the resource dependence theory (Pfeffer & Salancik, 2003).

2.4. Willingness to Pay for Alternative Housing

The actualization of sustainable housing, and earthships, is influenced by the willingness of people to pay for and adopt them (Khan et al., 2020). It is important to note that attitudes have psychological and cultural dimensions, for example, intentions, perceptions, and beliefs. A consumer with a positive attitude toward the environment and awareness is more willing to pay (WTP) than a consumer who has such perspective and understanding (Zhang et al., 2018). Khan et al. (2020) outlined some of the determinants of the willingness of people to pay for sustainable housing. These included recycling behavior, perceived consumer effectiveness, age, gender, personal income, educational level, marital status, and environmental attitudes. According to Booth et al. (2021), a feasibility study undertaken on the Energy Savings Trust in Scotland attempted to evaluate the possibilities of earthships as a feasible type of cheap eco-housing in Scotland. Their findings demonstrated that earthship structures were economically viable in cost, design, building methods, labor needs, building control, and planning requirements (Booth et al., 2021; Energy Saving Trust, 2004). Environmental valuation

has proven to be an effective tool for rethinking our use of natural resources and ecosystem services. It is a non-market valuation decision-making tool for ensuring environmental sustainability (Guijarro & Tsinaslanidis, 2020). Environmental goods and services are public goods characterized by non-excludability and non-rivalry. However, they are significantly different from other kinds of public goods, are not traded in conventional markets, and often exist in the form of externalities (Guijarro & Tsinaslanidis, 2020; Quah & Tan, 2019; Harris & Roach, 2018).

Environmental goods and services, because they exist as externalities and are considered a public good, they are susceptible to over-exploitation and degradation, a theory known as the tragedy of the commons espoused by Gareth Hardin (Hardin, 1998). Environmental valuation is one way of addressing the tragedy of the commons since it helps in appreciating the actual value of the environmental good and ecosystem services consumed. This way, people are motivated to adopt sustainable ecological behaviors.

Contingent valuation (CV) is a stated preference valuation method or tool that uses a survey format to elicit respondents' selling and buying behaviors relative to a hypothetical market or referendum (Li et al., 2018). Willingness-to-accept (WTA) and willingness-to-pay (WTP) are two distinct contingent valuation tools and are amongst the most widely used environmental valuation tool. While willingness-to-accept pay relates to monetary compensation for a scenario that decreases welfare (WTA), willingness-to-pay (WTP), on the other hand, relates to a scenario that improves welfare (Harris & Roach, 2018).

Booth et al. (2021), in similar research conducted in the United Kingdom, titled “Insights into Public Perceptions of Earthship Buildings as Alternative Homes,” found that the respondents had a higher appreciation of the environmental good earthships provide vis-à-vis the cost of constructing or owning one. The respondents were, therefore, more responsive and liberal about adopting earthships as a sustainable housing alternative (Booth et al. 2021). However, they outlined administrative bottlenecks as a major barrier to adopting earthships as sustainable housing. Obtaining the appropriate governmental licenses and authorization for planning/building was thus viewed as a key impediment to adopting earthships. Obtaining a loan or other financial help and locating suitable building plots were seen as the second most significant impediments to earthship building/living (Booth et al., 2021).

2.5 History of Earthships

Earthships fall within the general ambit of sustainable housing and have become topical within the discourse of sustainable human development. The history of earthships dates to the 1970s when architect Michael Reynolds decided to create an autonomous housing structure deemed to be a sustainable and self-sustaining alternative to conventional housing technologies (Reynolds, 1990; Freney, 2014). The creation of earthships, while predicated upon sustainability and sustainable development, marks a significant paradigm shift in designing and building sustainable or autonomous housing alternatives (Harkness, 2011; Ekvall, 2019).

An earthship is primarily a building built from natural and recycled materials in an energy-efficient manner to provide water, electricity, and food for itself (Earthship Biotechture, 2022). According to Ekvall (2019), it is a passive solar-heated earth-sheltered building with tire walls that is self-sufficient in renewable energy, water collection, and sewage management (Ekvall, 2019). This may have a significant impact in terms of reducing human ecological and carbon footprint.

Earthships typically originated in the Southwest as experimental constructions on a desert plateau near Taos, where they have since blossomed into fully functional, off-grid dwellings (Elf Donaldson, 2021). In 1972, Michael Reynolds constructed his first home, the Thumb House, and a year later, he filed for a copyright on his design. His early designs used recycled materials, such as car tires, bottles, and cans, to build energy-efficient and sustainable homes. The concept of earthships evolved, with Reynolds experimenting with new designs and materials to improve the functionality and sustainability of the homes (Teller & Teller, 2013; Al-Homoud, 2011).

Michael Reynolds (1970) developed the concept of earthships in response to his concerns about conventional housing's effects on the environment and people's health. He aimed to create eco-friendly homes that drew their energy from renewable resources, were powered off the grid, and used locally sourced and recycled materials (Villalobos, 2020). Reynolds predicted the earthship would “reduce and ultimately remove the stress involved with living on this planet, to both humans and the rest of life” (Freney, 2014).

2.6 The Design of Earthships

The earthship is an “autonomous” structure, meaning it functions independently and can exist off the grid (Ekvall, 2019; Harkness, 2011). The construction of earthships is intended to be collaborative and self-directed, as opposed to the traditional labor marketplaces employed by volume home builders (Smith & Seyfang, 2013). Earthships were originally built with rammed earth and recycled materials such as waste tires and aluminum cans. Recently, the development of insulated walls has also been found to be more feasible in specific climates across the U.S. and in many European countries (Malhotra, 2009).

The design of an earthship is based on a series of principles that aim to create a self-sustaining and energy-efficient living environment. These principles include building with natural and repurposed materials, passive solar design, thermal mass, rainwater harvesting, sewage treatment, and food production. The layout of an earthship typically includes a greenhouse, living area, sleeping area, and bathroom. The greenhouse acts as a thermal buffer, regulating the temperature of the living space and providing a space for growing food (Ekvall, 2019; Booth et al., 2021).

The walls of an earthship are constructed using a combination of rammed earth, tires, and bottles. Rammed earth walls provide thermal mass, which helps regulate the home’s temperature. Tires are stacked and filled with earth, creating a sturdy and durable structure. Bottles are used as insulation, providing an air gap that helps trap heat inside the home. The home is heated using passive solar design, which involves orienting the

building to face south and using large windows to allow sunlight to enter the home.

Thermal mass inside the home helps to retain heat during the day and release it at night, creating a comfortable living environment (Ekvall, 2019; Freney, 2014).



Figure 1: Earthship Facing Southwards to Maximize Thermal and Solar Heating (Ecowatch, 2023).

As part of the earthship design principles, rainwater is collected, renewable energy is generated through solar and wind power, sewage is treated, thermal energy is used to heat and cool, natural and recycled materials are used, and the house is built out of natural materials (Erbil, 2018). The roof of an earthship is designed to collect rainwater, which is then stored in cisterns for later use (Quinntana, 2012). First, water is collected from the roof and cleaned to a safe drinking level. Second, greywater is cleansed in greywater planters from sinks and showers. Finally, the recovered water is used as toilet water. Finally, as blackwater, it is sent to a reed bed, where reeds and plants

cure it and restore it to nature as clean water. Never in the system's various stages is greywater accessible to humans (Spasojevic-Santic & Stanojlovic, 2016; Hewitt & Telfer, 2012).

Earthships typically have exterior walls made of used tires filled with dirt, which provide heat and cooling for the home (Prinz, 2015). A typical Northern Hemisphere earthship has exterior walls packed with 300 pounds of soil in a brick-like fashion to a height of 8 feet (Kruis & Heun, 2007). The exterior walls of a typical Northern Hemisphere earthship are filled with 300 pounds of soil packed into brick-like patterns to a height of 8 feet (Kruis & Heun, 2007).



Figure 2: Tires Filled with Dirt in a Brick-Like Pattern (Earthship Bioteecture, 2023).

Interior walls are made from a honeycomb of aluminum or glass, bottles, and drink cans set in concrete (Prinz, 2015). The bottles filter sunshine and use patterns and hues to illuminate the interior. The metal cans are arranged in rows inside the walls to produce a similar aesthetic effect, but instead of allowing light to pass through, they reflect it (Villalobos, 2020).



Figure 3: The Interior Design of an Earthship with Metal Cans and Glass Bottles (Ecowatch, 2023).

2.7 Benefits to the Establishment of Earthships

Earthships have been proven to be a feasible autonomous dwelling alternative in terms of cost, design, building methods, labor needs, building control, and planning requirements. A feasibility study conducted in Scotland under the Earthship Communities Research Project revealed that earthships were a viable alternative in terms of cost compared to other building technologies (Booth et al., 2021). Earthships are cost-

effective because they are made from recycled materials that are often discarded. These materials are inexpensive and can be found in abundance, making them a great alternative to traditional building materials. Using recycled materials also reduces the cost of waste management, which can be a significant expense for conventional housing (Ekvall, 2019; Krius & Heun, 2007).

According to Samardzioska et al. (2019), it is estimated that earthship houses require 20 percent less investment to build than conventional or traditional houses. While there may be significant gains for the homeowner regarding investment and operating costs, there are substantial savings regarding the substitution effect of not depending on virgin resources.

Aziz et al. (2013) research in “investigating the performance of car tires used in the construction of driveways for eco-houses” showed that waste tires act as heat sinks, reducing house surface temperatures. In addition, tires filled with soil act as a thermal mass for heating and cooling, and this can keep a constant temperature within the earthship even with climates as high as 45°C (113°F) and as low as -30°C (-22°F) (Erbil, 2018). Earthships can therefore maintain a comfortable indoor temperature without mechanical heating or cooling systems, reducing energy consumption and costs. Also, simply using waste in the construction of earthships minimizes the amount of waste that can be recycled and disposed of (Grubba, 2019). Earthships help reuse materials otherwise discarded in landfills or left unclean (Krius & Heun, 2007).

Another significant benefit of earthships is water conservation. Water remains a paradoxically abundant yet scarce resource since it is not evenly distributed globally. Global freshwater use has increased by a factor of six during the last millennium and has been growing at about one percent per year since the 1980s. It is estimated that in a Business-as-usual scenario, global freshwater demand will outstrip supply by 40 percent by 2030 (UNWWDR, 2021). The design of earthships includes a rainwater harvesting system that captures and filters rainwater for use in the home. This includes using a combination of roof catchments, cisterns, and filters to collect and purify water for drinking, cooking, and bathing. Additionally, earthships incorporate a greywater system that recycles water from sinks, showers, and washing machines to irrigate plants and flush toilets. This means that earthships can function off-grid, reducing dependence on municipal water supplies and saving water resources (Ekvall, 2019; Spasojević-Šantić & Stanojlović, 2016).

Earthships are constructed using recycled and natural materials, such as earth-filled tires, bottles, and cans. These materials are readily available and inexpensive, reducing construction costs and minimizing waste. Using recycled and natural materials also contributes to the sustainability of earthships by reducing the carbon footprint associated with the manufacture and transportation of building materials (Kruis & Heun, 2007; Chiveralls, 2018).

Research has shown that over the average life span of most buildings, more than 80 percent of the total amount of the building's energy consumption occurs in its

operation phase (Costa et al., 2019; Rosselló-Batle et al. 2010; Suzuki & Oka, 1998). Thus, reducing energy consumption in the operating phase of a building's life can translate to significant savings in greenhouse gas (GHG) emissions. Adopting more holistic and environmentally friendly construction materials and techniques, such as earthships, will significantly reduce total GHG emissions and help combat climate change (Ekvall, 2019; Pacheco-Torgal, & Jalali, 2012).

Similarly, earthships promote food security and sustainable agriculture by adopting and incorporating greenhouse agriculture practices in their design. Thus, helping to maintain biodiversity and ecological integrity. Greenhouse farming, when compared to open field cultivation, (i) reduces the impact of biotic and abiotic stressors such as climate, weeds, pests, and diseases; (ii) increases the efficiency with which resources (such as water, energy, and nutrients) are used; and (iii) significantly reduces the production and accumulation of greenhouse gases (GHGs) (Forkuor et al., 2022; Benke & Tomkins, 2017). Furthermore, greenhouse farming provides higher yields while using less area than open-field cultivation (Kenwar, 2011). Earthships incorporate greenhouse farming technology, providing space for growing food crops while acting as a thermal buffer, regulating the temperature of the living space. Growing food on-site promotes sustainable living by reducing the carbon footprint associated with the transportation of food and by providing a source of fresh agricultural produce (Ekvall et al., 2019; Freney, 2014).

The benefits of earthships include exceptional insulation properties, low to zero energy costs, and low construction costs. The Brighton Earthship in the United Kingdom is an example of how earthships may benefit society, where thousands of people visited the earthship and engaged in sustainability discussions contributing to grassroots innovation (Smith & Seyfang, 2013). Earthship homes replicate in virtually any climate and meet the needs of people of all socioeconomic levels due to their adaptability (Herbert, 2016).

Furthermore, earthships are inherently designed to generate minimal household waste by incorporating the “3Rs”; thus, reduce, reuse, and recycle. However, about half of the materials used to construct the earthship are made up of recyclable wastes. The amount of waste generated globally varies depending on the source and type of waste. However, the World Bank estimates that the world generated 2.01 billion metric tons of municipal solid waste (MSW) in 2016, with this figure anticipated to rise to 3.4 billion metric tons by 2050 (Kaza et al., 2018). Compostable waste, such as kitchen scraps, may be composted and used as organic manure for greenhouse farming. This way, food losses, and wastage are significantly reduced. Food loss and waste (FLW) represent about 8 to 10 percent of global greenhouse gas emissions (GHGs). According to the UNEP's Food Waste Index Report, an additional 17 percent of food is wasted in retail and at the consumer level, especially in households (UNEP, 2021). Thus, earthships present a viable means for significantly improving sustainable waste management and reducing waste generation globally.

Additionally, earthships, with their focus on sustainable and eco-friendly living, have great potential to improve ecotourism exports by meeting the growing demand for green accommodations (Elf Donaldson, 2021). Ecotourism is a growing sector of the tourism industry that focuses on sustainable travel and nature-based experiences. In a recent report on tourist consumer trends, the World Travel and Tourism Council (WTTC) has observed a significant shift towards sustainable tourism, with 69 percent of travelers actively seeking sustainable travel options (WTTC, 2023). As more people become aware of the environmental impact of their travel, there is an increasing demand for sustainable and environmentally friendly green accommodations. Thus, creating a significant incentive for investing and expanding Earthship Biotechnology. Earthships may present an aesthetic appeal for tourists, thus attracting international tourist arrivals.

2.8 Barriers to the Establishment of Earthships

A study conducted by Booth et al. (2021) titled " Insights into Public Perception of Earthships Building as Alternative Houses" sought to explore public perceptions of the benefits and barriers of earthship buildings to understand their demand by potential home builders. In their quest to analyze the challenges of earthships buildings, Booth et al. (2021) considered ten (10) factors perceived as the main challenges of earthship buildings. These are; the use of waste materials in the construction process, futuristic or alternative building design, obtaining the necessary permits and permissions for planning or building, securing a loan or other financial support, identifying suitable building plots unsuitable for densely populated urban areas, labor-intensive building process, the carbon

footprint of accessing materials that may not be available locally, in a cold climate the sloped glazing would create major heat lost, and water and energy dependence on purely renewable resources (Booth et al., 2021).

The research postulates that the major factor of the perceived challenges of earthship buildings was the inability to obtain the necessary regulatory permits and permissions for planning or building. This was followed by the challenge of securing loans or other financial support and identifying suitable building plots. The research findings revealed that the challenge of the futuristic or alternative building design was the least important challenge towards earthship buildings. In summary, the main challenge of earthship buildings is administrative or preparatory issues. For instance, all houses require planning permissions, but the journey for conventional homes through the approval process is relatively smooth compared to alternative housing. Ben-Alon (2020) found barriers to establishing earthships to be obtaining needed building permits and translating earthships into urban contexts. This was iterated in Herbert (2016), where the author stated that zoning codes were the main challenges of constructing earthships and would need to be amended to promote green buildings in Detroit, Michigan.

Hewitt and Telfer (2012) coined that the atypical nature of an earthship building is the most significant impediment to mainstream production. The conformity of earthship buildings to conventional buildings will make alternative or earthship buildings lose their philosophy of using environmentally friendly materials.

2.9 Criticisms on Earthships

Worstman (2022) carried out a project to build sustainable homes for the people of Muhanga, Rwanda, affected by the anti-thatching campaign in 2011. The initial plan was to make earthships as sustainable homes, but this was impossible as the design was expensive. The writer then concluded that constructing earthships is not attainable for people of lower economic statuses. Thus, there is the need to novate and pilot earthship designs and techniques tailored to a specific geographic area.

Earthships do not attain thermal comfort through passive solar heating, according to research investigations by Grindley and Hutchinson (1996), Kruis and Heun (2007), Ip and Miller (2009), and Hewitt and Telfer (2012) (Ekvall, 2019). Space heating is required in very cold seasons to achieve thermal comfort during the evening. Thus, while earthships are known to achieve thermal comfort in the daytime, thermal comfort is significantly impacted during very cold periods, thus requiring supplementary heating (Grindley & Hutchinson, 1996). Similarly, it has been shown that earthships may only guarantee consistent water supply partially through their catchwater and gray water system (Kruis & Heun, 2007), and thus homeowners must consider other alternative sources of water to supplement household needs. Noteworthy, whilst earthships may only partially self-reliant regarding water supply, they help reduce drought and water stress severity by emphasizing the judicious and efficient use of water. The earthship design employs close-loop technologies whenever practical to capture enough water for survival

everywhere where annual precipitation exceeds 200 mm, which is true for most places on Earth (Hewitt & Telfer, 2012).

A significant limitation and drawback of earthships is the paucity of research data regarding the Life Cycle Assessment of tire walls or self-sufficient homes built with tires (Ekvall, 2019). Rammed earth tires are not currently included in building regulations, and hence frequently lack formal recorded testing procedures and guidelines; many building engineers and inspectors in the building community lack confidence in the reliability and strength of this construction alternative. This frequently makes rammed earth tire walls as the primary structural wall a challenging, if not impossible, alternative strategy for building homes (Zimmerman, 2011).

In contrast, Hewitt and Telfer (2012) argue the suitability of using rammed tires in constructing earthships. The earth-rammed tires are covered with a layer of render up to 25 mm thick, limiting the chance of them catching fire. Similarly, there is growing worried about contaminants seeping from car tires into buildings, particularly at very high temperatures. The risk of chemical leakage from tires is significantly decreased or low if the tires are suitably damp-proofed (Hewitt & Telfer, 2012).

According to Hewitt and Telfer (2012), the level of autonomy provided by earthships makes them suited for rural settings, particularly where connection to any type of household grid is challenging. However, the existing domestic grids are more efficient and practical in urban areas with tiny lots and residences constructed close together.

Thus, in wealthy countries, there is less demand for off-grid structures because most needs are met by substantial infrastructure (Hewitt & Telfer, 2012).

The literature above highlights the importance of taking community members' perceptions in sustainable housing initiatives. Building codes and climatic conditions are area specific and can potentially affect the acceptance and adoption of sustainable houses. These two factors are discussed in the following chapters.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1. Introduction

The study aimed to assess residents' perceptions in Brookings County and identify factors that will influence their willingness to adopt earthships as sustainable homes. To achieve this, a survey was carried out to solicit residents' views. This chapter provides information on the profile of the study area, the research methodology adopted for the study, the methods of data collection and the sampling techniques used, and the methods employed in analyzing the data obtained from the data collection processes.

3.2 Study Area

This research was carried out in the cities of Brookings County, South Dakota. Brookings County presents an interesting case study for examining the feasibility of earthships due to its abundant land area, unique climate patterns, building regulations, and community dynamics. The county has a sustainability council that advocates investment strategies geared toward sustainability. The county is the fifth largest county in South Dakota and has its county seat located in the city of Brookings. The cities used for data collection are Brookings, Aurora, Bruce, Volga, White, Elkton, Bushnell, and Sinai.

3.2.1 Location

Brookings County is in the far east of the state and borders the state line of Minnesota. Understanding the study area's location helps identify outliers and anomalies concerning the location of responses received. It also helps to link the place and regulations, trends, and social factors unique to that area.

3.2.2 Topography and Drainage

The geographical terrain of the County is characterized by open flatlands, dotted with lakes and ponds. The county has a land area of 792.21 square miles and a water area of 12.73 square miles (2020 Decennial Census). Topography and drainage affect spatial patterns, hydrological processes, land use, and land cover. Knowledge of this can help identify site selection for earthship construction and determine ideal position of the earthship to maximize solar exposure during the winter months in the county.

3.2.3 Climate

The County's humid continental climate is characterized by harsh cold winters and moderately warm and moist summers (USA Facts, 2022). Winter months extend from December to March with an average low of 4°F while summer runs from June to August with an average high temperature of 82°F (Weather Atlas, 2022). The area receives an average of 212 days of sunlight per year, 26 inches of rain per year, on average, and an average of 35 inches of snow per year, which is higher than the United States' average snow collection of 28 inches per year (National Weather Service, 2022). Knowing the extreme temperatures in the county allows builders to incorporate proper

insulation, passive heating, and cooling strategies into the earthship design. For this research, respondents' knowledge of the climate will influence their perceptions of benefits and barriers to establishing earthships in the County.

3.2.4 Socio-Demographic Characteristics

Brookings County has a population of 34,375. Concerning race, 92 percent of residents are white. Black or African American residents comprise 1.7 percent, American Indian residents 1.3 percent, and Asians comprise 2.9 percent of the County's population. The median household income is \$59,178. Forty-three percent of the population have attained a bachelor's degree or higher and 96.2 percent are high school graduates or higher (2020 Decennial Census). Socio-demographic characteristics of Brookings County can help understand age groups and income levels that are more likely to adopt earthships than others. Knowledge of residents' level of education will influence their behavior toward sustainability and perceptions of earthships.

Figure 4 shows a map of Brookings County with its surrounding towns and cities used in this study.

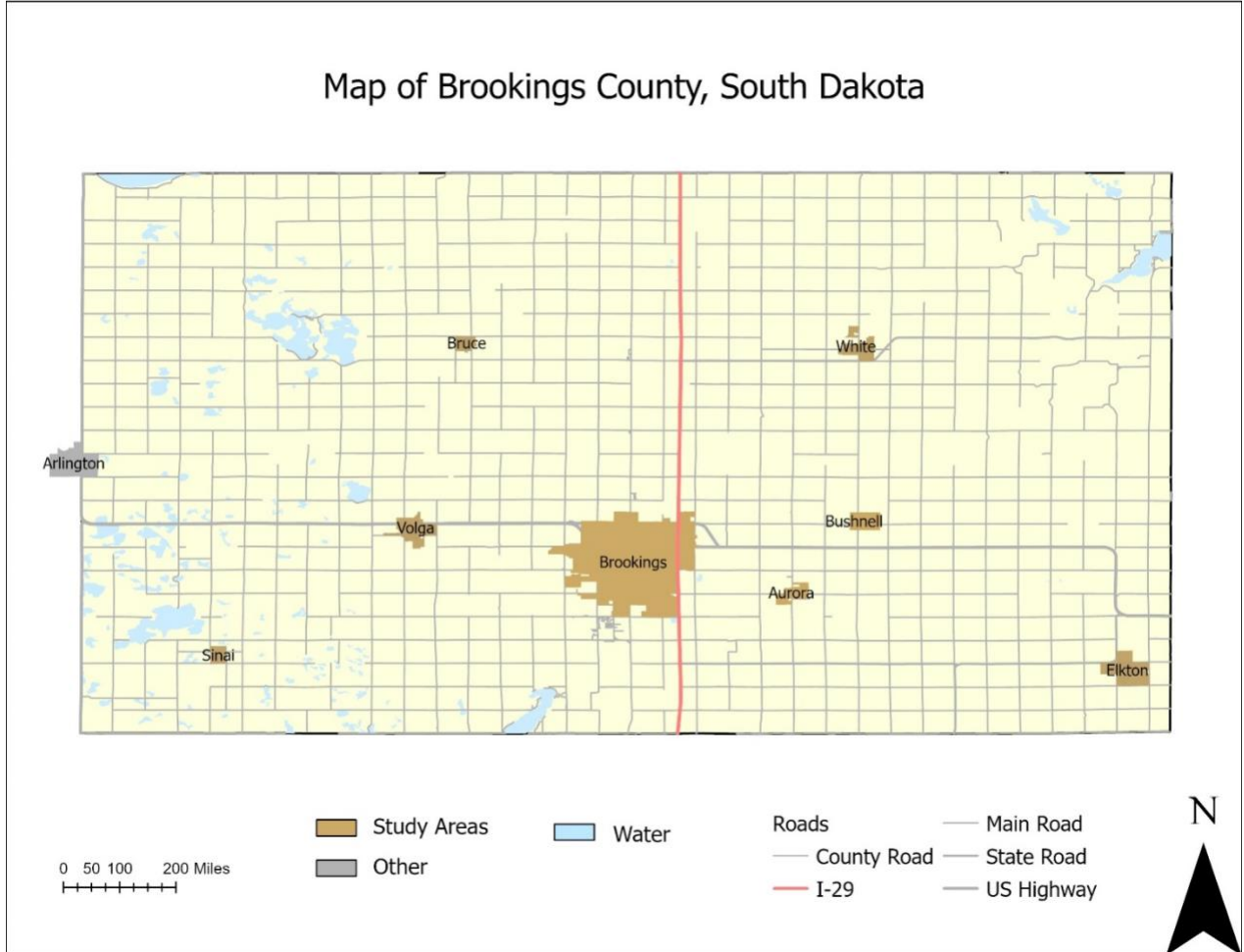


Figure 4: Map of Study Area (Brookings County, South Dakota)

3.3 Research Design

A research design refers to the overall study strategy (Bloomfield & Fisher, 2019). Research designs are essential in organizing problems that arise during the planning and execution of research, including developing the research idea, selecting methods and procedures, analyzing, and interpreting data, and preparing a written report of the findings (Khadzin, 2021).

For this research, quantitative and qualitative approaches were employed to help explain the findings from the data acquired. Quantitative research aims to describe and explain phenomena through numerical values derived from observations (Taherdoost, 2022). The study used frequency and percentages to quantify similar responses. This helped to determine the number of people who viewed earthships to have significant benefits or barriers. In qualitative research, data are expressed using words rather than numbers, which means the study focuses on the nature of phenomena, the context in which they occur, or the perspectives from which they can be viewed (Busetto et al., 2020). Additional comments from respondents were analyzed and presented as reported speeches to further understand their views on establishing earthships in the County.

3.3.1 Sources of Data

Primary sources were used to acquire data for this study. Primary data were sourced directly from residents in Brookings County. Four hundred surveys were distributed to residents in the county. This exercise occurred from February 15th to April 12th, 2023. The study employed primary data sources to get firsthand data on the perceptions of residents and their willingness to adopt earthships.

3.3.2 Sample Size Determination

The research will be conducted in the cities and towns of Brookings County. These locations are Brookings, Volga, Aurora, Elkton, White, Bruce, Bushnell, and Sinai. The sample size was calculated using Slovin's formula (1960) along with a confidence interval of 95 percent, giving a 0.05 margin of error. The sample size was calculated

using the county's total number of housing units. As defined by the US Census Bureau, a housing unit is "a house, an apartment, a mobile home, a group of rooms, or a single room that is occupied (or if vacant, is intended for occupancy) as separate living quarters."

3.3.3 The Slovin's Formula

Slovin's formula has been widely used in quantitative and qualitative research to estimate the sample size of a population under study. Michael Slovin developed Slovin's formula in 1960 as a statistical sampling method to ensure the unbiased nature of chosen samples. The formula is used best for population sampling, especially if there is uncertainty about the population's behavior (Tejada, 2012). Slovin's formula is represented by:

$$n = \frac{N}{[1+Ne^2]}$$

where n is the sample size, N is the population size and e is the margin

of error.

Research done by Wulandari and Kurniasih (2019) on "Community preferences for social forestry facilitation programming in Lampung, Indonesia", adopted Slovin's formula to calculate the number of members of the Women Farmer Group that were active in the forestry designation programs within the community. Another research done by Rukuni and Maziriri (2020) adopted Slovin's formula to obtain the opinions of customer satisfaction with retail Covid-19 readiness and customer behavioral intentions. After applying the formula to ten retail stores, equivalent to 220,000 customer population

in Bloemfontein, South Africa, a sample size of 401 was acquired. This helped to get enough representative responses for the total population of 220,000 customers.

It should be emphasized that the formula is based on simple random sampling, which is not always practical or appropriate in all study circumstances. In other cases, other sampling approaches, such as stratified sampling or cluster sampling, maybe more suited (Tejada, 2012).

N=12230

n=387

The sample size for each of the cities (**N_i**) was calculated using the housing units for each city (**N_o**) as a fraction of the total number of housing units in the county (**N**), multiplied by the sample size for the county (**n**).

That is,
$$N_i = \frac{N_o}{N} \times n$$

Table 1: Total Number of Housing Units per City and Sample Size Estimation

Town/City	Housing Units	Sample Size
Brookings	10,031	317
Volga	938	30
Aurora	474	15
Bushnell	33	1
Elkton	328	10
White	252	8
Bruce	117	4
Sinai	57	2

Total	12230	387
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3.3.4 Research Instrumentation

The study employed an online survey to gather data from residents. A survey is a method of gathering information about a participant's opinions, behaviors, attitudes, and characteristics. A survey consists of a set of structured questions that respondents are asked to answer either in writing, through an online form, on the phone, or in person (Rubinfeld, 2004). Depending on the question format, respondents may be asked multiple-choice questions, open-ended questions, Likert-scale questions, or a combination of the three (Board, 2019). In surveying, geographers examine patterns of human activities, perceptions, and behaviors, as well as the distribution of physical features on Earth. Some areas where geographers have utilized surveys in research include assessing land use and land cover patterns in different regions (Lewis & Marantz, 2019), collection of regional and national census data, and studying human behaviors over time (Cucchiaro et al., 2020). Online surveys have been proven to provide a wider reach of respondents and this is why the research uses this method to gather data.

The online survey was structured using QuestionPro, which is a web-based software for constructing and administering surveys in both qualitative and quantitative research methods. The link to the online survey was printed on flyers that were shared to residents. Residents could partake in the survey by either scanning the QR code with their mobile phones or typing the website address on the flyer. This made it easier for the

respondents to answer the questions at their convenience and have enough time for the survey. Online Platforms on Facebook such as the Brookings Rummage were also used to distribute the survey. The survey was approved by South Dakota State University's Institutional Review Board (IRB). A copy of the research survey is attached to the Appendix ([Page 74](#)).

3.3.5 Sampling Techniques

Purposive sampling was adopted to gather data from residents in Brookings County who were either homeowners or tenants to assess their perceptions and their willingness to adopt earthships. Residents were contacted through businesses, and churches, and using simple random sampling to distribute the surveys to the residents in their homes and on the streets. Data were collected between February 15th and April 12th. Below are the names of businesses and churches that participated in the data collection process.

Table 2: Churches Involved in Data Collection

Church	Address
Holy Life Tabernacle	241 Mustang Pass, Brookings
Gracepoint Wesleyan Church	1420 Orchard Drive, Brookings
Faith Reformed Church	1330 Main Avenue South, Brookings
United Church of Christ	828 8th Street South, Brookings

First Reformed Church	601 E 1st Street, Volga
First Lutheran Church	623 Kasan Avenue, Volga

Table 3: Businesses Involved in Data Collection

Business	Address
Dakotaland Federal Credit Union Brookings	2423 6th Street, Brookings
Village Square Mall	1833 6th Street, Brookings
University Marketplace	988 22nd Avenue S, Brookings
Wells Fargo Bank	527 Main Avenue, Brookings
Brookings Cinema 8	219 6th Street, Brookings
Pheasant Restaurant & Lounge	726 Main Avenue South, Brookings
Brookings Dental Clinic	2215 Derald Drive, Brookings
United States Postal Service	500 Main Avenue, Brookings
Flavor Indian & Asian Fare	501 Main Avenue, Brookings
Century 21 Krogman & Company	323 22nd Avenue, Brookings

Brookings Public Library	515 3rd Street, Brookings
Slumberland Furniture	409 12th St S, Brookings

3.4 Data Analysis

3.4.1. Descriptive Statistics

Descriptive analysis was done to analyze data on the residents' perceptions on earthships. Descriptive statistics are used to define, illustrate, and summarise the essential elements of a dataset uncovered in a study, and they are displayed in a summary that explains the dataset and its parameters (Mishra et al., 2019). Data were taken from QuestionPro and transferred into STATA software in Excel. Results were communicated using tables and charts.

Table 4: Data Description for Perceptions of Residents

Benefits	Barriers
Rainwater and greywater harvesting	Obtaining the necessary permits
Use of renewable energy resources	Use of repurposed materials in the construction
Using locally sourced construction material	Labor intensive building process
Eliminate energy bills through living entirely off-grid	Unsuitable for densely populated urban areas

Water and energy dependence on
 purely renewable resources
 Extreme winter temperatures

Source: (Booth et al., 2021)

3.4.2. Coding and Thematic Analysis

Coding and thematic analysis were used to analyze additional comments from respondents on their perceptions of earthships. Coding can be described as the process of categorizing quantitative or qualitative data to facilitate analysis. During the coding process, similar themes, ideas, concepts, and keywords are searched through the text and coded as appropriate (Adu, 2019). Comparing data in this way makes it easier to identify patterns that need further investigation. The codes used for the research were ‘age’, ‘prior knowledge’, ‘money’, ‘view of sustainability’, and ‘home ownership’. These codes informed the themes that were used to analyze the qualitative data. The process of thematic analysis of qualitative data entails categorizing the data into themes that express the meaning of a particular subject and presenting evidence for the themes using the data (Braun & Clarke, 2022).

3.4.3. Theoretical and Analytical Frameworks

The willingness to adopt earthships by the respondent in the county can be viewed as a binary choice, expressed in Equation (1).

$$Y = \begin{cases} 1 & \text{if willing to adopt earthship} \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

A respondent will consider adopting an earthship if the person perceives that the benefit of adopting the earthship is greater than the benefit of not adopting the earthship. Y denotes the latent dependent variable (WTA). This is expressed in Equation (2) as follows:

$$E(U^Y) > E(U^N) \quad (2)$$

Where $E(U^Y)$ represents the expected utility or benefit of adopting the earthship and $E(U^N)$ the expected utility of not adopting the earthship.

3.4.4. The Probit Model

The Probit model was used to analyze data on the factors influencing the willingness of residents to adopt earthships. A Probit model is a statistical model used for binary outcomes, where the dependent variable can take only two possible values, usually coded as 0 and 1 (Liu et al., 2023). For this research, the dependent variable “willingness to adopt” would have two possible outcomes: whether respondents would adopt earthships or not. We asked the respondents if they would consider buying or building an earthship and related their views to socio-demographic characteristics and prior knowledge of earthships. Probit models can be applied to examine the determinants of a binary outcome, estimate probabilities of success or failure, and allow for the estimation of marginal effects which quantify the change in probability while holding all other variables constant (Luque-Fernandez et al., 2019; Gomila, 2021).

Table 5: Data Description for Factors Influencing Residents’ Willingness to Adopt Earthships.

Variable	Description
Willingness to Adopt (WTA)	Would you consider buying or building an earthship? (1 = Yes, 0 = No)
Age	Age range (1=18-24, 2=25-34, 3=34-44, 4=45-54, 5=55-64, 6=65+)
Gender	1= Male, 0=Female
Education	Highest educational level completed (1 = high school or less, 2=some college/technical school, 3 = 4-year college degree, 4 = Advanced degree)
Income	1= \$20,000 or less 2= \$20,000 to \$50,000 3=\$20,000 to \$50,000 4= \$50,000 to \$100,000 5= \$100,000 to \$150,000 6=\$150,000 to \$200,000, 7= More than \$200,000
Sustainability	Importance of sustainability to the county (1 = Not at all important, 2 = Slightly Important, 3 = Moderately important, 4 = Extremely important).
Prior knowledge	Prior knowledge of Earthships (1=Yes, 0=No)
Years of residency	(1= Less than 5 years, 2=5 to 10 years, 3=15 to 20 years, 4=More than 20 years)
Home ownership	1= Homeowner, 0 =Tenant)

The model is expressed in Equation (3) – Equation (4).

$$Y_i^* = \beta_i X + \mu_i \quad (3)$$

Where X denotes a vector of explanatory variables influencing respondents' willingness to adopt earthship, β_i denotes a vector of coefficients corresponding to the independent variables, and μ_i is the error term.

The WTA earthship is expressed empirically in Equation (4) as:

$$WTA = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_n X_n + \mu_i \quad (4)$$

The combination of both quantitative and qualitative techniques to gather and analyze data will help assess respondents' perceptions and their willingness to adopt earthship. The next chapter reveals findings from the data collected using both research techniques.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1. Introduction

This chapter analyzes and presents responses from an online survey conducted within Brookings County for this study. There was a total of two hundred and four (204) responses. Data were collected from eight (8) towns and cities in the County. These are Brookings, Volga, Aurora, White, Bruce, Elkton, Bushnell, and Sinai (Table 6). Results on residents' perceptions of the benefits and barriers of establishing earthships in the County are presented using graphs and charts. At the same time, comments from responses are analyzed qualitatively to support numeric values. This chapter also reveals the main factors that would significantly influence residents' willingness to adopt earthships as sustainable homes. The research results are interpreted and discussed in this chapter according to the research objectives. Relevant literature is linked with results to explain the findings from the data gathered.

Table 6: Number of Responses from Online Survey by Location.

Town /City	Responses
Brookings	152
Bushnell	2
Elkton	14
White	3
Volga	15
Aurora	8
Bruce	7
Sinai	3
Total	204

4.2. Socio-Demographic Characteristics of Respondents

The socio-demographic characteristics of respondents surveyed are presented in Table 7 according to gender, age, educational qualification, annual gross income, and home ownership.

Table 7: Socio-Demographic Characteristics of Respondents

Variable	Frequency	Percentage (%)
Gender		
Male	126	62
Female	78	38
Age		
18-24	26	13
25-34	41	20
35-44	41	20
45-54	37	18
55-64	28	14

65+	31	15
Educational Level		
High School or Less	19	9
College/Technical School	38	19
Four-Year College Degree	88	43
Advanced Degree (Masters, etc.)	59	29
Annual Gross Income		
\$20,000 or less	19	10
\$20,000 to \$50,000	64	32
\$50,000 to \$100,000	72	36
\$100,000 to \$150,000	28	14
\$150,000 to \$200,000	7	4
More than \$200,000	7	4
Homeowners	68	33
Tenants/Renters	136	67

The results show that most respondents (62 percent) identified as males and 32 percent as females (Table 7). All respondents were aged 18 and over with those aged between 55 and above representing 29 percent of the total respondents. According to the latest census report by the United States Census Bureau (2021), Brookings County is currently the 5th populous county in the state of South Dakota with 34,375 residents. This represents a percentage change of about 7.5 percent since the last count in 2010. The adult population in Brookings has also experienced a significant boost with a 4.7 percent increase, a difference of about 1214 from the last count in 2010 (US Census Bureau, 2023a). The results (Table 7) depict the county's youthful and active labor force. Regarding annual gross income, about 10 percent of the respondents had an annual gross income of \$20,000 or less, \$20,000 to \$50,000 32 percent, and the remainder (58 percent) had an annual gross income of at least \$50,000 (Table 7). This result is consistent with

data from the US census bureau (2021) which currently estimates the real median household income at about \$70,784 (Semega and Kollar, 2022; Shrider et al., 2021). Also, per capita income in Brookings County is currently pegged at about \$29,775 with about 12.6 percent of residents in Brookings County living below the poverty line (US Census Bureau, 2023b).

Regarding accommodation types, the results show that only 33 percent of the respondents were homeowners and 67 percent were tenants/renters (Table 7). The high presence of renters/tenants can be attributed to South Dakota State University, where the increasing student population creates the demand for renter-occupied units. The university has a two-year live-on-campus requirement however, a significant proportion of students must consider off-campus accommodation options (SDSU, 2023). Furthermore, according to Harvard University's Joint Centre for Housing Studies (JCHS), the national homeownership rate will continue to rise due to the aging of more millennials into their 30s and high-income gains among these young individuals (JCHS, 2021).

4.3. Prior Knowledge of Earthships

Out of the 204 responses, 139 which represents 68 percent of respondents had no prior knowledge of earthships while 65 (32 percent) respondents had heard of the concept before taking the survey.

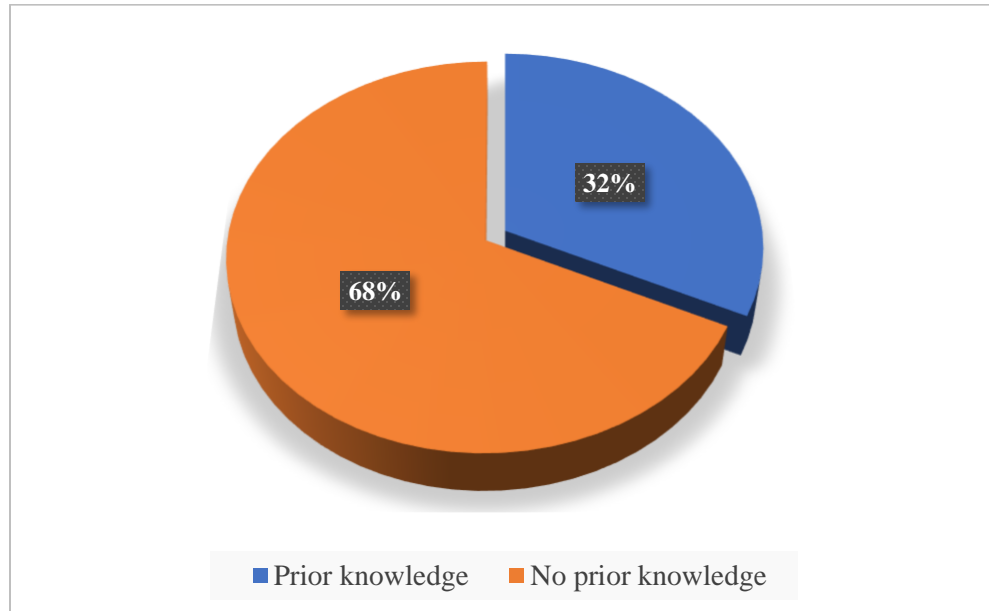


Figure 5: Respondents' Prior Knowledge of Earthships

Respondents knew about alternative homes that promoted sustainability but the earthship concept was new to them. One respondent expressed their views as follows:

“I have studied a lot about sustainable building construction being in the architecture field and am hoping this starts to become more relevant in the Midwest.” [Respondent 178: Male: 35-44 years: Brookings]

Earthships largely fall under the broad mix of sustainable and autonomous housing alternatives, however, it is considered a budding and nascent sustainable housing alternative albeit having been first introduced in 1972 by Michael Reynolds (Ekvall, 2019). According to Lee et al. (2021) in a study to investigate the public’s perceptions of passive houses in Korea, more than 95 percent of the respondents had familiarity with

passive houses. Educational seminars/workshops (48.3 percent), the internet (33.6 percent), the Korean Passive House homepage (31.8 percent), and others, were major sources of information/knowledge about passive homes. Relating Lee et al. (2021) to prior knowledge of earthships in the county shows that more research and education on earthships can change people's perceptions towards their benefits and potentially affect willingness to adopt them as sustainable homes.

According to the adoption process theory propounded by Rogers and Shoemaker (1971), innovations are not immediately adopted following their introduction. The multi-phase adoption process is outlined as follows: awareness, interests, evaluation, trial, and adoption (Beamish et al., 1987). Knowledge and exposure (Awareness) to earthships innovations is pivotal and foremost following the adoption process proposed by Rogers and Shoemaker (1971). Similarly, according to Tran et al. (2020), external environmental factors such as information asymmetry may inhibit the adoption of sustainable housing technologies such as earthships.

4.4. Respondents' View of Sustainability in Brookings County.

Respondents were asked to rate how important they thought sustainability was in the County. This was done using a Likert scale for level of importance. The results revealed that about 40 percent of people viewed sustainability as extremely important, 33 percent as moderately important, 24 percent as slightly important, and 3 percent saw it as unimportant (Figure 6). Overall, it can be gathered from the data that there is a positive view of the importance of sustainability in Brookings County.

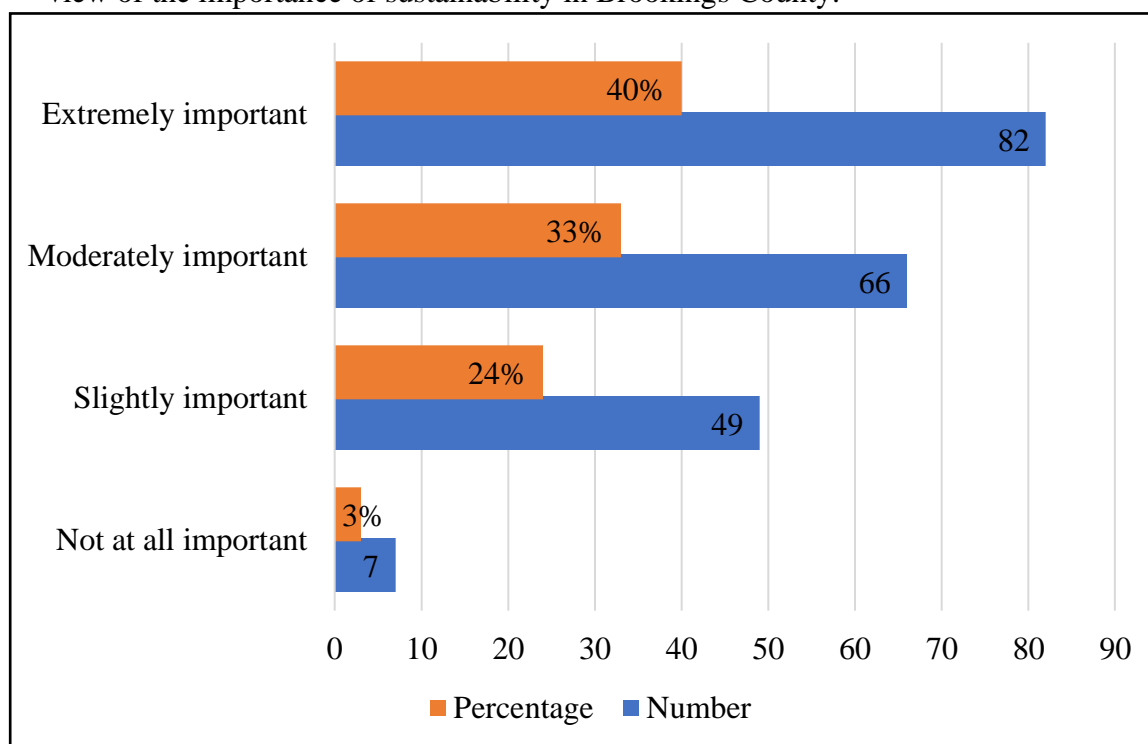


Figure 6: Respondents' View of Sustainability in Brookings County.

The results from the Likert scale show a strong appreciation of the importance of sustainability in the County with only 3 percent of the respondents considering sustainability as “Not at all important” (Figure 6). This finding is consistent with research showing that people are becoming concerned about environmental issues that inhibit

sustainability and sustainable development (UNICEF, 2022). The Brookings City Sustainability Council was established in 2011 under Ordinance No. 04-11 pursuant to the relevant provisions of the United States Constitution. The major aims and functions of the Brookings Sustainability Council can be subsumed under three broad themes thus, 'Action', 'Education,' and 'Advocacy' (Brookings Sustainability Council, 2015). The council is enjoined by the provisions of the Ordinance to communicate and educate citizenry or residents on the need to adopt sustainability practices in city planning and in their everyday lives. The presence of the council, amongst others, explains the high appreciation of sustainability as an important issue in Brookings.

4.5. Perceptions of Benefits of Earthships

Respondents were asked to rate their perceived benefits of earthships in order of significance. The use of renewable energy resources was viewed by most respondents as very significant (43 percent). The second benefit perceived in the same light was using locally sourced materials in the construction process (37 percent). Thirty percent (30 percent) of respondents perceived rainwater and greywater harvesting to be a significant benefit of earthships to the county. From Table 8, it can be concluded that the general perception of respondents was that earthships have significant benefits.

Table 8: Perceived Benefits of Earthships

Benefit	Not significant at all	Slightly significant	Moderately significant	Very significant	Extremely significant
Rainwater and greywater harvesting	3%	17%	35%	30%	14%
Use of renewable energy resources	2%	7%	19%	43%	29%
Using locally sourced construction material	4%	8%	32%	37%	8%
Eliminate energy bills through living entirely off-grid	3%	22%	23%	29%	23%

Regarding the perceived benefits of earthships, the use of renewable energy, rainwater harvesting, and greywater reuse, as well as the use of recycled and locally sourced construction materials, was considered a foremost and significant benefit by the respondents (Table 8). This finding is supported by the fact that the dependence on non-renewable energy sources, i.e., fossil fuels in most traditional housing structures, contributes significantly to GHG emissions and increases the earth's carbon footprint, which makes up about 60 percent of the world's ecological footprint (Global footprint network, 2019). Research has shown that savings in greenhouse gas emissions can be achieved for conventional buildings by reducing energy consumption during the operation phase of the building. This brings into sharp focus, the importance of earthships

in terms of diversifying the energy mix and reducing dependence on fossils and non-renewable energy sources. In principle, earthships are designed to have next to zero or negligible emissions footprint.

According to the International Energy Agency's (IEA) report on renewable energy, renewable electricity capacity is projected to increase by more than 60 percent between 2020 and 2026, exceeding 4,800 gigawatts globally. China, Europe, the United States, and India are the major drivers of this projected growth in renewable energy, together they account for more than 80 percent of renewable energy expansion globally (IEA, 2021). The observed growth trajectory creates a significant opportunity and incentive for the establishment of earthships given its reliance on renewable energy and the presence of a burgeoning renewable energy market.

Also, many respondents perceived the use of locally sourced materials as an important benefit of earthships (Table 8). Earthships help to reduce over-dependence on virgin resources and to encourage a circular economy approach towards promoting resource conservation and sustainability. This way the carbon footprint associated with manufacturing and transporting building materials is significantly reduced. Furthermore, it has been shown that countries with biocapacity deficits or very high EF tend to import more resources than they export (Global footprint network, 2019; Shvarts et al., 2014). Using cheap and readily available or otherwise discarded construction materials such as earth-rammed car tires and bottles can reduce the initial construction cost of the earthships making them sustainable and affordable housing alternatives.

Furthermore, the respondents perceived rainwater harvesting, and greywater treatment as an equally significant benefit of earthships (Table 8). The economics of water is such that it is both an abundant and yet scarce resource (Gleick, 1993). Global water use increased by more than a factor of five throughout the twentieth century, with greater increases expected in the future (Harris and Roach, 2018). Similarly, Tietenberg and Lewis (2012) argue that, if we were simply to add up the available supply of fresh water (total runoff) globally and compare it with current consumption rates, supply exceeds consumption by more than 10 folds. Earthships provide a very important service by reducing reliance on municipal water systems. Also, the volume of water available for consumption in the household increases considerably. The treatment and reuse of greywater in the Earthship Biotope ensure the safe discharge of liquid waste into the environment.

Two respondents made expressed their perception of the benefits of earthships to the county:

“It seems like more and more people are looking at disconnecting from society and this would help with that, besides, there are people looking for ways to be more self-sufficient.” [Respondent 118: Male:45-54 years: Volga]

“Efficiencies in heating and cooling are very important. I have had geothermal heat for 22 years.” [Respondent 98: Male: 55-64years: Aurora]

The comments above supports the empirical values of respondents perceiving the use of renewable sources of energy to be a significant benefit of earthships.

4.6. Perceptions of Barriers to the Establishment of Earthships in the County

Results from Figure 7 show that 50 percent of respondents perceive extreme winter temperatures to be a significant barrier to the establishment of earthships in the county. This is a significant proportion that could potentially be a barrier to earthships in the county. Forty-three percent (43 percent) of participants viewed water and energy dependency on purely natural resources.

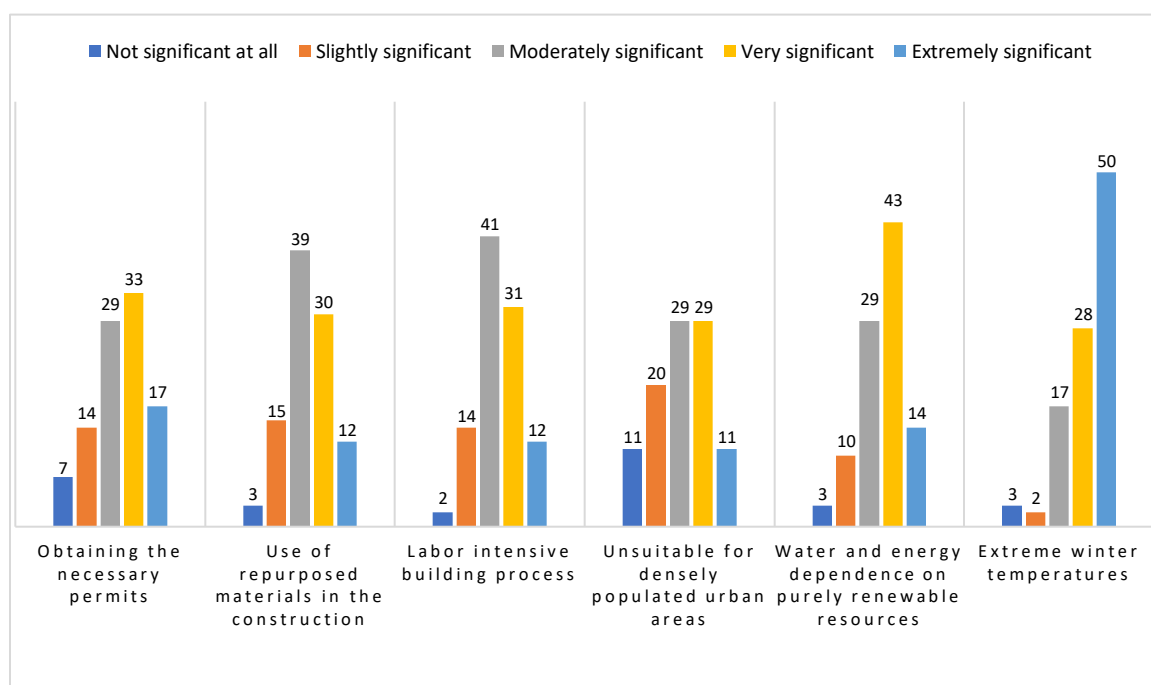


Figure 7: Perceived Barriers to Establishing Earthships (%)

The research results show that a significant proportion of the respondents (50 percent) consider extreme winter temperatures as a barrier or disincentive to Earthship Biotechnology (Figure 7). Comments revealed respondents' perception of extreme winter temperatures being a significant barrier to the establishment of earthships:

“I don’t know how well it would work in this climate.” [Respondent 36: Female: 35-44years: Brookings]

“My biggest concern with an earthship in Brookings County would be extremely cold during the winter when it is frequently cloudy and solar may not have as much of an impact to generate heat.” [Respondent 16: Male: 25-34years: Aurora]

This is particularly borne out of the reliance on passive solar heating which has been the focus of nearly all research studies (Booth et al., 2021). The thermal performance of earthships may be keenly affected by the building design and the prevailing climatic conditions (Kruis and Heun, 2007). For instance, Grindley and Hutchinson (1996) in a thermal performance study of five U-shaped earthship modules in the desert of New Mexico, USA suggested that shading must be added to the building design to avoid overheating during the summer months. Also, the authors show that considering the prevailing climatic conditions in the UK, earthships were thermally efficient requiring minimal space heating in the winter months. The design is such that the thickness of the structural wall (~1 m thick) made with earth-rammed tires helps to cool the building in summer and warm the building in winter (Booth et al., 2021).

Conversely, Ip and Miller (2009) posit that earthships can efficiently regulate external severe temperatures, however, to reach satisfactory thermal comfort conditions during extreme cold periods, some additional heating may be required (from occupants and powered appliances) or improvements made to the heat transfer from the conservator

(Booth et al., 2021; Ip and Miller, 2009). To address the issue of thermal performance, especially in colder regions, Barnas et al. (2017) proposed modifications to the design of earthship buildings so that they can be adapted for colder climates.

Another perceived barrier to adopting earthships in the study area was the dependence on water and energy mainly from renewable sources (Figure 7). This may be due to the shift from a disposable and consumption-based lifestyle to one that is more eco-centric and conservationist which many people might consider discomforting. In principle, earthships promote behavior choices aimed at the reasonable and efficient use of water and energy. The supply of these resources, e.g., water may be limited depending on the geographical area, and as such one might require other alternative sources of water or energy to supplement household needs (Oteng-Pepurah et al., 2018). A strong case is made for greywater reuse by Chen and Fagan (2015) who posit that greywater is the most used and otherwise wasted water globally. Evidence from the US indicates that approximately 140 gallons of greywater is generated on average per family per day. By reusing greywater, total family water use can be reduced by as much as 15 to 35 percent (Juan et al., 2016; Chen and Fagan; 2015). According to Oteng-Pepurah et al (2018), public perception towards greywater use has mainly favored non-potable uses. However, upscaling reuse for drinking and other residential purposes has seen a significant decline in acceptance. This perception of impaired quality largely corroborates this study's findings (Figure 7).

In contrast to the findings in Figure 7, Booth et al. (2021) found that obtaining the necessary permits and permissions for planning/building was ranked a foremost barrier to adopting earthship biotecture. This is especially the case for most states in the USA where one needs a permit to construct an earthship since the designs are not included in most state building codes and zoning laws. According to Wisevoter (2023), South Dakota is among the states that have no restrictions or offer incentives for rainwater harvesting. The Department of Energy and World Population Review have also confirmed that rainwater harvesting in South Dakota is legal. This is one policy that can promote the establishment of earthships in Brookings County.

Chapter 86, Article III, Division 1, Section 86-81 of the Brookings Code of Ordinances requires property owners to connect all toilet facilities to the city's municipal sewer within 90 days of notice, provided that the municipal sewer is within 200 feet of the property line. However, property owners can construct a private sewer system and must obtain a permit before the private sewer system is constructed. However, earthship construction in the County would not be affected by this regulation since they are completely off-grid and offer wastewater treatment options within the home.

The code of ordinances permits establishing wind energy conversion systems (WECS), as an accessory use only, in certain districts. These wind systems should have a total height of 125 feet or less, a swept area of 2,000 square feet or less, and a peak performance of 100 Kw or less (Chapter 94, Article VI, Division 2, Section 94-367). This could be a barrier to earthship building in the county. As the knowledge of the

importance of earthships increases, building codes in the county can be amended to support earthship construction.

4.7. Factors Influencing Willingness to Adopt Earthships

The derivate of the prediction function, which by default is the chance of success following the Probit, is the marginal effect of an independent variable (age, gender, etc.). Marginally, the derivative for each observation is evaluated and the average of the marginal effects is reported (Boggess, 2023). It describes how changes in an independent variable affect the predicted outcome while holding other variables constant (Mize et al., 2019). Table 9 presents the results of the determinants of the willingness of respondents to adopt earthship in the study area. The interpretation and discussion of the result are based on the marginal effects of the variables.

Table 9: Probit Regression Showing Factors Influencing Willingness to Adopt Earthships

Variable	Marginal Effect	Std. Error	P-Value
Age			
25-34	-0.390	0.149	0.009
35-44	-0.135	0.160	0.399
45-54	-0.187	0.175	0.284
55-64	-0.073	0.177	0.679
65+	-0.165	0.192	0.390
Gender	0.075	0.091	0.411
Education			
College/Technical School	0.304	0.163	0.063
Four-Year College Degree	0.389	0.150	0.010

Advanced Degree (Masters, etc.)	0.266	0.162	0.102
Annual Gross Income			
\$20,000 to \$50,000	0.263	0.161	0.103
\$50,000 to \$100,000	0.341	0.179	0.056
\$100,000 to \$150,000	0.155	0.206	0.451
\$150,000 to \$200,000	0.386	0.240	0.107
More than \$200,000	0.159	0.319	0.620
Years of Residency			
5 to 10 years	0.114	0.136	0.401
15 to 20 years	0.304	0.134	0.024
More than 20 years	0.076	0.134	0.567
Home Ownership	-0.395	0.136	0.004
Prior Knowledge	0.410	0.106	0.000
View of Sustainability			
Slightly Important	0.158	0.147	0.283
Moderately Important	0.456	0.149	0.002
Extremely Important	0.728	0.141	0.000
Constant	-2.230	0.961	0.020
Number of observations	196		
LR chi2 (16)	79.08		
Prob > chi2	0.000		
Pseudo R2	0.294		
Log Likelihood	-95.077		

Independent variables such as age, education, gross income, and years of residency are categorical variables. As such, in the estimation, the first category for each variable was set as a benchmark to which the other categories are compared. The p-values show the significance levels of the independent variables. A p-value < 0.01, p-value < 0.05, and p-value < 0.001 indicate significance levels of 10 percent, 5 percent, and 1 percent respectively.

Age

The results show the age category (25-34) is negative and significant at 1 percent. This means that people who are within the age group of 25-30 are 39 percent less likely to adopt earthships compared to their counterparts who are 18-24 years old. Survey participants revealed how their age influenced their willingness to adopt earthships with the comments below:

“Interesting concept. If younger, might consider this if available.” [Respondent 14: Male: 65+: Brookings]

“I am in favor of earthships, but I don't think they'd be for me, at this stage of my life.” [Respondent 121: Female: 55-64 years: Volga]

“The reason I am not interested in the earthships is because of my age, my lack of money and resources to help me with the project.” [Respondent 152: Female: 55-64 years: Brookings]

“Investing the time and money to live in an earthship /sustainable home is not really on my radar, nor would it be a priority to me at this point in my life.

Interesting to be exposed to the concept, though.” [Respondent 204: Male: 45-54 years: White]

Respondents with ages 45 years and above saw their age as the factor negatively influencing their willingness to adopt earthships. Age plays a significant role in influencing people's willingness to adopt earthships. Younger generations may be more willing to change lifestyles and habits to suit that of living in an earthship. Older

generations may have to include their health and mobility as a considerable factor when adopting earthships.

Education

The results from the probit regression (Table 9) show that the respondents who had attained a four-year degree are 30.4 percent more likely to adopt earthships compared to those who have a high school education or less, which is significant at 10 percent. Also, people who have attained a four-year degree are 38.9 percent more likely to adopt earthships than people who have a high school education or less, which is significant at 1 percent.

This can be attributed to the fact that; one's level of education and awareness may significantly influence their appreciation of the environment and sustainability. Education is critical in terms of improving access to information and promoting awareness. For instance, increasing people's awareness of sustainability within their communities can encourage them to implement sustainability principles and practices in their day-to-day activities.

Furthermore, according to Semega and Kollar (2022), per capita income is significantly associated with higher education. Higher income means the more practical and feasible it becomes to fund the establishment of earthships. In most states, unemployment rates with higher education tend to reduce significantly. Thus, the more skills people have, the more employable they are as such individuals with higher levels of

education have a lower average unemployment rate than those with less education (Wolla and Sullivan, 2017).

Annual Gross Income

Regarding gross annual income, the results show that gross income of \$50,000 to \$100,000 is significant at 10 percent. This means that people who earn a gross income of \$50,000 to \$100,000 are more likely to adopt earthships compared to those who earn \$20,000 to \$50,000.

Participants expressed how their income would affect their willingness to adopt earthships:

“Would be interesting to have Earthship houses, but too expensive for me.”

[Respondent 38: Female: 25-34years: Aurora]

“All the qualities of an earthship are things I’d want to upgrade/improve in my own home, but don’t have the money for.” [Respondent 40: Female:35-44years Brookings]

The comments above highlight the role annual gross income plays in influencing willingness to adopt earthships. An individual's income plays a significant role in their decision to adopt an earthship and other environmentally friendly housing options. People with higher incomes may have more resources and opportunities to explore and invest in alternative housing solutions, while individuals with lower incomes might face financial constraints and other barriers to doing so.

Home Ownership

Homeownership, which is a binary variable, is significant at 1 percent. It implies that homeowners are 39.5 percent less likely to adopt earthships than tenants. The views of homeowners were stated as follows:

“The biggest barrier for me is that I already have a home and wouldn’t want to move.” [Respondent 23: Female: 35-44years: Brookings]

“I would not replace my current home, but would build one for a student to live in on my property” [Respondent 45: Male: 45-54years: Brookings]

Results show that respondents who owned homes saw that as a factor that would negatively influence their willingness to adopt earthships.

According to Harvard University's Joint Centre for Housing Studies (JCHS), the national homeownership rate is continuing to rise, owing to the aging of more millennials into their 30s and robust income gains among these young individuals (JCHS, 2021). Also, household prices have significantly increased with low interest rates and supply shortages driving home prices. The initial high construction cost for most earthships buildings makes them less attractive to low-income households.

Years of Residency

The results also show that at a 5 percent significance level, people with 15 to 20 years of residency in the county are 30.4 percent more likely to adopt earthships than those with less than 5 years of residency. This clearly shows that the number of years a

person resides in Brookings County can influence their willingness to adopt earthships as sustainable homes.

Prior Knowledge of Earthships

People with prior knowledge of earthships are 41 percent more likely to adopt earthships compared to respondents who do not have prior knowledge of earthships, which is significant at 1 percent.

Respondents shared their views on prior knowledge as follows:

“There is an ‘earth house’ in Elkton that I have always loved.” [Respondent 15:

Female: 35-44years: Brookings]

“I have thought about sustainable housing but was not familiar with the term earthships.” [Respondent 106: Male: 35-44years: Brookings]

“I know a little about earthships but know a lot more about rammed earth construction.” [Respondent 166: Male: 45-54 years: Volga]

Prior knowledge of earthships can contribute to people having a positive perception of earthships and their awareness of adopting earthships as sustainable homes. People who had been exposed to the concept of earthships beforehand can be less fearful of the unknown, and this will increase their willingness to investigate and explore this lifestyle.

View of Sustainability

The Probit Model revealed that respondents who viewed sustainability as moderately significant are 45.6 percent more likely to adopt earthship than those who saw it as

insignificant. This had a significance level of 1 percent. Also, people who viewed sustainability as extremely important to the county are 72.8 percent more likely to adopt earthships, which is also significant at 1 percent. Some of the comments made on the view of the importance of sustainability in the county are:

“I’m always interested in saving energy and money. But always so expensive to do anything.” [Respondent 99: Female: 35-44years: White]

“This is an interesting concept in a time when global warming, water, and food resources are going to continue to be in jeopardy.” [Respondent 101: Male: 25-34years: Elkton]

Those who are environmentally conscious or who are deeply committed to sustainability are more likely to respond positively to Earthships to align their lifestyle with their morals. Human behavior is considered very complex, with multiple factors influencing perceptions and choices. These factors may include an individual’s physical location and orientation of the body, experience, background, knowledge level, beliefs, attitudes, values, and personal preferences (Yttredal and Homlong, 2020; Lueg, 2014).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Sustainable development has been considered a resonating factor in the dimensions of natural resources and environmental management. Land use forms such as establishing human settlements remain a critical source of CO₂ emissions and other greenhouse gases, leading to global warming. Activities such as residential heating, cooling, electrical consumption, and transportation in the United States contribute significantly to greenhouse emissions. Although there is an increased need for homes, bridging the housing deficit while maintaining natural and ecological integrity is a major challenge that needs to be addressed. One of the viable options to address this hurdle is the adoption of earthships, which serve as sustainable or alternative homes that utilize renewable energy and practices with a smaller ecological footprint on the environment.

This thesis explores the feasibility of earthships as sustainable and self-sufficient housing pathways by specifically examining the benefits and barriers of earthships using descriptive statistics. Additionally, I analyzed the factors that affect people's willingness to adopt earthships in Brookings County employing a Probit regression model, taking into consideration factors such as people's perception of sustainability, prior knowledge of earthships, and socio-demographic factors. The data were collected using QuestionPro. A total of 204 eligible responses were obtained in the survey. Several key findings have

emerged throughout the research, shedding light on the potential benefits and challenges associated with earthships. Based on the perceived benefits of earthships, I found that most respondents (43 percent) considered the use of renewable energy resources as a significant benefit of earthships. Besides using renewable energy sources, using locally sourced materials in the construction process was considered the second most significant benefit of earthship. Fifty-two (52 percent) of respondents perceived eliminating energy bills through living entirely off-grid as a very significant or extremely significant benefit of earthships. The results suggest that the respondents believed that earthships have significant benefits.

Concerning the perceived barriers to the establishment of earthships, the results show that 50 percent of respondents perceive extreme winter temperatures to be a significant barrier to the establishment of earthships in the county. Also, water and energy dependence on purely renewable sources and obtaining the necessary permits emerged as perceived barriers to establishing earthships. In addition, most respondents view the using repurposed materials in construction as unsuitable for densely populated areas and as moderately significant barriers to establishing earthships.

As expected, the Probit results on the factors affecting willingness to adopt earthships reveal, that the view of sustainability has a positive and significant correlation with the willingness to adopt earthships. People value sustainability, which is important for the environment. Besides, factors such as educational level, annual gross income, years of residency, and prior knowledge of earthships make people likely to adopt

earthships in the study area. In contrast, the age of the respondents and homeownership have been found to have a negative effect on their willingness to adopt earthships. This implies that older people and people who own homes are less likely to adopt earthships.

Promoting the adoption of earthships as sustainable and eco-friendly options requires addressing perceived barriers such as extreme weather. This could involve providing more information on the suitability of earthships for the area's climate.

5.2 Limitations to Research

Although data collection and analysis have achieved this research's objectives, some limitations to the study were observed. The concept of earthships is new to the residents of Brooking County, as many had not heard of the term before, and there was no known record of an earthship building in the county. This affected the interest of some respondents in taking part in the survey. The data collection process occurred from February to April, which were winter months, and posed a challenge to the distribution of surveys to respondents. Data availability was another challenge, as only responses were gathered instead of the estimated number of 387 responses. This affected the research results as more data could have given different results. The building codes in the county were not formulated to address the design principles of earthships, making it challenging to identify specific regulations that would be barriers to the establishment of earthships in the county. Another limitation was that churches were the only religious body in the survey. This could raise the issue of biased research and affect the data and interpretations of the results of this study.

5.3 Recommendations for Future Research

While earthships present intriguing opportunities for sustainable living, further research must address obstacles and offer a thorough understanding of their viability in various situations. Future research on earthships can include the long-term performance of earthships and provide region-specific recommendations to conserve time and resources. Communicating the benefits of earthships such as rainwater and greywater harvesting, using renewable energy sources, and cost-effectiveness could make people well-informed about the benefits of earthships. Research should investigate cost-effective construction methods and materials to make earthships more accessible and affordable. Earthships can create avenues for ecotourism within smaller communities and as such future research can focus on interests of community stakeholders in building earthships for ecotourism purposes. By addressing these research areas, we can deepen our understanding of the feasibility of earthships and provide valuable insights for policymakers, designers, and individuals considering this alternative housing option.

APPENDIX

RESEARCH SURVEY

You are invited to participate in our survey "Feasibility of Earthships as Sustainable Homes in Brookings County". This survey is conducted by a graduate student in the Geography Department at South Dakota State University. It will take approximately 10 to 15 minutes to complete the questionnaire. Your participation in this study is completely voluntary. There are no foreseeable risks associated with this project. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any point. You must be 18 or older to participate. Your consent is implied by participating. It is very important for us to learn your opinions. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential. If you have questions at any time about the survey or the procedures, you may contact Whitney Yeboah by email at whitney.yeboah@jacks.sdstate.edu

Thank you very much for your time and support. Please start with the survey now by clicking on the Start button below.

Whitney Yeboah, Graduate Student

George White, Advisor

Are you a resident of Brookings County?

Yes

No

SECTION I: Knowledge and Perceptions of Earthships

An Earthship is an off-grid and self-sufficient type of passive solar home built from recycled and natural materials. Earthships are built using six design principles: recycled materials, thermal heating, and cooling, solar and wind electricity, water harvesting, contained sewage treatment, and food production. These six design principles meet the six basic human needs, which are shelter, food, energy, clean water, garbage management, and sewage treatment. For more information on earthships, please watch the youtube video below: <https://www.youtube.com/watch?v=JJ2izXcxhsQ>



1. Did you have prior knowledge about earthships?

Yes

No

2. How important is sustainability to the County?

Not at all important Slightly important Moderately important

Extremely important

3. Which of these six design principles of earthships do you think would contribute to Sustainability the most?

Building with natural and repurposed materials

Thermal/Solar heating and cooling

Solar and Wind electricity

Water harvesting

Contained sewage treatment.

Food production

4. Please rate the level of significance of the following benefits of earthships.

Benefit	Not significant at all	Slightly significant	Moderately significant	Very significant	Extremely significant
Rainwater and greywater harvesting	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use of renewable energy resources	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Using locally sourced construction material	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Eliminate energy bills through living entirely off-grid	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
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5. Please rate the level of significance of the following barriers to establishment of earthships in the County.

Barriers	Not significant at all	Slightly significant	Moderately significant	Very significant	Extremely significant
Obtaining the necessary permits	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use of repurposed materials in the construction	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Labor intensive building process	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Unsuitable for densely populated urban areas	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Water and energy dependence on purely renewable resources	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Extreme winter temperatures	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

SECTION II: Willingness to Adopt Earthships

6. Would you consider buying or building an Earthship?

Yes

No

7. If yes, how many rooms would you like the Earthship to have?

2

4

3

5

8. Would you be interested in learning the skills needed to build your own Earthship?

- Yes No

9. How much are you willing to pay to acquire an Earthship?

- \$80,000 - \$100,000
 \$100,000 – \$150,000
 \$150,000 - \$200,000
 \$200,000 and above

SECTION III: Socio-Demographic Characteristics

10. Please indicate your age range.

- 18-24 25-34 35-44 45-54 55-64 65+

11. Please indicate your gender.

- Male Female

12. What is the highest level of school you have completed?

- High School or Less
 College/Technical School
 Four-Year College Degree
 Advanced Degree (Masters, etc.)

13. Please indicate your annual gross income.

- \$20,000 or less
- \$20,000 to \$50,000
- \$50,000 to \$100,000
- \$100,000 to \$150,000
- \$150,000 to \$200,000
- More than \$200,000

14. Which of these cities do you reside in?

- | | |
|------------------------------------|---------------------------------|
| <input type="checkbox"/> Brookings | <input type="checkbox"/> Volga |
| <input type="checkbox"/> Bushnell | <input type="checkbox"/> Aurora |
| <input type="checkbox"/> Elkton | <input type="checkbox"/> Bruce |
| <input type="checkbox"/> Arlington | <input type="checkbox"/> Sinai |

15. How many years have you been a resident in the county?

- Less than 5 years
- 5 to 10 years
- 15 to 20 years
- More than 20 years

16. Are you a homeowner or a tenant?

- Homeowner Tenant

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