Title: Earthship Buildings: Stakeholder Opinions of their Contribution Towards Sustainable Alternative Housing in the United Kingdom

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Abstract
Society requires additional affordable housing to meet its growing demands. Further, people expect their homes to meet sustainability targets and for the lifestyles they proffer to accord with low impact living. Earthship buildings are marketed as being an epitome of sustainable alternative housing. Built by reusing or repurposing mostly reclaimed urban waste products, their design includes the utilization of low embodied energy materials, passive solar heating and cooling, photovoltaic power systems, rainwater harvesting, solar hot water heating, along with black and grey water treatment systems. Thus, Earthship buildings are considered exemplars for contributions to both the sustainability and climate change agendas. This study explores stakeholder opinions of whether Earthship buildings can contribute towards the future of alternative housing in the United Kingdom (UK). Opinions were sought through questionnaire survey completed by UK members of online social media groups whose shared focus is related to sustainability (n=50). Results reveal that the public believe the main benefits are their minimal environmental impact and also their reliance on renewable energy resources; whilst the main barriers are identifying suitable building plots and obtaining the necessary planning permissions to build. Notwithstanding the participants included in this study already have an interest in sustainability issues, it is surmised that the general public deem the general principles of Earthships are an acceptable choice of alternative home/living. However, whilst the uptake of Earthship homes are proving increasing popular in some parts of the world, the upmost concern within the UK setting is the reality of finding somewhere suitable to build an Earthship and then being given the required authorisations to construct the building. Therefore, the study recommends a need for future Earthship investigations to review the bureaucratic obstacles encountered during land searches and acquisitions and, alongside this, appraise the challenges of gaining the necessary planning permissions.

Keywords: Sustainable construction, Alternative living, Sustainability, Waste management, Off grid.

1. Introduction

Earthships were originally the creation of Michael Reynolds (in the 1970s) and are a concept aimed at being as sustainable as possible, through the minimisation of environmental impacts during the construction design/process of an Earthship and also through the subsequent off–grid living/lifestyle (Hewitt and Telfer, 2007; Purdy, 2011; Prinz, 2015). An Earthship is a type of passive solar house made from natural and recycled materials, where the desire is to be as fully self–sufficient as possible through recycling of rainwater, production of solar energy by a photovoltaic system, passive solar techniques and potentially wind turbines for electricity production (Bobbette, 2005; Rockwood, 2014). The fundamental purpose of Earthships was to evolve the way humans live, to make small steps to reduce their negative impact on the environment, to inspire people to act and to empower positive change towards reduced carbon emissions and to make homes that are self–reliant (Spasojevic–Santic, 2016; Hagbert and Bradley, 2017).

Adopting alternative lifestyles, by constructing Earthship homes and embracing off–grid living, is probably a choice too far for many in society, so traditional homes are likely to remain the choice of traditional people (Daigle and Vasseur, 2019). However, for those wanting to embrace an alternative home/living, it is important to recognise and acknowledge the potential benefits and barriers of Earthship homes by gauging the perceptions of those

already interested in alternative and sustainable living. Therefore, the aim of this study is to explore stakeholder opinions of whether Earthship buildings can contribute towards the future of alternative housing in the UK.

2. Background

Earthships are amongst the most popular alternative sustainable buildings constructed around the world, with many thousands already built (Kratzer, 2014). They exist on many continents, as private homes (e.g. USA), guest hostels (e.g. Argentina), eco–resorts (e.g. Fiji), community centres (e.g. Haiti), survival shelters (e.g. Philippines), training centres (e.g. Czech Republic), museums (South Africa) and even a school (e.g. Uruguay) (Booth *et al*., 2021). Since their initial conception, the overall design of Earthships has evolved to improve thermal performance, water and energy efficiency, and has evolved to ease the construction process and to minimise costs. This has resulted in a variety of designs suited to different climates and budgets being proposed (Freney, 2014). As homes, they have been designed to accommodate from one to four bedrooms, have living/lounge rooms, kitchens and bathrooms, just like traditional homes, and even included garages too .

Figure 1 shows a schematic plan of a two bedroomed Earthship home. As with all Earthship buildings, three walls of the property comprise of earth–rammed, staggered recycled tyre walls, banked with approximately one metre of soil for thermal mass, and a fourth wall almost entirely fronted by glazing, which is angled for maximum solar gain (south–facing in the northern hemisphere). The tyre walls are load–bearing and anchored down. They serve as the connection for a pitched, heavily insulated roof that supports skylights that brighten the rooms beneath. They are designed so that no heating facilities are required, and only minimal power is needed from solar panels and/or wind turbines. Rainwater is harvested from the metal panel roof and channelled towards large underground storage tanks. Once filtered it can be used by the building occupants. Waste grey water is directed towards planters to provided water for food–bearing plants and toilet flushing; whereas, waste black water drains to outside septic tanks or botanical wastewater treatment units. Most of the building materials and internal fit–out of many Earthships are often natural products and reused items (e.g. windows, doors, bathroom suites, and kitchen units, amongst others) and recycled items (e.g. glass bottles embedded in walls to allow light into rooms and to add aesthetic attraction) (Reynolds, 1990, 1991, 1993).

An earlier study (Booth *et al*., 2021) has already identified a list of known benefits and barriers of Earthships. In that study, public visitors to the Brighton Earthship were asked to complete a hard–copy questionnaire that revealed the participants believe the reclamation of rainwater and greywater, renewable energy consumption and use of recycled materials included in the design/build are the major benefits of Earthship buildings, whilst the opportunity for a modern living style in a conservative lifestyle/setting, having a building that is cheaper than an ordinary home and the possibility of living totally off grid are considered the least beneficial reasons for building Earthship homes. Results also reveal that the public believe acquiring necessary permits/permissions to build may be more complicated, securing financial support (mortgage/loan) may be more challenging, and identifying/attaining suitable building plots are major barriers of Earthship buildings, whilst the futuristic/alternative building design, being built from waste materials and being entirely

dependent on renewable resources (rainfall/wind/sunshine) are considered the least important barriers to building Earthship homes.

To date, only two Earthship buildings exist in the UK (Brighton, England (Figure 2); and Fife, Scotland) and neither are used as private homes. However, with an ever–increasing awareness of environmental issues amongst the general public, there is an increase in interest in sustainable homes and, given the shortage and affordance of traditional mass housing, there is growth in those seeking alternative eco–homes and communities in the UK and also across other European nations. This is evidenced by the LILAC (Low Impact Living Affordable Community) co–housing eco–build households in Leeds (UK) (Chatterton, 2013; Living in Lilac, 2020); the Ashley Vale Yard co–operative self–build development in Bristol (UK) (Broer and Titheridge, 2010); the Hedgehog self–build housing cooperative in Brighton (UK) (Grand Designs, 1999); the Almere assisted self–build schemes in the Province of Flevoland (Netherlands) (Bossuyt, 2020); the Vauban district of co–operative sustainable housing in Freiburg (Germany) (Coates, 2013); and the Eco–Habitat Groupé housing in Grenoble (France) (Bresson and Denefle, 2015).

3. Research Design and Methodology

The philosophical underpinning of the study follow a positivism–based stance (i.e. a fact–based investigation (DiVanna, 2010)), using a deductive research approach (i.e. an inquiry derived from exploring an empirical world (Kennedy, 2018)), which enabled the researchers to adopt a questionnaire as the data collection instrument to solicit public opinions of the benefits and the barriers of Earthship homes/living.

3.1 Data Collection

Section one of the questionnaire was designed to capture the participant's personal details; Section two comprised ten statements used to determine apparent benefits of Earthship homes/living (Table 1), cited in a random order to avoid any preference; and, similarly, Section three comprised seven statements used to determine apparent barriers of Earthship homes/living, again cited in a random order to avoid any preference. For Sections two and three, participants were asked to indicate their scoring for each statement on a five–point Likert–type scale (5 = extremely important, 4 = very important, 3 = moderately important, 2 = slightly important, or 1 =not important) (Barnette, 2010), in a horizontal grid system stored as ordinal data. A purposive sampling strategy (Morse, 2004) was employed because the study specifically sought the opinions of those persons already interested in sustainability related matters. As the study was conducted during the Covid–19 pandemic it was necessary to approach potential participants through online social media groups (e.g. Facebook) and conduct the data collection process through an online platform compliant with national GDPR guidelines (e.g. Qualtrics) (Sue and Ritter, 2007).

University ethical approval was granted for the study. Approval meant that all participants were informed about the study through an upfront participant information statement, which primed participants that their involvement was entirely voluntary, their responses would be anonymous and it also explained how their data would be used, stored and ultimately deleted. Before each participant gave their consent to take part, persons were told they could choose to withdraw from the study at any time, which including up to two–weeks after taking part in the study.

3.2 Data Analysis

The primary data were entered into Microsoft Excel (2016 version). As with many other environmental and sustainability studies (Begum *et al*. 2009; Owalana and Booth 2016; Bailey *et al*., 2021), a weighted average method was used to analyse and rank the questionnaire data. The following weighted average formula was used to calculate the average score for each statement (Equation 1). Where WAS_i denotes the weighted average score for each statements i, j denotes the numerical value for each ranking level in which 1 is allocated to the lowest rank and 5 is allocated to the highest rank, n_{ij} denotes the number of respondents for statements i with ranking level j, and N denotes the total number of respondents for the question.

$$WAS_i = \frac{\sum_{j=1}^{5}(\alpha_j n_{ij})}{N}$$

Equation 1: Formula for the Weighted Average Score

An additional formulation was required to address the weakness of the weight average score, which did not account for the degree of variation between the responses. Hence, a coefficient of variation was added to each of the weighted average scores to compute the Benefit/Barrier Index Value (BIV) (Equation 2), which determined the final rankings, and where BIV_i denotes the Benefit/Barrier Index Value for each of the statements i, and δ_i denotes the standard deviation for each statements i.

$$BIV_i = WAS_i + \frac{WAS_i}{\delta_i}$$

Equation 2: Formula for the Benefit/Barrier Index Value

4. Results

The questionnaire was distributed to online members of several Facebook groups whose focus is chiefly related to sustainability (e.g. "*Sustainable Living UK*" and "*Off Grid UK, Home–Steading and Self–Sufficiency*", amongst others). Once a participant's consent was given, they were asked to first confirm they were UK residents. This was important to ensure all the responses were relevant to the boundaries of the study's design. A total of 50 participants (63% female; 35% male; 2% non–binary) completed the questionnaire.

According to Denscombe (2014), sampling and sample size adequacy can be determined based on precedence. Thus, the 50 responses recorded in this study accords with the sample sizes used in other environmental and sustainability studies that have used surveys. For instance, Owolana and Booth (2016) relied on 40 responses; Bailey *et al*. (2020) used 49 respondents; and Booth *et al*. (2021) relied on a sample population of 31 participants in their Earthship study. Further, each of these examples employed the same data analysis approach used in this study.

4.1 Benefits of Earthship Homes/Living

The questionnaire listed ten statements considered to be the main advantages of Earthship homes/living (Table 1). Analysis of the questionnaire responses (Table 2) was used to list the benefit statements in a ranked order of importance (Table 3; Figure 2).

Table 1: List of the known benefits of Earthship homes/living (adapted from Booth *et al*. 2021)

Code	Benefit Statements
BF–a	Earthships use locally sourced construction materials
BF–b	Earthships are cheaper to build than ordinary dwellings
BF–c	Earthships minimise our environmental impacts
BF–d	Earthships use of recycled materials in their design/build
BF–e	Earthships eliminate utility bills through living entirely off–grid
BF–f	Earthships use renewable energy resources
BF–g	Earthships promote rainwater and greywater harvesting
BF–h	Earthships support the shift towards food self–sufficiency
BF–i	Earthships offer an opportunity for modern living style in a conservative lifestyle/setting
BF–j	Earthships enhance the aesthetics of building within natural landscapes

Table 2: Questionnaire responses and the calculation of weighted average parameter values for the benefit statements

Code	Extremely important	Very important	Moderately important	Slightly important	Not important	WAS	δ	BIV	Rank
BF–a	22	19	6	3	0	4.20	0.87	9.02	7
BF–b	15	17	12	4	2	3.78	1.08	7.27	9
BF–c	34	12	3	1	0	4.58	0.70	11.17	1
BF–d	19	21	8	2	0	4.14	0.82	9.16	6
BF–e	24	18	5	3	0	4.26	0.87	9.17	5
BF–f	29	16	3	1	0	4.49	0.70	10.87	2
BF–g	26	18	5	0	1	4.36	0.82	9.68	3
BF–h	18	12	16	2	1	3.90	1.02	7.74	8
BF–i	22	19	7	2	0	4.22	0.83	9.29	4
BF–j	14	15	12	5	3	3.65	1.17	6.77	10

Table 3: List of the benefit statements in ranked order

Rank	Code	Ranked Benefit Statements
1	BF–c	Earthships minimise our environmental impacts
2	BF–f	Earthships use renewable energy resources
3	BF–g	Earthships promote rainwater and greywater harvesting
4	BF–i	Earthships offer an opportunity for modern living style in a conservative lifestyle/setting
5	BF–e	Earthships eliminate utility bills through living entirely off–grid
6	BF–d	Earthships use of recycled materials in their design/build
7	BF–a	Earthships use locally sourced construction materials
8	BF–h	Earthships support the shift towards food self–sufficiency
9	BF–b	Earthships are cheaper to build than ordinary dwellings
10	BF–j	Earthships enhance the aesthetics of building within natural landscapes

The results reveal Earthships minimise our environmental impacts and Earthships use renewable energy resources are considered the most important benefits offered by Earthship homes/living, while Earthships enhance the aesthetics of building within natural landscapes

and Earthships are cheaper to build than ordinary dwellings are considered the least important benefits offered by Earthship homes/living. Similar to the findings of Booth *et al*. (2021), this indicates that environmental drivers are the main motivators towards the uptake Earthship homes/living.

4.3 Barriers of Earthship Homes/living

The questionnaire listed seven statements considered to be the main disadvantages of Earthship homes/living (Table 4). Analysis of the questionnaire responses (Table 5) was used to list the barrier statements in a ranked order of importance (Table 6; Figure 3).

Table 4: List of the known barriers of Earthship homes/living (adapted from Booth *et al*. 2021)

Code	Barrier Statements
BA–a	It is difficult to identify suitable Earthship building plots
BA–b	Earthships are unsuitable for densely populated areas
BA–c	Earthships designs are unsuitable in cold climates
BA–d	Earthships are dependent purely renewable sources for their water and energy
BA–e	Obtaining the necessary permits and permissions to construct Earthship buildings
BA–f	It is difficult to secure a loan or other financial support for Earthships
BA–g	Constructing Earthships is a labour–intensive process

Table 5: Questionnaire responses and calculation of the weighted average parameter values for the barrier statements

Code	Extremely important	Very important	Moderately important	Slightly important	Not important	WAS	δ	BIV	Rank
BA–a	25	16	5	3	1	4.22	0.99	8.50	1
BA–b	2	9	12	12	13	2.48	1.19	4.56	7
BA–c	3	9	23	11	4	2.92	0.98	5.91	6
BA–d	7	21	13	5	3	3.49	1.05	6.81	3
BA–e	23	16	7	2	2	4.12	1.05	8.04	2
BA–f	14	15	8	6	7	3.46	1.37	5.98	4
BA–g	7	14	17	5	6	3.22	1.18	5.95	5

Table 6: List of the barrier statements in ranked order.

Rank	Code	Ranked Barrier Statements
1	EB–a	It is difficult to identify suitable Earthship building plots
2	EB–e	Obtaining the necessary permits and permissions to construct Earthship buildings
3	EB–d	Earthships are dependent purely renewable sources for their water and energy
4	EB–f	It is difficult to secure a loan or other financial support for Earthships
5	EB–g	Constructing Earthships is a labour–intensive process
6	EB–c	Earthships designs are unsuitable in cold climates
7	EB–b	Earthships are unsuitable for densely populated areas

The results reveal that difficult to identify suitable Earthship building plots and obtaining the necessary permits and permissions to construct Earthship buildings are considered the most significant barriers to Earthship homes/living, while Earthships are unsuitable for densely populated areas and Earthships designs are unsuitable in cold climates are considered the least significant barriers to Earthship homes/living. Again, this is similar to the findings of

Booth *et al*. (2021), because this indicates that it is the administrative/preparatory issues that are the main challenges towards the uptake Earthship homes/living.

5. Discussion

Earthships minimise environmental impacts was the leading benefit. This accords with underlying principles of the Earthship philosophy (Earthship Biotecture, 2022). For instance, in terms of the building materials used to construct an Earthship, these are chiefly recycled products (e.g. the vehicle tyres used to create the load bearing walls that are filled with rammed earth) or reused artefacts (e.g. the reclaimed doors and windows, etc.). Similarly, the occupation of the building is designed to achieve low impact living (Seyfang, 2010). This is exemplified by the building being entirely off–grid, regarding its water resources, energy supplies and wastewater treatment, plus it also aids food self–sufficiency.

Earthships use of renewable energy resources was the second most important benefit. Again, this is linked to underlying principles of the Earthship philosophy. For instance, self–sufficiency is a key feature of Earthship buildings. One aspect of self–sufficiency includes a reliance on using off–grid energy supplies. Many Earthships rely on photovoltaic solar panels and/or their own wind turbines to generate their electricity supplies. Storing the energy in banks of batteries, for when the sun is not shining or the wind is not blowing, is an expensive but necessary choice (Puranen *et al*., 2021).

Identifying suitable Earthship building plots was the leading barrier. Whilst this can be an issue for any house builder, the general design of Earthships, with tyre walls built directly on top of a sub–soil layer, means the ideal site needs to be fairly flat. In some ways, the popularity for building Earthships in Taos is aided by the flatness of the desert settings. However, expanses of available flat land in the UK, which is not classified as greenbelt land, is very limited. Further, alongside this requirement, Earthships also need much larger plots of land compared to the modern–day housing estates crammed with box–like housing produced by mainstream housing developers (West and Emmitt, 2004). To necessitate Earthships, or communities of Earthships, will need sizeable parcels of land that are probably only available on the outer limits of our towns and cities.

Obtaining the necessary permits and permissions to construct Earthships was the second most important barrier. Meeting the expectations of planning policies and the requirements of building regulations can be a challenge for many housing developers. However, as Earthships are not the norm in the UK, to enable Earthships (or communities of Earthships) to be built will require a planning authority to understand and want to engage with the Earthship philosophy. Currently, whilst there are only two Earthships in the UK (e.g. Brighton, England; Fife, Scotland) neither are used as homes (to date). However, it is clear that the Brighton and Hove City Council planning authority does understand the principles of Earthship homes/living because they originally approved permission for the development of sixteen Earthship homes (one–bed, two–bed and three–bed houses), including some for social housing, to be built on the seafront overlooking the Brighton marina (BBC, 2007; Booth *et al*., 2021). Unfortunately, though, this housing development never emerged because of the financial crash in 2008.

Expanding Earthship opportunities to other places in the UK could be possible. For instance, the Welsh Government's forward–think sustainable development policy (i.e. Welsh Assembly Government, 2009) seems to be a possible doorway to building Earthship homes. Their 'One Planet Developments' planning guidance for sustainable rural communities are defined as '*development that through its low impact either enhances or does not significantly diminish environment quality*' (Welsh Assembly Government, 2012). Moreover, the scheme expects the buildings to be built in open countryside, which may widen the search opportunities for suitable plots of land and, in doing so, address the main Earthship barrier. However, to facilitate the uptake of Earthships across the UK will require an understanding of public opinions towards their perceived benefits and barriers, to which this study has hopefully contributed some early steps.

6. Conclusions and Recommendations

The purpose of this study was to explore stakeholder opinions of whether Earthships buildings can contribute towards the future of alternative housing in the UK. Whilst the study purposively targeted the views of participants who it could be argued are already 'signed–up' to the sustainability agenda, gathering the views of this group of participants is particularly important in understanding and gauging the primary stages of determining the possible uptake of Earthship homes/living in the UK.

The results reveal Earthships minimise our environmental impacts and Earthships use renewable energy resources are considered the most important benefits offered by Earthship homes/living, while Earthships enhance the aesthetics of building within natural landscapes and Earthships are cheaper to build than ordinary dwellings are considered the least important benefits offered by Earthship homes/living. The results also reveal that difficulties in identifying suitable Earthship building plots and obtaining the necessary permits and permissions to construct Earthship buildings are considered the most significant barriers to Earthship homes/living, while Earthships are unsuitable for densely populated areas and Earthships designs are unsuitable in cold climates are considered the least significant barriers to Earthship homes/living.

This indicates there is an appreciation and understanding of the main Earthship principles amongst the participants of what Earthship homes/living could offer society in the UK. However, they also indicate that there is probably an essence of reality of being able to and being allowed to build an alternative home in the UK. Breaking away from traditional homes and changing the expectations of planning authorities is not unthinkable but, it is hoped, with an increase in mandatory requirements for more sustainable homes to be built and for more homeowners to adjust their lifestyles and behaviours to meet sustainability targets, there may be an opportunity for Earthships to contribute towards alternative homes in the UK.

The labour–intensive nature of the building process does not lend itself to large scale construction in a country with relatively high labour costs. However, the potential for Earthship living to form part of the housing stock and to act as a testing ground for the development and promotion of alternative technologies and materials that are sustainable does have some merit.

Finally, based on the findings, and the limited number of Earthships studies conducted today, the study recommends a need for future Earthship studies to investigate opportunities to overcome the obstacles encountered during identification and acquisition of plots, and alongside this, appraise the challenges of gaining the necessary planning permissions and securing financial loans for self–builders. Further, given the labour–intensive nature of creating an Earthship building, and recognising the shortfall in available affordable housing for younger generations, opinions on the uptake of Earthships amongst 20–35 year olds could be the focus of future studies.

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Figure 1: A schematic plan of a typical Earthship two–bedroomed home.

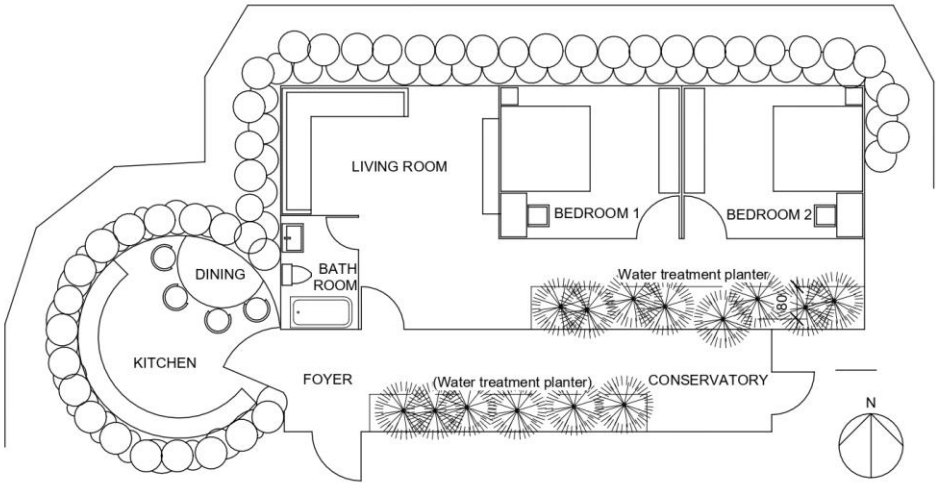

Figure 2: A photograph of an Earthship building in the UK.