Public evaluation of two-storey earth sheltered houses for sustainable communities in Wales, UK

J.R. Littlewood, BSc (Hons), PhD [1]
D. Smith, BA (Hons) [2]
A.J. Geens, BEng (Hons), PhD, CEng, MCIBSE, FIHEEM, MIMgt [3]

[1] Research Fellow/Lecturer, University of Glamorgan, School of Technology, Division of Environment & Geography, CF37 1DL, UK. Phone: +44 1443 482151. Fax: +44 1443 482169. E-mail: jrlittle@glam.ac.uk
[2] Senior Manager Renewable Energy, The Groundwork Trust, Bridgend, CF32 9TF, UK. Phone: +44 1656 722315. E-mail: debrasm@hotmail.com
[3] Senior Lecturer, University of Glamorgan, School of Technology, Division of Environment & Geography, CF37 1DL, UK. Phone: +44 1443 482176. Fax: +44 1443 482169. E-mail: ajgeens@glam.ac.uk

ABSTRACT
This paper presents the results from a pilot study of potential user response, to a sustainable community of two-storey semi-detached earth sheltered houses (esh units), in the UK. A response rate of 42% resulted in data being collected in 2001, by postal questionnaire surveys from a Welsh social housing provider, considering developing esh units for its prospective tenants. The first part of the paper evaluates the design of the esh units, and its simulated thermal performance, used as an example of two-storey esh units suitable for sustainable housing communities in the UK. The remainder of the paper discusses the results of the study in terms of the characteristics of the respondents, their attitudes towards the design of the esh units, projected internal temperatures, and their overall attitudes towards earth sheltered living. The study found that the respondents to the questionnaire survey viewed living in a sustainable community of two-storey esh units as very favourable. This paper will prove useful to developers considering developing esh units for their tenants and prospective purchasers, in the UK and Europe.

1. INTRODUCTION

At the beginning of the 21st century there are many issues facing developers of residential units, in the UK, particularly as there has been a predicted need for just under four million, and 225 thousand new homes to be built in England and Wales, respectively by 2016 (DETR 1998a, Cavill 1999). The issues include increasing the current density of housing developments from 30 houses to 50 houses per hectare; curbing carbon dioxide emissions from water and space heating, yet still providing houses with comfortable internal temperatures; reducing the destruction of greenfield land; and building houses which allow the occupants to feel part of a community (DETR 1999). There is one exception to increasing housing densities, and that is where houses are designed with a sustainable ethos, and are part of a sustainable community (DETR 1998b). One answer to the housing need, which will address the above issues, is to develop sustainable communities of earth sheltered houses (esh units). This paper reports the findings of a pilot study of consumer attitudes within Wales, toward living in a two-storey earth sheltered house (esh unit), which could be built as part of a sustainable community in Wales.

2. EARTH SHELTERED HOUSING

Readers should not confuse esh units with underground houses, i.e. houses that are built below ground level, and rely on rooflights surmounted on their roofs for daylighting. Esh units are houses, which can be built into a sloping site, and have been built on flat sites. The most common form, and energy efficient esh unit type found in the UK is the exposed south wall type (ESWT), (Littlewood 1998, 2001). In the ESWT esh unit, earth from the excavation of the construction site is placed on top of the esh unit's roof. Earth is also abutted up to all the external walls (except that which faces within 30 degrees of south), and sloped at a minimum angle of 45 degrees, down to the existing ground level. Esh units have been developed around the world in a variety of designs from one to three storeys (Baggs 1991, Sterling 1981), with over 4 million in China, a few 100 in Australia, 10,000 in North America (Dineen 1987), and between 30 to 40 in the UK (Littlewood 2001). It is difficult to give a precise number of esh units within each country in Europe, since the authors have been unable to source a definitive study by academics or professionals, in comparison to America, Australia and the UK. However, during the 1970s, Sterling (1981) identified 40 single-storey esh units in Valbonne, France. Once developed, esh units are considered a relatively sustainable form of housing, and according to Baggs (1991), Sterling (1981), Carpenter (1994), Carmody (1985), White (1998), and Littlewood (2002a), this form of housing can reduce the need for active space heating, and its associated CO_2 emissions. However, space heating can only be eliminated if a number of features are used, which include building the house into an earth banking, which is well drained, and sheltering the roof and walls with earth of between 250 and 1500 mm thickness (from the external structure outwards), (Baggs 1991, Sterling 1981, Carpenter 1994, Carmody 1985). Other features include designing the house around passive solar design principles, which include orientating exposed high performance (1.5 W/m^2K) windows within 30 degrees of south, appropriately positioned super-insulation (0.2 to 0.13 W/m^2K), ventilation heat-recovery systems, inclusion of a passive sunspace, and using a massive structure, for thermal storage (IEA 1997, Winter 1998). Other advantages of esh units, include greater sound insulation than in a conventional heavy mass, or timber frame house (Baggs 1991). In addition, if the earth which shelters an esh unit, is planted with grass and indigenous plants, it will retain and re-introduce natural wildlife habitats, which in turn can process harmful CO_2 emissions through photosynthesis (Wells 1998, Littlewood 1998, 2001).

In the UK, and towards the end of the 20^{th} century, esh units have been receiving greater attention from potential designers, developers and self-builders, as a result of the successful occupation and monitoring of five single-storey esh units, at Hockerton, in the North of the UK (BRECSU 2000). Typically, esh units have been constructed as single-storey houses in the UK and therefore cannot achieve medium density development. However, the esh unit included as part of the pilot study reviewed in this paper, was designed in a two-storey format, and therefore would use approximately 50% less land in it's footprint than a single storey esh unit, of the same useable floor area. Therefore, greater unit (or dwelling) densities could be achieved with two-storey esh units than with single storey esh units.

3. EXISTING RESEARCH

The greatest research undertaken into the design and development of esh units, originated from the USA, in partnership with the Underground Space Centre, Minnesota USA between 1975 and 1985 (Carmody 1993). The popularity of esh units in the USA, increased

dramatically from 1973 to 1985, as a direct result of the oil crisis (Sterling 1981). In 1973 there were only a few hundred esh units dotted around the USA, but by the end of 1975, there were a few thousand (Sterling 1981). To date the only research study undertaken in the UK to address the public's perception towards esh units was that by Littlewood in 1998, which was part of a PhD research programme, but was not published. Littlewood, targeted the perceptions of the public who had previously expressed an interest in living in an esh unit. The main aim of the study was to ascertain which design features incorporated into esh units, would be acceptable, and which design features may dissuade would be occupiers from renting or purchasing such housing.

In 2000, one of Wales' largest developers (discussed as market1, hereafter) and owners of affordable homes, expressed an interest in developing a series of esh units, based on research finding from Littlewood's (2001) PhD research programme. Therefore, a pilot study was undertaken in 2001, to establish whether there was a market for esh units in Wales, which included sending 50 questionnaire surveys to a selection of staff and tenants from market1.

4. EXPERIMENTAL HOUSE

Because esh units are a relatively unknown housing concept to the general public in the UK, an artist's impression and predicted temperature profile of the demonstration esh unit, designed by Littlewood (2001), was included with the 50 questionnaires sent to market1 (see Figure 1.1, and Figure 1.2. The esh units were designed as a pair of semi-detached dwellings, with three bedrooms, and on two-storeys, which is the UK's most common, and desired house type by both single and family purchasers (Nichol 1998, Hooper 1998, DETR 1998b). Each esh unit also included a garage, which is seen as a desirable feature in an UK house. The roof of the garage provides access to the private roof garden. The esh units do not include any form of active space heating, but rely on heat losses from occupants, lighting and other appliances. In addition, the esh units are designed following the passive solar design and earth sheltering principles discussed above in section 2. For more details on the design and thermal performance of the esh units refer to Littlewood (2001, 2002a).

5. FINDINGS

The response rate of 42% from market1, is deemed to be very good for postal questionnaires, as Fellows (1997) points out, the expected response rate is only 10%. It could be concluded that the high response rate indicates that the topic of developing and living in esh units is of general interest to potential tenants, owner-occupiers, and developers in Wales.

5.1 Characteristics of respondents

The gender of respondents were 52% women and 48% male, which contradicts Stuart's (1979) research, which dictated that the majority of visitors, and positive respondents to esh units in Carolina, USA were male. The majority of respondents were well-educated (77%), and in professional roles. The age distribution of respondents was in five groups, 22 to 25 (9%), 26 to 30 (9%), 31 to 40 (31%), 41 to 49 (20%) and 50 to 59 (31%). Over half (61%) of the respondents were aware of esh units, and knew the principles of earth sheltering, which is not surprising since market1 had followed the progress of Littlewood's (2001) research for a number of years.

5.2 Consumer attitudes towards alternative housing developments

The following responses were asked, as they are particular features of Littlewood's esh unit, but the respondents were not asked to relate their comments towards Littlewood's esh unit.

85% of respondents felt there was a need to develop houses, with a reduced visual impact, particularly in the countryside. The knowledge that CO_2 emissions are one of the main greenhouse gases attributable to housing in the UK, and which cause climate change, is probably why 100% of respondents wanted to live in a house which curbed these emissions. This latter finding is important, when 98% of respondents wanted to curb the need for active space and water heating, but required comfortable internal temperatures of between 18-23 C^o. Three bedrooms, as standard were favoured by 75% of respondents, and a house with plenty of private garden space by 80%. This latter point is particularly interesting since 85% of respondents felt that housing should be developed, which reduces the amount of land currently used, i.e. respondents believe housing densities should be increased. If housing densities increase, then garden sizes must be reduced. The advantage of esh units, over conventional housing in the UK, particularly Littlewood's esh unit, is that having no rear garden saves land, and the front garden could almost be removed. Yet, there is still a private garden of 60 m^2, on the roof, to meet the respondent's needs.

5.3 Consumer attitudes towards Littlewood's esh unit

In order to test whether the respondents had any pre-conceived attitudes towards living in an esh unit, they were asked to rate their impressions of the esh unit in Figure 1.1 and 1.2. Unobtrusive, innovative, appealing and aesthetically pleasing were the most popular impressions (91%) of Figure 1.1. However, the negative impressions of Figure 1.1, were that the respondents felt that it would be dark (9%), there would be a lack of view (9%), and a need for two exposed external walls (9%). However, these latter respondents would still consider living in an esh unit. Carmody (1985), also documented similar negative impressions towards esh units. Since only a small percentage of respondents had negative feelings towards the esh unit, an emphasis should be placed on changing people's misconceived ideas through demonstration projects.

5.4 Consumer attitudes towards a community of esh units

From the minor (9%) negative feedback in section 5.2 above, the majority (91%) of respondents would consider living in an esh unit, if it were situated in a rural (42%), urban (15%), suburban (19%), or inner city area (9%). It is pleasing to note that at the beginning of questionnaire, 39% of respondents were not aware of esh units. Yet, after reading through the questionnaire survey and the enclosed documentation (Figure 1.1 and 1.2), 31% of these 39% respondents would consider living in such a dwelling. There were a high percentage of respondents (91%) who would pay up to 5% more for an esh unit, if the utility bills and the visual impact of the dwelling were reduced. Ford (1998) predicts that earth sheltered buildings could cost up to 5% more than conventional buildings, in relation to their insulation requirements. Interestingly, for a developer of affordable homes, the respondents felt that esh units should be offered for sale (61%), shared equity between tenant and the developer (23%) and mixed tenures (38%). These three purchase/rental options have recently been successful at Bioregional's zero energy sustainable community (BedZed) in London, which consists of 82 houses and flats, completed in Spring 2002 (Bioregional 2002). Another feature of sustainable communities, which proved popular (42% yes, and 42% maybe) was for land to be included which could be used to produce organic food-crops. The production of organic food-crops at BedZed is documented at Bioregional (2002) and Littlewood (2002b). Most of the respondent wanted to live in a community of 11 to 20 units (42%), with 21 to 50 units and 6 to 10 units providing the same response (19%), 1 to 5 (9%). Only one respondent wished to live in a community of up to 100 esh units. Following the responsible attitude toward

increasing housing densities the majority of respondents felt that a mix of semi-detached and terraced esh units should be built in a sustainable community (66%).

5.5 The future of esh units in sustainable communities

It is surprising that after 91% of respondents suggested that they would live in an esh unit as part of a sustainable community, only 71% of respondents felt there was a future for this type of housing in Wales. Perhaps this is some indication of the difficulty there is in developing innovative houses in the UK, and particularly Wales. However, the overall response in the comments section on the questionnaire survey, was a need for at least one demonstration project, to be built in Wales, with a series of two-storey esh units, to test the practical application of living in such dwellings. A live demonstration project, which is lived in by real people, is one project which the authors of this paper are trying to establish in Wales. To date, such an idea has had the support of market1, and by the Chairman of the National Assembly for Wales' Sustainability and Energy Group.

6. CONCLUSIONS

A history of earth sheltered houses (esh units) which have been built around the world has been discussed, and it is seen that the Exposed South wall type, is the most energy efficient and common type of earth sheltered house (esh unit), in the UK. It is seen that esh units are becoming better known in the UK due to the completion and occupation of five such dwellings in the UK, in 2000. Most of the existing research into the public attitudes towards esh units was conducted in the USA between 1973 and 1985. This paper presents the first known survey in the UK, which addresses public attitudes towards living in an esh unit, as part of sustainable community. The findings of the survey, which had a 42% response rate, suggest that 91% of respondents would like to live in an esh unit, if it were one of twenty semi-detached, or terraced esh units with two-storeys, in a sustainable community, with mixed tenures, including rental, and purchase options. It is concluded that there is a need to build a demonstration project of two-storey esh units in Wales, to publicise the benefits of esh units, which the authors of this paper are currently working on, with a number of partners.

7. REFERENCES

Baggs S. A. 1991. Australian earth Covered Building. New South Wales University Press, Kensington, Australia.

BRECSU. 2000. The Hockerton Housing project – design lessons for developers and clients: New Practice Profile 119. BRECSU, Watford, UK.

Carmody J. Sterling R. 1985. Earth Sheltered Housing design. Underground Space Centre, University of Minnesota, Minneapolis, USA.

Carmody, R, J. Sterling, R. 1993. Underground space design. Underground space centre, University of Minnesoat, Minneapolis, USA.

Carpenter P. 1994. Sod It, An introduction to earth sheltered development in England and Wales, Coventry University, Coventry, UK.

Cavill, N. 1999. Housebuilders still upbeat despite cut in homes target. *Building*. 1 April, pp 12.

DETR. 1998a. Opportunities for change – Consultation paper on a revised UK strategy for sustainable development. DETR, London.

DETR. 1998b. General Information Report 53: Building a sustainable future – homes for an autonomous community. DETR, Watford, UK.

DETR. 1999. Planning policy guidance note 3: housing. DETR, London, UK.

Dineen M. 1987. Homes of the future. Vision (Halifax Building Society Bulletin), Summer, pp 39-41
Hooper A. Nicol C. The design and planning of residential space: Standard house types in the
Littlewood J. R. Penn R. G. Wild S. Earth Sheltered Housing: A Sustainable Form of Housing for the UK. Presented at The European Network for Housing Research Conference, Cardiff, Wales, September 1998.
Littlewood, J, R. (2001). A study of the design and thermal performance of two-storey earth sheltered houses for the UK climate, Ph.D. thesis, University of Glamorgan, Pontypridd, UK.
Littlewood, J, R. Geens, A, J. The thermal performance of a two storey earth sheltered house with single adult occupancy, for a temperate climate. *Proceedings of the First International Conference on Construction in the 21st Century (CITC2002) "Challenges and Opportunities in Management and Technology"* 25-26 April 2002, pp. 771-778, ISBN: 1-884342-01-9, Miami, Florida, USA.
Littlewood, J.R. Cook, R. Smallwood, I. Community based sustainable and organic food crop production, in the UK, a solution for the 21st century. *With referees,* Sustainable Building Conference, 2002.
Roskrow, B. 1997. Mastering The Art of The Innovator. *HouseBuilder*. November, pp 43.
Roskrow, B. 1998. One Person Households: What They Really Want. *HouseBuilder*. May 1998, pp 4.
Sterling R. 1981. Earth Sheltered Homes – Plans and designs. Underground Space Centre, University of Minnesota, Minneapolis, USA.
Wells M. 1998. The Earth Sheltered House – An architect's sketchbook. Chelsea Green Publishing Company, Vermont, USA.
White N. 1998. Hockerton Housing Project – Information pack. Hockerton Housing Project Ltd, Hockerton, Nottinghamshire, UK.
IEA. 1997. Solar energy houses – strategies, technologies, examples. James and James, London, UK.
Winter, S. 1998. The passive solar design and construction handbook. John Wiley & Sons, Inc, New York, USA.

Figure 1.1**: Artist's impression of Littlewood's pair two-storey esh units**

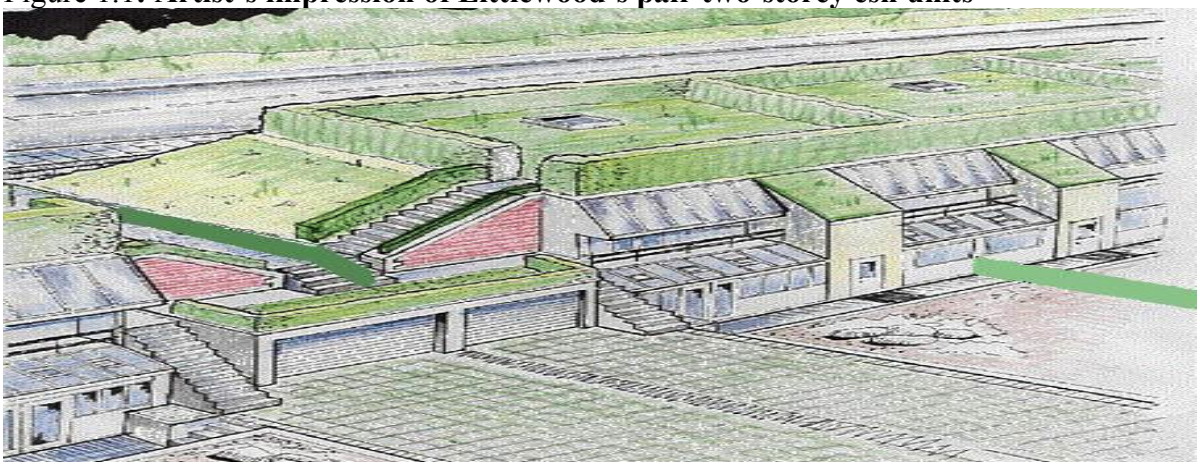

Figure 1.2: **Resultant temperature in the lounge compared with the eternal temepratures on the two coldest days of the year**