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# Designing an Environmentally Conscious Retirement Village: Potential, Constraint, and Lessons Learned.

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## Abstract

This paper focuses on the design of a proposed Retirement Village. By concentrating on the socio-economic needs of the village, the design goal was to create a secure environment for retired people that provided comfortable and affordable accommodation within a landscaped setting whilst enjoying the benefits of communal services. The housing project was designed as an apparently conventional British development, but one in which alternative energy sources, energy and water conservation, and storm water management measures were integrated. During the development of the project, extensive information on new and alternative building services systems was gathered to enable evaluation and implementation of low environmental impact systems within the constraints at this particular project.
A rigorous appraisal of "state of the art" environmental technologies has been incorporated into the design procedure, with consequent long-term advantages for the community. Most of the measures have been evaluated by using the *C*arbon *A*batement *R*elative *B*alance *F*inancial *A*ssessment Methodology (CARB FA). Apart from simple financial analysis, the designers, consultants, and developer were able to evaluate quantitatively the actual cost of reducing carbon emissions. The design proposals also include an innovative water management measures scheme, which has been assessed by qualitative and quantitative analyses. The design decisions taken inevitably are related to country and location but the methodologies followed here have the potential to be used for projects throughout the world. The scheme provided information about the difficulties and constraints related to environmentally sensitive design. The capital cost of Zero Energy housing is very high, but a number of mechanical and architectural measures can be incorporated into developments with a reasonable pay back period. When considered in an overall economic sense, which attributes a value to avoided carbon emissions, the sustainability of such measures can be accurately assessed.

# 1 Introduction

The built environment presently contributes about half of the world's air pollution through energy servicing via fossil fuels, and in the UK, housing accounts for 28% of the UK national annual carbon dioxide emissions, of which 53% is due to space heating [1,2]. Also, it has been proven that an increased concentration of $CO_2$ and other greenhouse gases in the atmosphere is leading to global warming [3].

Data available from commercial related sources includes initial and installation costs of sustainable and renewable energy technologies related to construction. However, there is little information on life cycle costs, such as investment Pay Back Periods [PBP] and Whole Life Costs [WLC]. Evaluating the environmental profile by Envest2 [5] it was possible to measure the environmental performance and emissions of the project's life with respect of manufacture, in use, and the potential energy consumption during 60 years life period. The outcomes indicate that the proportion between "Embodied Energy in Materials & Energy During Construction" and "Energy Consumed During Occupation" is equal to 0.91 $\underset{-}{\sim}$ 1:10. It is clear therefore that improved management of the energy consumed during lifetime of the projects is essential.

The project examined is the outcome of a research partnership between Kenneth Holmes Associates, Hall Bros, and Coventry University with the aim of developing an environmentally and eco friendly "village" in Walsgrave area. The specific project is a "Retirement Village", which consists of 45 individual dwellings, together with 133 apartments in a number of blocks and to provide a community hub with a range of facilities to support the village residents.

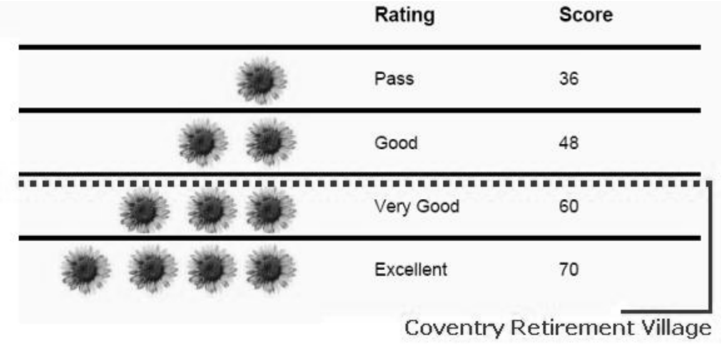
# 2 Building Structure and Other Architectural Design Parameters

The environmental impacts of construction include a wide range of issues, including climate change, mineral extraction, ozone depletion and waste generation. Assessing such different issues in combination requires subjective judgments about their relative importance. To enable such assessments, the Building Research Establishment's (UK) [BRE] Ecopoints methodology is used. [4]. Each environmental issue was measured using ENVEST2 software [5] and by comparing each environmental impact to a "norm", each impact was been measured on the same scale. [6] The materials used therefore were examined on a number if Life Cycle sustainability issues such as: Climate change, fossil fuel depletion, ozone depletion, human toxicity in air, human toxicity in water, waste disposal, water extraction, acid deposition, ecotoxicity, eutrophication, summer smog, and minerals extraction. An exampled based on the different options for the wall construction is shown in table 1.

Table 1. Normalised Values of Whole Life Costs of Wall Construction in Relation to the Lowest Values. Data derived from BRE Envest 2 Materials Database

| | ENVEST Outcomes | | Normalised Values to the Lowest Value | |
|---|---|---|---|---|
| | Ecopoints | Whole Life Cost (£) – 60 Years Life Cycle | Ecopoints | Whole Life Cost (£) – 60 Years Life Cycle |
| Timber Stud | 568 | 64,218 | 100 | 100 |
| Block | 489 | 46,223 | 362 | 150 |
| Brick | 135 | 30,813 | 421 | 208 |
| Natural Stone | 1569 | 2,887,500 | 1162 | 9371 |

The sustainability of architectural features was assed using the “EcoHomes” rating [7]. “EcoHomes” balances environmental performance with the need for a high quality of life and a safe and healthy internal environment. The preliminary report on the project indicates that after commissioning it may achieve an average of “Very Good” rating in relation to $CO_2$ emission, drying space availability, Eco-labeled goods, provision of external lighting, public transport, cycle storage, local amenities, HCFC emissions, NOx emissions, reduction of surface water runoff, timber basic building element, recyclable materials, environmental impact of materials, internal & external water use, protection of ecological features, change of ecological value of site, building footprint, day lighting, sound insulation, and private space. See figure 1.



| Rating | Score |
|---|---|
| Pass | 36 |
| Good | 48 |
| Very Good | 60 |
| Excellent | 70 |

Coventry Retirement Village

Figure 1- The Coventry Retirement Village has the potential to score 62/109 points available. [7]

## 3 Energy Related Passive Design Measures

Three procedures which may be used to predict the energy reduction potential of a no added cost Passive “Solar Heating Design” have be applied to selected houses of the retirement village. All three methods confirm that there are potential benefits to be made although there is some variation between the outputs of each. See figure 2. [8]

For both the ‘Passive Solar Heating Designs’ and ‘Conventional’ designs the constructions used offer the same accommodation, they use the same materials and are of the same size. The only difference between them is with respect to configuration of their components and physical orientation. It follows that the PSHD solution should be achievable for little or no extra cost compared with the conventional building. The results suggest that dwellings with latitude near 52$^{o}$ South, and weather characteristics equivalent to UK climate, will benefit from PSHD if glazing is concentrated in those walls orientated within 30$^{0}$ of south. For ‘Conventionally’ designed dwellings, the dwelling’s orientation will have a marginal effect on its energy demands.

In this project the likely impacts of high insulation standards on overheating were not been examined. It must be recognized that the application of PSHD may well necessitate precautions against summer overheating such as the provision of external shading devices and high levels of ventilation. Orme M. [9] investigated the impact of high levels of insulation, according to current UK regulations, for conventional dwellings and suggested low carbon strategies for maintaining summer comfort conditions. Orme concluded that natural night cooling would be beneficial for all housing types, although most effective in thermally heavyweight construction. However, if a passive solar heated dwelling is designed and constructed successfully, it can still incur problems if the building occupants or users are not made aware of how to operate it correctly.

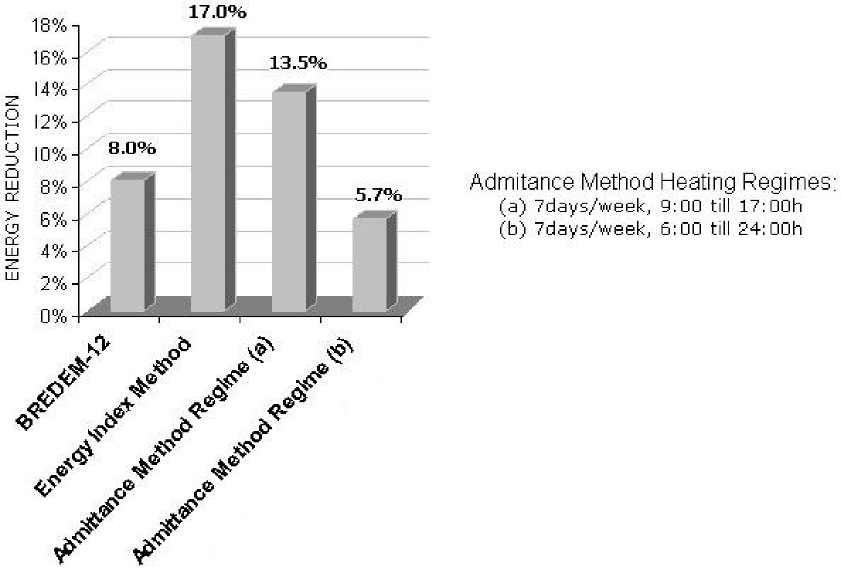


Figure 2 – Summary of the Energy Reduction Potential of South Facing Passive Solar Heating Design in Relation to a Conventional build Dwelling in Coventry.

The suggested modification to the conventional designed dwelling will offer potential social benefits for occupants who will enjoy contact with the outside and access to natural light and fresh air within their living rooms and kitchens during the daylight period.

# 4 Renewable and Sustainable Energy Technologies

Financial comparisons based on both theoretical analysis and the study of installations into existing buildings exist, but they have important shortcomings, i.e. many relate to individual renewable systems as opposed to integrated building systems combinations whereas others do not value comparison at the $CO_2$ reduction cost as well as the investment pay back period between different systems.

The “CARB Financial Analysis” methodology [10] was therefore used in this project. CARB is an acronym for:

- *Carbon Abatement*: as it evaluates the potential Carbon-dioxide reduction from different technologies;
- *Relative*: as all the technologies examined are dependant on various primary sources;
- *Balance*: as the cost of surplus $CO_2$, i.e. the difference between the existing and proposed source, is quantified.

CARB FA is presented in fig 3. Two main variables are used for appraisal: the ‘financial pay back period’ of the project, and the ‘cost of 1kg$CO_2$ saved per annum’. These are plotted on the x-y axes of a graph respectively. Note that the ‘y’ axis is logarithmic as the ‘cost of 1kg$CO_2$ saved per annum’ varies significantly between different technologies. On the graph, the minimum, mean, and maximum estimates of the Social Costs of Carbon Emissions are plotted. The minimum and maximum predictions are the horizontal thick dashed lines, with the mean as a thin dashed line between. These figures were published in January 2002 in a UK Government Economic Service (GES) working paper

'Estimating the Social Cost of Carbon Emissions' was published as a joint DEFRA-Treasury publication. [11]

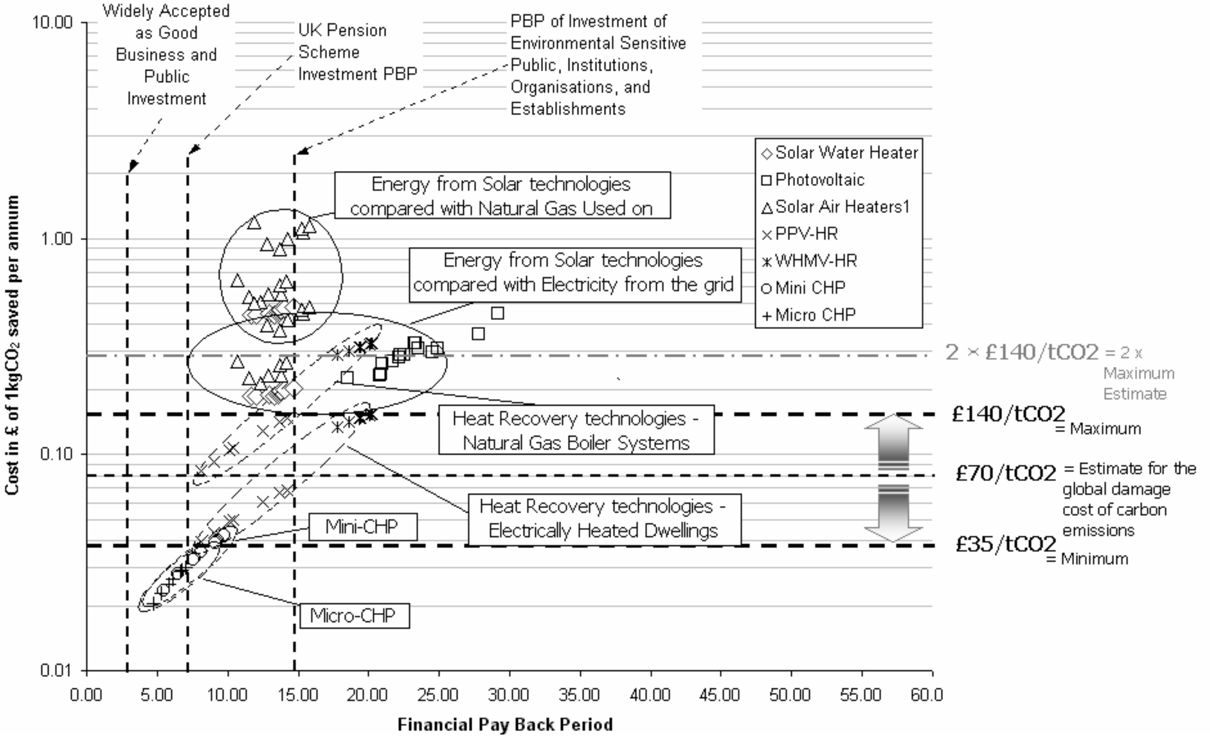


Figure 3- The CARB Assessment for the examined project. Pay Back Period in Years *[Note: £1=1.46€]*

The GES paper suggested £70/$tCO_2$ (within a range of £35 to £140/$tCO_2$ i.e. £0.035- £0.14/$kgCO_2$) as an illustrative estimate for the global damage cost of carbon emissions. If the costs of the worst expected climate change costs are doubled then the horizontal, grey long dark-dot line as shown in the figure applies. By using this methodology, the investor is able to compare the financial and environmental cost returns of different technologies.

The projected cost of $CO_2$ saved is shown at £70/tonne for UK. At this level, all technologies, which are represented above the middle black dashed line are therefore 'environmentally uneconomically'. Technologies that are feasible are those below this line and would produce a net contribution to $CO_2$ avoidance. The best economic choice within this group is likely to be those with minimum pay back period. Changing the assumptions regarding the nominal cost of $CO_2$ saved simply moves the black dashed line up (higher cost), or down (lower cost).

According to the analysis, the best option with regard to environmental conscious decisions and earliest pay back period (PBP) is the Combined Heat and Electricity Production (or Combined Heat Power = CHP), especially for community installations. The renewable energy technologies that can be intergraded in the structure of the buildings are only solar energy based which is paradoxically in a country such as UK. Wind energy harvesting is immature for integration into urban buildings. Heat pump technologies, which use the temperature difference of the inner space and upper soil temperatures cannot be characterized as a cost effective renewable energy source, and have not been examined. The choice between solar panels for the production of electricity, or of the generation of hot water, or air, depends on the type of the energy that is replacing, i.e. natural gas or low tariff electricity. [12]

## 5 Water Management Technologies

Permeable pavements, such as those marketed by Formpave, will be used to conserve land by combining parking with surface water handling within a single construction element, and to reduce impact of runoff on receiving waters.

Typical annual rainfall and the roof surface area of the average domestic home indicate that it is unlikely that sufficient rainwater will be harvested to support all the water need of a dwelling. The actual figure would average out at about 35% of the domestic household's daily water usage. Taking into account the cost of a complete rainwater system, average payback periods are likely to be in excess of 20 years.

Nationwide residential water consumption studies have indicated that almost 30% of indoor water consumption can be attributed to toilet use. [13] The quantity of water consumed in the WCs can be minimized by reducing flush volume and introducing dual flush.

Most 'water saver' showers introduce air or atomize the water drops to improve wetting for a given flow rate. The result feels like a 'power shower' but with perhaps 4–9 liters of water per minute rather than 12–20 that might be delivered by 'power showers'.

"Flow regulation valves" are justified in terms of improved performance alone (balanced dynamic pressure, reduced splashing). Regulation by showerheads and aerators were also been considered where appropriate and can have efficiency advantages. Supply restrictor valves are low cost and readily available.

A simplified installation cost return analysis is shown in figure 4 [13]. The barriers for further water conservation are: Reactive consumers, lack of information, lack of water Standards -high perception of risk-, perception of low value due to the abundance of water, and apathy.

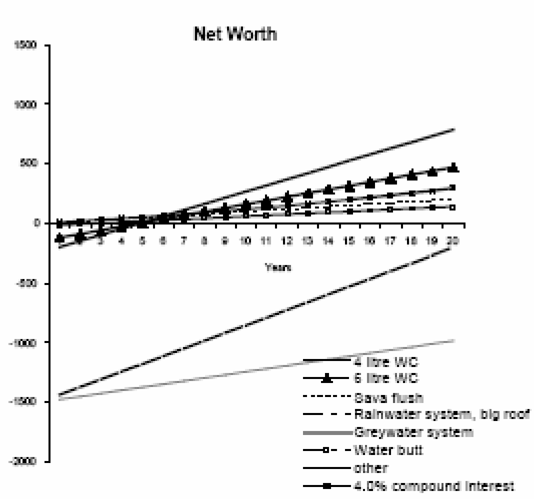


Figure 4 Pay back period of water management/reduction measures. [13]

# 6 Conclusions

Designing environmentally friendly projects is a complex procedure. Each of the professionals involved has a different prospective for the meaning of “environmental consciousness” and “sustainability”. In order to fulfill all the needs of such a project, a holistic approach is recommended, and all the issues related to conventionally designing developments have to be reassessed. For the project under examination, the design was development through a multidisciplinary team, and issues relating to the building structure, human behavior architectural features (i.e. recycling, eco-labels of products used, ecological diversity of the common areas), building services, passive design, renewable/sustainable energy sources, and water management were identified on early stages.

In some situations, some of the “sustainable features” were working against each other. For example, a timber structural building with external building façade would be the most environmentally acceptable construction, but such decision would contravene the architectural brief. It has to be mentioned that almost all of the potential clients, who are elderly, have lived their life in buildings with brick façades. Small design variations could jeopardize the success of the project. The final recommendation to the client is a structural timber frame construction incorporating bricks as the external surface, and acceptable approach for all the design involved parties.

During the design stage, it was recognized that optimizing solar energy for space heating might be an economic way of reducing fuel bills and the overall energy budget. Interest in the opportunities provided by solar energy, as a renewable energy source, has been increasing over the last decade even though the climate in the UK is not as favorable for solar energy projects as in lower latitude climates. Simulations by a number of tools revealed that passive heating design is beneficial but with a small energy reduction potentials.

Nowadays, sustainability is directly related to the production of energy from renewable and sustainable sources. Integrating such technologies is an expensive approach, but is the only way to further reduce the energy requirements of future developments. It is recommended that reduction of energy to be achieved firstly by increasing external envelope insulation, and sealing air gaps in the external structure. It is a paradox that the only renewable energy technologies for a cloudy weather climate such as England’s are those that are based on solar energy as the primary energy, i.e. photovoltaic panels and panels for the production of hot water. Cogeneration of heat and electricity to a community level found to be the best option for the following decade.

Considering the water management during the life time of the building, preservation measures have to be integrated in the design stage as early as possible. Simple measures might achieve a PBP of investment less than 5 years. With regards to surface water, permeable pavements, such as Formpave, have a number of benefits in relation to the not financial attractive rainwater harvesting systems.

Finally, it has to be mentioned that sustainability is not a low cost exercise. Most of the technologies / materials / products examined and proposed have pay back period more than 10-20 years. Sustainable design of buildings is a long-term commitment based on Whole Life Cycle cost of the final product, i.e. the retirement village.

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