# OPTIMISING THE RELATIONSHIP BETWEEN PASSIVE SOLAR DESIGN OF NEW HOUSING AND THE ECONOMICS OF CONSTRUCTION AND LAND VALUE

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In recent years the focus of mass housing developments built by speculative developers in the UK has broadly been on maximising density whilst retaining a predominantly detached housing form. This economically led strategy, aimed at maximising sale values, can conflict with the aim of radically reducing environmental impacts. That is, deep, closely spaced detached houses with narrow frontages are difficult to reconcile with the principles of good passive solar design. Whilst a variety of products have been developed to enable design professionals to model and assess the environmental performance (especially in energy use terms) of individual buildings, there are currently no tools for modelling the performance of whole developments, based on variables such as site layout, density, orientation and topography. Using passive solar design as an exemplar for sustainable development offers the opportunity to improve the environmental, spatial and aesthetic performance of speculative developments. This paper describes the development of a tool for planners and developers to optimise the passive solar characteristics of housing developments through an environmental site assessment, encouraging the use of basic environmental design techniques early in the design process.

Keywords: housing; land value; passive solar design; sustainability; life cycle

## INTRODUCTION

This research has investigated the use of passive solar design, as an exemplar of environmental design, for whole developments, as a means to overcoming the resistance to adopting sustainable housing practices. With the emphasis in current housing construction on density rather than environmental objectives, and a lack of expertise in planning, designing and building environmentally sensitive projects, there is a need for a method, which ascertains the sustainability of a site. With this in mind, the aim of this research was to produce a framework for an environmental site assessment tool for the optimisation of passive solar detached housing layouts in a development during the planning process. This product will be useful to planners in ascertaining the potential of a site, and providing detailed recommendations for a site. It is further argued that a system, which can ascertain the potential of a site at an early stage of the design, can aid in the acceleration of the planning process. The framework produced for the research has demonstrated the potential for such a system, which requires further work to develop it for practical application.

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# BACKGROUND TO RESEARCH

**Introducing the need for long-term housing goals**

The construction industry has a history of achieving short-term goals, without reaching sustainable, long-term objectives for housing. Many inner city residential areas, in particular, are obsolete little over fifty years after they have been built, for a variety of reasons such as poor planning, changing demographics, lifestyle and societal change and loss of amenities. The Urban Task Force has been created to find 'radical solutions' to solving this problem (ODPM, 1998), and environmental, ecological, or green design, as it has variously been called, is a means, if used appropriately, of helping to achieve sustainable, long-term housing goals. Sustainable design covers many complex criteria, which this research has not dealt with, but the research does cover aspects of economic value and environment central to a more sustainable design.

Recently there has been an increased awareness of issues affecting the environment. The Rio Summit's aim for reducing emissions, the Kyoto protocol directly affecting subsequent governmental commitments; and the recognition of global warming and climate change have all contributed to awareness of sustainability issues. Issues affecting the environment have resulted in a drive not only to produce ever more radical, energy efficient buildings, but has expanded to incorporate a whole series of other aspects on the environmental agenda in a quest for what has come to be known as *'sustainability'*, a complex topic which influences all aspects of development (Jackson, 2003; Edwards & Pawley, 2000).

Cutting edge projects have encouraged, at a somewhat sedate pace, improvements in building standards demanded by legislation culminating recently in improved thermal efficiency of building envelopes in spring 2001 (2002 in Scotland) primarily aimed at reducing $CO_2$ emissions. Attempts have been made to create homes, which demand much less energy than their 'standard' contemporaries, or make use of renewable energy sources. Borer & Harris (1998); Kachadorian (1997); Yannas (1994, [2]); offer examples. Many of these radical homes can be characterised as showcase developments, which employ all manner of state-of-the-art techniques, as well as sound, basic passive solar principles, to produce often expensive, prestige homes designed to demonstrate what is possible. The theory is generally that a trickle-down effect will ensure that the benefits ultimately reach a mass housing market.

There is a growing belief, encouraged by government, that long-term goals should not be forgotten in favour of short-term monetary objectives. Initial cost will always be important and many of the showcase projects have a short-term flaw in that it has generally been understood by the wider construction industry that there must be a monetary penalty when demonstration developments are transferred, in a somewhat diluted form, into the more affordable mass market.

This research suggests that the **whole design approach needs re-orientating** so that long term environmental policy goals related to climate change, for example, can be achieved. The research aimed to establish that long-term housing objectives can be achieved through environmental design with significant emission reduction and cost benefits. It used passive solar as an exemplar to develop a framework for a tool for **environmental site assessment.**

**Passive solar design as an exemplar for sustainable design**

Passive solar design, a broad term for designing buildings which are orientated towards the equator to benefit from solar heat gains (at high latitudes), requiring to face approximately south in the northern hemisphere, is a holistic design method for reducing the need for non-renewable fuel (Kachadorian, 1997; Balcomb, 1992). In this case orientation simply means the direction the solar collector faces in plan and its vertical tilt to the solar angle (Borer & Harris, 1998; Littlefair, 1991). In the northern hemisphere, the greatest quantity of solar energy is received on a South face, assuming it is not shaded by some obstruction, with roof glazing collecting more solar radiation compared to a greater area of vertical glazing.

Ensuring that the orientation of glazing faces due south is not critical as solar gains from windows facing 25 degrees off due south are only slightly lower than the maximum solar gain possible (Borer & Harris, 1998; BRECSU, 1997; BRECSU, 1995; Yannas, 1994; Littlefair, 1991). The further north the building, the closer to due south the preferred orientation, however, and the consequences of overshadowing become pronounced. This has a consequence with the building form and location of a development, in addition to orientation. In real terms an ideal site, which complements a passive solar design is not likely to occur. In addition, it is unlikely that a solar heated home will make the heating system redundant, although it will reduce the energy dependency from non-renewable sources while promoting more reliance on renewable energies (DTI, 2000; EC, 2000; DTI, 1999).

Beyond the issue of solar gain, passive solar design encompasses concepts such as thermal mass, air-tightness, super-insulation, green building construction, waste reduction, renewable material, fuel and embodied energy, with few other design approaches making full use of all these features. Where *all* these strategies are used the greatest savings in terms of heating and emissions are possible and an appropriately designed passive solar home can reduce heating costs by up to 70% (Deveci, 2000) and reduce emissions by similar proportions, thus benefiting both occupier and environment.

There are some grey areas in the definition of what constitutes passive solar design. For example, whilst insulation undeniably forms part of solar design strategies, can a building, which is simply very highly insulated, be described as a passive solar design?

With the advent of inexpensive insulation, better window and structural technology, there is the possibility that low-energy design can reduce heating costs *without* the need to be facing south, and this was considered in the research. The argument for passive solar in this case would be that, perhaps, in a passive solar home more environmentally friendly material is used and that daylight offers aesthetic and psychological benefits related to sunlight that a simple super-insulated house would not. Passive Solar also allows the integration of ‘active’ solar methods of providing renewable energy into a home, thus enabling long-term objectives to be achieved through flexibility and change of use.

Negative characteristics of low-energy designs, such as the perception of high capital costs, need to be overcome before they can be applied to mass housing, however, but investigation into built developments provides evidence that passive solar projects provide better benefits to the home buyer and environment than current construction and layouts (Yannas, [1] & [2], 1994). The environmental site assessment proposed as part of this research will need to overcome the reluctance in using low-energy designs such as passive solar to make the planning and development processes more receptive to the advantages that passive solar, in particular, has over current construction, it's layouts and energy use.

**Current methods of construction and the rationale for change**

Primarily due to the high cost of building land, current methods of residential development focus on grouping homes with minimised foot-prints - detached or semi-detached dwellings which minimise road frontage while maximising density - within predetermined site boundaries. It may be surmised that the reasons for current methods of development are not only derived from business market demands, but also compounded by government calling for higher housing densities, such as through the Urban Task Force (DETR, 1996). As a result, land values increase still further and building density becomes critical for developers. Whilst on the face of it a high development density for detached homes can be seen as a basic requirement for 'sustainable' developments (in that less green-field land is built upon) such a narrow definition of sustainable development ignores aspects of the building performance. In particular the energy performance; of the building as a system (DETR, 2000); the site as a whole; and, the consequent reduction of pollutants. It should be noted that without an environmental strategy, a site with higher density would simply mean more pollution, in a smaller space.

The tensions between current mainstream building practice and sustainable development are both complex and far reaching (Edwards & Pawley, 2000). Many see sustainable development as an idealistic moral high ground, rather than a serious mainstream option (Edwards & Pawley, 2000; Serchuk, 2000). For the Government to overcome this, the publication, "*Building a Better Quality of Life*" (2000) aimed to stimulate sustainable development and details the aspects that the Government associates with sustainable development. This by no means overcomes the problems associated with the practical application of environmental developments, but is a sign of increasing awareness and a step forward.

Previous studies by the DETR and the DTI (BRESCU, 1997 and 1995) indicate that there is some reluctance to adopt passive solar design principles fully, for a number of reasons. In particular, constructors/developers currently build dense, narrow-fronted and detached or semi-detached housing primarily to suit market demand, with dwellings traditionally facing each other across a distribution road. With passive solar design, the orientation requires to be to the south, (though there is some degree of flexibility), with implications for the streetscape.

The fact that current housing development patterns can provide more homes on most sites compared to a more sustainable, passive solar development is a major factor against any form of alternative housing layout. As a result of this problem, sustainable developments may be less profitable because they have a lower density (the primary reasons for high densities are land value and government housing targets (DETR, 2000; Edwards, 2000; DETR, 1996).

Bordass (2000) highlights that one reason why environmental design is not accepted in common building practice is because it is seen as, 'special'. The connotations of a building, or development, being 'special', whatever that may be, results in poor economic value in terms of re-sale value – categorised as a high risk if you need to sell a home.

This research proposes that using a **balanced passive solar design**, within a **sustainable development,** will enable current aesthetic and spatial approaches to housing to take on an enhanced level of environmental acceptability.

The authors suggest that the resolution of the tension between current methods of housing construction and environmental methods, such as passive solar design, lie in the combination of the following;

1. Addressing issues of long-term land value through planning;
2. Improved government driven incentives for passive solar dwellings which take account of the density imperative; and
3. Improved information on the benefit to the purchaser of passive solar homes and the reduction of $CO_2$ emissions.

**Restrictions at the planning stage**

The planning stage is the ideal time to adopt passive solar principles, but there is some key obstacles described by Yannas ([1], 1994) namely; the lack of design information; credibility and applicability; marketability; lack of incentive; costs; and design quality. Local planning officials have little enforceable influence if they want to encourage environmental issues, such as type of insulation or renewable fuel, since they have no way of enforcing the principles of environmental design at such a specific level.

In addition, planning officials have to deal with a number of pressures, of which environmental concerns may be low on the priority list. Aspects of environmental design are often vague during the planning stage, leading to a flaw in the decision making process if professionals are not properly trained in environmental architecture. Bordass (2000) states that it is often difficult for environmental ‘green’ professionals to differentiate between an environmentally friendly dwelling and one, which claims to be. If environmental design professionals find it difficult, how can planning officers be expected to differentiate, without proper training, or an appropriate site assessment tool?

Across the construction industry housing developers plan, design and build on very similar principles, which restricts innovation in housing making alternative principles, such as environmental design, difficult to adopt (Blackler, 2002). Issues such as sustainability, green design and brown-field sites can be, as Cullingworth and Nadin (2002) describe, ‘extraneous’ - meaning they have additional cost risk to the homebuyer. On the other hand these concerns are central to the objectives of the planning office and government (Cullingworth & Nadin, 2002). In short, the principal housing form of densely packed, detached homes built to minimum building regulation standard is the result of economic imperatives coupled to risk aversion.

Currently, the only place where a change can be made to the developer’s planning methods is at the planning consent stage; however the adoption of environmental designs at this stage still relies on government incentives. For an environmental design to be adopted, one incentive that a housing developer may find attractive would be a rapid planning consent. It is hoped that the tool developed will speed up the planning consent for the housing developer, if adopted during the planning stage.

## METHODOLOGY FOR THE DEVELOPMENT OF THE ENVIRONMENTAL SITE ASSESSMENT

The development of the environmental site assessment tool in the research has included four key activities as follows:

- preliminary site investigations
- developing housing databases
- financial considerations
- data representation

**Preliminary site investigations**

The main aim of the research was to create a product termed the 'environmental site assessment tool', for use during the planning of housing developments. Very little definitive information on a site, its buildings, their aesthetic design and their specification will be known at this stage. Therefore, a tool, which assesses a site's potential, needs to work from limited criteria such as simple shapes and building footprints. This research was also aware from an early stage that the potential users would be unable to differentiate between what is, and what is not, an environmental design.

The preliminary research began by analysing variables such as height, footprint, area, topography and density of a sample of local housing sites in Aberdeenshire, chosen from the Aberdeenshire Local Plan. In order to optimise passive solar in the north-east of Scotland, over-shadowing distances needed to be calculated to allow for full year access to the sun, meaning that passive solar site densities are limited according to height of dwellings and solar angle. Comparison between existing and proposed sites against an optimised passive solar alternative was undertaken to analyse if significant differences in densities occur.

**Developing housing databases**

The required data for the environmental site assessment is readily available from most environmental sources, and involves mathematically determining distances and angles to establish, for example, the accurate over-shadowing distance. Research into passive solar design in the 1970's and 80's established much of the parameters surrounding passive solar and this tool has brought together the existing knowledge on the topic. The tool also aims to ensure that this information is brought together in a user-friendly manner for those not familiar with the principles of passive solar design.

The tools main output, it was determined at an early stage, is to compare passive solar alternatives against a standard home – termed the base home. In order to establish design of the base home, a database of the current typologies of the main housing developers in the Northeast was established. This allowed the creation of an average home for the Northeast of Scotland (the base home). As a comparative alternative an optimised passive solar home was derived by investigation of solar case studies at similar latitudes to Britain, as well as a case study situated in Aberdeen.

By using energy calculating software a range of passive solar homes, on a $m^2$ basis, were derived to form an environmental housing database. The database has been integrated into the environmental site assessment so that costs and emissions can be obtained from this passive solar database, without any prior knowledge of how these buildings operate. These buildings can be selected from the database using simple specifications. A similar methodology was used by Turrent (1981) to establish the effects of a range of benefits accrued by using passive solar, and this research uses a similar system, brought up to date to include recent building regulation changes, to establish the same benefits.

In addition to the databases created for standard and passive housing types, databases have been embedded into the assessment procedure so as to select appropriate housing types. These databases are needed to determine elements of simplified housing types, such as storey height and house footprint, in order to establish key passive solar trade-offs between current methods of construction and passive solar.

The environmental site assessment was created using information garnered primarily from BRE sources, and calculates the effect density and site topography has upon a passive solar design. The tool can determine the effect changing the density has upon a passive solar development, and adjusts the costs and emissions accordingly. The aim is to establish the effect of the trade-off that is required for a passive solar development, in comparison to current methods of development, in order to fulfill a sites density target.

**Financial considerations**

The key output from this analysis is the determination of the costs involved. The main costs are the energy costs, and these are arrived at with the use of energy calculating software. The software used to calculate costs can be inaccurate in comparison with historical data from existing buildings, but as a comparative analysis between standard and passive homes it provides decision making statistics.

The costs in the analysis are not only based on the energy elements of each home, but also on the whole life cycle costs. The assessment procedure includes an exemplar life cycle costing element to the analysis. At this stage the life cycle cost component of the tool is restricted. Future evolutions of this assessment procedure will see a more integrated role using whole life costs in determining the monetary costs and benefits of various options.

**Data representation**

The outcome of the product is a graphical model (of emissions against whole life costs), which has been developed to rate a project. The output is scaled between the conventional alternative (the base home in this case) and the optimised passive solar design. The site will be graded according to government objectives, most notably the commitment made by the government to the Kyoto Protocol.

The graphical model can allow the user to visualise the potential benefits of alternative design systems, simply and with maximum user friendliness. The key policy commitments of reducing $CO_2$ emissions by 20%, and reducing domestic energy use by 30% by 2010, all part of the obligation to meet the Kyoto Protocol, are the key targets in the graphical model.

The environmental site assessment is not intended to ‘predict the future’, as it is based on current information and can only make future predictions within approximate ranges. What this site assessment can do is compare conventional designs against various environmental designs, and give the planner of a housing development feedback regarding the potential of any given site.

The model is in the preliminary stages of testing, before undergoing more rigorous testing amongst housing planners who have some expertise of environmental design.

The testing is aimed at establishing the usability of the tool, its potential and the need for further refinements and amendments.

## CONCLUSIONS

Passive solar homes are built to benefit from a free source of energy, and some experience with passive solar design suggests that this can be achieved without significant capital cost increases (Deveci, 2000). The passive solar home, therefore, provides an ideal model for environmental designs and can significantly reduce heating costs and emission. Passive solar homes provide an ideal foundation for a more sustainable environment. In northern climates, however, passive solar densities are restricted by low solar angle in winter. This has been confirmed by investigations of sites in the Northeast of Scotland. The environmental site assessment offers a tool to overcome these problems and to determine the potential savings a passive solar site has over current methods of construction.

The preliminary research discovered that in the north-east of Scotland, because of the low solar angle in winter, an optimised passive solar development, appropriately spaced for all year solar access, had low densities (an average of just under 25 dwellings per hectare on the sites analysed). This highlighted a significant problem as the average dwelling per hectare for the north east of Scotland using current construction techniques was between 35-45dph, some as high as 60dph. There was a significant discrepancy between the two, highlighting the need for a tool to establish what this means in terms of cost and emissions.

The main product of the research has been a tool producing an environmental site assessment, which can determine the potential of a site in a comparative analysis between current methods of development and an optimised passive solar development. At this stage the tool is a prototype and aims to showcase the possibility of what can be achieved and overcome the complex issues which result in the lack of use of environmental, sustainable design. Piloting of the product has highlighted problem areas, which are the subject of current research, but has also highlighted the usefulness of and need for such a product.

The environmental site assessment needs further testing amongst planners and housing developers. The output of a graphical model of emissions against whole life cost will be developed further, and the addition of a more numerical output is to be explored. The indication at this stage is that the research will produce a useful tool for determining the potential of any given site given basic site parameters.

The environmental site assessment has been pilot tested to ascertain if it 'works' but the tool also needs to be tested to ascertain what **value** such a tool, if implemented, has to the planners of housing projects. The next stage of the research will look at this aspect.

## REFERENCES

Balcomb, J. Douglas. (1992). *Passive Solar Buildings.* MIT Press.

Behling, Sophie & Behling, Stefan. (2000). *Solar Power.* Prestel Publishing Ltd

Blackler, Zoë. (2002). TCPA document points finger at bad design. Architects Journal (Internet website), Published 27 September at 11:44. Available from: http://www.ajplus.com, Date visited: 28/09/02 12:27

Bordass, Bill. (2000). Cost and Value: Fact and Fiction. *Building Research and Information* 28 (5/6), pp 338-352

Borer, Pat & Harris, Cindy. (1998). *The Whole House Book.* The Centre for Alternative Technology (CAT).

Building Research Energy Conservation Research Unit (BRECSU) (1997) *Passive Solar House Design - The Farrans.* General Information leaflet 25, Study, Best Practice Programme, Energy Efficiency Office, Department of the Environment.

Building Research Energy Conservation Research Unit (BRECSU) (1995) *Passive Solar House Design: Barrat Study*. General Information leaflet 22, Best Practice Programme, Energy Efficiency Office, Department of the Environment.

Cullingworth, Barry & Nadin, Vincent (2002) *Town and Country Planning in the UK* 13th Edition, Routledge, London.

Department of the Environment, Transport and Regions (DETR) (2000) *Building A Better Quality of Life: A Strategy for more Sustainable Construction*. The Stationary Office Books, London.

Department of the Environment, Transport and Regions (DETR) (1996) *Urbanisation in England*. The Stationary Office Books, London.

Department of Trade and Industry (DTI) (2000), *Passive solar design: new & renewable energy programme,* Department of Trade and Industry (Internet). Available from: http://www.dti.gov.uk/renewable (Date Visited: 19/02/01 16:19)

Department of Trade and Industry (DTI) (1999); *New and Renewable Energy: Prospects for the 21st Century,* Department of Trade and Industry (Internet). Available from: http://www.dti.gov.uk/renew/policy/ (Date visited: 23/10/02, 14:02)

Deveci, Gokay, Scott, Jonathan; Edge, Martin & Martin, Peter (2000) Towards Zero-Heating: Affordable Models for Environmentally Friendly Housing in Scotland. IN: *Laying Siege to Toytown,* RIAS, Conference paper, Dundee.

Edwards, Brian & Pawley, Martin (2000) Sustainability: Today's Agenda for Tomorrow - Part 1. *Architect's Journal*, Vol. 212, no. 1 p41-44.

Edwards, Brian (2000) *Sustainable Housing: Principles and Practice.* E & FN Spon, London, Chapter 1, 'Sustainable Housing: Architecture, Society and Professionalism, pp 12-35.

European Commission (EC) (2000) *Towards a European strategy for the security of energy supply*, Commission of the European Communities, The European Commission, Brussels (Internet). Available from: http://europa.eu.int/comm/dgs/energy_transport/index_en.html (Date Visited:- 21/02/01 11:06)

Jackson, T. (2003) Models of Mammon – a cross disciplinary in pursuit of the 'sustainable consumer'. IN: *Craig, T. ed. Crossing Boundaries - The Value of Interdisciplinary Research: Proceedings of the Third Conference of the EPUK Network*, The Robert Gordon University, Aberdeen.

Kachadorian, James (1997) *The passive solar house: using solar design to heat and cool your home.* Chelsea Green Publishing Company, Canada, 1997

Littlefair, Paul (1991) *Site Layout Planning for Daylight and Sunlight: A Guide to Good Practice.* Building Research Establishment Report, BRE, 1991

Office of the Deputy Prime Minister (ODPM) (1998) Urban Task Force: Prospectus. Office of the Deputy Prime Minister (Internet). Available from: http://www.odpm.gov.uk/stellent/groups/odpm_urbanpolicy/documents/page/odpm_urbpol_608466.hcsp (Date Visited:- 12/08/03 12:38).

Serchuk, Dr Adam (2000) 'The Environmental Imperative for Renewable Energy'. *Solar Today* (Internet) November/December Available from: http://www.solartoday.org (Date Visited: 05/06/01 15:00).

Stevenson & Williams (2000) Sustainable Housing Design Guide. *Research Report, Scottish Homes.*

Turrent, D; Doggett, J & Ferraro, R, (1981) Passive Solar Housing in the UK, *a report for the Energy Technology Research Unit, Energy Conscious Design, Milton Keynes.*

Yannas, Simos [1] (1994) *Solar energy and housing design, Vol 1: principles, objectives, and guidelines.* Architectural Association.

Yannas, Simos [2] (1994) *Solar energy and housing design, Vol 2: examples.* Architectural Association