Robert Samuels 1994

Energy Users, Energy Efficiency and Ecological Sustainability in Housing:

An extract from an Australian Evaluation of Energy Efficient Houses project

ABSTRACT

Sustainability in design implicates a wide range of issues including renewable energy, energy in-use, energy in-materials, and urban design issues. The role of the energy user/consumer is, however, often overlooked, but their attitudes to and knowledge of energy issues and their energy efficient behaviours in their dwellings are vital forms of environmental interaction and responsibility. A recently completed post occupancy evaluation indicates the importance of lifestyle issues in energy consumption; and a possible mismatch between designer/builder expectations and householder thermal comfort experiences. It is suggested that energy efficiency as a goal be clearly linked to its associated role in sustaining environmental quality, and that the thermal comfort and lifestyle-amenity - rather than energy saving - potentials of climate appropriate design be emphasised. It is proposed that solar efficient design is a *potential built-in* to housing, and that associated *life quality potentials* are more likely to be influential in both the adoption of such housing in the marketplace, and in its efficient operation.

INTRODUCTION

The interaction between household users, house design and environmental sustainability is complex. Sustainability in design implicates a wide range of issues including renewable energy, operational energy efficiency (ie energy in-use), the re-useability and solar/renewable retrofitting of buildings, the embodied energy (ie energy in-materials) toxicity and recyclability of materials, energy consumed in construction, maintenance and demolition, biodiversity management (ie protection of plants and animals), and waste minimisation. Urban design issues such as integrated housing and public transportation, mixed zoning (eg. mixed residential and commercial land-uses), solar-access subdivision planning, and the decentralisation of urban facilities to residential areas, similarly, cannot be excluded from a holistic sustainable design scenario ie one which takes account of life-cycle and environmental costs of the built environment (ESD Working Reports, 1991; Samuels, 1994).

Life Cycle Costing includes taking account of the total energy costs of development, from the initial mining of raw materials to their eventual disposal in a landfill, not forgetting the energy consumed to contruct the building and operate and maintain it during its lifetime. Environmental costs to the biosphere, marine life, flora and fauna and human kind need also to be assessed, however difficult the procedure might prove to be, and these costs subtracted from benefits accruing, or GNP calculations. *Real* costs and benefits of developments are thus obtained.

Often overlooked, however, is the role of the user in the energy-environment equation. We may well design and build solar efficient (SED) and ecologically sustainable (ESD) housing, but unless we simultaneously raise both the environmental consciousness and the energy literacy (or knowledge) of the users of these buildings, there is a likelihood that the *SED potentials built-in* to the buildings will not be realised. The majority of ESD systems, fortunately, once built-in, are independent of user interaction, at least until the stage when materials can be recycled, and buildings can be re-used or retrofitted.

The recognition, and implementation, of a *benign design paradigm* is intended to reduce the environmental impact of the built environment on the natural environment; and to sustain the quality of life of the inhabitants of the earth, since their physical health and psychological well-being is also dependant on the quality of the global environment.

The role of users in the benign design paradigm implicates their attitudes and behaviours ie their knowledge, motivations, preferences, satisfactions and actions or activities- in a word, their experiences - within the given context of climatic conditions, and the built-in architectural potentials.

ARCHITECT'S AND USER'S CONCEPTIONS

Architects and users, however, do not perceive and interpret buildings in the same way, given their differing skills, vocabularies and values. It is important for architects to recognise that householders are likely to have different priorities and preferences to them (Groat, 1982; Rapoport, 1982; Purcell & Nasar, 1992); and that householders themselves play a vital role in the energy performance of their houses (Samuels, 1988a, 1988b; Ballinger et al, 1991). Their energy efficient *behaviours* in their dwellings are a form of 'environmental responsibility' ie every kW/hr of electricity consumed results in one kilogram of CO_2 - the major greenhouse gas - being emitted into the atmosphere. The less energy consumed, the less polluting by-products generated.

THE NATIONAL EVALUATION OF ENERGY EFFICIENT HOUSES *POE*

A recently completed Australian post occupancy evaluation - 'A National Evaluation of Energy Efficient Houses' (Ballinger, Samuels et al, 1991) - or NEEHA - assessed 'energy efficient' and 'standard' houses in the Sydney, Adelaide, Melbourne and Perth regions. Building design characteristics were evaluated - in terms of passive solar and energy efficiency potentials (or climatic appropriateness), annual energy consumption figures, and user responses relating to householder expectations, experiences and evaluations. These user appraisals were in terms of both seasonal *thermal comfort* satisfactions and preferences, and (non-thermal) *amenity* or lifestyle quality satisfactions (daylight penetration, indoor/outdoor contact, and spatial and temporal use of the dwelling).

EMPIRICAL ADVANCES IN THERMAL COMFORT EVALUATION

Thermal Comfort has been recognised as a major component of user satisfaction in buildings for several decades, and research on the notion is extensive. There are, however, several shortcomings in the 'classic' approach - the so-called 'thermal comfort equation'. Mention will be made of only some aspects relevant to this statement, and interested readers can refer to the NEEHA report for a more detailed analysis.

The comfort equation consistently *over- or under-estimates* comfort temperatures in the residential context ie householders seem to accept (or even tolerate) thermal conditions that the standardised comfort codes would consider as uncomfortable. For example, in a London sample of 140 households, Baillie et al (1986) reported an average preferred living room temperature during winter of 16.3^{o}C i.e. 6-8 degrees below that which the comfort equation predicts. An example extracted from the NEEHA data seems to indicate a similar pattern. 75% of winter temperatures recorded in the living rooms of the Sydney sample were less than 18^{o}C, yet only 28% of respondents indicated that they would like to feel warmer i.e. were uncomfortable. Thermal balance theory would predict a temperature in the order of 23-25^{o}C (based on an average clothing insulation factor ie a 'clo' level of about 0.5).

The classic thermal comfort equation's "neutral" temperature is defined as "that ambient temperature at which a person *does not know* whether (s)he would prefer a warmer or cooler environment" (Fanger,1977). In contrast, environmental preference as defined in the NEEHA project involves an active and conscious choice; and it is recognised that comfort can be experienced as being 'slightly cool' in warm conditions, for instance - not necessarily neutral at all.

Individual differences within and between households are also known to be a major predictor of comfort expectations and associated energy consumption levels. The classic comfort equation cannot deal with individual idiosyncrasies, and simply assumes that a certain percentage of people will be dissatisfied.

The mismatch between expected (ie theoretical) and empirical (ie determined from observation and/or experiment) comfort levels can have important consequences in the level of energy consumed nationwide.

THE NEEHA T*evaL* TECHNIQUE. A *Thermal Evaluation* or (T*eval*) concept evolved from the use of Environmental Response Loggers in the NEEHA research. These are electronic recording devices that automatically record temperature and humidity and which were modified to allow occupants to record not only their *thermal sensations* but also their *thermal preferences* during various seasons. The logger was installed in the most frequently used livingroom area in each house, for three seasons of the year, and for a month at a time. T*eval* is a measure of the difference between thermal sensation and the thermal evaluation measure indicating a preference to "feel warmer, or cooler, or no different". Where the difference between the sensation vote and the comfort evaluation is zero, the respondent is said to be comfortable or satisfied. Any variation from this equivalence position is considered to be a discomfort (or dissatisfaction) evaluation.

The T*eval* measure is 'phenomenologically valid' in the sense that it taps into everyday and habitual experiences in a person's own home. It is believed that some unusual results unearthed via the use of this technique indicate that such user evaluations have not been afforded their proper place in the theory and practice of design for thermal comfort. This has implications for energy efficiency and environmental sustainability too, because when people are uncomfortable they have a higher likelihood to use energy to attain their comfort expectations. The unusual results are described below (see pie-charts/Fig 1). Suffice it to say here that where households consistently record more *cold discomfort* than warm discomfort, in a country with a climate such as Australia, this should give us serious cause to re-consider whether designers have understood the reality of the situation, as seen from the householder's perspective.

DESIGN FEATURES AND ENERGY CONSUMPTION

The relationships between *design features and energy consumption* in the NEEHA research proved to be extremely complicated, although orientation and insulation did appear to be playing an important role. Floor mass alone seemed to bear no relationship to energy conservation, but there were indications of a positive link between floor mass and thermal comfort during cold periods. Significant correlations are tabled below (seeTable 1).

TABLE 1

STATE	SED Architectural Characteristics & Energy Efficiency
Sydney	Northerly orientation of house
	E-W axis (shallow plan)
	Cavity brick/external walls
	RFL insulation in roof/ceiling
Adelaide	Bulk insulation in roof/ceiling
	Bulk insulation in walls/timber frame
Melbourne	E-W shallow axis
	Cross-draft ventilation
Perth	Slab on the ground
	Bulk insulation/cavity walls

OTHER-THAN ENERGY EFFICIENCY CONSIDERATIONS

The NEEHA findings strongly suggested that *other than energy efficiency* considerations play a significant role in energy usage in the home.

First, motivations for buying a house did <u>not</u> revolve around energy efficiency. Issues such as price, neighbourhood, spatial aspects and size predominated. When looked at as a group, however, the energy-comfort-amenity cluster accounted for 30% of motivations relating to decisions made before purchasing a home.

Second, while households occupying the energy efficient houses in two of the city-regions consumed less than the average energy consumption for the whole sample in those States (as expected), their counterparts in the other two States consumed *more.* Lifestyle factors are suspected to be at the root of this unexpected finding. The energy efficient (or climate appropriate) houses were, however, consistently *experienced as more thermally comfortable and amenable* than the 'standards', in all the States.

The co-incidence of these findings reinforces the notions that both the household and the house are important factors to take into consideration in promoting energy efficiency, and that comfort and amenity (or qualitative) issues might outweigh economy of energy as either a goal to be achieved, or as a determinant in daily behaviour patterns.

Other findings indicated that the experience of *winter discomfort* in livingroom areas was an issue of relevance to respondents nationally, and in all housing types investigated (see Sydney example, Figure 1), as was *discomfort in bedrooms* during winter.

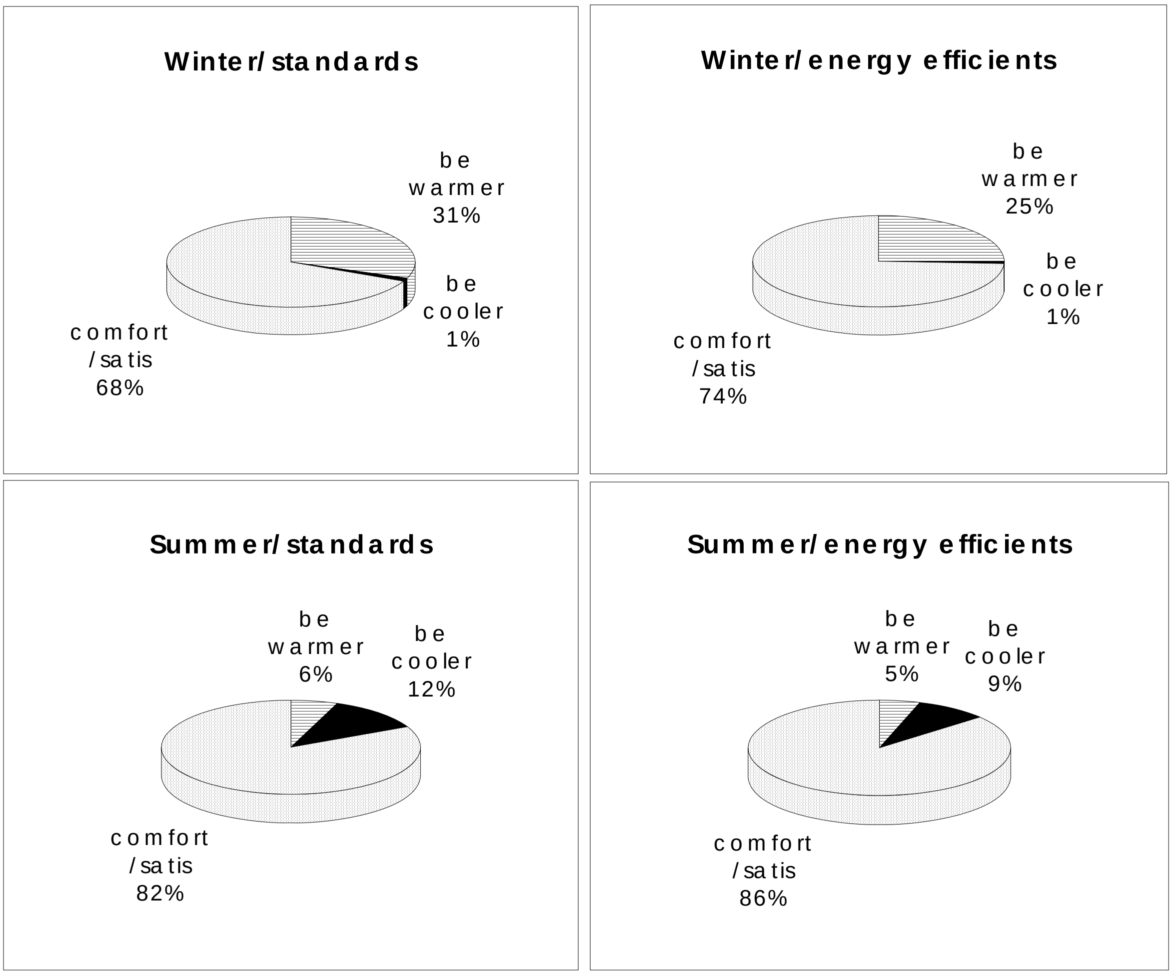
The Sydney winter/summer comfort/discomfort pie-charts (Figure 1, below) indicate that winter dissatisfaction (desire to be warmer) in livingroom areas is much greater than summer dissatisfaction (desire to be cooler) in both the 'standard' and 'energy efficient' houses (and that the 'energy efficient' houses are experienced as relatively more comfortable in both seasons).

It is also interesting to note that some people would have preferred to have been warmer *in summer*, which suggests that prescriptive designs that result in fixed/predetermined shading systems could be failing to meet the expectations of users. A flexible or adjustable shading system, albeit possibly more expensive initially, could overcome this.

These results suggest that energy efficiency design guidelines (in the southern hemisphere), which recommend or even suggest south-facing bedrooms, or extensive shading for north facing living room areas, should be updated with such post-occupancy user evaluations.

It cannot be assumed that design professionals and policy-makers know the preferences, values and experiences of householders.

Figure 1: SYDNEY Comfort/Discomfort Evaluations



CONCLUSION

It would seem to be realistic to recognise that energy efficient or solar efficient design is a *potential built-in* to climate appropriate housing, and that associated *life quality potentials* are more likely to be influential in both the adoption of such housing in the marketplace, and in its efficient operation. It is suggested that energy efficiency as a goal be clearly linked to its associated role in sustaining environmental quality, and that the thermal comfort and lifestyle amenity potentials of climate appropriate design be emphasised.

A multi-dimensional approach, focused on energy, environment, comfort and amenity, rather than on energy efficiency alone, would seem to be the most appropriate strategy for architects to adopt, and economies of energy can be anticipated *as a consequence.*

All things being equal, where users are dissatisfied with thermal comfort conditions they are likely to use energy to achieve their lifestyle expectations.

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