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ENERGY, COMFORT, AMENITY AND SOLAR EFFICIENT DESIGN

ABSTRACT
The National Evaluation of Energy Efficient Houses (or NEEHA) project was carried out in the Adelaide, Sydney and Melbourne regions between 1989 and 1990, and in the Perth region in 1991. The overall aim of the research project was an assessment of the performance of 146 Australian houses (86 of them categorisd as 'energy efficient'), in comparison with control groups of standard houses. Given the complex nature of 'people-place' interrelationships, a multi-methodological approach was adopted. Research techniques employed included interviews of occupants in their houses, seasonal questionnaires, recordings of 'potentially' energy efficient design characteristics of each house, the extraction of annual energy-consumption figures, and the use of 'environmental response loggers' - electronic devices which recorded temperature and humidity conditions, and occupant reactions to these conditions. The major objective was to uncover occupant or user experiences of the houses, in terms of their attitudes and behaviours relating to the **e**nergy used in the running of their houses, their thermal **c**omfort and lifestyle **a**menity (satisfactions regarding natural daylight penetration eg). This interrelationship was termed the '**ECA** cluster' , and represented an assessment of environmental preferences.

1 INTRODUCTION

The rationale for concentrating on the role of the *user*, in the research reported here, is that there is often a tendency for the *occupants* of buildingsto be overlooked as the prowess of renewable technologies multiplies, and the availability of clean energy sources becomes more realistic. We may well design and build solar efficient and ecologically sustainable buildings, but unless both the environmental consciousness and energy literacy of the occupants of these buildings are simultaneously raised there is a high likelihood that the efficiency *potentials* built-in to the buildings will not be realised.

Moreover, architects and building users do not perceive and interpret buildings in the same way, given their differing skills, vocabularies and values. Householders are likely to have different priorities and preferences to architects and developers (Hershberger, 1970; Rapoport, 1982; Purcell & Nasar, 1992), and seem to play a salient role in the energy performance of their houses (Ballinger et al, 1991) over and above the efficiency potentials embedded by a designer in the dwelling.

Their energy efficient *behaviour* in their dwellings, on a day-to-day basis, is also a form of environmental accountability *ie*, on average, the aftermath of every kWh of electricity *consumed* in Australia - generated from standard (± 30% efficient) coal-fired power stations - is one kilogram of CO_2 emitted into the atmosphere, not to mention the sulphur dioxide, and nitrogen oxides.

It cannot be assumed that architects and builders, or solar engineers know people's preferences. Nor can they predict their behaviours. Field studies which evaluate the experiences of users, whatever the building type, is suggested here as a technique that can provide information on such issues. Moreover, this information on attitudes and consumption behaviour is as vital as the development of physical apparati in the ultimate acceptability and adoption of renewable technologies on a wide scale.

2 THE NEEHA THERMAL COMFORT EVALUATION (T*EVAL)*

The NEEHA research evaluated thermal comfort as: a function of cultural expectations and personal habits, of past thermal experiences, of levels of information and of behavioural intentions, of comfort/convenience rather than energy units purchased, of potentials for personal control, of day-to-day behavioural patterns, and of unpredictable attitudinal variables such as ecological ideologies.

Only in such a contextual framework can thermal comfort be a meaningful concept for the consideration of designers of solar efficient housing.

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 comfort can be experienced as being 'slightly cool' in warm conditions, for instance - not necessarily neutral at all.

The NEEHA *Thermal Evaluation or* (T*eval*) concept and data evolved from the use of Environmental Response Loggers, which had been modified to allow occupants to record both their thermal sensations and their related thermal preferences during various seasons. The logger was installed in the most frequently used livingroom area in each house, during three seasons, for a month at a time.

T*eval* is measure of the difference between thermal sensation and a 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

3 FINDINGS

Results were classified into two distinct analytic formats: Thermal Evaluations logger data) - relating to comfort and design; and Environmental Preferences (questionnaire and interview data) - relating to energy and design.

3.1 Comfort and Design

The *Thermal Evaluation* logger findings suggested that the experience of *winter discomfort in livingrooms* was an issue of importance to respondents nationally, and in all housing types investigated. The preference of respondents to also be warmer in spring reinforced this finding.

Further evidence of winter dissatisfaction - *ie* insufficient winter-sun penetration in *bedrooms* - also emerged from the environmental preference analyses, relating to all types of housing investigated.

People also considered the attainment of comfort in livingrooms and bedrooms to be of similar importance.

The co-incidence of these findings suggests that Australian architects and home builders are possibly designing with an under-emphasis on winter bedroom comfort. Furthermore, energy efficiency design guidelines which recommend north-facing livingrooms, with bedrooms relegated to the south-side, or 'suggest' such a design principle, should be updated with post-occupancy user evaluations such as these.

COMFORT/DISCOMFORT RESPONSE: ALL STATES

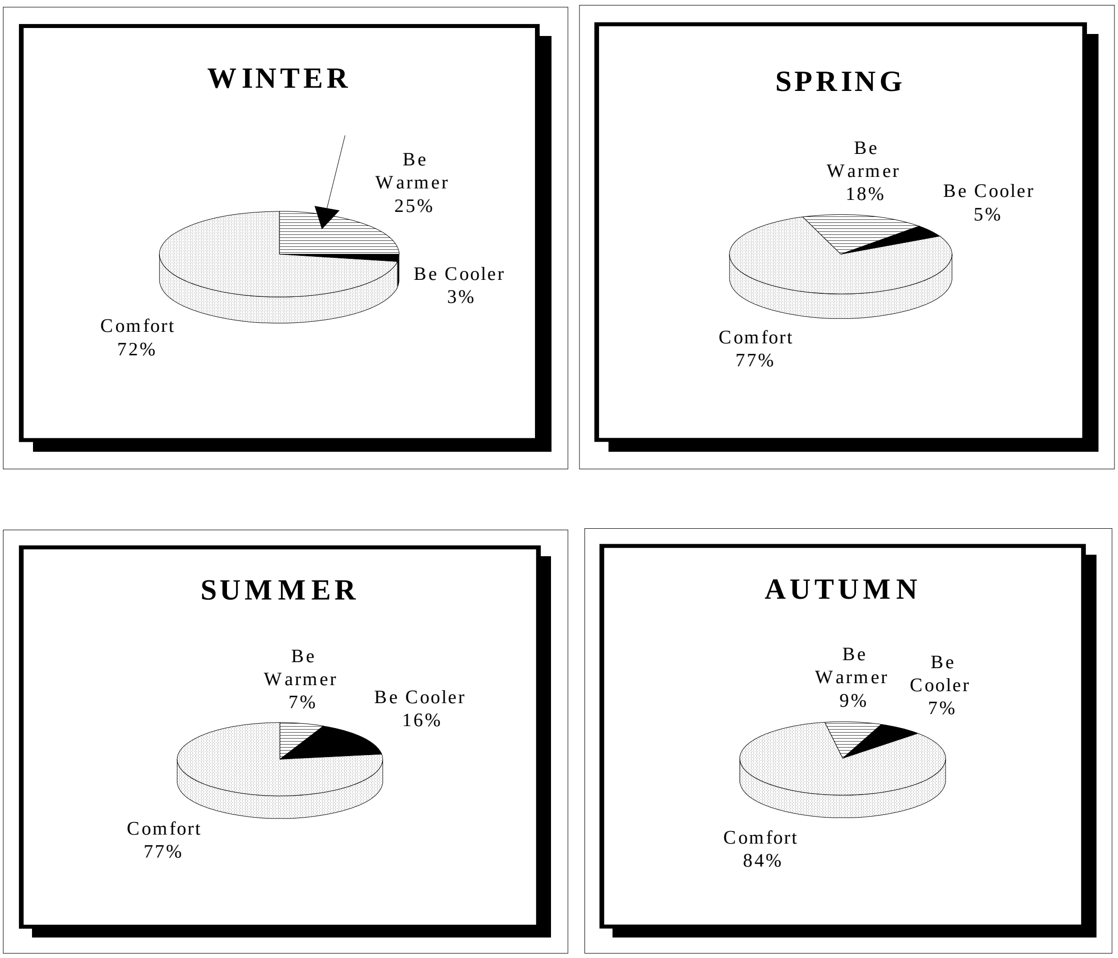

FIGURE 1:

Comfort/Discomfort Response: Livingroom Areas, all States and all House Types

The Comfort/Discomfort charts indicate that the desire to be warmer in livingrooms is the most important discomfort issue in three of the four seasons, and that winter dissatisfaction generally is greater than summer dissatisfaction. Overall, autumn is experienced as the most comfortable period.

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 shading systems could be failing to meet the expectations of users. Where economically feasible, an adjustable shading system could overcome this.

3.2 Energy And Design

Energy figures utilised in the study are a combination of electricity and gas consumption.

The relationships between design features and energy consumption, derived from the *Environmental Preference* analyses, proved to be extremely complicated. A large measure of inconsistency between States was the norm. It is difficult to generate guidelines from these findings, although <u>orientation and insulation</u> seem to play important roles.

Design factors were occasionally found to be interactive, for example: thermal mass in the floor, a shallow E-W axis and a northerly orientation seemed to be positively linked with low energy consumption in Adelaide, while insulation, a square floor plan and a northerly orientation seemed to have a similar effect in Perth - the only common element being the northerly orientation of the livingroom glazing.

Thermal mass in the floor seemed to bear no significant relationship to low energy consumption (other than in Perth).

3.3 ECA and Design

The ECA cluster is a reflection of environmental preferences derived from evaluating Energy, Comfort and Amenity assesments of householders together, rather than considering only comfort, or only energy, as the case may be. The relationship between ECA components and architectural design issues is discussed briefly below.

Findings indicated a positive link between thermal *mass* in the floor and thermal *comfort* during cold periods in three of the States. Households living in houses with timber floors, however, experienced the opposite.

While the households occupying the energy efficient houses in two of the city-regions (Sydney and Adelaide) consumed less than the average energy consumption for the whole sample in those States (as expected), their counterparts in the other two States (Melbourne and Perth) consumed *more* than the average. Lifestyle factors are suspected of being at the root of this unexpected finding.

Nonetheless, the energy efficient (or climate appropriate) houses in the sample were consistently *experienced* as more thermally comfortable and amenable than their standard counterparts, in all four States.

TABLE 1

STATE	ARCHITECTURAL Characteristics & LOW ENERGY USE
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

Table 1 indicates the *solar efficient design* or SED architectural characteristics which correlated significantly with low energy use

4 ENERGY, USERS AND DESIGN

In general, the NEEHA findings strongly suggested that issues *other-than* energy-efficient design play a significant role in energy usage patterns in the home.

Lifestyle (expectations, disposable income, household behaviour patterns - heating patterns, especially), Lifecycle (family size, and type) and Lifeworld (attitudes and values, sense of environmental responsibility) appear to be as important as physical design and regional climatic influences in determining energy use.

Moreover, *motivations* for buying a house were not found to revolve around energy efficiency or saving energy as a resource, but, rather, were directed towards issues such as neighbourhood amenity and spatial aspects. However, when looked at as a group, the 'ECA' cluster accounted for 30% of the motivations of the householders who built their homes *ie* made design and comfort decisions themselves. This finding has relevance in so far as it describes the complex interactional motivations of home owners; and because it begins to suggest a more subtle approach or strategy for promoting energy efficiency.

5 SUMMARY OF MAJOR THEMES AND FINDINGS

* A variety of interacting factors influence residential energy consumption

* Energy efficient design is a vital strategy in reducing overall energy consumption, but occupant lifestyle issues are equally important in achieving these design objectives

* Design factors are sometimes interactive *ie* a combination of solar efficient design elements being more successful than one or other element in isolation

* Orientation and Insulation seem to play important roles in energy consumption

* Prescriptive/fixed shading design does not allow user intervention as climatic/seasonal conditions vary, leading to discomfort and increasing the likelihood that energy will be consumed to restore comfortable conditions

* With regard to temperature conditions *in livingrooms during winter*, a preference to be warmer was the thermal *dis*comfort issue most frequently experienced by householders, in all house types, and all States

* Inadequate levels of *sunlight penetration in bedrooms during winter* was also an important *dis*satisfaction issue mentioned by residents in all types of housing and in all States

* Houses designed to be solar efficient were found to be experienced as significantly more thermally comfortable and amenable (providing for a more pleasant lifestyle) than the standard houses.

General recommendations deriving from the NEEHA research suggest that:

* Information transfer to, and education of, households is necessary to ensure that potentially energy efficient houses are operated efficiently

* It is important for design and building practitioners and renewable energy engineers to appreciate the importance of user preferences, satisfactions, thermal comfort and lifestyle expectations - in order to design/build houses that are user-appropriate as well as climate-appropriate, and hence enhance their adoption in the market.

In essence, these findings suggest that energy-conscious and energy-literate *households* inhabiting potentially energy efficient *houses* are the two key variables which, interacting together, can result in an energy efficient housing sector.

6 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.

Energy conservation is less likely to be a goal actively pursued in its own right, and should be clearly linked to its associated role in sustaining environmental quality.

Simultaneously, the thermal comfort and lifestyle amenity potentials embodied or inherent in climate appropriate design should be emphasised.

Such an approach is deemed more likely to influence consumer housing choices, and economies of energy can be anticipated as a consequence.

The relevance of householder expectations, experiences and evaluations should be appreciated in any policy or program aimed at increasing the rate of adoption of climate-appropriate housing, and/or at increasing the rate of adaptation of existing homes via solar energy (passive solar) and renewable energy (active solar) retrofits/renovations.

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

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