From: Aynsley [mailto:buildingenergetics@gmail.com]
Sent: Friday, 16 April 2010 3:40 PM
To: Dawson, Geoffrey (SEN)
Subject: claimed inadequacy of BCA on condensation in hot climates issues

Geoff

An additional statement is provided to incorporate into the original statement. It contains statements re condensation and the regulation impact statement for the current BCA.

NOTE: The authors of the 8-page paper attached were members of the team at The University of New South Wales that developed the initial HERS software model for air conditioned houses. Deo Prasad is currently chairperson of the Standards Australia EN-003 committee on Energy Efficiency and Thermal Performance of Buildings.

Regards

Dick Aynsley

Geoff Dawson,
Principal Research Officer
Senate Environment, Communications and the Arts Committee

16 April 2010

ADDITIONAL COMMENTS FROM DR. RICHARD AYNSLEY TO ATTACH TO ORIGINAL SUBMISSION

Dear Mr Dawson,

Condensation and Insulation

I am unaware of any formal public submissions to the Senate enquiry regarding an important issue regarding condensation with respect to building insulation. This issue has the potential to be even more problematic than the current insulation concerns. It will also be a difficult problem for the BCA to address. The ABCB is aware of the types of potential problems as I have information the ABCB is about to release a BRANZ report on such problems in New Zealand some years ago.

Basically, in order to prevent severe indoor mold problems and damage to timber construction from wood rot, it is essential to have the appropriate type of vapour barriers installed in the appropriate position in roof wall and floor construction and adequate air flow though cavities in building construction to prevent condensation occurring within building insulation.

The nub of the problem is that there vapour barrier materials such as building paper, plastic sheeting and aluminium foil are available in a range of permeability. The current widespread use of "building paper wrap" over timber frames (advocated in the BCA) can lead to severe degradation of timber by wood rot in some Australian climates. To further complicate the matter the location of such barriers need to be located on the warmer side of insulation where the temperature does not fall below the dewpoint of the air. Given the significant seasonal and diurnal variations in temperature and humidity the "warmer side"can be on both sides of insulation.

A further complication is determining the critical source of water vapour in a building. Frequently people assume that the most critical source will be from outdoor weather conditions, although it could equally be from indoor human activity such as cooking and bathing.

Recent increases in the amount of insulation installed in buildings has increased the risk of condensation. More insulation in a roof means that there will be a greater temperature difference across the insulation. This can increase the possibility of the dewpoint temperature occurring within the insulation leading to interstitial condensation within the insulation. This degrades the R-value of the insulation and promotes mold growth and wood rot.

In severe cases condensation occurring within building construction can lead to structural damage or the building being condemned on health grounds due to mold growth.

The BCA Regulation Impact Statement on Building Energy Efficiency Provisions
"Studies carried out show a benefit in more insulation in all locations" is based on computer modeling using the discredited Accurate energy rating software. This software does not adequately model latent heat exchanges, or energy exchanges and thermal comfort in naturally ventilated or evaporatively cooled building or the cooling effects of elevated air speeds (see Kordjamshidi et al). It should be noted that some of the authors of the Kordjamshidt paper are from SOLARCH at the University of New South Wales and were contributors to the HERS software adopted for the BCA and fully aware of its limitations.

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Modeling Efficient Building Design: A Comparison of Conditioned and Free-Running House Rating Approaches

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Abstract: There has long been a concern that rating building thermal performance based on predicted space loads in conditioned mode is inappropriate to achieve overall energy efficiency of houses in temperate climates. Buildings designed to be free running may achieve better results using a more appropriate rating system. This study, using simulation, predicts the thermal performance of houses in two different operation modes: conditioned and free running. The thermal performance of houses in the conditioned mode is indicated by predicted annual energy requirements (MJ/m^2). Thermal performance in the free-running mode is indicated by annual degree discomfort hours (DDH). The paper investigates the correlation between the indicator of thermal performance of simulated houses in a conditioned operation mode and the indicator of thermal performance of those houses in a free-running operation mode. Despite a strong relationship between these two indicators, some significant differences become clear leading to a discussion of the persistent technical problems and issues that are encountered when attempting to optimize energy efficient architectural designs. The results of this study confirm the necessity of a new House Rating Scheme (HRS) incorporating an appropriate indicator for free-running buildings.

Keywords: Energy efficiency design, Thermal comfort, Housing, House Rating Scheme

Introduction

Evaluation of building thermal performance at the design stage aims to improve design quality. Design quality here is taken as the provision of pleasant indoor conditions for building occupants. This can be obtained in any architectural design by consuming more energy. However, in the interest of sustainable development, efforts are needed to minimize energy consumption, and in response, House Energy Rating Schemes (HERS) have been developed.

HERS are systems to evaluate the performance of dwellings. The objective of any HERS is generally to promote energy efficient design to reduce energy requirements and Greenhouse Gas Generation (GHG). The majority of developed rating systems use simulation to assess building performance in terms of predicted relative annual energy requirements. Some, such as the FirstRate tool in use in the state of Victoria, Australia, are based on a regression model, rather than hourly simulations. Regardless of the method applied for building performance assessment, the indicator to assess efficient design of a building has generally been energy use.

The chosen indicator plays an important role in the reliability of any building performance assessment system. Although energy minimization is promoted as an energy efficient housing strategy (Boland, Kravchuk, Saman & Kilsby, 2003), low energy use does not necessarily support energy efficiency (Olofsson, Meier & Lamberts, 2004). Energy minimization is related to the efficiency of appliances as much as it is to the fabric of the building. As well, it has been argued that a simple normalized energy based rating is not sufficient to convey the credibility of an energy efficient design (Kordjamshidi, King & Prasad, 2005a, 2005b; Soebarto, 2000; Thomas & Thomas, 2000; Williamson, 2000).

Other studies have proposed multi-criteria assessment of building performance for energy efficiency assessment (Soebarto & Williamson, 2001; Roulet *et al.*, 2002; Chen *et al.*, 2006), and that appropriate indicators should be developed to determine the efficiency of a building independent of its appliances. Patterson (1996) and Haas (1997) have discussed the concepts underlying the definition of energy efficiency indicators for policy purposes.

These studies demonstrated critical methodological problems in defining those indicators.

An appropriate rating system should evaluate the actual performance of a building, including investigating its free-running performance. In developing a free-running rating framework, the question of correlation between the performance of buildings in their free-running and conditioned modes arises. It was assumed that any specific measures to enhance the thermal behavior of a free-running building would also improve its behavior in conditioned mode. However, the preliminary comparative analysis in this study demonstrated contradictory results.

This paper uses regression analysis to point out some relevant differences between design for a conditioned house and design for a free-running house.

Definitions

Conditioned building: A building that is provided with an energy supply applied to heat/cool air or surfaces to maintain its indoor conditions within a defined comfort zone.

Free running: The state of a building that is naturally ventilated and does not use any mechanical equipment to maintain or improve its indoor thermal condition.

Building mode: The state of a building in terms of being free-running or conditioned mode of energy operation.

House type: House type in this study refers to being single-storey or double-storey design.

House construction: Refers to the predominant heavyweight or lightweight materials of walls and floors.

Building Performance Assessment

Building performance assessment is an approach to the design and construction of a building (Preiser, 2005; Preiser & Vischer, 2005). It deals with post-occupancy performance evaluation for further building construction or renovation (Bordass & Leaman, 2005; Preiser, 2005) often by using simulation programs. It is a key strategy to reduce the environmental impact of buildings and is used to ensure the quality of a building during the process of design.

Building performance is assessed by a numerical measure of an indicator. The indicator should be a value derived from a parameter that describes the state of a building. Thus, for example, for thermal performance, two different indicators would be defined to evaluate the building performance dependent on its state (conditioned or free running). The thermal quality of a building can be evaluated in terms of annual energy requirements in its conditioned mode, or an aggregated annual thermal comfort condition in its free-running mode. The latter demonstrates the actual performance of the building, and addresses multiple aspects of efficiency in a particular architectural design (Kordjamshidi *et al.*, 2005a).

An important parameter in evaluating the thermal performance of a house should be its occupancy scenario. The authors have previously suggested that multiple occupancy scenarios are likely to help refine a practical rating scheme. The preliminary study (Kordjamshidi *et al.*, 2005b) was conducted using an earlier version of the AccuRate software, known as NatHERS, the mandated simulations rating tool in Australian jurisdictions. That study considered six different occupancy scenarios, which were determined in respect to the period of time when a particular room of a house might be occupied. It demonstrated the significant impact of occupancy scenarios on ranking houses in terms of efficiency, particularly where the houses are operated in the free-running mode. This study considers only one of those occupancy scenarios for simulations, in which houses are assumed to be occupied for 18 hours between (0600-2400) in their living zones and 6 hours (0000-0600) in their bedroom zones.

Methods to Assess the Thermal Performance of Houses in Free-Running Mode

A free-running building can be evaluated based on achieved thermal comfort. Fanger's comfort theory (Fanger, 1982) is applied in some standards (eg, ISSO. 1990; and ISO 7730 as cited in Olesen & Parsons (2002)) and in many empirical studies as a basis for aggregating temperature exceedence hours. However, the inapplicability of this model for free-running buildings has been well documented (Bouden & Ghrab. 2005; Davis Energy Group, 2004; de Dear, 2004; de Dear & Brager, 2001, 2002; de Dear, Brager & Cooper, 1997; Forwood, 1995; Kumar & Mahdavi, 1999). A similar method, in which environmental and personal variables are included, needs to be developed for free-running building assessment.

Degree Discomfort Hours (DDH) is a unit for measuring the extent to which the indoor temperature of a free-running space falls outside comfort boundaries. Many studies, conforming to the ASHRAE (2004) standard consider 80% occupants' acceptability to determine the boundaries of comfort conditions. In this study, the bounds of comfort temperatures for free-running buildings were determined based on an adaptive thermal comfort model (ASHRAE, 2004: de Dear & Brager, 2002), but for a more conservative 90% occupant acceptability.

$$T(N)= 0.31\ T + 17.8 \qquad (1)$$

where T= average monthly temperature (de Dear & Brager, 2002)

The boundaries of the comfort zone corresponding with 90% and 80% thermal acceptability in free-running houses are shown in Figure 1 for the Sydney, Australia climate. The temperature bounds for 90% acceptability were applied for the living zone. The lower temperature bound of the 90% acceptability band was pulled down for the bed zone during the sleeping period (0 – 6 a.m.) because it is assumed that occupants will use a blanket if they feel cold.

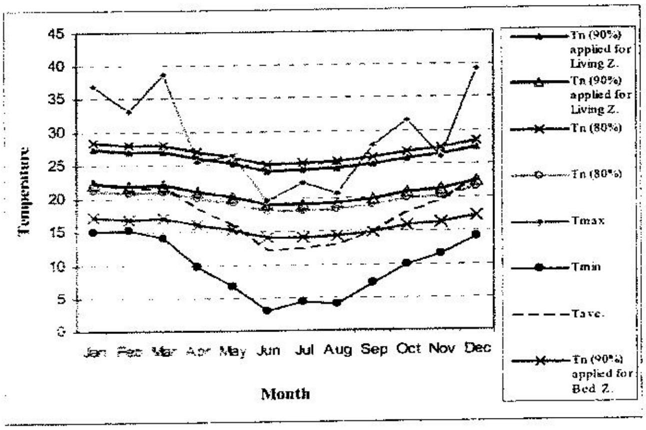

***Figure 1:** Maximum and minimum temperature and thermal neutrality comfort bands for the Sydney climate*

Although the adaptive comfort model does not require humidity or air speed (ASHRAE, 2004) one cannot ignore the effect of humidity in the sensation of temperature, particularly in a warm humid climate. The effect of humidity on Environmental Temperature was accounted for by employing a simplified equation proposed by Szokolay (1991).

Air movement through a house is a complex function of internal space arrangement and operable doors and windows. There is no suitable simplified tool available to investigate cross ventilation for free-running buildings accurately. However, in computing a building's annual energy requirement, the potential beneficial use of natural ventilation is accounted for in the AccuRate software by a factor related to the potential for physiological cooling. This will be described in further detail in the following section.

In the Degree Discomfort Hour concept, each discomfort hour has the effect being weighted by a factor equal to its 'distance' in degrees from the comfort range. It means the value of an hour 2°K above or below the comfort range is equal to the value of two hours with 1°K out of comfort range. For more accuracy in the computation of the indoor comfort condition, 'cooling degree hours' in winter and 'heating degree hours' in summer were removed from the aggregated annual degree discomfort hours (Kordjamshidi *et al.*, 2005b). Other weighting regimes have been used and described by some authors (Breesch & Janssens, 2004; Olesen, 2004; Olesen, Seppanen & Boerstra, 2006).

Methods to Assess the Thermal Performance of Houses in Conditioned Mode

The performance of conditioned houses was indicated by area normalized annual energy requirements (MJ/m²). To predict annual energy requirements of houses in the conditioned operation mode, the notion of thermal comfort is implied in the thermostat settings. These thermostat settings indicate when heating and cooling is turned on in the computer simulations. Different thermostat strategies for discretionary heating and cooling of houses in temperate climate results in different prediction of energy requirements (Williamson & Riordan, 1997). This study relies on the method applied in the AccuRate software, approved for use by the Building Code of Australia. Table 1 gives the AccuRate software thermostat settings for the Sydney climate in this study.

The software application used for the simulations is AccuRate from the Australian CSIRO national research organization. This software is adapted for Australian climates and has the capability for analysing energy consumption, and hourly temperatures of a free-running building (Isaacs, 2005). It has been validated using BESTTEST (Delsante, 2004). One of the main features of the software is its capability to consider the beneficial use of natural ventilation in computing cooling energy requirements. The benefit of suitable natural ventilation is a combination of mass transport cooling by volumetric air exchange when appropriate, and physiological cooling depending on a simplified model of internal air velocity related to regional wind speed and direction. Thus its output results for conditioned houses in terms of annual energy requirement are thought to be more reliable compared to results from other software, which ignores the impact of natural ventilation in air-conditioned buildings.

Heating and cooling are invoked in AccuRate, when they are required. Heating is applied for a conditioned zone if its environmental temperature at the end of the hour without heating is below the heating thermostat setting. Cooling is applied if the zone at the end of the hour without cooling or ventilation is outside the bound of thermal comfort. The boundaries of comfort region, in the psychometric chart is determined between 12g/kg absolute humidity (AH) at the top, 0g/kg AH at the bottom and ET* line based on (cooling thermostat +2.5) degrees at the right. If the zone temperature is above the outdoor temperature, ventilation is turned on, then new temperature and air speed is calculated. If the

Table 1: Thermostat settings in conditioned houses for the Sydney, Australia climate.

Zones	Heating temperature (°C)	Cooling temperature (°C)
Living	20	24.5
Bedroom	18	24.5

Table 2: General measurement of six typical houses.

House	Number of floors	Floor area (m²)	External wall (m²)	Window area (m²)	Ceiling area (m²)	Internal wall (m²)
1A	1	138.2	137	32.4	138.2	96.6
1C	1	155.4	150	24.8	155.4	88.1
1D	1	244.9	196.5	45.9	244.9	160.4
2A	2	292.8	256.7	50	166	156.1
2C	2	315.7	260	56.5	136.3	182.3
2D	2	229	234	40	144.4	174.4

air speed is above 0.2m/s, the described comfort region is extended in two ways: the 90% relative humidity (RH) line is considered for the top boundary and the right boundary is an ET* where:

$T = 6(V-0.2) - 1.6 (V-0.2)2$ and (2)

V is estimated indoor speed (m/s)

If the conditioned zone is still outside the comfort bounds, the zone openings are closed and cooling is invoked, therefore the zone temperature at the end of the hour is the same as cooling thermostat setting.

The Research Study Sample

It is impractical to take into account all different house typologies. After an initial investigation attention was focused on six 'typical' detached houses, single storey and double storey, designed for New South Wales, Australia (SOLARCH, 2000) with the following characteristics as shown in Table 2.

Simulations

A total of 582 houses were simulated for analysis. The models were generated from the six typical houses and were different from each other in terms of 17 design variables (Table 3). Each model (house) was simulated for two different operation modes, free-running and conditioned mode. Thus the total number of simulation used in this study is 1164 simulations, which were subject to a regression analysis.

Correlation and Regression: Results and Discussion

Multiple regression analyses are typically used to identify those variables, among a series of predictors, that best predict the variation in a dependent variable, and to provide an estimate of how much variation in the dependent variable can be explained by variation in those predictor variables. In this paper we have first used simple correlation to estimate the strength of the relationship between thermal performance of simulated houses in the free-running mode and the performance of those same houses in the conditioned mode. As mentioned above, in our data set of simulations the thermal performance of houses in free-running mode is indicated by Degree Discomfort Hours (DDH) (predictor) and the thermal performance in the conditioned mode is indicated by Predicted Annual Energy Requirement (PAER) in MJ/m^2 (dependent).

A question arises as to whether the data are suitable for the type of statistical analysis applied. Previous building studies employing simulations and correlation and/ or regression analyses include Ben-Nakhi and Mahmoud (2004), Krichkanok (1997) and Thornton, Nair and Mistry (1997). Also of interest is that regression analysis applied exclusively to simulated data underpins the development of some current rating tools (for example FirstRate, the mandated house energy rating tool in the state of Victoria, Australia), and the regulatory impact studies that support them (Energy Efficient Strategies, 2002)). In the case of the analyses reported in this paper, it is worth noting that the simulation outcomes used for the regression analysis are continuous values rather than grouped data. Some input variables are dichotomous (as in single storey/ double storey type), but combine with building configuration parameters to yield ratio data as inputs to the simulations (such as wall are, floor area, etc.; see Fahrmeir & Tutz (1991) for a review of the typical sources of data frequently collected in grouped and ungrouped form).

The data used for regression analysis was generated from typical types of building and location. Other locations and different types of housing such as town house and apartment may yield different

Table 3: House parameters for simulations

Code	Parameter descriptions	Variation of parameter
X1	Wall colour	Light, medium and dark color (solar absorbance)
X2	Wall insulation	R = 0, 1, 1.5, 2, 3 (m^2 K/W)
X3	Ceiling insulation	R = 0, 1, 2, 3, 4 (m^2 K/W)
X4	Floor insulation	R = 0, 1, 1.5, 2 (m^2 K/W)
X5	Roof colour	Light, medium and dark color (solar absorbance)
X6	Orientation	0, 45, 90, 135, 180, 225, 270, 315 degrees
X7	Glazing type	Single glazing: reflective, tone and clear Double glazing: clear and tone
X8	Window covering	Open weave, closed weave, heavy drape and heavy drape + pelmet
X9	Internal wall construction	Plasterboard, concrete block, brick plasterboard and cavity brick
X10	Percentage of open able window	25%, 50% and 75%
X11	Window eave width	0, 450, 600, 1000 mm
X12	Infiltration	0, 1, 2, 5 (air change / hour)
X13	Percentage of window to wall ratio (north and south sides)	0, 15%, 25%
X14	Percentage of window to wall ratio (east and west sides)	0, 15%, 25%
X15	House type	Single storey and double storey
X16	Typical house	6 architectural house design
X17	House construction	Heavyweight and lightweight

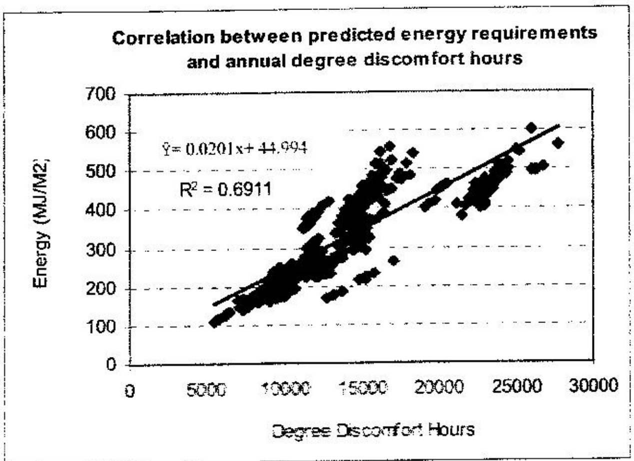

Figure 2: Correlation between thermal performances of simulated houses in different operation modes

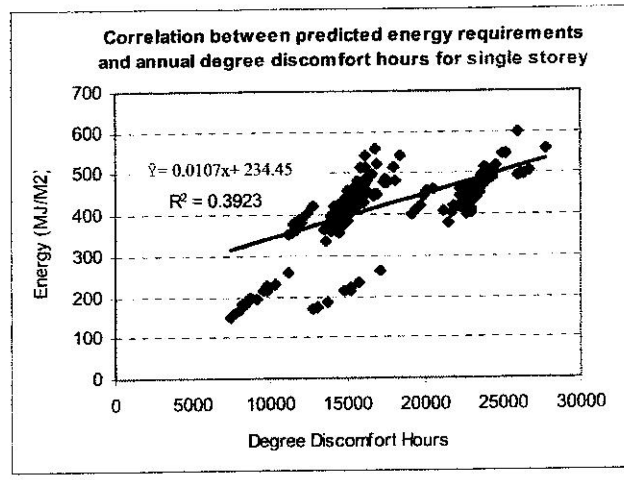

Figure 4: Correlation between indicators of thermal performance of simulated single storey houses in different operation modes

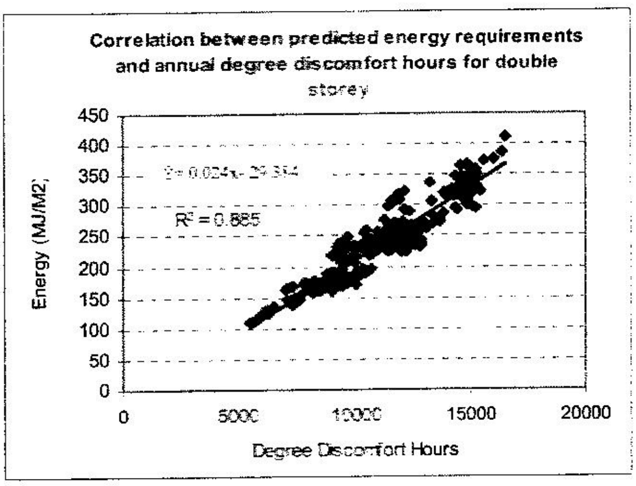

Figure 3: Correlation between indicators of thermal performance simulated double storey houses in different operation modes

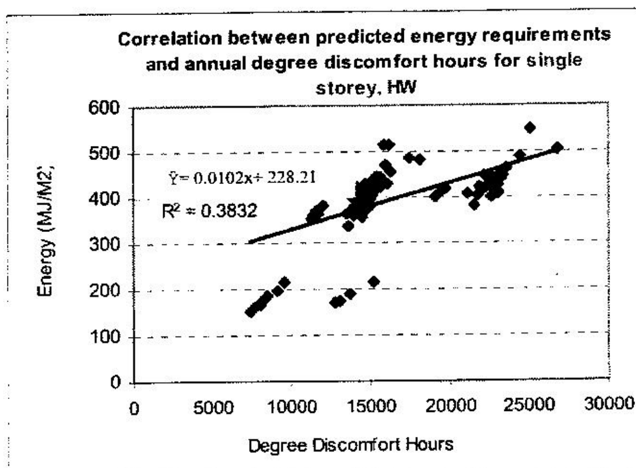

Figure 5: Correlation between indicators of thermal performance of single storey houses with heavy weight construction

regression coefficients. Even if the result cannot be generalized for all building types and climates, the general trend observed in this study demonstrates a significant point that should be considered in an efficient architectural design, particularly in any regulatory framework for a house rating scheme.

Figure 2 shows that the correlation between the two indicators is, as we would expect, positive and significant r = 0.83 (R^2 = 0.69). On a bivariate basis, that suggests that 69% of the variation in predicted energy (MJ/m²) can be explained statistically by its relation to DDH. The scatter diagram in Figure 2 demonstrates the strength of that relationship. Nevertheless, close observation of the points in Figure 2 also suggests that there appear to be at least two or more separate linear clusters of points. This observation led in the study first to separate the models in two groups: single storey (SS) and double storey (DS).

To clarify further the relationships in Figure 2, parallel correlation analyses were then conducted for double-storey (Figure 3) and single-storey (Figure 4) buildings. The data points in Figure 3 (the double-storey cases), describe a much clearer linear relationship between the variables, with r = 0.94 (R^2 = 0.88). The results in Figure 4 (for the single-storey cases) are equally clear, but there is more than one linear cluster of data points. Given the evident spread between those clusters, it is not surprising that for the Single Storey cases as a whole the correlation, though still strong, is now r = 0.63 (R^2 = 0.39).

The strong correlation in double-storey houses refers to the architectural design of these houses. The annual thermal performance of a house strongly depends on the thermal performance of its living zone, because this zone is occupied ¾ time. By generally disposing the bed zone above the living zone in the DS houses, the external surface area of the living zone in these house types was less than that in single storey houses. Therefore the free-running performance of a single storey house is more affected by outdoor climate than that of a double storey house. The difference between free-running and conditioned performance of a single storey house is more than that of a double storey house.

This observation points to a key difference between the characteristic thermal performance of two storey and single storey houses, and reflects immediately on the likely reliability of any system, which assesses those house types together under a single rating framework.

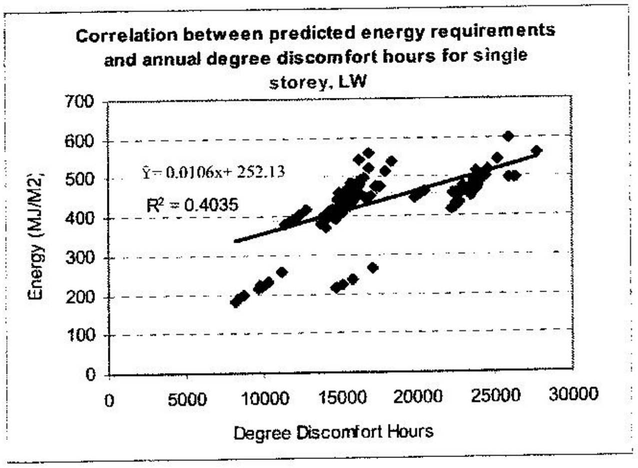

***Figure 6:** Correlation between indicators of thermal performance of single storey houses with light weight construction*

One of the key variables in the simulation data set is whether dwelling construction is light weight (LW) or heavy weight (HW). Figures 5 and 6 focus on the single-storey cases and describe the impact of the LW versus HW variable on the relationship indicated in the previous scatter plot (in Figure 4). As it happens, the introduction of the LW/HW variable did nothing to clarify the meaning of the two clusters of linear points that appeared in Figure 4. Analyses to understand better the pattern of points in Figure 4 are ongoing and will be reported in a subsequent paper.

These observations suggest that the effects of the building envelope on the quality of thermal performance of a building depend on its operation mode. Regression analysis of house performances demonstrated that technical strategies to improve thermal performance of a conditioned house do not necessarily improve its thermal performance in free-running mode.

Table 3 listed the 17 variables (parameters) which are amenable to appropriate variation by the simulation software, and are considered likely to have significant impacts on predicted annual energy requirements (MJ/m²). Multivariate regression analysis was used to estimate how important these 17 variables are in two contexts: predicting energy (MJ/m²) for conditioned houses, and predicting DDH for free-running houses.

We refer first to the impact of those variables in predicting the performance of houses in conditioned mode. It was demonstrated that the 17 variables (parameters) do very well in explaining any variation in energy, the dependent variable, with $R^2 = 0.840$. In contrast, these predictors explain only 54% ($R^2 = 0.537$) of the variation in DDH for free-running houses. In other words, nearly half the variation in DDH for free-running houses is not explained by those same 17 variables. To a significant degree, the amount of unexplained variance for free-running houses is among the more important findings of our analyses, and is clearly a starting point for further research.

Table 4: Ranking of house parameters due to their relative importance on the houses' thermal performance

Conditioned Mode (MJ/M²)				Free-Running Mode (DDH)			
Rank	**Building parameters**	**Beta**	**Sig.**	**Rank**	**Building parameters**	**Beta**	**Sig.**
1	X15	-0.749	p< 0.001	1	X15	-0.6	p< 0.001
2	X3	-0.364	p< 0.001	2	X3	-0.266	p< 0.001
3	X17	0.274	p< 0.001	3	X17	0.242	p< 0.001
4	X12	0.095	p< 0.001	4	X12	0.084	p< 0.01
5	X5	0.09	p< 0.001	5	X4	0.067	p< 0.05
6	X2	-0.084	p< 0.001	6	X6	0.059	0.062
7	X16	-0.059	p< 0.01	7	X9	-0.049	0.088
8	X6	0.05	p< 0.01	8	X7	-0.045	0.138
9	X1	0.035	p< 0.05	9	X11	0.041	0.173
10	X9	-0.026	0.132	10	X16	-0.038	0.204
11	X14	0.02	0.262	11	X5	0.027	0.354
12	X13	0.019	0.282	12	X2	-0.023	0.450
13	X10	-0.015	0.407	13	X8	-0.021	0.482
14	X8	-0.013	0.452	14	X14	0.014	0.629
15	X4	0.013	0.469	15	X13	0.011	0.721
16	X11	-0.011	0.524	16	X1	0.01	0.745
17	X7	-0.005	0.802	17	X10	-0.003	0.924

We turn now to Table 4. For both the parallel analyses of conditioned mode and the free-running mode, the most important predictors, in order, were House Type (X15), Ceiling Insulation (X3), House Construction (X17) and Infiltration (X12). Beyond that point both the sequence and the statistical significance of the variables (according to their beta coefficients) vary considerably. For example, Roof Colour (X5) and Wall Insulation (X2) are clearly significant in the conditioned mode analysis, but are well down the list (and far from statistically significant) in the free-running analysis. We note that this should not be taken to mean that Roof Colour and Wall Insulation are irrelevant for free-running houses, only that the multivariate analyses have shown other factors to be more important.

With respect to Table 4, it can be seen that the variable 'house type' (X16), which reflects different architectural design and house size among typical houses, is not a strong parameter in predicting annual performance of a house as a function of energy (MJ/m²), or

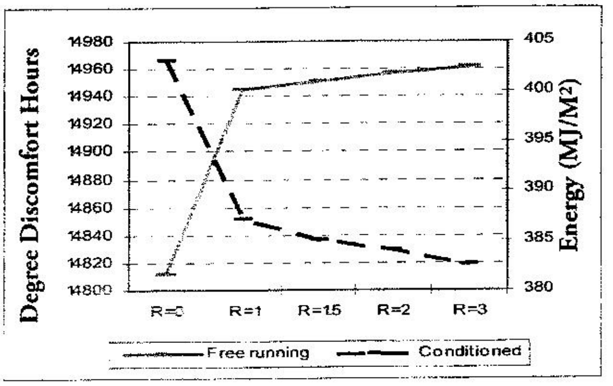

Figure 7: The effect of increasing wall insulation resistance in improving the annual performance of typical house (D1) as a function of PAER and DDH

thermal comfort (DDH). However, its contribution in predicting (MJ/m^2) is more than that for DDH. This is to be expected, in as much as discomfort is itself independent of weighting by the effect of the size of the occupied space. In contrast, house size can not be ignored in predicting energy requirements. The reason why (X16) is not in priority in ranking the 17 variables for conditioned house performance is that for the energy based rating, total predicted energy requirement is normalized against house area. Arguably, this is an inherent unreliability of the normalized indicator as a basis for energy efficiency evaluation in an 'energy base' rating system, an issue more extensively discussed in Thomas (2000).

These observations have the clear implication that it cannot be assumed that a design for good predicted building performance in conditioned mode achieves good thermal performance in its free-running mode. A design for conditioned building is reasonably related to the building envelope characteristics and fabric of the building. Ultimately it relates to those attributes that protect or isolate the building interior from the environmental loads, to maintain indoor thermal comfort conditions with minimum energy consumption to overcome those loads. The determinants of free-running performance are more complex, as has long been implied by the alternative terminology 'climate responsive'.

The evidence of this argument is seen in the effect of some of the parameters. One example is the effect of wall insulation on the annual thermal performance of single storey houses (Figure 7). The simulated annual performance of a typical house model (D1) in conditioned mode achieved a 5% improvement in response to the addition of R3 wall insulation. However the same change degraded its annual free-running performance.

Conclusions

It seems self-evident that an energy rating should aim to be a reliable technique to assess energy efficient architecture design. This study supports commonly held views that there is a need to develop a house rating scheme for free-running buildings. Since in a moderate climate the criteria for enhancing the thermal behavior of free-running buildings can be shown to differ from those for buildings operated in a conditioned mode, the former cannot be evaluated in an energy rating model.

While promotion of naturally ventilated buildings would seem to be the best response to sustainability and reduced energy consumption in moderate climates, they have been missed in the rating systems. The issue appears even more important, when one considers the impact on the broader objectives of sustainable development in the building sector, of a perceived continuing inability to support the design of such buildings. The expected outcome of further work by the authors is a framework for an appropriate rating scheme for free-running houses.

Acknowledgement

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