Why are Rating Schemes always wrong? Regulatory frameworks for passive design and energy efficiency

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ABSTRACT: Why are rating schemes always wrong? And if they are right, why don't they tell us what we want? It would appear self-evident that buildings which are passively designed to maintain thermal comfort should be promoted as responding to sustainable development and energy efficient design objectives. Unfortunately regulations and standards that have been developed for evaluating energy efficiency of buildings are still almost exclusively based on energy loads, through which some values of passive architectural design are sacrificed. This paper reviews the evolution of these types of regulations in one jurisdiction in Australia to highlight the limitations of current regulations and standards.

Two small comparative studies are reported. One identifies unforeseen regressive outcomes in multi-residential developments in Sydney, where codes requiring natural ventilation have failed to take account of differences between the appropriate methods for improving energy efficiency in air-conditioned and naturally ventilated dwellings. The other deals with some variables to illustrate that the method to improve the energy efficient design of an air conditioned building is different from the method to improve the performance of a naturally ventilated building.

The paper proposes a new aggregate framework for buildings assessment in terms of energy efficient design and thermal comfort.

Keywords: energy, comfort

1. INTRODUCTION

"As sustainability increases in breadth, design for it becomes more complex" [1].

In efforts to promote sustainability in the building sector a variety of national and international regulations and standards have been developed to encourage designers towards energy efficient design. The most common characteristic of rating systems is that the basis for assessing buildings' energy efficiency is the annual energy requirement. However, a number of authors have noted that there is no guarantee that a building which is defined as 'low energy' is necessarily energy efficient when occupied [2, 3]. One Australian study comparing the actual performance of an occupied house with 'rated performance, concludes that passive architectural design can not be evaluated appropriately by current rating systems [4]. These arguments highlight the inability of such rating systems to respond adequately to the objectives of sustainability [5]. It seems safe to suggest that more studies need to be conducted to ascertain relationships between 'energy efficient design' and actual likely energy consumption.

The purpose of this paper is to illustrate these points, firstly by calling attention to some unintended consequences in regulations which have been developed for energy efficient design in NSW.

The second goal is to examine likely building performance in free running[1] and conditioned mode, in response to common variables to improve the building's efficient design. Again, the results emphasize that a low energy building is not necessarily an energy efficient building, and that an efficient building design should not only be assessed based on its energy requirement. This issue is elusive, but of importance in revising regulations and building rating systems.

2. EVOLUTION OF REGULATIONS AND HERS IN NSW, AUSTRALIA

An overview of the many national and international regulation/standards developed for the building sector makes clear that so far all have been set up to cut energy demand of buildings. It has already been suggested by other authors that some 'Energy Conservation Regulation' does not cope satisfactorily with long term climate protection requirements [6].

It has also been noted that "Australia does not have a strong heritage of buildings from the late 20th

[1] Free running is the state of a building in which it is naturally ventilated and does not use any mechanical equipment to improve/maintain its indoor thermal condition

century that respond well to its climate" [7]. Buildings have been designed to give satisfaction of some objectives of low cost, architectural style and neighbourhood rather than thermal comfort [7, 8]. Although rating systems have been intended to underpin legislation to reduce the harmful effects of the building sector on the environment, they have been unable to deal with some aspects such as energy embodied, building size [9] and free running buildings [10].

Australian governments have taken a leading role in improving the thermal performance of buildings through developing legislation and tools. The Nationwide House Energy Rating Scheme (NatHERS) was initiated in 1993 and implemented as the Energy Smart Home Policy in NSW after 1998. Despite its adoption by local government, who are responsible for the actual planning approval, being voluntary, by 2002 approximately 74% of all dwelling approvals in the State were on the basis of rating certificates issued under that policy, most by accredited assessors using the NatHERS simulation software.

Other initiatives have also had significant impacts on energy efficiency outcomes in residential design. In the state of NSW, the quality of the design of 'residential flat buildings' (known elsewhere as 'apartments') was more generally criticised. To rapidly develop the quality of these buildings to higher level of amenity, regulations at the State government, rather than local approval level were introduced. State Environmental Planning Policies (SEPPs) generally establish consistent objectives and processes within the planning system.

Of special interest is the impact over the last three years of one such policy, SEPP65. SEPP65 applies only to 'multi-unit' dwelling construction above three storeys, and was argued as significant for environmental planning owing to "the economic, environmental, cultural and social benefits of high quality design". The policy itself enumerates ten 'quality principles' of fairly generic application. However, a model code (the Residential Flat Design Code) gives effect to the policy through a performance based framework, which in key areas includes numeric 'rules of thumb'. Almost predictably, the rules of thumb have come to be treated throughout the jurisdiction as de facto 'deemed to satisfy standards', and of these, the greatest interest has been related to minimum standards of *solar access* and *cross-ventilation*. In relation to both of these climate responsive design strategies, there is an assumption of amenity value, with the strong suggestion of general energy efficiency outcomes.

At the same time, most local government authorities continued to enforce the use of NatHERS, the rating tool accepted as a bench mark to evaluate the energy efficiency of building design. NatHERS simulation software, while taking into account 'mass transport' cooling by natural ventilation under suitable conditions, does not consider in its calculation of an annual energy load the effect of air movement on summer thermal comfort (and therefore the way artificial cooling is controlled by occupants).

Most recently, and arguably in response to crises in the electricity demand and water supply, a newer SEPP takes as its exclusive objectives contributions to sustainable development by potable water conservation, and by minimizing consumption of energy from non-renewable resources to conserve the environment and reduce greenhouse gas emissions. The SEPP introduces BASIX, a web-delivered planning compliance instrument, initially setting a target for new dwellings of 25% energy reduction compared to current norms, rising to 40% in mid 2006 [11]. BASIX rewards some elements of passive design such as natural ventilation. However, in the area of thermal comfort, it still relies on examining the active appliances and their energy requirements to assess the likely performance of a building.

A new version of NatHERS, to be called AccuRate, will account more for 'physiological cooling' attributable to natural ventilation to modify predicted cooling energy requirements. But AccuRate still leaves open the question that an energy base rating is unable to address the issues for passive architectural design that would be investigated in free running performance.

3. ENERGY EFFICIENCY AND RATING

Building rating systems are already based on the assumption that an 'energy efficient' building will be a low energy consuming building. 'Efficiency' is measured by predicted annual energy use, typically normalised against the volume or area of the building. Rating schemes to date are generally also based on the principle that the efficiency of a building should be evaluated based on the performance of the building design and building fabric. In practice, efficiency is dependent on the efficiency of appliances relatively more than the physical properties of buildings, and is completely dominated in benign climates by occupant behaviours.

This issue is relevant to many aspects of architectural design, such as design to take advantage of cross ventilation.

4. ENERGY EFFICIENT DESIGN ADVICE AND RATING

In the relatively benign temperate climates of south eastern Australia, it is commonly assumed that a dwelling designed for cross ventilation is more energy efficient than that with no complying cross ventilation. Logically, therefore, this type of building should achieve a better result through rating assessment. Otherwise, the reliability of the rating will be under question.

A number of small studies were undertaken as part of compliance reporting consultancies. One such study, of 63 apartments designed for the Sydney climate, is reported here. Like all the other similar analyses, it shows that apartments with nominal compliance for cross ventilation could not achieve higher ratings under the energy load dominated rating scheme. It was apparent that the majority of the 'lowest rated' dwellings were the larger cross ventilated apartments.

The likely explanation is not hard to find. There was a reliable correlation between design for cross ventilation, and the ratio of external wall and glazing to apartment floor area. By uncritically increasing that ratio, designers have been ignoring the fact that the total energy use of most Sydney apartments will show greater benefit from reduced heating requirements in winter, if they have reduced external surface area due to shared walls, floors and ceilings, than they can from assumed cooling reductions achieved by increased surface area (and increased glazing) characteristic of cross-ventilated dual or multi-aspect designs. The most energy conserving designs identified by the rating tool tend to be the more compact single aspect apartments, which share a greater proportion of their parameter wall with similarly conditioned neighbours.

4.1 Predicted cooling/heating load

Examination of the predicted ratio of heating/cooling loads for each category of apartment suggests the linkage between designs for cross ventilation and 'good performance' is even more uncertain.

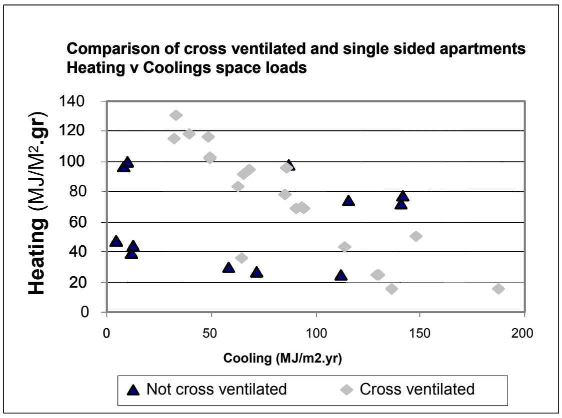

Figure 1: Predicted comparative heating and cooling loads of apartments

Note: The graph is slightly ambiguous in as much as many apartments are identical, and therefore not distinguishable as data points.

It can be readily seen from this comparison (Figure 1) that cross ventilated apartments, because of their greater external wall and glazing areas, have a range of possible ratios of heating to cooling requirements. Overall they are systematically less 'energy efficient' than the compact single aspect apartments.

4.2 Natural ventilation and cooling load

It is important to note that in climates like that of Sydney, some patterns of 'excessive' natural ventilation may not reduce aggregate energy use for cooling, especially in dwellings that are otherwise air conditioned.

The primary effective passive cooling strategy in Sydney is night-time ventilation in conjunction with generally massive construction. It has the effect of reducing the average internal temperatures, and also the maximum internal temperature reached during the subsequent day. Notably, this effect is largely dependent on a regime of keeping the windows closed at all times when the external temperature exceeds the internal temperature. If properly managed, such natural ventilation regime can significantly improve and extend comfort conditions, and significantly reduce aggregate and peak cooling loads.

However, this regime of restricted daytime air exchange is counter-intuitive for most Sydney people. The more usual usage is that windows are thrown open for air movement to produce a sensation of 'freshness' during benign summer mornings. In a climate like Sydney, and more particularly the climate variation as one moves away from the direct benefit of the sea breezes, such air exchange is often already a source of additional heat load. In reality, the air movement is necessary to compensate for the fact that the incoming air is actually warmer than the air exhausted from the dwelling. Often as a consequence, the unacceptable overheated period in the afternoon starts earlier, lasts longer, and is more severe than if morning ventilation were more restrained. This afternoon overheating is then typically controlled by air conditioning, consuming more, not less energy.

If, in addition, the designed night-time ventilation is curtailed because windows are shut to avoid possible excessive noise, winds and wind driven rain, uncomfortable peak interior temperatures can be reached in advance of the external peak, and sustained for a much longer part of the day.

5. REGULATIONS AND RATING SYSTEMS APPLICABLE FOR PASSIVE ARCHITECTURE DESIGN

An objective of passive architecture design is to provide a comfortable indoor environment, using the natural environment, as much of the time as possible without relying on supplementary energy.

A technique to enhance the annual thermal behaviour of a conditioned building may not be applicable to improve its performance as free running. It means that passive architectural design can not be satisfactorily assessed based on annual energy requirements alone. The assessment basis should emerge from the meaning of passive design, which is not relying on mechanical equipment for thermal comfort. Whether ratings advice improves the thermal behaviour of passive design building should therefore be investigated in terms of their 'free running performance'.

6. COMPARISON BETWEEN THERMAL BEHAVIORS OF A BUILDING

The question of whether advice to improve the thermal behaviour of a conditioned house will necessarily enhance its performance as free running was examined by a small study of dwelling performance for the Sydney climate. The study compared different types and construction of individual residential buildings. The following reports a small part of this study for a single storey/heavy weight house.

The current pre-release of the AccuRate software was used for simulation. The typical single storey house was examined in two modes, as free running and conditioned. Its thermal performance was evaluated as a function of annual energy requirement (MJ/M^2) for its conditioned mode, and as a function of 'annual degree discomfort hours' for its free running mode. A general description of the house is given below (Table 1).

Table 1: Typical house description

Number of floors	1
Total floor area	244.9 m^2
Conditioned floor area	197.9 m^2
External wall area	196.5 m^2
Internal wall area	160.4 m^2
Window area	45.9 m^2

A thermostat setting for conditioned mode was determined between 18-24.5ºC, using Auliciems' equation [12].

For free running mode, thermal comfort temperature was defined for 90% occupant acceptability based on ASHRAE Standard 55 [13]. It was computed for each month separately based on the hourly environmental temperatures. The boundaries of a comfort zone for the Sydney climate illustrated in Figure 2 are applied for the living zone. For the Bed zone during the sleeping period, the lower limit of the band was pulled down by 5 ^oC. It was assumed that the living zone and bed zone are occupied between 6-24 and 0-6 respectively.

The effect of humidity was considered to compute the hourly effective temperature in the free running mode; for this purpose indoor humidity was assumed approximately same as outdoor humidity. A degree hour concept was applied to compute the annual discomfort measure.

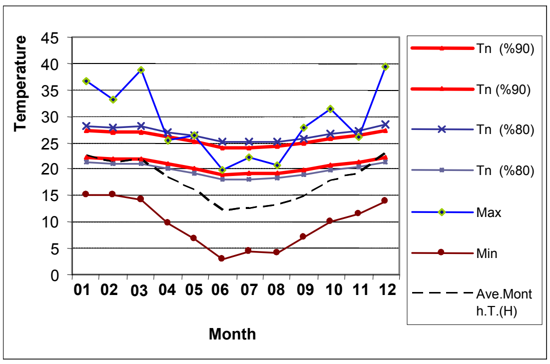

Figure 2: Boundaries of comfort temperature in the Sydney climate

Figures 3 - 6 focus on illustrating some significant differences between the variation of annual thermal performance of the typical house in free running and conditioned mode, each in response to change in one fabric parameter. The parameters considered are the level of wall insulation, floor insulation, wall colour and the proportion of windows to wall.

Figure 3 depicts the situation in which additional insulation of $R=3m^2.K/W$ in the external wall reduces the annual predicted energy requirement of the house by 5%, but increases the annual degree discomfort hours in free running mode.

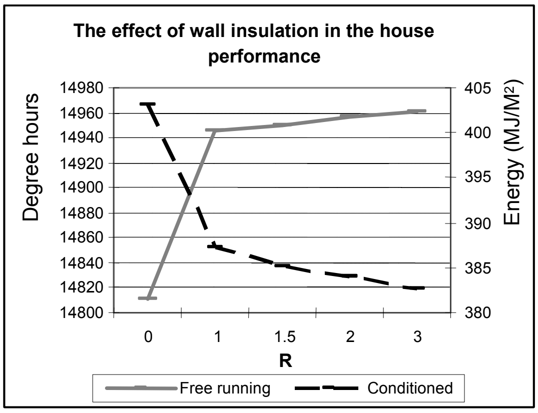

Figure 3: Predicted comparative annual energy requirements and degree discomfort hours of typical house to wall insulation changes

A relatively similar outcome can be seen in Figure 4 in relation to increased resistance of floor insulation. The addition of an insulation layer under the floor of the typical house improves the house thermal performance in conditioned mode by reducing the annual energy requirement; but, again, this addition degrades the aggregate measure of thermal performance of the house in free running mode.

The reason refers to the *seasonal performance* of the house. Although insulation improves the winter performances of both conditioned and free running buildings, it degrades the summer building performance because it slows cooling when outdoor temperature is less than indoor temperature. Wall insulation (R3.0) improved the *winter* performance of the conditioned house by 9.5% and free running house by 0.4%. It degraded their summer performance by 0.8% and 4.6% respectively.

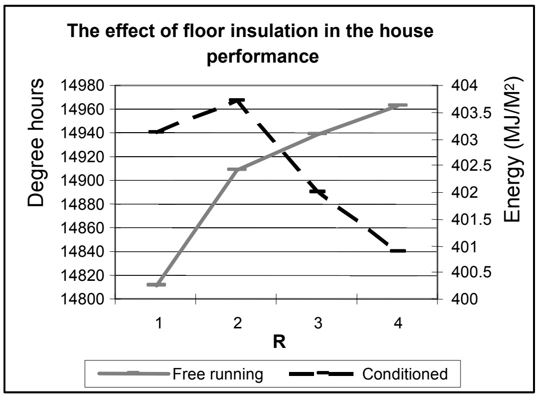

Figure 4: Predicted comparative annual energy requirements and degree discomfort hours of typical house to floor insulation changes

Figure 5 shows the impact of external wall colour. This change could enhance the comfort based performance of the house by 1.5%, while diminishing the performance of the house in conditioned mode by 2%. The different seasonal effect of wall colour in the thermal performance of the house depended on its mode. The harmful effect of external wall colour in the summer performance of the conditioned house was greater than that for its free running mode; however it improves the winter performance of both house modes.

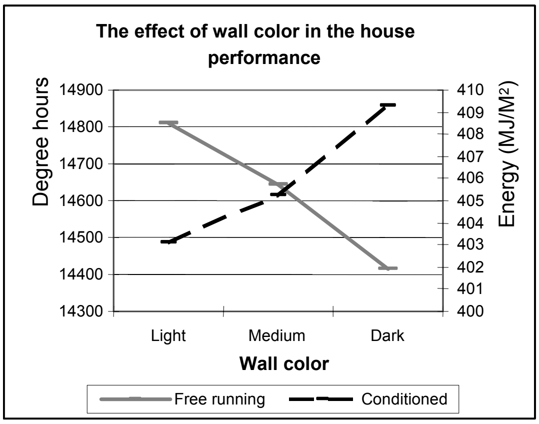

Figure 5: Predicted comparative annual energy requirements and degree discomfort hours of typical house to wall colour changes

Different effects of increasing the proportion of windows on the thermal performance in different modes are compared in Figure 6. When the ratio of windows in both north and south orientation increased by 25%, a slight improvement in free running performance was predicted, while this modification degraded performance in conditioned mode. Higher window ratios appear to enhance the beneficial use of solar radiation in winter and natural ventilation in summer, thus improving *both* seasonal performances of free running houses in this climate. In contrast this change deteriorated both seasonal performances in conditioned mode, owing to increased conductive heat flux between indoor and out door environment.

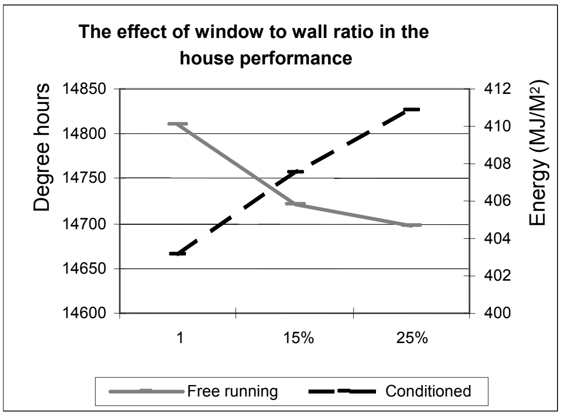

Figure 6: Predicted comparative annual energy requirements and degree discomfort hours of typical house to windows ratio changes

7. CONCLUSION

Regulations, codes, standards and rating systems in the building sector require further investigation to achieve the main objective of sustainability. This paper reports some research that suggests the necessity of a regulatory framework for passive design and energy efficiency that should be different from what has been developed so far.

The behaviour of a free running building to take advantage of the natural environment differs from that for a conditioned building. The latter is effectively designed as an insulated box for which the effort is to reduce the heat conduction to reduce annual energy requirements. For this reason some advice (such as higher external surfaces resistance) gives an enhancement in performance. In contrast a free running building, particularly during summer, needs to achieve potentially greater and faster changes of temperature, to eliminate discomfort temperatures for longer, in order to modify the quality of its indoor environment.

Hence the mandated measures to improve the performance of free running buildings should be different from that for air-conditioned buildings. Likely thermal performance of a building should be evaluated as free running. A free running rating could be aggregated with the current rating systems, resulting in better promotion of passive architectural design.

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