NATHERS: SCIENCE AND NON-SCIENCE

T.J. Williamson, S. O'Shea and V. Menadue
School of Architecture, Landscape Architecture & Urban Design
The University of Adelaide, Australia
terry.williamson@adelaide.edu.au

SUMMARY

A paper by Williamson at the most recent ANZAScA conference speculated from limited data that the Australian Nationwide Home Energy Rating scheme (NatHERS) failed its *commonly held* objective because there was most likely little correlation between the rating and actual household heating and cooling energy consumption. Data has now been collected from a sample of relatively new households in and around Adelaide to corroborate (or otherwise) the scheme. This paper begins by exploring the "official" and the common statements or objectives of the scheme. The common understanding for the scheme is that *a house with a higher rating will on average use less energy for heating and cooling compared to one with a lower rating*. Taking Popper's demarcation between science and non-science as *falsifiability* then this statement is science-like while the "official" statement is not. The common statement is tested by comparing NatHERS ratings with actual heating and cooling energy consumption (and greenhouse gas emissions) and found to be wanting. The paper concludes with some suggestions to bring the scheme in line with expectations.

BACKGROUND

The Nationwide House Energy Rating scheme (NatHERS) (or its derivation *FirstRate*) is now implemented in many jurisdictions in Australia as a mandatory requirement. A dwelling must receive a minimum 3 to 4 Star rating in order to obtain a building or planning approval. The Star rating is based on a computer simulation of the proposed dwelling using the CSIRO software engine CHENATH[1]. To produce a NatHERS rating the simulation uses a year of hourly weather data assumed to be the most appropriate to the location chosen from a database of twenty-eight climate sets. In accordance with the location the dwelling is fixed to operate under a standard control regime. The assumed number of occupants (and associated casual loads) is altered as a function of the dwelling floor area. The Star rating is derived from the sum of the heating and cooling energy loads expressed in MJ/m^2 of conditioned floor area. The scale that relates the MJ/m^2 measure to the different Star levels was determined by each jurisdiction but the basis of these decisions is not in the public domain.

NatHERS Publicity

Williamson (2000) outlined the history of NatHERS and described how, over the years it has received a deal of publicity in the popular and industry press. For example, an early statement in the CSIRO newsletter *Innovation* in 1995 links the objectives of the scheme to reducing energy and greenhouse gases and cost-effectiveness:

> *"The Nationwide House Energy Rating Scheme (NatHERS) will give houses a rating of up to five stars, according to their design, heating and cooling energy requirements. The scheme will reduce <u>household energy use</u> and <u>greenhouse gas emissions</u> by providing information on the design and selection of cost-effective energy-efficient housing."*[2] *[our emphasis]*

An appreciation of the language used in such statements is important to appreciate the systematic way in which the discourse has developed a common conceptual understanding of the scheme's purpose. A search on the internet reveals several websites that describe the scheme and all express

---

[1] Although both the rating scheme and the rating software are known as NatHERS, in this paper NatHERS refers in general to the scheme.

2 Quoted from Innovation, No.12, 1995, p.24, a newsletter of CSIRO, Division of Building, Construction and Engineering. Information attributed to the Commonwealth Department of Primary Industries and Energy, Energy Efficiency Branch, Canberra.

these same conceptions. A website operated by an accredited HERS assessor in New South Wales promotes the scheme on the basis of reduced energy-consumption, improved comfort and cost savings:

"House energy rating …… encourages a reduction of energy consumption in the home and therefore reduced greenhouse gas emissions, at the same time making the home more comfortable……. On a scale of 0 to 5 stars, a 5 star rating means a thermally comfortable house that minimises the need for heating in winter and cooling in summer, improving your comfort…. Savings up to 40% of energy bills should be possible in most houses by reducing artificial heating and cooling." (http://www.acay.com.au/~sutho/houseratings.html, available on-line, 28 july 2001)

And yet another website promotes the National *(sic)* House Energy Rating Scheme as a means of reducing energy consumption, greenhouse gases and cost while at the same time improving comfort:

"The scheme measures the amount of energy required to keep a home comfortable and produces a rating out [of] 5 stars, not unlike the energy rating stickers on whitegoods. The aim is to reduce the amount of energy consumed in cooling and heating homes and consequently the amount of greenhouse gases released to the atmosphere. A home with a rating of 5 stars will be much cheaper to run and more comfortable to live in than one of 2 stars, and produce less pollution…….. Please note: The scheme only covers the building envelope and does not cover appliances or hot water systems." (http://www.omen.net.au/~awoodrof/HERAust/htmlfiles/MoreonNatHERS.html, available on-line, 28 July 2001)

While the political and other statements outlined above indicate that NatHERS is aimed at reducing energy consumption, greenhouse gas emissions and costs the "official" NatHERS documentation provides a significant semantic and methodologically different spin on the objective of the scheme. In describing the purpose of the scheme the NatHERS computer software manual says,

"NATHERS provides a rating of between 0 and 5 stars, which shows the potential of the house to have low energy requirements for heating and cooling. The house is assumed to operate under a standard occupancy schedule appropriate for the given location. The resulting rating is based on a detailed computer simulation of the house using hourly weather data……. NATHERS is designed to provide an energy rating for houses in any location in Australia…...." (Unknown, 1999, p1-2) [our emphasis]

NatHERS AND SCIENCE

Scientific statements (theories, laws and the like) can often have an instrumental or practical purpose in that they can be applied to inform an appropriate human action to satisfy certain *a priori* requirements. Such technological predictions form the basis of engineering. For example, statements from the domain of science about the behaviour of materials are used to design buildings to withstand assumed loading conditions. In a similar way NatHERS (the scheme) derives from scientific thinking. It is aimed at providing householders with an objective prediction of the likely (energy) performance of a dwelling or as Larsson and Cole put it,

"The public are now accustomed to being able to obtain factual reports on the performance of toasters, cars and electronic equipment, and they are also becoming used to seeing product labels that symbolize the achievement of certain levels of performance. Can buildings be far behind?" (Larsson and Cole 1998).

Indeed appliance energy labelling has become commonplace in Australia and is based upon several important principles:

- products are physically tested under standard circumstances in tests specified by Australian Standards (for electrical appliances) or Australian Gas Association Standards (for gas appliances),
- each appliance must satisfy a performance test that demonstrates that the particular product can satisfactorily carry out its primary function, such as keeping food cold or cleaning dishes to a specified standard, and

- the energy rating is calculated to reflect the energy efficiency with which the product performs its specified function, for example, for a gas space heater it is calculated as gas consumption per square metre of floor area heated to standard conditions or for refrigerators it is calculated from the energy consumption per litre of storage capacity, with adjustments for varying temperatures of freezer and fresh food compartments and defrost systems.

Energy labelling provides a marketing 'carrot' to inform consumer choice and through this encourage product improvement. The 'carrot' relates directly to a proposition akin to "*a 5 star refrigerator will consume less energy than an equivalent 2 star model.*" Taking Popper's (Popper, 1972 p37) position that the demarcation between scientific statements and statements of pseudo-science or non-science are their "*falsifiability, or refutability, or testability*" then such a statement can be seen as science-like: subjecting competing appliances to the standard test can easily test the statement. The question is, "*Can a NatHERS rating be viewed the same as appliance energy labelling?*"

In investigating this question we must first recognize, as seen above, that there are two propositions about the objective of NatHERS – the "official" version and the commonly accepted version. One commentator on the Williamson (2000) paper expressed the logic behind the "official" formulation saying; "*NatHERS must work. It has physics on its side. If you take a 2 Star house and compare it in exactly the same situation to a 5 Star house then the latter must potentially use less energy.*"[3] Again taking Popper's line of demarcation between scientific propositions and statements of pseudo-science or non-science as their "*falsifiability, or refutability, or testability*" then the "official" statement about NatHERS is immediately consigned to the category of non-science. Apart from logistical difficulties of conducting a suitable experiment to test such a statement there is a methodological problem: it is a well-documented fact that the thermal behaviour of people is contingent on the context (see for example, Cloher, 1981; Williamson & Riordan, 1997; Nicol, 2001). This means that it can never be assumed that people in a 2 star house will behave the same if placed in a 5 star house. Because the differences in behaviour will most likely effect energy consumption there is no logical way that the potential of NatHERS to reduce energy consumption makes sense and can be tested.

On the other hand the common (and we believe politically intended) formulation of the NatHERS objective, "*that a dwelling with a higher Star rating will on average use less energy (and produce less greenhouse gases) for heating and cooling compared to a house with a lower rating*" conveys a deal of consumer information and is capable of refutation. The statement would be corroborated if, for example in a survey, a significant positive correlation was observed between the NatHERS ratings of a sample of houses and the annual energy consumption attributed to heating and cooling.

CORROBORATION SURVEY

To undertake such corroboration (admittedly in a limited geographical context), data were collected from 31 households in and around the Adelaide metropolitan area. Each householder in the experiment answered an advertisement placed in the *Advertiser* newspaper inviting participants in an *Energy-Efficient House Design* research project. To qualify, each household had to satisfy a number of criteria; the house had to be less than ten years old and be more or less continuously occupied by a regular number of occupants with a stable use pattern over the last five years. Further, the householders had to be willing to participate in an interview and give permission for the researchers to have access to their utility accounts. The houses that qualified to be included in the study ranged in style from "solar-efficient" mud brick construction to "standard" project builder designs. The sample included a range of floor areas, numbers of occupants, a variety of heating and cooling appliances and use patterns likely to be typical of the larger population. Apart from the fact that the participants self-selected for the project by answering the advertisement, they could be considered a random collection. In such an experiment there is no optimum number of participants. All that can be said is, the greater the number, the greater will be the degree of corroboration (or lack of corroboration).

Once admitted to the study a detailed interview was conducted with the household. This interview covered issues such as household composition, dwelling construction, dwelling use patterns, energy appliances and their use, and attitudes to energy management and thermal comfort. For all cases working drawings were obtained for the house. These were checked for accuracy, modifications

[3] Personal communication with commentator who wished to remain anonymous.

recorded and measured, and the position of trees and other shade causing elements noted. All details required for input to the NatHERS simulation were collected.

Figure 1: "Solar-efficient" mud brick construction

Figure 2: A standard project home

Each participating household signed a document giving the researchers permission to access their utility bills. This data identified;

- Electricity Consumption – Quarter number, date of issue, bill period, units used (kWh), and off peak units used (kWh) where applicable.
- Gas Consumption – Quarter number, date of issue, bill period, units used MJs
- Oil – Date of issue, bill period, total amount, litres

Fire wood consumption was identified during the household interview: the type of wood heater, how regularly this was used, the amount of wood used (tonnes per year) and the type of wood were recorded.

Determination of Annual Heating and/or Cooling Energy Consumption

Electricity and gas accounts are issued to householders at approximately quarterly intervals. The actual date of billing various between households and the actual billing period may vary between successive accounts. Domestic electricity consumption in South Australia is billed at two rates, the "M" tariff for general consumption and the "J" tariff for off-peak uses such as storage water heaters and certain heating systems (eg heated floors). Gas is billed at one rate. Electricity consumption for the two tariff rates "M" and "J" and gas consumption was obtained from the supply companies covering the years 1998, 1999, 2000 and part 2001. The problem is to estimate heating and/or cooling energy consumption from the overall period energy consumption. The method developed is as follows.

For the general case were for a household electricity supplies both heating and cooling energy for each period we can write,

$$a_1 x + b_1 y + c_1 z = d_1 \qquad (1)$$

$$a_2 x + b_2 y + c_2 z = d_2 \qquad (2)$$

$$a_3 x + b_3 y + c_3 z = d_3 \qquad (3)$$

..

$$a_i x + b_i y + c_i z = d_i \qquad (i)$$

Where: ***x*** = total consumption for the household attributable to heating over all periods of analysis
y = total consumption for the household attributable to cooling over all periods of analysis
z = total other household electricity consumption over all periods of analysis
a, b, c = coefficients expressing the fraction of the relevant components x, y and z for each individual period.
d = total electricity consumption for individual periods.

To estimate the coefficients ***a*** and ***b*** it is assumed that heating and cooling use (and therefore energy consumption) is climate dependent. Daily maximum and minimum daily temperatures were obtained from the Adelaide Bureau of Meteorology that covered the study years. From this data Heating Degree Days (HDD) and Cooling Degree Days (CDD) could be calculated for each billing period. Therefore,

$$a_i = \frac{HDD_i}{\sum HDD} \quad \text{and similarly} \quad b_i = \frac{CDD_i}{\sum CDD}$$

The HDD base and the CDD base were varied for each household so that the statistical fit (R^2) between the model and the data was maximized. The optimum HDD ranged from 12°C to 19°C, while the CDD ranged from 23°C to 26°C. The ancillary electricity consumption is assumed to comprise a component that is constant for all periods (eg appliance standby, fish tanks) and a part that varies with the period mean temperature (eg. water heating, refrigerator(s), lights) such that,

$$c_i = k_i \left[1.0 + \frac{\left(\overline{T}_{ave} - \overline{T}_i \right)}{\overline{T}_{ave}} \right] \tag{4}$$

Where:

$k_i = \frac{PeriodDays}{TotalDays}$, $\overline{T}_{ave}$ average daily temperature for all days, $\overline{T}_i$ average temperature for period

The over-determined system of equations is be reduced to a well-defined set of normal equations with three variables by least squares best fit. The normal equations to be solved are of the form,

$$\alpha_1 x + \beta_1 y + \gamma_1 z = \delta_1 \tag{5}$$

$$\alpha_2 x + \beta_2 y + \gamma_2 z = \delta_2 \tag{6}$$

$$\alpha_3 x + \beta_3 y + \gamma_3 z = \delta_3 \tag{7}$$

The solution values of x, y and z are converted to annualized values by multiplying by $365 / TotalDays$. Annual household heating gas consumption is found in a similar manner by in effect setting $\boldsymbol{b}_i$ to be zero. For each household the energy consumption values derived from this model were checked for consistency against the appliance survey and the reported use patterns collected during the survey. The model showed a remarkable ability to predict the actual household situation, for example, it would show precisely when no electric heater (or cooler) was used. Overall the model produced a significant fit with the data (R^2=0.66, p<0.05) indicating that the heating and cooling energy consumption is estimated with a good degree of accuracy.

THE RESULTS

Space in this paper precludes showing all results but Figures 3 to 6 show the main findings. Because the Star rating in NatHERS is derived directly from the sum of heating and cooling load, expressed as MJ/m^2, it is this figure, taken from each simulation run, that is compared to the actual "measured" values.

NatHERS software version 2.31 was used in this study. An important aspect in generating the results was a cautious consideration of the inevitable assumptions made in fitting non-standard construction and other details to the required computer software input format. In each case, assumptions were carefully noted, and where the software manual gave insufficient or conflicting guidance, advice was sought from Dr Angelo Delsante, CSIRO. For each household, the sensitivity of assumptions was tested in order to gain the most credible simulation result.

Figure 3 shows the anticipated "common" relationship between the NatHERS energy load and the actual household heating and cooling energy consumption; a lower NatHERS energy load (meaning a higher Star Rating) would correspond to a lower household (heating and cooling) energy consumption. The data trend line and the correlation statistics indicate that no significant correlation exists.

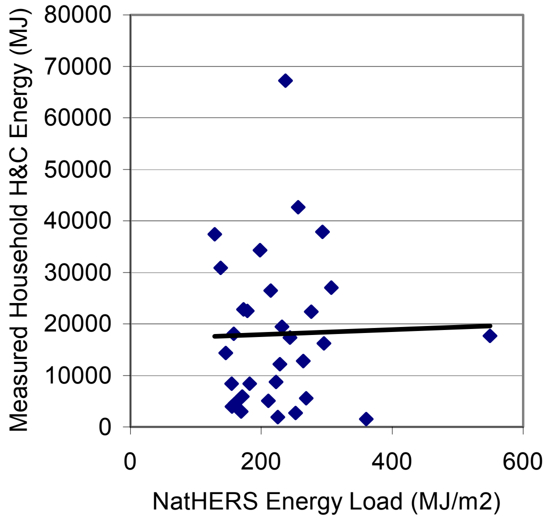

Figure 3: NatHERS (MJ/m^2) vs Total Household Consumption for Heating & Cooling (MJ)
Note: N=31, R2=0.0007, p>0.8

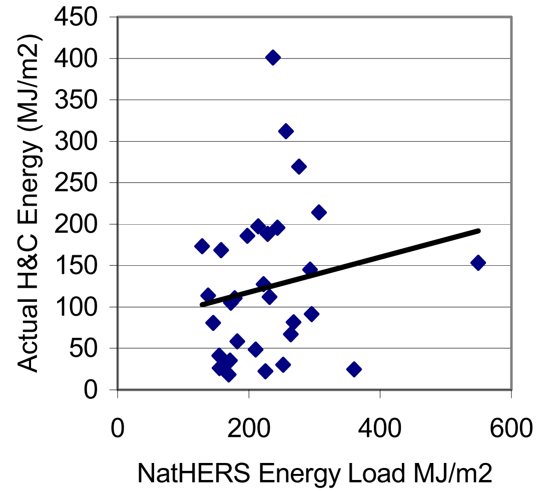

Figure 4: NatHERS (MJ/m^2) vs Total Household Heating and Cooling per Conditioned Floor Area (MJ/m^2)
Note: N=31, R^2=0.035, p>0.30

The second comparison, Figure 4, is with the NatHERS rating energy load (MJ/m2) and the sum of the heating and cooling consumption divided by the measured conditioned floor area. Again no significant correlation is observed. When the NatHERS rating is compared to the "measured" level of CO_2 emissions, based on the full fuel cycle, again as seen in Figure 5, no significant correlation is seen. The negative slope means that, if anything, a higher rating could correspond to a higher emission level. When the calculated NatHERS heating load only is compared with the household heating energy consumption, as shown in Figure 6, again no significant correlation is observed. In none of the cases illustrated above does the removal of the outlier data points significantly alter the lack of correlation.

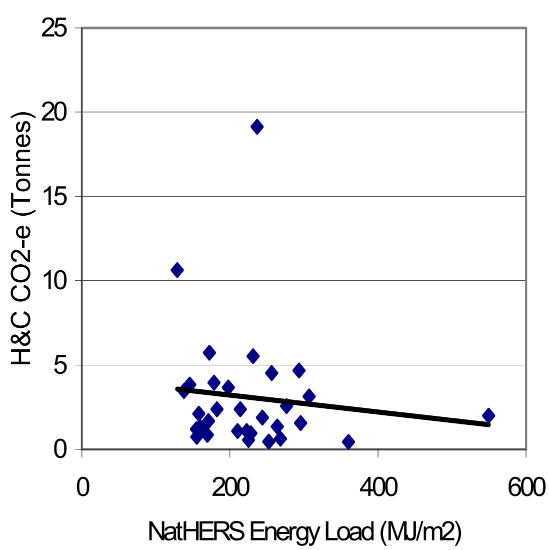

Figure 5: NatHERS (MJ/m^2) vs Total Greenhouse Gas Emission for Heating and Cooling (Tonnes)
Note: N=31, R^2=0.013, p>0.50

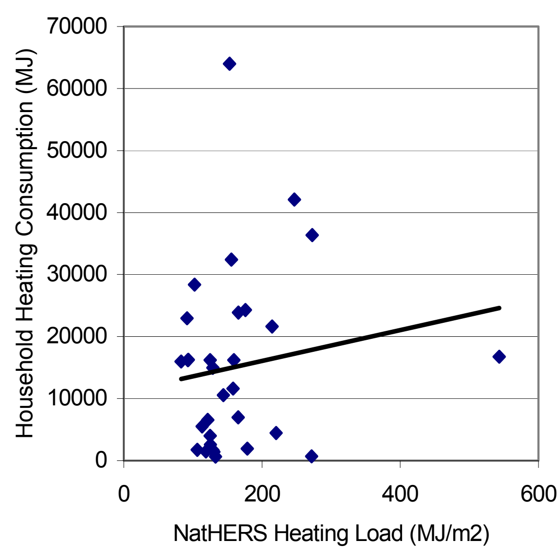

Figure 6: NatHERS Heating Load Only (MJ/m^2) vs Household Heating Energy (MJ)
Note: N=31, R^2=0.022, p>0.4

DISCUSSION

Le Corbusier writing in 1931 stated "……..architecture is governed by standards. Standards are a matter of logic, analysis and precise study. Standards are based on a problem that has been well stated. Standardisation is imposed by the laws of selection and are an economic and social necessity." (Le Corbusier, 1931). Here he was arguing for a process that today we accept as a norm – that a rigorous scientific approach should be applied when developing standards. Was this the case in the development of NatHERS? Various tests were undertaken to verify the correctness of the software (Delsante, 1995a; 1995b). Although this was necessary it was not sufficient corroboration of the scheme as a whole. During the NatHERS development no testing of the scheme against reality was conducted, but as discussed above, the "official" version of the purpose of the scheme could not in any event be logically tested. The results presented in this paper now indicate that the commonly held purpose of NatHERS, that higher Star Ratings will mean reduced household energy consumption and greenhouse gas emissions, could not be corroborated.

Yet there may be hope. One reason for the lack of corroboration would appear to be the early decision that the rating scheme should be fuel neutral. (Akin to specifying the fuel performance of a car based solely on the aerodynamic properties of the body.) If however the efficiency of the heating and cooling appliances are taken into account, then a tentative energy consumption figure can be estimated. It is tentative because it is based on fictitious occupancy assumptions. As shown in Figure 7, using the present NatHERS occupancy assumptions, this computation over-estimates the "actual" energy consumption by a factor of approximately two. However now there is a small but significant correlation between this "equivalent" energy estimate and the "actual" figure (R^2=0.185, $p<0.05$). (Removing the outliers in this case results in R^2=0.36.) Refinements in the occupancy patterns and other factors would no doubt reduce the unexplained behaviour and make possible a viable house energy rating scheme that would meet the everyday expectations.

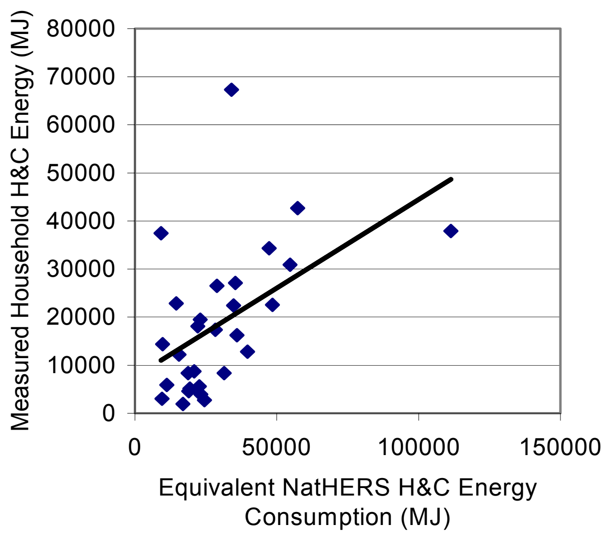

Figure 7: Equivalent NatHERS Energy Consumption vs Actual Energy Consumption

Note: N=31, R^2=0.185, p<0.05

In offering an explanation of the present scheme during its development Ballinger and Cassell said,

> *"While the energy used by appliances is obviously important, the task of developing a viable HERS is so great that these have been excluded for the present. There is however no reason that they could not be included at a later date." (Cassell & Ballinger, 1996)*

This paper has demonstrated that the present scheme does not fulfill common expectations. While not underestimating the difficulties in developing an effective HERS scheme, in particular dealing with the machinations of bureaucrats and the demands of self-interested industry groups, if NatHERS is to be revised then this work must be based on accepted scientific method.

Acknowledgements

First, we thank the generous support of all the householders that contributed to this study. We also thank AGL and Origin Energy who supplied the electricity and gas consumption figures. To Angelo Delsante and Jim Woolcock we offer our special thanks for the valuable support and advice on NatHERS data input. Alan Pears provided insights into appliance testing.

References

AGO. (1998). *The National Green House Strategy: Strategic Framework for Advancing Australia's Greenhouse Response*. Canberra: Australian Greenhouse Office.

Cassell, D. J., & Ballinger, J. A. (1996). The Development and Capabilities of the Nationwide House Energy Rating Scheme. In *Proc. of Conference-Second National Energy Efficient Building and Planning Seminar* (pp. 1-6). Wollongong: Paraclete Building Consultants.

Cloher, D. V. (1981). *Domestic Insulation and Savings in Energy Consumption Domestic Space Heating and Cooling: Adelaide 1776/77 and 1979/80*. Adelaide: S.A. Dept Mines and Energy.

Delsante, A. E. (1995a). *An Empirical Validation of CHENATH,The National Home Energy Rating Scheme Simulation Engine* (DBCE Doc. 95/78 (M)). Melbourne: CSIRO, Division of Building Construction and Engineering.

Delsante, A. E. (1995b). *A Validation of CHENATH, The National Home Energy Rating Scheme Simulation Engine, Using Inter-Program Comparisons* (DBCE Doc. 95/79 (M)). Melbourne: CSIRO, Division of Building Construction and Engineering.

Howard, J. (1997). *Safeguarding the Future: Australia's Response to Climate Change (A Statement to Parliament).* Canberra: Australian Greenhouse Office.

N.G.S.C. (Dec,1992). *National Greenhouse Response Strategy*. Canberra: National Greenhouse Response Committee, AGPS.

Nicol, J. F. (2001). Characterising Occupant Behaviour in Buildings: Towards a Stochastic Model of Occupant Use of Windows, Lights, Blinds, Heaters and Fans. In R. Lamberts, C. Negrao, & J. Hensen (Eds.), *Proceedings of 7th IBPSA Building Simulation Conference BS'01* (pp. Vol 2, 1073-1078). Rio de Janeiro: International Building Performance Simulation Association.

Popper, K. R. (1972). *Conjectures and Refutations: The Growth of Scientific Knowledge* (4th ed.). London: Routledge and Kegan Paul.

Unknown. (1999). *User Guide for NatHERS: The Computer Simulation Tool for House Energy Rating-Version 2.31.*

Williamson, T. J. (2000). A Critical Review of Home Energy Rating in Australia. In V. Soebarto & T. Williamson (Eds.), *Proc. of Conference ANZAScA 2000*. Adelaide: Australian and New Zealand Architectural Science Association.

Williamson, T. J., & Riordan, P. (1997). Thermostat Strategies for Discretionary Heating and Cooling of Dwellings in Temperate Climates. In J. D. Spitler & J. L. M. Hensen (Eds.), *Proc. of 5th IBPSA Building Simulation Conference* (Vol. I, pp. 1-8). Prague: International Building Performance Simulation Association.