IS THE NEW GENERATION OF BUILDING ENERGY RATING SOFTWARE UP TO THE TASK? - A REVIEW OF ACCURATE

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ABSTRACT

The AccuRate software is a greatly improved version of NatHERS, which has been used to rate dwellings for more than 10 years. Many of the limitations of NatHERS have been addressed in AccuRate, and the key ones are described in this paper. These include improved natural ventilation modelling, user-defined constructions, improved modelling of roofspaces, sub-floor spaces, skylights and horizontal reflective air gaps, and the availability of many more zones. Examples of the effects of such improvements are given. Some results from the comparison of AccuRate's simulation engine with other internationally-recognised software programs are also given.

KEY WORDS

Building energy; simulation; rating tools; dwellings.

INTRODUCTION

The history of using simulation software to rate residential buildings in Australia goes back to the early 90s, with the introduction of the Nationwide House Energy Rating Scheme (NatHERS), a joint federal, state and territory government initiative. CSIRO was asked to develop software that could calculate annual totals of hourly heating and cooling energy requirements for residential buildings. Star ratings (from 0 to 5 stars) were assigned on the basis of the sum of these requirements, and the star bands were set by each state or territory jurisdiction.

Because of time limitations, it was not possible to develop new software custom-designed for the task, in particular a new user interface, the development of which can be very time-consuming. Instead, an existing user interface that had been developed by the then Gas & Fuel Corporation of Victoria was adapted and interfaced with CSIRO's existing simulation engine for residential buildings (which had been used in the CHEETAH and ZSTEP software). At the time the resulting software package (which, unfortunately in hindsight, was also called NatHERS) was intended to be viewed as a prototype of what could be done, but, as is the way of things, it ended up having a much longer life span than was ever envisaged.

In adapting the Gas & Fuel user interface, a deliberate decision was made to keep data input requirements as simple as possible while still retaining the ability to adequately model typical dwellings, which at the time were considered to be single-storey detached houses. Thus for example, the number of zones that could be described by the user were limited to four (Living, Bedrooms, Other Conditioned, and Unconditioned), and the available building elements (walls, floors, etc, called constructions) were limited to a fixed list. In the same spirit, roofspace and subfloor zones were automatically created if necessary, but were limited to one of each and the details could not be varied by the user (e.g. the sub-floor wall height).

However such limitations, while successful in keeping data input requirements and run times down, have become increasingly restrictive as dwellings and construction materials and practices have become more diverse. Additionally, NatHERS was criticised for not giving adequate credit to designs that relied on natural ventilation to maintain comfort. This was seen to be a particular problem in sub-tropical and tropical areas. A perception arose that NatHERS was favouring air conditioned ‘sealed box’ designs. While many of the criticisms of the software were justified, some arose from misunderstandings. Firstly, although the star rating was indeed based on the sum of annual heating and cooling energy requirements, and thus on calculations that assumed that heating and cooling were switched on when required, there was no intention to force buildings to be conditioned. The annual energy was simply a useful figure of merit that in effect gave an indication of how uncomfortable the building would be in the absence of heating or cooling. With respect to cooling, NatHERS always attempted to ventilate a zone first (using the simple ventilation model described below), and only imposed cooling if the zone temperature with ventilation remained above the thermostat setting.

Nevertheless it is true that the ventilation model in NatHERS is very simple, and does not take in to account wind direction, opening sizes and locations (both in the façade and between rooms), and the effect of ventilation-induced air movement on comfort. Because of these and other limitations, a new version was needed. In 2002 the Energy Efficiency & Greenhouse Group (E2G2), which manages the Nationwide House Energy Rating Scheme for the intergovernmental Ministerial Council on Energy, agreed to fund a major overhaul of the NatHERS software, comprising

- A significantly improved simulation engine.
- A new user interface to support the engine improvements and eliminate unnecessary limitations in the old user interface.
- A new report.

The project was administered by the Australian Greenhouse Office and the resulting software was called AccuRate. This paper describes and illustrates these improvements.

KEY IMPROVEMENTS IN THE ACCURATE SOFTWARE

Modelling of natural ventilation

In NatHERS, ventilation rates in habitable zones are specified only as a function of wind speed, v, as follows:

$$\mathrm{ACH} = A + B^{*}v, \text{ if } v < 1 \text{ m/s}, \tag{1}$$

or

$$\mathrm{ACH} = A + B^{*}\sqrt{v}, \text{ if } v > 1 \text{ m/s}, \tag{2}$$

where ACH is the air change rate in air changes per hour, and *A* and *B* are constants; typically *A* = 3 and *B* = 10. Equation (2) is intended to allow (very roughly) for partial window closure at higher wind speeds.

Such a simple approach does not take into account the effect of wind direction, the size and location of openings, and the effect of the floor plan and openings between rooms on cross-ventilation performance.

In order to address these deficiencies, the AccuRate engine incorporates a 'network' model of ventilation (Li *et al*., 2000). In this model, the flow rates through openings (between indoors and outdoors, or between zones) are calculated as a function of wind speed, wind direction, and opening size. In each zone the flow rates through all the openings and the temperatures of the incoming air flows are used to calculate the effect on the temperature of each zone.

The network model can account for both buoyancy-driven flows (also know as stack-effect flows, which arise because of a temperature difference between zones and/or between indoors and outdoors), and wind-driven flows. For each external opening, it requires the wind speed and direction, the pressure coefficient as a function of wind direction, and the temperature difference across the opening.

The wind speed in the weather data file used by AccuRate is normally measured at the local airport. To obtain an estimate of site wind speed, the weather file wind speed is multiplied by a reduction factor based on the user-selected terrain category and the height of the opening above ground. The effect of local shielding is taken into account by multiplying the ventilation rate calculated from the network model by a shielding factor (see Swami and Chandra, 1988). The shielding factor is automatically linked to the user-selected terrain category.

The wind direction at the building site is assumed to be the same as given in the weather data file, in the absence of any suitable method to convert this to a site wind direction. Pressure coefficients are estimated using published methods for simple building shapes, with corrections for wing walls and courtyards (Swami and Chandra, 1988).

In zones with single-sided ventilation (openings in only one façade), the network model described above will not properly account for the wind-driven component of the ventilation rate. In such zones, the model developed from measured data by Dascalaki *et al*. (1995) is used to calculate the flow rate.

The interaction of natural ventilation, comfort, and cooling

Once the flow rates at each opening are known (both from outdoors and from other zones), the effect on the temperature of each zone can be calculated. This accounts for one of the benefits of natural ventilation, namely heat removal. The other benefit is the effect of indoor air movement generated by natural ventilation on human comfort. In order to account for this, a comfort index is required that takes into account air temperature, air speed, mean radiant temperature, and humidity (occupants are assumed to be sedentary and to be wearing clothing appropriate for the conditions). An earlier study (Aynsley and Szokolay, 1998) of available comfort indexes, commissioned for the Nationwide House Energy Rating Scheme, concluded that ET* (new effective temperature) was the most suitable index to use. ET* is used as follows.

A neutral temperature must first be established, i.e. the temperature at which occupants feel neither too warm or too cool. The Szokolay and Aynsley study recommended the use of Auliciems' (1981) expression:

$$T_n = 17.6 + 0.31T_m, \qquad (3)$$

where T_n is the neutral temperature and T_m is the mean monthly outdoor air temperature. For simplicity, the January value of T_m is used in AccuRate to establish the neutral temperature for all months (for cooling purposes).

The cooling thermostat is set equal to the neutral temperature, up to a limit of 28.5°C, above which both are taken to be 28.5°C. The upper temperature limit of the comfort zone at 50% relative humidity is taken to be the neutral temperature plus 2.5 degrees, corresponding to 90% acceptability (de Dear and Brager, 1998). The comfort zone boundaries on a psychrometric chart are determined by lines of ET* based on the upper temperature limit at 50% relative humidity, and the moisture content of the air. Figure 1 shows the comfort zone boundaries for Darwin on a psychrometric chart. The smaller region is for air movement below 0.2 m/s, while the larger region is for 1 m/s indoor air movement. Normally the lower horizontal boundary would be placed at 4 g/kg in either case. However, because cooling should not be invoked in AccuRate simply because the air is too dry (i.e. below 4 g/kg), the boundaries have been placed at 0 g/kg. For no air movement, the right boundary is the ET* line corresponding to the neutral temperature (which for Darwin is 26.5°C). The acceptable dry-bulb temperature (on the horizontal axis) decreases as the humidity increases because of the negative slope of the ET* line.

With air movement, the top boundary corresponds to 90% relative humidity and the right boundary is the ET* line which passes through the 50% RH line at a temperature of (Neutral Temperature + 2.5 + T), (Szokolay, 2003) where

$$T = 6*(v - 0.2) - 1.6*(v - 0.2)^2, \qquad (4)$$

where v is the indoor air speed (m/s). This expression for T, which represents the cooling effect of air movement, is taken from a review by Szokolay (2000). The effect of indoor air movement can be substantial: for example, at an indoor air speed of 1.0 m/s, the effect is 3.8 degrees.

At each hour the zone temperature and humidity with natural ventilation and no cooling is first calculated. The air speed at each opening is calculated by dividing the flow rate at the opening by the opening area. The air speed in the zone is then estimated as the mean of the air speeds at the openings in that zone. The zone temperature and humidity with this air speed are then compared to the comfort zone (extended according to the air speed). If the zone condition is within the comfort zone the calculation proceeds to the next hour. Otherwise, the ventilation is switched off (i.e. user-controlled openings are closed) and the cooling energy required to maintain the zone temperature at the cooling thermostat setting is calculated.

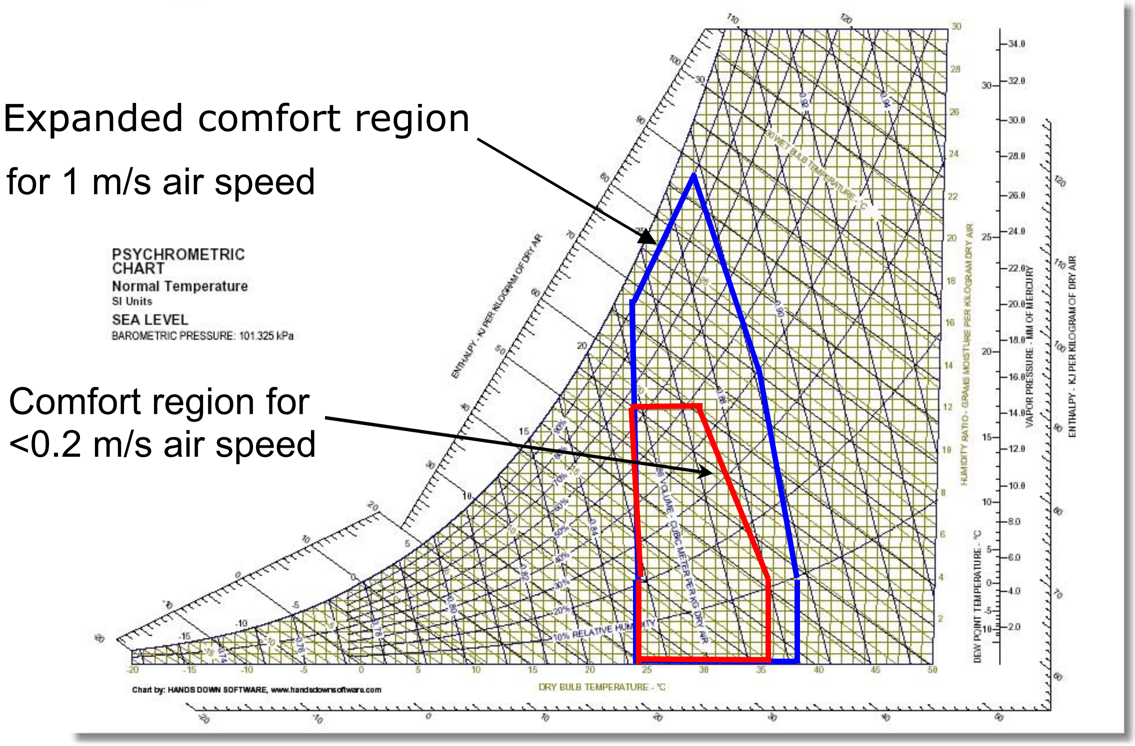

Figure 1. Comfort region in Darwin for air movement below 0.2 m/s (smaller region), and expanded comfort region for air movement of 1 m/s

Openings for natural ventilation consist of permanent openings and user-controlled openings. Openings in walls (external or between zones), floors and ceilings can be specified as being either permanent or user-controlled. Window and door openings are always user-controlled. Since permanent openings are open 24 hours a day, 365 days a year, natural infiltration will occur even in cold weather. User-controlled openings in a zone are opened if the zone temperature exceeds a threshold value and exceeds the outdoor temperature minus 4 degrees. The threshold value is at or slightly below the cooling thermostat setting. The subtraction of 4 degrees from the outdoor temperatures is designed to allow ventilation to occur even if the outdoor air is slightly warmer to take advantage of any cooling effect due to air movement.

User-controlled openings also have an associated ‘stickiness’ period. This specifies the number of hours that must elapse after an opening/closing action before the opening state can change again. It was recently introduced into AccuRate to avoid unrealistic operation of openings every hour. The default stickiness period is 3 hours.

Effect of new natural ventilation model

To illustrate the effect of AccuRate’s ventilation model on cooling energy predictions, two houses were compared in Brisbane. House 1 is a typical large two-storey ‘box’, with the living areas downstairs and the sleeping areas upstairs. A qualitative assessment of the cross-ventilation potential would rate the ground floor as good and the first floor as moderate. House 2 has a typical Queenslander floor plan (long and narrow) with good cross-ventilation potential. The houses were simulated using the old NatHERS ventilation model or the new ventilation model (both implemented in AccuRate, so that all other things are equal). Table 1 compares the cooling results.

Table 1. Comparison of old and new ventilation models for two houses in Brisbane.

	Annual cooling energy (MJ/m^2)		**Improvement (%)**
House	**Old ventilation model**	**New ventilation model**	
1	158.9	151.4	**4.7**
2	149.6	114.9	**23.0**
Difference (%)	**5.8**	**24.0**	

The results can be viewed in two different ways. If we compare the effect of the old ventilation model (which does not account for cross-ventilation performance) with the new ventilation model, we see that changing to the new model improves house 1 (with moderately good cross ventilation) only by about 5%, whereas it improves house 2 (with good cross-ventilation) by 23%. Alternatively, we can see that with the old model, house 2 is about 6% better than house 1, but with the new model it is 24% better.

House 2 was also run where the openings that allow cross-ventilation were closed. The cooling energy was 167.8 MJ/m^2, an increase of 46%.

User-defined constructions

In contrast to NatHERS, AccuRate generally allows the user to build new constructions from a fixed list of materials, and to modify existing constructions. New constructions can be saved to user-specified libraries, to allow their re-use in future projects. The material list is fixed because adding materials or modifying material properties requires specialised knowledge. However, the list is quite comprehensive, and currently contains 60 materials other than insulations and air gaps, 70 insulations, and 260 air gaps. If additional materials need to be added, a small update file can be sent to users (or downloaded from a website).

Users cannot, however, create or modify windows, skylights and roof windows. This is because they are complex systems (for example they comprise an opaque frame as well as glazing) which require specialised knowledge to specify correctly. However, all window systems (over 1000) that have been WERS-rated will be available in AccuRate.

Roofspaces

Roofspaces (attics) are geometrically and thermally complex. A detailed model of heat flows in a roofspace would require considerable research, backed by field and laboratory measurements that are not yet available for typical Australian roofspaces. In the USA, a detailed model has been developed and is backed by measurements (Ober and Wilkes, 1997). However, it assumes that the room below the roofspace is maintained at a constant temperature, that the attic has a specific geometry, and that the attic infiltration rate can be calculated from a knowledge of the areas of openings and their locations. None of these assumptions, particularly the last, apply very well to Australian conditions. Because of this a simpler model, as described below, was incorporated into AccuRate. Nevertheless, this model is still an improvement on the roofspace model in the current version of NatHERS.

In the new model, the roofspace is represented by three zones: the roofspace air; the surface representing the under-side of the roof construction; and the surface representing the top of the ceiling construction. The two surfaces exchange heat via radiation, and also exchange heat with the roofspace air via convection. The radiative heat transfer coefficient is calculated at each time step (usually one hour) as a function of the surface temperatures and the combined emissivity of the two surfaces, calculated as if the surfaces were parallel plates with a view factor of one. Thus gable ends do not participate in the radiative heat exchange calculation, although they are connected (directly) to the roofspace air. The convective heat transfer coefficients are also calculated at each time step and depend on the surface temperature, the roofspace air temperature, the direction of heat flow (up or down), and the estimated air speed over the surface. The air speed is estimated from the roofspace air change rate and the surface areas (this is an area of great uncertainty). The algorithms for the convective heat transfer coefficients are the same as those used by Ober and Wilkes (1997).

The roofspace air can be infiltrated with outdoor air. The air change rate in typical Australian roofspaces not well known, and for the current version it is simply calculated as a linear function of outdoor wind speed. The values of the coefficients depend on the type of roof surface (e.g. steel or tiles), whether the roofspace is sarked or not, and whether the roofspace is deliberately ventilated. At this stage the coefficients used are the same as those used in NatHERS.

Although it is still very simple compared to reality, the model does take into account some key features: the direction of heat flow at the roof and ceiling surfaces, the emissivity of the surfaces, and the ventilation rate.

Sub-floor spaces

Like roofspaces, sub-floor spaces are also geometrically and thermally complex, although perhaps less so. The new subfloor space model is very similar to the new roofspace model: each subfloor is represented by three zones: the subfloor air, the surface representing the underside of the floor construction; and the surface representing the top of the subfloor floor (often simply the ground itself). Radiative and convective exchanges between these zones are treated in the same way as is done for the roofspace model. Thus, like gable ends, subfloor walls do not participate in the radiative heat exchanges but are coupled directly to the subfloor space air.

Estimating infiltration rates in sub-floor spaces presents similar problems to roofspaces. In NatHERS, the infiltration rate used for enclosed sub-floors is

$$Q = 3 + 1.0v_a \qquad (5)$$

where Q is the air change rate in air changes per hour (*ach*), and v_a is the airport wind speed. Thus for a wind speed of 3.0 m/s, (5) gives an air change rate of 6 *ach*. Measurements of average infiltration rates in the sub-floor spaces of four real houses in Melbourne, undertaken by the CSIRO and the University of Adelaide in 1997 and 1998, were reviewed and suggested that average air change rates over short periods of a week or so were considerably higher than given by (5) – of the order of $5.6v_a$ *ach*, or 16.8 *ach* for a wind speed of 3.0 m/s. However the results were not incorporated into AccuRate because of the very small sample size, and also because the measurements suggested that the air flow paths were complex – some the air flowing into the sub-floor space appeared to come from the wall cavity rather than from outdoors.

Recently, further theoretical work by CSIRO and the University of Adelaide has established a new estimate of the sub-floor infiltration air change rate for cases where the sub-floor is isolated from the wall cavity, or where an unobstructed wall cavity does not exist. This has been incorporated into AccuRate and is given by

$$Q = aP(0.0009612 + 0.0004968Gv_a)/(A_fH), \tag{6}$$

where a is the area of sub-floor ventilation openings (mm^2/m), P is the perimeter, A_f is the floor area, H is the floor height above ground, and G is a shielding and wind speed factor. User-selectable available values for ventilation opening areas range from 6000 mm^2/m down to 1000 mm^2/m, depending on the house location and whether an impervious membrane has been laid on the ground. The value Q of varies with house shape, but a typical case gives $Q = 0.46 + 0.34v_a$, or 1.5 *ach* at 3 m/s, a considerable reduction on the NatHERS model.

Note that for sub-floors connected to an unobstructed wall cavity, the NatHERS model is still used, pending further research.

Skylights

The NatHERS skylight model did not take into account several important features of skylights, the most significant one being the presence of a shaft connecting the roof-mounted top glazing to the zone lit. This resulted in solar heat gains probably being overestimated in typical configurations, with a resulting increase in cooling energy. In the AccuRate skylight model, the following parameters are taken into account, and are user-controlled:

- Area, direction, pitch
- Type of top glazing and frame
- Length, reflectance and insulation of shaft
- Zone lit
- Presence of bottom diffuser

The types of top glazing have been increased by the addition of TDDs (Tubular Daylighting Devices). Conventional skylights have shallow convex top glazings and rectangular diffusely reflecting shafts, whereas TDDs have smaller, hemispherical top glazings and cylindrical, highly reflective shafts. The solar transmittances of the two types are different and special equations are included in AccuRate's simulation engine to account for TDDs.

Roof windows are a new category of skylights that have been added to AccuRate. They are treated in the same way as windows, except that they can be tilted off the vertical, and are embedded in roofs rather than walls.

Comparison of skylight solar heat gains

To illustrate the differences between the NatHERS and AccuRate skylight models, the AccuRate solar heat gains through a conventional 1 m^2 skylight were calculated as a function of various parameters for a skylight located in Canberra at 12 noon on 1 January. For NatHERS, the solar heat gain was 655 W. The AccuRate solar heat gains for the various parameters are compared in Table 2. The results show that even a modest shaft length significantly reduces solar heat gains to the zone lit.

Table 2. AccuRate calculations of heat gains from a conventional 1 m^2 horizontal single-glazed clear skylight with a shaft reflectance of 0.75.

	Heat gain to zone lit (W)	
Shaft length (m)	**With bottom diffuser**	**No bottom diffuser**
0.1	591	789
0.5	453	604
1.0	324	432

Dependence of air gap resistances on heat flow direction

Insulation products that rely on low-emissivity surfaces, such as reflective foil laminates, are commonly used, especially in walls and roofspaces. Their performance is entirely context-dependent, especially where non-vertical reflective air gaps are created in a construction. In such cases the air gap thermal resistance depends strongly on the direction of heat flow (up or down), as well as on other factors such as the temperatures and emissivities of the facing surfaces and the gap width. An example of this dependence is shown in Table 3.

Table 3. Typical thermal resistance of a sealed horizontal air gap as a function of heat flow direction and emissivity. The air gap is 90 mm wide. Surface 1 always has an emissivity of 0.90.

	Air gap thermal resistance	
Emissivity of surface 2	**Heat flow up (m^2.K/W)**	**Heat flow down (m^2.K/W)**
0.90	0.15	0.18
0.20	0.33	0.58
0.05	0.46	1.27

The NatHERS software did not account for the dependence on heat flow direction, nor did it allow the user to vary the surface emissivities or thicknesses of air gaps. AccuRate takes into account the following parameters:

- Width of gap
- Emissivity of each surface
- Heat flow direction
- Angle from horizontal

At each hour, AccuRate calculates the surface temperatures of each non-vertical air gap, establishes the direction of heat flow, and uses the appropriate value of thermal resistance. While the air gap resistance also depends on the temperature difference across the gap and the mean temperature, the values used in AccuRate do not depend on these parameters, but are fixed at reasonable values. The software could be further refined by calculating the air gap resistance at each time step according to the actual values of the surface temperatures, rather than using fixed resistances. However, doing so would increase the calculation time, and the additional accuracy obtained may well be illusory given the difference between real installations and the idealising assumptions inherent in such calculations.

To illustrate the effect of adjusting air gap resistances as a function of heat flow direction only, a lightweight house with a roof insulated only with a highly reflective horizontal air gap, and no roofspace, was simulated in Townsville. For this air gap the heat flow up resistance was 0.49 m^2.K/W, while the heat flow down resistance was 1.57 m^2.K/W. Table 4 compares the annual total (heating+cooling) energy calculated with the air gap resistance depending on heat flow direction, or with the resistance fixed to the heat flow up value, or fixed to the heat flow down value.

Table 4. Total energy for a lightweight house in Townsville as a function of roof air gap resistance characteristic

Air gap resistance	**Total energy (MJ/m^2)**
Depends on heat flow direction	370.0
Always up	442.3
Always down	352.7

As might be expected in this climate, fixing the resistance to the up value gives a significant error, but even fixing it to the down value, which would occur most of the time, gives a error of about 5%.

Additional zones

As noted in the introduction, the NatHERS software was limited to four habitable zones, of which three could be conditioned. This has turned out to be too restrictive, especially for two-storey houses where upstairs rooms must be zoned separately from downstairs rooms. The AccuRate simulation engine can accommodate up to 99 zones. However, the user interface often creates special zones not apparent to the user, and so the number of user zones available is less than 99. The current recommendation for AccuRate users is to limit the number of user zones to 20. This not only allows for special zones, but also ensures that calculation times are not too long. Twenty or so zones should be ample for describing even complex dwellings.

In AccuRate, all zones that are not of type roofspace or sub-floor can be independently conditioned. However, when the software is in rating mode, zones of type Living, Living/Kitchen, or Bedrooms are automatically conditioned.

Effect of house size

Because the sum of the annual heating and cooling energy requirements divided by the conditioned floor area is used as the basis for the star rating, large dwellings tend to achieve higher ratings than otherwise-similar small dwellings. This is because the energy requirements essentially depend on the total surface area, but the rating is based on the floor area. Because a large dwelling has a smaller ratio of total surface area to floor area, its MJ/m^2, and hence its rating, will tend to be better. This is an undesirable effect since it can be seen as encouraging large dwellings, which, other things being equal, will consume more energy than small dwellings. It was dealt with in the FirstRate software (but not unfortunately in the NatHERS software) by adding an adjustment, based on conditioned floor area and location, to the MJ/m^2 obtained from the simulation engine, and then calculating the star rating. The adjustment was zero for dwellings with a conditioned floor area of about 200 m^2, positive for larger areas and negative for smaller areas. Unfortunately the adjustment only depended on conditioned floor area, and not on the total energy. In extreme cases this could have led to the adjustment being larger than the total calculated energy.

Thus for AccuRate, an adjustment *factor*, F, that depends on the conditioned floor area and location, is calculated according to an AGO-commissioned study (Isaacs, 2005). If E is the total energy calculated by the simulation engine, then the area-adjusted energy used to establish the star rating is $E(1 - F)$. Figure 2 shows an example of the factor for the Brisbane climate. The applicable range of floor areas is 50 m^2 to 1000 m^2. The effect can be substantial: for example, for a 100 m^2 house the adjustment factor will decrease the MJ/m^2 by about 15%. Similarly, for a so-called 'McMansion' house of 400 m^2, the adjustment factor will increase the MJ/m^2 by 20%.

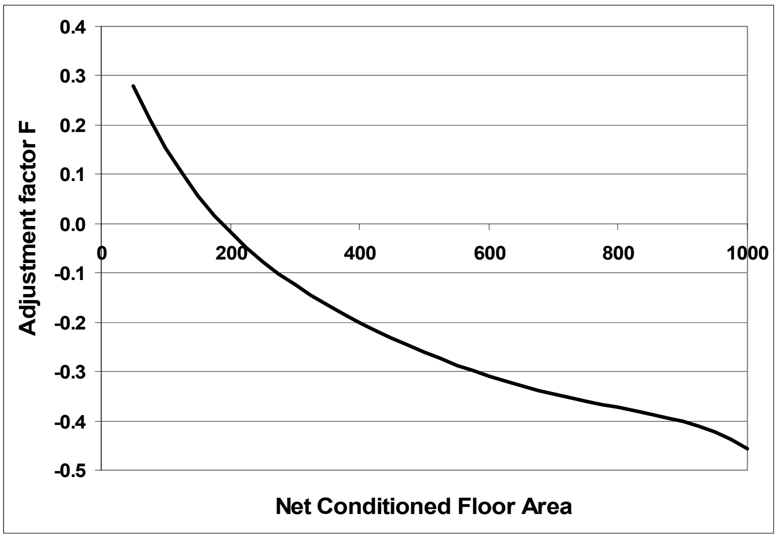

Figure 2. Area adjustment factor for Brisbane

BESTEST VALIDATION

In 2004 the AccuRate simulation engine was tested using the International Energy Agency BESTEST protocol (Delsante, 2004). BESTEST involves comparing a candidate program with the results from a set of eight 'reference' programs from Europe and the USA, for a carefully chosen series of variations of a simple and meticulously described test building. BESTEST is a very powerful tool for revealing program bugs or deficiencies: if the candidate program differs significantly from the reference results for a particular building variation, it is very likely that the candidate program is deficient in some way, and the nature of the variation can give a good indication of where to start looking.

Building variations include changing the mass of the building, rotating the building, and shading the windows. Only a few examples of the results can be given here. Figures 3 and 4 give the results for annual heating energy, while Figures 5 and 6 give the results for annual cooling energy (note that because Denver weather data was used, south windows face the equator). In these figures the acceptable ranges are shown by horizontal lines. In some cases acceptable ranges were not set by BESTEST, while in others one of the reference programs was excluded from determining the ranges. BESTEST did not test natural ventilation modelling (mainly because natural ventilation models were not available in most of the reference programs when the tests were first designed). The most relevant test case involved a sudden specified increase in the ventilation on a hot day at 1900. The results are shown in Figure 7.

Overall the BESTEST comparisons were very satisfactory. Cooling energy predictions tended to be at the high end of the reference program ranges, especially for high-mass buildings and for night setback (i.e. a lower thermostat setting at night). The process revealed one minor bug in the AccuRate engine, illustrating the power of the method.

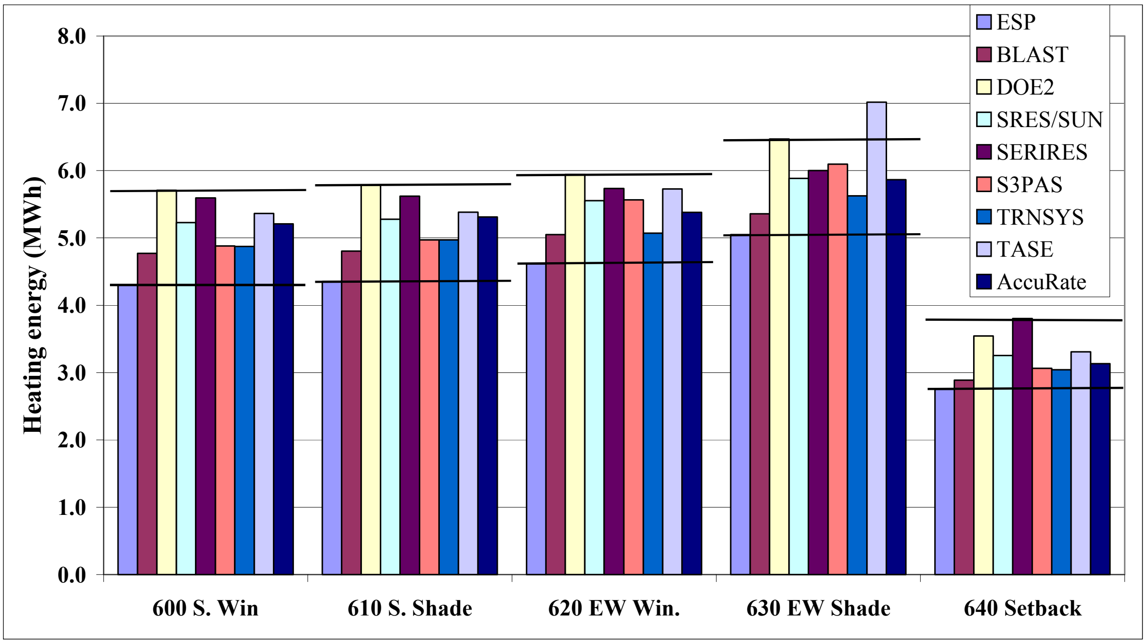

Figure 3. BESTEST comparisons of low-mass annual heating energy. The reference program ranges are shown as horizontal lines.

CONCLUSIONS

In developing AccuRate, a serious effort was made to address the limitations of the NatHERS software. The key improvements have been described in this paper, and numerous other improvements have also been implemented. With respect to natural ventilation modelling, it is important to bear in mind that this presents a very difficult challenge for any software that must calculate, in as short a time as possible, hourly temperatures and heating and cooling energies in multizone buildings for 8760 hours. It is still a subject of research.

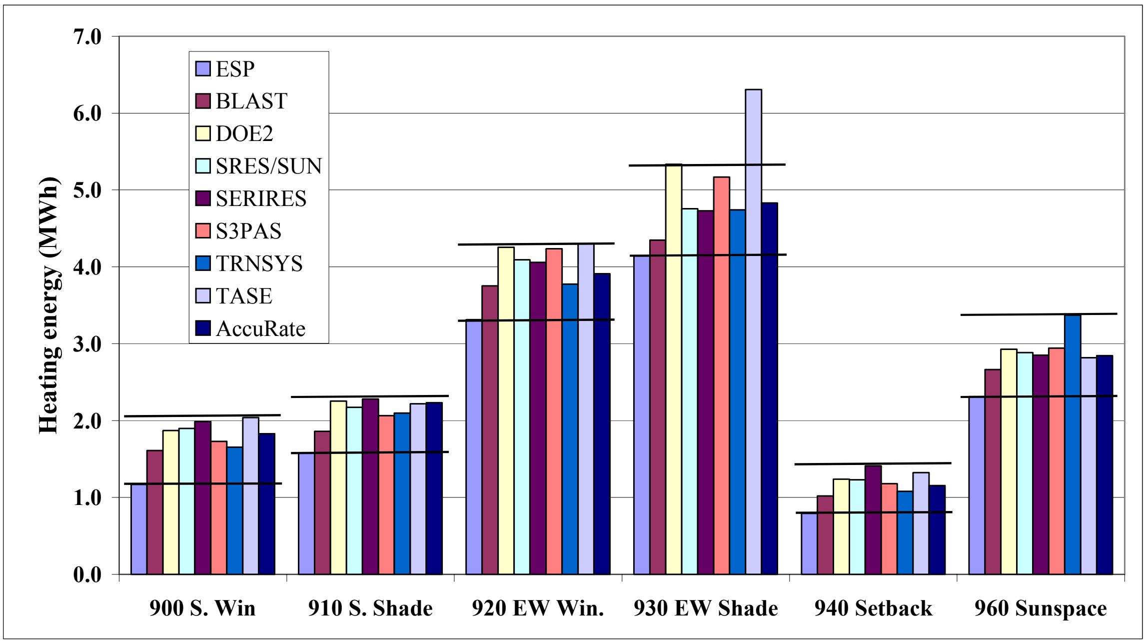

Figure 4. BESTEST comparisons of high-mass annual heating energy. The reference program ranges are shown as horizontal lines.

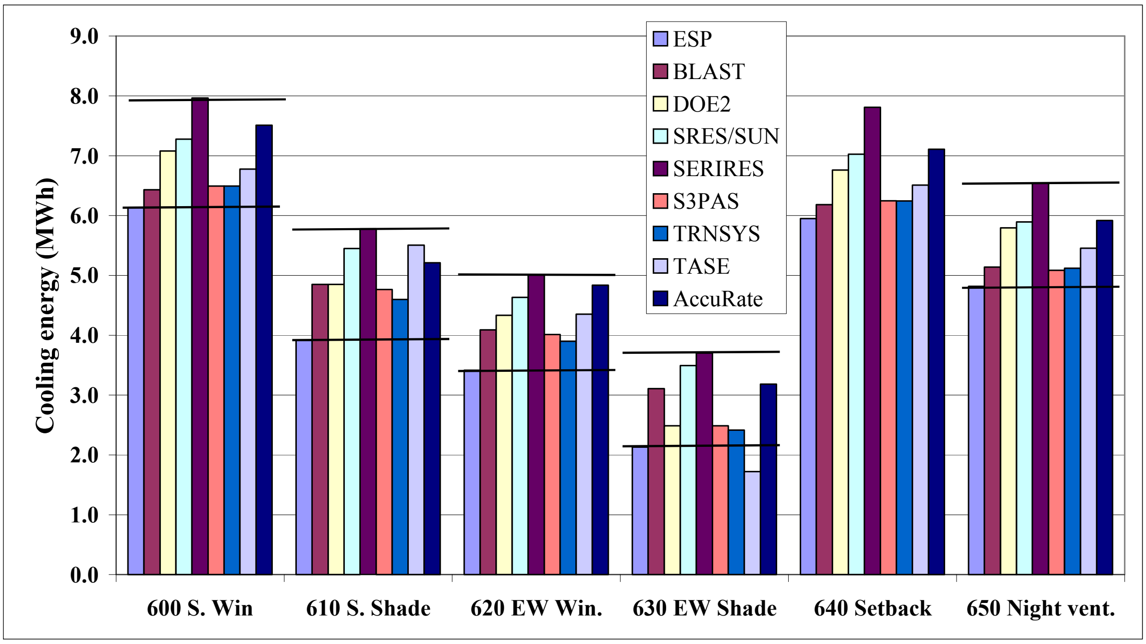

Figure 5. BESTEST comparisons of low-mass annual cooling energy. The reference program ranges (where set) are shown as horizontal lines.

With improvements come some costs. For example, it is important to separate rooms that, if combined into one zone, would create a cross-ventilation potential that does not in fact exist. But increasing the number of zones in the model increases the data entry time and the execution time. Greater user control over the building description, for example the ability to create new constructions, increases the potential for error, or the possibility that required information is not known. The former problem can be minimised by training (and AccuRate already has an extensive Help file which will be

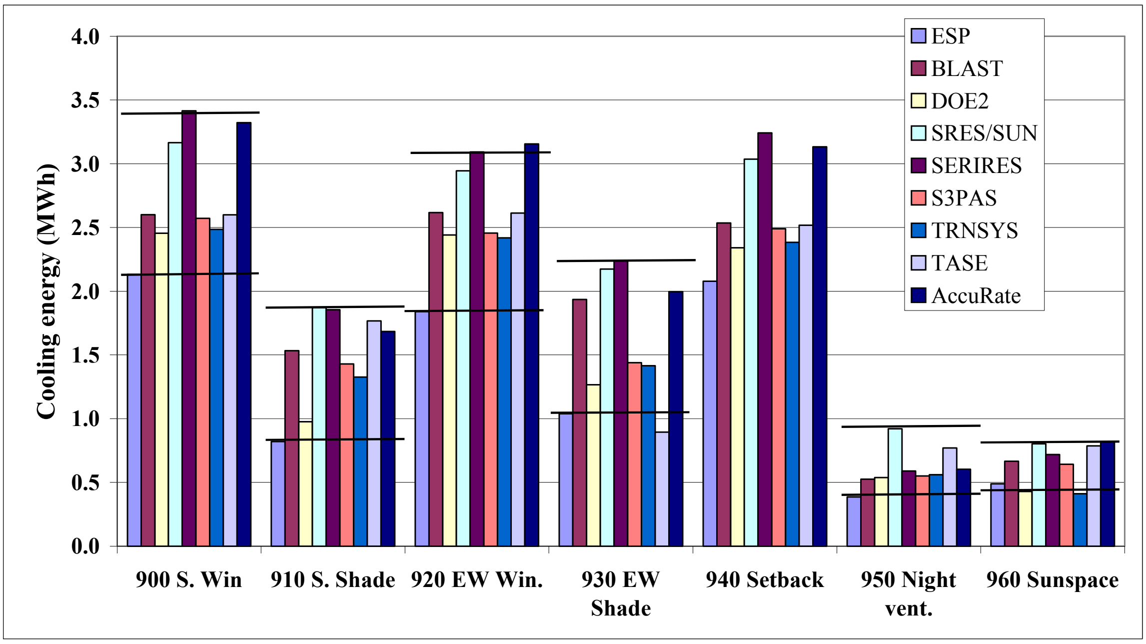

Figure 6. BESTEST comparisons of high-mass annual cooling energy. The reference program ranges (where set) are shown as horizontal lines.

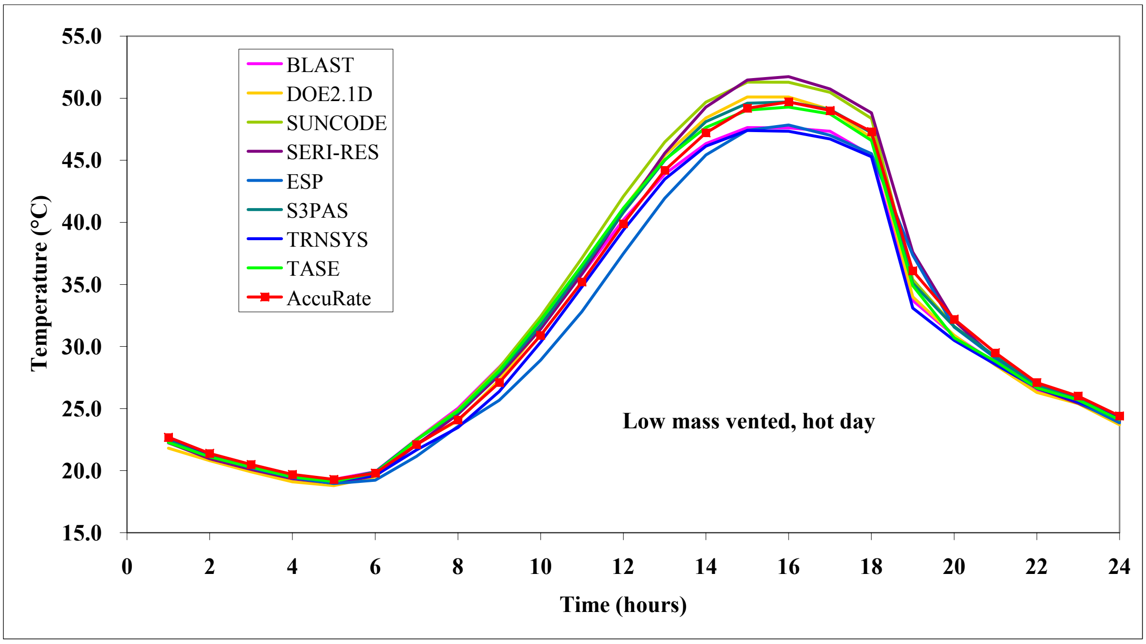

Figure 7. BESTEST comparisons of indoor temperatures in a low-mass unconditioned building on a hot day, with a sudden increase in ventilation rate at 19:00 hours.

regularly updated), while the latter problem can be dealt with by guidelines, defaults, or, if necessary, freezing certain parameters for rating purposes.

During the latter stages of its development AccuRate has been used to simulate many real dwellings, some of them quite complex. While some simplifications and compromises had to be made, no major problems were encountered. As with any tool or rating system, there will be some buildings or building features than cannot be adequately handled, but AccuRate is up to the task of modelling the vast majority of dwellings.

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REFERENCES

Auliciems, A. (1981). “Towards a Psycho-Physiological Model of Thermal Perception”. Int. J. of Biometeorology, 25, 190-122.

Aynsley, R.M. and Szokolay, S.V. (1998). “Options for assessment of thermal comfort/discomfort for aggregation into NatHERS star ratings”. James Cook University Report.

Dascalaki, E., Santamouris, M., Argiriou, A., Helmis, C., Asimakopolous, D.N., Papadopolous, K., and Soilemes, A. (1995). “Predicting Single-Sided Natural Ventilation Rates in Buildings”. Solar Energy 55(5), 327-341.

de Dear, R.J. and Schiller Brager, G. (1998). “Developing an Adaptive Model of Thermal Comfort and Preference”. ASHRAE Trans., Vol .104(1A), 145-167.

Delsante, A. (2004). “A Validation of the AccuRate Simulation Engine Using BESTEST”. Report to the Australian Greenhouse Office. CSIRO Manufacturing & Infrastructure Technology report, CMIT(C)-2004-152.

Isaacs, T. (2005). Report to Australian Greenhouse Office on area correction factors.

Li, Y., Delsante, A.E. and Symons, J.G. (2000). “Prediction of Natural Ventilation in Buildings With Large Openings”. Building and Environment 35, 191-206.

Ober, D.G. and Wilkes, K.E. (1997). “An Energy Calculation Model for Attics, Including Radiant Barriers”. Final report for ASHRAE Research Project RP717.

Swami, M.V. and Chandra, S. (1988) “Correlations for Pressure Distribution of Buildings and Calculation of Natural Ventilation Airflow”. ASHRAE Transactions, Vol. 94(1), 243-266.

Szokolay, S.V. (2000). “Dilemmas of Warm-Humid Climate house Design: Heavy vs. Lightweight + Cooling Effect of Air Movement”. Proc. PLEA 2000, Cambridge, UK, 144-149.

Szokolay, S.V. (2003). Private communication.