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Estimated fuel savings for a passive solar timber drying kiln in Australia

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ABSTRACT

The fuel savings of a solar kiln with supplemental heating, compared with a conventional kiln (fossil fuel heating only) running the same drying schedule, were estimated for 30 sites around Australia, using regressions developed by Tschernitz (1986). The annual fuel savings varied from a low of 2 per cent at Hobart to a high of 38 per cent at Darwin for a 22 m^3 capacity kiln. By simulated addition of extra insulation (R=1.76) to the transparent surfaces at night-time, the annual fuel savings increased to 28 per cent and 56 per cent for Hobart and Darwin, respectively. Fuel savings for a solar kiln of 84 m^3 capacity were similar. In general, fuel savings for the lower southern parts of Australia were of no practical use for solar kilns without extra night-time insulation. Kilns in lower southern parts with extra night-time insulation, or kilns of either type in the remainder of Australia, had estimated fuel savings which were of practical significance. As an example in evaluating the significance of solar kilns, an 84 m^3 solar kiln with extra night-time insulation was estimated to save \$26 050 in electricity or \$10 357 in gas heating annually in Perth. The same solar kiln was also estimated to reduce CO_2 emissions by 41 tonnes annually when heating with gas.

INTRODUCTION

In recent times CALM has received an increasing number of enquiries for solar kilns from timber producers in Western Australia, the eastern states of Australia, and Fiji. Three sawmillers in W.A. are now using CALM solar assisted kilns operationally to dry hardwoods, and three more are considering them. One sawmiller is performing operational trials upon softwood. The managers of these sawmill firms were able to see the solar kilns at the Wood Utilisation Research Centre, Harvey and assesss their performance first hand. With enquiries coming from further afield it is increasingly difficult to estimate performance because of the different climates involved.

The performance of solar kilns has been measured by several researchers in various locations around the world (Little 1984; Simpson and Tschernitz 1989), but the information available to date is insufficient to make generalizations upon new sites or new kiln designs. One measure of performance for a kiln which has supplemental heating is the proportion of heat provided by solar radiation (the solar fraction). In Sri Lanka a solar kiln with a timber capacity of 16 m^3 with a wood fired burner had a solar fraction of 48 per cent during the dry season (Simpson and Tschernitz 1989). Measurements of a large commercial kiln in Mississippi, U.S.A. with 1.05 m^2 of water solar collectors per m^3 of kiln capacity revealed a 22 per cent solar fraction over 6 months (Little 1984). Other performance ratings, such as drying efficiency, also have large ranges (Plumptre 1985).

We needed a study of possible solar contribution to the heat requirements of a kiln which would give at least a performance comparison between Harvey and other locations around Australia. This study is based primarily upon the work of Tschernitz (1986) where regressions between fuel savings and climatic conditions were developed from detailed heat load calculations for nine U.S.A. locations. Although these regressions were derived for only two kiln designs, one species (commercial red oak (*Quercus* sp.)), one thickness (25 mm) and are theoretically based, they can be used as a first approximation for solar kiln performance or inter-site comparisons.

The efficiency or performance of a solar kiln was stated by Plumptre (1985) to depend upon:

1. Latitude.
2. Climate—temperature, humidity and insolation.
3. Initial and final moisture contents of the charge.
4. Species and permeability of the timber.
5. Thickness of timber, size of stickers and shape of stack.
6. Design of kiln.

One other factor this author would also consider is:

7. Drying schedule

With this multitude of factors it is very difficult to estimate the performance of a solar kiln for a particular operation and location. As stated previously, this study is based largely on the methods of Tschernitz (1986), and attempts to reduce the complexity of the performance question by estimating kiln fuel savings, knowing the climate and latitude of the location. The estimates are performed for two specific kiln designs, while keeping factors 3, 4, 5 and 7 constant.

SITES AND CLIMATIC DATA

Thirty sites around Australia were chosen to give a broad coverage of areas that possess existing timber resources and for which sufficient climatic data were available. A few sites that are remote from log production forests were included to allow interpolation. Other sites can be evaluated with the procedure described below if sufficient climatic data are available[1].

Three climatic factors were used in this study: mean monthly values of total solar radiation, absolute humidity and temperature. These climatic factors were not available for a sufficient number of regional sites and thus estimation techniques were used from the available data to allow inclusion of some sites in this study. Mean monthly minimum and maximum temperatures were available for all sites, and their arithmetic mean was used as the mean monthly temperature of the site.

Where solar radiation data is not available it is commonly estimated from the mean monthly sunshine hours using the modified Angstrom equation (Reddy 1987):

$$\frac{\overline{H}}{\overline{H}_0} = a + b\frac{\overline{n}}{\overline{N}}$$

where $\overline{H}$ = mean monthly solar radiation on a horizontal surface
$\overline{H}_0$ = mean monthly extraterrestrial radiation for the site
a,b = empirical constants for the site
$\overline{n}$ = mean monthly hours of bright sunshine
$\overline{N}$ = mean monthly maximum of bright sunshine hours (i.e. the day length of the average day of the month)

Day length and extraterrestrial radiation are calculated from the latitude as described by Reddy (1987).

There are several ways of using this modified Angstrom equation; which are differentiated by the technique used to estimate the empirical constants. One may estimate the coefficients from world-wide correlations (Samuel 1991) or use coefficients from a nearby site with a similar climate. The accuracy of estimates from nearby sites has been questioned by Reddy (1987) and Duffie and Beckman (1991). Duffie and Beckman (1991) gave an example of estimating Madison's solar radiation from constants from the nearest meteorological station (Blue Hill), resulting in a 22 per cent discrepancy from the yearly average solar radiation measured at Madison. Even with this known inaccuracy the modified Angstrom equation is useful because of the sparseness of solar radiation data.

Initially the intention in this study was to use constants derived at each capital city for other sites in the State. This method was rejected because the relationships were not available in the literature and paired monthly values of solar radiation and bright sunshine hours were not readily available. It was decided to use the next best: mean empirical constants derived from six Australian sites over eight to fifteen years (Hounam 1969). The mean empirical constants from that Australian study (0.27 and 0.50 for *a* and *b*, respectively), were applied to the 13 sites where only sunshine hours data were available (Appendix 1).

Most sites chosen for this study had mean monthly relative humidity values at 9 a.m. and 3 p.m. only. The arithmetic mean of these two values is not necessarily the true daily mean. Erbs *et al.* (1985) described the diurnal fluctuation of relative humidity of nine United States locations as a Fourier series:

$$\overline{RH_h} = \overline{RH_d} + A(0.4672\cos(t'-0.666) + 0.0958\cos(2t'-3.484) + 0.0195\cos(3t'-4.147) + 0.0147\cos(4t'-0.452))$$

where $\overline{RH_h}$ = mean monthly relative humidity at a particular hour of the day
$\overline{RH_d}$ = mean monthly relative humidity for all hours of the day
A = mean monthly amplitude of relative humidity
t' = dimensionless time
$= 2\pi(t-1)/24$

OR expressed as

$$\overline{RH_h} = \overline{RH_d} + f_t A \qquad (1)$$

where f_t = time factor at hour t
$= 0.4672\cos(t'-0.666)$
$+0.0958\cos(2t'-3.484)$
$+0.0195\cos(3t'-4.147)$
$+0.0147\cos(4t'-0.452)$

By evaluating equation (1) for the two times of the day one obtains:

$$\overline{RH_{t1}} = \overline{RH_d} + f_{t1} A \qquad (2)$$
$$\overline{RH_{t2}} = \overline{RH_d} + f_{t2} A \qquad (3)$$

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[1] Smoothed, interpolated data may be generated for any Australian site by the ESOCLIM package (available from the Centre for Resources and Environmental Studies, Australian National University).

By substituting equation (3) into (2) and rearranging one obtains an equation for the monthly mean:

$$\overline{RH_d} = (\overline{RH_{t1}} - \frac{f_{t1}}{f_{t2}}\overline{RH_{t2}})/(1 - \frac{f_{t1}}{f_{t2}}) \qquad (4)$$

OR $$\overline{RH_d} = (\overline{RH_9} + 0.246\overline{RH_{15}})/1.246 \qquad (5)$$

where $f_{t1} = f_9 = 0.128$
$f_{t2} = f_{15} = -0.520$

Equation (5) was used to estimate the mean monthly relative humidity for those sites where the local time was equivalent to solar time. It is solar time upon which the diurnal variation of relative humidity is dependent. Where the local time differed by 15 mins or more from solar time the time factors were evaluated with the true solar time entered into equation (4). No compensation was made for the relatively recent and irregular 'daylight saving' practice (where local time is brought forward an hour in some States during summer). Finally, the estimated mean monthly relative humidity values were converted to absolute humidity using ASHRAE (1985) equations.

The validity of using Erbs *et al.* (1985) equation was examined by comparing relative humidity (RH) averaged from 3-hourly readings (Bureau of Meteorology, 50 years of records) with those estimated by equation (4) from two times per day for the same period, for two sites in Australia (Table 1). The estimated mean RH for the months varied from correct to as poor as 7 RH percentage units less than the 3-hourly calculated mean. Sydney was estimated better than Perth (Belmont AMO), with annual RH errors of 2 and 6 RH percentage units, respectively. The influence of these changes upon the yearly fuel savings (using the technique described below) was assessed for the two sites. The fuel savings changed from 40.7 and 31.9 per cent for estimated RH means to 40.3 and 31.7 per cent for the calculated RH means, for a 84 m^3 kiln with extra night-time insulation in Perth and Sydney, respectively. For this study where average yearly performance is the most important outcome these errors in the mean RH are tolerable.

The sources of climatic data and the various estimation techniques used are specified for each site in Appendix 1.

Calculation Method for Fuel Savings

To calculate the amount of fuel saved by using a solar kiln with supplemental heating, one needs to calculate the energy demand (wood drying and heat losses) and the energy supplied from solar heating. The ambient weather conditions, knowledge of the kiln's size and construction, the kiln's setpoints plus the rate of drying are all required for this calculation. To be very accurate these factors must be calculated over short time periods, normally hourly. These calculations are understandably complex and time consuming, even when performed on digital computers. Confounding the problem is that each species, timber thickness, drying schedule, kiln size and insulation alters the outcome. Obviously, one needs to simplify and select certain parameters to reduce the calculation load.

Tschernitz (1986) performed the energy calculations and fuel savings for a reduced set of combinations of kiln and other parameters. Specifically, Tschernitz performed calculations on one species (commercial red oak), one thickness (25 mm) and one drying schedule (low temperature, 28 days long) for six kiln sizes in nine locations in the United States of America using a time step of one day. The effect of insulating the solar collecting surfaces at night was also calculated.

Fuel savings in this paper are **not** expressed as the amount of solar heat absorbed in the solar kiln because one needs to account for the greater heat loss of the solar kiln through the transparent surfaces (which have lower insulation values than conventional kiln walls, as discussed below). The percentage of fuel saved refers to the reduction of the heat load of a conventional kiln by substitution with a solar kiln;

$$\text{Fuel savings} = \frac{Q_m}{Q_c - Q_p} = \frac{Q_{sg} - (Q_s - Q_c)}{Q_c - Q_p} \text{x}100 \quad (6)$$

where Q_c = conventional heat load including Q_p
Q_p = electric fan power
Q_s = solar kiln heat load (i.e. for wood drying and heat losses)
Q_{sg} = solar gain (i.e. amount of energy absorbed from solar radiation)
Q_m = net solar gain (or loss) = $Q_{sg} - (Q_s - Q_c)$

The theoretical kiln considered was a conventional rectangular prism shape with solar collecting surfaces incorporated into the structure of the kiln on the roof, north (i.e. converted for southern hemisphere), east and west walls (Fig. 1).

The thermal resistance (R value) of the opaque slab, opaque walls and the night-time insulated transparent walls or roof was assumed to be 1.76 m^2.K/W (0.1 Btu/(ft^2.h.°F)) and similarly an R value of 0.23 m^2.K/W (0.75 Btu/(ft^2.h.°F)) for the uninsulated, transparent surfaces. The transparent surfaces were assumed to have a solar transmission of 85 per cent. The actual construction details were left to the kiln builder to decide.

Although the collectors in this study have been referred to as passive, they are better described as a hybrid type because air is blown across the absorber surface by fans, but the size and orientation of the absorbers is determined by the kiln's shape. Thus the system does not have the design freedom, nor performance, of a kiln with external collectors (an active system).

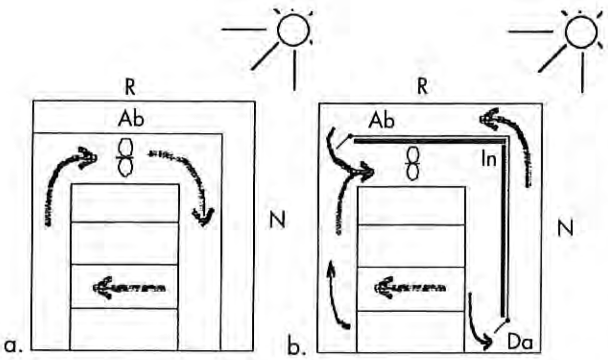
From the nine locations Tschernitz (1986) developed regressions relating fuel savings to the ambient conditions (temperature, humidity and solar radiation) and kiln characteristics (size and use or not of night-time insulation). Thus it is now possible to

TABLE 1

Comparison of estimated mean relative humidity with calculated mean relative humidity (per cent) for two sites.

BELMONT AMO (PERTH)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN	53	53	56	64	72	78	78	75	72	67	61	58	66
EST.	50	50	53	61	66	71	71	68	65	61	56	53	60
ERROR	-3	-3	-3	-3	-6	-7	-7	-7	-7	-6	-5	-5	-6
SYDNEY													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN	71	73	73	71	71	71	67	64	64	65	67	69	69
EST.	69	72	71	70	71	71	65	63	61	63	64	66	67
ERROR	-2	-1	-2	-1	0	0	-2	-1	-3	-2	-3	-3	-2

Mean = arithmetic mean of the eight (3-hourly) values of RH from the Bureau of Meteorology (%).
Est. = weighted mean from 9 a.m. and 3 p.m. values of RH from the Bureau of Meteorology (%) using the technique from Erbs *et al.* (1985).



Where R = roof
Ab = absorber surface for solar radiation
In = insulation material
N = north wall (in southern hemisphere)
Da = damper

Figure 1. Theoretical kiln designs comparing the effects of (a) no night-time insulation and (b) with extra night-time insulation. After Tschernitz (1986).

predict the amount of fuel saved by using a solar kiln if the mean monthly values of temperature, absolute humidity and solar radiation and the latitude are known. The form of Tschernitz's equation is:

$$\text{Fuel savings} = a_0 + a_1T + a_2S + a_3H + a_4L \quad (7)$$

where $a_0 - a_4$ = coefficients for each kiln size, insulation and month
T = mean monthly temperature (°F)
S = mean monthly solar radiation on a horizontal surface (Btu/ft^2.day)
H = mean absolute humidity (lb water/lb air)
L = latitude (degrees)

These regressions were used in this study to estimate the fuel savings for kilns with timber capacities of 22 m^3 or 84 m^3, with or without night-time insulation for thirty locations in Australia using Equation (7). The mean monthly climatic values were obtained or estimated as described above, and the fuel savings calculated for each month for each of the four kiln size/types[1], using the coefficients derived by Tschernitz (1986) (included here as Appendix 2).

Estimated Fuel Savings

The estimated average annual fuel savings for the four kiln types are presented for the south-west of Western Australia (Fig. 2) and for eastern Australia (Fig. 3). For kiln type 1 (22 m^3, no extra night-time insulation) the annual fuel savings varied from a low of 2 per cent at Hobart to a high of 38 per cent at Darwin. For kiln type 3 (22 m^3, with extra night-time insulation) the fuel savings varied from 28 per cent at Hobart to 56 per cent at Darwin. The fuel savings of kiln types 2 and 4 (84 m^3 kilns, with and without extra night-time insulation) have similar values. The full set of climatic data and fuel savings are given in Appendix 3 for all thirty sites. Thus, the fuel savings of a solar assisted kiln without extra night-time insulation is insignificant in the lower southern parts of Australia (such as southern Victoria and Tasmania) while all other kiln types and locations represent fuel savings of practical significance.

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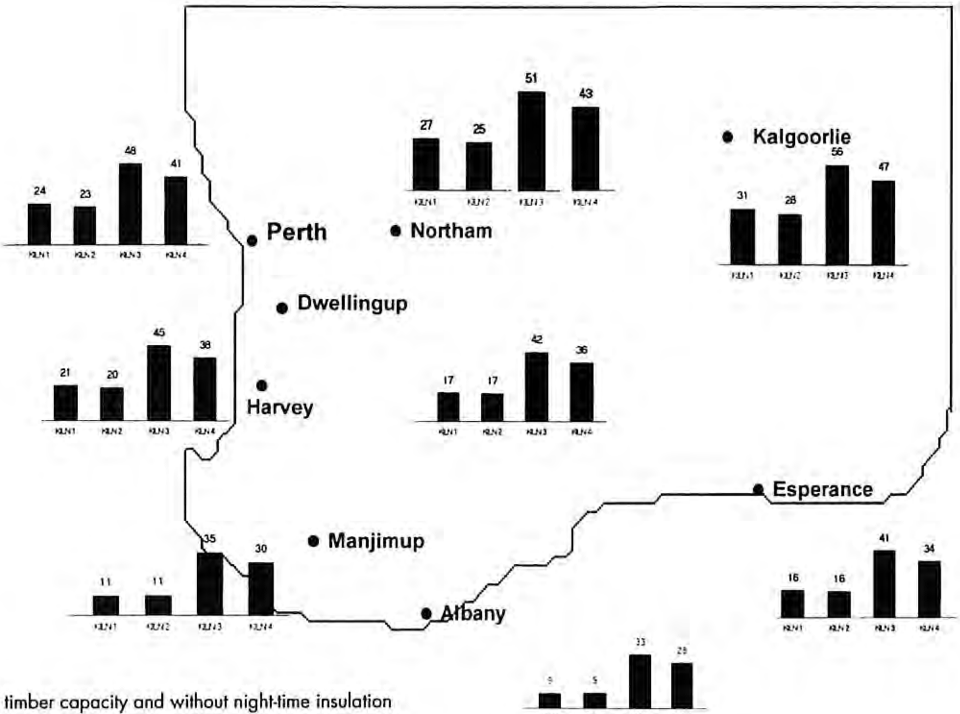
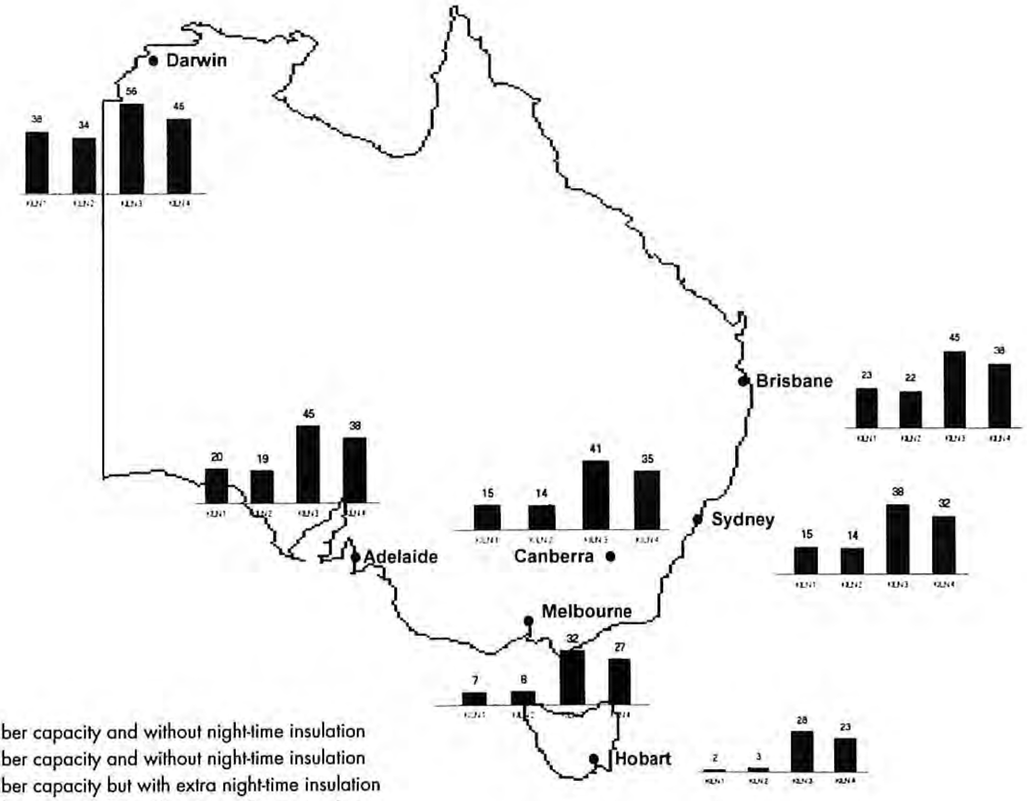
[1] From here on referred to simply as a kiln type.



Where

Kiln 1 is 22 m³ timber capacity and without night-time insulation
Kiln 2 is 84 m³ timber capacity and without night-time insulation
Kiln 3 is 22 m³ timber capacity but with extra night-time insulation
Kiln 4 is 84 m³ timber capacity but with extra night-time insulation

Figure 2. Performance of solar assisted kilns in south-western Australia—per cent fuel savings when compared with non-solar kilns.



Where

Kiln 1 is 22 m³ timber capacity and without night-time insulation
Kiln 2 is 84 m³ timber capacity and without night-time insulation
Kiln 3 is 22 m³ timber capacity but with extra night-time insulation
Kiln 4 is 84 m³ timber capacity but with extra night-time insulation

Figure 3. Performance of solar assisted kilns in eastern Australia—per cent fuel savings when compared with non-solar kilns.

From Figures 2 or 3, it can be clearly seen that extra night-time insulation provides a marked improvement upon fuel savings. As an example, night-time insulation for a 22 m^3 kiln in Perth improves fuel savings from 24 per cent to 48 per cent.

The monthly variation of fuel savings for kiln type 1 is less for the northern site of Brisbane compared with the southern site of Perth (Fig. 4) owing to the less variable climate of Brisbane. Similar annual patterns are revealed for kiln type 3, although the annual variation is less and the fuel savings of higher value (Fig. 5). Figure 4 shows the fuel savings for Perth drop to a negative value (–1 per cent) for June – a situation in which more supplementary heat is required for a solar assisted kiln than a conventional kiln. This situation occurs for other southern sites in winter months for kiln types 1 and 2 (i.e. no extra night-time insulation) (Appendix 3). The larger the annual variation the greater the required capacity of the supplementary heater.

How to Use these Estimates

Because the estimates in this study are based upon theoretical principles without verification from actual kilns, caution must be exercised in their usage. As the calculation method is the same for all sites, consideration of the differences between sites is likely to be of greater accuracy than the accuracy of the actual, or absolute, performance values. This inference will be of great benefit when data on performance of actual kilns in Australia become available.

For now, the estimates can be used to assess the general feasibility of a solar style of kiln. Fuel savings in dollars can be estimated by:

Annual saving (\$) = Per cent fuel savings x annual heat load x fuel price

As an example, the annual heat load for a conventional 84 m^3 kiln running the lower temperature solar schedule in Perth is 1.43×10^6 MJ (1420 MJ m^{-3} of timber, derived from Tschernitz (1986)). The annual fuel savings for a solar kiln with insulation would be \$26 050[1] when using electric heating elements or \$10 357[2] when using a direct-fired gas burner. This is equivalent to a reduction in CO_2 emissions of 176 t or 41 t[3] for electrical or gas heating, respectively.

Strictly speaking, the estimates provided and the feasibility assessment should only be applied to timber which dries in a similar manner to the 'commercial red oak' evaluated by Tschernitz (1986) and of the same thickness (25 mm). One may, with fair confidence, apply the above feasibility assessment to the drying of 25 mm boards of other species with a similar basic density to 'commercial red oak' (0.56 kg m^{-3} (Tschernitz and Simpson 1979)). It is logical to assume that even greater fuel savings are possible for thicker boards because the solar heat will provide a greater proportion of the lower heat load (owing to the slower drying).

Implications for other Kiln Designs

In designing a solar kiln, one needs to consider how the advantageous features of the Tschernitz (1986) generalized designs can be implemented. To obtain a similar performance to that estimated in this paper one requires an approximately equal area of absorber, and similar insulation values. The roof plus northern wall absorber area for the 22 and 84 m^3 kilns were 60 and 160 m^2, respectively. The thermal resistance (R) of the opaque walls and slab referred to in this paper was 1.76 $m^2.K.W^{-1}$, and 0.23 for the transparent roof and walls. The opaque wall insulation value can easily be achieved by 50 mm of fibreglass batts (R = 1.27 (ASHRAE 1989)) with an inflated twin plastic skin (R = 0.48 (Wong 1977[4])). Achieving the night-time insulation value of 1.76 $m^2.K.W^{-1}$ chosen by Tschernitz (1986) for the transparent surfaces with extra insulation can be difficult. If the insulation is stationary as shown in Figure 1, common insulation materials (batt or loose fill) can easily achieve the required value. However, if one needs to use a movable thermal screen due to the absorber being draped over the timber (as in the CALM Solar Assisted Kiln) the insulation value given above may not be achievable. An R value of approximately 0.5 can be expected from the thermal screen (Cotton and Bailey 1983). The total insulation value of the twin skin plus thermal screen (R=1.0) falls well short of that assumed in the calculations (R=1.76). Thus, the performance of kilns similar to the CALM Solar Assisted Kiln will be approximately midway between the night-time insulated and no night-time insulated kiln values calculated here.

CONCLUSIONS

This study has shown that heat load calculations can reveal much about the performance of a solar kiln. Assuming the method to be fairly accurate, the estimates of solar contributions in kilns at most of the Australian sites considered in this study, indicated considerable fuel savings by using a solar kiln. This is particularly so when using extra night-time insulation of a high insulation value, although achievement of such high values of insulation can be difficult in some kiln designs.

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[1] 397 600 kWh @ \$0.1598 x 41% fuel savings. SECWA 1992 tariffs.

[2] 1.43×10^6 MJ ÷ 3.6 MJ/unit ÷ 75% burning efficiency x \$0.0477/unit x 41%. SECWA 1992 tariffs.

[3] Using conversions of 0.3 and 0.07 tonnes of CO_2/GJ of end use energy, for electricity and gas respectively. (Western Australian Greenhouse Co-ordination Council 1991)

[4] Calculated for an air gap of 13 mm, effective emittance of IR modified polyethylene of 0.6, internal kiln temperature of 60°C and external temperature of 30°C.

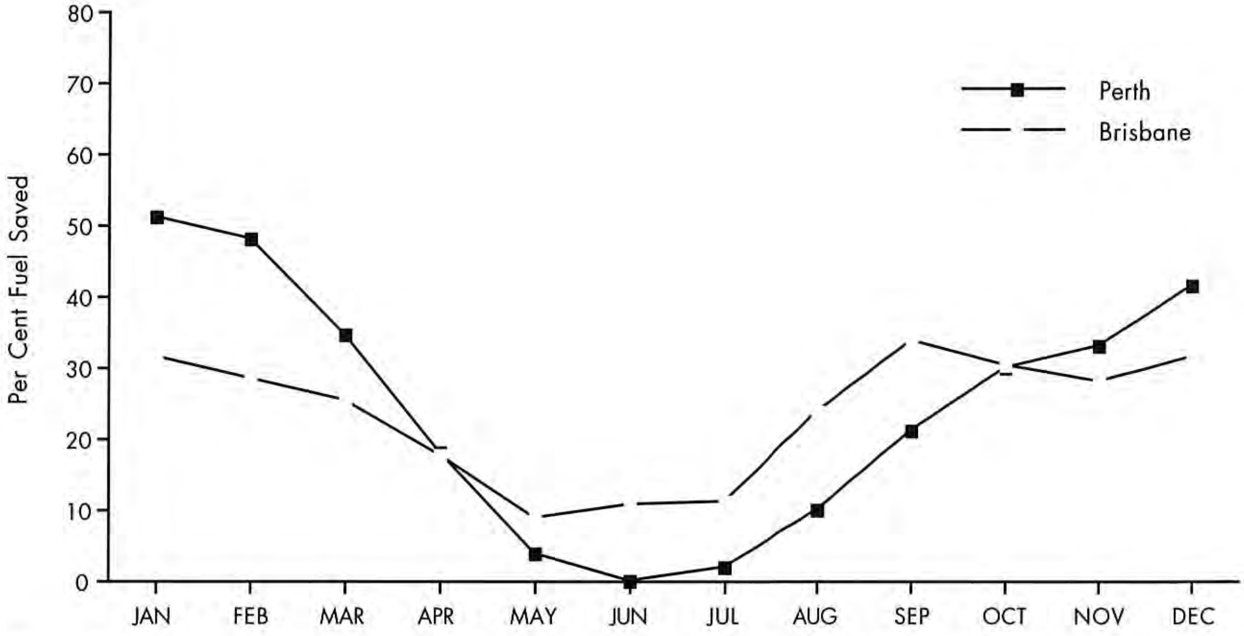

Figure 4. Estimated monthly variation of fuel savings in kiln type 1 (22 m³ and no night-time insulation) for Perth and Brisbane.

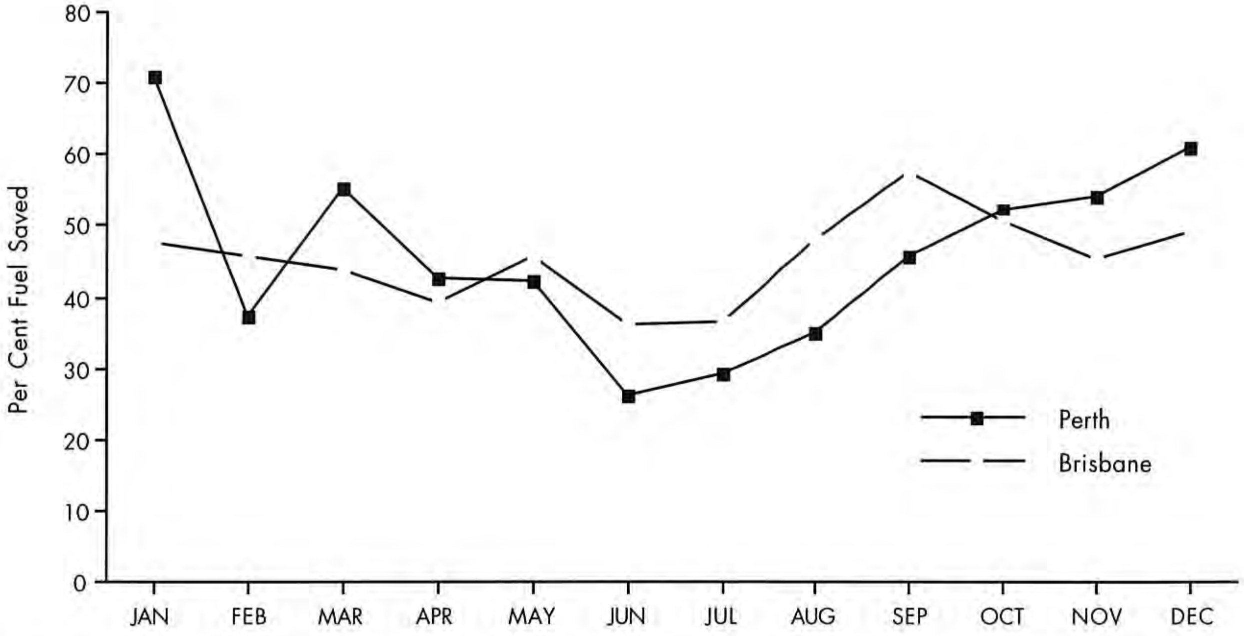

Figure 5. Estimated monthly variation of fuel savings in kiln type 3 (22 m³ but with extra night-time insulation) for Perth and Brisbane.

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REFERENCES

ASHRAE (1985). ASHRAE Handbook—Fundamentals. American Society of Heating, Refrigerating & Air-Conditioning Engineers Inc., Atlanta.

ASHRAE (1989). ASHRAE Handbook—Fundamentals. American Society of Heating, Refrigerating & Air-Conditioning Engineers Inc., Atlanta.

Cotton, R.F. and Bailey, B.J. (1983). A laboratory method for evaluating glasshouse thermal screen materials. National Institute of Agricultural Engineering, Silsoe, U.K. Divisional Note 1155. (unpublished).

Duffie, J.A. and Beckman, W.A. (1991). Solar engineering of thermal processes. John Wiley & Sons, New York.

Erbs, D.G., Klein, S.A. and Beckman, W.A. (1985). A simple distribution method for two-dimensional temperature/humidity bin data. *ASHRAE Transactions* **91**, 413–425.

Frick, R.A., Walsh, P.J., Rice, S.P. and Leadbeater, M. (1988). Australian solar radiation data handbook. Department of Primary Industries and Energy, Canberra.

Hounam, C.E. (1969). Revised regression equations for estimation of solar radiation over Australia. *Australian Meteorological Magazine* **17**, 91–94.

Little, R.L. (1984). Industrial use of solar heat in lumber drying: a long-term performance report. *Forest Products Journal* **34** (9), 22–26.

Plumptre, R.A. (1985). Solar drying kilns for sawnwood. *Forest Products Abstracts* **8** (2), 33–45.

Reddy, T.A. (1987). The design and sizing of active solar thermal systems. Clarendon Press, Oxford.

Samuel, T.D.M.A. (1991). Estimation of global radiation for Sri Lanka. *Solar Energy* **47** (5), 333–337.

Simpson, W.T. and Tschernitz, J.L. (1989). Performance of a solar/wood energy kiln in tropical latitudes. *Forest Products Journal* **39** (1), 23–30.

Tschernitz, J.L. and Simpson, W.T. (1979). Drying rate of northern red oak lumber as an analytical function of temperature, relative humidity, and thickness. *Wood Science* **11** (4), 202–208.

Tschernitz, J.L. (1986). Solar energy for wood drying using direct or indirect collection with supplemental heating: A computer analysis. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. Research Paper FPL – RP – 477. Madison, WI.

Western Australia Greenhouse Co-ordination Council (1991). Greenhouse strategy for Western Australia. Appendix D.

Wong, H.Y. (1977). Handbook of essential formulae and data on heat transfer for engineers. Longman, London.

APPENDIX 1

Source of climatic data and solar time adjustment for the thirty sites.

SITE	CLIMATIC DATA SOURCE	TIME ADJUSTMENT (hours)
W.A.		
Perth AMO	F	–0.25
Albany AMO	F	0
Kalgoorlie	F	0
Esperance	B	0
Manjimup	E	–0.25
Dwellingup	E	–0.25
Harvey	E*	–0.25
Northam	E	–0.25
N.T.		
Darwin	F	–0.73
QLD.		
Brisbane	F	0
Townsville	B	–0.25
Innisfail	B	–0.25
Rockhampton	F	0
Theodore	E	0
Warwick	E	0
N.S.W.		
Sydney	F	0
Wagga Wagga	F	0
Orange	E	0
Inverell	E	0
A.C.T.		
Canberra	F	0
S.A.		
Adelaide	F	–0.25
Mt Gambier	F	0
Kyancutta	E	–0.50
VIC.		
Melbourne	F	–0.33
Mildura	F	–0.50
Kyabram	E	–0.33
Sale East	E	0
TAS.		
Hobart	F	0
Launceston	E	0
Swansea	E	0

F = All climatic data from Frick *et al.* (1988).

B = All climatic data from the Bureau of Meteorology.

E = Temperature and relative humidity direct from the Bureau of Meteorology, solar radiation estimated from bright sunshine hours (Bureau of Meteorology) using the Hounam (1969) equation.

* = Relative humidity values from Bunbury (40 km SW of Harvey).

APPENDIX 2

Coefficients used for fuel savings estimates (Equation 7) – extracted from Tschernitz (1986). Six month adjustment made for the southern hemisphere.

KILN 1 22 m^3 Without night-time insulation

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
a0	−194.05	−186.48	−196.36	−140.90	−115.06	−75.76	−69.15	−73.90	−71.25	−84.80	−129.44	−157.15
a1	1.9259	1.8534	1.5451	1.1706	0.6970	0.4720	0.4139	0.4907	0.6904	1.0375	1.2783	1.5786
a2	0.0352	0.0366	0.0445	0.0450	0.0529	0.0534	0.0527	0.0491	0.0413	0.0306	0.0314	0.0314
a3	−1274.6	−1514.1	−393.2	−715.9	38.7	−13.2	20.8	−186.5	−1163.1	−1685.2	−1159.3	−1203.6
a4	0.6832	0.8009	1.2326	0.8585	0.8445	0.2183	0.1251	0.1457	0.0007	0.1435	0.5695	0.6210

KILN 2 84 m^3 Without night-time insulation

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
a0	−152.35	−143.06	−147.57	−107.46	−87.52	−59.21	−55.26	−58.49	−52.66	−55.58	−98.39	−120.46
a1	1.5918	1.4851	1.2238	0.9346	0.5730	0.4133	0.3673	0.4196	0.5558	0.8174	1.0339	1.2889
a2	0.0317	0.0327	0.0372	0.0364	0.0408	0.0401	0.0399	0.0380	0.0332	0.0252	0.0280	0.0282
a3	−1270.8	−1437.7	−492.2	−619.1	−14.0	−21.2	19.8	−124.6	−945.5	−1550.3	−1073.7	−1196.0
a4	0.4485	0.5225	0.8177	0.5549	0.5400	0.0892	0.0409	0.0508	−0.1334	−0.1328	0.3117	0.3748

KILN 3 22 m^3 With extra night-time insulation

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
a0	−176.82	−170.08	−198.28	−95.33	−79.84	−61.46	−58.63	−65.47	−49.41	−65.76	−117.46	−140.11
a1	1.8459	1.7242	1.4543	0.9804	0.5161	0.4001	0.3837	0.4727	0.6300	0.9610	1.1965	1.5009
a2	0.0392	0.0420	0.0524	0.0464	0.0572	0.0598	0.0579	0.0535	0.0445	0.0339	0.0364	0.0353
a3	−1636.3	−1799.6	−339.9	−1560.4	724.4	−571.6	−460.7	−546.9	−1736.4	−2053.4	−1323.8	−1508.7
a4	0.7428	0.9449	1.6765	0.7612	0.9498	0.7164	0.6723	0.6378	0.1605	0.2713	0.6891	0.6522

KILN 4 84 m^3 With extra night-time insulation

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
a0	−137.48	−128.88	−148.77	−69.04	−59.99	−47.37	−46.18	−51.14	−35.51	−38.95	−88.31	−105.69
a1	1.4949	1.3574	1.1247	0.7469	0.3998	0.3206	0.3117	0.3376	0.4840	0.7239	0.9408	1.2004
a2	0.0350	0.0371	0.0439	0.0379	0.0451	0.0462	0.0448	0.0422	0.0363	0.0282	0.0324	0.0316
a3	−1569.7	−1674.0	−443.9	−1321.9	−621.1	−478.4	−382.2	−418.9	−1398.0	−1854.8	−1192.3	−1443.2
a4	0.4984	0.6402	1.1854	0.4739	0.6680	0.5138	0.4957	0.4636	0.0176	0.0000	0.4127	0.3996

APPENDIX 3

Climatic values and percentage fuel savings of a passive solar kiln based on Tschernitz regressions.

SOL RAD = total solar radiation (kJ m^{-2})
ABS HUM = absolute humidity ((kg water/kg dry air) x 10 000)
RH = relative humidity (%)
TEMP = average temperature (°C)

Kiln type 1 is 22 m^3 timber capacity and without extra night-time insulation
Kiln type 2 is 84 m^3 timber capacity and without extra night-time insulation
Kiln type 3 is 22 m^3 timber capacity and with extra night-time insulation
Kiln type 4 is 84 m^3 timber capacity and without extra night-time insulation

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
LOCATION 1 PERTH LATITUDE 31.93													
SOL RAD	29200	25500	21300	15200	10800	8800	9500	12300	16800	21900	25300	28300	18742
ABS HUM	95	99	94	87	78	74	69	68	70	73	79	88	81.2
RH	50	50.5	53.2	60.7	66.5	71	71	68.5	65	60.5	55.5	53	60.5
TEMP	24.1	24.5	22.5	18.9	15.8	13.9	12.9	13.2	14.3	16.3	18.9	21.5	18.1
KILN 1	51	47	35	18	4	-1	2	18	21	30	34	42	24
KILN 2	51	45	32	15	3	-2	-0	7	17	27	34	42	23
KILN 3	71	67	55	42	42	26	29	35	45	52	54	61	48
KILN 4	66	61	48	34	23	19	22	25	37	46	49	58	41
LOCATION 2 ALBANY LATITUDE 34.95													
SOL RAD	24700	20600	16400	11500	8800	7600	8300	10800	14400	18600	21100	24600	15617
ABS HUM	84	93	88	87	79	73	69	67	68	71	76	79	77.8
RH	59.2	63.8	64.8	73.6	77.6	80.8	80.2	78	74.6	70.6	67.8	61	71.0
TEMP	19.5	19.8	18.7	16.5	14.1	12.4	11.7	11.7	12.5	14	15.8	18	15.4
KILN 1	25	19	9	0	-4	-7	-4	2	11	18	17	24	9
KILN 2	25	21	11	1	-4	-7	-5	1	8	17	19	27	9
KILN 3	44	39	28	25	33	21	24	29	35	39	36	44	33
KILN 4	43	37	26	20	16	15	18	20	28	35	34	42	28
LOCATION 3 ESPERANCE LATITUDE 33.83													
SOL RAD	25870	24990	18430	13080	9180	7910	8580	11670	16400	20610	24880	26610	17351
ABS HUM	101	104	99	91	80	71	66	67	72	76	84	92	83.6
RH	65	66	67.6	69.8	71.8	72.8	72.4	70.6	69.6	67.4	65.8	64.2	68.6
TEMP	20.8	21.1	20	18	15.5	13.5	12.6	13.1	14.4	15.7	17.8	19.6	16.8
KILN 1	30	35	19	9	-2	-5	-3	7	20	25	30	32	16
KILN 2	32	35	19	8	-2	-5	-4	5	16	23	31	34	16
KILN 3	49	56	39	33	35	23	26	34	44	47	51	51	41
KILN 4	47	52	34	27	18	17	19	24	35	42	47	49	34
LOCATION 4 MANJIMUP LATITUDE 34.25													
SOL RAD	23771	21458	18016	12046	9097	7395	8709	11385	14364	19308	22683	24672	16075
ABS HUM	82	89	87	82	75	70	65	64	64	64	69	75	73.8
RH	54.2	58.5	64	72.7	78.5	83	82.7	78.7	73.2	65.2	60.2	55.5	68.9
TEMP	20.5	20.6	18.7	15.7	13.3	11.4	10.4	10.7	11.9	13.7	16.1	18.7	15.1
KILN 1	25	24	14	1	-5	-9	-4	4	10	20	22	27	11
KILN 2	28	26	15	1	-5	-9	-5	2	8	19	24	29	11
KILN 3	44	44	35	26	33	19	25	31	35	42	42	46	35
KILN 4	43	42	31	21	17	14	18	22	28	38	39	44	30
LOCATION 5 DWELLINGUP LATITUDE 32.72													
SOL RAD	26665	23772	19793	13505	10565	7928	9387	12192	15146	20806	24628	27688	17673
ABS HUM	82	89	85	83	76	71	65	63	65	64	69	74	73.8
RH	48.7	53	58.2	72.2	79.7	84.2	83.2	80	74.5	63	56.7	50	67.0
TEMP	22.2	22.2	20	16.1	13.1	11.3	10.3	10.4	11.8	14.2	17	20.2	15.7
KILN 1	39	36	23	6	1	-7	-1	7	13	25	29	38	17
KILN 2	41	36	23	6	-0	-7	-2	4	10	23	30	40	17
KILN 3	59	56	44	31	38	20	27	33	37	47	49	58	42
KILN 4	55	52	39	26	21	15	20	24	30	42	46	55	36

Appendix 3 Continued

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
LOCATION 6	**HARVEY**	**LATITUDE**	**33.13**										
SOL RAD	26788	24146	20657	13860	10754	8174	9471	12640	16182	21180	24446	27516	17985
ABS HUM	90	93	98	98	90	82	78	74	70	69	72	78	83
RH	50	51	60	73	82	85	86	81	72	62	55	50	67
TEMP	23.3	23.55	21.6	18.4	15.4	13.35	12.5	12.5	13.55	15.6	18	21.1	17.4
KILN 1	42.2	41.4	30.9	11.5	4.8	-3.9	1.5	10.7	18.2	27.6	30.8	40.2	21
KILN 2	43.3	40.5	28.8	9.9	3.0	-4.5	-0.6	7.3	14.7	25.3	30.9	40.9	20
KILN 3	61.6	61.6	52.0	34.9	42.9	22.9	29.1	36.7	42.4	49.9	51.0	59.9	45
KILN 4	57.8	56.2	45.5	28.4	22.9	16.8	21.5	26.4	34.0	44.2	46.9	56.4	38
LOCATION 7	**NORTHAM**	**LATITUDE**	**31.75**										
SOL RAD	27760	24464	21078	14529	11940	9137	10721	13663	17089	23114	27166	30073	19228
ABS HUM	82	92	85	82	71	71	66	64	64	64	63	69	72.8
RH	40.5	46.2	49.2	62.5	70.7	81.5	82.2	77.5	70.2	56.7	44	38.2	60.0
TEMP	25.3	25	22.6	18.1	14.1	11.8	10.7	11	12.6	15.9	19.7	23.4	17.5
KILN 1	52	46	34	13	7	-1	6	14	21	34	42	54	27
KILN 2	52	45	32	12	5	-2	3	16	17	31	41	53	25
KILN 3	72	66	55	39	45	26	34	40	46	57	63	75	51
KILN 4	67	60	48	32	27	20	25	29	37	50	58	69	43
LOCATION 8	**KALGOORLIE**	**LATITUDE**	**30.78**										
SOL RAD	29600	25200	20900	16800	12000	10600	11400	14300	19800	24000	26000	28900	19958
ABS HUM	86	92	85	75	65	60	56	54	52	57	64	75	68.4
RH	40.9	46.7	48.7	55.5	63.1	69.1	69.7	61.7	49.7	43.9	40.3	39.3	52.4
TEMP	26	24.9	22.8	18.7	14.4	11.8	10.7	11.9	14.9	18.2	21.4	24.4	18.3
KILN 1	59	48	33	23	7	6	9	17	35	42	42	52	31
KILN 2	58	46	31	20	5	3	5	12	29	38	41	51	28
KILN 3	79	68	53	49	44	34	37	44	61	65	63	72	56
KILN 4	73	62	47	40	27	26	28	32	49	57	57	67	47
LOCATION 9	**ADELAIDE**	**LATITUDE**	**35**										
SOL RAD	29600	26200	19600	13700	9700	8300	8000	11200	16000	21800	24900	27100	18008
ABS HUM	77	80	76	70	68	64	61	60	58	61	65	70	67.5
RH	47.2	49	52.2	58	68.2	74	75	70.2	61.5	55	50.5	48	59.1
TEMP	21.7	21.8	19.8	16.9	13.9	11.7	10.9	11.7	13.2	15.7	17.9	19.8	16.3
KILN 1	48	46	25	11	-0	-4	-6	4	19	31	34	38	20
KILN 2	49	45	24	16	-1	-5	-7	2	15	28	33	39	19
KILN 3	70	68	46	37	36	25	23	31	44	54	54	58	45
KILN 4	65	62	41	30	20	18	16	22	35	47	50	54	38
LOCATION 10	**MT GAMBIER**	**LATITUDE**	**37.75**										
SOL RAD	24500	22200	16100	10900	7700	6400	7000	9600	13300	18000	20800	23600	15008
ABS HUM	74	81	78	73	69	64	61	60	60	61	65	68	67.8
RH	57.3	61.7	65.9	73.7	81.4	85.8	85.6	80.6	74	68.4	64.4	59	71.5
TEMP	17.9	18.1	16.6	13.8	11.5	9.6	9	9.6	10.8	12.3	14.1	16.2	13.3
KILN 1	22	23	6	-4	-10	-14	-12	-4	6	15	15	20	5
KILN 2	26	25	8	-3	-9	-13	-11	-5	4	14	17	23	6
KILN 3	42	44	26	22	27	15	18	24	31	38	35	39	30
KILN 4	41	42	24	18	12	11	13	16	24	34	33	38	25
LOCATION 11	**KYANCUTTA**	**LATITUDE**	**33.13**										
SOL RAD	25901	22868	19712	13972	10853	8947	10139	12640	15564	20749	24907	26112	17697
ABS HUM	67	74	80	74	72	65	63	61	60	56	53	59	65.3
RH	36.5	41	51.5	59.5	71.7	76.2	77.5	70.7	61.7	47	37.2	36.7	55.6
TEMP	23.7	23.4	20.8	17.4	14	11.5	10.8	11.8	13.7	16.7	19.6	21.6	17.1
KILN 1	44	40	26	12	3	-2	3	10	17	31	38	40	22
KILN 2	45	39	25	10	2	-3	1	7	14	28	37	41	20
KILN 3	64	60	46	37	41	27	32	37	42	53	58	60	46
KILN 4	60	55	41	31	23	20	24	26	34	47	53	56	39

Appendix 3 Continued

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
LOCATION 12	MELBOURNE	LATITUDE	37.83										
SOL RAD	24200	21600	16000	11000	7400	5900	6700	9100	12600	17400	21000	23700	14717
ABS HUM	81	87	81	74	67	61	57	57	58	61	68	74	68.8
RH	55.5	59	61	67.2	73.5	77.5	76.2	70.5	64.3	59.3	58.1	55.8	64.8
TEMP	19.9	20	18.4	15.4	12.5	10.3	9.5	10.7	12.4	14.4	16.4	18.4	14.9
KILN 1	27	26	10	-0	-11	-16	-13	-5	5	17	21	25	7
KILN 2	30	27	11	-0	-9	-14	-12	-5	4	16	21	27	8
KILN 3	46	47	31	25	26	13	17	22	30	39	40	45	32
KILN 4	44	43	27	20	12	9	12	15	23	35	37	43	27
LOCATION 13	MILDURA	LATITUDE	34.25										
SOL RAD	28300	25300	20700	15100	10500	8800	9600	12600	16900	21700	26000	28900	18700
ABS HUM	82	89	81	73	69	62	58	58	58	60	65	70	68.8
RH	42.9	47.6	51.3	61.1	72.5	78.5	76.5	69.5	58.7	50.2	45.2	41.5	58.0
TEMP	24.3	23.9	21.1	16.8	13.2	10.5	9.8	11.3	13.7	16.7	19.7	22.3	16.9
KILN 1	52	48	32	16	2	-3	0	19	22	33	40	49	25
KILN 2	52	46	30	13	0	-4	-2	6	18	29	39	48	23
KILN 3	72	69	53	42	39	26	30	37	48	55	61	69	50
KILN 4	67	62	47	34	22	19	22	27	38	49	55	64	42
LOCATION 14	KYABRAM	LATITUDE	36.33										
SOL RAD	25528	23412	19693	13931	9784	7609	8526	11287	15266	20553	24940	27193	17310
ABS HUM	67	74	76	71	66	58	53	56	58	59	55	57	62.5
RH	41.3	43.8	54.4	66.4	78.6	83.9	82.1	76.9	70.4	58.7	45.3	39.5	61.8
TEMP	21.7	22.4	19.3	14.9	11.4	8.4	7.6	9.2	10.9	14	17.1	19.9	14.7
KILN 1	38	41	25	9	-2	-10	-6	3	13	25	34	40	17
KILN 2	40	40	24	8	-3	-18	-7	1	10	23	33	41	17
KILN 3	58	62	48	36	36	20	24	31	38	48	55	61	43
KILN 4	55	56	42	29	20	14	18	22	31	42	50	57	36
LOCATION 15	SALE EAST	LATITUDE	38.1										
SOL RAD	23357	20535	16987	12319	8940	6998	8466	11126	14645	19020	22371	23870	15719
ABS HUM	88	92	88	75	66	59	53	56	60	68	73	81	71.6
RH	63.8	66	70.1	73.3	78.4	81.4	77.4	75.9	72.4	70.8	67.2	65.2	71.8
TEMP	18.9	19.2	17.5	14.4	11.4	9.1	8.4	9.5	11.2	13.3	15.2	17.3	13.8
KILN 1	20	19	12	3	-5	-12	-6	3	11	18	21	22	9
KILN 2	24	21	12	2	-5	-11	-7	0	8	17	22	25	9
KILN 3	39	40	33	29	33	19	26	31	36	41	42	41	34
KILN 4	38	37	29	23	18	13	19	22	29	36	38	40	29
LOCATION 16	SYDNEY	LATITUDE	33.93										
SOL RAD	24300	20000	17600	13100	9800	8400	8800	12500	16000	19300	21200	24800	16317
ABS HUM	117	123	113	93	77	65	56	58	65	79	92	107	87.1
RH	69	71.8	71.4	70	70.6	70.6	65.4	62.6	61.2	63	64.4	66.4	67.2
TEMP	22.2	22.4	21.2	18.3	15	12.8	11.7	12.8	14.9	17.4	19.5	21.4	17.5
KILN 1	28	20	18	9	0	-3	-2	11	20	24	23	31	15
KILN 2	30	22	18	8	-0	-4	-3	7	16	22	24	32	14
KILN 3	46	38	38	33	38	25	27	38	44	46	42	49	38
KILN 4	43	35	33	27	20	19	20	27	35	40	38	46	32
LOCATION 17	CANBERRA	LATITUDE	35.32										
SOL RAD	27600	24300	19400	13900	10000	8900	8600	11500	16300	20800	25100	26700	17758
ABS HUM	82	89	79	65	55	48	45	45	50	56	62	70	62.2
RH	54.9	60.7	62.7	69.3	75.9	79.3	78.9	73.1	67.5	61.4	56.1	52.5	66.0
TEMP	20.3	19.9	17.6	13.1	8.9	6.4	5.6	6.8	9.4	12.6	15.4	18.6	12.9
KILN 1	37	32	18	5	-5	-6	-7	2	16	23	29	33	15
KILN 2	39	33	19	4	-5	-7	-8	-0	13	22	29	35	14
KILN 3	57	54	40	33	33	25	23	29	42	47	50	53	41
KILN 4	55	50	36	27	19	19	17	21	34	42	46	51	35

Appendix 3 Continued

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
LOCATION 18 WAGGAWAGGA LATITUDE 35.25													
SOL RAD	27300	24800	20000	14600	9800	7900	8600	11300	16000	20900	25700	28100	17917
ABS HUM	86	94	84	73	66	58	54	56	60	65	69	74	69.9
RH	46.7	51.5	55.3	65.9	77.9	83.3	83.5	78.3	71.5	63.1	53.7	45.9	64.7
TEMP	23.5	23.5	20.5	15.6	11.4	8.6	7.5	9	11.2	14.5	17.9	21.5	15.4
KILN 1	46	45	28	12	-3	-9	-6	2	16	26	36	45	20
KILN 2	47	43	27	10	-3	-9	-7	0	13	23	35	45	19
KILN 3	66	66	50	38	35	21	24	30	41	49	57	65	45
KILN 4	62	59	44	31	19	15	17	21	33	43	51	60	38
LOCATION 19 ORANGE LATITUDE 33.32													
SOL RAD	25299	23554	19539	14711	11097	8725	9991	13137	16637	22014	25660	27352	18143
ABS HUM	76	82	74	64	55	47	43	45	49	49	62	69	59.7
RH	56.2	61.6	65.1	73.1	79.4	83.6	81.0	78.4	73.0	68.6	62.6	56.6	70.0
TEMP	18.8	18.4	15.9	12.1	8.6	5.6	4.6	5.9	8.1	9.0	13.7	17.0	11.4
KILN 1	24	24	12	4	-2	-8	-2	8	15	21	26	29	13
KILN 2	28	27	14	4	-3	-8	-4	4	12	20	27	32	13
KILN 3	44	46	33	33	36	22	28	35	42	45	47	50	38
KILN 4	43	44	31	27	22	16	21	25	34	41	44	48	33
LOCATION 20 INVERELL LATITUDE 29.78													
SOL RAD	24109	23531	21603	16051	12704	10856	12093	15682	19026	22800	25577	26029	19172
ABS HUM	97	95	89	73	63	54	48	49	51	62	68	83	69
RH	53.1	54.9	58.7	61.7	69.9	73.7	71.3	66.9	58.1	54.7	48.9	50.4	60
TEMP	23.5	22.7	20.4	16.7	12.4	9.4	8.0	9.2	12.2	16.0	19.2	21.8	15.9
KILN 1	34	36	32	18	10	5	10	21	29	34	37	38	25
KILN 2	36	36	30	16	7	2	6	15	23	30	36	38	23
KILN 3	52	56	54	45	48	36	41	50	55	57	58	57	51
KILN 4	49	52	47	37	30	27	31	37	44	50	53	53	42
LOCATION 21 BRISBANE LATITUDE 27.42													
SOL RAD	24200	22200	19700	14900	11800	11100	11300	15100	19000	20300	21900	24100	17967
ABS HUM	130	135	130	112	89	75	67	67	75	88	102	118	99.0
RH	64.6	67.2	68.6	67.8	66.4	65.1	62.9	59.1	57.2	57.6	58.2	61.2	63.0
TEMP	25	24.9	24	21.8	18.5	16.1	15	15.9	18.2	20.6	22.8	24.3	20.6
KILN 1	31	29	25	17	9	11	11	24	34	31	28	32	23
KILN 2	33	30	25	15	7	7	7	18	28	28	29	33	22
KILN 3	48	46	43	39	46	37	37	48	57	50	45	48	45
KILN 4	45	43	38	32	26	28	28	35	46	45	42	46	38
LOCATION 22 TOWNSVILLE LATITUDE 19.25													
SOL RAD	21290	20020	19820	17200	15220	14670	15720	18270	21970	24310	24610	23440	19712
ABS HUM	163	174	162	138	117	94	91	97	109	128	150	163	132.2
RH	68.2	74.5	73	69.7	68	64.5	65.2	64.5	64	64.7	66.7	68.2	67.6
TEMP	27.8	27.5	26.6	24.7	22.4	19.9	19.2	20.3	22.3	24.8	26.8	27.9	24.2
KILN 1	22	18	22	23	23	29	34	39	46	41	34	29	30
KILN 2	25	20	23	21	19	22	25	31	38	38	35	31	27
KILN 3	35	31	36	43	61	51	56	60	66	59	50	44	49
KILN 4	35	30	33	36	35	39	42	45	54	53	47	42	41
LOCATION 23 INNISFAIL LATITUDE 17.53													
SOL RAD	18780	17300	16290	13840	11920	16010	13040	15560	16030	19960	20690	19770	16599
ABS HUM	169	179	168	152	139	119	112	117	115	121	139	152	140.2
RH	75.5	81.2	79	80	82	80	78.2	75.7	69.2	65.2	65.7	69	75.1
TEMP	26.7	26.5	25.9	24	22.2	20.1	19.5	20.7	21.9	23.8	25.9	26.5	23.6
KILN 1	9	4	4	6	6	35	21	27	23	29	22	16	17
KILN 2	14	8	8	7	6	27	16	22	20	29	24	20	17
KILN 3	21	15	15	24	44	56	40	45	41	45	36	29	34
KILN 4	22	17	16	21	19	43	30	33	34	42	35	30	29

Appendix 3 Continued

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
LOCATION 24 ROCKHAMPTON LATITUDE 23.38													
SOL RAD	22200	20700	20000	17400	14000	13700	14200	17000	19900	22200	23500	24300	19092
ABS HUM	151	155	145	120	97	82	77	80	90	104	121	137	113.3
RH	67.4	70.6	70.3	67.5	67.1	67.7	67.9	63.3	60.9	58.9	59.4	62.4	65.3
TEMP	26.8	26.4	25.5	23.1	19.8	16.9	16	17.6	20.2	23	25.3	26.5	22.3
KILN 1	26	23	25	25	17	23	25	32	38	37	34	34	28
KILN 2	28	24	25	22	14	17	18	25	32	34	34	35	26
KILN 3	40	37	41	47	55	47	49	55	59	56	50	49	49
KILN 4	39	35	37	39	32	36	37	41	49	50	47	47	41
LOCATION 25 THEODORE LATITUDE 24.83													
SOL RAD	22033	20679	19561	16692	14051	12638	14411	16756	19728	22746	24465	24230	18999
ABS HUM	134	133	123	98	83	69	64	66	71	88	103	122	96
RH	58.9	60.3	60.9	58.9	63.1	65.9	64.3	59.5	53.1	52.3	51.9	55.5	59
TEMP	27.2	26.6	25.1	22.0	18.2	14.7	14.0	15.5	18.6	22.1	24.9	26.6	21.3
KILN 1	35	35	36	30	24	18	25	31	37	41	43	42	33
KILN 2	36	33	32	25	18	12	18	23	30	35	40	40	29
KILN 3	51	51	56	53	62	48	56	59	62	62	62	58	57
KILN 4	47	46	47	43	39	36	42	44	50	53	55	53	46
LOCATION 26 WARWICK LATITUDE 28.2													
SOL RAD	23240	21635	19916	16791	13362	11590	13403	16355	19483	22548	25019	24767	19009
ABS HUM	114	116	108	88	73	62	55	54	61	74	89	100	83
RH	62	65	67	67	71	74	70	63	59	58	59	58	64
TEMP	23.5	22.95	21.55	18.2	14.4	11.3	10.2	11.55	14.45	17.8	20.5	22.65	17.4
KILN 1	26	24	21	19	11	9	17	26	32	34	33	31	24
KILN 2	29	26	22	17	9	6	11	19	27	31	34	33	22
KILN 3	43	42	40	44	49	37	45	51	57	55	52	49	47
KILN 4	41	40	36	37	30	28	34	38	47	50	49	47	40
LOCATION 27 DARWIN LATITUDE 12.42													
SOL RAD	20100	20200	20100	22300	20400	19700	20500	22100	23600	24700	24100	22700	21708
ABS HUM	188	188	184	159	130	107	104	118	141	162	177	186	153.7
RH	76.3	77.3	75.3	64.6	57	52.6	52.3	55.6	59.3	63.3	68	72.6	64.5
TEMP	28.2	28	28.1	28.3	26.9	25.1	24.8	25.9	27.7	29	29.2	28.9	27.5
KILN 1	12	13	18	43	47	55	59	59	54	43	32	23	38
KILN 2	17	17	20	38	38	43	45	47	47	41	33	26	34
KILN 3	24	24	29	61	85	76	79	77	72	59	46	36	56
KILN 4	25	25	28	52	53	58	61	58	60	53	44	36	46
LOCATION 28 HOBART LATITUDE 42.83													
SOL RAD	22600	19600	14300	10100	6400	5100	6000	8600	12600	17100	20100	21800	13691
ABS HUM	75	76	72	66	59	53	50	52	54	58	63	68	62.2
RH	60.8	62	65	68	73.2	75.2	74.6	73	67.4	64.6	63	62.2	67.4
TEMP	17	17	15.7	13.3	10.6	8.6	8	8.8	10.4	12.2	13.9	15.4	12.6
KILN 1	16	15	3	-4	-13	-20	-17	-8	3	14	16	16	2
KILN 2	20	17	4	-3	-12	-18	-15	-8	1	12	17	18	3
KILN 3	36	37	24	23	24	12	16	22	29	37	36	35	28
KILN 4	35	35	22	18	11	8	11	15	22	32	33	34	23
LOCATION 29 LAUNCESTON LATITUDE 41.55													
SOL RAD	24159	21599	17092	11912	7914	6106	7329	9998	13966	19629	23465	24966	15677
ABS HUM	69	72	72	65	59	53	50	52	55	58	61	67	61.1
RH	58.4	60.4	66.9	73.9	80.6	83.8	83.2	80.3	75.3	71.3	65.8	62.8	71.9
TEMP	16.6	16.7	15	12	9.3	7.1	6.5	7.5	9.2	10.9	12.9	14.9	11.6
KILN 1	19	20	19	-0	-9	-17	-12	-3	7	18	22	22	6
KILN 2	23	22	11	-0	-9	-16	-12	-5	4	16	23	25	7
KILN 3	40	43	33	27	29	15	21	27	33	42	44	42	33
KILN 4	39	40	29	22	15	11	15	18	25	36	40	41	28

Appendix 3 Continued

LOCATION 30 SWANSEA LATITUDE 42.13

SOL RAD	22415	19390	15504	11087	7598	5890	7164	9929	13610	18594	21367	23133	14640
ABS HUM	73	76	73	68	61	55	52	52	53	56	64	68	62.6
RH	60.6	63	65.4	70.6	75.2	76.2	75.8	72.4	66.2	62.2	64.2	62.8	67.9
TEMP	16.8	16.8	15.6	13.4	10.9	9.1	8.2	9.1	10.7	12.3	14	15.2	12.7
KILN 1	15	13	6	-0	-8	-16	-11	-2	7	18	19	18	5
KILN 2	19	16	7	-0	-8	-15	-11	-4	5	16	20	21	5
KILN 3	34	35	29	26	29	16	22	28	34	42	40	38	31
KILN 4	34	33	25	21	15	11	15	19	26	36	36	37	26