

Energy saving performance of Tenmat Firefly 120 loft covers

Commercial in Confidence

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1 Introduction

This report details the work undertaken under contract number TT//F09323 on behalf of Tenmat Ltd. The work involves calculating the energy saving performance of Tenmat loft covers. In particular the energy saving performance under the Australian climate was considered.

The energy saving performance was assessed by calculating the conduction and air-tightness heat loss components through a down-light installed according to Australian regulations and a down-light with Tenmat loft cover installed with insulation over the top.

The heat loss components were used along with average heating and cooling requirements for 5 Australian cities to produce measures of energy saved when using the Tenmat loft cover.

2 Methodology

In order to assess the energy savings due to the Tenmat loft cover, two situations are examined:

1. A down light with no cover
2. A down light with a Tenmat loft cover and insulation over the top

The total heat loss co-efficient based on conduction and air-tightness was calculated for both situations as detailed in sections 2.1 to 2.4 below, using the thermal material properties given in Table 1.

Table 1 Materials

Material	Thermal conductivity/ $Wm^{-1}K^{-1}$	Thickness/ m
Loose-fill cellulose insulation	0.040	0.12
Plasterboard	0.21	0.013
Down-light	50.00	0.001
Tenmat loft cover	0.035	0.010

The thermal conductivity values in Table 1 come from BS EN 10456:2007 apart from the value for the Tenmat loft cover, which was supplied by Tenmat. Note that due to the lack on any down-light R-values, it has been assumed to be equivalent to a 1mm thick sheet of steel.

The heat loss co-efficient was used to calculate heating and cooling energy requirements, energy costs, and CO₂ savings for 5 Australian cities with the intention of producing a representative measure of the energy saving performance of the Tenmat loft cover under the Australian climate.

In addition a calculation has been made for what thickness of insulation would be required to save an equivalent amount of energy to that saved with the use of the Tenmat loft cover.

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2.1 Calculation of conductive losses for down-light only

For the down light with no cover there are effectively two paths for the conduction losses:

1. The un-insulated area surrounding the down-light
2. The down-light

In order to calculate the conductive heat losses, the areas and thermal resistances are calculated for the two conduction paths. For the purposes of these calculations it is assumed that the down light has a diameter of 90mm (a size commonly used in Australia) the area of the un-insulated area can be calculated using the requirement that insulation must not come within 200mm of the down light, see Figure 1.

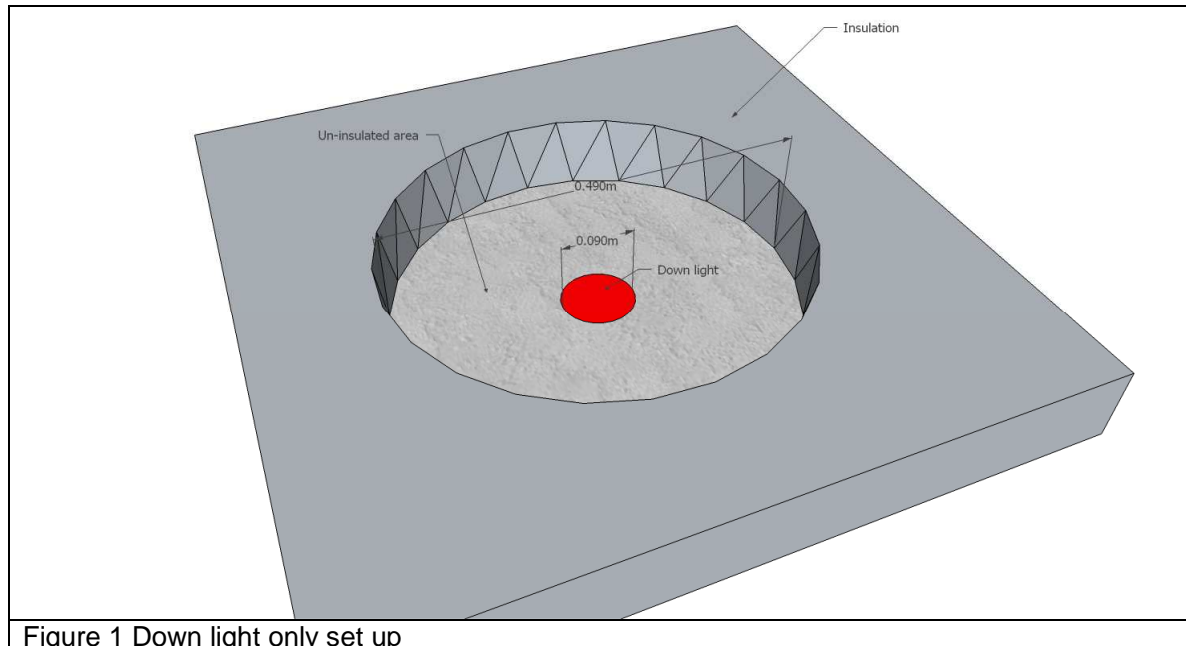


Figure 1 Down light only set up

Hence the area of the down-light is given by equation 1.

$$A_{dl} = \pi \times 0.045^2 = 6.36 \times 10^{-3} \text{ m}^2 \quad \text{Equation 1}$$

The area of the un-insulated area is given by equation 2

$$A_{un} = \pi \times 0.245^2 - A_{dl} = 0.182 \text{ m}^2 \quad \text{Equation 2}$$

Now the thermal resistance of each heat flow path is given equation 3:

$$R_p = t_m \lambda_m^{-1} + R_{sf1} + R_{sf2} \quad \text{Equation 3}$$

Where: t_m is the thickness of the material making up the conduction path
 λ_m is the thermal conductivity of the material making up the conduction path

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R_{sf1} and R_{sf2} are the surface resistances on the two face of the material. These are taken to be internal surface resistances according to BS EN ISO 6946:1997 the surface resistances take on three values, $0.10\text{Km}^2\text{W}^{-1}$ for upwards heat flow, as would be the case for heating the living area. $0.17\text{Km}^2\text{W}^{-1}$ for downwards heat flow, as would be the case for cooling the living area, and $0.13\text{Km}^2\text{W}^{-1}$ for horizontal heat flow.

The R-values in for the paths calculated according to Equation 3 with the values in Table 1 are given in Table 2.

Table 2 R-values

Conduction path	Heating R-value/ m^2KW^{-1}	Cooling R-value/ m^2KW^{-1}
Un-insulated area (13mm plasterboard)	0.262	0.402
Down light	0.200	0.340

Using these values, the thermal transmittance times total area (UA) is calculated according to Equation 4. The UA value gives the amount of heat flowing through the down light and un-insulated area per Kelvin of temperature difference.

$$UA = A_{un}R_{un}^{-1} + A_{dl}R_{dl}^{-1} \quad \text{Equation 4.}$$

Which yields: $UA_{\text{heating}} = 0.726\text{WK}^{-1}$
 $UA_{\text{cooling}} = 0.471\text{WK}^{-1}$

2.2 Calculation of conductive losses for down-light and Tenmat loft cover

For the Tenmat loft cover there are effectively three paths for the conduction losses (it is assumed that the insulation is taken up to the edges of the down light and the faces of the down-light sticking out above the insulation have more insulation attached to them):

1. The insulated area surrounding the down-light
2. The top of the cover
3. The sides of the cover

Figure 2 shows the approximate set-up, without the insulation covering the down-light for clarity.

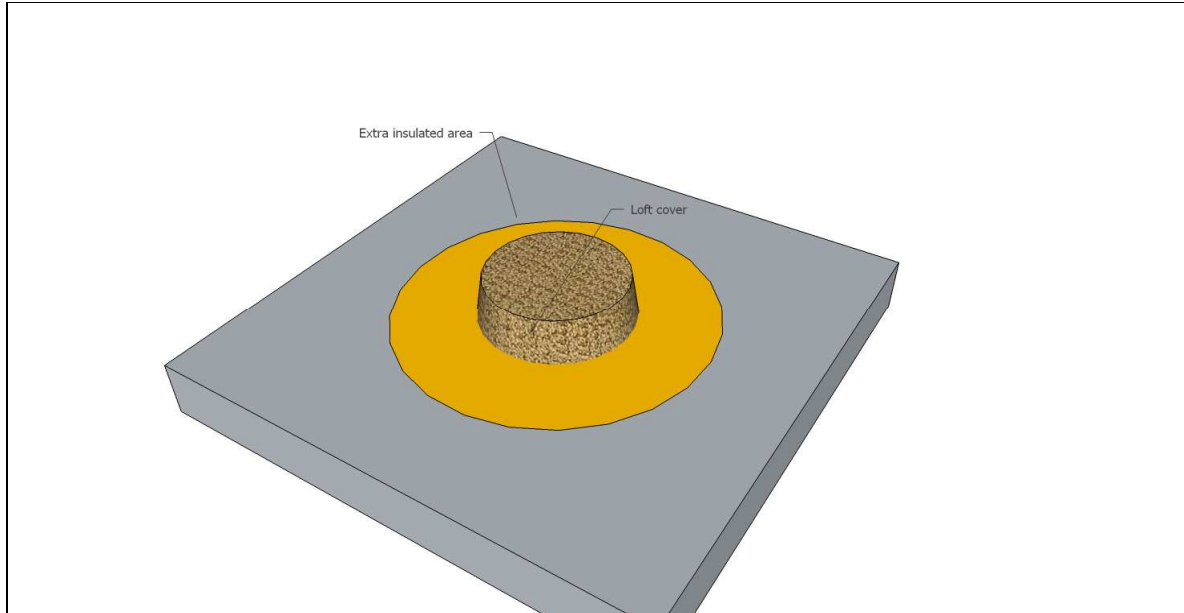


Figure 2 Tenmat loft cover set-up

Note that for the purposes of the calculation, the linear thermal bridges due to changes in the orientation of the insulation have been neglected. This is because the two linear thermal bridges (See Figure 3) affect the conduction losses in different ways:

1. The thermal bridge where the top of the cover meets the side of the cover has an angle of greater than 180° , this thermal bridge will tend to increase heat loss.
2. The thermal bridge where the sides of the down-light meets the main ceiling insulation has an angle of less than 180° , this will tend to reduce the heat loss (assuming continuous insulation).

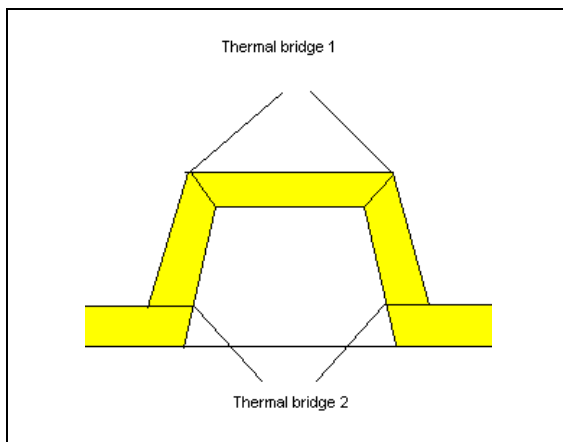


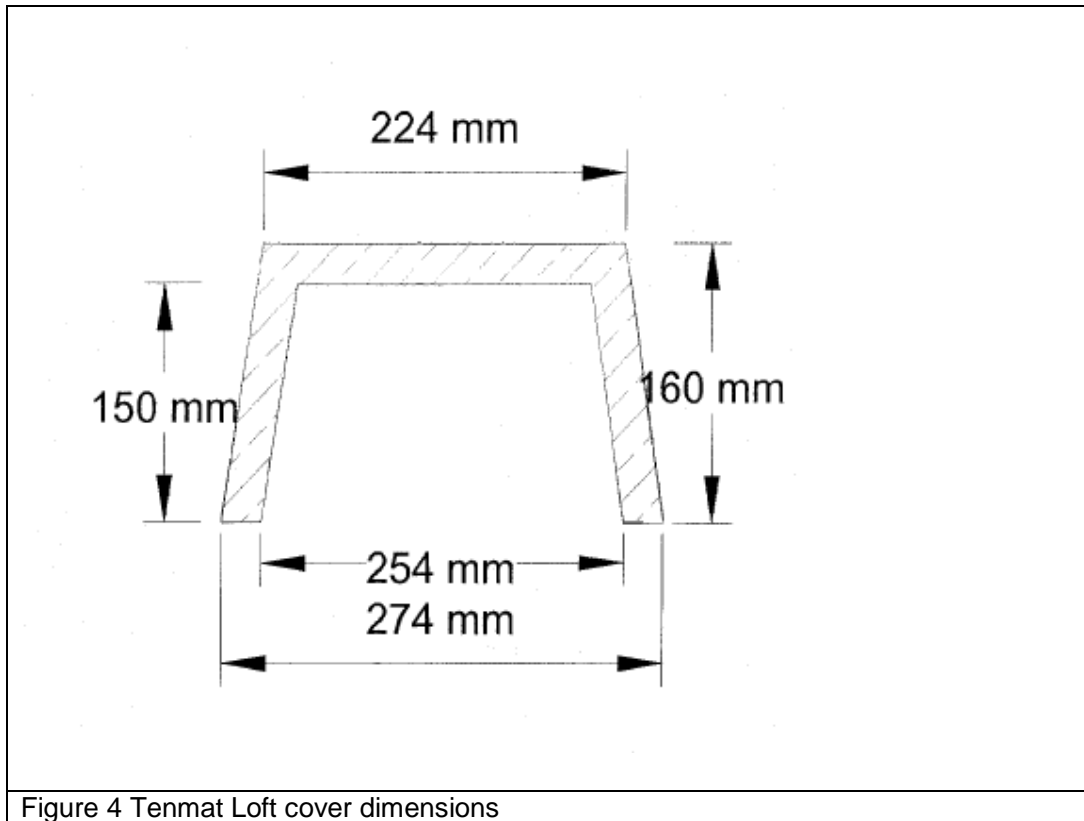
Figure 3 Approximate location of Linear Thermal bridges (not to scale)

As the length of the 2nd thermal bridge is greater than the first due to the larger circumference at the bottom of the Tenmat loft cover, the net effect of the two bridges

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will be a reduction in conductive heat loss. Therefore neglecting the effect of thermal bridges will produce conservative heat loss values.

In order to calculate the conductive heat losses through the three paths, the areas and thermal resistances need to be calculated. A diagram of the dimensions of the Tenmat loft cover can be seen in Figure 4. Note that for the purposes of the calculation the heat loss area is taken to be the internal surface area of the Tenmat loft cover.



In order to calculate the area of the sides of the Tenmat loft cover sticking above the ceiling insulation, the loft cover must be thought of as a cone, see Figure 5.

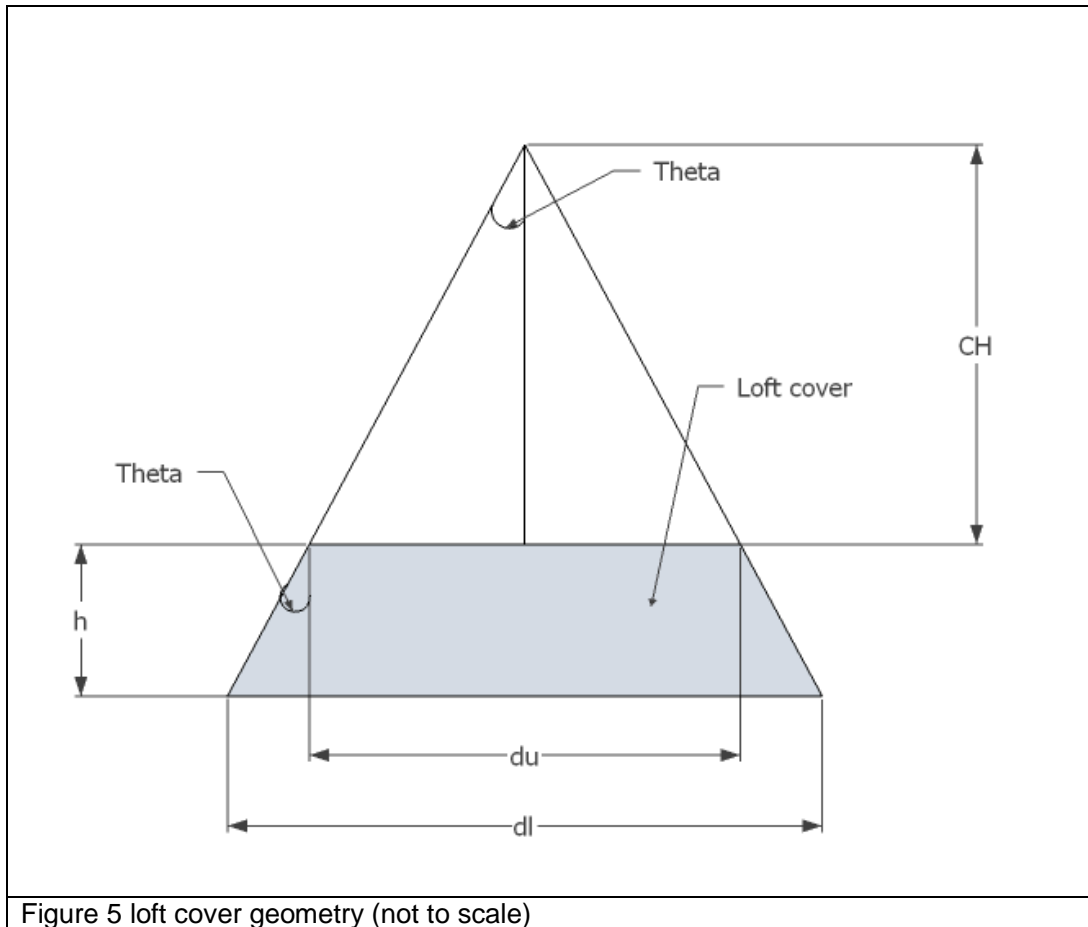
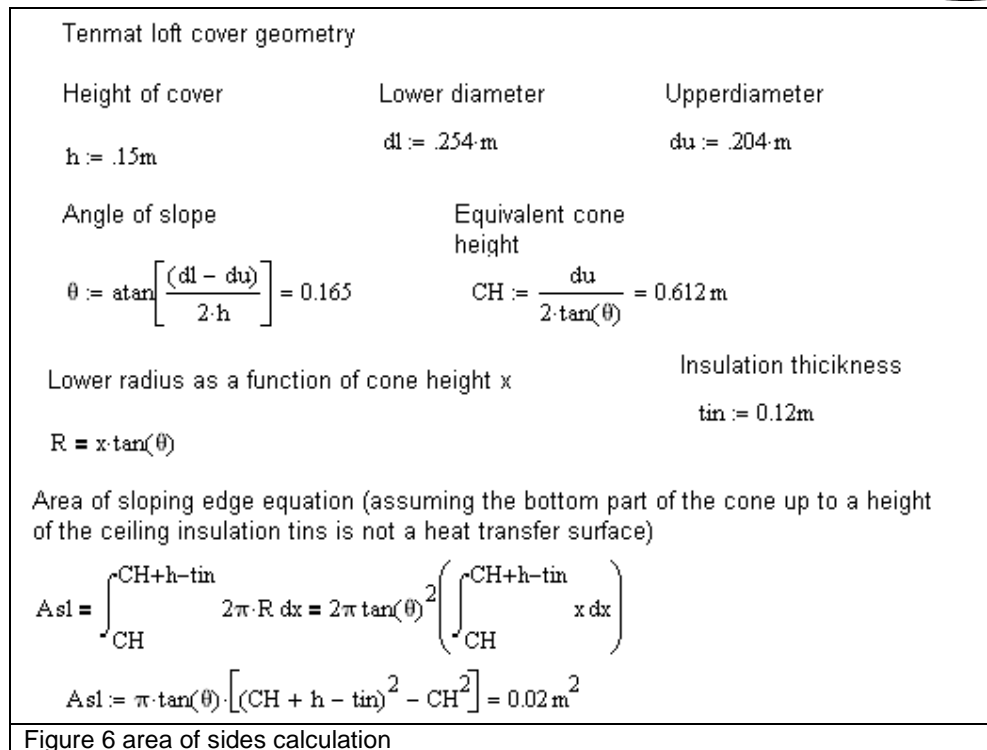


Figure 5 loft cover geometry (not to scale)

Using this geometry the area of the sides of the Tenmat loft cover (path 3) is calculated as follows:



The area of the top of the Tenmat loft cover (path 2) is given by equation 5:

$$A_{it} = \pi \times 0.102^2 = 0.033 \text{ m}^2 \quad \text{Equation 5}$$

The area of the insulated plasterboard area is given by equation 6:

$$A_{ipb} = \pi \times (0.245^2 - (\tan(\theta)(CH+h-tin))^2) = 0.149 \text{ m}^2 \quad \text{Equation 6}$$

The thermal resistances through each path are calculated according to Equation 3 and given in Table 3. Note that in this case the heat loss paths consist of two materials hence the R values for each material are included in the total R calculation. For path three the thermal resistance does not change between heating and cooling because in both cases the surface resistances are for horizontal heat flow.

Table 3 R-values

Path	Heating R-value/ m^2KW^{-1}	Cooling R-value/ m^2KW^{-1}
Path 1 plasterboard and insulation	3.22	3.36
Path 2 Loft cover and insulation	3.48	3.62
Path 3 Loft cover and insulation	3.54	3.54

The UA values are then calculated according to Equation 4

Which yields: $UA_{\text{heating}} = 0.061\text{WK}^{-1}$
 $UA_{\text{cooling}} = 0.059\text{WK}^{-1}$

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2.3 Calculation of air tightness losses

Air-tightness tested according to the principles of BS EN 1026 have been performed on a down-light with and without a Tenmat loft cover. The results are given in the Chiltern Dynamics report Chilt/P09020/01. The results from these tests have been used as the basis for the air-tightness calculations.

The air-leakage value used in the calculations is taken as the measured leakage at 2Pa, which is $1.55\text{m}^3\text{h}^{-1}$ for no cover, and $0.05\text{m}^3\text{h}^{-1}$ with the Tenmat loft cover on. Note that the air-tightness at 2Pa figures have been taken from the actual experimental data points, not the results derived from the best fit curve. This is because, the best fit curves are inaccurate at the lower limits of the range. This is particularly in the case of the downlighter only results, where the best fit curve suggests that the air-tightness should be $1.9\text{m}^3\text{h}^{-1}$, where as the experimental results show an air tightness of $1.55\text{m}^3\text{h}^{-1}$ which is a 25% percent difference. As a matter of principle experimental data should always be preferred over empirically derived values.

The ventilation heat losses are then calculated according to Equation 7.

$$H_{vn} = \rho_a C_{va} V_{av} (3600)^{-1} \quad \text{Equation 7}$$

Where: H_{vn} is the ventilation heat loss in WK^{-1}

ρ_a is the density of air equal to 1.23kgm^{-3}

C_{va} is the specific heat capacity of air equal to $1008\text{Jkg}^{-1}\text{K}^{-1}$

Which yields:

No cover $H_{vn} = 0.534\text{WK}^{-1}$

Tenmat Loft Cover $H_{vn} = 0.017\text{WK}^{-1}$

2.4 Total heat loss co-efficient

The total heat loss co-efficient as given by the sum of the ventilation and conduction losses calculated in the previous sections and are shown in Table 4.

Table 4 Total heat loss

	Total Heat loss/ WK^{-1} (Heating)	Total Heat loss/ WK^{-1} (Cooling)
No cover	1.260	1.005
Tenmat Loft Cover	0.078	0.076

3 Results and discussion

3.1 Percentage reduction in heat losses

The heat loss co-efficients given in Table 4 show that the Tenmat loft covers give a significant reduction in energy use compared with down lights with no cover. The percentage energy reduction can be calculated according to Equation 8.

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$$\text{Percentage reduction} = 100 - 100H_{\text{cover}}H_{\text{nocover}}^{-1}$$

Which yields:

Percentage energy reduction, heating = 93.1%

Percentage energy reduction, cooling = 92.4%

3.2 Performance of covers in Australian climate

The real world energy saving performance of the Tenmat loft covers in Australia can be examined by looking at the heating and cooling requirements in various Australian locations.

The 5 most populous cities in Australia are Sydney, Melbourne, Brisbane, Perth and Adelaide. These 5 cities contain approximately half of Australia's population, hence calculating the energy savings in these sites should provide a good measure of the energy saving potential of the Tenmat loft covers in Australia.

The approximate average yearly heating and cooling demand in degree days (based on 1961-1990 averages) for the cities are given in Table 5 (taken from http://www.bom.gov.au/jsp/ncc/climate_averages/degree-days/index.jsp?mctype=3&period=an&product=cdd18#maps), with heating degree days having a base temperature of 12°C, two cooling degree day figures have been shown one for cooling having a base of 24°C and one for cooling with a base temperature of 18°C.

Table 5 Heating and cooling degree days

City	Heating degree days	Cooling Degree days @ 18°C	Cooling degree days @ 24°C
Sydney	250	500	50
Melbourne	375	250	25
Brisbane	50	1000	100
Perth	75	750	125
Adelaide	175	500	100

The heating energy loss per down light per year can be calculated by multiplying the degree days figure by the heat loss coefficient and converting Watts into kWh. Results are displayed in Table 6, with 2 cooling figures for the different base temperatures.

Table 6 Energy requirements

City	Heating Energy per year per down-light/ kWh		Cooling Energy per year per down-light @ 18°C/ kWh		Cooling Energy per year per down-light @ 24°C/ kWh	
	No loft cover	Loft cover	No loft cover	Loft cover	No loft cover	Loft cover
Sydney	7.56	0.47	12.06	0.912	1.21	0.0912
Melbourne	11.34	0.70	6.03	0.456	0.60	0.0456
Brisbane	1.51	0.09	24.12	1.824	2.41	0.1824
Perth	2.27	0.14	18.09	1.368	3.02	0.228
Adelaide	5.29	0.33	12.06	0.912	2.41	0.1824
Average	5.59	0.35	14.47	1.09	1.93	0.15

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Tables 7 and 8 below displays various measures of energy performance for the Tenmat loft cover based on the values in Table 6. The calculated values are:

- Total electrical energy heating and cooling requirement per down light per year. This is calculated by assuming that heating is by means of electrical resistance heaters and the cooling is by means of an air conditioning system with a COP of 350%, 2 figures .
- Electrical energy saved per year per down-light with cover. This is the difference between the electrical energy with and without the cover.
- CO₂ saved per down light per year. This is calculated assuming that 0.97kg of CO₂ is created for each kWh of electricity. This figure was supplied by Tenmat.

Table 7 Measures of energy performance with 18^oC cooling base temperature

City	Electricity use per year per down light @24 ^o C/ kWh		Electricity saved per year per down-light with cover cooling @18 ^o C/ kWh	CO ₂ saved per year per down light with cover/ kg
	No loft cover	Tenmat Loft cover		
Sydney	11.01	0.73	10.28	9.97
Melbourne	13.06	0.83	12.23	11.86
Brisbane	8.40	0.61	7.79	7.56
Perth	7.44	0.53	6.91	6.70
Adelaide	8.74	0.59	8.15	7.91
Average	9.73	0.66	9.07	8.80

Table 8 Measures of energy performance with 24^oC cooling base temperature

City	Electricity use per year per down light @24 ^o C/ kWh		Electricity saved per year per down-light with cover cooling @24 ^o C/ kWh	CO ₂ saved per year per down light with cover/ kg
	No loft cover	Tenmat Loft cover		
Sydney	7.90	0.49	7.41	7.19
Melbourne	11.51	0.72	10.80	10.47
Brisbane	2.20	0.15	2.06	1.99
Perth	3.13	0.21	2.92	2.84
Adelaide	5.98	0.38	5.60	5.43
Average	6.15	0.39	5.76	5.58

3.3 Performance of covers in a representative ceiling configuration

For these calculations the representative ceiling will have total area 16m² with 10% timber joists by area and the remaining area made up of 120mm cellulose insulation and 6 down lights. The bottom of the ceiling is faced with 13mm plasterboard.

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The R-values and relative areas can be seen in Table 9.

Table 9. R-values and areas

	R value/ m^2KW^{-1}	Area, no down lights/ m^2	Area with down lights/ m^2
Insulation	3.27	14.40	13.27
Timber	1.40	1.60	1.60

Now using the values in Table 8 and the heating total heat loss co-efficients given in Table 4 the UA values for three ceiling configurations are calculated and displayed in Table 10.

Table 10 UA values for 3 ceiling configurations

Configuration	UA/ WK ⁻¹
Ceiling	5.56
Ceiling with down lights	12.77
Ceiling with down lights and loft cover	5.68
Percentage energy saved with Tenmat loft covers, compared to ceiling with down lights only	56%

Based on the figures in Table 10 it can be demonstrated that it would be impossible to achieve the same UA value as the ceiling with loft covers by increasing the insulation thickness in the case of the ceiling with down lights only. This is because even with zero heat loss through the insulated area (infinite thickness insulation) the UA value would still be 7.56WK⁻¹ due to the losses through the down lights, which is greater than the UA value for the ceiling with Tenmat covers of 5.68WK⁻¹.

4 Conclusion

Based on the assumptions detailed in this report, calculations have shown that a down-light with a Tenmat loft cover with 120mm of loose-fill cellulose insulation over the top will reduce heat flow due to conduction and air-tightness losses by 93% over a down-light installed as per Australian regulations when under heating conditions. The Tenmat loft cover will reduce heat flow by 92% under cooling conditions.

Based on the heat loss calculations and when used under the 1961-1990 average heating and cooling requirements of the 5 largest Australian cities. Using a cooling degree day base temperature of 18°C the Tenmat loft cover will on average save 9.07kWh of electrical energy per year per down-light, assuming electrical resistance heating and air conditioning with a COP of 350%. This corresponds to a CO₂ saving of 8.80kg per year per down-light assuming a conversion factor of 0.97kg CO₂ kWh⁻¹.

Using a cooling degree day base temperature of 24°C the Tenmat loft cover will on average save 5.76kWh of electrical energy per year per down-light, assuming electrical resistance heating and air conditioning with a COP of 350%. This corresponds to a CO₂ saving of 5.58kg per year per down-light assuming a conversion factor of 0.97kg CO₂ kWh⁻¹.

The total savings per dwelling can be calculated by multiplying these figures by the total number of down lights. For example based on the assumptions in this report a house with 20 down-lights would save 20x5.58=115.2kWh of electricity per year and 20x5.58=111.6 kg of CO₂ per year.

When calculations were made on a representative ceiling of area of 16m² with 6 down lights, it was found that it would be impossible to achieve a similar heat loss as the ceiling with Tenmat covers by increasing the insulation thickness in the case of the ceiling with un-covered down lights.

It should be noted that the heat loss due to convection from the hot light fitting has been neglected in the calculation, as there is currently no standard test method for assessing this convection.

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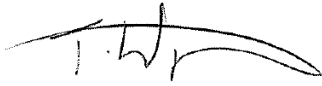
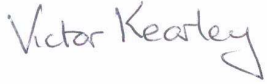


Neglecting this component of heat loss means that the figures presented in the report for energy saving with the Tenmat loft cover will be conservative. This is because in practise the convection will significantly increase the energy loss in the down-light only case and it is expected that the Tenmat loft cover will eliminate or significantly reduce this convection.

At the time of writing there is a possibility of a small testing program to produce an indicative assessment of these convective losses. If the program goes ahead, the calculations in the report will be updated to take into account the new data.

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5 Authorisation

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