BEATING THE HEAT:
ASSESSING SOLAR GAIN FOR GREEN BUILDING INDEX

Ar Chan Seong Aun – Founder of Arkitek Daya Seni (ADS)

PAM President
2013 – 2015

LAM Board Member
2011 – 2021

MGBC President
2018 – 2020

GREEN BUILDINGS ARE COOLER

UBBL BY-LAW 38A

ROOF INSULATION & BUILDING ENVELOPE

25 March 2022

Ar Chan Seong Aun
President Malaysia GBC 2018-2020
PAM President 2013-2015
Chairman GBI Accreditation Panel 2015-2016
M. Arch. B. Arch (NZ), P. Arch, APAM


DATO' DR. AR. KEN YEANG
WORLD RENOWNED ECO-ARCHITECT
PAM GOLD MEDALIST 2011
So designing to respond to climate is the first aspect of green design.

DESIGNING IN TROPICAL CLIMATE

- Architect depend on feel, intuition and experience to design for climate
- BUT INTUTION has its limitations
- Architects need to BENCHMARK their designs in terms of how much HEAT goes into their building, especially so in the TROPICAL climate.

green building index

1

BY-LAW 38A OF UBBL 1984

UBBL BY-LAW 38A AMENDMENT 2012 ENERGY EFFICIENCY IN BUILDINGS

1. New or renovated non-residential buildings with air-conditioned space exceeding 4,000 square metres shall be –

    a) designed to meet the requirements of MS 1525 with regards to the Overall Thermal Transfer Value (OTTV) and the Roof Thermal Transfer Value (RTTV); and

    b) provided with an Energy Management System.

MS1525:2007

1. **MS1525:2007 is a Code of Practice (CP), and is now incorporated into UBBL, hence a CP becomes part of a By-law.**

   a) Applies to non-residential, air-conditioned buildings, ≥ 4,000 sq m. (pending revision)

   b) Architects and Engineers must submit OTTV & RTTV calculations.

   c) Requirement for Energy Management Control system is under Clause 9.

BUILDING ENVELOPE

“the external portions of a building through which thermal energy is transferred”

and

“this thermal transfer is the major factor affecting interior comfort level and energy usage”.

MS1525:2007

THERMAL RESISTANCE

Relationships between thermal conductivity, thermal resistance and U-value

$$k = \text{Thermal conductivity}$$

$$R = \frac{\text{Material thickness}}{k}$$

$$U = \frac{1}{R}$$

ROOF THERMAL RESISTANCE

Roof thermal resistance (residential)

SSTH
75%

DSTH
50%

5S Flat
40%

Legend: Single Storey Terrace House (SSTH), Double Storey Terrace House (SSTH), 5 Storey (5S)

ENVELOPE THERMAL RESISTANCE

Envelope thermal resistance (non-residential)

FACTORIES
25%

LOW RISE
60%

HIGH RISE
80%

THERMAL RESISTANCE

Solar Heat Gain in typical Malaysian homes

	Single Storey Terrace	Double Storey Terrace	Five Storey Flats	Eight Storey Apartments
Gross Floor Area	880	1,408	60,500	81,680
Roof over Envelope Area	68%	45%	30%	18%
Wall over Envelope Area	32%	55%	70%	82%
North-South Facing				
Roof Solar Heat Gain in kWh/day	30	24	363	306
Total Solar Heat Gain in kWh/day	35	33	726	908
Roof over Total Solar Heat Gain	**86%**	**73%**	**50%**	**34%**
East-West Facing				
Roof Solar Heat Gain in kWh/day	30	24	363	306
Total Solar Heat Gain in kWh/day	40	43	842	1,141
Roof over Total Solar Heat Gain	**75%**	**55%**	**40%**	**27%**

MS1525:2007 CLAUSE 5.2

OTTV **applies to building envelope**

MS1525:2007 CLAUSE 5.5

Roof U-value **refers to the thermal transmittance of the roof construction**

MS1525:2007 CLAUSE 5.6

RTTV **applies to roof with skylights**

2

OTTV FOR BUILDING ENVELOPE

CONCEPT OF **OTTV**

A design criterion for building envelope known as the Overall Thermal Transfer Value (OTTV) has been adopted. The OTTV aims at achieving the design of building envelope to reduce heat gain through the building envelope and hence reduce the cooling load of the air-conditioning system.

The OTTV…should not exceed 50 W/m^2

CONCEPT OF **OTTV**

Assumptions

The concept of OTTV is based on the assumption that the envelope of the building is completely enclosed.

In the OTTV formulation, the following items are not considered:

- **internal shading devices e.g curtains**
- **solar reflection or shading from adjacent buildings**

CONCEPT OF **OTTV**

MS1525:2007 Clause 5.2.2 says

The formula for the OTTV of any given wall orientation is as follows:

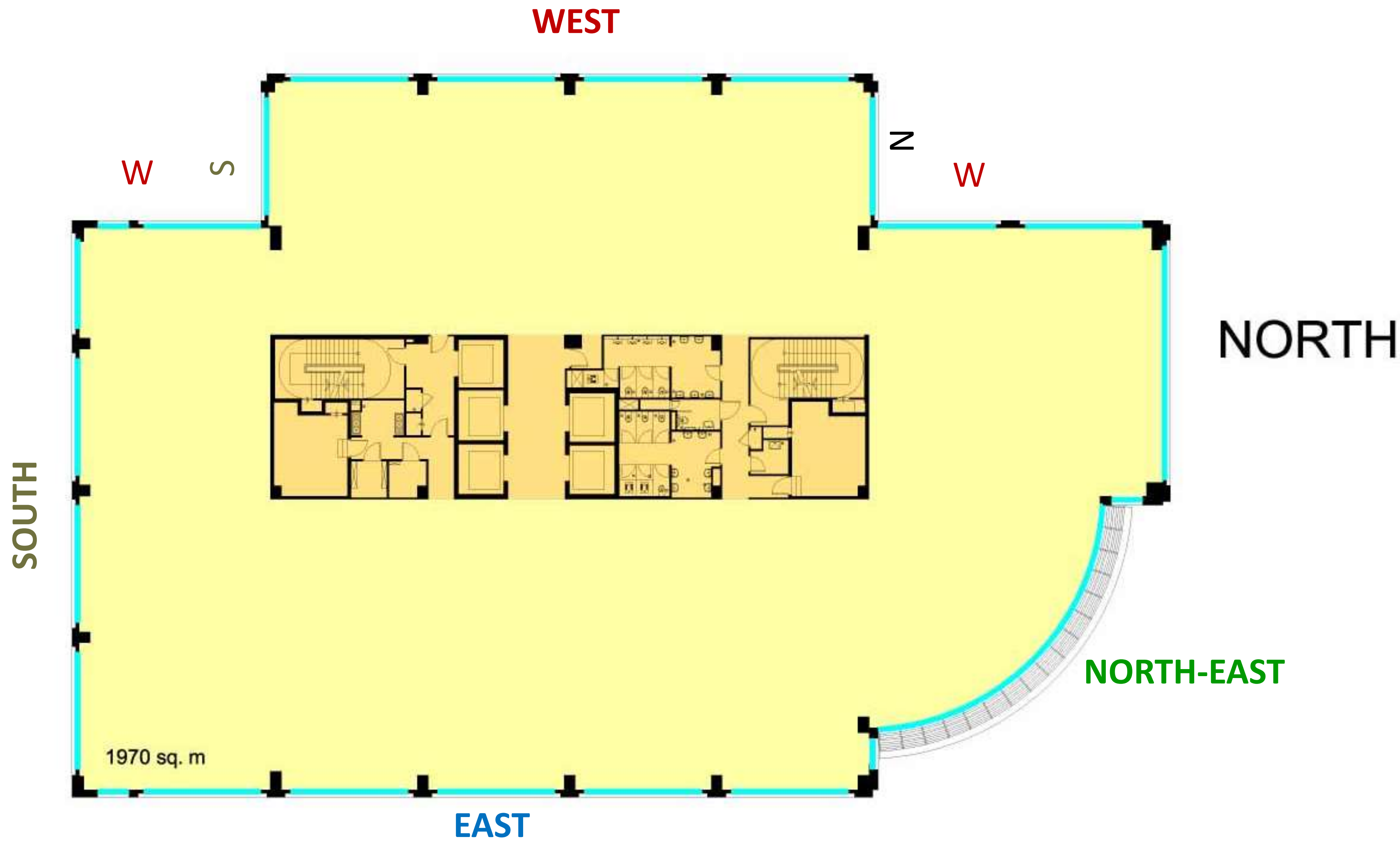
$$OTTVi = 15\alpha(1 - WWR)U_w + 6(WWR)U_f + (194 \times CF \times WWR \times SC)$$

OTTV =

Heat Conduction through Walls	+	Heat Conduction through Windows	+	Solar Heat Gain through Windows
0.2% to 5%		**10% to 20%**		**70% to 85%**

SAMPLE BUILDING
MENARA UAC

MENARA UAC



MENARA UAC

South Elevation

Total Window Area = x = 693 sq.m.

Total Wall Area = y = 2,933 sq.m.

$$WWR = \frac{x}{y} = \frac{693}{2,933} = 0.24$$

MENARA UAC

HEAT CONDUCTION THROUGH WALLS

OTTV Calculation for Menara UAC, Mutiara Damansara

HEAT CONDUCTION THROUGH WALLS	ELEVATION	Façade Area (A) m^2	Constant	Solar Absorption Factor (α)	Window to Wall Ratio (WWR)	(1 - WWR)	U-Value W/m^2k (Uv)	Orientation Correction Factor (CF)	Shading Coeff (SC = $SC_1 \times SC_2$)	Termal Transfer Value (OTTV)	A x OTTV
	North Wall (Alumn. Cladding)	1187.7	15	0.1	0.39	0.61	0.92	N/A	N/A	0.84	999.8
	South Wall (Alumn. Cladding)	2933.8	15	0.1	0.24	0.76	0.92	-	-	1.05	3,077.0
	East Wall (Alumn. Cladding)	2010.5	15	0.1	0.43	0.57	0.92	-	-	0.79	1,581.5
	West Wall (Alumn. Cladding)	2430.7	15	0.1	0.35	0.65	0.92	-	-	0.90	2,180.3
	North-East Wall (Alumn. Cladding)	683.2	15	0.1	0.46	0.54	0.92	-	-	0.75	509.1
	TOTAL WALL OTTV		15 x α x (1 - WWR) U							4.32	8,347.7

OTTV = Heat Conduction through Walls + Heat Conduction through Windows + Solar Heat Gain through Windows

MENARA UAC

HEAT CONDUCTION THROUGH WINDOWS

OTTV Calculation for Menara UAC, Mutiara Damansara

	ELEVATION	Façade Area (A) m^2	Constant	Solar Absorption Factor (α)	Window to Wall Ratio (WWR)	(1 - WWR)	U-Value W/m^2k (Uv)	Orientation Correction Factor (CF)	Shading Coeff (SC = $SC_1 \times SC_2$)	Termal Transfer Value (OTTV)	A x OTTV
HEAT CONDUCTION THROUGH WINDOWS	North Window (Single, Grey)	1187.7	6	N/A	0.39	N/A	6.31	N/A	N/A	14.77	17,536.9
	South Window (Single, Grey)	2933.8	6	-	0.24	-	6.31	-	-	9.09	26,657.7
	East Window (Single, Grey)	2010.5	6	-	0.43	-	6.31	-	-	16.28	32,730.5
	West Window (Single, Grey)	2430.7	6	-	0.35	-	6.31	-	-	13.25	32,209.2
	North-East Window (Single, Grey)	683.2	6	-	0.46	-	6.31	-	-	17.42	11,898.3
	TOTAL WINDOW OTTV		6 x WWR x U							70.80	121,032.6

OTTV = Heat Conduction through Walls + Heat Conduction through Windows + Solar Heat Gain through Windows

MENARA UAC

SOLAR HEAT GAIN THROUGH WINDOWS

OTTV Calculation for Menara UAC, Mutiara Damansara

SOLAR HEAT GAIN THROUGH WINDOWS	ELEVATION	Façade Area (A) m^2	Constant	Solar Absorption Factor (α)	Window to Wall Ratio (WWR)	(1 - WWR)	U-Value W/m^2k (Uv)	Orientation Correction Factor (CF)	Shading Coeff (SC = $SC_1 \times SC_2$)	Termal Transfer Value (OTTV)	A x OTTV
	North Window Shading	1187.7	194	N/A	0.39	N/A	N/A	0.9	0.56	38.13	45,290.1
	South Window Shading	2933.8	194	-	0.24	-	-	0.92	0.56	23.99	70,375.1
	East Window Shading	2010.5	194	-	0.43	-	-	1.23	0.56	57.46	115,522.7
	West Window Shading	2430.7	194	-	0.35	-	-	0.94	0.56	35.74	86,879.4
	North-East Window Shading	683.2	194	-	0.46	-	-	1.09	0.56 x 0.69	37.59	25,678.6
	TOTAL SOLAR HEAT GAIN		194 x CF x WWR x SC							192.91	343,746.0

OTTV = Heat Conduction through Walls + Heat Conduction through Windows + Solar Heat Gain through Windows

green building index

OTTV Calculation for Menara UAC, Mutiara Damansara

	ELEVATION	Façade Area (A) m^2	Constant	Solar Absorption Factor (α)	Window to Wall Ratio (WWR)	(1 - WWR)	U-Value W/m^2k (Uv)	Orientation Correction Factor (CF)	Shading Coeff SC = $SC_1 \times SC_2$	Termal Transfer Value (OTTV)	A x OTTV
HEAT CONDUCTION THROUGH WALLS	North Wall (Alumn. Cladding)	1187.7	15	0.1	0.39	0.61	0.92	N/A	N/A	0.84	999.8
	South Wall (Alumn. Cladding)	2933.8	15	0.1	0.24	0.76	0.92	-	-	1.05	3,077.0
	East Wall (Alumn. Cladding)	2010.5	15	0.1	0.43	0.57	0.92	-	-	0.79	1,581.5
	West Wall (Alumn. Cladding)	2430.7	15	0.1	0.35	0.65	0.92	-	-	0.90	2,180.3
	North-East Wall (Alumn. Cladding)	683.2	15	0.1	0.46	0.54	0.92	-	-	0.75	509.1
	TOTAL WALL OTTV		15 x α x (1 - WWR) U								8,347.7
HEAT CONDUCTION THROUGH WINDOWS	North Window (Single, Grey)	1187.7	6	N/A	0.39	N/A	6.31	N/A	N/A	14.77	17,536.9
	South Window (Single, Grey)	2933.8	6	-	0.24	-	6.31	-	-	9.09	26,657.7
	East Window (Single, Grey)	2010.5	6	-	0.43	-	6.31	-	-	16.28	32,730.5
	West Window (Single, Grey)	2430.7	6	-	0.35	-	6.31	-	-	13.25	32,209.2
	North-East Window (Single, Grey)	683.2	6	-	0.46	-	6.31	-	-	17.42	11,898.3
	TOTAL WINDOW OTTV		6 x WWR x U								121,032.6
SOLAR HEAT GAIN THROUGH WINDOWS	North Window Shading	1187.7	194	N/A	0.39	N/A	N/A	0.90	0.56	38.13	45,290.1
	South Window Shading	2933.8	194	-	0.24	-	-	0.92	0.56	23.99	70,375.1
	East Window Shading	2010.5	194	-	0.43	-	-	1.23	0.56	57.46	115,522.7
	West Window Shading	2430.7	194	-	0.35	-	-	0.94	0.56	35.74	86,879.4
	North-East Window Shading	683.2	194	-	0.46	-	-	1.09	0.56 x 0.69	37.59	25,678.6
	TOTAL SOLAR HEAT GAIN		194 x CF x WWR x SC								343,746.0
	OVERALL BUILDING OTTV	9245.9								51.17	473,126.3

WAYS TO IMPROVE OTTV

1. Identify which component contributes the most to OTTV.
2. Review Solar Correction Factor (CF) in Table 4.
3. Review glass selection and its Shading Coefficient (SC).
4. Review sunshades and its Shading Coefficient (SC) in Tables 5, 6 and 7.
5. Review Window-to-gross exterior wall area ratio (WWR).

$$OTTVi = 15\alpha(1 - WWR)U_w + 6(WWR)U_f + (194 \times CF \times WWR \times SC)$$

SUMMARY

Clause 5.2

OTTV applies to building envelope, where

OTTV $\leq$ 50 W/m^2

Clause 5.5

Roof U-value refers to the thermal transmittance of the roof, where

Roof U-value $\leq$ 0.4 - 0.6 W/m^{2}K

Clause 5.6

RTTV applies to roof with skylights, where

RTTV $\leq$ 25 W/m^2

3

U-VALUE CALCULATIONS FOR LIGHTWEIGT ROOFS WITH REFLECTIVE INSULATION

Table A1: RSI of enclosed air space for ε=0.03

		RSI of Enclosed Air Space for Heat Flow Down at Tm=27.5°C, ε=0.03, ΔT=15°C (m^2K/W)																								
		Enclosed Air Space (m)																								
		0.005	0.010	0.015	0.020	0.025	0.030	0.035	0.040	0.045	0.050	0.055	0.060	0.065	0.070	0.075	0.080	0.085	0.090	0.095	0.100	0.105	0.110	0.115	0.120	0.125
Angle (°)	0	0.184	0.356	0.514	0.655	0.780	0.892	0.992	1.082	1.164	1.238	1.305	1.366	1.422	1.474	1.521	1.564	1.602	1.637	1.669	1.698	1.724	1.747	1.769	1.788	1.806
	5	0.184	0.356	0.513	0.650	0.766	0.863	0.944	1.012	1.072	1.124	1.171	1.214	1.252	1.287	1.319	1.348	1.374	1.398	1.420	1.440	1.459	1.476	1.492	1.506	1.520
	10	0.184	0.356	0.512	0.644	0.752	0.837	0.901	0.950	0.993	1.030	1.062	1.092	1.118	1.142	1.165	1.185	1.203	1.220	1.236	1.251	1.265	1.277	1.290	1.301	1.312
	15	0.184	0.356	0.511	0.639	0.738	0.811	0.861	0.896	0.925	0.950	0.972	0.992	1.010	1.027	1.042	1.057	1.070	1.082	1.094	1.105	1.116	1.126	1.136	1.145	1.154
	20	0.184	0.356	0.510	0.633	0.725	0.788	0.825	0.847	0.866	0.882	0.896	0.909	0.921	0.933	0.943	0.954	0.963	0.973	0.981	0.990	0.999	1.007	1.015	1.023	1.030
	25	0.184	0.356	0.509	0.628	0.712	0.765	0.792	0.804	0.814	0.823	0.831	0.839	0.847	0.854	0.862	0.869	0.876	0.883	0.890	0.897	0.904	0.910	0.917	0.924	0.930
	30	0.184	0.356	0.508	0.623	0.700	0.744	0.761	0.764	0.767	0.771	0.775	0.779	0.783	0.788	0.793	0.798	0.803	0.808	0.814	0.819	0.825	0.831	0.837	0.842	0.848
	35	0.184	0.356	0.507	0.618	0.688	0.724	0.732	0.729	0.726	0.725	0.726	0.727	0.729	0.731	0.734	0.738	0.741	0.746	0.750	0.754	0.759	0.764	0.769	0.774	0.779
	40	0.184	0.356	0.506	0.613	0.677	0.705	0.706	0.696	0.689	0.685	0.682	0.681	0.681	0.682	0.684	0.686	0.689	0.692	0.695	0.699	0.703	0.707	0.712	0.716	0.721
	45	0.184	0.356	0.505	0.608	0.666	0.687	0.681	0.666	0.656	0.649	0.644	0.641	0.639	0.639	0.640	0.641	0.643	0.645	0.648	0.651	0.654	0.658	0.662	0.666	0.670
	50	0.184	0.356	0.504	0.600	0.646	0.661	0.654	0.640	0.631	0.624	0.620	0.618	0.617	0.616	0.617	0.619	0.620	0.623	0.626	0.629	0.632	0.636	0.640	0.644	0.648
	55	0.184	0.356	0.503	0.593	0.628	0.637	0.629	0.616	0.608	0.602	0.598	0.596	0.595	0.595	0.596	0.598	0.600	0.602	0.605	0.608	0.611	0.615	0.619	0.623	0.627
	60	0.184	0.356	0.501	0.585	0.611	0.615	0.606	0.594	0.586	0.581	0.578	0.576	0.575	0.576	0.577	0.578	0.580	0.583	0.585	0.589	0.592	0.595	0.599	0.603	0.607
	65	0.184	0.356	0.500	0.578	0.595	0.594	0.584	0.574	0.566	0.561	0.559	0.557	0.557	0.557	0.558	0.560	0.562	0.564	0.567	0.570	0.574	0.577	0.581	0.585	0.588
	70	0.184	0.356	0.499	0.571	0.580	0.574	0.564	0.554	0.548	0.543	0.541	0.539	0.539	0.540	0.541	0.543	0.545	0.547	0.550	0.553	0.556	0.560	0.563	0.567	0.571
	75	0.184	0.356	0.498	0.564	0.565	0.556	0.546	0.536	0.530	0.526	0.524	0.523	0.523	0.523	0.525	0.527	0.529	0.531	0.534	0.537	0.540	0.544	0.547	0.551	0.555
	80	0.184	0.356	0.496	0.557	0.551	0.539	0.528	0.519	0.514	0.510	0.508	0.507	0.507	0.508	0.509	0.511	0.513	0.516	0.519	0.522	0.525	0.528	0.532	0.535	0.539
	85	0.184	0.356	0.495	0.551	0.538	0.523	0.512	0.503	0.498	0.495	0.493	0.493	0.493	0.494	0.495	0.497	0.499	0.502	0.504	0.507	0.511	0.514	0.517	0.521	0.524
	90	0.184	0.356	0.494	0.544	0.526	0.508	0.496	0.489	0.484	0.481	0.479	0.479	0.479	0.480	0.481	0.483	0.486	0.488	0.491	0.494	0.497	0.500	0.503	0.507	0.510

ε is surface emittance. Effective emittance, E is approximated as E=ε in most practical cases. (see Equation 6.2(3) in AS/NZ 4859.2:2018)

Table B: RSI of attic space with reflective or non-reflective surface

Source: AS/NZS 4859.2:2018 Table 14, Heat Flow Down.

Airspace Type	RSI (m^2K/W)	
	IR Non-Reflective	IR Reflective
Non-Ventilated	0.28	1.09
Natural Ventilation	0.46	1.36

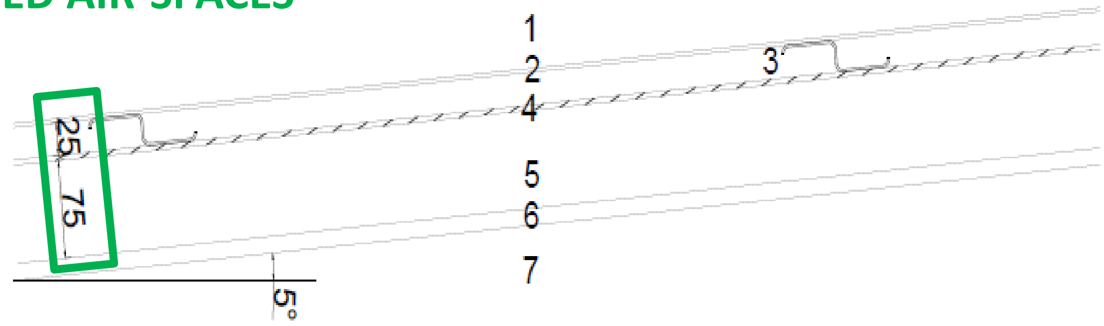
1.Non-reflective surface has an emittance of greater than 0.05. (Source: MS 2095:2014)
2.Reflective surface has an emittance of not greater than 0.05. (Source: MS 2095:2014)
3.Non-Ventilated refers to no opening, or opening ratio less than 1:600.
4.Natural Ventilation requires that the minimum opening ratio shall be 1:600 of the vented space. (Source: US 2015 International Residential Code)

Category	Code 1	Type	Code2	Read As
Roof	r	Light Weight	LW	rLW
		Heavy Weight	HW	rHW
Material	m	Metal	M	mM
		Tile	T	mT
Insulation	i	Reflective Insulation Single Sided	RISS	iRISS
		Reflective Insulation Double Sided	RIDS	iRIDS
		Radiant Barrier Single Sided	RBSS	iRBSS
		Radiant Barrier Double Sided	RBDS	iRBDS
		Mass	M	iM
		NO insulation	NO	iNO
Ceiling	c	Inclined	I	cI
		Horizontal	H	cH
		NO Ceiling	NO	cNO
Attic	a	Ventilated	V	aV
		UnVentilated	UV	aUV
		NO Attic	NO	aNO

1.Example of reflective insulation building materials: single-sided or double-sided reflective surface laminated onto air bubble pack, radiant barrier with enclosed air space, foam, etc. (Source: MS 2095:2014)
2.Example of radiant barrier building materials: single-sided or double-sided reflective surface laminated onto woven, paper, film, etc. (Source: MS 2095:2014)

EXAMPLE 1: METAL DECK + FOIL

- ROOF PITCH 5°
- FOIL INSULATION ε=0.03
- ENCLOSED AIR-SPACES



Roof	Lightweight (rLW)
Material	Metal (mM)
Insulation	Reflective Insulation Double Sided (iRIDS)
Ceiling	Inclined (cI)
Attic	No (aNO)
Code	rLW_mM_iRIDS_cI_aNO

Layers	Thermal Conductivity (W/mK)	Thermal Resistance (m^2K/W)
1) External Air Film	-	0.044
2) Metal Deck	47.600	0.000
3) 25mm Purlin + Enclosed Air Space	-	0.766
4) Reflective Insulation Double Sided	-	0.150
5) 75mm Rafter + Enclosed Air Space	-	1.319
6) Plasterboard 13mm thk	0.250	0.048
7) Internal Air Film	-	0.160
	Total R =	2.487
	U-Value =	1/R

U-Value (W/m^2K) = 0.40

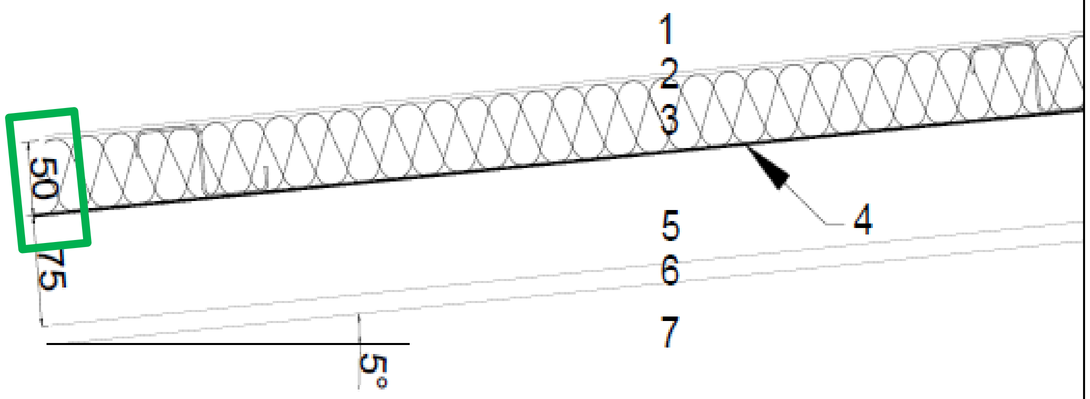
Table A1: RSI of enclosed air space for ε=0.03

	RSI of Enclosed Air Space for Heat Flow Down at Tm=27.5°C, ε=0.03, ΔT=15°C (m^2K/W)																								
	Enclosed Air Space (m)																								
Angle (°)	0.005	0.010	0.015	0.020	0.025	0.030	0.035	0.040	0.045	0.050	0.055	0.060	0.065	0.070	0.075	0.080	0.085	0.090	0.095	0.100	0.105	0.110	0.115	0.120	0.125
0	0.184	0.356	0.514	[illegible]	[illegible]	[illegible]	0.992	1.082	1.164	1.238	1.305	1.366	1.422	[illegible]	[illegible]	[illegible]	1.602	1.637	1.669	1.698	1.724	1.747	1.769	1.788	1.806
5	0.184	0.356	0.513	[illegible]	0.766	[illegible]	0.944	1.012	1.072	1.124	1.171	1.214	1.252	[illegible]	1.319	[illegible]	1.374	1.398	1.420	1.440	1.459	1.476	1.492	1.506	1.520
10	0.184	0.356	0.512	[illegible]	[illegible]	[illegible]	0.901	0.950	0.993	1.030	1.062	1.092	1.118	[illegible]	[illegible]	[illegible]	1.203	1.220	1.236	1.251	1.265	1.277	1.290	1.301	1.312
15	0.184	0.356	0.511	0.639	0.738	0.811	0.861	0.896	0.925	0.950	0.972	0.992	1.010	1.027	1.042	1.057	1.070	1.082	1.094	1.105	1.116	1.126	1.136	1.145	1.154
20	0.184	0.356	0.510	0.633	0.725	0.788	0.825	0.847	0.866	0.882	0.896	0.909	0.921	0.933	0.943	0.954	0.963	0.973	0.981	0.990	0.999	1.007	1.015	1.023	1.030
25	0.184	0.356	0.509	0.628	0.712	0.765	0.792	0.804	0.814	0.823	0.831	0.839	0.847	0.854	0.862	0.869	0.876	0.883	0.890	0.897	0.904	0.910	0.917	0.924	0.930
30	0.184	0.356	0.508	0.623	0.700	0.744	0.761	0.764	0.767	0.771	0.775	0.779	0.783	0.788	0.793	0.798	0.803	0.808	0.814	0.819	0.825	0.831	0.837	0.842	0.848
35	0.184	0.356	0.507	0.618	0.688	0.724	0.732	0.729	0.726	0.725	0.726	0.727	0.729	0.731	0.734	0.738	0.741	0.746	0.750	0.754	0.759	0.764	0.769	0.774	0.779
40	0.184	0.356	0.506	0.613	0.677	0.705	0.706	0.696	0.689	0.685	0.682	0.681	0.681	0.682	0.684	0.686	0.689	0.692	0.695	0.699	0.703	0.707	0.712	0.716	0.721
45	0.184	0.356	0.505	0.608	0.666	0.687	0.681	0.666	0.656	0.649	0.644	0.641	0.639	0.639	0.640	0.641	0.643	0.645	0.648	0.651	0.654	0.658	0.662	0.666	0.670
50	0.184	0.356	0.504	0.600	0.646	0.661	0.654	0.640	0.631	0.624	0.620	0.618	0.617	0.616	0.617	0.619	0.620	0.623	0.626	0.629	0.632	0.636	0.640	0.644	0.648
55	0.184	0.356	0.503	0.593	0.628	0.637	0.629	0.616	0.608	0.602	0.598	0.596	0.595	0.595	0.596	0.598	0.600	0.602	0.605	0.608	0.611	0.615	0.619	0.623	0.627
60	0.184	0.356	0.501	0.585	0.611	0.615	0.606	0.594	0.586	0.581	0.578	0.576	0.575	0.576	0.577	0.578	0.580	0.583	0.585	0.589	0.592	0.595	0.599	0.603	0.607
65	0.184	0.356	0.500	0.578	0.595	0.594	0.584	0.574	0.566	0.561	0.559	0.557	0.557	0.557	0.558	0.560	0.562	0.564	0.567	0.570	0.574	0.577	0.581	0.585	0.588
70	0.184	0.356	0.499	0.571	0.580	0.574	0.564	0.554	0.548	0.543	0.541	0.539	0.539	0.540	0.541	0.543	0.545	0.547	0.550	0.553	0.556	0.560	0.563	0.567	0.571
75	0.184	0.356	0.498	0.564	0.565	0.556	0.546	0.536	0.530	0.526	0.524	0.523	0.523	0.523	0.525	0.527	0.529	0.531	0.534	0.537	0.540	0.544	0.547	0.551	0.555
80	0.184	0.356	0.496	0.557	0.551	0.539	0.528	0.519	0.514	0.510	0.508	0.507	0.507	0.508	0.509	0.511	0.513	0.516	0.519	0.522	0.525	0.528	0.532	0.535	0.539
85	0.184	0.356	0.495	0.551	0.538	0.523	0.512	0.503	0.498	0.495	0.493	0.493	0.493	0.494	0.495	0.497	0.499	0.502	0.504	0.507	0.511	0.514	0.517	0.521	0.524
90	0.184	0.356	0.494	0.544	0.526	0.508	0.496	0.489	0.484	0.481	0.479	0.479	0.479	0.480	0.481	0.483	0.486	0.488	0.491	0.494	0.497	0.500	0.503	0.507	0.510

ε is surface emittance. Effective emittance, E is approximated as E=ε in most practical cases. (see Equation 6.2(3) in AS/NZ 4859.2:2018)

EXAMPLE 2: METAL DECK + MASS & FOIL INSULATIONS

- ROOF PITCH 5°
- ENCLOSED AIR-SPACES



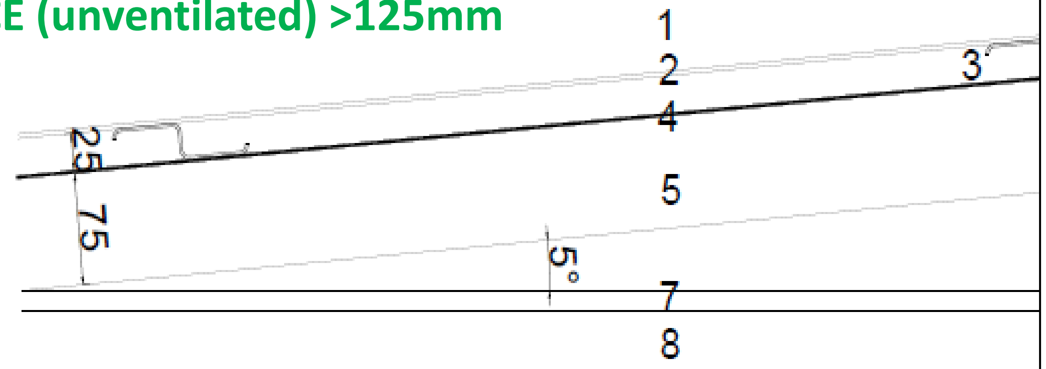
Roof	Lightweight (rLW)
Material	Metal (mM)
Insulation	Mass (IM) + Radiant Barrier Single Sided (iRBSS) facing down
Ceiling	Inclined (cI)
Attic	No (aNO)
Code	rLW_mM_iM+iRBSS_cI_aNO

Layers	Thermal Conductivity (W/mK)	Thermal Resistance (m^2K/W)
1) External Air Film	-	0.044
2) Metal Deck	47.600	0.000
3) 50mm 40kg.m3 Mass Insulation	0.036	1.388
4) Radiant Barrier Single Sided (facing down)	-	0.000
5) 75mm Rafter + Enclosed Air Space	-	1.319
6) Plasterboard 13mm thk	0.250	0.048
7) Internal Air Film	-	0.160
	Total R =	2.959
	U-Value =	1/R

U-Value (W/m^2K) = 0.34

EXAMPLE 3: METAL DECK + RADIANT BARRIER ONLY

- ROOF PITCH 5°
- ATTIC SPACE (unventilated) >125mm



Roof	Lightweight (rLW)
Material	Metal (mM)
Insulation	Radiant Barrier Double Sided (iRBDS)
Ceiling	Horizontal (cH)
Attic	Unventilated (aUV)
Code	rLW_mM_iRBDS_cH_aUV

Layers	Thermal Conductivity (W/mK)	Thermal Resistance (m^2K/W)
1) External Air Film	-	0.044
2) Metal Deck	47.600	0.000
3) 25mm Purlin + Enclosed Air Space	-	0.766
4) Radiant Barrier Double Sided	-	0.000
5) 75mm Rafter	-	0.000
6) Attic Space (unventilated)	-	1.090
7) Plasterboard 13mm thk	0.250	0.048
8) Internal Air Film	-	0.160
	Total R =	2.108
	U-Value =	1/R

U-Value (W/m^2K) = 0.47

Table B: RSI of attic space with reflective or non-reflective surface

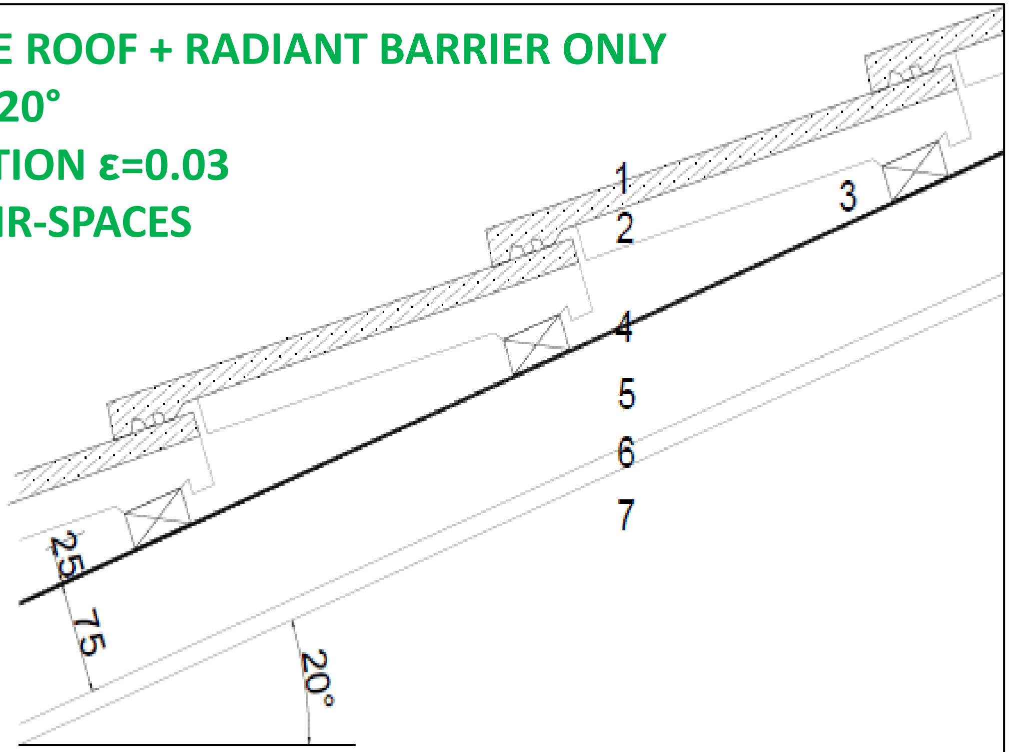
Source: AS/NZS 4859.2:2018 Table 14, Heat Flow Down.

Airspace Type	RSI (m^2K/W)	
	IR Non-Reflective	IR Reflective
Non-Ventilated	0.28	**1.09**
Natural Ventilation	0.46	1.36

1. Non-reflective surface has an emittance of greater than 0.05. (Source: MS 2095:2014)
2. Reflective surface has an emittance of not greater than 0.05. (Source: MS 2095:2014)
3. Non-Ventilated refers to no opening, or opening ratio less than 1:600.
4. Natural Ventilation requires that the minimum opening ratio shall be 1:600 of the vented space. (Source: US 2015 International Residential Code)

EXAMPLE 4: TILE ROOF + RADIANT BARRIER ONLY

- ROOF PITCH 20°
- FOIL INSULATION ε=0.03
- ENCLOSED AIR-SPACES



Roof	Lightweight (rLW)
Material	Tile (mT)
Insulation	Radiant Barrier Double Sided (iRBDS)
Ceiling	Inclined (cI)
Attic	No (aNO)
Code	rLW_mT_iRBDS_cI_aNO

Layers	Thermal Conductivity (W/mK)	Thermal Resistance (m^2K/W)
1) External Air Film	-	0.044
2) 12mm Roof Tile	0.836	0.014
3) 25mm Purlin + Enclosed Air Space	-	0.725
4) Radiant Barrier Double Sided	-	0.000
5) 75mm Rafter + Enclosed Air Space	-	0.943
6) Plasterboard 13mm thk	0.250	0.048
7) Internal Air Film	-	0.160
	Total R =	1.934
	U-Value =	1/R

U-Value (W/m^2K) = 0.52

Table A1: RSI of enclosed air space for ε=0.03

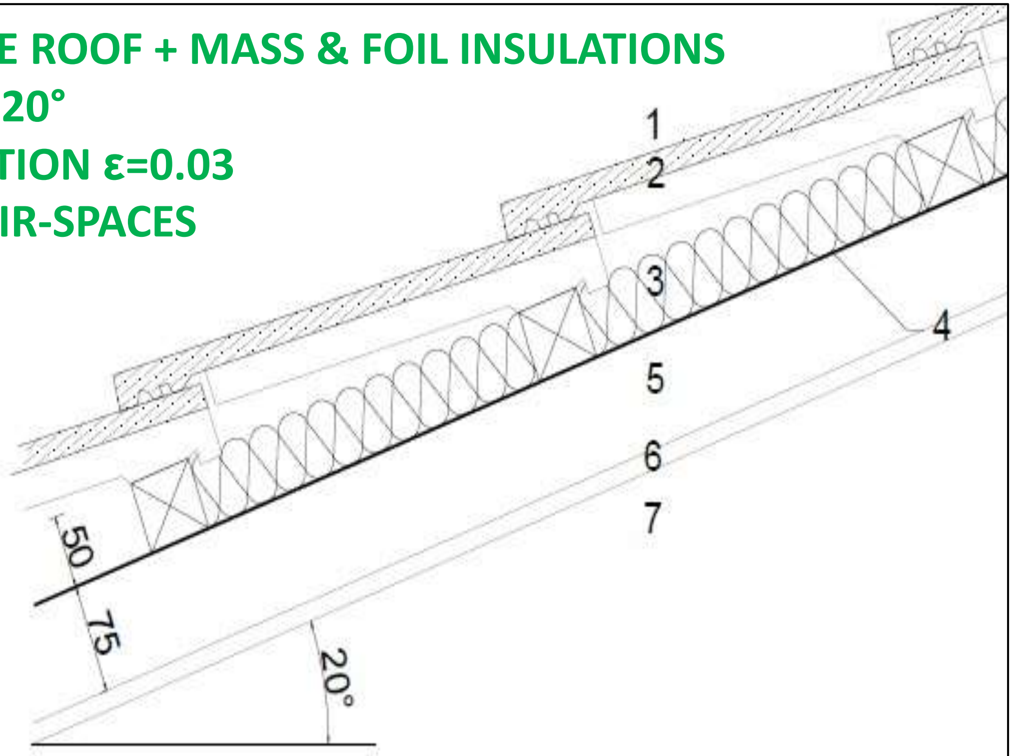
		RSI of Enclosed Air Space for Heat Flow Down at Tm=27.5°C, ε=0.03, ΔT=15°C (m^2K/W)																							
		Enclosed Air Space (m)																							
		0.005	0.010	0.015	0.020	0.025	0.030	0.035	0.040	0.045	0.050	0.055	0.060	0.065	0.070	0.075	0.080	0.085	0.090	0.095	0.100	0.105	0.110	0.115	0.120	0.125
Angle (°)	0	0.184	0.356	0.514	0.655	0.780	0.892	0.992	1.082	1.164	1.238	1.305	1.366	1.422	1.474	1.521	1.564	1.602	1.637	1.669	1.698	1.724	1.747	1.769	1.788	1.806
	5	0.184	0.356	0.513	0.650	0.766	0.863	0.944	1.012	1.072	1.124	1.171	1.214	1.252	1.287	1.319	1.348	1.374	1.398	1.420	1.440	1.459	1.476	1.492	1.506	1.520
	10	0.184	0.356	0.512	0.644	0.752	0.837	0.901	0.950	0.993	1.030	1.062	1.092	1.118	1.142	1.165	1.185	1.203	1.220	1.236	1.251	1.265	1.277	1.290	1.301	1.312
	15	0.184	0.356	0.511	[illegible]	[illegible]	0.811	0.861	0.896	0.925	0.950	0.972	0.992	1.010	[illegible]	[illegible]	1.057	1.070	1.082	1.094	1.105	1.116	1.126	1.136	1.145	1.154
	20	0.184	0.356	0.510	[illegible]	**0.725**	[illegible]	0.825	0.847	0.866	0.882	0.896	0.909	0.921	[illegible]	**0.943**	[illegible]	0.963	0.973	0.981	0.990	0.999	1.007	1.015	1.023	1.030
	25	0.184	0.356	0.509	[illegible]	0.712	0.765	0.792	0.804	0.814	0.823	0.831	0.839	0.847	0.854	0.862	0.869	0.876	0.883	0.890	0.897	0.904	0.910	0.917	0.924	0.930
	30	0.184	0.356	0.508	0.623	0.700	0.744	0.761	0.764	0.767	0.771	0.775	0.779	0.783	0.788	0.793	0.798	0.803	0.808	0.814	0.819	0.825	0.831	0.837	0.842	0.848
	35	0.184	0.356	0.507	0.618	0.688	0.724	0.732	0.729	0.726	0.725	0.726	0.727	0.729	0.731	0.734	0.738	0.741	0.746	0.750	0.754	0.759	0.764	0.769	0.774	0.779
	40	0.184	0.356	0.506	0.613	0.677	0.705	0.706	0.696	0.689	0.685	0.682	0.681	0.681	0.682	0.684	0.686	0.689	0.692	0.695	0.699	0.703	0.707	0.712	0.716	0.721
	45	0.184	0.356	0.505	0.608	0.666	0.687	0.681	0.666	0.656	0.649	0.644	0.641	0.639	0.639	0.640	0.641	0.643	0.645	0.648	0.651	0.654	0.658	0.662	0.666	0.670
	50	0.184	0.356	0.504	0.600	0.646	0.661	0.654	0.640	0.631	0.624	0.620	0.618	0.617	0.616	0.617	0.619	0.620	0.623	0.626	0.629	0.632	0.636	0.640	0.644	0.648
	55	0.184	0.356	0.503	0.593	0.628	0.637	0.629	0.616	0.608	0.602	0.598	0.596	0.595	0.595	0.596	0.598	0.600	0.602	0.605	0.608	0.611	0.615	0.619	0.623	0.627
	60	0.184	0.356	0.501	0.585	0.611	0.615	0.606	0.594	0.586	0.581	0.578	0.576	0.575	0.576	0.577	0.578	0.580	0.583	0.585	0.589	0.592	0.595	0.599	0.603	0.607
	65	0.184	0.356	0.500	0.578	0.595	0.594	0.584	0.574	0.566	0.561	0.559	0.557	0.557	0.557	0.558	0.560	0.562	0.564	0.567	0.570	0.574	0.577	0.581	0.585	0.588
	70	0.184	0.356	0.499	0.571	0.580	0.574	0.564	0.554	0.548	0.543	0.541	0.539	0.539	0.540	0.541	0.543	0.545	0.547	0.550	0.553	0.556	0.560	0.563	0.567	0.571
	75	0.184	0.356	0.498	0.564	0.565	0.556	0.546	0.536	0.530	0.526	0.524	0.523	0.523	0.523	0.525	0.527	0.529	0.531	0.534	0.537	0.540	0.544	0.547	0.551	0.555
	80	0.184	0.356	0.496	0.557	0.551	0.539	0.528	0.519	0.514	0.510	0.508	0.507	0.507	0.508	0.509	0.511	0.513	0.516	0.519	0.522	0.525	0.528	0.532	0.535	0.539
	85	0.184	0.356	0.495	0.551	0.538	0.523	0.512	0.503	0.498	0.495	0.493	0.493	0.493	0.494	0.495	0.497	0.499	0.502	0.504	0.507	0.511	0.514	0.517	0.521	0.524
	90	0.184	0.356	0.494	0.544	0.526	0.508	0.496	0.489	0.484	0.481	0.479	0.479	0.479	0.480	0.481	0.483	0.486	0.488	0.491	0.494	0.497	0.500	0.503	0.507	0.510

ε is surface emittance. Effective emittance, E is approximated as E=ε in most practical cases. (see Equation 6.2(3) in AS/NZ 4859.2:2018)

green building index

EXAMPLE 5: TILE ROOF + MASS & FOIL INSULATIONS

- ROOF PITCH 20°
- FOIL INSULATION ε=0.03
- ENCLOSED AIR-SPACES



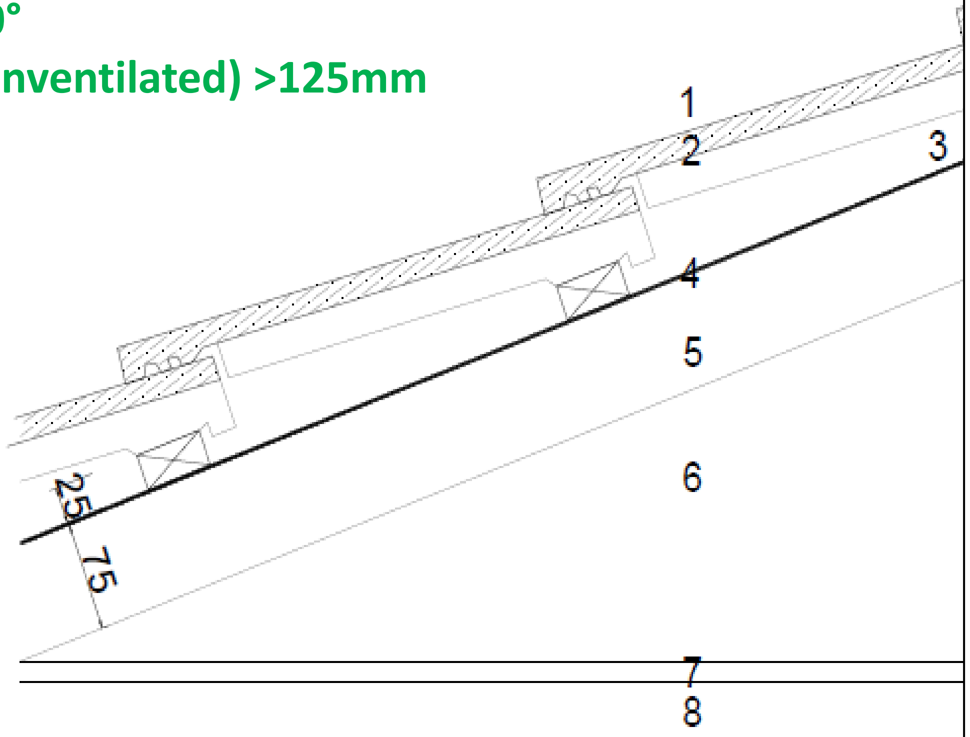
Roof	Lightweight (rLW)
Material	Tile (mT)
Insulation	Mass (iM) + Radiant Barrier Single Sided (iRBSS) facing down
Ceiling	Inclined (cI)
Attic	No (aNO)
Code	rLW_mT_iM+iRBSS_cI_aNO

Layers	Thermal Conductivity (W/mK)	Thermal Resistance (m^2K/W)
1) External Air Film	-	0.044
2) 12mm Roof Tile	0.836	0.014
3) 50mm 40kg/m3 Mass Insulation	0.036	1.388
4) Radiant Barrier Single Sided (facing down)	-	0.000
5) 75mm Rafter + Enclosed Air Space	-	0.943
6) Plasterboard 13mm thk	0.250	0.048
7) Internal Air Film	-	0.160
	Total R =	2.597
	U-Value =	1/R

U-Value (W/m^2K) = 0.39

EXAMPLE 6: TILE ROOF + FOIL INSULATIONS

- ROOF PITCH 20°
- ATTIC SPACE (unventilated) >125mm



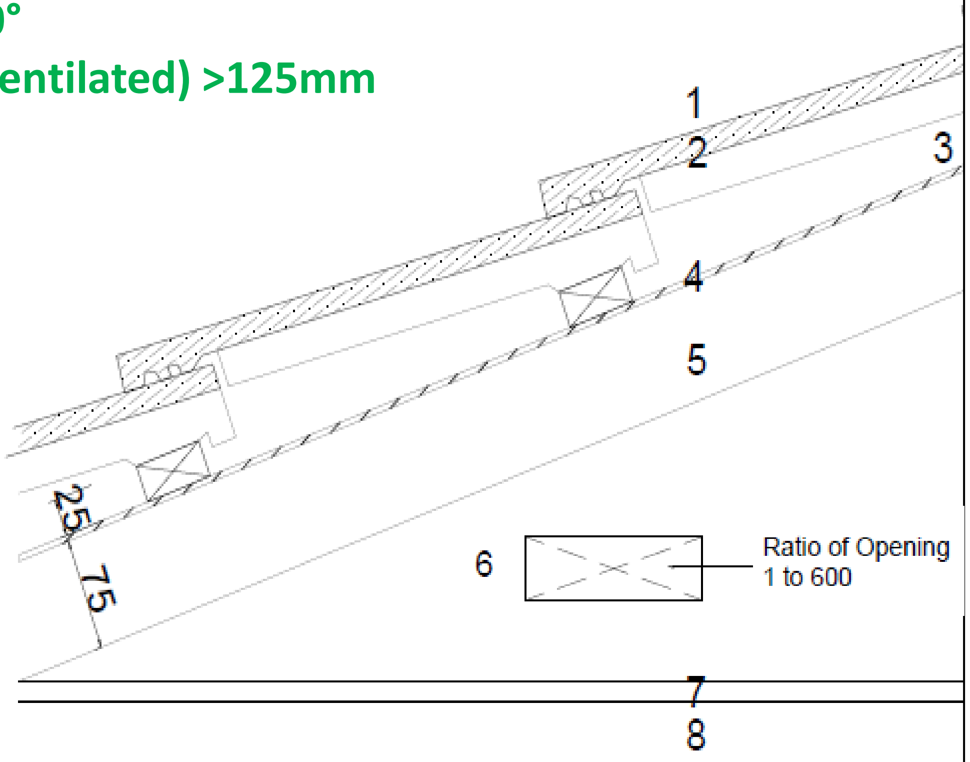
Roof	Lightweight (rLW)
Material	Tile (mT)
Insulation	Radiant Barrier Double Sided (iRBDS)
Ceiling	Horizontal (cH)
Attic	Unventilated (aUV)
Code	rLW_mT_iRBDS_cH_aUV

Layers	Thermal Conductivity (W/mK)	Thermal Resistance (m^2K/W)
1) External Air Film	-	0.044
2) 12mm Roof Tile	0.836	0.014
3) 25mm Purlin + Enclosed Air Space	-	0.725
4) Radiant Barrier Double Sided	-	0.000
5) 75mm Rafter	-	0.000
6) Attic Space (unventilated)	-	1.090
7) Plasterboard 13mm thk	0.250	0.048
8) Internal Air Film	-	0.160
Total R =		2.081
U-Value =		1/R

U-Value (W/m^2K) = 0.48

EXAMPLE 7: TILE ROOF + FOIL INSULATIONS

- ROOF PITCH 20°
- ATTIC SPACE (ventilated) >125mm



Roof	Lightweight (rLW)
Material	Tile (mT)
Insulation	Reflective Insulation Double Sided (iRIDS)
Ceiling	Horizontal (cH)
Attic	Ventilated (aV)
Code	rLW_mT_iRDS_cH_aV

Layers	Thermal Conductivity (W/mK)	Thermal Resistance (m^2K/W)
1 External Air Film	-	0.044
2 12mm Roof Tile	0.836	0.014
3 25mm Purlin + Enclosed Air Space	-	0.725
4 Reflective Insulation Double Sided	-	0.150
5 75mm Rafter	-	0.000
6 Attic Space (ventilated)	-	1.360
7 Plasterboard 13mm thk	0.250	0.048
8 Internal Air Film	-	0.160
	Total R =	2.501
	U-Value =	1/R

U-Value (W/m^2K) = 0.40

Table B: RSI of attic space with reflective or non-reflective surface

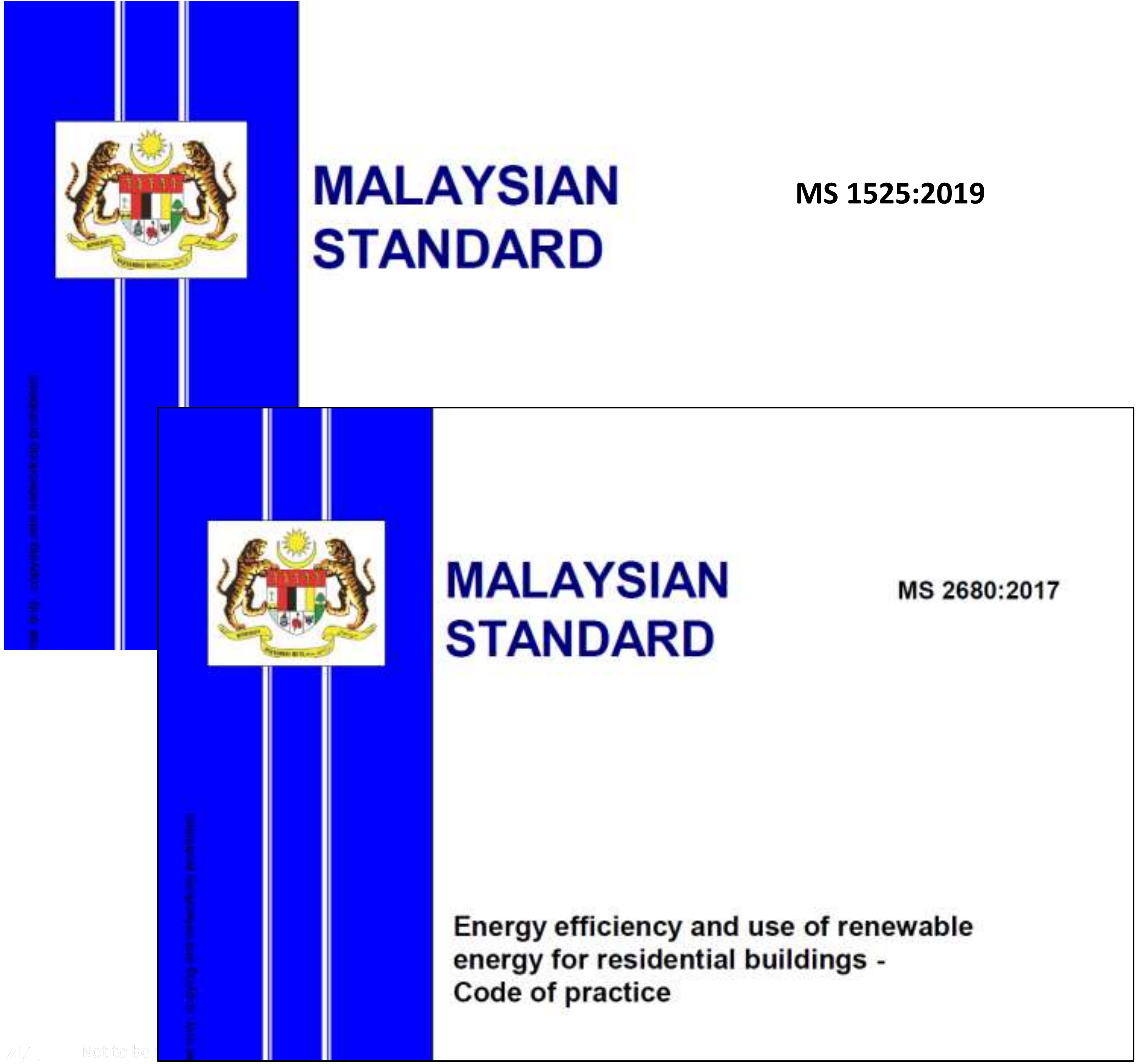
Source: AS/NZS 4859.2:2018 Table 14, Heat Flow Down.

Airspace Type	RSI (m^2K/W)	
	IR Non-Reflective	IR Reflective
Non-Ventilated	0.28	1.09
Natural Ventilation	0.46	**1.36**

1. Non-reflective surface has an emittance of greater than 0.05. (Source: MS 2095:2014)
2. Reflective surface has an emittance of not greater than 0.05. (Source: MS 2095:2014)
3. Non-Ventilated refers to no opening, or opening ratio less than 1:600.
4. Natural Ventilation requires that the minimum opening ratio shall be 1:600 of the vented space. (Source: US 2015 International Residential Code)

DIALOGUE SESSION

Photo by **Tima Miroshnichenko** from **Pexels**


MALAYSIAN
STANDARD

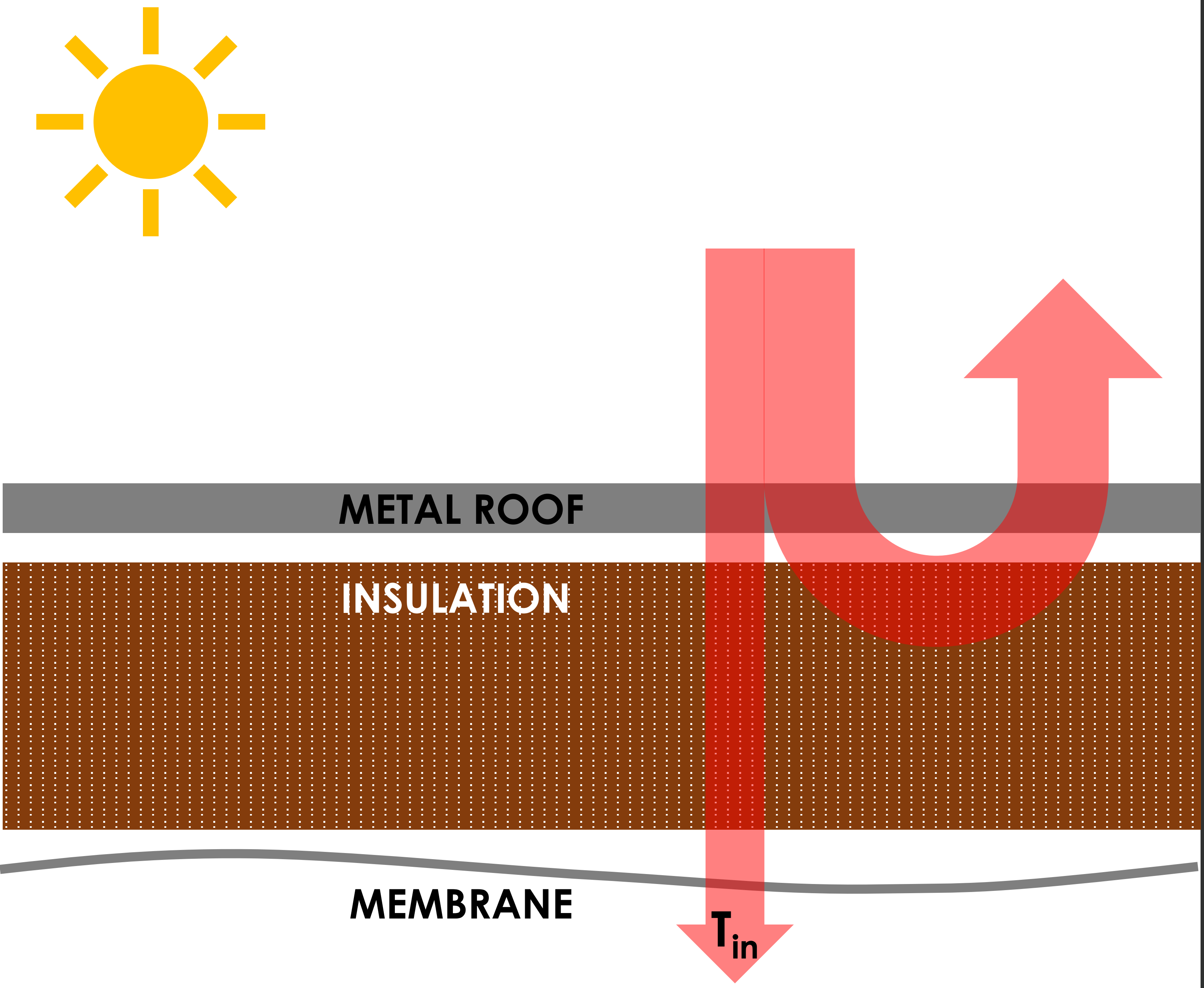
MS 1525:2019

MALAYSIAN
STANDARD

MS 2680:2017

Energy efficiency and use of renewable
energy for residential buildings -
Code of practice

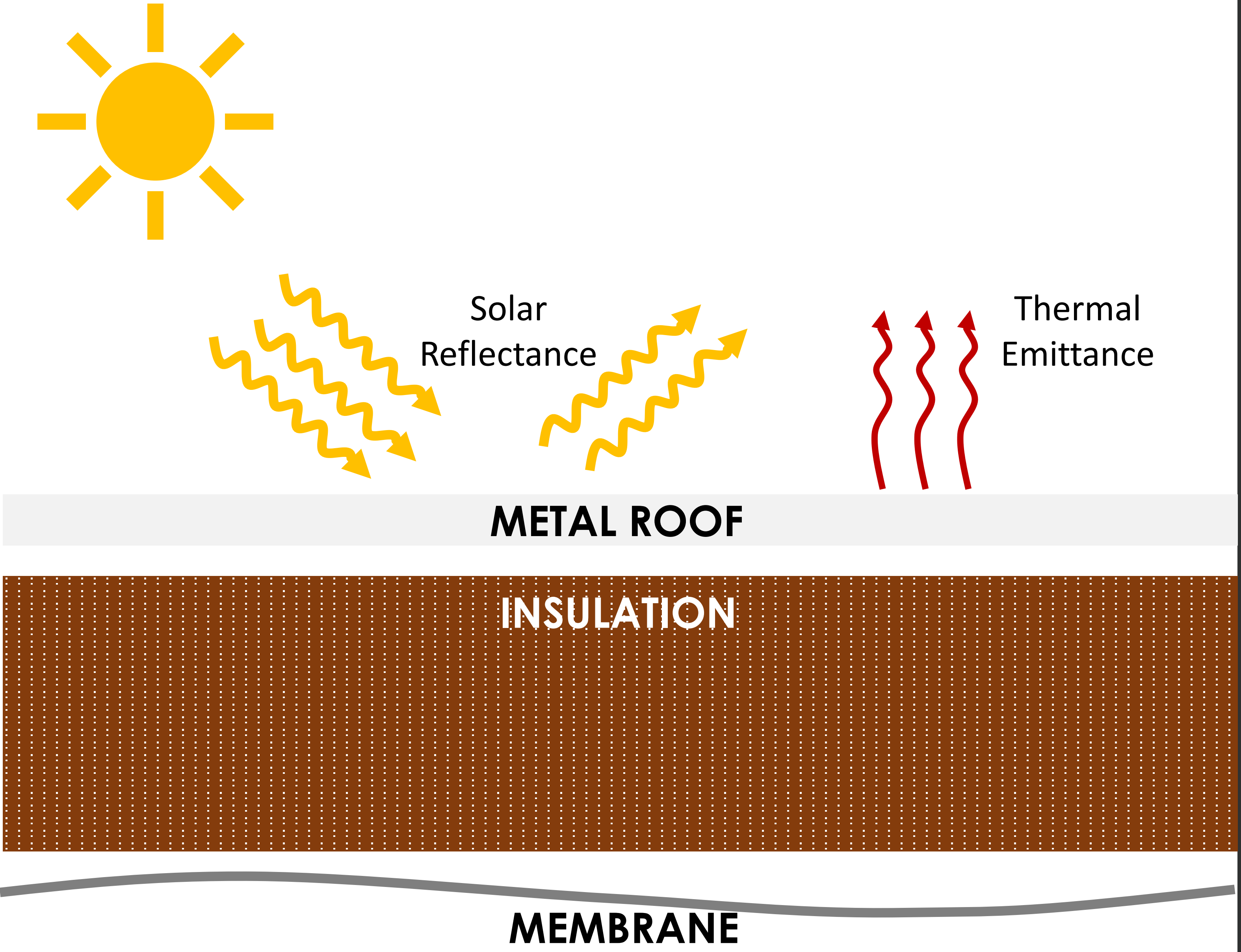
WHAT'S THE DIFFERENCE BETWEEN MS 1525 & MS 2680?



ROOF THERMAL TRANSMITTANCE VALUE (RTTV)

Source:

IMPACT OF SOLAR REFLECTANCE ON RTTV



WHAT IS THE COST INCREMENT TO GO GREEN?

WHAT IS THE ROI FOR GREEN BUILDING?

Photo by **Anna Nekrashevich** from **Pexels**

ASK US ANYTHING!

SUMMARY

Photo by Luca Nardone from Pexels