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COOL ROOFS COST BENEFIT ANALYSIS

Volume 13 – Alice Springs, Darwin and Hobart: Analysis and Results of the Climatic and Energy Performance of Cool Roofs. Description and Results of Building Case Studies.

Prof Mattheos Santamouris[1]
Prof Agis M. Papadopoulos[2]
Dr Riccardo Paolini[1]
Dr Ansar Khan[3]
Dr Carlos Bartesaghi Koc[4]
Dr Shamila Haddad[1]
Dr Samira Garshasbi[1]
Dr Samaneh Arasteh[1]
Dr Jie Feng[1]

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Authors

Prof Mattheos Santamouris[1], Prof Agis M. Papadopoulos[2], Dr Riccardo Paolini[1], Dr Ansar Khan[3], Dr Carlos Bartesaghi Koc[4], Dr Shamila Haddad[1], Dr Samira Garshasbi[1], Dr Samaneh Arasteh[1], Dr Jie Feng[1]

Research team

Prof Mattheos Santamouris[1], Prof Deo Prasad[1], Prof Agis M. Papadopoulos[2], A/Prof Lan Ding[1], A/Prof Paul Osmond[1], Dr Riccardo Paolini[1], Dr Carlos Bartesaghi Koc[4], Dr Shamila Haddad[1], Dr Samira Garshasbi[1], Dr Jie Feng[1], Dr. Jean Jonathan Duverge[1], Dr Samaneh Arasteh[1], Kai Gao[1]

International contributors

Stelios Diakrousis[5], Dr Ansar Khan[2], Prof Denia Kolokotsa[5], Prof Agis M. Papadopoulos[2], Kurt Shickman[6], Dr Afroditi Synnefa[1 5]

[1] School of Built Environment, University of New South Wales, Australia
[2] Department of Mechanical Engineering, Aristotle University Thessaloniki, Greece
[3] Department of Geography, Lalbaba College, University of Calcutta, India
[4] School of Architecture and Built Environment, Faculty of Engineering, Computer and Mathematical Sciences, The University of Adelaide, Australia
[5] Technical University of Crete, Greece
[6] Global Cool Cities Alliance, USA

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UNSW SYDNEY, NSW 2052, AUSTRALIA
T +61 (2) 9385 1000 | F +61 (2) 9385 0000 |
ABN 57 195 873 179

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Built Environment
High Performance Architecture

B01-B17
ALICE SPRINGS
DARWIN
HOBART

COOL ROOFS
COST BENEFIT ANALYSIS

All building types
2022

BUILDINGS 01-17

B01 Low-rise office building without roof insulation

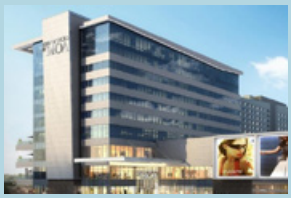
B02 High-rise office building without roof insulation

B03 New low-rise office building with roof insulation

B04 New high-rise office building with roof insulation

B05 New low-rise shopping mall centre

B06 New mid-rise shopping mall centre



B07 New high-rise shopping mall centre

B08 New low-rise apartment

B09 New mid-rise apartment

B10 New high-rise apartment

B11 Existing standalone house

B12 Existing school

B13 Existing low-rise office building with roof insulation

B14 Existing high-rise office building with roof insulation

B15 Existing low-rise shopping mall centre

B16 Existing high-rise shopping mall centre

B17 New standalone house

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Reference scenario

Reference building as described in Appendix with a conventional roof. Use of two sets of climatic data including one climatic data simulated by Weather Research Forecast (WRF) for the current condition for two summer months and one measured annual weather data.

Scenario 1:
Reference with cool roof scenario

Same building as in the reference scenario with a cool roof. Use of two sets of climatic data including one climatic data simulated by WRF for the current condition for two summer months and one measured annual weather data.

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1

ANNUAL COOLING AND HEATING LOAD UNDER TWO SCENARIOS - ALICE SPRINGS[a]

[a] Reference scenario and scenario 1; estimated for eleven weather stations in Alice Springs using measured annual climate data.

Table 1. Annual cooling and heating loads for all building types for two scenarios including reference scenario and reference with cool roof scenario (scenario 1) using annual measured weather data for COP=1 for heating and cooling.

#	Building type	Reference scenario				Scenario 1 Reference with cool roof scenario			
		Annual cooling load (kWh/m²)		Annual heating load (kWh/m²)		Annual cooling load (kWh/m²)		Annual heating load (kWh/m²)	
		Sensible	Total	Sensible	Total	Sensible	Total	Sensible	Total
B01	Low-rise office building without roof insulation	101.3	110.1	2.6	4.9	65.8	72.3	3.1	5.7
B02	High-rise office building without roof insulation	72.3	79.3	1.1	2.6	66.4	73.0	1.3	2.9
B03	New low-rise office building with roof insulation	69.8	77.4	1.3	3.0	66.6	73.8	1.4	3.2
B04	New high-rise office building with roof insulation	67.5	74.4	0.9	2.3	66.9	73.7	0.9	2.3
B05	New low-rise shopping mall centre	272.7	304.0	1.7	4.9	266.0	297.1	1.7	5.0
B06	New mid-rise shopping mall centre	265.8	296.8	1.4	4.3	262.6	293.6	1.4	4.4
B07	New high-rise shopping mall centre	263.1	294.1	1.3	4.2	261.0	292.0	1.3	4.2
B08	New low-rise apartment	53.7	65.8	7.2	11.9	50.2	62.2	7.5	12.4
B09	New mid-rise apartment	52.3	64.6	6.7	11.2	50.3	62.5	6.9	11.5
B10	New high-rise apartment	51.3	63.6	6.4	10.9	50.1	62.4	6.6	11.1
B11	Existing standalone house	61.6	71.1	13.0	15.7	41.2	49.6	15.8	18.7
B12	Existing school	89.0	107.3	2.6	14.0	86.8	104.5	2.7	14.2
B13	Existing low-rise office building with roof insulation	82.1	90.4	1.6	3.5	65.4	72.2	1.8	4.0
B14	Existing high-rise office building with roof insulation	69.3	76.3	0.9	2.4	66.5	73.2	1.0	2.5
B15	Existing low-rise shopping mall centre	283.8	314.8	1.7	5.7	253.0	283.5	1.8	6.0
B16	Existing high-rise shopping mall centre	265.3	296.1	1.3	4.4	256.2	286.9	1.3	4.5
B17	New standalone house	50.2	59.6	10.6	13.0	38.8	47.7	11.4	13.9

Application of cool roofs in individual building (scenario 1) in an existing low-rise shopping mall centre is projected to reduce the annual total cooling load by 37.8 kWh/m².

Application of cool roofs in individual building (scenario 1) in an existing high-rise office building without insulation is projected to reduce the annual total cooling load by 6.4 kWh/m².

Table 2. Annual cooling load saving, heating load penalty, and total cooling and heating saving for reference scenario versus reference with cool roof scenario (scenario 1) for all building types using annual measured weather data for COP=1 for heating and cooling.

#	Building type	Annual cooling load saving				Annual heating load penalty		Annual total cooling & heating load saving			
		Sensible		Total		Sens.	Total	Sensible		Total	
		kWh/m²	%	kWh/m²	%	kWh/m²		kWh/m²	%	kWh/m²	%
B01	Low-rise office building without roof insulation	35.5	35.0	37.8	34.4	0.5	0.9	35.0	33.7	37.0	32.2
B02	High-rise office building without roof insulation	5.9	8.2	6.4	8.0	0.2	0.3	5.7	7.8	6.1	7.4
B03	New low-rise office building with roof insulation	3.2	4.6	3.6	4.7	0.1	0.1	3.2	4.5	3.5	4.3
B04	New high-rise office building with roof insulation	0.6	0.9	0.6	0.9	0.0	0.0	0.6	0.8	0.6	0.8
B05	New low-rise shopping mall centre	6.7	2.5	6.9	2.3	0.0	0.1	6.7	2.4	6.8	2.2
B06	New mid-rise shopping mall centre	3.2	1.2	3.2	1.1	0.0	0.0	3.2	1.2	3.2	1.1
B07	New high-rise shopping mall centre	2.0	0.8	2.0	0.7	0.0	0.0	2.0	0.8	2.0	0.7
B08	New low-rise apartment	3.5	6.6	3.6	5.5	0.3	0.4	3.2	5.2	3.2	4.1
B09	New mid-rise apartment	2.0	3.8	2.0	3.2	0.2	0.3	1.8	3.0	1.8	2.4
B10	New high-rise apartment	1.2	2.3	1.2	1.9	0.1	0.2	1.1	1.8	1.1	1.4
B11	Existing standalone house	20.4	33.1	21.5	30.2	2.8	3.0	17.6	23.6	18.5	21.3
B12	Existing school	2.2	2.5	2.8	2.6	0.1	0.2	2.2	2.4	2.6	2.1
B13	Existing low-rise office building with roof insulation	16.6	20.3	18.2	20.1	0.3	0.5	16.4	19.6	17.7	18.8
B14	Existing high-rise office building with roof insulation	2.9	4.1	3.1	4.1	0.0	0.1	2.8	4.0	3.0	3.9
B15	Existing low-rise shopping mall centre	30.8	10.8	31.3	9.9	0.1	0.3	30.7	10.7	31.0	9.7
B16	Existing high-rise shopping mall centre	9.0	3.4	9.2	3.1	0.0	0.1	9.0	3.4	9.1	3.0
B17	New standalone house	11.4	22.8	12.0	20.1	0.8	0.8	10.7	17.6	11.1	15.3

the annual cooling load saving in a low-rise office building without insulation is 37.8 kWh/m², while the corresponding heating penalty is just 0.9 kWh/m².

The annual heating penalty of cool roofs is significantly lower than the annual cooling load savings in all building types.

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ANNUAL COOLING AND HEATING LOAD UNDER TWO SCENARIOS - DARWIN[b]

[b] Reference scenario and scenario 1; estimated for eleven weather stations in Darwin using measured annual climate data.

Table 1. Annual cooling and heating loads for all building types for two scenarios including reference scenario and reference with cool roof scenario (scenario 1) using annual measured weather data for COP=1 for heating and cooling.

#	Building type	Reference scenario				Scenario 1 Reference with cool roof scenario			
		Annual cooling load (kWh/m²)		Annual heating load (kWh/m²)		Annual cooling load (kWh/m²)		Annual heating load (kWh/m²)	
		Sensible	Total	Sensible	Total	Sensible	Total	Sensible	Total
B01	Low-rise office building without roof insulation	170.2	264.9	0.0	0.0	107.7	174.6	0.0	0.0
B02	High-rise office building without roof insulation	119.3	189.0	0.0	0.0	108.7	172.4	0.0	0.0
B03	New low-rise office building with roof insulation	111.6	183.3	0.0	0.0	106.3	171.2	0.0	0.0
B04	New high-rise office building with roof insulation	110.0	175.1	0.0	0.0	108.9	172.6	0.0	0.0
B05	New low-rise shopping mall centre	343.2	596.0	0.0	0.0	329.7	580.1	0.0	0.0
B06	New mid-rise shopping mall centre	334.7	584.1	0.0	0.0	328.1	576.9	0.0	0.0
B07	New high-rise shopping mall centre	332.1	581.0	0.0	0.0	327.4	575.9	0.0	0.0
B08	New low-rise apartment	88.1	217.8	0.0	0.0	74.6	206.2	0.0	0.0
B09	New mid-rise apartment	83.1	214.9	0.0	0.0	74.8	207.8	0.0	0.0
B10	New high-rise apartment	79.9	212.6	0.0	0.0	74.8	208.3	0.0	0.0
B11	Existing standalone house	108.3	197.1	0.0	0.0	62.7	152.8	0.0	0.0
B12	Existing school	65.4	274.9	0.0	0.0	62.4	267.1	0.0	0.0
B13	Existing low-rise office building with roof insulation	136.3	222.8	0.0	0.0	105.4	171.3	0.0	0.0
B14	Existing high-rise office building with roof insulation	114.2	182.1	0.0	0.0	108.5	172.3	0.0	0.0
B15	Existing low-rise shopping mall centre	389.3	648.2	0.0	0.0	324.3	575.1	0.0	0.0
B16	Existing high-rise shopping mall centre	346.4	596.4	0.0	0.0	325.3	573.0	0.0	0.0
B17	New standalone house	91.7	186.1	0.0	0.0	53.5	151.9	0.0	0.0

Application of cool roofs in individual building (scenario 1) in an existing low-rise office building without insulation is projected to reduce the annual total cooling load by 90.3 kWh/m².

Application of cool roofs in individual building (scenario 1) in an existing high-rise office building without insulation is projected to reduce the annual total cooling load by 16.6 kWh/m².

Table 2. Annual cooling load saving, heating load penalty, and total cooling and heating saving for reference scenario versus reference with cool roof scenario (scenario 1) for all building types using annual measured weather data for COP=1 for heating and cooling.

#	Building type	Annual cooling load saving				Annual heating load penalty		Annual total cooling & heating load saving			
		Sensible		Total		Sens.	Total	Sensible		Total	
		kWh/m²	%	kWh/m²	%	kWh/m²		kWh/m²	%	kWh/m²	%
B01	Low-rise office building without roof insulation	62.5	36.7	90.3	34.1	0.0	0.0	62.5	36.7	90.3	34.1
B02	High-rise office building without roof insulation	10.6	8.9	16.6	8.8	0.0	0.0	10.6	8.9	16.6	8.8
B03	New low-rise office building with roof insulation	5.3	4.8	12.0	6.6	0.0	0.0	5.3	4.8	12.0	6.6
B04	New high-rise office building with roof insulation	1.1	1.0	2.5	1.4	0.0	0.0	1.1	1.0	2.5	1.4
B05	New low-rise shopping mall centre	13.5	3.9	16.0	2.7	0.0	0.0	13.5	3.9	16.0	2.7
B06	New mid-rise shopping mall centre	6.6	2.0	7.2	1.2	0.0	0.0	6.6	2.0	7.2	1.2
B07	New high-rise shopping mall centre	4.7	1.4	5.2	0.9	0.0	0.0	4.7	1.4	5.2	0.9
B08	New low-rise apartment	13.5	15.3	11.6	5.3	0.0	0.0	13.5	15.3	11.6	5.3
B09	New mid-rise apartment	8.3	9.9	7.1	3.3	0.0	0.0	8.3	9.9	7.1	3.3
B10	New high-rise apartment	5.1	6.4	4.3	2.0	0.0	0.0	5.1	6.4	4.3	2.0
B11	Existing standalone house	45.6	42.1	44.3	22.5	0.0	0.0	45.6	42.1	44.3	22.5
B12	Existing school	3.0	4.7	7.8	2.9	0.0	0.0	3.0	4.7	7.8	2.9
B13	Existing low-rise office building with roof insulation	30.9	22.7	51.5	23.1	0.0	0.0	30.9	22.7	51.5	23.1
B14	Existing high-rise office building with roof insulation	5.7	5.0	9.7	5.4	0.0	0.0	5.7	5.0	9.7	5.4
B15	Existing low-rise shopping mall centre	65.0	16.7	73.1	11.3	0.0	0.0	65.0	16.7	73.1	11.3
B16	Existing high-rise shopping mall centre	21.1	6.1	23.4	3.9	0.0	0.0	21.1	6.1	23.4	3.9
B17	New standalone house	38.2	41.6	34.3	18.4	0.0	0.0	38.2	41.6	34.3	18.4

Application of cool roofs in individual building (scenario 1) in a new high-rise office building with insulation is projected to reduce the annual total cooling load by 2.5 kWh/m².

The annual heating penalty of cool roofs is equal to zero in all types of buildings.

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ANNUAL COOLING AND HEATING LOAD UNDER TWO SCENARIOS - HOBART[c]

[c] Reference scenario and scenario 1; estimated for eleven weather stations in Hobart using measured annual climate data.

Table 1. Annual cooling and heating loads for all building types for two scenarios including reference scenario and reference with cool roof scenario (scenario 1) using annual measured weather data for COP=1 for heating and cooling.

#	Building type	Reference scenario				Scenario 1 Reference with cool roof scenario			
		Annual cooling load (kWh/m²)		Annual heating load (kWh/m²)		Annual cooling load (kWh/m²)		Annual heating load (kWh/m²)	
		Sensible	Total	Sensible	Total	Sensible	Total	Sensible	Total
B01	Low-rise office building without roof insulation	6.1	6.3	6.5	13.0	2.8	2.9	9.2	17.3
B02	High-rise office building without roof insulation	3.4	3.5	4.0	9.0	2.9	3.0	4.5	9.8
B03	New low-rise office building with roof insulation	3.5	3.6	3.7	8.2	3.2	3.3	3.8	8.6
B04	New high-rise office building with roof insulation	3.1	3.2	3.0	7.4	3.1	3.2	3.0	7.5
B05	New low-rise shopping mall centre	63.6	66.8	3.6	10.8	60.7	63.9	3.7	11.1
B06	New mid-rise shopping mall centre	58.0	61.2	3.2	10.5	56.7	59.9	3.2	10.6
B07	New high-rise shopping mall centre	56.0	59.1	3.1	10.5	55.2	58.3	3.1	10.6
B08	New low-rise apartment	0.8	0.9	35.0	51.5	0.7	0.7	36.0	52.7
B09	New mid-rise apartment	0.7	0.8	34.1	50.6	0.6	0.7	34.7	51.3
B10	New high-rise apartment	0.6	0.7	33.9	50.4	0.6	0.6	34.2	50.9
B11	Existing standalone house	2.6	2.8	40.0	47.5	0.7	0.7	48.1	56.3
B12	Existing school	5.5	5.5	6.5	41.3	5.2	5.2	6.6	41.9
B13	Existing low-rise office building with roof insulation	4.3	4.5	4.8	10.4	2.9	3.0	5.5	11.8
B14	Existing high-rise office building with roof insulation	3.2	3.3	3.3	8.0	3.0	3.1	3.4	8.3
B15	Existing low-rise shopping mall centre	61.0	64.0	4.1	13.4	49.4	52.2	4.4	14.2
B16	Existing high-rise shopping mall centre	54.5	57.5	3.2	11.4	51.3	54.3	3.3	11.6
B17	New standalone house	1.3	1.4	29.5	35.9	0.6	0.6	31.4	38.1

Application of cool roofs in individual building (scenario 1) in an existing low-rise shopping mall centre is projected to reduce the annual total cooling load by 11.8 kWh/m².

Application of cool roofs in individual building (scenario 1) in an existing high-rise office building without insulation is projected to reduce the annual total cooling load by 0.5 kWh/m².

Table 2. Annual cooling load saving, heating load penalty, and total cooling and heating saving for reference scenario versus reference with cool roof scenario (scenario 1) for all building types using annual measured weather data for COP=1 for heating and cooling.

#	Building type	Annual cooling load saving				Annual heating load penalty		Annual total cooling & heating load saving			
		Sensible		Total		Sens.	Total	Sensible		Total	
		kWh/m²	%	kWh/m²	%	kWh/m²		kWh/m²	%	kWh/m²	%
B01	Low-rise office building without roof insulation	3.3	54.3	3.4	53.7	2.7	4.3	0.6	4.9	-0.9	-4.9
B02	High-rise office building without roof insulation	0.5	14.4	0.5	14.1	0.5	0.8	0.0	-0.2	-0.3	-2.5
B03	New low-rise office building with roof insulation	0.3	8.0	0.3	7.9	0.2	0.4	0.1	1.4	-0.1	-0.8
B04	New high-rise office building with roof insulation	0.0	1.5	0.0	1.4	0.0	0.1	0.0	0.2	0.0	-0.3
B05	New low-rise shopping mall centre	2.9	4.5	2.9	4.3	0.1	0.3	2.8	4.1	2.6	3.4
B06	New mid-rise shopping mall centre	1.3	2.2	1.3	2.1	0.0	0.1	1.3	2.1	1.2	1.7
B07	New high-rise shopping mall centre	0.8	1.5	0.8	1.4	0.0	0.1	0.8	1.3	0.7	1.0
B08	New low-rise apartment	0.2	19.8	0.2	20.2	1.0	1.3	-0.9	-2.4	-1.1	-2.1
B09	New mid-rise apartment	0.1	12.6	0.1	12.9	0.6	0.7	-0.5	-1.4	-0.6	-1.2
B10	New high-rise apartment	0.0	7.8	0.1	7.9	0.3	0.4	-0.3	-0.9	-0.4	-0.7
B11	Existing standalone house	2.0	74.4	2.1	74.7	8.1	8.8	-6.1	-14.4	-6.7	-13.3
B12	Existing school	0.3	6.0	0.3	6.0	0.1	0.7	0.2	1.8	-0.3	-0.7
B13	Existing low-rise office building with roof insulation	1.4	32.6	1.4	32.2	0.7	1.4	0.7	8.2	0.0	0.0
B14	Existing high-rise office building with roof insulation	0.2	6.9	0.2	6.8	0.1	0.3	0.1	1.4	0.0	-0.4
B15	Existing low-rise shopping mall centre	11.6	19.0	11.8	18.4	0.2	0.8	11.3	17.4	11.0	14.2
B16	Existing high-rise shopping mall centre	3.1	5.8	3.2	5.6	0.1	0.2	3.1	5.3	3.0	4.3
B17	New standalone house	0.7	53.0	0.7	53.9	1.9	2.2	-1.2	-4.0	-1.4	-3.9

Application of cool roofs in individual building (scenario 1) in a new high-rise office building with insulation is projected to not reduce the annual total cooling load.

The annual heating penalty of cool roofs for all types of buildings ranges between 0.0 and 8.1 kWh/m².

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CONCLUSIONS

ALICE SPRINGS

• In low-rise buildings without/with low level of insulation, the cooling load saving by implementation of cool roofs in individual buildings (scenario 1) is quite significant. For instance, application of cool roofs in individual building (scenario 1) in an existing low-rise office building without insulation is projected to reduce the annual total cooling load by 37.8 kWh/m^2.

• In high-rise buildings with no insulation/with low level of insulation, the cooling load saving by implementation of cool roofs in individual buildings (scenario 1) is remarkable. For instance, application of cool roofs in individual building (scenario 1) in an existing high-rise office building without insulation is projected to reduce the annual total cooling load by 6.4 kWh/m^2.

• The annual heating penalty of cool roofs is significantly lower than the annual cooling load savings in all building types. For instance, the annual cooling load saving in a low-rise office building without insulation is 37.8 kWh/m^2, while the corresponding heating penalty is just 0.9 kWh/m^2.

DARWIN

• In low-rise buildings without/with low level of insulation, the cooling load saving by implementation of cool roofs in individual buildings (scenario 1) is quite significant. For instance, application of cool roofs in individual building (scenario 1) in an existing low-rise office building without insulation is projected to reduce the annual total cooling load by 90.3 kWh/m^2.

• In high-rise buildings with no insulation/ with low level of insulation, the cooling load saving by implementation of cool roofs in individual buildings (scenario 1) is remarkable. For instance, application of cool roofs in individual building (scenario 1) in an existing high-rise office building without insulation is projected to reduce the annual total cooling load by 16.6 kWh/m^2.

• In high-rise buildings with high insulation, the cooling load saving by implementation of cool roofs in individual buildings (scenario 1) is noticeable. For instance, application of cool roofs in individual building (scenario 1) in a new high-rise office building with insulation is projected to reduce the annual total cooling load by 2.5 kWh/m^2.

• The annual heating penalty of cool roofs is equal to zero in all types of buildings.

HOBART

• Simulations results show that cool roofs may have a negative impact on total heating and cooling loads in all building types excluding some commercial buildings. Also, the application of cool roofs can slightly decrease the annual cooling and heating loads of commercial buildings.

• In low-rise buildings without/with low level of insulation, the cooling load saving by implementation of cool roofs in individual buildings (scenario 1) is remarkable. For instance, application of cool roofs in individual building (scenario 1) in an existing low-rise shopping mall centre is projected to reduce the annual total cooling load by 11.8 kWh/m^2.

• In high-rise buildings with no insulation/ with low level of insulation, the cooling load saving by implementation of cool roofs in individual buildings (scenario 1) is minimal. For instance, application of cool roofs in individual building (scenario 1) in an existing high-rise office building without insulation is projected to reduce the annual total cooling load by 0.5 kWh/ m^2.

• In high-rise buildings with high insulation, the cooling load saving by implementation of cool roofs in individual buildings (scenario 1) is noticeable. For instance, application of cool roofs in individual building (scenario 1) in a new high-rise office building with insulation is projected to reduce the annual total cooling load by 2.5 kWh/m^2.

• The annual heating penalty of cool roofs for all types of buildings ranges between 0.0 and 8.1 kWh/m2.

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UNSW - SCHOOL OF BUILT ENVIRONMENT
High Performance Architecture

Sydney, NSW 2052
Australia

Phone
+61 (02) 9385 0729

Email
m.santamouris@unsw.edu.au

Website
https://www.unsw.edu.au

UNSW SYDNEY

SCHOOL OF BUILT ENVIRONMENT
High Performance Architecture

UNSW SYDNEY, NSW 2052
Australia

Phone
+61 (02) 9385 1000

Email
m.santamouris@unsw.edu.au

Website
https://www.unsw.edu.au