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Cool Roofs in APEC Economies: Review of Experience, Best Practices And Potential Benefits

APEC Energy Working Group

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1. Executive Summary

Cool Roof technologies and their benefits in reducing surface temperature and UHI are generally well understood and agreed, with research, standardisation most advanced/established in the US. There are numerous initiatives in US promoting use of Cool Roofs. EU is pushing ahead through the EU Cool Roof Council.

Most APEC member economies however do not have specific regulation or legislation pertaining to Cool Roofs and the implementation of Cool Roofs is still in its infancy in Asia. There are no clear examples of Cool Roof policy, regulation, incentive or implementation (with the exception of Japan). Overall Cool Roof systems do not appear to be a well established form of energy efficiency technology in South East Asia.

Other focus of energy efficiency in buildings relate to building envelope thermal transfer, mechanical systems and energy use within buildings, such as energy efficient lighting, air conditioning, and appliances.

In developed economies where buildings are relatively modern and built to high R-value standards, Cool Roofs will not have a dramatic effect on the cooling load so energy savings will be relatively small. In developing economies the proportion of air-conditioned buildings, especially dwellings, is substantially less than in developed economies and thus the potential for thermal load reduction from the implementation of Cool Roofs much greater. However, most occupiers of low or non-insulated buildings will not have air-conditioning so although the thermal load may reduce there is no tangible energy saving.

Cool Roofs might have a small effect on mitigating the Urban Heat Island (UHI) such locations. UHI was not part of this study; however significant literature highlights the contribution of Cool Roofs to UHI mitigation.

Whilst it can be argued that other SE Asian economies may not have requirements for thermal performance of roofs as stringent as those in Singapore, it is generally viewed that in time they will seek to revise their building codes to improve roof thermal performance and that this will most likely be achieved through reduced U-values rather than secondary mitigation methods such as Cool Roofs. The Singapore U-values used in this study represent a conservative baseline which is deemed a better standpoint upon which to base estimated savings on a macro level in terms of energy cost, greenhouse gases and air quality for the tropical region. The potential savings shown in this study are therefore based predominantly on new construction with specific levels of roofing insulation matching current standards. Existing stock with less or no insulation would have greater savings. In addition, the implementation of Cool Roof technology on unconditioned buildings could offer improved comfort to occupiers and may avoid the need for cooling equipment installation.

From international observation, for Cool Roofs to be successfully established, there needs to be government policy and intervention. Equally, the standardisation of product performance is important in creating industry benchmarks allowing comparison between different Cool Roof products. It also provides confidence to the industry on the performance of the products.

The establishment of Cool Roof Council(s) in the APEC region would be a useful platform to coordinate the development of standardisation methods, policy and research into Cool Roofs; however, incentive and regulation through legislation and building codes are viewed as more effective ways of moving the building industry in South East Asia towards widespread implementation of Cool Roof technology. However, in the South East Asian region, climate, culture, lifestyle and architectural styles vary in each economy, so regulations and standards must be established by each economy taking into account such variations.

In addition, a worldwide information exchange is essential in building reliable product standard[s] and that many discussions should be had with the Cool Roof Rating Council to form mutual understandings in rating coating colours vs. heat reflectant effect.

Simulations have shown that the potential for HVAC system load savings per km^2 in South East Asian economies are considerably greater than in the APEC region as a whole, mostly due to the overwhelming demand for cooling in the tropical environment.

An absolute model for any Annual HVAC Load Saving would however need to be based on micro level data concerning the number of new and old buildings and the number of each building type in each location. This study worked on national and international macro levels and as such, attributing precise factors was not possible.

Whilst a macro level study of this kind can be useful in indicating potential savings on an overall level, the regulations, standards, climates, architecture and demands from the built environment across the APEC region vary wildly, from member economy to member economy. It is therefore not possible to directly develop specific policy recommendations for the region as a whole or any sub-regions without further studies. To facilitate this, micro level member economy specific assessments should be carried out in order to find absolute values for the potential savings possible.

2. LISTS OF TABLES & FIGURES

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3. ABBREVIATIONS

ACMV	–	Air Conditioning and Mechanical Ventilation System
ANSI	–	American National Standards Institute
APEC	–	Asia-Pacific Economic Cooperation
AQG	–	Air Quality Guidelines
ARI	–	Acute Respiratory Tract Infection
ASEAN	–	Association of South East Asian Nations
ASHRAE	–	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	–	American Society for Testing and Materials
BCA	–	Building & Construction Authority [Singapore]
BM	–	Biomass
BSD	–	Building System & Diagnostics Pte Ltd.
BUR	–	Built-up Roofing System
C	–	Celsius (Centigrade)
CA	–	California, USA
CDM	–	Clean Development Mechanism
CER	–	Certified Emission Reduction
CFC	–	Chlorofluorocarbon
CFFA	–	Chemical Fabrics and Film Association
CH_4	–	Methane
CIA	–	Central Intelligence Agency
CL	–	Coal
CO	–	Carbon Monoxide
CO_2	–	Carbon Dioxide
CO_2e	–	Carbon Dioxide Equivalent
CRRC	–	Cool Roof Rating Council
CSPE	–	Chlorosulphonated Poly Ethylene
DEDE	–	Department of Alternative Energy Development and Efficiency [Thailand]
DOE	–	Department of Energy [USA]
€	–	Euro
E	–	Emissivity
EPA	–	Environmental Protection Agency [USA]
EPDM	–	Ethylene Propylene Diene Monomer
ESCI	–	Energy Smart Communities Initiative [Japan & USA]
ETTV	–	Envelope Thermal Transfer Value
EU	–	European Union
EU-CRC	–	European Union Cool Roof Council

EU-ETS	–	European Union Emissions Trading Scheme
F	–	Fahrenheit
GCCA	–	Global Cool Cities Alliance
GHG	–	Greenhouse Gas
GS	–	Natural Gas
GW	–	Gigawatt
gWh	–	Gigawatt hour
HFC	–	Hydrofluorocarbon
HVAC	–	Heating, Ventilation and Air Conditioning System
IPCC	–	Inter-governmental Panel on Climate Change
Kg	–	Kilogram
$kgCO_2e$	–	Kilograms of Carbon Dioxide Equivalent
Km	–	Kilometre
Kt	–	Kiloton
KW	–	Kilowatt
kWh	–	Kilowatt Hour
LBL	–	Lawrence Berkeley National Laboratory [USA]
LBL-HIG	–	Lawrence Berkeley National Laboratory Heat Island Group
LEED	–	Leadership in Energy and Environmental Design [USA]
MEGTW	–	Ministry of Energy, Green Technology and Water [Malaysia]
MND	–	Ministry of National Development [Singapore]
MW	–	Megawatt
mWh	–	Megawatt Hour
NC	–	Nuclear
NCAR	–	National Center for Atmospheric Research [USA]
NGO	–	Non-governmental Organisation
NOx	–	Mono-nitrogen Oxides (NO & NO_2)
NO	–	Nitric Oxide
NO_2	–	Nitrogen Dioxide
N_2O	–	Nitrous Oxide
NUS	–	National University of Singapore
OL	–	Oil
OPC	–	Ordinary Portland Cement
OTC	–	Over The Counter (Carbon Credit Market)
OTTV	–	Overall Thermal Transfer Value
O_3	–	Ozone
$PM_{2.5}$	–	Particulate Matter of less than 2.5µg
PM_{10}	–	Particulate Matter between 2.5µg and 10µg
PNG	–	Papua New Guinea

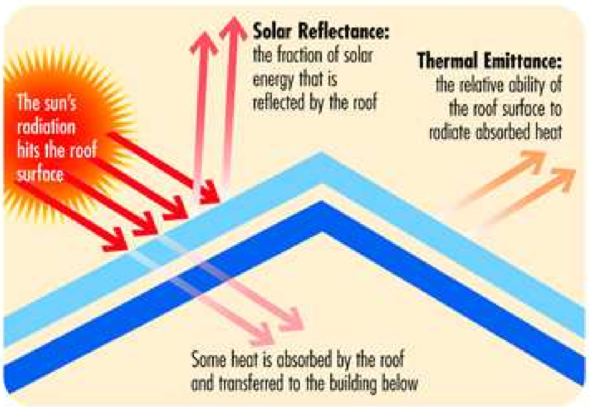
PVC	–	Polyvinyl Chloride
RTTV	–	Roof Thermal Transfer Value
RW	–	Renewable
SBTC	–	Sustainable Building Technology Council [USA]
SCBI	–	UNEP Sustainable Buildings and Construction Initiative
SO_2	–	Sulphur Dioxide
SR	–	Solar Reflectance
SRI	–	Solar Reflectance Index
t	–	Metric Tonne
tCO_2e	–	Tonnes of Carbon Dioxide Equivalent
TPO	–	Thermoplastic Olefin
TW	–	Terawatt
tWh	–	Terawatt Hour
ųg	–	Microgram
UHI	–	Urban Heat Island
UK	–	United Kingdom of Great Britain and Northern Ireland
UN	–	United Nations
UNEP	–	United Nations Environment Programme
USA	–	United States of America
USD	–	US Dollars
USGBC	–	United States Green Building Council
UV	–	Ultraviolet
VER	–	Voluntary/Verified Emission Reduction
WHO	–	World Health Organisation
WS	–	Waste

4. INTRODUCTION

Cool Roofs are essentially roofing systems that have been designed to reflect the sun's energy away from a roof's surface, thereby reducing the heat transfer into the building. The benefits of Cool Roof technology has been well researched, showing good potential to reduce the temperature of the roof and thus the indoor environment of the building, reducing the building cooling energy consumption. Cool Roof technology is also considered financially and technically viable, providing a cost effective solution to increase the energy efficiency performance of buildings.

In simple terms, Cool Roof technology consists of reflective roofing materials[1]. The sun's radiant energy is simply reflected back toward the sky from which it came. Reflective materials can also help keep the building's surrounding environment (i.e., the city) cool, by reflecting solar energy back out into space.

Figure 4.1 – What is a Cool Roof?



Source: Cool Roof Rating Council[2]

Despite the benefits, Cool Roofs have not been extensively adopted internationally, particularly in hot climates such as Asia where it has the largest potential benefit. The main barriers for implementation appear to be a lack of the following:

- Awareness;
- Political drivers;
- Incentives;
- Local industry experience; and
- Substantiated research in the region.

With this setting, the Asia-Pacific Economic Cooperation (APEC) commissioned Building system & Diagnostics Pte Ltd. (BSD) to carry out a study to review the current Cool Roof industry in terms of local expertise, best practice and policies in APEC.

[1] http://eetd.lbl.gov/coolroof/
[2] http://www.coolroofs.org/

5. Objectives And Work Programme

5.1. Objectives

The objectives of this study are as follows:

- To compile information on the experience of APEC member economies in terms of the implementation of Cool Roofs;
- To characterise the energy, Greenhouse Gas (GHG) and air quality benefits through computer modelling; and
- To develop policy recommendations to implement Cool Roof technologies in developing APEC member economies.

5.2. Work Programme

The study was carried out through a number of phases:

Phase 1: Establish network of experts- Identify a network of local experts on Cool Roof research, applications and policy.

Phase 2: Collect information on Cool Roof experience- Research into Cool Roof technologies and products in the region.

Phase 3: Estimate energy and GHG savings from Cool Roofs- Develop a model to estimate the potential energy and GHG savings from widespread implementation of Cool Roofs.

Phase 4/5: Prepare report- report will consists of following sections: 1) review of experience in APEC economies 2) characterisation of Cool Roof benefits in APEC region, 3) estimate of potential benefits and 4) review of locally available materials and technologies.

6. Scope of Study

The study focuses particularly on the **South East Asian economies in APEC**. However, the research and experience of Cool Roofs covered all APEC members as well as other international regions such as the EU.

Figure 6.1 – APEC Member Economies

Source: American Chamber of Commerce Viet Nam[3]

The APEC member economies are currently listed as[4]:

- Australia;
- Brunei-Darussalam;
- Canada;
- Chile;
- Peoples' Republic of China;
- Hong. Kong, China;
- Indonesia;
- Japan;
- Republic of Korea;
- Malaysia;
- Mexico;
- New Zealand;
- Papua New Guinea;
- Peru;
- Republic of the Philippines;
- Russia;
- Singapore;
- Chinese Taipei;
- Thailand;
- USA;
- Viet Nam.

[3] http://www.amchamvietnam.com/645
[4] http://www.apec.org/About-Us/About-APEC/Member-Economies.aspx

7. Cool Roofs

7.1. Cool Roof Science

According to the US Lawrence Berkeley National Laboratory (LBL) Study on Cool Roofs[5], one of the best measures for keeping solar heat out of buildings is simply to use reflective roofing materials. The sun's radiant energy is then simply reflected back toward the sky from which it came. Reflective materials also help keep the building's surrounding environment (i.e. the city) cool, by reflecting solar energy back out into space.

Besides high solar reflectance, a high infrared emittance is also desirable. Infrared emittance is a measure of the ability of a surface to emit its energy in the form of heat radiation. Fortunately, most roofing materials (excepting bare metals) have a high infrared emittance. Good convective heat transfer is also desirable: as the temperature of the roof increases in the sun, some of the heat can be carried away by the outside air. In some roofing systems air can circulate underneath the outer roofing material (e.g., tile and wood shake systems). Attic venting also can be used to intercept heat before it penetrates into the conditioned space. Finally, of course, thermal insulation is effective in reducing, but not eliminating, the flow of unwanted heat.

7.1.1. Urban Heat Island (UHI) – (information from LBL Heat Island Group[6])

Urban Heat Islands do not form part of this study as a whole, although they merit mention as significant literature highlights the contribution of Cool Roofs to UHI mitigation[6a].

Urban areas covered with concrete pavements and buildings have a tendency to absorb heat from the sun. As a result, temperatures in most cities are warmer than suburban rural areas. During the winter this is a small asset. However, during the summer the heat island causes discomfort, increases cooling use, subsequent energy consumption and urban pollution.

Studies by the LBL Heat Island Group (LBL-HIG) state that the annual maximum temperatures in Los Angeles show a cooling trend from the 1880s to the 1930s, probably because of increased irrigation and rapidly expanding orchards around the city. Since the 1940s, the temperatures have increased by about 6℉ (1℃ per decade). Data from other cities also indicates an increase in urban temperatures ranging from 0.2℉ to 0.8℉ per decade. The increas ed summertime temperatures cause increased cooling requirements. In Los Angeles, it is estimated that about 1-1.5 gigawatts (GW) of power are used to compensate the impact of the heat island effect. This increased power costs the Los Angeles ratepayers about $100,000 per hour, about $100 million per year.

The impact of the heat island is also seen in smog. The formation of smog is highly sensitive to temperatures; the higher the temperature, the higher the formation and, hence, the concentration of smog. In Los Angeles at temperatures below 70℉, th e concentration of smog (measured as ozone) is

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[5] http://eetd.lbl.gov/coolroof/
[6] http://eetd.lbl.gov/HeatIsland/LEARN/Overview/
[6a] Navigant Consulting Inc,, 2009.

below the national standard. At temperatures of about 95°F all days are smoggy. Cooling the city by about 5°F would have a dramatic impact on smog conc entration.

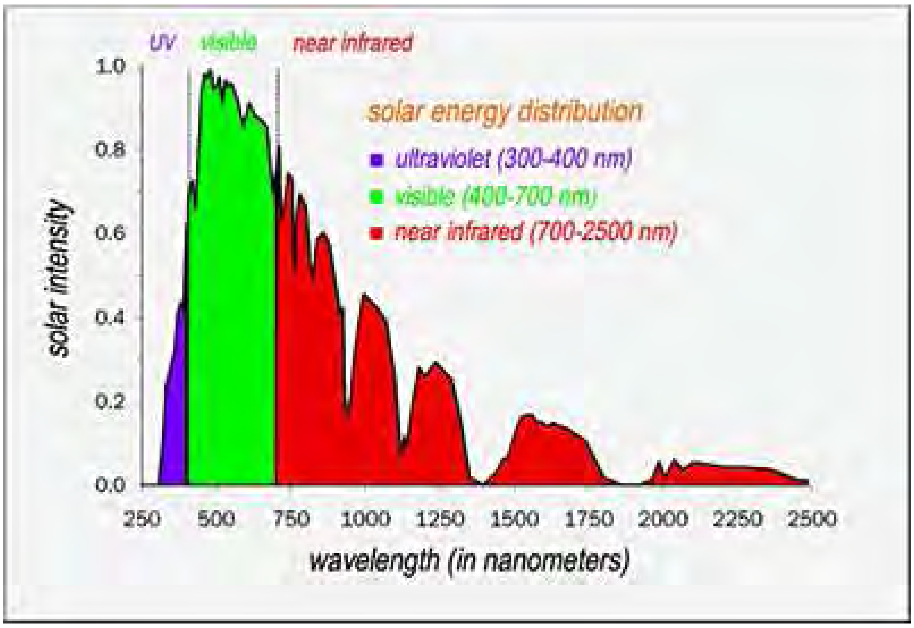
Measures to cool heat islands are simple and have been known to human beings for centuries, the most common being reflective surfaces and trees. Reflective roofs on a building directly reduce the heat conduction into the building and reduce air-conditioning use. Similarly, trees shading a building reduce air-conditioning use. Furthermore, many reflective surfaces (roofs and pavements) and urban vegetation in a neighbourhood alter the surface energy balance and result in a lower ambient temperature, in turn leading to further reductions in air-conditioning energy use and urban smog.

7.1.2. Science of Cool Roofs

Cool Roofs are roof products made from highly reflective and emissive materials that can significantly reduce the temperature of the roof and subsequently transfer of heat through the roof. To understand how Cool Roof works, it is essential to understand the scientific properties of Cool Roofs, i.e. solar reflectance and thermal emittance.

Solar energy intensity varies over wavelengths from about 250 to 2500 nanometres. White or light coloured Cool Roof products reflect visible wavelengths. Coloured Cool Roof products reflect in the infrared energy range:

Figure 7.1 – Solar Intensity vs. Wavelength



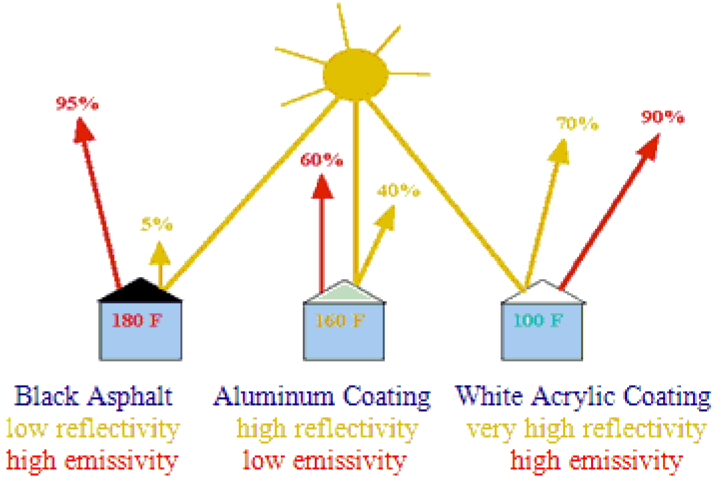
Source: Lawrence Berkeley National Laboratory[7]

On a hot, summer, sunny day, a black roof that reflects 5 percent of the sun's energy and emits more than 90 percent of the heat it absorbs can reach 180°F (82°C). A metal roof will reflect the majority of

[7] http://newscenter.lbl.gov/feature-stories/2004/08/27/cool-colors-cool-roofs/

the sun's energy while releasing about 25 percent of the heat that it absorbs and can warm to 160℉ (71℃). A Cool Roof will reflect and emit the majo rity of the sun's energy and reach a peak temperature of 120℉ (49℃):

Figure 7.2 - What Makes a Roof Coating Cool?



Source: Dr Lisa Gartland[8]

Solar reflectance (SR), commonly known as albedo, is expressed either as a decimal fraction or a percentage. A value of 0 indicates that the surface absorbs all solar radiation, and a value of 1 represents total reflectivity. Thermal emittance is also expressed either as a decimal fraction between 0 and 1, or a percentage. Another method of evaluating coolness is the solar reflectance index (SRI), which incorporates both solar reflectance and emittance in a single value. SRI quantifies how hot a surface would get relative to standard black and standard white surfaces. It is defined such that a standard black (reflectance 0.05, emittance 0.90) is 0 and a standard white (reflectance 0.80, emittance 0.90) is 100. The use of SRI as a combined measurement of reflectance has been disputed, since it has been shown that two different products with identical SRI numbers can yield significantly different energy savings results depending on what geographic region they are applied in, and the climatic conditions present in this region.

Cool Roofs are an effective alternative to bulk attic insulation under roofs in humid tropical and subtropical climates. Bulk insulation can be entirely replaced by roofing systems that both reflect and emit solar radiation back into the atmosphere. This dual function is crucial, and relies on the performance of Cool Roof materials in both the visible spectrum (which needs to be reflected) and far infra-red which needs to be emitted.

Cool Roofs can also be used as a geo-engineering technique to tackle global warming based on the principle of solar radiation management, provided that the materials used not only reflect solar energy, but also emit infra-red radiation to cool the planet. This technique can give between 0.01-0.19 W/m^2 of globally averaged negative forcing, depending on whether cities or all settlements are so treated[9]. This is generally small when compared to the 3.7 W/m^2 of positive forcing from a doubling of CO_2.

8 http://www.nationalcoatings.com/cr_truths_and_myths.htm
9 http://www.atmos-chem-phys-discuss.net/9/2559/2009/acpd-9-2559-2009.pdf

However, in many cases it can be achieved at little or no cost by simply selecting different materials. Further, it can reduce the need for air conditioning, which causes CO_2 emissions which studies have shown worsen global warming[10]. However, despite the benefits of Cool Roofs, the technology has not been widely implemented.

7.1.3. Benefits of Cool Roofs

The benefits of Cool Roofs are well known and cited in scientific research. Reducing the temperature of the roof results in less heat being transferred to the building below, thereby reducing the cooling demand. However, there are also a number of other benefits including enhancing air quality in cities.
Cool Roofs offer both immediate and long-term savings in building energy costs. White reflective membranes, metal roofing with "Cool Roof" pigments, coated roofs and planted or green roofs can:

- Reduce building heat-gain, as a white or reflective roof typically increases only 5–14 °C (10–25 °F) above ambient temperature during the day.
- Save on summertime air conditioning expenditures.
- Enhance the life expectancy of both the roof membrane and the building's cooling equipment.
- Improve thermal efficiency of the roof insulation;
- Reduce the peak demand for electric power on hot days.
- Reduce resulting air pollution and greenhouse gas emissions.

Cool Roofs are particularly beneficial for buildings located in hot and sunny climate, such as in South East Asia. However, even in colder climates they are still considered useful and will not generally have a negative impact.

7.2. Cool Roof Technologies

This chapter discuss the technical aspects of Cool Roofs with relation to the physics and science of how Cool Roof works, and what the technical components of a Cool Roof are. This is essential to develop a common foundation for the analysis and discussion throughout the study.

7.2.1. The Physics of Cool Roofs

Absorptance and reflectance of building materials are usually measured across the solar spectrum, since they will be exposed to that range of wavelengths and these are the major characteristics responsible for urban heat gain/loss. The emissivity of building materials, on the other hand, is usually measured in the far-infrared part of the spectrum, since most building materials don't get hot enough to radiate at the shorter near-infrared, visible, and UV wavelengths.

Installation of high-albedo roof coatings or paint is most cost-effective if done during new construction or when buildings are scheduled for re-roofing.

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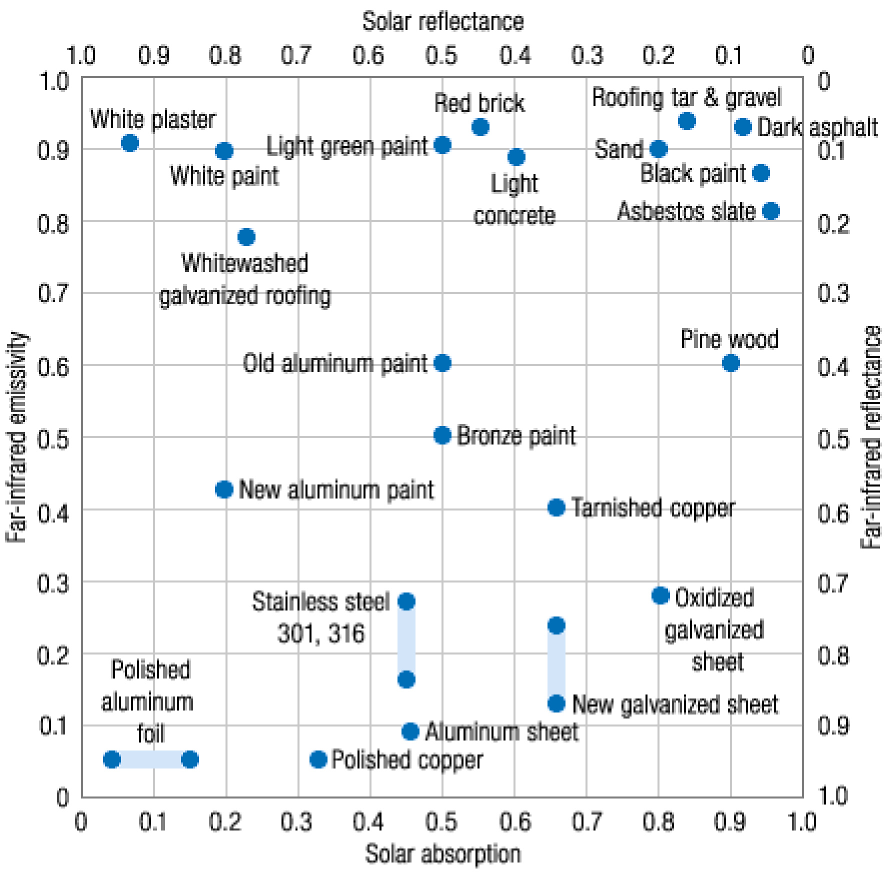
[10] http://www.motherearthnews.com/Green-Homes/Cool-Roof-White-Roof.aspx

The complement of reflectance is absorptance; whatever radiant energy incident on a surface that is not reflected is absorbed. Absorptance is also rated from 0 to 1, and can be calculated from the relation: reflectance + absorptance = 1. An ideal exterior surface coating for a cooling climate would have reflectance near 1.0, absorptance near zero, and infrared emissivity near 1.0 to radiate absorbed heat back to the sky. White plaster very nearly achieves this combination, as shown in Figure 7.3 below.

7.2.2. Spectral Characteristics of Building Materials

Even though many metals have a high solar reflectance, if emissivity is low the material will not reject heat effectively. For example, polished aluminium foil has a very high solar reflectance, but its emissivity is low, so it retains heat. Note its placement in the lower portion of the graph. The best performing materials for cooling load reduction have both high albedo and high emissivity, and are in the upper left hand section.

Figure 7.3 - Spectral Characteristics of Building Materials



Source: ESource Business Energy Advisor[11]

Buildings typically have solar reflectance in the 0.20 to 0.35 range, although dark roofs can be as low as 0.05. Both walls and roofs can be treated with light-coloured paints or other finishes increasing reflectance to about 0.70. Walls can be treated with exterior grade latex paints (which are unsuitable

[11] http://www.esource.com/escrc/0013000000DP22YAAT/BEA1/OMA/OMA_BuildingEnvelope/OMA-08

for roofs), while special compounds formulated and marketed specifically for heat load reduction are available for roofs. The differences between standard paints and “specialty paints” are relatively small, and relate more to durability, fire protection, application ease, waterproofing and crack-sealing performance than to cooling load reduction. ‘Aluminized’ roof coatings are also available; they are less effective than white coatings at reflecting incoming radiation and reducing roof temperature.

A basic rule of thumb is that metallic objects have low emissivity and nearly everything else is high. For example, there is a slight difference in emissivity between black and white paints (0.95 versus 0.90), but they are nearly equal when compared to bare metal at about 0.35. Ceramic content, paint base, and other factors do not matter much, although the inclusion of metal in paints, as in aluminized roof coatings, may reduce emissivity. Surfaces that are most promising for albedo increase meet all of the following criteria:

- Dark or metallic existing surface;
- Poor insulation;
- High solar insolation;
- Large ratios of surface area to enclosed volume; and
- Environment where cooling season dominates energy considerations.

In April 1997, the US Department of Energy (DOE) and Environmental Protection Agency (EPA) introduced two labels for roofing materials. The first is a quantitative “Solar Reflectance Index”, similar to the yellow Energy Guard appliance labels. The second is Energy Star[12], marking the coolest one-third of the products on the market. Traditional roofing materials have SRI’s of five percent (brown shingles) to 20 percent (green shingles). White shingles with SRI’s of around 35 percent were used in the 1960s, but were discontinued because they appeared dirty. Today, manufacturers treat white shingles with a fungicide to prevent discoloration. Smooth “self-washing” shingles have SRI’s of up to 62 percent.

7.2.3. Types of Cool Roof Application

The type of Cool Roof materials used usually depends on the type of roof structure (all information in this section from Abolin Co., 2010 unless specified)[13].

Low sloped Cool Roof

The term ‘low sloped roofs’ typically refers to roofs with a profile of no more than 5cm vertically over 30cm horizontally, or a 2:12 pitch. Low sloped roofs are usually found in commercial, industrial, warehouse type buildings and usually consist of a single ply membrane and/or a coating. There are generally 4 main types of single ply membrane. The properties of low-sloped roofing materials are seen in Figure 7.4 below.

- Ethylene Propylene Diene Monomer (EPDM) or "Rubber" EPDM materials have been used as a roofing material in the United States since the early 1960's. EPDM is a synthetic rubber material that is formulated with extensive flexibility for use as membrane sheet roofing. EPDM

[12] http://www.energystar.gov
[13] Abolin Co., 2010.

is manufactured as a vulcanized (cured) membrane. Uncured EPDM is manufactured for use as a flashing material. EPDM can only be bonded to a like material with an adhesive when making seams. This adhesive can be seam tape and some liquid adhesives. EPDM membranes range in thickness of 1mm to 2mm. Only fully cured EPDM will bond together creating a molecular linkage. EPDM membranes exhibit good resistance to ozone, UV rays, weathering, and abrasions. EPDM has good low temperature flexibility. EPDM is resistant to some acids and solvents. On the other hand exposure to animal fats, vegetable oil and petroleum based products should be avoided.

- Polyvinyl Chloride (PVC) polymers were originally produced in Germany during the 1950's. The basic chemical resin is a relatively hard material that requires the addition of plasticizers to make it supple and pliable for use as flexible membrane roofing. Polyvinyl chloride (PVC) thermoplastic membranes, are produced through the polymerization of vinyl chloride monomers.

- TPO roof membranes are compounded from a blend of polypropylene and ethylene-propylene rubber polymers. TPO membranes exhibit positive physical properties, such as heat aging, cold temperature flexibility, puncture resistance and tear strength. They are resistant to damage from animal fats, hydrocarbon oils, and vegetable oils. They will not support the growth of microorganisms.

- Chlorosulphonated Poly Ethylene (CSPE) (commercially known as Hypalon) is the most expensive cool single-ply roofing material. It provides good weather resistance, fire resistance, and durability. The material is thermoplastic when installed, so heat welds are applied to the seams; the roofing cures to thermoset within days.

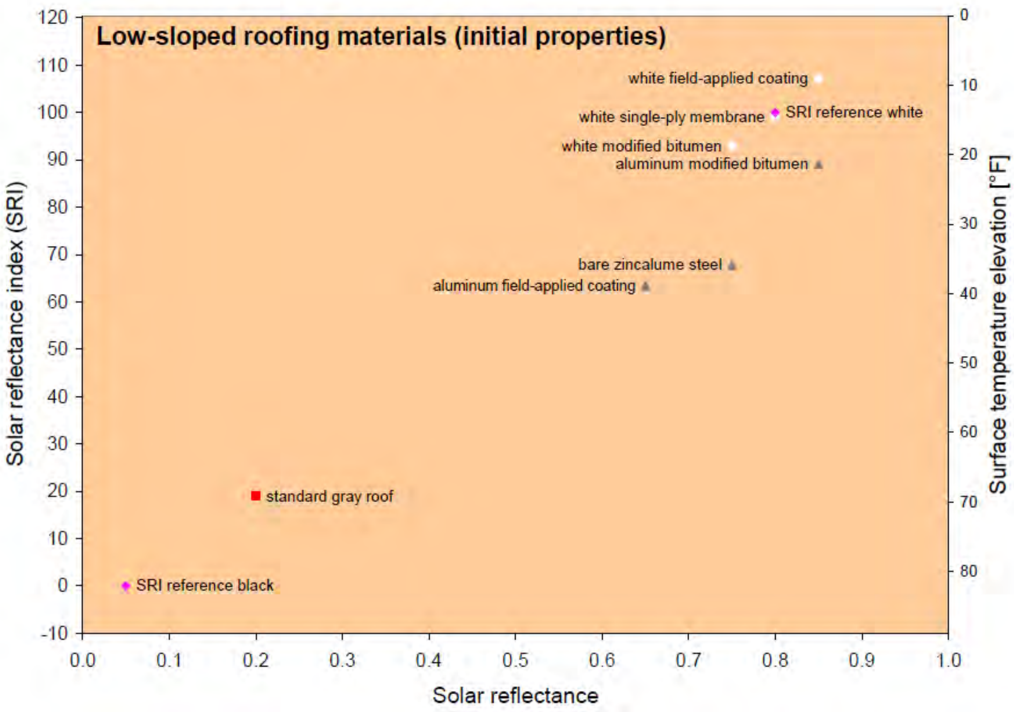
Steep-sloped Cool Roof

Most Cool Roof programs traditionally focus on low sloped roofing sector, but are becoming increasingly common in the steep-slope roof sector. The properties of steep-sloped roofing materials are seen in Figure 7.5 below. Common steep-slope roofing materials include:

- Roof Shingles and Tiles - These are roof coverings consisting of individual overlapping elements. These elements are normally flat rectangular shapes that are laid in rows without the side edges overlapping. Shingles have been made of various materials such as wood shingle, slate shingle, asbestos-cement, bitumen-soaked paper covered with aggregate (asphalt shingle) or ceramic. Tiles usually are made of clay, natural stone, metal (see metal roofing) or concrete.

- Metal Roofs are roofing systems using metal sheets or tiles as the waterproofing layer. There are different types of metal roof to suit different building forms and structures. Metal roofs can be applied on top of existing roofs, on boarded roofs, or, for most systems, directly onto roof purlins. Metal roofs are typically pre-coated so they lend themselves well to Cool Roofs. Light colours can be used and many suppliers are able to supply “Cool” versions of darker colours with special pigmentation which allows them to behave similarly to much lighter colours.

Figure 7.4 – Initial Solar Reflectance, SRI and Surface Temperature Elevation (Surface Temperature – Outside Air Temperature) of Products for Low-sloped Roofs[14]



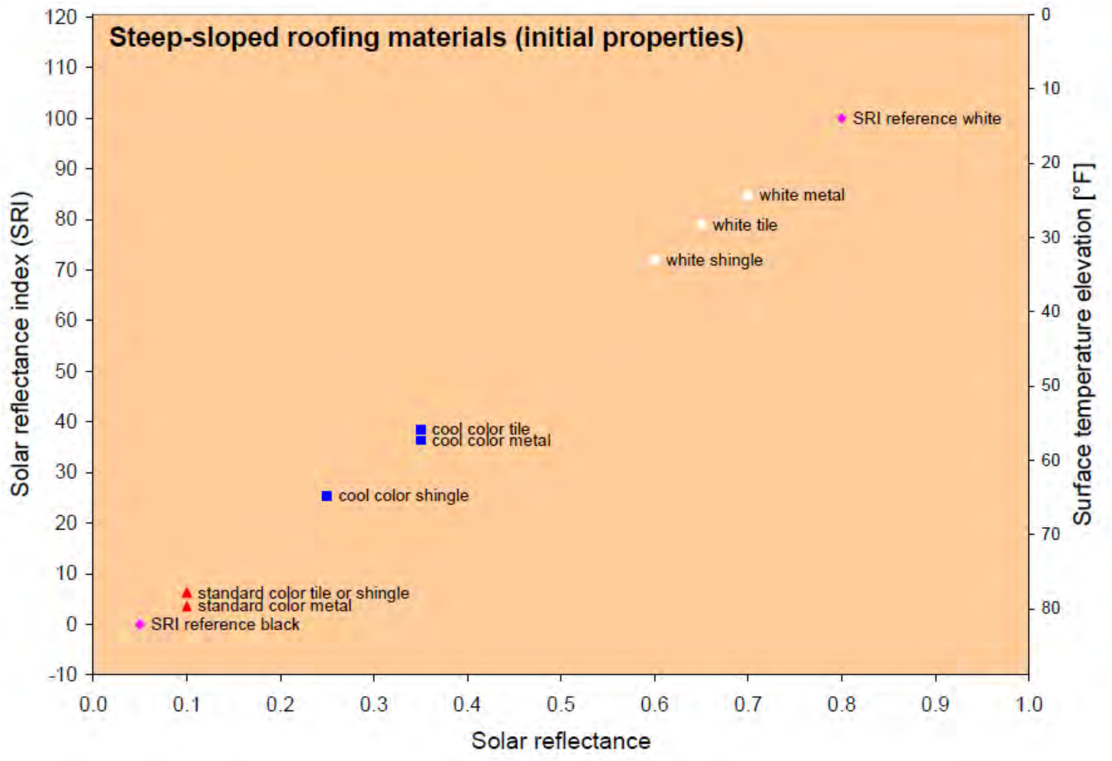
- Built-Up Roofing Systems (BUR's) are one of the oldest and most dependable roofing systems on the market today. The built-up roof system consists of multiple layers of bitumen, which are the waterproofing medium, and fibreglass roofing felts, which are the reinforcements, combining to form a uniform solid surface. Each type of base, cap, and ply felt is designed to perform a specific function in the roofing system. These various forms permit the installation of Built-Up Roofing Systems over many different substrates. The bitumen is also available in various grades to accommodate other variations that may be encountered i.e., slope, products, deck, and weather conditions. Cool Roof materials and technologies improve the thermal performance of built-up roofs under solar radiation. BUR roofs mostly appear light grey or tan and have a solar reflectance of 0.15-0.25. They are usually applied hot and topped with aggregate rocks or capsheets.

- Modified Bitumen Roofing is similar to both BUR and Single-Ply membrane roofs. Materials are either plastic or rubber. The ordinary colours are black or grey with a solar reflectance of only about 0.05 to 0.2. Modified Bitumen Roofing consists of composite sheets of asphalt bitumen modified with polymers. They are installed in single or multiple layers, and the layers are adhered with hot asphalt, torching down or cold adhesive. Modified bitumen roofs offer benefits over other systems currently marketed for low slope roofing applications. They share many similarities to single ply membranes, add to that a base layer two to three ply built up roof, making the modified bitumen roofing system much less susceptible to problems. The tough and tenacious properties of the modified bitumen blend coupled with high tensile

[14] http://coolcolors.lbl.gov/assets/docs/fact-sheets/Cool-roof-Q%2BA.pdf

polyester and/or fibreglass reinforcements provide excellent resistance to foot traffic, punctures, dropped tools, hail storms and other abuse. This makes these products ideal for buildings with high traffic roofs, such as those with mechanical equipment, and schools or structures where objects can be thrown onto the roof.

Figure 7.5 - Initial Solar Reflectance, SRI and Surface Temperature Elevation (Surface Temperature – Outside Air Temperature) of Products for Steep-sloped Roofs[10]



7.3. Cool Roof Policies

This section analyses the national and regional regulation and policies with relation to supporting the implementation of Cool Roofs across selected APEC member economies.

The analysis identifies relevant energy efficiency policy and initiatives within each APEC economy followed by any specific programmes relevant to Cool Roofs. The mechanisms and approach of the policies (e.g. tax incentives, mandatory standards) are detailed where available. Key institutions involved in the Cool Roof industry are also identified.

Most APEC economies do not have specific regulation or legislation pertaining to Cool Roofs, maintaining an overall ETTV/RTTV/OTTV value (building Envelope, Roof and Overall Thermal Transfer Value respectively) set out via regulation or encouraged through green building standards. Cool Roofs can contribute towards achieving the standards therein.

Exceptions are the USA and Japan (see below for more details)

7.3.1. International Policy Related to Cool Roofs

As part of the international efforts to tackle climate change, energy efficiency forms a large part of national and international environmental policies. Energy efficiency is often preferred in energy policies because of its perceived 'quick win' cost effective solution. It has thus been a focus and feature in policy development.

The building industry has often been targeted as part of the overall energy efficiency drive as it is regarded as having the largest potential for implementing energy reduction and efficiency measures. These initiatives commonly include measures such as low energy lighting, efficient heating and air conditioning systems and low thermal transfer for building fabrics.

The political support for implementation of Cool Roofs in APEC varies between regions and economies. The most active are in North America where there are a number of incentives available to encourage use of Cool Roofs, as well as number of mandatory requirements in certain regions of the US along with US state and federal departments.

The Clean Energy Ministerial, Global Superior Energy Performance Partnership Cool Roofs and Pavements Working Group[14a] aims to advance policies and actions that increase the solar reflectance of urban surfaces, through activities such as demonstration projects, the development and sharing of best practices, research to refine the understanding of the potential of cool roofs and pavements to mitigate the urban heat island effect and global warming, and the promotion of inclusion of cool roofs and pavements in building codes. APEC member economies participating in this Partnership are: Australia, Canada, Japan, Republic of Korea, Mexico, Russia and The United States.

In addition, the Global Cool Cities Alliance (GCCA)[14b] aims to advance policies and programs that increase the solar reflectance of buildings and pavements to promote cool buildings, cool cities, and, most importantly, to mitigate the effects of climate change through global cooling through the development of five different program areas which together are designed to ensure that a range of mechanisms, from municipal action to advancements in research and development, act in concert to accelerate the adoption of cool roofs, specifically:

- **100 Cool Cities** – Recruit and obtain commitments from 100 major cities – "100 Cool Cities" – across the globe by 2015, with widespread installation of cool surfaces by 2020.
- **Corporate Leadership** – Support the voluntary adoption of cool surfaces by commercial and industrial building owners, with 20 major global corporations actively committed to cool roofs and pavement installation by 2013.
- **Building Codes and Specifications** – Promote the inclusion, by 2015, of cool surfaces – mainly white roofs – in the building and pavement codes of key US states and major foreign countries.
- **Financial Mechanisms** – Develop financial mechanisms, by 2015, that broadly support the installation of cool surfaces in the US and other key countries.

[14a] http://www.cleanenergyministerial.org/our_work/buildings_and_industry/cool_roofs.html

- **Research and Development** – Ensure that information about cool surface research, development, and demonstrations is broadly disseminated

Founding City members are:

- Athens, Greece
- Chinese Taipei
- Singapore
- Chicago, USA
- New York City, USA

United States of America

Politically, the United States have been keen endorsers of Cool Roof technologies. In addition to participation in the Clean Energy Ministerial, Global Superior Energy Performance Partnership Cool Roofs and Pavements Working Group, there have been large drivers for implementation of Cool Roofs at the state as well as federal level. There have also been voluntary initiatives such as Leadership in Energy and Environmental Design (LEED) which awards building owners/designers with credits relating to adoption of Cool Roof measures. The only jurisdictions that have actually established pass/fail criteria for "Cool Roofs" are in the U.S: ENERGY STAR, California and Chicago. Others are discussing it and several (e.g. the EU) have established general guides.

Some of the US initiatives are as follows:

California's Title 24

California's Title 24 Building Energy Efficiency Code[15] sets an energy budget for residential and non-residential buildings. Under the code there is a prescriptive requirement for Cool Roofs. Cool Roofs are classified as those that meet 0.70 reflectance and 0.75 emittance. The standard from California is as in Table 7.1 below.

Energy Policy Act 2005

The Energy Policy Act 2005[16] established tax credits for energy improvements to existing homes: provides a 30% funding up to $1,500 for energy efficiency measures including use of Cool Roof coatings.

US Department of Energy

In July 2010 the US Department of Energy announced a series of initiatives to more broadly implement cool roof technologies on DOE facilities and buildings across the APEC member economy.

[14b] http://www.globalcoolcities.org/
[15] http://www.energy.ca.gov/title24/
[16] http://www1.eere.energy.gov/femp/regulations/epact2005.html

As part of the new efforts, DOE will install a cool roof, whenever cost effective over the lifetime of the roof, during construction of a new roof or the replacement of an old one at a DOE facility.[17]

Table 7.1 – Cool Roof Performance Requirements of CA Title 24

Roof Type	Solar Reflectance	Thermal Emittance	SRI
Low-slope non-residential	≥ 0.55	≥ 0.75	≥ 64
Steep-slope non-residential	≥ 0.20	≥ 0.75	≥ 64
Low-slope residential	≥ 0.55	≥ 0.75	≥ 64
Steep-slope residential	≥ 0.20	≥ 0.75	≥ 64

All values after three years ageing.

New York City Cool Roofs

In the US, there have also been city initiatives such as the New York City Cool Roofs initiative[18] which aims to paint one million square foot of rooftop in white reflective paint. The initiative is a collaboration between NYC Department of Buildings, NYC Service and the Community Environment Centre.

Energy Star

As well as the Cool Roof rating, Cool Roof products are also able to apply for a label under the Energy Star program[11]: a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy designed to reduce greenhouse gas emissions and help businesses and consumers save money by making energy-efficient product choices.

For low slope roof applications, a roof product qualifying for the Energy Star label under its Roof Products Program must have an initial solar reflectivity of at least 0.65, and weathered reflectance of at least 0.50, in accordance with EPA testing procedures. Warranties for reflective roof products must be equal in all material respects to warranties offered for comparable non-reflective roof products, either by a given company or relative to industry standards

LEED

LEED is a voluntary, continuously evolving national standard for developing high performance sustainable buildings. LEED provides standards for choosing products in designing buildings, but does not certify products.

17 http://apps1.eere.energy.gov/news/news_detail.cfm/news_id=16175
18 http://www.nyc.gov/html/coolroofs/html/home/home.shtml

To receive the LEED Sustainable Sites credit[19], at least 75% of the surface of a roof must use materials having a Solar Reflective Index (SRI) of at least 78. This criterion may also be met by installing a vegetated roof for at least 50% of the roof area, or installing a high albedo and vegetated roof that, in combination, meets this formula: (Area of SRI Roof/0.75)+(Area of vegetated roof/0.5) = Total Roof Area.

Green Globes

The Green Globes system[20] is used in Canada and the United States. In the U.S., Green Globes is owned and operated by the Green Building Initiative (GBI). In Canada, the version for existing buildings is owned and operated by BOMA Canada under the brand name 'Go Green' (Voir vert[21]).

Green Globes uses performance benchmark criteria to evaluate a building's likely energy consumption, comparing the building design against data generated by the EPA's Target Finder, which reflects real building performance. Buildings may earn a rating of between one and four globes. This is an online system; a building's information is verified by a Green Globes-approved and trained licensed engineer or architect. To qualify for a rating, roofing materials must have a solar reflectance of at least .65 and thermal emittance of at least .90. As many as 10 points may be awarded for 1-100 percent roof coverage with either vegetation or highly reflective materials or both.

ANSI & ASHRAE

The American National Standards Institute (ANSI) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) have both developed green building standards with specifications for Solar Reflective Index (SRI) levels for roofs. Table 7.2 below states the minimum SRI factor required and summarises the US Cool Roof standards.

Additionally, In November 2010, U.S. President Obama and Japan's Prime Minister Kan launched the Energy Smart Communities Initiative (ESCI) for the Asia Pacific region (see Japan below).

European Union

The EU has recently been following the footsteps of the US, not only with participation in the Clean Energy Ministerial, Global Superior Energy Performance Partnership Cool Roofs and Pavements Working Group, but also with the establishment of the European Union Cool Roof Council (EU-CRC)[22]. This is considered a significant step in establishing the platform towards standardising Cool Roof products, encourage and sponsor research programmes and generating awareness within the building industry to implement Cool Roofs. The stated goals of the EU-CRC are to:

- Support policy development by improving understanding of the actual and potential contributions by Cool Roofs to heating and cooling consumption in the EU;
- Remove market barriers and simplify the procedures for the integration of Cool Roofs in construction;

[19] http://www.usgbc.org/ShowFile.aspx?DocumentID=1095
[20] http://www.thegbi.org/commercial/about-green-globes/
[21] http://www.voirvert.ca/
[22] http://coolroofs-eu-crc.eu/

- Change the behaviour of decision-makers and stakeholders to improve acceptance of Cool Roofing technologies; and
- Promote the development of innovative legislation, codes, permits and standards concerning Cool Roofs.

The EU-CRC is also in the process of developing its own database of Cool Roofing products which currently includes over 100 products from six companies in Germany, Greece and Italy. The minimum requirements to be listed in the database will be determined by a combination of factors including the product performance with respect to the roof slope and the effects of aging on the materials. In addition to creating this database, the EU-CRC is working to identify the potential policy issues and opportunities for introducing Cool Roof technology in the EU based on lessons learned from the introduction of Cool Roofing standards in the United States.

Table 7.2 – Summary of US Cool Roof Standards[23]

Cool Roofing at a Glance

		Solar Reflectance	Emittance	Solar Reflectance Index
ENERGY STAR®	Low slope[1] Initial Aged[2]	 0.65 0.50		
Green Globes™		0.65	0.90	78 [3]
California Title 24[3]	Low slope Initial Aged [2]	 0.70 0.55	0.75	64 [4]
USGBC LEED	Low slope			78 [3] (min 75% of roof)
ANSI/GBI 01-2010	Low slope			78 (min. 40% of roof)
ASHRAE Standard 189.1	Low slope			78 (min. 75% of roof)

1. A roof surface having a maximum slope of 2 inches rise for 12 inches run.
2. Three years' exposure
3. Roughly equivalent to, for example, 0.65 reflectance and 0.90 thermal emittance, although a number of different combinations of reflectance and emittance can achieve this value.
4. May not apply in every climate zone.

[23] http://www.vinylroofs.org/wp-content/uploads/2011/06/aec-cool-roofing-course.pdf

7.3.2. Asia & Oceania (APEC member economies) Building Energy Efficiency Policies & Best Practices

There has been significant development in energy efficiency policies in Asia; most nations now have developed some form of energy efficiency policy for the built environment, either on a mandatory level or an incentives level.

Besides Japan, no other APEC member economies in Asia or Oceania appear to have any initiatives supporting Cool Roof implementation specifically. However, there are a number of initiatives which supports energy efficiency measures in buildings and can potentially act as a vehicle for introducing Cool Roof policies. A summary description of the main initiatives for each of the APEC member economies is described below:

Australia

In addition to participation in the Clean Energy Ministerial, Global Superior Energy Performance Partnership Cool Roofs and Pavements Working Group, at a national level, the National Framework for Energy Efficiency is Australia's national plan to reduce energy consumption through codes, standards, and programs, and outlines possibilities and goals[24].

Until February 2011 the government also funded a Green Loans program to promote and assist energy efficiency initiatives in Australian homes by providing free home sustainability assessments. The assessments were voluntary and provided householders with valuable information and advice on the actions they could take around their home to save energy and water. This program has now closed[25] and was due to be replaced by the Green Start program, which has also been shelved[26].

Australia has two green building rating systems: The National Australian Built Environment Rating System (NABERS) is a government initiative to measure and compare the environmental performance of existing Australian buildings. The NABERS ratings for office buildings include: Energy; Water; Waste and Indoor environment[27].

The Green Star environmental rating tools for new buildings benchmark the potential of buildings based on nine environmental impact categories: Management; Indoor Environment Quality; Energy; Transport; Water; Materials; Land Use & Ecology; Emissions and Innovation[28].

As yet there is no specific Cool Roof legislation in any of the states or federal territories of Australia. The South Australian Government released a consultation paper in December 2010 regarding the introduction of Cool Roof Regulation into state law and proposing wider amendment of the Federal Building Code of Australia[29] to incorporate specific requirements for roof albedo into existing energy efficiency codes at both state and federal level[30].

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24 http://www.ret.gov.au/Documents/mce/energy-eff/nfee/default.html
25 http://www.climatechange.gov.au/government/programs-and-rebates/green-loans.aspx
26 http://ecogeneration.com.au/news/green_start_program_cancelled/054030/
27 http://www.nabers.com.au/
28 http://www.gbca.org.au/green-star/
29 http://www.abcb.gov.au/
30 http://www.sa.gov.au/upload/franchise/Water,%20energy%20and%20environment/climate_change/documents/cool_roofs/Cool_roofs_discussion_paper.pdf

The Vinyl Council of Australia is also promoting Cool Roof technology to its members, as seen at the recent Green Cities exhibition in Melbourne in March 2011[31], however there is no specific policy measure relating to use of Cool Roofs in Australia.

Japan

In addition to participation in the Clean Energy Ministerial, Global Superior Energy Performance Partnership Cool Roofs and Pavements Working Group, at a national level, Japan's Act for the Rational Use of Energy, first passed in 1979 and last updated in 2008 as the Energy Efficiency and Conservation Law[32], is the law under which all building energy codes are passed. The law also helps raise public awareness and support for energy efficiency, as well as goals and standards[33].

In addition, the government established a committee to promote mitigation of the Urban Heat Island (UHI) effect, which subsequently developed an 'Outline of the Policy Framework to Reduce UHI' in 2004.

Since April 2001 Tokyo Metropolitan Government has provided subsidies for and required the greening of rooftops and wall surfaces for new grounds and buildings that have a ground surface of over 1,000m² (250m²for public facilities). 54.5ha of rooftops have been greened as of January 1, 2005[34].

In November 2010, U.S. President Obama and Japan's Prime Minister Kan launched the Energy Smart Communities Initiative (ESCI) for the Asia Pacific region[35]. ESCI has four key pillars: *Smart Transport, Smart Buildings, Smart Grid,* and *Smart Jobs and Consumers*. ESCI aims to foster green growth, sustainable development and long-term job creation throughout the Asia-Pacific. It also aims to help realise the APEC Leaders' goal to reduce the energy intensity of their economies by 25 percent by 2030, and help guide the way to possible adoption of a more ambitious goal to cut the region's energy intensity by up to half.

Since buildings account for one-third of all energy use in the APEC region, the Smart Buildings pillar of ESCI investigates cost-effective ways to bolster energy efficiency in both new and existing buildings, with a range of approaches adapted to the tropical, temperate and cold climates of APEC economies, including research in Cool Roof technology.

Japan has also been making superior performance building materials using the performance evaluation method, and promoted the comprehensive improvement of the residential environment.

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[31] http://www.vinyl.org.au/Innovativecoolrooflaunched
[32] http://www.gov-online.go.jp/pdf/hlj_ar/vol_0021e/22-23.pdf
[33] http://www.eccj.or.jp/law/revised/10aug2005.pdf
[34] http://www.iea.org/work/2006/heat/5-e_Kondoh.pdf
[35] http://api.ning.com/files/OA3O8X-iR4pOjU-7sqnlRbsvex3VkKqYVgn9P6yG3zzXT0kvuq1hwI2QadKUou5*0pofDV*rovtJpkzd4Jd*BWl-Qhhg5FAt/ESCIActionNetworkBackgrounder.pdf

In addition, Japan's Green Building Rating System, *Comprehensive Assessment System for Built Environment Efficiency* (or CASBEE) is a voluntary green building rating system that assesses new, existing, and renovated buildings on extraordinary energy efficiency measures[36].

Singapore

In Singapore there has been a considerable effort from government to drive forward energy efficiency measures in the building sector. Singapore has had a mandatory energy code for buildings since the 1980s and these have been revised periodically since then[37]. The energy code covers elements such as the building envelope, air conditioning, lighting, electrical and service water heating. Several tax incentive programmes have been introduced for energy efficiency equipment and mechanical systems.

Energy Smart[38] is a building efficiency benchmarking and award system for commercial office buildings, hotel buildings, and factories. Buildings in these categories may submit an application for the Energy Smart Label award which promotes energy efficiency and resource conservation by annually recognizing the highest performing building in each category. To be eligible, buildings must be in the top twenty five percentile in terms of energy efficiency for their respective building stock. Air quality, thermal comfort, ventilation, and lighting levels are also evaluation considerations. Champions are inducted into a distinctive group, currently at fifteen, of celebrated and renowned buildings. The program was developed by the National Environment Agency (NEA) along with the Energy Sustainability Unit (ESU), a branch of NUS.

In 2005 the Singapore Building & Construction Authority (BCA) launched the BCA Green Mark Scheme[39] to encourage energy efficient buildings. From 2008, all new building and large renovated buildings has been required to meet the basic Green Mark level. Under the scheme however, there has been no specific criteria to encourage use of Cool Roof technology.

Additional programs promoting energy efficiency and sustainability include the 2008 Code on Environmental Sustainability of Buildings[40]. This code covers many facets of energy efficiency in residential and commercial construction. The code references old standards on energy efficiency as well as establishes new ones, and sets up checklists for residential and commercial buildings. The code enforces standards on building envelope, indoor air quality, lighting, ventilation, and HVAC, as well as water efficiency and other environmental quality measures. Bonus points are awarded for use of renewable resources.

At a National strategic level there is also the National Climate Strategy: Singapore's approach to national climate change through energy efficiency and renewable resources. It enables further action, and promotes energy efficiency throughout the APEC member economy[41]., however for now there is no specific policy measure relating to use of Cool Roofs in Singapore.

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36 http://www.ibec.or.jp/CASBEE/english/index.htm
37 http://www.bdg.nus.edu.sg/BuildingEnergy/energy_masterplan/index.html
38 http://www.e2singapore.gov.sg/buildings/energysmart-building-label.html
39 http://www.bca.gov.sg/greenmark/green_mark_buildings.html
40 http://www.bca.gov.sg/EnvSusLegislation/others/Env_Sus_Code.pdf
41 http://app.mewr.gov.sg/data/ImgUpd/NCCS_Full_Version.pdf

Malaysia

Under the Malaysia Plan[42] (now in its 10th version) strategies are discussed to promote energy efficiency in buildings. The Plan is administered by the Ministry of Energy, Green Technology and Water. Under the plan they will specify greater energy efficiency standards in the building code (Uniform Building By-Laws (UBBL)). However this does not relate to the use of Cool Roofs.

There is also a Building Energy Benchmark Program encouraging tenants to report their energy use and participate in the program. Tenants who participate are given a report on their energy use and GHG emissions and strategies for reducing energy, as well as the opportunity to participate in other government-sponsored programs[43].

There is no specific policy measure relating to use of Cool Roofs in Malaysia.

Thailand

Thailand has an energy efficiency standard for buildings since the introduction of the Building Energy Code through the Energy Conservation Promotion Act in 1992. Compliance was required for large buildings (defined as larger than 10,000m^2 or consumes 20m mega joules of energy a year). There have been a number of revisions of the code since then, but have not been mandatory for all buildings. Building energy efficiency is calculated on an OTTV and RTTV basis and sets specific requirements for lighting and HVAC systems[44].

The 2007 Energy Conservation Promotion Act[45] establishes mandatory measures which businesses must take in order to promote energy efficiency. The Energy Conservation Program, or ENCON[46], is the government tool to promote energy efficiency and renewable energy use. The Program sets goals, and allows the government to determine which standards must be adopted and enforced in order to meet these goals and establishes the ENCON Fund.

There is no specific policy measure relating to use of Cool Roofs in Thailand and no current plans to implement Cool Roofs into the Building Energy Code directly. However, in parallel to make it more effective the government sets standards in terms of energy efficiency for materials and equipment felt to have a significant impact on energy conservation (according to survey responses).

In addition, APEC held a workshop in Bangkok in June 2011 to define and mobilize the Building Envelope Research And Development Materials Testing And Rating Centre identified as a key action item in APEC's Energy Smart Communities Initiative (SB-2)[43a]. The workshop brought together public, private and academic sector stakeholders involved in developing a model Building Envelope Energy Efficiency Centre to then be replicated in other APEC economies.

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42 http://www.epu.gov.my/html/themes/epu/html/RMKE10/rmke10_english.html
43 http://bcap-ocean.org/state-country/malaysia
43a http://www.apec.org/Events-Calendar.aspx
44 http://www.energy-based.nrct.go.th/Article/Ts-3%20development%20of%20a%20building%20energy%20code%20for%20new%20buildings%20in%20thailand.pdf
45 http://bcap-ocean.org/sites/default/files/2-1-E.pdf
46 http://bcap-ocean.org/sites/default/files/859_8661.pdf

The purpose of the Building Envelope Research And Development Materials Testing And Rating Centre (SB-2) is to provide accurate, consistent performance data essential to promoting trade in energy-efficient building envelope materials – such as insulation, cool roofs and advanced windows - through a rating and certification program, supporting infrastructure for code compliance and training in best practice design and simulation.

Philippines

Energy efficiency and conservation form a key part of Philippines energy policy. 2004 National Energy Efficiency and Conservation Plan is the Philippines' national plan to reduce energy use. It relies heavily on public awareness, training, and appliance labeling, but also develops a public-private relationship between government and companies to report energy consumption[47].

A Government Energy Management Program was formed to promote use of energy efficiency technologies and practices in all government facilities[48] as part of the Philippines National Building Code 2005, which although mandatory, contains only voluntary standards on energy efficiency concerning building shells, lighting, HVAC, and water heating[49].

There is also motivation for green construction on a voluntary basis through a Recognition Award Program: a program which rewards exemplary buildings and companies that have improved efficiency. It is not actually a rating system, but a method of awarding specific buildings and companies[50].

In 2009 the Local Government of Quezon City launched the Implementing Rules and Regulation, Part 1 (IRR-1) for Green Infrastructures in pursuant to Section 24 of SP 1917 S-2009, also known as the Green Building Ordinance of 2009. Section 3.15 pertains to Green Roofs, being "buildings that have rooftops that are dedicated to plants and trees"[51].

There is no specific policy measure relating to use of Cool Roofs in the Philippines.

Indonesia

The National Master Plan for Energy Conservation, or RIKEN, was first passed in 1995 and updated in 2005 and is Indonesia's National Energy Efficiency Plan. It establishes the need for further implementation of specific energy conservation programs and energy audits and reports, and sets the goal of reducing the national energy intensity by 1% each year[52].

As an ASEAN member, Indonesia adopted voluntary commercial energy codes in 1992. The code applies to building envelope, lighting, and HVAC. Unfortunately, it is believed that the codes are not understood or adhered to by builders and designers in Indonesia. USAID believes that if the codes were enforced, Indonesia would experience 20% energy savings[53].

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47 http://www.doe.gov.ph/neecp/default.htm
48 http://www.climateworks.org/download/?id=476e8f05-d63b-4a18-ab75-a8b24002f0ac
49 http://bcap-ocean.org/code-information/philippines-national-building-code
50 http://www.doe.gov.ph/EE/RAP.htm
51 http://www.quezoncity.gov.ph/images/stories/IRR/IRR.pdf
52 http://www.asiaeec-col.eccj.or.jp/st-takes/pdf/indnsa/1_3_a.pdf
53 http://bcap-ocean.org/code-information/indonesia-commercial-building-energy-code

In addition, the 2007 Law on Energy, which was approved by the legislative and executive branches of Indonesian government, gives the government the power to manage all of the APEC member economy's energy use. This is meant to improve the energy security of the economy, make sure that all sectors use energy efficiently, and promote the use of sustainable energy[54].

The Green Building Council of Indonesia established the Greenship green building rating system for existing and new buildings in 2010, with a focus on green initiatives and OTTV calculation based on national standard SNI 03-6389-2000[55].

There is no specific policy measure relating to use of Cool Roofs in Indonesia.

Peoples' Republic of China

China adopted building energy standards in stages, starting with an energy design standard for residential buildings in the Heating Zone in north China in 1986, and revised in 1995. This was followed by a standard for tourist hotels in 1993, and then standards for residential buildings in the Hot-Summer Cold-Winter Region in central China in 2001 and the Hot-Summer Warm-Winter Region in south China in 2003. A national energy efficient design standard for public buildings (similar to commercial buildings) was adopted in 2004.

In addition, a revised national energy design standard for residential buildings that combines the three previous regional standards was completed in early 2007, along with an update to the Energy Conservation Law at the same time[56]. Preceding these national or regional standards, there have been also local standards in major cities, such as Beijing, Shanghai, Wuhan, and Chongqing.

Enforcement of building energy standards have been problematic, particularly in the early years, but with continuing programs led by the Ministry but implemented locally, compliance to the energy standards is now good in the leading cities, e.g. Beijing and Shanghai, adequate in the major cities, but still spotty in the smaller cities and towns. Although China's building energy efficiency program remains focused on the enforcement of building energy codes, there have been recent efforts to go beyond that through demonstration buildings, building performance ratings (2006), and green building rating systems (ecological housing 2001, green Olympics 2004, green buildings 2006[57]). Although these remain exploratory, public concern about the environment, energy waste, and climate change has increased rapidly in recent years, and may lead to major changes in China's booming construction industry[47].

There is no specific policy measure relating to use of Cool Roofs in the Peoples' Republic of China

Chinese Taipei

Chinese Taipei adopted building energy standards for air-conditioned non-residential buildings in 1995 and for residential buildings in 1997. These are mandatory national standards that are being rigorously implemented, with demonstrated compliance needed in order for a building permit to be granted. At

[54] http://www.esdm.go.id/prokum/uu/2007/uu-30-2007-en.pdf
[55] http://www.gbcindonesia.org/images/stories/TimRating/GREENSHIP%20NB%20Summary-en.pdf
[56] http://www.mallesons.com/MarketInsights/marketAlerts/2008/Documents/9325994W.htm
[57] https://docs.google.com/Doc?id=ddfgxmx9_29hs74dhgv

present, the standards cover only the performance of the building envelope, although for the non-residential standard, energy performance criteria for the HVAC and lighting systems have been also proposed. In addition to the mandatory building energy standard, Chinese Taipei has also been working towards voluntary building energy efficiency programs such as building energy labelling, a very successful green building certification program, as well as DSM programs[47].

The Non-Residential Energy Efficiency Standard 1995 is a fairly simple code and covers only building envelope. It uses an equation (ENVLOAD) to determine the annual cooling load based on area, and then sets an allowable envelope load[58].

In 2009 the government introduced the 2009 Energy Efficiency Strategy[59]: Chinese Taipei's Energy Saving Measures for the Built Environment which sets goals for 2015 for energy efficiency and cutting GHG emissions. It provides building strategies, case studies, and promotes overall building efficiency.

The EEWH is a voluntary building rating system that uses four categories: Ecology, Energy-Saving, Waste Reduction, and Health. It helps serve as a promotional label for sustainable construction with criteria such as energy savings (for building envelope and lighting and HVAC systems), CO_2 emission reduction, construction waste reduction, water conservation; garbage and sewage improvements; biodiversity; and indoor environmental quality[60].

There is no specific policy measure relating to use of Cool Roofs in Chinese Taipei.

Hong Kong

Hong Kong's efforts to develop building energy standards started with the commissioning in 1990 of a consultant report on building energy regulations concluding with the recommendation that Hong Kong adopt an OTTV (Overall Thermal Transfer Value) standard for the building envelope. Such a Building (Energy Efficiency) Regulation was introduced in July 1995 with "suitable" OTT values for the walls and roofs of commercial buildings and hotels. "Commercial buildings" refer to offices, shops, department stores, and other buildings with commercial purposes, but do not include schools, residential buildings, factories, or garages. In practice, the code has been applied to any air-conditioned building.

A Code of Practice for Overall Thermal Transfer Values in Buildings (OTTV Code) was published by the Buildings Department to provide technical guidance on the OTT values. In addition to the OTTV standard, which affects only the construction of the building envelope, the Hong Kong government also develop separate standards for lighting, air-conditioning, and electrical equipment (all in 1998), and for lifts and elevators (2000). Thus, by 2000 these five standards together contained the same scope as more comprehensive standards such as ASHRAE 90.1 in the US. In 2005, all five of these standards were revised, with a performance-based option added to the building envelope standard[47].

Since 2000 the Hong Kong BEAM, a voluntary classification standard for rating green buildings, has been in existence. Similar to LEED, buildings can achieve a "green building" status based on how

[58] http://bcap-ocean.org/state-country/taiwan-chinese-taipei
[59] http://bcap-ocean.org/sites/default/files/Building_Awareness_FirstEdition_Final.pdf
[60] http://gsp.stsipa.gov.tw/eng/main03_2.html

sustainable the building is. It creates a specific set of standards and is geared toward design and construction professionals[61].

The Hong Kong Energy Registration Scheme for Buildings (HKEERSB) is the accepted voluntary set of codes for energy efficiency. The program consists of 5 Building Energy Codes (BECs): Lighting Installations, Air Conditioning Installations, Electrical Installations, Lift and Elevator Installations, and a Performance Based Code checklist. Buildings can register as HKEERSB in any or all of the code categories. Compliance can be prescriptive or performance based. Legislation has been introduced to the Legislative Council to make the HKEERSB mandatory for all new buildings, based especially because of the support it received from the public[62].

In addition, the Greenhouse Gas Reporting and Removal for Buildings Program encourages tenants to report their energy use and participate in the program. Tenants who participate are given a report on their GHG emissions and strategies for reducing energy, and thus GHG emissions, as well as saving money on energy costs[63].

There is no specific policy measure relating to use of Cool Roofs in Hong Kong.

New Zealand

Clause H1 of the New Zealand Building Code (NZBC) is the reference of all energy codes mandatory in New Zealand, and applies to all new construction. Clause H1 was first published in 1992; the 2007 update is the third edition. The code sets standards for thermal envelope, air flow, passive daylighting, water heaters, lighting, and others. It also provides a verification method which includes a performance index. The code references may New Zealand standards, which are otherwise voluntary[64].

The New Zealand Government's Energy Efficiency and Conservation Authority runs ENERGY WISE[65], a public education program and clearinghouse for information on residential energy saving strategies. The program functions with the support of suppliers, installers, manufacturers, and retailers and offers information on product rebates, driving tips, appliance rating and labelling, and funding opportunities for efficient equipment such as solar heat pumps.

Interest-free loans are available for participants in Residential e – "a comprehensive, national, voluntary environmental rating scheme that evaluates the environmental attributes and performance of New Zealand's buildings using a suite of rating tool kits developed to be applicable to each building type and function."

The New Zealand Green Building Council (NZGBC) has developed a rating scheme called *Green Star*[66] in partnership with the building industry, which is a program for commercial buildings. It uses a

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61 http://www.beamsociety.org.hk/general/home.php

62 http://bcap-ocean.org/code-information/hong-kong-energy-regisration-scheme-buildings
63 http://www.epd.gov.hk/epd/english/climate_change/files/CAGuidelines_Eng.pdf
64 http://bcap-ocean.org/code-information/new-zealand-building-code-clause-h1
65 http://www.energywise.govt.nz/
66 http://www.nzgbc.org.nz/index.php?option=com_content&view=article&id=17&Itemid=117

suite of rating tool kits which are applicable to different building types and functions. In addition there is a parallel program for residential buildings: *Homestar*[67].

Further programmes by the Energy Efficiency and Conservation Authority exist to support and promote energy efficiency, energy conservation, and the use of renewable sources of energy. The programmes are delivered through partnerships, with the private sector, community groups, industry associations and central and local government[68] and all stem from the National Energy Efficiency and Conservation Strategy[69]: New Zealand's 2007 national plan to reduce energy consumption through new programs, government strategies, and establishes goals on consumption and emissions. This has since become a companion document to the New Zealand Energy Strategy[70].

There is no specific policy measure relating to use of Cool Roofs in New Zealand.

Papua New Guinea

The Papua New Guinea Sustainable Development Program Ltd. (PNGSDP)[71] was established in 2002, when BHP Billiton divested its 52% shareholding in the Ok Tedi Mining Ltd (OTML) following concerns about the long-term environmental impact of the mine, and the social and economic repercussions of this impact. PNGSDP has the task of applying the funds coming from OTML which are assigned for the development of the PNG, in particular the people of the Western Province.

A private company, PNGSDP allocates two thirds of the Company's Development Funds to its National Programs. PNGSDP initiates programs on its own and also in collaboration with the Government and other development partners. PNGSDP has supported a number projects nationwide in transport infrastructure, energy development, agriculture, forestry and micro finance services. The development impact of its interventions particularly in transport infrastructure and micro finance are highly visible however no programs relating to energy efficiency in building codes are known to exist in either the private or public sector.

As a result, no known building energy codes or specific policy measures relating to use of Cool Roofs exist.

There is record of one LEED project (under LEED New Construction v2009) having been carried out in Papua New Guinea according to the LEED Projects Directory[72], however the project details are confidential according to the directory.

Brunei-Darussalam

No known building energy codes or specific policy measures relating to use of Cool Roofs exist.

There is record of one LEED project (under LEED New Construction 2.2) having been carried out in Brunei-Darussalam according to the LEED Projects Directory[71]. Registered in 2010 this may be the

67 http://www.nzgbc.org.nz/index.php?option=com_content&view=article&id=50&Itemid=45
68 http://www.eeca.govt.nz/eeca-programmes-and-funding/programmes
69 http://www.eeca.govt.nz/sites/all/files/nzeecs-07.pdf
70 http://www.med.govt.nz/templates/ContentTopicSummary____19431.aspx
71 http://www.pngsdp.com/
72 http://www.usgbc.org/LEED/Project/CertifiedProjectList.aspx

Knowledge Hub (or K-Hub) which is claimed to be Brunei's first commercial green building[73], however this is speculation and the project details are confidential.

Republic of Korea

Although government-affiliated research institutes, universities, and utility companies have investigated building energy efficiency since the mid-80's, Korea did not formally adopt a building energy standard until 2004. However, in addition to participation in the Clean Energy Ministerial, Global Superior Energy Performance Partnership Cool Roofs and Pavements Working Group, Korea has since put in place a comprehensive program to minimize building energy consumption coupling the mandatory standards with voluntary efforts in building energy labelling, a Green Building Certification System[74], and financial incentive programs[47].

The Building Design Criteria for Energy Saving (BDCES) is South Korea's mandatory building energy code. It was adopted in 2001, and has been revised many times the last time being in 2008. The BDCES contains both mandatory and recommended standards in a wide range of areas including design/construction basics, mechanical equipment, electrical equipment, and renewable energy procedures. The code is a product of Korea's existing standards and other standards gathered and revised from codes in the US, UK, Germany, Canada, and Japan. Korea opted to make their code more simple (like Japan's) in order to implement the code easier[75].

All policy stems from the National Basic Plan for Energy[76]: the Republic of Korea's national strategy to reduce energy consumption through codes, standards, and programs and outlines possibilities and goals. In addition the government has introduced tax breaks and lower interest rates for homeowners and businesses that use energy efficient buildings or make energy improvements[77].

There is no specific policy measure relating to use of Cool Roofs in the Republic of Korea.

Viet Nam

The only known building energy code in Viet Nam is the Energy Efficiency Commercial Code 2005, which is a set of guidelines for efficiency and conservation. It is mandatory for all buildings 2,500 square meters in floor area or bigger, but few in the industry know about the code and the Ministry of Construction does little to enforce it[78].

The 2007 Energy Conservation Program[79] is a national policy for the period of 2007-2015 that promotes efficiency and energy monitoring, and proposes further development of electricity generation plants. A vision plan for 2025 is also proposed.

There is no specific policy measure relating to use of Cool Roofs in Viet Nam.

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73 http://www.bedb.com.bn/bisop_devlocalbusiness.html
74 http://www.greenbuilding.or.kr/eng/html/sub02_1.jsp
75 http://bcap-ocean.org/code-information/korea-building-design-criteria-saving-energy
76 http://www.apec-vc.or.kr/?p_name=database&gotopage=7&query=view&unique_num=ED2008060121&skey
77 http://www.kemco.or.kr/new_eng/pg02/pg02080000.asp
78 http://bcap-ocean.org/code-information/vietnam-energy-efficiency-commercial-code-402005qd-bxd
79 http://bcap-ocean.org/sites/default/files/110.2007.QD-TTg.pdf

7.3.3. State of Cool Roofs in Asia

Cool Roof systems do not appear to be a well established form of energy efficiency technology in South East Asia. The majority and more recognised passive energy efficiency measures used in the region are generally the following:

- Glazing (coatings and multiple glazing);
- Heat transfer measures (insulating fabric for walls, roofs, floors etc); and
- Solar shading technologies.

Other focus of energy efficiency in buildings relate to mechanical systems and energy use within buildings, such as energy efficient lighting, air conditioning, and appliances.

This is due in part to a lack of government drivers in the region to encourage the use of Cool Roofs as the majority of government initiatives in the region seem to focus on systems.

7.3.4. Cool Roof Councils

Cool Roof councils can play a major role in driving forward implementation of Cool Roofs. The US Cool Roof Council (or Cool Roof Rating Council – CRRC) is the only national council established in an APEC member economy and has been instrumental in defining standardisation protocols and definitions and a database source for Cool Roof products. This is an essential first step in bringing together multiple stakeholders in research, industry and policy makers. The role of the Cool Roof Council can be summarised by the CRRC mission statement:

- To implement and communicate fair, accurate, and credible radiative energy performance rating systems for roof surfaces;
- To support research into energy related radiative properties of roofing surfaces, including durability of those properties; and
- To provide education and objective support to parties interested in understanding and comparing various roofing options.

7.4. Cool Roof Products

7.4.1. Cool Roof Product Types

A wide range of Cool Roof products are commercially available. Below is a list of definitions of Cool Roof technologies as commercially available product types[80]. Examples of each type are listed in the Cool Roof Rating Council (CRRC) Rated Products Directory.

- ***Built-up Roofing (BUR) (includes asphalt and coal tar pitch):*** Built-up Roofing consists of built-up layers of coated asphalt and insulation applied on site and can be covered with a capsheet (or surfacing material).

- ***Foam Roof Systems:*** Foam systems can also be divided into field-applied and factory-applied categories. Field-applied foam systems are similar to field-applied coatings, as they are sprayed on in liquid form and harden as they set on top of the roof. Factory-applied foam systems are formed into rigid panels and coated with a reflective coating. The foam usually gives the roof system additional insulation properties.

- ***Metal:*** Metal roofing products can be shaped to look like shingles or shakes, or to fit unique curvatures, in addition to a typical "standing seam" configuration. They come in a variety of textures and colours, including some darker "cool" colours with special additives that allow these dark colours to achieve significantly greater reflectance than previous versions of the same product.

- ***Modified Bitumen:*** Modified bitumen is bitumen (asphalt or tar) modified with plastic and layered with reinforcing materials then topped with a surfacing material. Like Built-up Roofing, the radiative properties of modified bitumen are determined by the surfacing material.

- ***Roof Coatings:*** Roof coatings can be divided into two categories: field-applied and factory-applied. Field-applied coatings are applied directly onto the roof surface, either on a new roof assembly or over an existing roof surface (and can be applied over top of just about anything, so long as the right coating is selected). Factory-applied coatings are applied at the factory prior to distribution. Examples of factory-applied coatings include coatings applied to metal and glazes that are applied to tiles.

- ***Shingles, Slate, or Tile****:* All of these products types use the same concept, where pieces fit together to form a roof. Asphalt shingles are fairly common for residential roofing applications, probably because they are relatively inexpensive and simple to install. Slate and tile products also come in a wide variety of colours, shapes and textures, and, because of their heavy mass, they have thermal properties that may yield additional energy savings beyond their reflectance and emittance properties.

- ***Single-Ply:*** Single-ply roofing is a pre-fabricated sheet of rubber polymers. Single-ply roofing is laid down in a single layer over a low or steep-sloped roof. The single-ply membrane can be

[80] http://www.coolroofs.org/HomeandBuildingOwnersInfo.html

loose-laid and weighted down with ballast or pavers or firmly set on the roof and attached with mechanical fasteners or adhesives. There are two main types of single-ply materials:

- ***Single-Ply-Thermoset (includes EPDM, Hypalon):*** Thermosets are materials that cannot be hot-air welded because it changes their physical characteristics. Instead, tape, or a contact cement, is used to seal the seams.

- ***Single-Ply–Thermoplastic (includes TPO, PVC, etc.):*** Single-Ply-Thermoplastic is a flexible sheet membrane which consists of compounded plastic polymers. When heat is applied onto the surface, the single ply-thermoplastic seams are melded together making the material seamless and effective. Most thermoplastics are manufactured to include a reinforcement layer (usually polyester or fibreglass) for extra durability and strength. There are various types of single-ply-thermoplastic such as PVC & TPO. *PVC* (polyvinyl chloride) is a synthetic polymer prepared from vinyl chloride. It tends to be more expensive than TPO, but is well known for long-term performance and is naturally fire-retardant. *TPO* (thermoplastic polyolefin) is a blend of polymers that can contain flame-retardants or UV absorbers.

Other products exist which are currently not included in the CRRC Rating Program:

- ***Ballasted Roofs:*** Ballasted roofs are roofing systems that include a waterproof material (like a single-ply membrane) weighed down with heavy materials, called a ballast. The ballast is typically some sort of stone or concrete paver.

- ***Green Roofs:*** Green roofs (also known as garden roofs or vegetated roofs) use plants as roof covering. Though technically not highly reflective, green roofs do provide similar energy savings and urban heat island mitigation benefits as Cool Roofs. They also absorb water, reducing storm water runoff. Green roofs are distinct from Cool Roofs and are not rated by the CRRC.

Example products are shown in Table 7.3 below, with specific values for Solar Reflectance, Thermal Emittance and SRI. Products are all taken from the CRRC Rated Products Directory[81].

[81] http://www.coolroofs.org/products/search.php

Table 7.3: Examples of Commercially Available Cool Roof Products

Example Product	Manufacturer	Type	Detail	Solar Reflectance		Thermal Emittance		SRI	
				initial	3 year	initial	3 year	initial	3 year
White Platinum	Conglas	built up roofing	fibre glass mat, asphalt and white finish roll	0.83	pending	0.83	pending	103.00	pending
SuperL II Ultra-Cool - white	PPG Industries	Applied coating (factory)	silicone polyester two-coat coil coatings	0.65	0.65	0.83	0.82	77.00	77.00
Acu-seal bright white	Advanced Coating Systems Inc.	Applied coating (field)	acrylic elastomeric coating	0.89	0.81	0.89	0.87	113.00	101.00
900 Series regal white	Kingspan	Metal	Outer face - Rib profiled embossed G-90 galvanized pre-painted steel	0.70	0.70	0.85	0.85	85.00	85.00
ERS-575	Ecology Roof Systems	Modified Bitumen	SBS modified bitumen applied onto a polyester reinforcement with a polypropylene film underside and a reflective white top surface	0.78	0.74	0.89	0.66	97.00	86.00
Arctic White Ballast Paver	Oldcastle Westile	Roof Pavers	lightweight concrete	0.65	pending	0.94	pending	80.00	pending
Landmark Solaris Santa Fe Blend & AR	Certain Teed Corp	Shingles or Shakes	Two-piece laminated fibre glass-based construction - solar reflective asphalt roofing shingle	0.40	pending	0.90	pending	45.00	pending
Sure-Flex White PVC	Carlisle SynTec Inc.	Single-ply thermoplastic	Single ply PVC	0.87	0.61	0.95	0.86	111.00	72.00
Hycrown	Conklin Company Inc.	Single-ply thermoset	high-grade Hypalon synthetic rubber sheet reinforced with polyester fibre	0.83	0.71	0.88	0.87	104.00	87.00

(Source: Cool Roof Rating Council Rated Products Directory, 2011)

Solar Reflectance, Thermal Emittance and SRI values are not available for tile, slate and aggregate products.

7.4.2. Availability of Cool Roof Materials in APEC Member Economies

The products listed above are taken from the Cool Roof Rating Council Rated Products Directory and are available throughout the USA and North America.

For most South East Asian APEC member economies, availability of Cool Roof products is through regional representatives of large companies such as Monier, BASF, ICI and Akzo Nobel with very few local manufacturing companies.

Australia:

Australia has various Cool Roof products available. The main international manufacturers are present; **Akzo Nobel** and **BASF**. See:

http://www.asiapacific.basf.com/apex/AP/AsiaPacific/en/ ; and

http://www.akzonobel.com/international/

Other companies offering Cool Roofs in Australia are listed below, many of whom are licensed distributors for the larger manufacturers:

Solar Cool (based in New South Wales) - http://www.solar-cool.com.au/index.html - distributor of **Insultec**, a UK thermal product

Cool Paints (based in Queensland) - http://www.coolpaints.com.au/ - distributor of Australian made Cool Roof products.

Metro (based in New South Wales) - http://www.metroroofrestoration.com.au/cool-roofs.html - also a distributor of **Insultec**, a UK thermal product

Crommelin (based in Western Australia) - http://www.crommelin.com.au/ - manufacturer and distributor of various construction industry products

Brunei-Darussalam:

No information regarding availability of Cool Roof products was found for this APEC economy.

Canada:

The main Cool Roof product manufacturers in Canada are the US based **GAF**, and **Akzo Nobel**. See:

http://www.gaf.com/Roofing/Commercial/Green-Roof-Central/Green-Roof-Central.aspx ; and

http://www.akzonobel.com/international/

In addition, the following firms specify Cool Roof coatings as products they install:

Spray Foam Canada (based in Newfoundland) - http://www.sprayfoamnewfoundland.com/cool-roof-coatings.html - distributor and installer of Cool Roof products.

Henry (based in California, USA; operating across North America) - http://www.henry.com/ - distributor of their own branded Cool Roof products.

Canada also benefits by proximity to the USA to all of the Cool Roof product manufacturers and distributors listed in the **Cool Roof Rating Council** Product Directory – http://www.coolroofs.org/products/search.php

Chile:

The main manufacturer present in Chile is **Akzo Nobel**. See: http://www.akzonobel.com/international/

Promotion of Cool Roof technology is becoming more prevalent, with a demonstration of the benefits of such being shown via the internet – for example:
http://www.tvsolar.com/view/5917/azotea-fresca-techo-fresco/

Peoples' Republic of China:

Information on the availability of Cool Roof Products in the Peoples' Republic of China was scant. The two main international Cool Roof manufacturers present are **BASF** and **Akzo Nobel**. See:

http://www.asiapacific.basf.com/apex/AP/AsiaPacific/en/ ; and

http://www.akzonobel.com/international/

In addition, Beijing based company **Beijing Zhishengweihua Technology Co. Ltd** specifies 'sun control paint' and 'solar reflective coatings' under its listed products. See: http://rongliheng.diytrade.com

Hong Kong:

The only manufacturer of Cool Roof products found in this APEC economy is **Akzo Nobel**. See: http://www.akzonobel.com/international/

Indonesia:

The two main international Cool Roof manufacturers present in Indonesia are **BASF** and **Akzo Nobel**. See:

http://www.asiapacific.basf.com/apex/AP/AsiaPacific/en/ ; and

http://www.akzonobel.com/international/

Monier also has a large presence. See: http://www.monier.co.id/products-services/roof-system-components/coolroof.html

Japan:

As with most Asian APEC economies, the two main Cool Roof manufacturers present are **BASF** and **Akzo Nobel**. See:

http://www.asiapacific.basf.com/apex/AP/AsiaPacific/en/ ; and

http://www.akzonobel.com/international/

Republic of Korea:

As with most Asian APEC economies, the two main Cool Roof manufacturers present in the Republic of Korea are **BASF** and **Akzo Nobel**. See:

http://www.asiapacific.basf.com/apex/AP/AsiaPacific/en/ ; and http://www.akzonobel.com/international/

Malaysia:

Again **Monier** had a large presence in this APEC economy, as well as **BASF** and **Akzo Nobel**. See:

http://www.monier.com.my/

http://www.asiapacific.basf.com/apex/AP/AsiaPacific/en/ ; and

http://www.akzonobel.com/international/

In addition **Colourcoil** is a Malaysian based company specialising in 'Cool Metal Roofs' with high SR (solar reflectance) values. See: http://www.colourcoil.com/index.html

Mexico:

The only main international manufacturer of Cool Roof products found in this APEC economy is **Akzo Nobel**. See: http://www.akzonobel.com/international/

In addition, **Redland Clay Tile** is a California based roof tile company with agents in Mexico offering Cool Roof products. See: http://www.redlandclaytile.com/home/

New Zealand:

The main manufacturer present in New Zealand is **Akzo Nobel**, both under its normal brand and also as **Dulux**. See:

http://www.akzonobel.com/international/ ; and

http://www.duluxacratex.co.nz/assets/pdf/spec-sheets/NZSA4179.pdf

Papua New Guinea:

No information regarding availability of Cool Roof products was found for this APEC economy.

Peru:

The only manufacturer of Cool Roof products found in this APEC economy is Akzo Nobel. See: http://www.akzonobel.com/international/

The Philippines:

The two main Cool Roof manufacturers present in the Philippines are **BASF** and **Monier**, under the brand **CPAC Monier**. See:

http://www.cpacmonier.com.ph/ ; and

http://www.asiapacific.basf.com/apex/AP/AsiaPacific/en/

Russia:

The only manufacturer of Cool Roof products found in this APEC economy is Akzo Nobel. See: http://www.akzonobel.com/international/

Singapore:

As with most Asian APEC economies, the two main Cool Roof manufacturers present in the Republic of Singapore are **BASF** and **Akzo Nobel**. See:

http://www.asiapacific.basf.com/apex/AP/AsiaPacific/en/ ; and

http://www.akzonobel.com/international/

Chinese Taipei:

The only manufacturer of Cool Roof products found in this APEC economy is **Akzo Nobel**. See: http://www.akzonobel.com/international/

Thailand:

As with most Asian APEC economies, the two main international Cool Roof manufacturers present in Thailand are **BASF** and **Akzo Nobel**. See:

http://www.asiapacific.basf.com/apex/AP/AsiaPacific/en/ ; and

http://www.akzonobel.com/international/

In addition, **Monier** has a presence under the brand of **CPAC Monier**. See: www.cpacrooftile.com/roofsystem-heat.asp

Also, Thai firm **Mahaphant** specify high solar reflectance roof coatings and tiles amongst their listed products – Cool Roof products by another name. See: www.mahaphant.com/en/our-products/product-hahaung-overview.jsp?prdid=55

USA:

There are two main international manufacturers of Cool Roof products present in the USA, namely **BASF** and **Akzo Nobel**. See:

http://www.basf.com/group/corporate/us/en/ ; and

http://www.akzonobel.com/international/

As previously mentioned, smaller manufacturers include **Redland Clay Tile** and **Henry**, both based in California. See:

http://www.redlandclaytile.com/home/ ; and

http://www.henry.com/

California is also home to the **Cool Roof Rating Council** and its comprehensive products database:

http://www.coolroofs.org/products/search.php

Viet Nam:

As with most Asian APEC economies, the two main international Cool Roof manufacturers present in Viet Nam are **BASF** and **Akzo Nobel**. See:

http://www.asiapacific.basf.com/apex/AP/AsiaPacific/en/ ; and

http://www.akzonobel.com/international/

In addition, Australian firm **Crommelin** has a presence under through agent **Duong Luan**, specifying 'heat resistant paint products. See: http://www.duongluan.vn/

8. SIMULATION METHODOLOGY

The computer models were developed by using information from existing buildings. Thermal properties of the common building elements were used as inputs to determine the cooling energy consumption. In order to provide a common basic for comparison, the general building materials used for the wall, floor and ceiling, and the occupancy schedules of the buildings were the same throughout the simulations. The roof coverings used for each building type in each location are specified below and were generally held to be the most common roof covering for that building type in those locations. Energy simulation studies were carried out using IES <VE> software based on data gathered from laboratory measurements of the normal and thermal paints.

The study was carried out in three main climatic zones:

- Tropical
- Sub-tropical
- Temperate

With city locations chosen respectively as:

- Singapore
- Brisbane, Australia
- Tokyo, Japan

Specific parameters are given in 'Assumptions' below. The study was carried out in the following sequence:

- A massing model of each building type was created using the IES<VE> software. Geometry details such as layout, shape, size, orientation were considered during model creation.
- Each building type was simulated with insulation (U-Values) matching minimum standards as defined by local building regulations.
- Each building type was simulated with a new conventional roof, an aged conventional roof and a Cool Roof with specific Solar Reflectance (SR) and Emissivity (E) values.
- The conventional roofs were aged according to the formula for ageing 3 years in California Title 24 S.118(i)2 and using β values specific to the product type.
- The Cool Roof products selected were applicable to the conventional roof type.
- The models were subjected to computer simulation using IES<VE> building energy simulation software, using weather data for each specific geographic location.
- The solar simulation was conducted to quantify the impact of the Cool Roof on the building cooling and/or heating load which contribute to the savings in energy consumption.
- The new and aged conventional roof models are the base model in each scenario. The Cool Roof model is then applied to each of the base models and the energy consumption of each model compared.
- The simulations were conducted for the whole year using weather data for the specified locations and the annual energy consumptions were extracted for the comparison.

In this study a two storey bungalow and a three storey industrial building were selected to be modelled and the following scenarios were generated:

- Baseline roof insulation with new conventional roof covering
- Baseline roof insulation with aged conventional roof covering
- Baseline roof insulation with new Cool Roof covering

9. BUILDINGS DESCRIPTIONS AND ASSUMPTIONS

9.1. BUILDING DESCRIPTION

Computer models of a 2-storey bungalow and a three storey industrial building were modelled using IES<VE> software. The buildings under study are based on buildings common in Singapore and are typical of buildings located in the APEC region. Figure 9.1 and 9.2 below show the 3D views of the models.

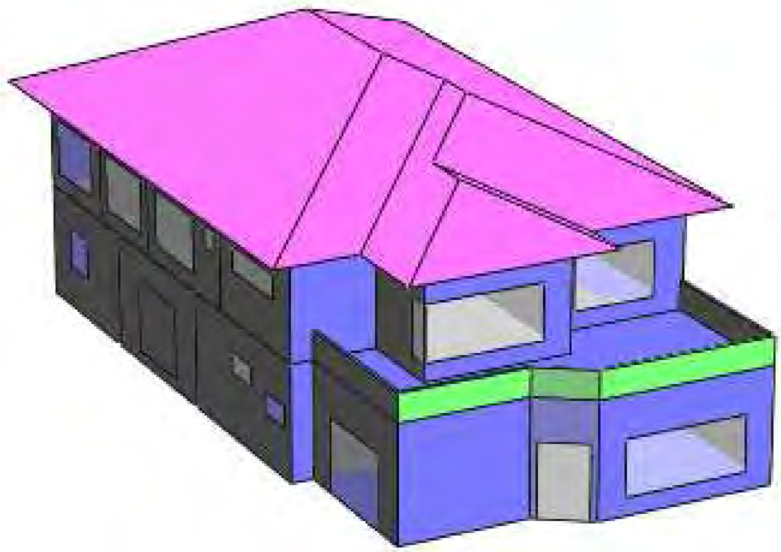

Figure 9.1 - 3D view of 2-storey bungalow

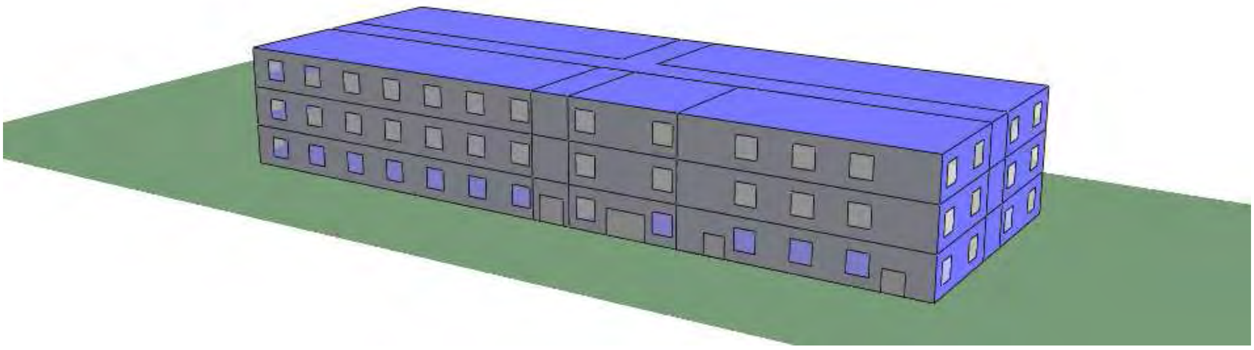

Figure 9.2 - 3D view of 3-storey industrial building

9.2. Building Envelope

Thermal properties of the common building elements were used as inputs to determine the cooling and/or heating energy consumption of the building. In order to provide a common basic for comparison, the internal conditions, such as lighting power density, electrical appliances used and the occupancy type and patterns, were used as the same throughout the simulations. The timing of the HVAC systems was set by typical occupancy type and patterns for the specific building type. The heating and cooling schedules are given in Table 9.12 below. Occupancy schedules differed between building types but were the same in each location.

The external walls were assigned as 100mm thick brick wall with plaster and paint on both sides.

The U-values for the roof insulation are the minimum standards taken from the local building regulations in each location[82] and are given in tables 9.5 - 9.10 below.

Whilst it can be argued that other SE Asian economies may not have requirements for thermal performance of roofs as stringent as those in Singapore, it is generally viewed that in time they will seek to revise their building codes to improve roof thermal performance and that this will most likely be achieved through reduced U-values rather than secondary mitigation methods such as Cool Roofs. Singapore U-values therefore represent a conservative baseline which is deemed a better standpoint upon which to base estimated savings on a macro level in terms of energy cost, greenhouse gases and air quality for the tropical region.

Most APEC economies within the sub-tropical and temperate climatic zones were found to have building codes specifying overall thermal performance standards for the building envelope, without specific requirements for roofs. In each of the respective climatic zones therefore, the two cities in question were chosen on the basis that their respective building codes did specify maximum U-values for roofs.

Tables 9.1, 9.2 and 9.3 below summarize the building envelope properties used in the simulations.

The Solar Reflectance (SR) and Emissivity (E) values for the conventional roof coverings were taken from the following sources:

- Clay tiles (Singapore Bungalow) - Red Clay Tile[83]
- Concrete Tiles (Brisbane & Tokyo Bungalow) - Red Concrete tile[82]
- Pitched w/ Corrugated Steel (Brisbane Industrial) - New Galvanised Steel[84]

The SR value for the Flat Concrete Roof (Singapore & Tokyo Industrial) was taken from the values given by Marceau and VanGeem (2007)[85]. A mixture of Ordinary Portland Cement (OPC) types and fine aggregate are used in concrete in these locations. Coarse aggregate tends to be darker and slag

[82] http://www.abcb.gov.au/
http://www.bca.gov.sg/PerformanceBased/others/RETV.pdf
http://www.mlit.go.jp/common/000038491.pdf
[83] http://eetd.lbl.gov/coolroof/tile.htm
[84] http://eande.lbl.gov/CoolRoof/metal.htm#metal
[85] http://www.concretethinker.com/Content/Upload%5C446.pdf

is occasionally used as it is 'greener' than OPC. From the results of Marceau and VanGeem, mixes and subsequent SR values were selected which reflect this use. A mean average of the SR values was then taken. See Table 9.4 below. The emissivity value was taken from data by Infrared Services Inc[86].

The conventional roof covering for the 'aged' scenario was aged in terms of solar reflectance (SR) applying the formula for ageing 3 years in California Title 24 S.118(i)2[87] and using β values specific to the product type[88]. The α value was set at 0.20 which was found to yield the lowest rms error. β values were given for an over-prediction rate of F=10% to create a conservative formula unlikely to overpredict Solar Reflectance in line with the other building parameters (See Sleiman et al, 2011). All other roof coverings used 'new' SR values. The β values are given in Table 9.11. The formula applied is:

$$\rho_a = [\alpha_0 + \beta [\rho_i - \alpha_0]$$

Where:

ρ_a	=	the aged solar reflectance
α_0	=	0.2 (the solar reflectance of an opaque soil layer (where rms error = <1.07)
β	=	the soiling resistance of the product type where F=10%.
ρ_i	=	the initial solar reflectance

The Cool Roof products were taken from the Cool Roof Rating Council Product Directory and were chosen as best matching the Conventional Roof in terms of material and aesthetic from the mid-range of SR values for available products. The codes for each product selected for the simulations are given in Tables 9.5 – 9.10 below, along with the thermal properties for each roof.

Whilst other Cool Roof models (Levinson & Akbari, 2007) have used weathered cool roof values in order to make the estimates of energy savings more conservative, this represented problems in terms of U-values. Whilst it is understood that in many scenarios there will be roofs which have little or no insulative value, baseline values for U-values in those scenarios which can be drawn on a macro level do not exist. Whereas the SR and E values of the roofs can be 'aged' 3 years using Sleiman's formula, the same does not apply for U-values. In the three chosen locations the code compliance baseline 3 years ago would have been the same as it is today. Each scenario therefore uses current code compliant U-values and draws comparisons between the following scenarios:

- A new conventional roof vs. a new cool roof (for a new development)
- An aged conventional roof vs. a new cool roof (as part of a refurbishment of an existing building)

86 http://www.infrared-thermography.com/material-1.htm
87 http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.PDF
88 Sleiman et al, 2011

Table 9.1 - Summary of building envelope properties used in simulation model - Singapore

Singapore - 2-Storey Bungalow	
Building Element	**Description**
Glazing	6mm clear glazing with U-value 5.69W/m^{2}K, SC 0.85
Floor	Reinforced Concrete Slab
Wall	Brick wall with plaster on both sides with light colour paint
Roof	Clay Tile Roof Case A – with new conventional clay tile roof Case B – with aged conventional clay tile roof Case C – with Cool Roof clay tiles
Singapore - Industrial Building	
Building Element	**Description**
Glazing	6mm clear glazing with U-value 5.69W/m^{2}K, SC 0.85
Floor	Reinforced Concrete Slab
Wall	Brick wall with plaster on both sides with light colour paint
Roof	Flat Concrete Roof Case A – with new conventional concrete roof Case B – with aged conventional concrete roof Case C – with Cool Roof field applied coating

Table 9.2 - Summary of building envelope properties used in simulation model - Brisbane

Brisbane - 2-Storey Bungalow	
Building Element	**Description**
Glazing	6mm clear glazing with U-value 5.69W/m^{2}K, SC 0.85
Floor	Reinforced Concrete Slab
Wall	Brick wall with plaster on both sides with light colour paint
Roof	Concrete Tile Roof Case A – with new conventional concrete tile roof Case B – with aged conventional concrete tile roof Case C – with Cool Roof concrete tiles
Brisbane - Industrial Building	
Building Element	**Description**
Glazing	6mm clear glazing with U-value 5.69W/m^{2}K, SC 0.85
Floor	Reinforced Concrete Slab
Wall	Brick wall with plaster on both sides with light colour paint
Roof	Low Pitched with Corrugated Steel covering Case A – with new conventional corrugated steel roof Case B – with aged conventional corrugated steel roof Case C – with Cool Roof metal roofing

Table 9.3 - Summary of building envelope properties used in simulation model - Tokyo

Tokyo - 2-Storey Bungalow	
Building Element	**Description**
Glazing	6mm clear glazing with U-value 5.69W/m^{2}K, SC 0.85
Floor	Reinforced Concrete Slab
Wall	Brick wall with plaster on both sides with light colour paint
Roof	Concrete Tile Roof Case A – with new conventional concrete tile roof Case B – with aged conventional concrete tile roof Case C – with Cool Roof concrete tiles
Tokyo - Industrial Building	
Building Element	**Description**
Glazing	6mm clear glazing with U-value 5.69W/m^{2}K, SC 0.85
Floor	Reinforced Concrete Slab
Wall	Brick wall with plaster on both sides with light colour paint
Roof	Flat Concrete Roof Case A – with new conventional concrete roof Case B – with aged conventional concrete roof Case C – with Cool Roof field applied coating

Table 9.4 – SR Values for differing concrete mixes (after Marceau & VanGeem, 2007)

Cement	Fine Agg	Coarse Agg	Slag	Code	SR
Plant R	Black	Eau Claire	-	CR/AB/CP	0.36
Plant R	Eau Claire	Eau Claire	-	CR/AE/CP	0.36
Plant S	Black	Eau Claire	-	CS/AB/CP	0.51
Plant S	Black	Eau Claire	Dark	CS/AB/CP/SD	0.54
Plant S	Black	Eau Claire	Light	CS/AB/CP/SL	0.57
Plant S	Eau Claire	Eau Claire	-	CS/AE/CP	0.42
Plant S	Eau Claire	Eau Claire	Dark	CS/AE/CP/SD	0.52
Plant S	Eau Claire	Eau Claire	Light	CS/AE/CP/SL	0.57
Plant S	Eau Claire	Eau Claire	Medium	CS/AE/CP/SM	0.54
Plant S	Limestone	Eau Claire	-	CS/AL/CP	0.53
Plant S	Limestone	Eau Claire	Dark	CS/AL/CP/SD	0.6
Plant S	Limestone	Eau Claire	Light	CS/AL/CP/SL	0.64
Plant S	McHenry	Eau Claire	-	CS/AM/CP	0.52

Mean Average SR	0.51

Table 9.5 - Roof properties for Clay Tile Roof 2-storey Bungalow – Singapore

Roof Type	Description	Emissivity	SR
Conventional	Conventional new clay tile	0.90	0.33
Conventional	Conventional aged clay tile	0.90	0.30
Cool	Cool Roof clay tiles	0.86	0.48
	Roof U-Value = **0.8 W/m²K**		
	CRRC Cool Roof Product Code:	0882-0060	

Table 9.6 - Roof properties for Flat Concrete Roof Industrial Building - Singapore

Roof Type	Description	Emissivity	SR
Conventional	Conventional new concrete slab	0.90	0.51
Conventional	Conventional aged concrete slab	0.90	0.38
Cool	Cool Roof field applied coating	0.89	0.76
	Roof U-Value = **1.20 W/m²K**		
	CRRC Cool Roof Product Code:	0646-0009	

Table 9.7 - Roof properties for Concrete Tile 2-storey Bungalow – Brisbane

Roof Type	Description	Emissivity	SR
Conventional	Conventional new concrete tile	0.91	0.18
Conventional	Conventional aged concrete tile	0.91	0.19
Cool	Cool Roof concrete tile	0.94	0.31
	Roof U-Value = **0.37 W/m²K**		
	CRRC Cool Roof Product Code:	1064-0020	

Table 9.8 - Roof properties for Corrugated Steel Covered Roof Industrial Building – Brisbane

Roof Type	Description	Emissivity	SR
Conventional	Conventional pitched roof with new corrugated steel panels	0.04	0.61
Conventional	Conventional pitched roof with aged corrugated steel panels	0.04	0.53
Cool	Cool Roof	0.85	0.71
	Roof U-Value = **0.37 W/m²K**		
	CRRC Cool Roof Product Code:	0778-0001	

Table 9.9 - Roof properties for Concrete Tile 2-storey Bungalow – Tokyo

Roof Type	Description	Emissivity	SR
Conventional	Conventional new concrete tile	0.91	0.18
Conventional	Conventional aged concrete tile	0.91	0.19
Cool	Cool Roof concrete tile	0.94	0.31
	Roof U-Value = **0.22 W/m²K**		
	CRRC Cool Roof Product Code:	1064-0020	

Table 9.10 - Roof properties for Flat Concrete Roof Industrial Building - Tokyo

Roof Type	Description	Emissivity	SR
Conventional	Conventional new concrete slab	0.90	0.51
Conventional	Conventional aged concrete slab	0.90	0.38
Cool	Cool Roof field applied coating	0.89	0.76
	Roof U-Value = **0.40 W/m^{2}K**		
	CRRC Cool Roof Product Code:	0646-0009	

Table 9.11 – Product Specific Ageing *β* Values where F=10%

Roof Type	Cool Roof Product Type	*β*
Concrete Tile	Tile	0.8
Clay Tile	Tile	0.8
Corrugated Steel	Metal	0.81
Concrete Slab	field applied coating	0.59

9.3. Assumptions

Whole building simulations were conducted for the buildings based on the weather data of the three specified locations.

The assumptions made in terms of internal load of the buildings are as follows:

Bungalow:	Lighting gain	– 10 W/m^2 (all areas)
	Equipment gain	– 5 W/m^2 (excluding corridors)
Industrial:	Lighting gain	– 15 W/m^2 (workshop/office)
Building		– 12 W/m^2 (all other areas)
	Equipment gain	– 25 W/m^2 (Workshop)
		– 16 W/m^2 (office)
		– 0 W/m^2 (all other areas)

The air conditioning, lighting and equipment usage follow the occupancy profiles.

Occupancy

Occupancy tables are given in Appendix A. The HVAC system was set to function in tandem with the occupancy times. During these times the internal temperature was set in accordance with the design set points given below.

Bungalow:

Bedrooms:

- Weekdays - occupied from midnight to 7am and from 8pm to midnight.
- Weekends - occupied from midnight to 7am, 9am-5pm and from 8pm to midnight

Living Room:

- Weekdays - occupied from 5am to 7am and from 6pm to 9pm.
- Weekends - occupied from 7am to 9am and from 5pm to 8pm.

Industrial Building:

- Weekdays - occupied from 8am to 6pm

The industrial building is assumed to be closed at weekends.

Heating & Cooling

Singapore experiences tropical climate all year round and therefore uses perennial HVAC cooling.[88a]

Brisbane experiences two distinct seasons: a hot and wet summer from September/October through until February/March; and a dry winter for the remainder of the year[89]. HVAC systems are only used in the particularly hot or cold times of year.

Tokyo experiences four distinct seasons[89a] and HVAC systems are generally used year round.

Table 9.12 below summarizes the heating and cooling schedules for the three locations and gives the design set temperatures for the different seasons where applicable as used in the simulations.

Table 9.12 – Annual Heating/Cooling Schedules

Climatic Zone	City	Heating/Cooling Schedule			
		Heating	Design Set Temp	Cooling	Design Set Temp
Tropical	Singapore[88b]	n/a	n/a	All Year	24℃ (c.75℉)
Sub-Tropical	Brisbane	July-August	22℃ (c.72℉)	October-February	24℃ (c.75℉)
Temperate	Tokyo[90]	September-February	20℃ (c.68℉)	March-August	26.2℃ (c.79℉)

88a http://en.wikipedia.org/wiki/Geography_of_Singapore#Climate_of_Singapore
88b Spring Singapore, 2009.
89 http://www.bom.gov.au/climate/averages/tables/cw_040913_All.shtml
http://www.bom.gov.au/climate/averages/tables/cw_066062_All.shtml
90 http://www.team-6.jp/about/action/01.html

10. SIMULATION RESULTS

The simulations were conducted for the whole year using weather data for the specified locations and the annual energy consumptions were extracted for the comparison.

Figures 10.1-10.3 show the annual energy usage for the Bungalow in the three locations for the three roof types.

Figures 10.4-10.6 show the annual energy usage for the Industrial Building in the three locations for the three roof types.

Tables 10.2-10.4 show the summarised energy usage and savings in each location for each type of building. The Climatically weighted averages are given in Table 10.5.

A full breakdown of the simulations is given in Appendix B.

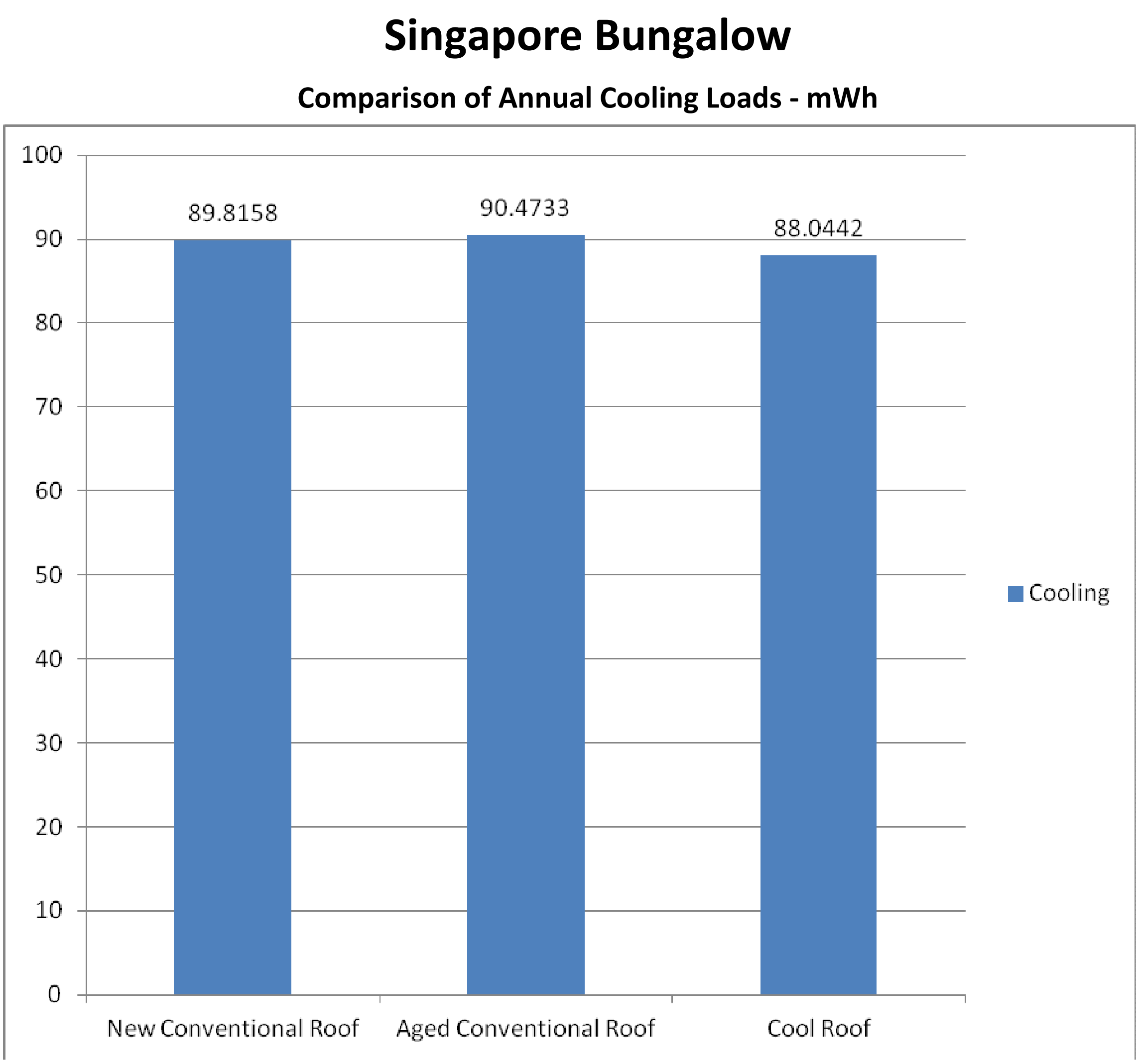

Figure 10.1: Annual Energy Usage for Bungalow in Singapore (Cooling Only)

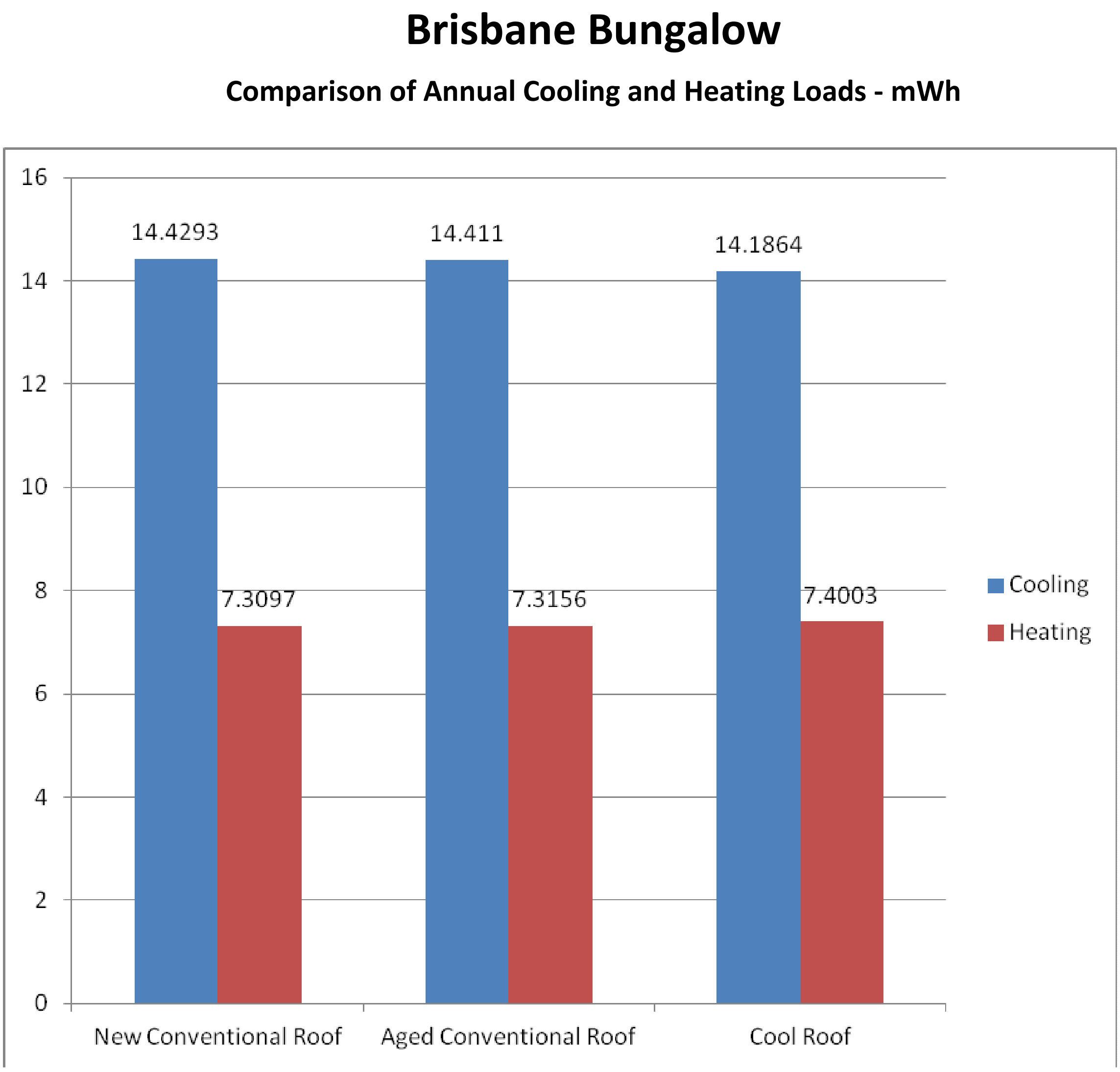

Figure 10.2: Annual Energy Usage for Bungalow in Brisbane (Cooling & Heating)

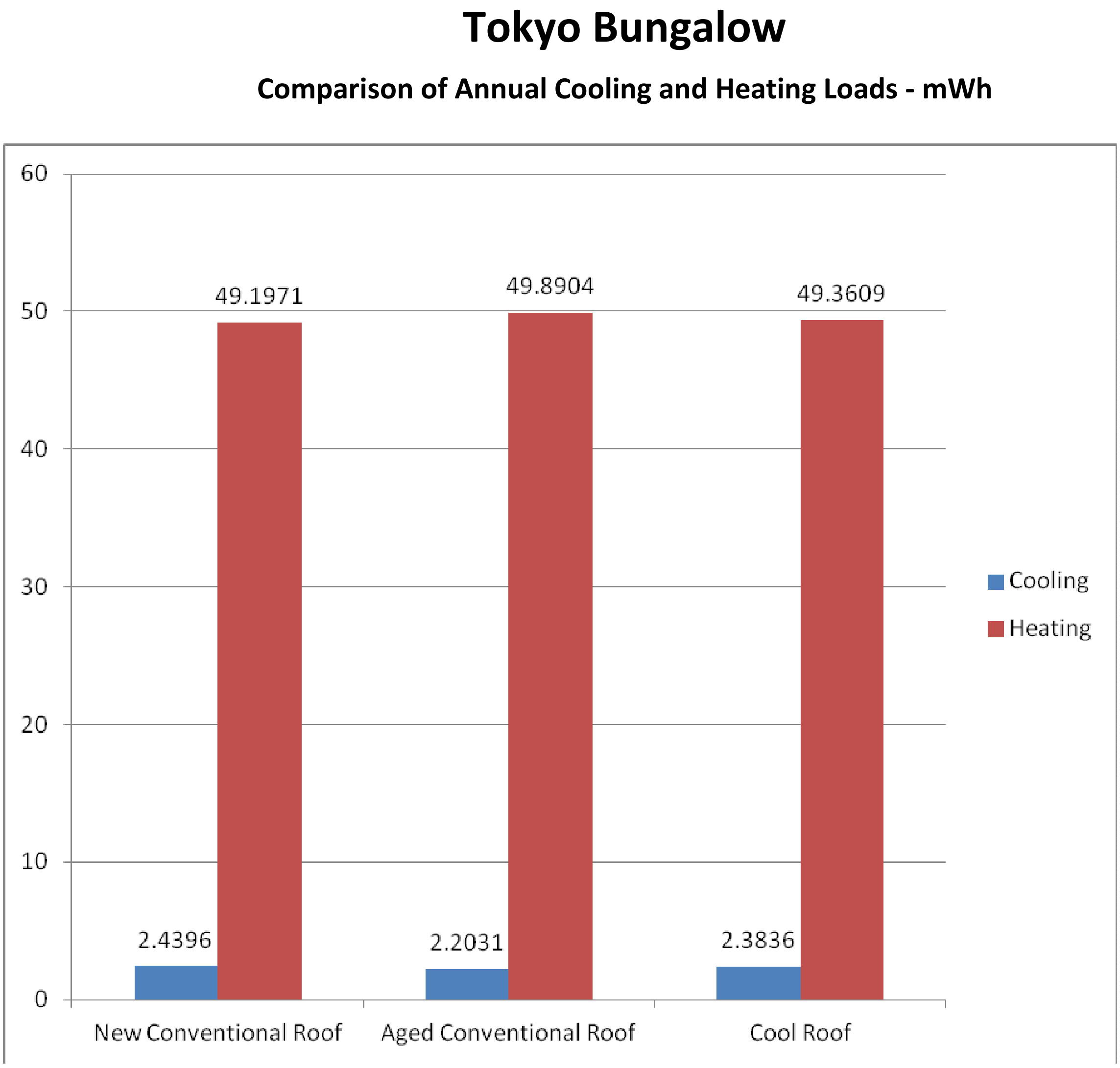

Figure 10.3: Annual Energy Usage for Bungalow in Tokyo (Cooling & Heating)

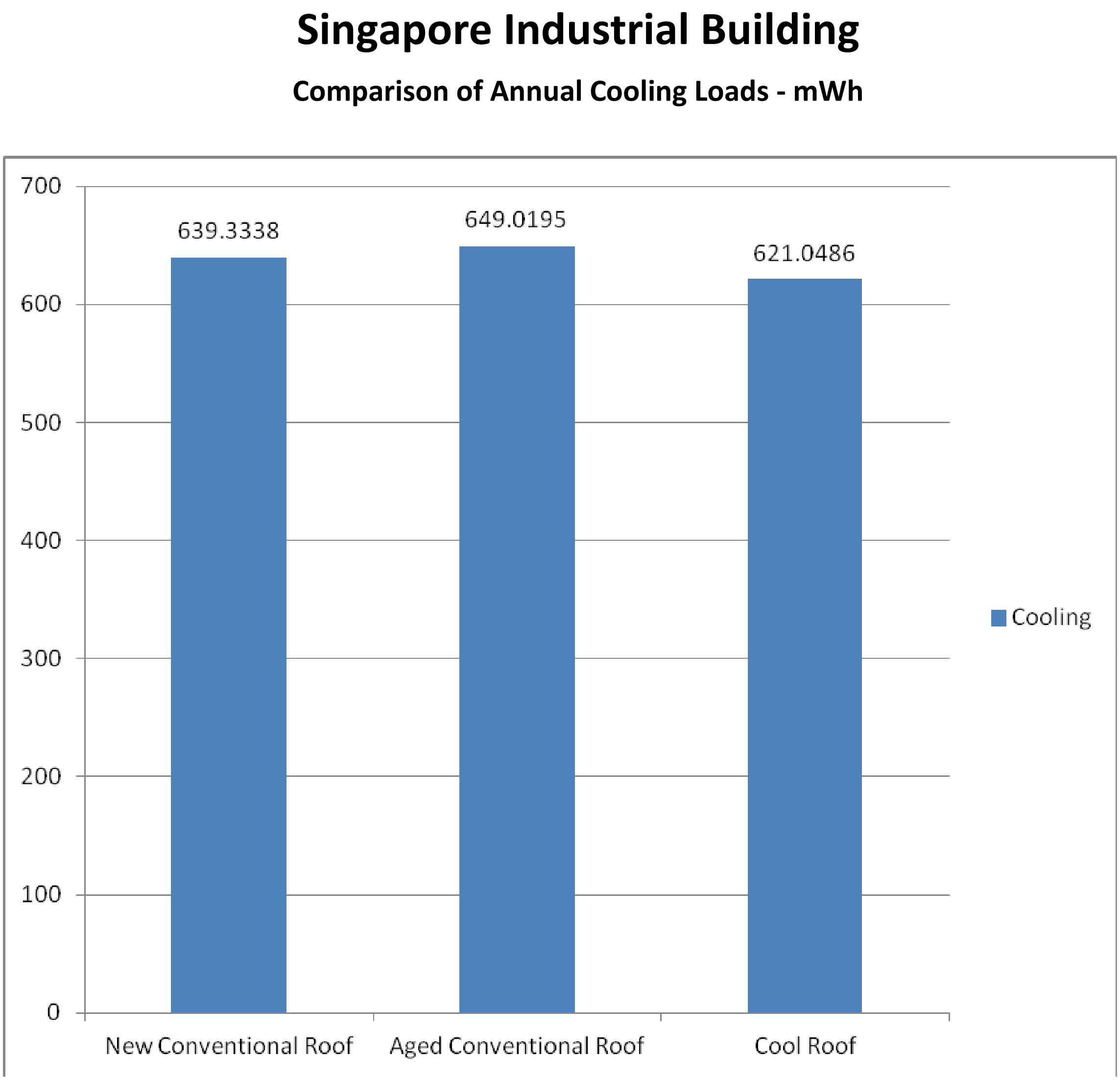

Figure 10.4: Annual Energy Usage for Industrial Building in Singapore (Cooling Only)

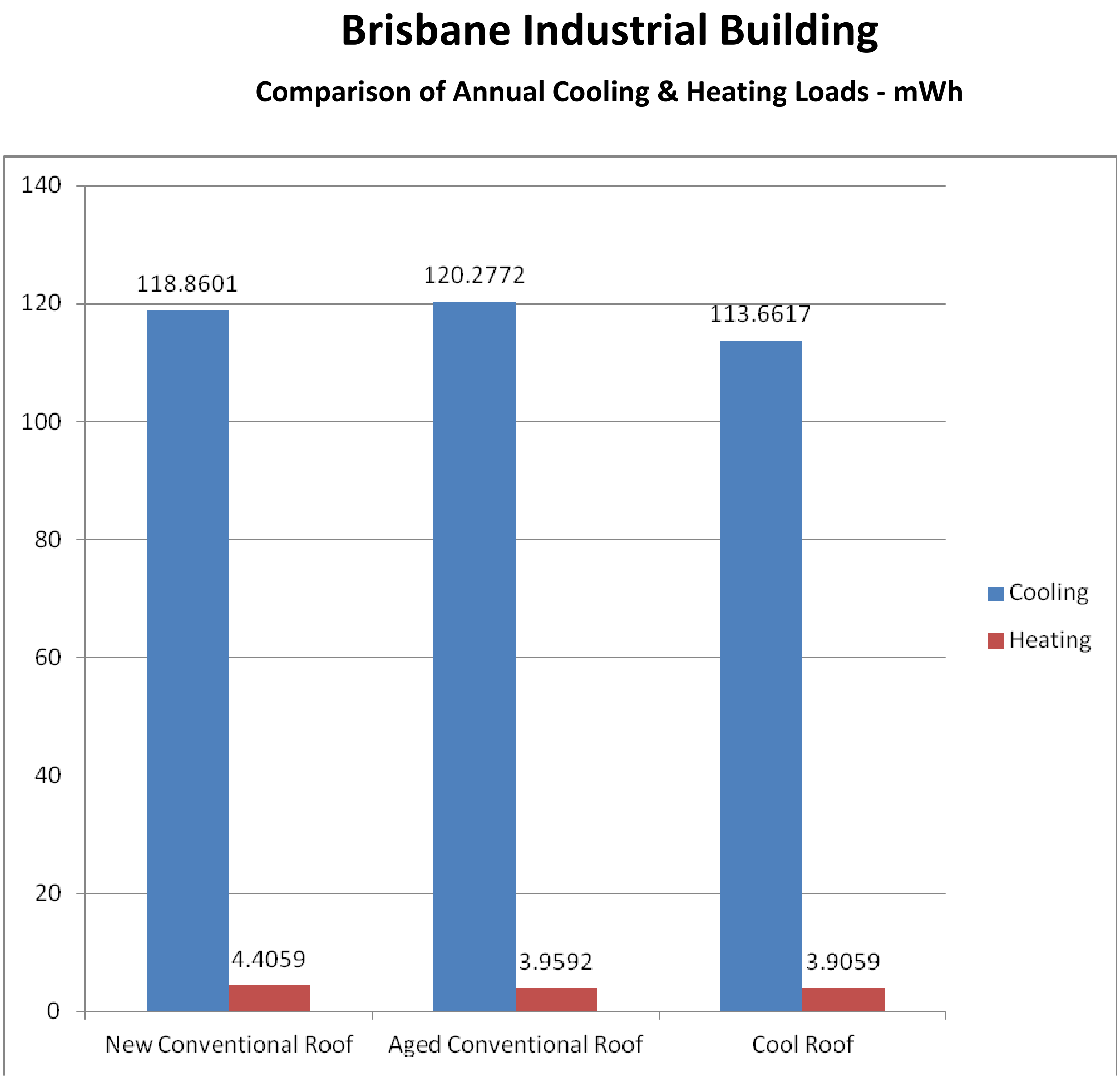

Figure 10.5: Annual Energy Usage for Industrial Building in Brisbane (Cooling & Heating)

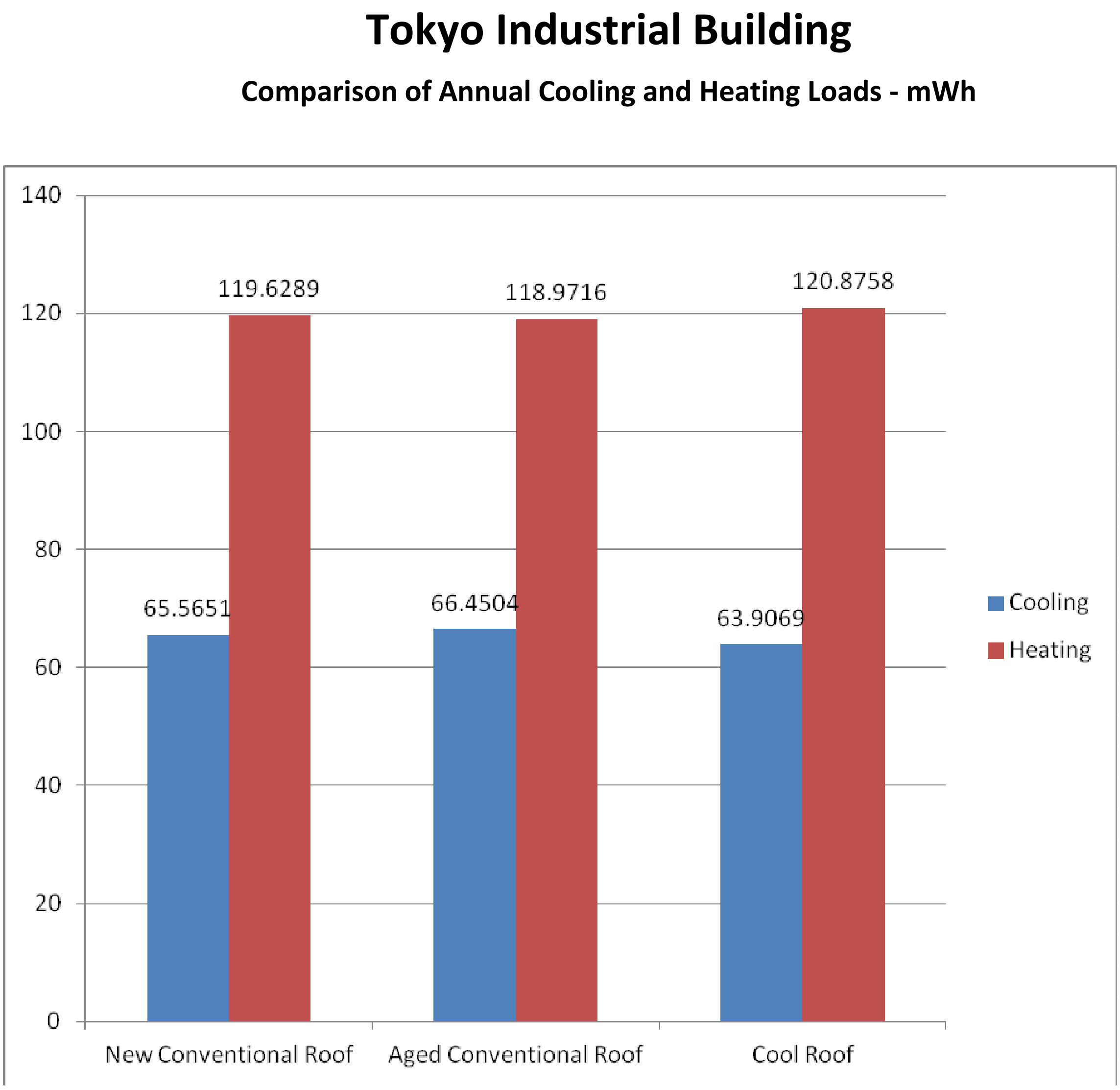

Figure 10.6: Annual Energy Usage for Industrial Building in Tokyo (Cooling & Heating)

A summary of all annual cooling and heating loads, total and average savings are given in Tables 10.2-10.4 below.

Table 10.1 – Building Gross Floor Areas

GFA	m2
Bungalow	206.783
Industrial Building	1897.86

Table 10.2 Summary of Annual Cooling and Heating Loads - mWh

		Loads - mWh					
		Bungalow			Industrial		
		New Conventional Roof (NCR)	Aged Conventional Roof (ACR)	Cool Roof (CR)	New Conventional Roof (NCR)	Aged Conventional Roof (ACR)	Cool Roof (CR)
Singapore	cooling	89.8158	90.4733	88.0442	639.3338	649.0195	621.0486
Tokyo	cooling	2.4396	2.2031	2.3836	65.5651	66.4504	63.9069
	heating	49.1971	49.8904	49.3609	119.6289	118.9716	120.8758
Brisbane	cooling	14.4293	14.411	14.1864	118.8601	120.2772	113.6617
	heating	7.3097	7.3156	7.4003	3.9592	3.9059	4.4059

Table 10.3 – Summary of Annual Cooling and Heating Savings - mWh

		Saving - mWh			
		Bungalow		Industrial	
		NCR-CR	ACR-CR	NCR-CR	ACR -CR
Singapore	cooling	1.7716	2.4291	18.2852	27.9709
Tokyo	cooling	0.056	-0.1805	1.6582	2.5435
	heating	-0.1638	0.5295	-1.2469	-1.9042
Brisbane	cooling	0.2429	0.2246	5.1984	6.6155
	heating	-0.0906	-0.0847	-0.4467	-0.5

Table 10.4 – Average Annual Savings per m^2 – **N.B. Figures are in kWh**

		Average Annual Figures				
		Average - kWh		Average - kWh/m2		Average Total - kWh/m2
		Bungalow	Industrial	Bungalow	Industrial	
Singapore		2100.35	23128.05	10.15727	12.18638	11.17182496
Tokyo	cooling	-62.25	2100.85			
	heating	182.85	-1575.55			
	total	60.3	262.65	0.29161	0.138393	0.215001381
Brisbane	cooling	233.75	5906.95			
	heating	-87.65	-473.35			
	total	73.05	2716.8	0.353269	1.431507	0.892387976

For economies with regions in more than one climatic zone, a mean average of the Annual HVAC Load Savings for the climatic zones that make up that economy is taken. For those economies with boreal and/or polar climatic zones, these zones have been disregarded and are not calculated. See Table 11.1 below for economy climatic zones of APEC member economies. For example, Chile has sub-tropical and temperate climatic zones so would use a mean average of the data from Brisbane and Tokyo.

Table 10.5 – Climatic Zone Average Savings

Climatic Averages	
	kWh/m2/year
Tropical	11.17182496
Tropical & Sub-tropical	6.032106469
Tropical, Sub-tropical & Temperate	4.093071439
Sub-tropical	0.892387976
Sub-tropical & Temperate	0.553694678
Temperate	0.215001381

As can be seen from the table above, Cool Roofs are most effective in tropical regions where the average savings per m2 per year are considerable higher than in the sub-tropical and temperate regions. This is unsurprising as there is considerable perennial solar heat gain in tropical environments which is undesired, hence the use of air-conditioning to counteract it. In sub-tropical and temperate regions which experience colder seasons, the heat gain is desirable and offsets the reliance on HVAC systems to heat the buildings. Using Cool Roofs in these regions all but eliminates this heat gain, increasing the heating load during the colder seasons. On an annual basis, this heating penalty drastically reduces any reduction in cooling load achieved during the warmer months.

For the purposes of this study, APEC member economies which contain tropical regions as well as sub-tropical and/or temperate regions benefit on a macro level from the considerable increased savings achievable in the tropical regions, offsetting the minimal savings in the other regions.

11. ENERGY, COST, GREENHOUSE GAS AND AIR QUALITY SAVINGS

11.1. DATA SOURCES AND ASSUMPTIONS

11.1.1. Dense Urban Areas & Roof Areas

The figures for dense urban areas of the APEC member economies were taken from Demographia.com and were selected on the basis of towns with populations of 100,000 persons or above[91].

Where such data was not available, as was the case for Brunei Darussalam and Papua New Guinea, the dense urban areas were calculated as 4% of the total land area (Akbari et al, 2008)[92].

The amount of dense urban area attributable to roofs was calculated at 25% of the respective dense urban area, in accordance with findings by Hashem Akbari of the Heat Island Group at the Lawrence Berkeley National Laboratory, California, wherein he attributed the total average coverage of the metropolitan areas studied as follows (Akbari et al, 2008):

- Vegetation - 29-41%
- Roofs - 19-25%
- Paved surfaces - 29-39%

In accordance with Akbari's own conclusion[93], a reasonable assumption is that a typical urban area is 25% roof.

Taking **Australia** as an example and applying the above premise, the calculations are carried out thus:

	km^2	m^2
Total Area[94]	7,741,220	-
Land Area[9]	7,682,300	-
Dense Urban Area*	9,834	9,834,184,855
Roof Area**	2,458	2,458,546,214

*towns with population >100,000 – from demographia.com
**as 25% of dense urban area

91 http://www.demographia.com/db-worldua.pdf
92 http://www.escholarship.org/uc/item/1bq1r839.pdf
93 http://www.climatechange.ca.gov/events/2008_conference/presentations/2008-09-09/Hashem_Akbari.pdf
94 https://www.cia.gov/library/publications/the-world-factbook/geos/as.html

11.1.2. Annual HVAC Load Savings

The cooling/heating load savings attributable to the roofs are taken as an average of the savings from the modelling simulations and are given in kWh/m^2/year. This is calculated as the difference in energy used to maintain a constant temperature as specified in Table 9.12 above during operational/occupied hours. The energy is in kWh/year which, when divided by the footprint area of the building gives the figure in kWh/m^2/year.

A mean average of the savings between the two scenarios below is calculated:

- New conventional roof vs. New Cool Roof
- Aged conventional roof vs. New Cool Roof

This mean figure (Mean Annual Saving), when multiplied by the estimated Roof Area gives a Total Annual HVAC Load Saving (see Table 11.8 and subject to the application of Building Type and Climatic Zones – see below):

Total Roof Area x (m^2)	Mean Annual Saving (kWh/m^2/year)	=	Total Annual HVAC Load Saving (kWh/year)

11.1.3. Application to Building Types and Climatic Zones

An absolute model for Annual HVAC Load Saving would be based on micro level data concerning the number of new and old buildings and the number of each building type in each location. Such data however was not available. In addition this study is working on national and international macro levels and attributing precise factors is beyond the scope herein. In each case the most reasonable assumption was to take a mean average of the results where applicable.

For each building type in each location a mean average of the scenarios in section 11.1.2 above was taken, giving two potential savings, one for each scenario in each location. A mean average of these figures was then taken to give the average saving for that location.

For economies with regions in more than one climatic zone, a mean average of the Annual HVAC Load Savings for the climatic zones that make up that economy is taken. For those economies with boreal and/or polar climatic zones, these zones have been disregarded and are not calculated. See Table 11.1 below for economy climatic zones of APEC member economies. For example, Chile has sub-tropical and temperate climatic zones so would use a mean average of the data from Brisbane and Tokyo. See Table 10.5 above for Climatic Zone Average Savings.

11.1.4. Cost of Electricity

To find the cost of electricity per kWh, an analysis of each economy's electricity provision was undertaken. In some economies all electricity is provided by one state-owned supplier. In these economies the standard peak domestic tariff was used. If the tariff was tiered, dependant on the amount used, an average of the tiered tariffs was calculated.

In other economies there is one supplier per region or state. In this case, the average of any tiered tariffs was undertaken as above and then the average for the combination of those states calculated.

In some economies consumers are free to choose their supplier from the open market. In those economies, it was attempted to identify the provider with the highest market share and then find an average of their peak domestic tariffs. In the absence of any indication of the highest market share, a provider was chosen at random and the average of their tariffs calculated.

All tariffs were calculated net of tax (see Table 11.9)

Analysis of the electricity market in Australia involved calculating the average of the tiered tariffs in each of the states and the federal territories. This gave an overall average figure for the standard peak domestic tariff of AUD$0.219 per kWh, net of tax

Table 11.1 – APEC Member Economies – Climatic Zones

	Climatic Zone				
APEC Member Economy	**Tropical**	**Sub-Tropical**	**Temperate**	**Boreal**	**Polar**
Australia	X	X	X		
Brunei Darussalam	X				
Canada			X	X	X
Chile		X	X		
People's Republic of China		X	X		
Hong Kong, China					
Indonesia	X				
Japan			X		
Republic of Korea			X		
Malaysia	X				
Mexico		X	X		
New Zealand			X		
Papua New Guinea	X				
Peru	X	X	X		
The Philippines	X				
Russia			X	X	X
Singapore	X				
Chinese Taipei		X			
Thailand					
The United States		X	X	X	X
Viet Nam	X	X			

Legend:	**Tropical**	**Sub-Tropical**	**Temperate**	**Boreal**	**Polar**

.

Using currency conversion factors from xe.com/ucc [95], this equates to USD$0.234 [96] per kWh. Multiplying this figure by the Total Annual HVAC Load Saving gives the Annual Cost Saving for Australia in US Dollars:

Cost of Electricity		Annual HVAC Load Saving		Annual Cost Saving
0.234 USD/kWh	x	10,063,005,290 kWh/year	=	USD$2,296,820,479

On this basis, even though the Annual HVAC Load Saving per roof is minimal, when applied on an APEC member economy level, the savings are not insignificant. See Table 11.9.

11.1.5. Greenhouse Gas Savings

In addition to calculating the potential cost saving, from the amount of electricity saved it is also possible to calculate the potential for reduction in Greenhouse Gas (GHG) emissions.

The energy used to power the HVAC systems has a footprint in terms of carbon emissions. A carbon footprint is a form of carbon calculation that measures the amount of carbon dioxide equivalent that an economy, a business, an industry or an individual produces or is responsible for. The footprint calculates the direct and indirect level of CO_2e emissions. Direct emissions include the burning of fossil fuels for energy and transportation and indirect emissions focus on the whole lifecycle of products from procuring raw materials to waste management[97].

Carbon conversion factors for each APEC member economy[98] were obtained showing the carbon footprint of grid electricity. These conversion factors show the amount of GHG's (expressed as carbon dioxide equivalent, or CO_2e[99]) emitted per unit of grid electricity produced in each location. Multiplying the amount of electricity used by the conversion factor gives the according equivalent amount of CO_2 released into the atmosphere.

The Total Annual HVAC Load Saving for each APEC member economy is multiplied by the respective conversion factor to show the Annual Potential Greenhouse Gas Savings, i.e. the amount of equivalent CO_2 that would have been released into the atmosphere without the savings. See Table 11.10.

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95 Correct as of 27th June 2011 – http://www.xe.com/ucc
96 This figure is rounded to 3 decimal places for clarity. The figure used in the calculation is correct to 8 decimal places.
97 http://www.epa.vic.gov.au/climate-change/glossary.asp#CAM
98 Data for Brunei Darussalam and Papua New Guinea was not readily available and has been extrapolated from other sources. No fuel data was available at all.
99 http://www.defra.gov.uk/publications/files/pb13309-ghg-guidance-0909011.pdf

For example – Australia:

Total Annual HVAC Load Saving	x	Conversion Factor	=	Annual Potential Greenhouse Gas Savings
≡				
10,063,005,290 kWh/year	x	0.794286 $kgCO_2e/kWh$[100]	=	7,992,904,220 $kgCO_2e/year$
			=	**7,992,904 tonnes CO_2e / year**

11.1.6. Carbon Offsetting

Using the GHG data from section 11.1.5 above, an indication can be drawn on the potential saving that can be achieved through the use of Cool Roofs and the subsequent avoidance of these emissions and the necessity to offset them.

A carbon offset is a monetary investment in a project or activity elsewhere that abates greenhouse gas (GHG) emissions or sequesters carbon from the atmosphere that is used to compensate for GHG emissions from your own activities. Offsets can be bought by a business or individual in the voluntary market (or within a trading scheme) and usually represent one tonne of CO_2e [95]. Three examples are drawn of offsetting options:

<u>Voluntary Emission Reductions</u>

Voluntary (or Verified) Emission Reductions (VER's) are a type of carbon offset credit exchanged in the voluntary or over-the-counter (OTC) market for carbon credits and are usually certified through a voluntary certification process. VER's are usually created by projects which have been verified outside of the Kyoto Protocol. One VER is equivalent to 1 tonne of CO2e emissions (tCO_2e). VERs may be developed and calculated in compliance with one of several VER standards which set out rules defining how emission reductions are measured.

The cost of VER's can vary depending on the type of scheme, the verification standard used and the desirability of the credit. For example, a wind farm project in China may only achieve around €7/tCO_2e.[101]

By contrast, a project helping villagers in Cambodia with efficient charcoal stoves may achieve as much as €15/tCO_2e[100]. This is due to the social aspect of the project as investors often feel that having offset credits of this nature in their annual report adds to the company's brand value, making the credit more desirable, hence pushing up the price compared to other projects.

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[100] Conversion rate taken from the Australian Dept of Climate Change & Energy Efficiency National Greenhouse Accounts (NGA) Factors, July 2010: http://www.climatechange.gov.au/~/media/publications/greenhouse-acctg/national-greenhouse-factors-july-2010-pdf.pdf
[101] http://www.firstclimate.com/

Certified Emission Reductions

Certified Emission Reductions (CERs) are a type of carbon offset credits issued by the Clean Development Mechanism (CDM) Executive Board for emission reductions achieved by CDM projects and verified by a Designated Operational Entity (DOE) under the rules of the Kyoto Protocol. CERs are used by Annex 1 countries in order to comply with their emission limitation targets or by operators of installations in order to comply with their obligations. CERs can be held by governmental and private entities on electronic accounts with the UN.

CERs are either long-term or temporary, depending on the likely duration of their benefit and are purchased from the primary market (purchased from original party that makes the reduction) or secondary market (resold from a marketplace). The most advanced trading platform for CER's is the European Union Emissions Trading Scheme (EU-ETS). An up to date 'spot price' for the EU-ETS is available through the website of one of the key trading firms involved in the market, Vertis Finance[101].

Offset Rates

In order to give a broad understanding of the impact of the GHG reductions from Cool Roofs, the potential cost saving for avoiding the need to offset the emissions is compared between the two types of VER mentioned above and the CER market. (For the CER market the EU-ETS spot price as of 24th June 2011 is used[102].)

Rate 1	-	VER example rate	-	€7/tCO_2e	-	USD \$9.92/tCO_2e [103]
Rate 2	-	VER example rate	-	€15/tCO_2e	-	USD \$21.25/tCO_2e
Rate 3	-	EU-ETS spot price	-	€12.05/tCO_2e	-	USD \$17.07/tCO_2e

Multiplying the chosen rate by the Total Annual HVAC Load Saving gives an indication of what would be required to offset the emissions from the energy that would have been consumed had no Cool Roof savings been implemented. This can be done on an APEC member economy specific basis or APEC wide. See Table 11.11.

It should be noted that carbon offset credits are only valid for one year. The aim of carbon management is such that by the time an annual footprint comes to be re-calculated and residual emissions offset, steps should have been taken to reduce emissions during that time, so that if operations have not changed, the amount of residual emissions requiring offset should be less. It is not meant to be viewed as a 'get out of jail free card'. The UK Department of Energy and Climate Change defined carbon neutrality, of which the process of carbon management is a part, thus:

"***Carbon neutral means that – through a transparent process of calculating emissions, reducing those emissions and offsetting residual emissions – net carbon emissions equal zero***"[104]

[102] http://www.vertisfinance.com/ - spot price correct as of 24th June 2011.
[103] Currency conversion correct as of 27th June 2011 – http://www.xe.com/ucc
[104] http://www.decc.gov.uk/en/content/cms/emissions/neutrality/neutrality.aspx

11.1.7. Air Quality

Clean air is considered to be a basic requirement of human health and well-being. However, air pollution continues to pose a significant threat to health worldwide. According to a World Health Organisation (WHO) assessment of the burden of disease due to air pollution[105], more than 2 million premature deaths each year can be attributed to the effects of urban outdoor air pollution and indoor air pollution (caused by the burning of solid fuels). More than half of this disease burden is borne by the populations of developing countries. As such, air pollution, both indoors and outdoors, is a major environmental health problem affecting everyone in developed and developing countries alike.

Impact on Health

The substances contained in air pollutant can enter the body through the respiratory system. The extent of penetration of contaminants into the body depends on the type of pollutant. Large-size particulates can be suspended in the upper respiratory tract, while small-sized particles and gases can reach the lungs. From the lungs, pollutants are absorbed by the circulatory system and spread throughout the body. The common types of health impacts are ARI's (acute respiratory tract infections) which include asthma, bronchitis and other respiratory disorders. Some contaminants are categorized as toxic and carcinogenic.

Impact on Crops

Plants that grow in areas with high pollution levels can be stunted and prone to diseases such as chlorosis, necrosis and black spots. Particulate deposited on plant surfaces can hinder the process of photosynthesis.

Acid Rain

The normal pH of rainwater is 5.6 due to the presence of carbon dioxide (CO_2) in the atmosphere. Other air pollutants such as sulphur dioxide (SO_2) and mono-nitrogen oxides (NO_x) react with water in the atmosphere, lowering the pH of rain water, forming 'acid rain'. Impacts of this include:

- Damage to crops;
- Heavy metals dissolving in soil thus affecting the quality of groundwater and surface water; and
- Corrosive damage to building components.

Greenhouse Effect

The Greenhouse Effect is caused not only by the presence of CO_2 but also chlorofluorocarbons (CFC's), hydrofluorocarbons (HFC's), methane (CH_4), ozone (O_3) and nitrous oxide (N_2O) in the troposphere absorbing solar heat radiation reflected by the earth's surface. As a result the heat is trapped in the troposphere causing the phenomenon known now as global warming. Impacts are well known, but the main issues are:

[105] http://www.who.int/mediacentre/factsheets/fs313/en/

- Thawing of polar ice caps; and
- Regional and global climate change.

Damage to the Ozone Layer

The Ozone Layer lies within the stratosphere at an altitude of approximately 20-35km and is a natural protective function of the Earth: filtering out ultraviolet-B (UV-B) radiation from the sun. The formation as decomposition of ozone molecules (O_3) occurs naturally in the stratosphere. Emissions of CFC's and HFC's reaching the stratosphere alter the rate of decomposition of ozone molecules so that it occurs faster that ozone formation. This leads to holes in the Ozone Layer allowing UV-B rays to pass un-filtered which can cause skin cancer in mammals and diseases in plants.

World Health Organisation (WHO) Guidelines

The WHO 2005 Air Quality Guidelines (AQGs) offer global guidance on reducing the health impacts of air pollution[106]. The guidelines apply worldwide and are based on expert evaluation of current scientific evidence. They recommend revised limits for the concentration of selected air pollutants: particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2 – although this is generalised into mono-nitrogen oxides - NO_x) and sulphur dioxide (SO_2), applicable across all WHO regions.

The WHO AQG's guidelines in terms of mean concentration for pollutants are set out below. In terms of particulate matter (PM), two measurements are used: PM_{10} (particle size between 2.5µm and 10µm) and $PM_{2.5}$ (particle matter of less than 2.5µm). The WHO AQG's recommend that the $PM_{2.5}$ guideline value is used: this study therefore focuses on $PM_{2.5}$, NO_x and SO_2. (Although the WHO AQG's do not mention carbon monoxide (CO), data was available and is therefore included. No data for ozone (O_3) emissions was available – ozone is therefore omitted from this analysis.

Particle Emission Calculation

Using the Annual HVAC Load Saving for each APEC member economy it is possible to calculate the indirect impact of that saving upon the generation of electricity and its associated emissions. Any analysis of the impact of these savings upon the general atmospheric air quality is beyond the remit of this report and is therefore not included.

For each APEC member economy the different sources of fuel for electricity generation were obtained from the CIA World Fact Book[107]. Figures were given as a proportion of the overall annual electricity generated in terawatt-hours per year (tWh/year). The fuels assessed were:

- Coal
- Oil
- Natural Gas
- Nuclear
- Renewable (incl. hydro, geo-thermal, Solar PV, Solar thermal, wind and tidal power)
- Biomass
- Waste

106 http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf
107 https://www.cia.gov/library/publications/the-world-factbook/index.html

Electricity generated from Nuclear and Renewable sources has no direct pollutant emissions in terms of the WHO AQG's[108]. Subsequently these energy sources are excluded from this analysis.

The figures for Australia, for example, show total annual electricity generation to be approximately 258 terawatt hours (tWh). Of this total, 198 tWh was generated using coal as fuel. Table 11.2 below shows the different proportions of fuels in Australia:

Table 11.2 - Composition of Electricity by Resource - Australia

tWh/year							
Coal	**Oil**	**Nat. Gas**	**Nuclear**	**Renewables**	**Biomass**	**Waste**	**Total**
198.0	2.8	39.0	0.0	16.0	2.2	0.0	258

For each type of fuel, emission figures for each of the above pollutants were obtained in terms of kg emitted per mWh of electricity generated[109]. These figures are broken down in Table 11.3 below:

Table 11.3 - Average Emissions from Electricity Generation, by Fuel

	kg/mWh						
	Coal	**Oil**	**Nat. Gas**	**Nuclear**	**Renewables**	**Biomass**	**Waste**
NO_x	2.727	7.773	1.818	0	0	1.205	2.455
SO_2	5.909	0.045	5.455	0	0	0.361	0.364
$PM_{2.5}$	0.290	0	0.058	0	0	0.252	0.037

Using the emission figures above and multiplying by the proportion of fuel, the amount of each pollutant emitted per fuel was calculated in kilotons per terawatt-hour (kt/tWh). **N.B.** the conversion rate for kg/mWh is the same as for kt/tWh (i.e. 1kg/mWh = 1kt/tWh)

108 http://www.nature.com/climate/2008/0810/pdf/climate.2008.99.pdf
109 http://www.seas.columbia.edu/earth/wtert/sofos/Albina_njt_ASMEpaper_final.pdf
http://www.biomassenergycentre.org.uk/portal/page?_pageid=77,109191&_dad=portal&_schema=PORTAL
http://www.biomasscenter.org/resources/fact-sheets/fse-biomass-emissions.html
http://www.theclimateregistry.org/downloads/2011/03/2011-Climate-Registry-Default-Emissions-Factors-Updated-3-21-11.pdf
http://www.poweronsite.org/AppGuide/Chapters/Chap4/4-3_Gas_Turbines.htm
http://www.epa.gov/cleanenergy/energy-and-you/affect/municipal-sw.html
http://www.eea.europa.eu/publications/technical_report_2008_4/at_download/file
http://www.ecmwf.int/research/EU_projects/HALO/pdf/paper_HALO_GEMS_emissions.pdf
http://www.iea.org/techno/essentials3.pdf
http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/5_3_Waste_Incineration.pdf
http://www.naturalgas.org/environment/naturalgas.asp#emission

For example, using Australian data for electricity generated by coal:

198	x	2.727	=	539.95
tWh/year from Coal		ktNO_x emitted/tWh		ktNO_x/year from coal

Applying the average fuel emissions for each pollutant, the total emission values for Australia are shown in Table 11.4 below:

Table 11.4 - Fuel / Pollutant Specific Emissions - Australia

		kt/year							
		Coal	Oil	Nat. Gas	Nuclear	Renewables	Biomass	Waste	Total
NO_x	kt/year	539.95	5.090	30.147	0	0	2.6510	0	**577.83**
SO_2	kt/year	1,169.98	15.274	1.755	0	0	0.7942	0	**1,187.81**
CO	kt/year	194.88	0.157	5.616	0	0	0.5302	0	**201.18**
$PM_{2.5}$	kt/year	57.42	0.161	0.983	0	0	0.000554	0	**58.56**

As can be seen, the total amount of NO_x emitted from electricity generation is **577.83 kt/year**. Any reduction in cooling load from the application of Cool Roof technology would have an indirect impact on the electricity demand. In broad terms this represents a reduction in the carbon dioxide emissions associated with the production of that electricity. In order to quantify this reduction, the Annual HVAC Load Saving is calculated as a proportion of the Total Annual Electricity Production for each APEC member economy. Using Australia as an example again:

The Total Annual Electricity Production for Australia is **258 tWh / year**.

The Total Annual HVAC Load Saving (from the energy modelling) for Australia is **10.06 tWh / year**.

This represents **3.89%** of the Total Annual Electricity Production, being the Total Annual HVAC Load Saving Percentage.

To calculate the reduction in emissions achievable through the implementation of Cool Roof technology and its indirect effect on reducing energy consumption in broad terms, the above figures for fuel/pollutant specific emissions are multiplied by the Total Annual HVAC Load Saving Percentage using the following formula:

Economy Annual NO_x Emissions from Electricity Production	x	Total Economy Annual HVAC Load Saving Percentage	=	Annual Achievable NO_x Emission Reduction

In the case of Australia this would equate to:

577.83	x	3.89%	=	22.48
kt NO_x/year				kt NO_x/year

The implementation of Cool Roof technology could therefore reduce NO_x emissions from electricity production by 22.48 kilotonnes per year. Applying this formula to all of the electricity generation related emissions for Australia gives the following results, as shown in Table 11.5 below:

Table 11.5 – Pollutant Specific Emissions - Australia

	Total Annual Emissions - kt/year	**Total Annual HVAC Load Saving Percentage**	**Annual Achievable Emission Reduction - kt/year**
NO_x	577.83	3.89	**27.79**
SO_2	1187.81	3.89	**46.21**
CO	201.18	3.89	**7.83**
$PM_{2.5}$	58.56	3.89	**2.28**

The same methodology is applied to all APEC member economies – see section 11.2 below[110].

[110] No data was available for Papua New Guinea – this member economy is therefore omitted from the Air Quality analysis

11.2. Estimated Savings

The total savings for the APEC region are shown in the summary table below (Table 11.6). A more detailed table breaking down the figures for each APEC member economy is on the following page.

The following points should be noted:

- The rate per kWh was taken from the standard peak rate for domestic grid electricity from each APEC member economy. This was either taken from the state provider, the provider with the largest market share, or taken as an average of all providers in the market, depending on available data. Rates are correct as of May/June 2011.

- Currency conversion to US Dollars were taken from xe.com/ucc and are correct as of 27th June 2011.

- The data for the potential reduction in air pollutants was estimated from average electrical generation figures for each APEC member economy, fuel emission figures and example plant efficiency rates specific to each economy.

The total savings for the APEC region as a whole are given in Table 11.6 below [111]:

Table 11.6 – Summary of Annual Savings from Cool Roofs for APEC Region

Annual HVAC Load Savings	134,628,570	mWh / year
Annual Cost Saving	$23,200,295,725	USD / year
Potential Reduction In Air Pollutants as a Result of Cool Roof Implementation		
NO_x	134.11	kt/year
SO_2	269.33	kt/year
CO	38.12	kt/year
$PM_{2.5}$	12.25	kt/year
Total GHG Savings per annum	111,383,364	tCO2e / year
CO2 offset costs	€ - Euro	$ - USD
VER @ 7€ / tCO2e	€ 779,683,545	$1,104,382,757
VER @ 15€ / tCO2e	€ 1,670,750,453	$2,366,534,479
EU-ETS @ 12.05€ / tCO2e	€ 1,342,169,530	$1,901,116,031

[111] The currency conversion was taken from xe.com/ucc and correct as of 27th June 2011.
The EU-ETS rate for offsetting CO2 was taken from the spot price and correct as of 24th June 2011.

11.2.1. Land, Dense Urban and Roof Areas

Using data from the CIA World Fact Book and Demographia.com it was possible to estimate the areas for each of the APEC member economies.

The figures for dense urban areas of each of the APEC member economies were selected for towns with populations of 100,000 persons or above. For those economies whose data was not available, the Akbari figure of 4% was applied (Brunei Darussalam and Papua New Guinea), after Akbari et al, 2008[49].

Table 11.7 – APEC Member Economy Dense Urban Areas

APEC Member Economy	total area	land area		dense urban area
Economy	km2	km2	m2	(4% - shaded) otherwise specified / km2
Australia	7,741,220	7,682,300	7,682,300,000,000	9,834
Brunei Darussalam[112]	5,765	5,265	5,265,000,000	211
Canada	9,984,670	9,093,507	9,093,507,000,000	11,929
Chile	756,102	743,812	743,812,000,000	1,246
People's Republic of China	9,596,961	9,569,901	9,569,901,000,000	47,402
Hong Kong, China	1,104	1,054	1,054,000,000	275
Indonesia	1,904,569	1,811,569	1,811,569,000,000	5,592
Japan[113]	377,915	364,485	364,485,000,000	22,862
Republic of Korea	99,720	96,920	96,920,000,000	3,323
Malaysia	329,847	328,657	328,657,000,000	3,600
Mexico	1,964,375	1,943,945	1,943,945,000,000	8,358
New Zealand	267,710	267,710	267,710,000,000	1,062
Papua New Guinea[111]	462,840	452,860	452,860,000,000	18,114
Peru	1,285,216	1,279,996	1,279,996,000,000	932
The Philippines	300,000	298,170	298,170,000,000	1,779
Russia	17,098,242	16,377,742	16,377,742,000,000	15,851
Singapore	722	712	712,000,000	466
Chinese Taipei	35,980	32,260	32,260,000,000	2,318
Thailand	513,120	510,890	510,890,000,000	2,719
The United States	9,826,675	9,161,966	9,161,966,000,000	166,619
Viet Nam	331,210	310,070	310,070,000,000	1,256

[112] Data for Brunei Darussalam and Papua New Guinea was not readily available and has been extrapolated in some cases.
[113] All Japan data is historic and does not take into account consequences of 2011 earthquake and tsunami

11.2.2. Annual HVAC Load Savings

Applying the Average Estimated HVAC Load Savings from the simulations, the Annual HVAC Load Savings for each of the APEC member economies were calculated to be:

Table 11.8 – APEC Member Economy Annual HVAC Load Savings

APEC Member Economy	Annual HVAC Load Savings - mWh / year
Australia	10,063,005
Brunei Darussalam	588,197
Canada	641,214
Chile	172,446
People's Republic of China	6,561,554
Hong Kong, China	61,249
Indonesia	15,617,609
Japan	1,228,831
Republic of Korea	178,610
Malaysia	10,054,876
Mexico	1,156,930
New Zealand	57,077
Papua New Guinea	50,592,727
Peru	954,091
The Philippines	4,969,568
Russia	851,982
Singapore	1,302,070
Chinese Taipei	517,148
Thailand	4,101,060
The United States	23,064,029
Viet Nam	1,894,299
TOTAL	134,628,570

11.2.3. Annual Cost Savings

The standard domestic peak rate for grid electricity was calculated for each of the APEC member economies in accordance with the assumptions above. This was then converted into US Dollars using rates from xe.com/ucc correct as of 27th June 2011.

Using this data, the potential Annual Cost Savings from the implementation of Cool Roofs is as follows:

Table 11.9 – APEC Member Economy Annual Cost Saving

APEC Member Economy	Cost of Electricity – USD/kWh[114]	Annual Cost Saving - USD / year[115]
Australia	0.23	2,296,820,479
Brunei Darussalam	0.11	65,093,473
Canada	0.10	65,064,346
Chile	0.25	43,617,517
People's Republic of China	0.15	1,012,775,795
Hong Kong, China	0.14	8,855,995
Indonesia	0.05	728,175,889
Japan	0.24	298,359,603
Republic of Korea	0.25	44,678,567
Malaysia	0.10	957,395,347
Mexico	0.11	125,924,098
New Zealand	0.17	9,983,257
Papua New Guinea	0.26	13,052,112,947
Peru	0.10	99,249,058
The Philippines	0.29	1,422,105,779
Russia	0.13	109,599,821
Singapore	0.17	224,483,740
Chinese Taipei	0.12	61,406,488
Thailand	0.07	282,710,706
The United States	0.09	2,140,341,922
Viet Nam	0.08	151,540,897
TOTAL		**$23,200,295,725**

[114] Standard average peak rate for domestic grid electricity - May 2011 (figures are net) - P.R.China figure taken from Sichuan Province as an example rate
[115] Currency conversions taken from xe.com/ucc and correct as of 27-6-11

11.2.4. Greenhouse Gas Savings

Emission factors for the grid electricity of each APEC member economy were obtained and applied to the data. This gave the potential Greenhouse Gas Savings that could be achieved with the implementation of Cool Roofs.

Not all countries had immediately obtainable data and in the case of Papua New Guinea had to be extrapolated from other sources.

Table 11.10 – APEC Member Economy Greenhouse Gas Savings

APEC Member Economy	Economy specific CO_2e emission for grid electricity		Greenhouse Gas Savings per annum
Economy	$kgCO_2e$ / kWh	$kgCO_2e$ / mWh	tCO_2e / year
Australia	0.794	794	7,992,904
Brunei Darussalam	0.755	755	444,088
Canada	0.302	302	193,490
Chile	0.412	412	71,048
People's Republic of China	0.745	745	4,888,357
Hong Kong, China	0.757	757	46,365
Indonesia	0.726	726	11,338,384
Japan	0.436	436	535,770
Republic of Korea	0.459	459	81,982
Malaysia	0.656	656	6,595,998
Mexico	0.550	550	636,427
New Zealand	0.214	214	12,215
Papua New Guinea	1.145[116]	1145	57,923,509
Peru	0.225	225	214,670
The Philippines	0.487	487	2,420,180
Russia	0.564	564	480,518
Singapore	0.476	476	619,916
Chinese Taipei	0.650	650	336,146
Thailand	0.529	529	2,169,461
The United States	0.590	590	13,599,590
Viet Nam	0.413	413	782,345
	Total tCO_2e / year	TOTAL	**111,383,364**

[116] Data for Papua New Guinea was not readily available and has been extrapolated. No fuel data was available at all.

11.2.5. Carbon Offset Abatement

Using the example rates as specified in section 11.1.6, the avoided cost of offsetting the CO_2 emissions saved by the implementation of Cool Roofs are as follows:

Table 11.11 – APEC Member Economy Carbon Offset Abatement

APEC member economy	Carbon Offset					
Economy	VER Example Rate 1 - Offset at €7 / tonne CO_2e	VER Example Rate 2 - Offset at €15 / tonne CO_2e	EU-ETS Spot Price*- €12.05 / tonne CO2e	Rate 1 - in USD**	Rate 2 - in USD	EU-ETS spot price - in USD
Australia	55,950,330	119,893,563	96,314,496	79,250,844	169,823,238	136,424,668
Brunei Darussalam	3,108,619	6,661,326	5,351,265	4,403,203	9,435,436	7,579,800
Canada	1,354,427	2,902,343	2,331,549	1,918,478	4,111,023	3,302,522
Chile	497,334	1,065,716	856,126	704,449	1,509,534	1,212,659
People's Republic of China	34,218,502	73,325,361	58,904,707	48,468,797	103,861,708	83,435,572
Hong Kong, China	324,557	695,480	558,702	459,719	985,112	791,374
Indonesia	79,368,689	170,075,761	136,627,528	112,421,779	240,903,812	193,526,062
Japan	3,750,392	8,036,555	6,456,032	5,312,243	11,383,378	9,144,647
Republic of Korea	573,874	1,229,730	987,883	812,864	1,741,851	1,399,287
Malaysia	46,171,989	98,939,976	79,481,781	65,400,313	140,143,529	112,581,968
Mexico	4,454,990	9,546,408	7,668,948	6,310,271	13,522,010	10,862,681
New Zealand	85,502	183,218	147,185	121,109	259,519	208,480
Papua New Guinea	405,464,565	868,852,640	697,978,288	574,320,284	1,230,686,322	988,651,345
Peru	1,502,693	3,220,056	2,586,778	2,128,489	4,561,048	3,664,042
The Philippines	16,941,257	36,302,694	29,163,164	23,996,444	51,420,951	41,308,164
Russia	3,363,625	7,207,768	5,790,240	4,764,407	10,209,443	8,201,586
Singapore	4,339,409	9,298,734	7,469,983	6,146,556	13,171,192	10,580,858
Chinese Taipei	2,353,022	5,042,189	4,050,559	3,332,937	7,142,009	5,737,414
Thailand	15,186,224	32,541,908	26,141,999	21,510,526	46,093,985	37,028,835
The United States	95,197,127	203,993,844	163,875,054	134,841,971	288,947,080	232,120,821
Viet Nam	5,476,418	11,735,182	9,427,263	7,757,073	16,622,298	13,353,246
	Rate 1 - 7€/tCO2e	Rate 2 - 15€/tCO2e	Rate 3 - 12.05€/tCO2e	Rate 1 in USD	Rate 2 in USD	Rate 3 in USD
Total	**€ 779,683,545**	**€ 1,670,750,453**	**€ 1,342,169,530**	**$1,104,382,757**	**$2,366,534,479**	**$1,901,116,031**

*EU-ETS spot price as at 24-6-11

**Euro/USD rate from xe.com/ucc and correct as of 27-6-11

11.2.6. Air Pollutant Reductions

Using the calculations specified in 4.4 above, the reduction in air pollutants for each APEC member economy has been calculated. Each stage of the process is shown in Table 11.12-11.17 below:

Table 11.12 - Composition of Electricity Generation by Fuel/Resource per APEC Member Economy[106]

APEC Member Economy	Composition of Electricity by Resource* - tWh/year							
Economy	CL	OL	GS	NC	RW	BM	WS	TOTAL
Australia	198.0	2.8	39.0	0.0	16.0	2.2	0.0	258.0
Brunei Darussalam	0.0	4.8	11.5	0.0	0.0	0.2	0.0	16.5
Canada	112.0	9.8	41.0	94.0	386.0	8.3	0.2	651.3
Chile	49.5	110.2	56.3	0.0	14.2	47.1	0.0	277.3
People's Republic of China	2733.0	23.0	31.0	68.0	598.0	2.4	0.0	3455.4
Hong Kong, China	45.7	0.0	27.8	0.0	0.0	0.6	0.0	74.1
Indonesia	61.0	43.0	25.0	0.0	20.0	0.0	0.0	149.0
Japan[117]	288.0	139.0	283.0	258.0	91.0	15.0	7.3	1081.3
Republic of Korea	192.0	15.0	81.0	151.0	6.3	0.5	0.2	446.0
Malaysia	9.3	247.1	192.9	0.0	7.5	28.7	0.0	485.5
Mexico	21.0	49.0	131.0	9.8	47.0	0.8	0.0	258.6
New Zealand	12.6	66.9	55.9	0.0	54.1	10.2	0.0	199.6
Papua New Guinea	DATA UNAVAILABLE							
Peru	4.7	71.0	7.5	0.0	14.5	51.3	0.0	149.0
The Philippines	16.0	4.9	20.0	0.0	21.0	0.0	0.0	61.9
Russia	197.0	16.0	495.0	163.0	167.0	0.0	2.5	1040.5
Singapore	0.0	527.1	16.5	0.0	0.0	0.0	0.0	543.7
Chinese Taipei	125.0	14.0	46.0	41.0	8.4	0.5	3.0	237.9
Thailand	32.0	1.7	102.0	0.0	7.1	4.8	0.0	147.6
The United States	2133.0	58.0	911.0	838.0	357.0	50.0	23.0	4370.0
Viet Nam	15.0	1.6	30.0	0.0	26.0	0.0	0.0	72.6
								13975.8 tWh/year

*Key:

CL - Coal
OL - Oil
GS - Natural Gas
NC - Nuclear
RW - Renewable
BM - Biomass
WS - Waste

[117] Figures as of 2008 - do not take into account consequences of 2011 Japan earthquake and tsunami

11.2.7. Fuel Specific Oxides of Nitrogen Emissions per APEC Member Economy

Table 11.13 - Fuel Specific NO_x Emissions per APEC Member Economy

APEC member economy	Oxides of Nitrogen emissions from electricity generation* - kt/year					
Economy	CL	OL	GS	BM	WS	TOTAL
Australia	539.95	5.09	30.15	2.65	0.00	577.83
Brunei Darussalam	0.00	8.71	8.86	0.25	0.00	17.82
Canada	305.42	17.82	31.69	10.00	0.49	365.43
Chile	134.95	200.42	43.55	56.72	0.00	435.63
People's Republic of China	7,452.89	41.81	23.96	2.89	0.00	7,521.56
Hong Kong, China	124.70	0.00	21.48	0.67	0.00	146.85
Indonesia	166.35	78.17	19.33	0.00	0.00	263.85
Japan[116]	785.38	252.70	218.76	18.08	17.92	1,292.83
Republic of Korea	523.58	27.27	62.61	0.60	0.49	614.56
Malaysia	25.40	449.25	149.08	34.61	0.00	658.35
Mexico	57.27	89.08	101.26	0.96	0.00	248.58
New Zealand	34.28	121.57	43.22	12.28	0.00	211.36
Papua New Guinea	DATA UNAVAILABLE					
Peru	12.69	129.14	5.82	61.79	0.00	209.43
The Philippines	43.63	8.91	15.46	0.00	0.00	68.00
Russia	537.22	29.09	382.64	0.00	6.14	955.08
Singapore	0.00	958.30	12.79	0.00	0.00	971.09
Chinese Taipei	340.88	25.45	35.56	0.60	7.36	409.85
Thailand	87.26	3.09	78.85	5.78	0.00	174.98
The United States	5,816.69	105.44	704.20	60.25	56.45	6,743.04
Viet Nam	40.91	2.91	23.19	0.00	0.00	67.00
						21,953.13
						kt/tWh

*Key:

CL - Coal
OL - Oil
GS - Natural Gas
NC - Nuclear
RW - Renewable
BM - Biomass
WS - Waste

11.2.8. Fuel Specific Sulphur Dioxide Emissions per APEC Member Economy

Table 11.14 - Fuel Specific SO_2 Emissions per APEC Member Economy

APEC member economy	Sulphur Dioxide emissions from electricity generation* - kt/year					
Economy	CL	OL	GS	BM	WS	TOTAL
Australia	1,169.98	15.27	1.76	0.79	0.00	1,187.81
Brunei Darussalam	0.00	26.14	0.52	0.08	0.00	26.73
Canada	661.81	53.46	1.85	3.00	0.07	720.18
Chile	292.41	601.36	2.54	16.99	0.00	913.30
People's Republic of China	16,149.30	125.47	1.40	0.87	0.00	16,277.02
Hong Kong, China	270.21	0.00	1.25	0.20	0.00	271.67
Indonesia	360.45	234.57	1.13	0.00	0.00	596.14
Japan[116]	1,701.79	758.25	12.74	5.42	2.65	2,480.84
Republic of Korea	1,134.53	81.83	3.65	0.18	0.07	1,220.25
Malaysia	55.05	1,348.01	8.68	10.37	0.00	1,422.10
Mexico	124.09	267.30	5.90	0.29	0.00	397.57
New Zealand	74.29	364.79	2.52	3.68	0.00	445.27
Papua New Guinea	DATA UNAVAILABLE					
Peru	27.49	387.50	0.34	18.51	0.00	433.84
The Philippines	94.54	26.73	0.90	0.00	0.00	122.17
Russia	1,164.07	87.28	22.28	0.00	0.91	1,274.54
Singapore	0.00	2,875.43	0.74	0.00	0.00	2,876.17
Chinese Taipei	738.63	76.37	2.07	0.18	1.09	818.34
Thailand	189.09	9.27	4.59	1.73	0.00	204.68
The United States	12,603.90	316.39	41.00	18.05	8.36	12,987.70
Viet Nam	88.64	8.73	1.35	0.00	0.00	98.71
						44,775.03
						kt/tWh

*Key:

CL - Coal
OL - Oil
GS - Natural Gas
NC - Nuclear
RW - Renewable
BM - Biomass
WS - Waste

11.2.9. Fuel Specific Carbon Monoxide Emissions per APEC Member Economy

Table 11.15 - Fuel Specific CO Emissions per APEC Member Economy

APEC member economy	Carbon Monoxide emissions from electricity generation* - kt/tWh					
Economy	CL	OL	GS	BM	WS	TOTAL
Australia	194.88	0.16	5.62	0.53	0.00	201.18
Brunei Darussalam	0.00	0.27	1.65	0.05	0.00	1.97
Canada	110.23	0.55	5.90	2.00	0.12	118.81
Chile	48.70	6.17	8.11	11.34	0.00	74.33
People's Republic of China	2,689.87	1.29	4.46	0.58	0.00	2,696.20
Hong Kong, China	45.01	0.00	4.00	0.13	0.00	49.14
Indonesia	60.04	2.41	3.60	0.00	0.00	66.05
Japan[116]	283.45	7.78	40.75	3.62	4.46	340.07
Republic of Korea	188.97	0.84	11.66	0.12	0.12	201.72
Malaysia	9.17	13.84	27.77	6.92	0.00	57.70
Mexico	20.67	2.74	18.86	0.19	0.00	42.47
New Zealand	12.37	3.74	8.05	2.46	0.00	26.63
Papua New Guinea	DATA UNAVAILABLE					
Peru	4.58	3.98	1.08	12.36	0.00	22.00
The Philippines	15.75	0.27	2.88	0.00	0.00	18.90
Russia	193.89	0.90	71.28	0.00	1.53	267.59
Singapore	0.00	29.52	2.38	0.00	0.00	31.90
Chinese Taipei	123.03	0.78	6.62	0.12	1.83	132.39
Thailand	31.49	0.10	14.69	1.16	0.00	47.43
The United States	2,099.34	3.25	131.18	12.05	14.06	2,259.87
Viet Nam	14.76	0.09	4.32	0.00	0.00	19.17
						6,675.52 kt/tWh

*Key:

CL - Coal
OL - Oil
GS - Natural Gas
NC - Nuclear
RW - Renewable
BM - Biomass
WS - Waste

11.2.10. Fuel Specific Particulate Matter $_{2.5}$ Emissions per APEC Member Economy

Table 11.16 - Fuel Specific $PM_{2.5}$ Emissions per APEC Member Economy

APEC member economy	$PM_{2.5}$ emissions from electricity generation* - kt/year					
Economy	**CL**	**OL**	**GS**	**BM**	**WS**	**TOTAL**
Australia	57.42	0.161	0.983	0.000554	0.000	58.56
Brunei Darussalam	0.00	0.276	0.289	0.000053	0.000	0.56
Canada	32.48	0.564	1.033	0.002092	0.007	34.09
Chile	14.35	6.349	1.420	0.011861	0.000	22.13
People's Republic of China	792.57	157.407	0.781	0.000605	0.000	950.76
Hong Kong, China	13.26	0.000	0.700	0.000141	0.000	13.96
Indonesia	17.69	2.477	0.630	0.000000	0.000	20.80
Japan[116]	83.52	8.006	7.132	0.003780	0.270	98.93
Republic of Korea	55.68	11.058	2.041	0.000126	0.007	68.79
Malaysia	2.70	14.233	4.860	0.007239	0.000	21.80
Mexico	6.09	2.822	3.301	0.000202	0.000	12.21
New Zealand	3.65	3.852	1.409	0.002567	0.000	8.91
Papua New Guinea	**DATA UNAVAILABLE**					
Peru	1.35	0.268	0.190	0.012922	0.000	1.82
The Philippines	4.64	0.922	0.504	0.000000	0.000	6.07
Russia	57.13	11.346	12.474	0.000000	0.093	81.04
Singapore	0.00	0.000	0.417	0.000000	0.000	0.42
Chinese Taipei	36.25	0.806	1.159	0.000126	0.111	38.33
Thailand	9.28	1.843	2.570	0.001210	0.000	13.69
The United States	618.57	122.850	22.957	0.012600	0.851	765.24
Viet Nam	4.35	0.864	0.756	0.000000	0.000	5.97
						2,224.08
						kt/tWh

*Key:

CL - Coal
OL - Oil
GS - Natural Gas
NC - Nuclear
RW - Renewable
BM - Biomass
WS - Waste

11.2.11. APEC Total Pollutant Specific Emissions

Table 11.17 - Total Pollutant Specific Emissions per APEC Member Economy

APEC Member Economy	Total Emissions Per Economy - kt/year			
Economy	**NO_x**	**SO_2**	**CO**	**$PM_{2.5}$**
Australia	577.83	1,187.81	201.18	58.56
Brunei Darussalam	17.82	26.73	1.97	0.56
Canada	365.43	720.18	118.81	34.09
Chile	435.63	913.30	74.33	22.13
People's Republic of China	7,521.56	16,277.02	2,696.20	950.76
Hong Kong, China	146.85	271.67	49.14	13.96
Indonesia	263.85	596.14	66.05	20.80
Japan	1,292.83	2,480.84	340.07	98.93
Republic of Korea	614.56	1,220.25	201.72	68.79
Malaysia	658.35	1,422.10	57.70	21.80
Mexico	248.58	397.57	42.47	12.21
New Zealand	211.36	445.27	26.63	8.91
Papua New Guinea	**DATA UNAVAILABLE**			
Peru	209.43	433.84	22.00	1.82
The Philippines	68.00	122.17	18.90	6.07
Russia	955.08	1,274.54	267.59	81.04
Singapore	971.09	2,876.17	31.90	0.42
Chinese Taipei	409.85	818.34	132.39	38.33
Thailand	174.98	204.68	47.43	13.69
The United States	6,743.04	12,987.70	2,259.87	765.24
Viet Nam	67.00	98.71	19.17	5.97
Total APEC Region	**21,953.13**	**44,775.03**	**6,675.52**	**2224.08**
	kt/year			

11.2.12. APEC Annual HVAC Load Savings & Percentage

Table 11.18 – Total Annual HVAC Load Saving Percentage per APEC Member Economy

APEC member economy	Total Annual Energy Production [106]	Total Economy Annual HVAC Load Savings	As fraction of total production - Total Annual HVAC Load Saving Percentage
Economy	**tWh/year**	**tWh/year**	**%**
Australia	258.0	10.063	3.900
Brunei Darussalam	16.5	0.588	3.574
Canada	651.3	0.641	0.098
Chile	277.3	0.172	0.062
People's Republic of China	3,455.40	6.562	0.190
Hong Kong, China	74.1	0.061	0.083
Indonesia	149.0	15.618	10.482
Japan[116]	1081.3	1.229	0.114
Republic of Korea	446.00	0.179	0.040
Malaysia	485.5	10.055	2.071
Mexico	258.6	1.157	0.447
New Zealand	199.6	0.057	0.029
Papua New Guinea	**DATA UNAVAILABLE**		
Peru	149.04	0.954	0.640
The Philippines	61.90	4.970	8.028
Russia	1,040.50	0.852	0.082
Singapore	543.67	1.302	0.239
Chinese Taipei	237.9	0.517	0.217
Thailand	147.60	4.101	2.778
The United States	4,370.00	23.064	0.528
Viet Nam	72.60	1.894	2.609
TOTAL	**13975.839**	**84.036**	**0.601**

11.2.13. APEC Air Pollution Reduction

Table 11.19 - Total Potential Air Pollutant Reduction per APEC Member Economy

APEC member economy	Potential Reduction In Air Pollutants as a Result of Cool Roof Implementation - kt/year			
Economy	**NOx**	**SO2**	**CO**	**$PM_{2.5}$**
Australia	22.54	46.33	7.85	2.28
Brunei Darussalam	0.64	0.96	0.07	0.02
Canada	0.36	0.71	0.12	0.03
Chile	0.27	0.57	0.05	0.01
People's Republic of China	14.28	30.91	5.12	1.81
Hong Kong, China	0.12	0.22	0.04	0.01
Indonesia	27.66	62.49	6.92	2.18
Japan[116]	1.47	2.82	0.39	0.11
Republic of Korea	0.25	0.49	0.08	0.03
Malaysia	13.63	29.45	1.19	0.45
Mexico	1.11	1.78	0.19	0.05
New Zealand	0.06	0.13	0.01	0.00
Papua New Guinea	**DATA UNAVAILABLE**			
Peru	1.34	2.78	0.14	0.01
The Philippines	5.46	9.81	1.52	0.49
Russia	0.78	1.04	0.22	0.07
Singapore	2.33	6.89	0.08	0.00
Chinese Taipei	0.89	1.78	0.29	0.08
Thailand	4.86	5.69	1.32	0.38
The United States	35.59	68.55	11.93	4.04
Viet Nam	1.75	2.58	0.50	0.16
Total APEC Region	**135.38**	**275.95**	**38.01**	**12.22**
	kt/year			

12. SURVEY OF GLOBAL COOL ROOF PRACTICES

12.1. EXPERT PANEL

As part of the deliverables of this study, a network of international experts in the Cool Roof industry was identified and compiled.

The objective of developing this expert panel is to build a network of expertise in various sectors to facilitate the implementation of Cool Roofs across APEC developing economies. For Cool Roofs to be implemented successfully across APEC developing economies, there needs to be a strong coherence and consensus between policy makers, industry and the research community.
The expert panel will thus comprise of three groups:

1. **Technical experts -** This group will consists of individuals or organisations who are associated with research into the performance of Cool Roofs. They will comprise primarily of academic researchers and industry consultants with an established record in carrying out simulation, testing and research on the benefits of Cool Roof technologies.

2. **Product experts -** This group comprises experts in development and application of Cool Roof products, consisting mainly of manufacturers and industry partners. They will be experienced in the practical aspects of Cool Roof, with knowledge of material sourcing, supply chain, economics and application opportunities/constraints.

3. **Policy experts -** Policy experts will comprise policy, government officials with an in depth knowledge of policy development and decision making, particularly in the energy efficiency sector. They will essentially provide experience in formulating policies which can build capacity in the region as well as encourage implementation of Cool Roofs across APEC.

4. **National Green Building Councils -** This group is the Green Building Councils from all APEC member economies where such councils (or equivalents) exist.

The expert panel will be primarily derived from, but not limited to APEC member economies. It is considered valuable to include other international experts who may be able to contribute to the expert panel. The expert panel will also distinguish between those that are based in APEC economies and those who are based in other regions.

12.1.1. Technical Experts

The technical expert panel will provide expertise in the science of Cool Roofs. Research and publications in Cool Roofs exist internationally and there are a number of academic institutions with extensive research experience in Cool Roofs.

United States

In the United States, there has been significant research carried out in Cool Roofs. Along with the establishment of the Cool Roof Rating Council, there has been a commitment at state and federal level to fund a number of research studies into Cool Roofs. The most established research institutions are as follows:

Lawrence Berkeley National Laboratory is considered one of the leading institutes in Cool Roof research studies. They have published widely in Cool Roof research and have one of the most cited list of publications on Cool Roofs. The LBNL Heat Island Group have carried out a large number of experimental and modelling studies evaluating the performance of Cool Roofs. Their main findings conclude that use of Cool Roofs can reduce peak electricity demand, saving between 10-40% of air conditioning expenditure depending on building characteristics and climatic conditions and reduction in the Urban Heat Island (UHI) effect by 1-2℃.

Oakridge National Laboratory is also a key contributor to Cool Roof research in United States. They were responsible for numerous papers on Cool Roofs as well as development of the DOE Cool Roof Calculator.

National Center for Atmospheric Research (NCAR) has also conducted research into the benefits of Cool Roof implementation particularly on the UHI effect and atmospheric implications of Cool Roofs. In a recent publication (Jan 2010) they demonstrated, using computer models, that if all the world's cities were painted white, they are able to reduce temperature in the cities by 0.7℉.

The ***Cool Roof Rating Council (CRRC)*** was created in 1998 primarily to develop standards for Cool Roofs but also to support research and disseminate information to industry.

Europe

Outside the US, there has been some research carried out in Europe, particularly the Mediterranean countries. Some of the more active institutions include ***National and Kapodistrian University of Athens*** and ***Technological Educational Institute of Crete***. Although outside the APEC sphere, these institutions has been actively involved with the establishment of the EU Cool Roof Council and have participated closely with the research and technical work programme.

The recently established ***EU Cool Roof Council*** has been a focal point for Cool Roof experts and stakeholders to collaborate in developing expertise in technology, research, market and policy.

Asia

Japan

Japan is one of the most active researchers of Cool Roofs in Asia. Key academic institutions in Japan include ***Matsuo laboratory (Meiji University***), ***Moriyama laboratory (Kobe university), Kondo Laboratory (Musashi Institute of Technology***. ***University of Tokyo, Department of Architecture*** has also done some studies into the effects and modelling of the UHI effect.

The ***Tokyo Metropolitan Government*** also carries out research and testing on Cool Roof experiments around Tokyo.

Hong Kong

Hong Kong-Department of Land Surveying and Geo informatics, Hong Kong Polytechnic University is also included.

Singapore

National University of Singapore (NUS) Department of Building, School of Design and Environment (Led by Professor Wong Nyuk Hien) has carried out some research into urban heat island. Their recent study on UHI in Singapore has for the first time quantified the energy savings related to increased ameliorating measures such as urban greenery and construction materials.

Nanyang Technological University in Singapore, Division of Thermal and Fluids Engineering are currently researching in the effect of using cool building pavement surfaces in Singapore.

Malaysia

The ***Faculty of Built Environment, University of Malaya, Universiti Kebangsaan*** and also the ***Universiti Teknologi Malaysia*** have carried out some research into UHI effects around Malaysia[118] and are included in the expert panel.

12.1.2. Product Experts

There are a large number of Cool Roof products available internationally. In the US, all Cool Roof products are required to be certified and registered with the Cool Roof Rating Council.

Cool Roof Coatings

Large material/chemical companies have also developed a range of Cool Roof coatings and products that are available internationally. The two most prominent chemical companies are **Akzo Nobel** and **BASF**.

The other main Cool Roof product manufacturer in Asia is **Monier Roof**.

The above companies were contacted to form part of the expert network as well as the following US based companies:

- GAF Materials Corp; and
- The Center for Environmental Innovation in Roofing

[118] http://www.shibaura-it.ac.jp/foreign_students/pdf/seatuc_3rd/01_arch_02.pdf

12.1.3. Policy Experts

The policy expert panel comprises individuals and persons from government departments with particular expertise in understanding the policy development process in the APEC developing economies.

They also comprise the relevant authority within the respective governments who would be involved and responsible for any prospective Cool Roofs initiatives.

Collectively, the panel has expertise in capacity building of energy policies within the region as well as experience with developing and implementing energy policies.

Intergovernmental Agencies

Intergovernmental agencies play an important role in building capacity for energy efficiency by providing research and funding to energy efficiency programmes as well as contributing to policy development. The most important intergovernmental agencies in the Asian region are as follows:

UNEP Sustainable Buildings and Construction Initiative (SBCI) is a division in UN Environment Programme which works to promote sustainability in the building sector. Its goals are to provide a common platform for stakeholder to address sustainability issues in the building sector, through development of tools and strategies and establishing baselines. It has so far not initiated research and programmes into the use of Cool Roofs.

APEC Energy Working Group, as sponsors of this study has a particular interest and expertise in Cool Roof implementation. The Efficiency and Conservation Expert Group have carried out a policy review of energy efficiency in the APEC economies and are well placed to advise on Cool Roof implementation.

The World Bank regards energy efficiency as a key target area in Climate Change and energy work programmes. They have been active in funding energy efficiency programmes in Asia targeting industries as well as buildings projects.

Asian Development Bank (ADB) is also keen drivers of energy efficiency in buildings. Like the World Bank, they have funded numerous energy efficiency projects across Asia. Examples of their projects include supporting implementation of energy efficiency programmes at a national level, such as a grant awarded to Viet Nam. Part of the programme involves formulating and enforcing energy efficiency building code[119].

National Government Agencies

United States - the Department of Environment - Office of Energy Efficiency and Renewable Energy leads the US Government's research, development and deployment efforts in energy efficiency initiatives. Their buildings program finance research such as that carried out in Lawrence

[119] http://www.adb.org/Documents/TARs/VIE/41077-VIE-TAR.pdf

Berkeley National Laboratory into Cool Roofs. The lessons and experience will be useful in developing Cool Roof implementation programmes across APEC.

Singapore - the Building & Construction Authority (BCA), Ministry of National Development (MND) is the leading authority in Singapore concerning energy efficiency in buildings. They are the involved in research into energy use in buildings and administer the Green Mark rating scheme in Singapore.

Malaysia - the Ministry of Energy, Green Technology and Water (MEGTW) and the Ministry of Energy, Communications and Multimedia are the main government bodies supporting energy efficiency initiatives in Malaysia.

Thailand - the Department of Alternative Energy Development and Efficiency (DEDE) is the ministry responsible for developing and implementing building energy efficiency codes and regulations.

Philippines - the Department of Energy is the overall ministry in charge of energy related policies and initiatives. In Philippines, there isn't a particular administrative body specifically looking at energy efficiency in the built environment.

In addition, the various national **Green Building Councils** are also potential agencies with the technical, product and policy capability. Green Building Councils from the following APEC economies were contacted and asked to participate:

- Australia
- Canada
- Chile
- Peoples' Republic of China
- Hong Kong
- Indonesia
- Japan
- Republic of Korea
- Malaysia
- Mexico
- New Zealand
- Peru
- The Philippines
- Russia
- Singapore
- Chinese Taipei
- USA
- Viet Nam
- World Green Building Council

No Green Building Council was found in the following APEC member economies:

- Brunei Darussalam
- Papua New Guinea
- Thailand

12.1.4. Summary of Expert Panel

Internationally, the United States is home to leading experts in Cool Roofs, as a result of the funding and policy initiatives. The establishment of the Cool Roof Rating Council, tax incentives, and regulations in the US both at the federal level and state level have driven Cool Roof research, development and implementation.

Outside the US, the EU region has active research and development programmes. The EU Cool Roof council has recently been established consolidating the various experts in science, research, products and policies.

Cool Roofs are generally in their infancy in Asia with little research or product awareness in the region. However, there are various research institutions across Asia, particularly in Japan who have carried out research into Cool Roofs and Urban Heat Islands.

Key contributors to the Expert Panel include technical and policy experts from the US, in particular their experience with standardisation of measuring Cool Roof performances, development of policy incentives and dissemination of information. Regional experts will be important to provide local context and policy landscape perspective.

Table 12.1 – Cool Roof Expert Network Summary

	Technical Experts	Product Experts	Policy Experts	Green Building Councils
APEC Developed Economies	Lawrence Berkeley National Laboratory (USA)	BASF (Singapore and Asia wide)	Tokyo Metropolitan Government (Japan)	Green Building Council Australia
	Oakridge National Laboratory (USA)	Akzo Nobel (Singapore and Asia wide)	Department of Energy (USA)	Canada Green Building Council
	National Center for Atmospheric Research (USA)	GAF Materials Corp (USA)	Ministry of National Development (Singapore)	Hong Kong Green Building Council
	Cool Roof Rating Council (USA)	Centre for Environmental Innovation in Roofing (USA)	Building & Construction Authority (Singapore)	Professional Green Building Council
	Meiji University (Japan)			Japan Green Building Council
	Moriyama Laboratory (Kobe University - Faculty of Engineering) (Japan)			Korea Sustainable Building Council
	Kondo Laboratory (Musashi Institute of Technology - now Tokyo City University) (Japan)			Green Building Council Russia

	University of Tokyo Dept of Architecture (Japan)			Singapore Green Building Council
	Hong Kong-Department of Land Surveying and Geoinformatics, Hong Kong Polytechnic University (Hong Kong)			Taiwan Green Building Council
	National University of Singapore (NUS) (Singapore)			U.S. Green Building Council
	Nanyang Technological University (Singapore)			
	University of Hiroshima (Japan)			
	NUS - Centre for Remote Imaging, Sensing and Processing (Singapore)			
APEC Developing Economies	University of Malaya (Malaysia)	Monier Roof (Malaysia)	Ministry of Energy, Green Technology and Water (Malaysia)	Chile Green Building Council
	Universiti Kebangsaan (Malaysia)		Department of Alternative Energy Development and Efficiency (Thailand)	China GB
	Universiti Teknologi (Malaysia)		Department of Energy (Philippines)	Green Building Council Indonesia
				Malaysia Green Building Council
				Consejo Mexicano de Edificacion Sustentable (Mexico)
				Consejo Peruano de Construccion Sostenible (Peru)
				Philippine Green Building Council
				Vietnam Green Building Council
Non-APEC	National and Kapodistrian University of Athens			
	EU Cool Roof Council			
	Technological Educational Institute of Crete			
International / Inter-governmental organisations			United Nations Environment Programme	World Green Building Council
			Asian Development Bank	

*Developed and Developing Economies are as defined by the World Bank[120].

[120] http://data.worldbank.org/about/country-classifications/country-and-lending-groups

12.2. SURVEY

12.2.1. Methodology

The objective of this research was to accumulate primary information in order to ascertain views on Cool Roof industry in APEC developing economies.

Research was conducted by self completion through an internet based survey platform.

The questionnaire was initially aired on 11th February 2011 through the URL ***http://www.zapsurvey.com/Survey.aspx?id=d3937d88-445e-4ab9-8a62-5baac4c81384*** and was distributed through a network of experts and APEC participants.

Due to software issues with the original survey internet platform, the survey was moved to a second platform and aired on 4th May 2011 through the URL ***https://www.surveymonkey.com/s/ZHWW778*** and redistributed through the same network of experts and APEC participants.

The questionnaire was closed on Monday 13th June 2011.

Total questionnaires submitted: 290 of which 29 were validated for analysis.

The full survey report (in Appendix C) contains findings at an aggregate level (total sample), as well as tables indicating splits by professional/industrial categories where appropriate.

The first seven questions of the questionnaire were universal. The remaining questions were industry specific, dependent upon the respondents' answer to a previous question regarding the industry they represented. From Question 8 onwards the respondents were divided into the following 8 groups:

- Group 1 – Academics
- Group 2 – Government / Inter-governmental Organisations / Non-governmental Organisations / Trade Associations
- Group 3 – Cool Roof Suppliers / Manufacturers
- Group 4 – Cool Roof Installers
- Group 5 – Building Owners
- Group 6 – Building Tenants
- Group 7 – Consultants (Building Professionals, Architect, Designer, Engineer etc.)
- Group 8 – Other

12.2.2. Sample Profile

Universe

The sample consisted mainly of key experts in the following fields:

- Technical Experts (Academia and Scientific institutions)

- Product Experts
- Policy Experts (Govt authorities, agencies, NGO's etc)

Also included were representatives, associates or stakeholders of the APEC Expert Group on Energy Efficiency and Conservation, as well as other interested individuals.

Questionnaires Submitted

Total questionnaires submitted: 290 of which 29 were validated for analysis.

A full copy of the questionnaire can be found in Appendix D.

Description of the sample:

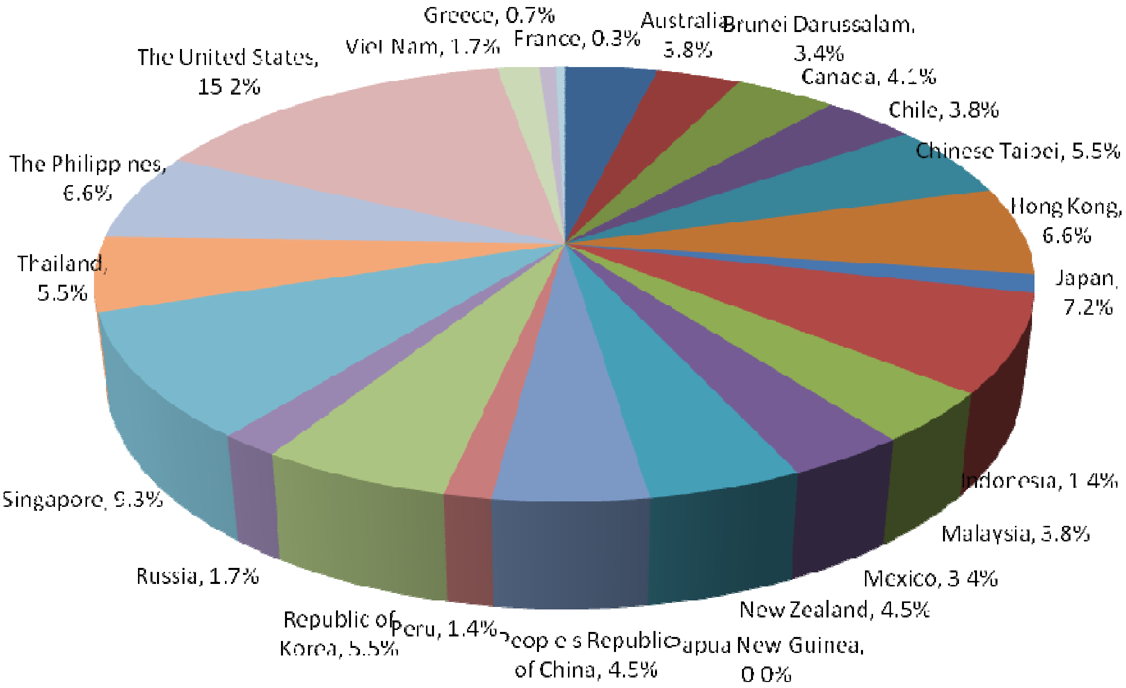
A description of the initial sample by economy is given in Table 12.2 below:

Table 12.2 – Description of Survey Sample by Economy

Economy	Persons Contacted	% of total
Australia	11	3.8%
Brunei Darussalam	10	3.4%
Canada	12	4.1%
Chile	11	3.8%
People's Republic of China	13	4.5%
Hong Kong, China	19	6.6%
Indonesia	4	1.4%
Japan	21	7.2%
Republic of Korea	16	5.5%
Malaysia	11	3.8%
Mexico	10	3.4%
New Zealand	13	4.5%
Papua New Guinea	0	0.0%
Peru	4	1.4%
The Philippines	19	6.6%
Russia	5	1.7%
Singapore	27	9.3%
Chinese Taipei	16	5.5%
Thailand	16	5.5%
The United States	44	15.2%
Viet Nam	5	1.7%
Greece	2	0.7%
France	1	0.3%
Total	**290**	

A graphical representation of the initial sample by economy is given in Figure 12.1 below:

Figure 12.1 – Chart of Survey Sample by Economy



Description of the responses:

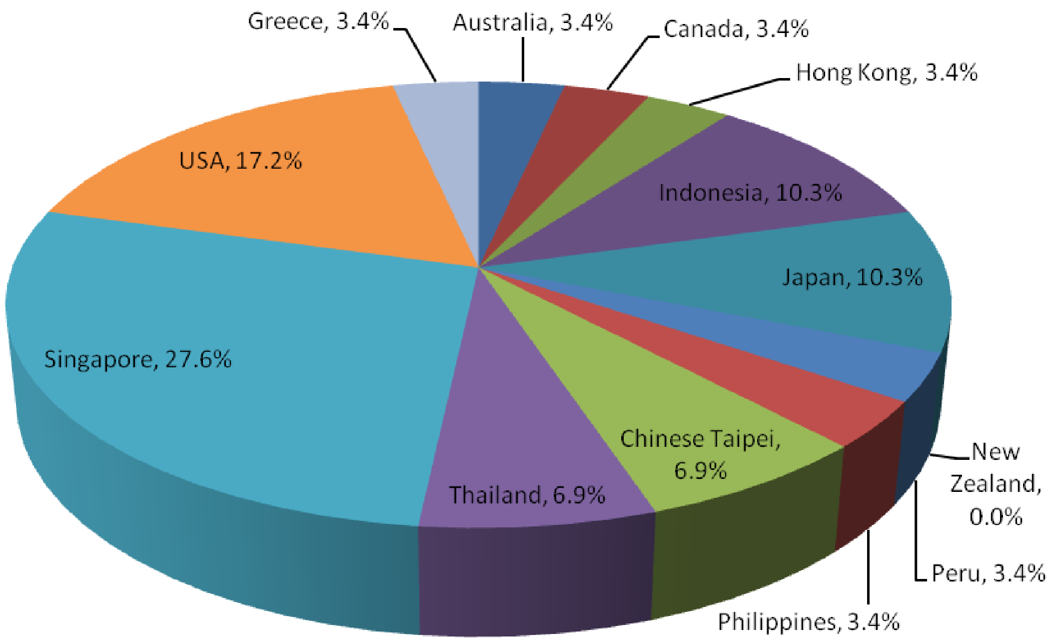
A description of the responses by economy is given in Table 12.3 below:

Table 12.3 – Description of the Responses by Economy

Economy	Responses	% of total
Australia	1	3.4%
Canada	1	3.4%
Hong Kong	1	3.4%
Indonesia	3	10.3%
Japan	3	10.3%
New Zealand	0	0.0%
Peru	1	3.4%
Philippines	1	3.4%
Chinese Taipei	2	6.9%
Thailand	2	6.9%
Singapore	8	27.6%
USA	5	17.2%
Greece	1	3.4%
Total	**29**	

A graphical representation of the responses by economy is given in Figure 12.2 below:

Figure 12.2 – Chart of the Responses by Economy



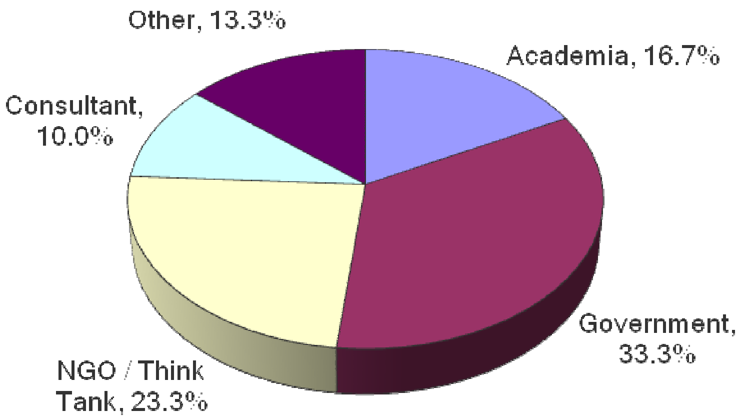
A description of the responses by industry/profession is given in Table 12.4 below:

Table 12.4 - Description of Responses by Industry/Professions

Industry/Professions	Responses	% of total
Academia	5	16.7%
Government	10	33.3%
NGO / Think Tank	7	23.3%
Consultant	3	10.0%
Other	4	13.3%
Inter-governmental Organisation	0	0.0%
Trade Association	0	0.0%
Cool Roof Supplier	0	0.0%
Building Owner	0	0.0%
Building Tenant	0	0.0%
Cool Roof Installer	0	0.0%
Total	**29**	

A graphical representation of the responses by industry/professions is shown in Figure 12.3 below:

Figure 12.3 – Chart of Responses by Industry/Profession



12.3. Results & Analysis

A full analytical report of the survey findings can be found in Appendix C. The main points are summarised here:

Most participants agreed that Cool Roofs play a role as an energy efficiency measure in buildings and had some impact upon reducing energy use.

The main barriers to Cool Roof implementation were thought to be a lack of awareness on the subject, leading to a lack of the skills and expertise necessary, together with little or no regulation or research on the topic. A lack of valid case studies to back up scientific data was also cited, as well as cost-benefit analyses.

In addition, despite a wide variety of products on the CRRC website, it was felt that, certainly in the USA where the predominant domestic roof covering is shingles, there was a lack of product choice in terms of Cool Roof shingles.

The general view was that government initiatives for promoting Cool Roofs are currently lacking and that governments should be doing more in this regard. Lax building energy efficiency standards were cited as one of the main issues in jurisdictions outside of California.

Most felt that promotion through building regulations was the most vital initiative currently lacking. Also cited were a lack of tax incentives/subsidies, research/case studies and modelling/calculation tools.

The establishment of Cool Roof Councils was for the most part not seen as a key ingredient by most respondents, the success of the CRRC notwithstanding – many respondents felt that other matters were more of a priority and might be more effective, such as requirements for Cool Roof standards through building regulations and codes.

Most felt that on the whole, the main responsibility for encouraging implementation of Cool Roofs in the various economies should rest with the Building Industries and Governments in each respective economy. However, all respondents felt that each stakeholder should take some form of responsibility and that it was not solely industry and government who were the drivers. There was also a call for architects and speciality consultants to take a key role in promoting the use of Cool Roof to clients.

In order to further promote Cool Roofs on a global scale, it was suggested that the establishment of a worldwide information exchange would help to build reliable product standards.

The recent earthquake in Japan has left the Government in a position where it is ready to introduce an incentive program to promote Cool Roofs, both through necessity in terms of energy efficiency, and opportunity due to the sheer scale of rebuilding required.

Some economies such as Chinese Taipei have installed Cool Roof products on some public building, but to date no clear mandate or requirement exists. For most South East Asian economies, mitigation of solar gain through roofs is limited to green roofs and roof plantations.

13. CONCLUSIONS

Cool Roof technologies and their benefits in reducing surface temperature and UHI are generally well understood and agreed. Cool Roof research, standardisation most advanced/established in the US. There are numerous initiatives in US promoting use of Cool Roofs. EU is pushing ahead through the EU Cool Roof Council. Most APEC member economies however do not have specific regulation or legislation pertaining to Cool Roofs, maintaining an overall ETTV/RTTV/OTTV value (building Envelope, Roof and Overall Thermal Transfer Value respectively) set out via regulation or encouraged through green building standards. Cool Roofs however can contribute towards achieving the standards therein

The implementation of Cool Roofs is still in its infancy in Asia and there are no clear examples of Cool Roof policy, regulation, incentive or implementation (with the exception of Japan) – most building energy mandating is through ETTV, RTTV and OTTV standards within environmental and building codes, with no specific requirements for Solar Reflectance and Emissivity. There appears to be some knowledge of Cool Roofs within the building industry but a general lack of awareness of the benefit, application and availability of Cool Roofs. Lack of understanding and standardisation are also an issue in implementing Cool Roofs. This in turn has led to little research being carried out, and manufacturers/roof installers/consultants being 'reluctant' to introduce Cool Roofs in building design and retrofit.

Overall Cool Roof systems do not appear to be a well established form of energy efficiency technology in South East Asia. The majority and more recognised passive energy efficiency measures used in the region are generally the following:

- Glazing (coatings and multiple glazing);
- Heat transfer measures (insulating fabric for walls, roofs, floors etc); and
- Solar shading technologies.

Other focus of energy efficiency in buildings relate to mechanical systems and energy use within buildings, such as energy efficient lighting, air conditioning, and appliances. This is due in part to a lack of government drivers in the region to encourage the use of Cool Roofs as the majority of government initiatives in the region seem to focus on systems.

In developed economies where buildings are relatively modern and built to high R-value standards, Cool Roofs will not have a dramatic effect on the cooling load so energy savings will be relatively small. In developing economies the proportion of air-conditioned buildings, especially dwellings, is substantially less than in developed economies and thus the potential for thermal load reduction from the implementation of Cool Roofs much greater. However, most occupiers of low or non-insulated buildings will not have air-conditioning so although the thermal load may reduce there is no tangible energy saving.

Cool Roofs might have a small effect on mitigating the Urban Heat Island (UHI) such locations. UHI was not part of this study; however significant literature highlights the contribution of Cool Roofs to UHI mitigation.

Potential Savings

Over the whole APEC region, the Total Annual HVAC Saving potentially achievable through the implementation of Cool Roofs is:

134,628,570 mWh

This represents a land mass of approximately 60million square kilometres and a dense urban area of 326,000 square kilometres. The annual saving potentials per square kilometre are:

Per km^2 land mass	-	**2.23 mWh**
Per km^2 dense urban area	-	**413 mWh**

The APEC member economies from South East Asia are[121]:

- Brunei Darussalam;
- Indonesia;
- Malaysia;
- Singapore;
- Thailand;
- The Philippines;
- Vietnam.

The Total Annual HVAC Load Saving potentially achievable through the implementation of Cool Roofs in South East Asia alone is:

38,527,678 mWh

This represents a land mass of approximately 3.2 million square kilometres and a dense urban area of 15,524 square kilometres. The annual saving potentials per square kilometre are:

Per km^2 land mass	-	**11.79 mWh**
Per km^2 dense urban area	-	**2,465 mWh**

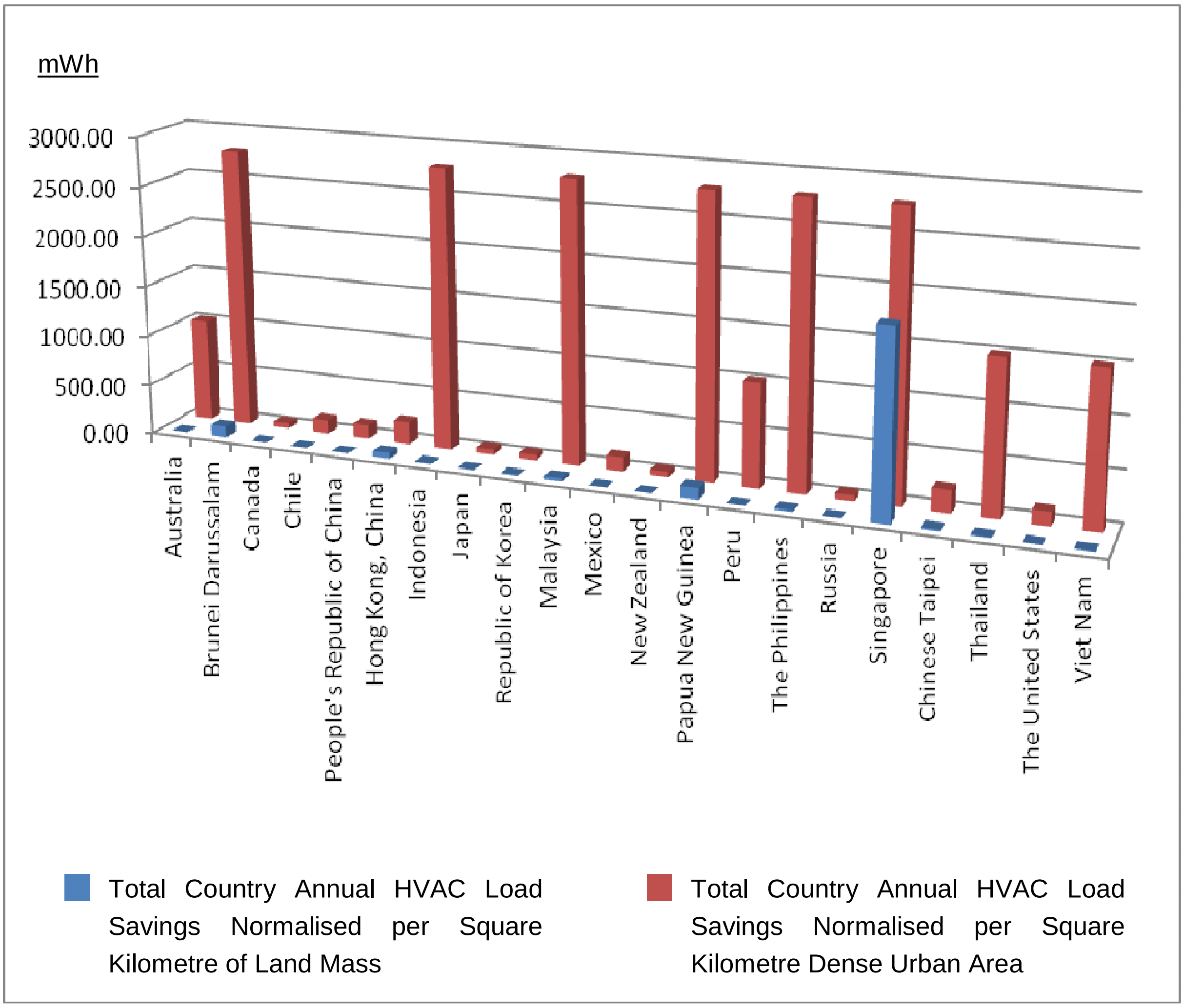
As can be seen, the potential for savings per km^2 in South East Asian economies are considerably greater than in the APEC region as a whole, mostly due to the overwhelming demand for cooling in the tropical environment. This is best shown in Figure 13.1 below where it is clear that the highest HVAC load savings per km^2 of dense urban area are achievable in South East Asia.

An absolute model for any Annual HVAC Load Saving would need to be based on micro level data concerning the number of new and old buildings and the number of each building type in each location. Such data however was not available. In addition this study is working on national and international macro levels and attributing precise factors was not possible. Furthermore, these calculations were based on computer models developed using information from existing buildings,

[121] http://www.aseansec.org/74.htm

wherein the thermal properties of the common building elements were used as inputs to determine the HVAC energy consumption. Internal HVAC loads were input as specified in section 9.3 and the overall HVAC energy savings from the implementation of Cool Roofs calculated. The inclusion of these loads offers a more realistic situation, in macro terms, as the majority of buildings will have internal loads similar to most, if not all, of the loads simulated. This however can reduce the visual impact of the reduction of heat conduction through the roof, which is in itself significant and is vastly reduced by the implementation of Cool Roof technology, as the internal loads will not be impacted upon by such implementation. The Cool Roof coatings can only impact on the conduction component of the roof.

Figure 13.1 – APEC Member Economies - Comparison of Total Annual HVAC Load Savings – Normalised per km^2 Land Mass and Dense Urban Area



This study does however indicate the significant potential for reduction in energy use from the implementation of Cool Roofs. Theoretically this would also lead to a reduction in Greenhouse Gas and pollutant emissions from power generation due the reduced HVAC energy requirements. In real terms however, the power would still be produced and would be used elsewhere, maintaining the Greenhouse Gas and pollutant emissions.

14. RECOMMENDATIONS

From international observation, for Cool Roofs to be successfully established, there needs to be government policy and intervention. Equally, the standardisation of product performance is important in creating industry benchmarks allowing comparison between different Cool Roof products. It also provides confidence to the industry on the performance of the products.

The establishment of Cool Roof Council(s) in the region would be a useful platform to coordinate the development of standardisation methods, policy and research into Cool Roofs; however, incentive and regulation through legislation and building codes are viewed as more effective ways of moving the building industry in South East Asia towards widespread implementation of Cool Roof technology. However, in the South East Asian region, climate, culture, lifestyle and architectural styles vary in each economy, so regulations and standards must be established by each economy taking into account such variations.

The respondents to the survey indicated that a worldwide information exchange is essential in building reliable product standard[s] and that many discussions should be had with the Cool Roof Rating Council to form mutual understandings in rating coating colours vs. heat reflectant effect. Participation with the Global Cool Cities Alliance and the Clean Energy Ministerial, Global Superior Energy Performance, Cool Roof Working Group would also be beneficial.

Furthermore, more specific local research into the benefits of Cool Roofs in the region is required, in particular:

- Effect of 'cool' products on walls of buildings. This is particularly applicable to South East Asian economies which have a high proportion of high rise blocks. As stated by Levinson & Akbari (2007)[122] in their study of the Potential Benefits of Cool Roofs on commercial buildings, "there is negligible heat transfer between floors in a conditioned building [the result being that] roof solar heat gain affects the heat balance of only the top floor in a multi-storey conditioned building. A study limited in this regard is therefore is not representative of many SE Asian economies which have a high proportion of such buildings, especially Singapore & Hong Kong. For an effective assessment of Cool Product potential in these regions on a micro level, a more effective method of assessment is required.

- Effect of 'cool products' on internal temperature of buildings without air conditioning in tropical climates in an effort to mitigate UHI.

Whilst a macro level study of this kind can be useful in indicating potential savings on an overall level, the regulations, standards, climates, architecture and demands from the built environment across the APEC region vary wildly, from member economy to member economy. It is therefore not possible to directly develop specific policy recommendations for the region as a whole or any sub-regions without further studies. To facilitate this, micro level member economy specific assessments should be carried out in order to find absolute values for the potential savings possible.

[122] http://www.springerlink.com/content/9r48k34558240825/fulltext.pdf

In addition, recent studies have indicated a possibility that widespread implementation of Cool Roofs, while potentially reducing urban heat island effects and urban HVAC load demand, could effectively raise global temperatures overall[123]. Further studies into this proposed phenomenon should be carried out before and large scale implementation policy is undertaken.

[123] http://www.environmentalleader.com/2011/10/28/white-roofs-could-raise-global-temperatures/

APPENDICES

APPENDIX A – Occupancy Schedules for Simulations

APPENDIX B - Full Breakdown of modelling and simulations

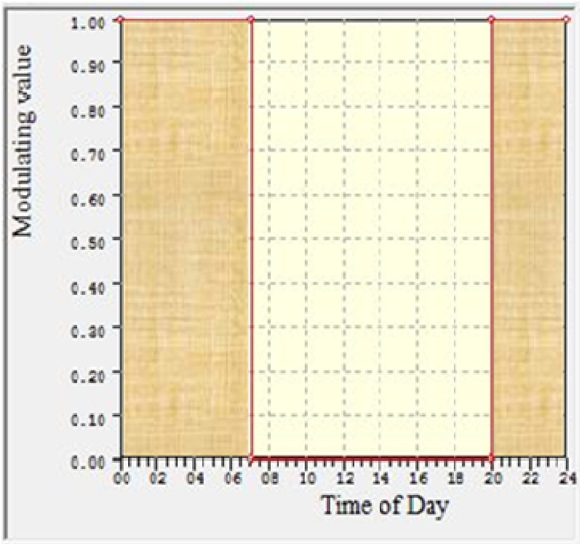
APPENDIX C – Survey Responses in full

APPENDIX D - Summary of Existing Cool Roof Policies

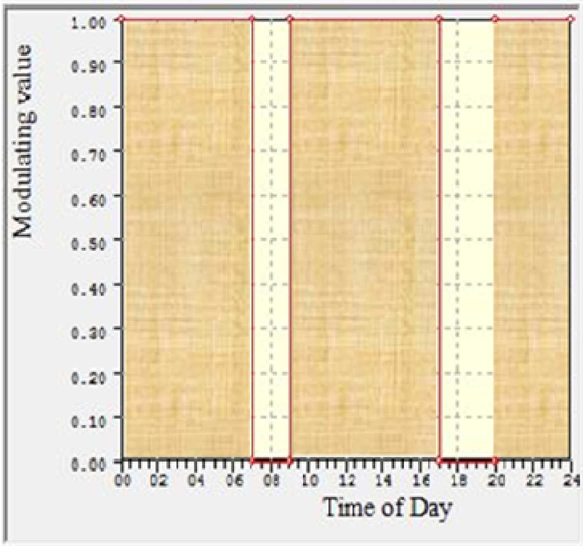
APPENDIX A – Occupancy Schedules for Simulations

Bungalow

Bedrooms

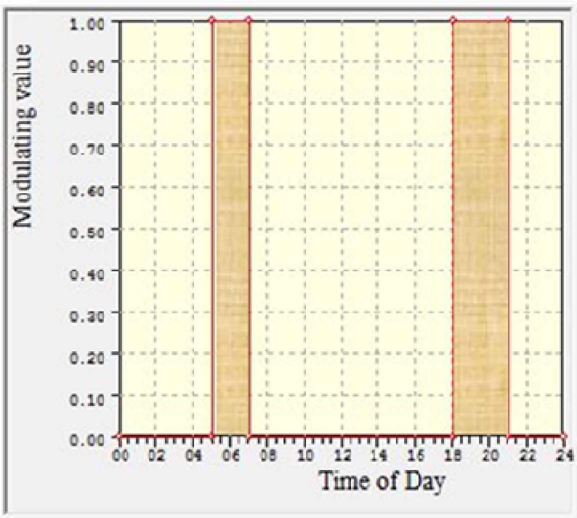


Weekday

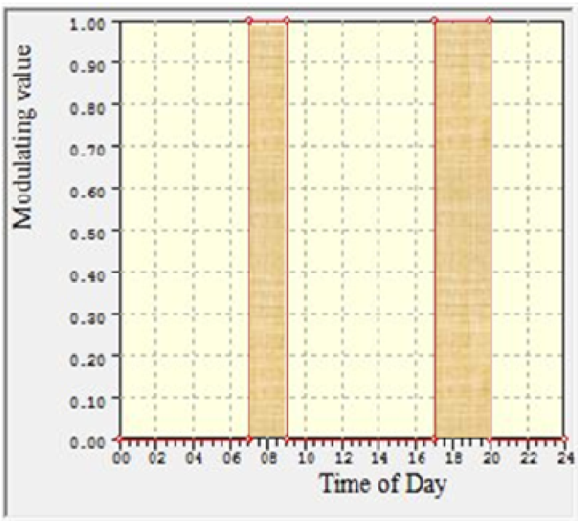


Weekend

Living

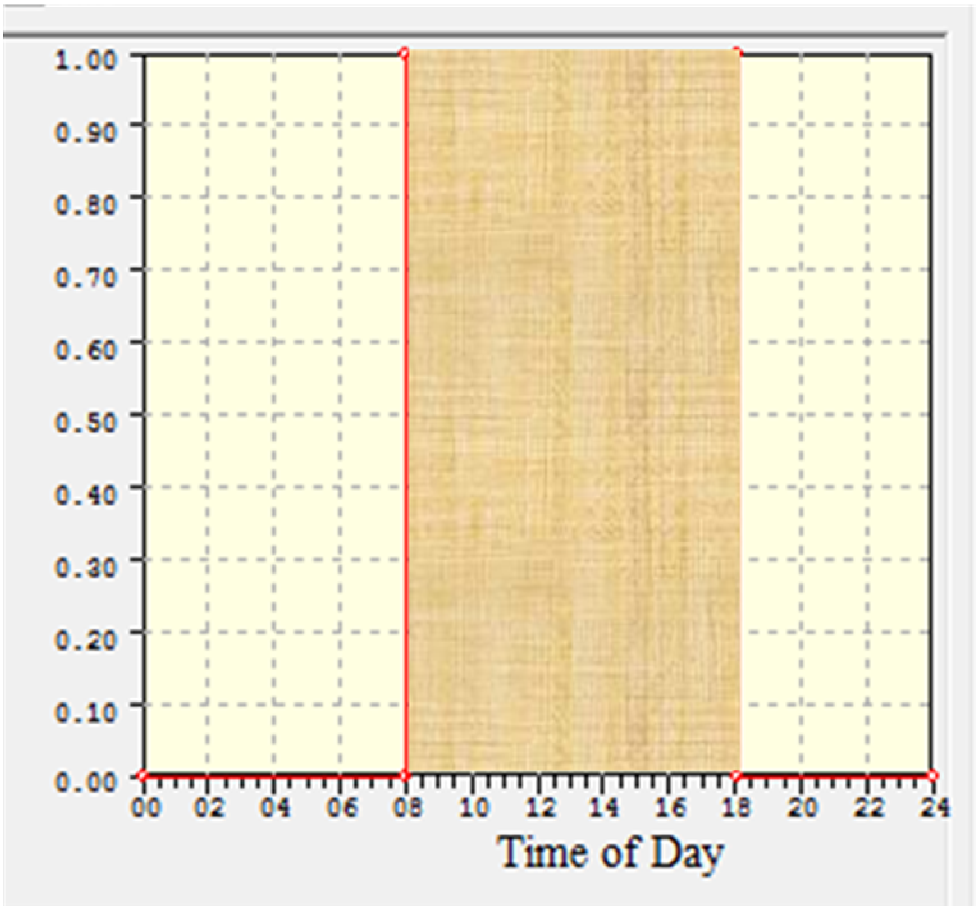


Weekday



Weekend

Industrial Building



Weekday

APPENDIX B - Full Breakdown of modelling and simulations

Appendix B

Thermal Simulation

STUDY ON POTENTIAL ENERGY SAVINGS OF COOL ROOF PAINT COATINGS ON ROOF APPLICATIONS

BSD
building system & diagnostics

AGENDA

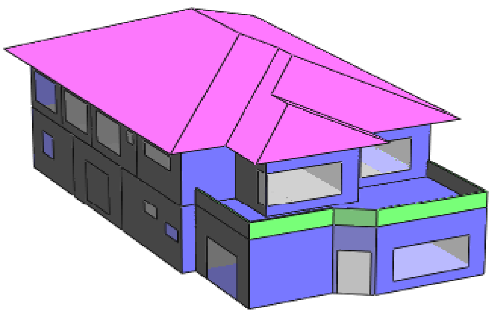
- Methodology
- Simulation Model Description
- Simulation Assumptions
- Results & Findings

METHODOLOGY

- IES <VE> Software was used to study the potential energy savings of thermal paints
- The study was carried out for
  - A typical 2-storey bungalow
  - A typical 3-storey industrial building with the following scenarios:

CASES	Description
A	building with conventional roof (New)
B	building with conventional roof (Old [i.e. Aged])
C	building with Cool Roof

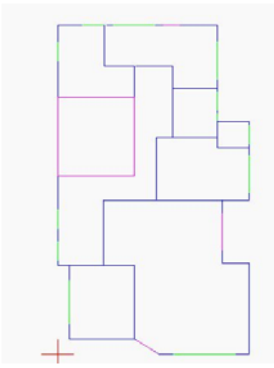
2-storey bungalow



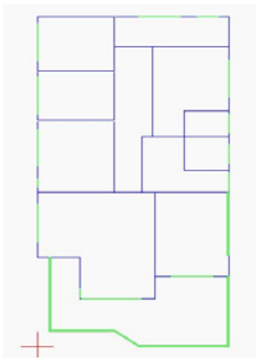
SIMULATION MODEL

Simplified Floor Plans

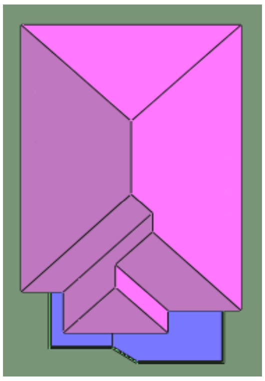
- The building thermal zones were modified into Simple Zones based on the occupancy types and ACMV systems



Level 1



Level 2

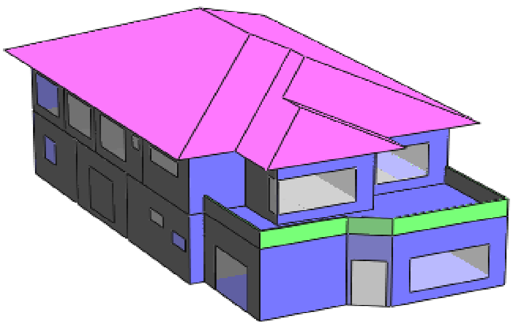


Roof Plan

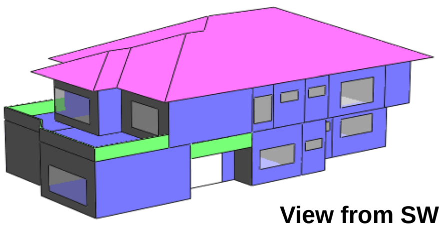
N

SIMULATION MODEL

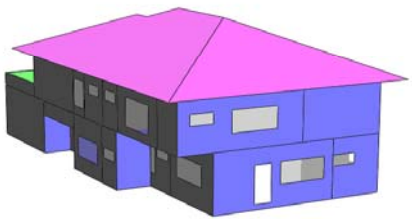
3D Views



View from NW



View from SW



View from SE

SIMULATION ASSUMPTION

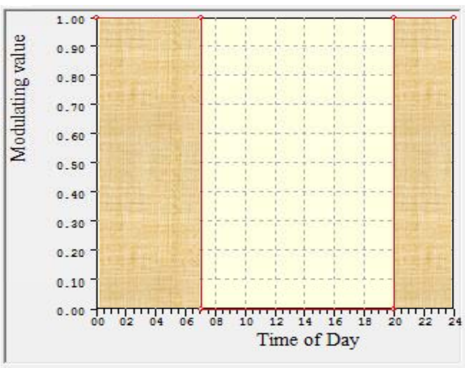
Building Envelope

BUILDING ELEMENT	DESCRIPTION
Glazing	6mm clear glazing with U-value 5.69W/m^2K, SC 0.85
Floor	RC slab
Wall Construction	Brick wall with plaster on both sides with light color paint
Roof	Clay Roof with insulation with Case A– with conventional roof (New) Case A– with conventional roof (Old) Case B– with Cool Roof

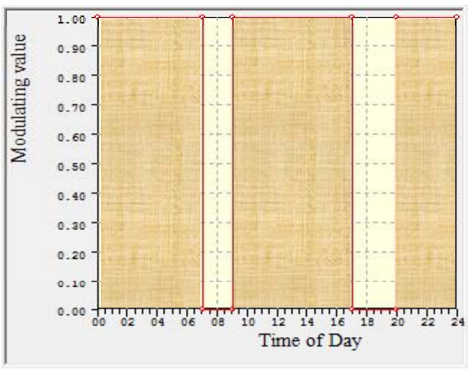
SIMULATION ASSUMPTION

Occupancy Schedules

Bedrooms



Weekday

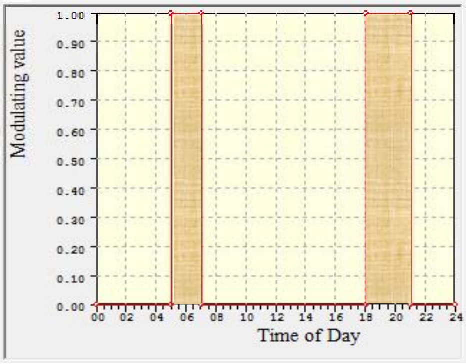


Weekend

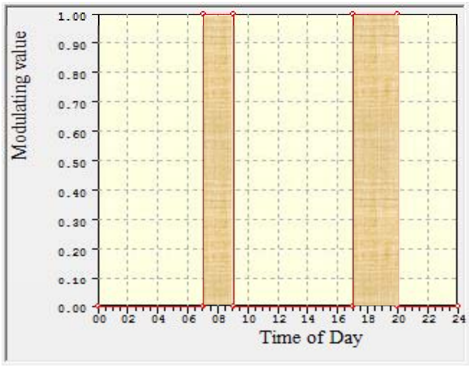
SIMULATION ASSUMPTION

Occupancy Schedules

Living Room



Weekday



Weekend

SIMULATION ASSUMPTION

Internal Heat Gain

	Occupancy load	Lighting power density	Equipment power density	HVAC
	Person	W/m²	W/m²	
Bedroom	2	10	5	AC/NV
Living room	6	10	5	AC/NV
Kitchen	2	10	5	NV
Corridor	1	10	0	NV

SIMULATION ASSUMPTION

Singapore Bungalow: Coating properties

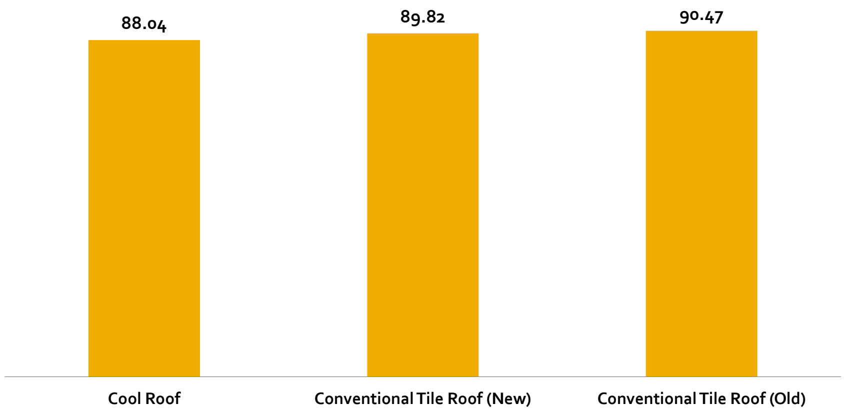
ITEMS		DESCRIPTION	E	SR
Roof Paint	A	Conventional Tile Roof (New)	0.9	0.33
	B	Conventional Tile Roof (Old)	0.9	0.3
	C	Cool Roof	0.86	0.48

Roof U-value: 0.8 W/m^2 K

RESULTS

Singapore Bungalow: Annual Cooling Load

Comparison of annual cooling load (MWh)



Annual Cooling Load Savings : 2.01% and 2.76%

SIMULATION ASSUMPTION

Brisbane Bungalow: Coating properties

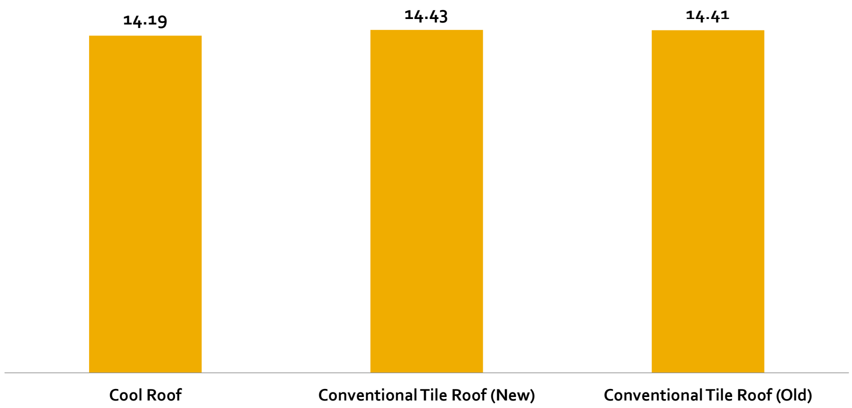
ITEMS		DESCRIPTION	E	SR
Roof Paint	A	Conventional Concrete Tile Roof (New)	0.91	0.18
	B	Conventional Concrete Tile Roof (Old)	0.91	0.19
	C	Cool Roof	0.94	0.31

Roof U-value: 0.37 W/m^2 K

RESULTS

Brisbane Bungalow: Annual Cooling Load

Comparison of annual cooling load (MWh)

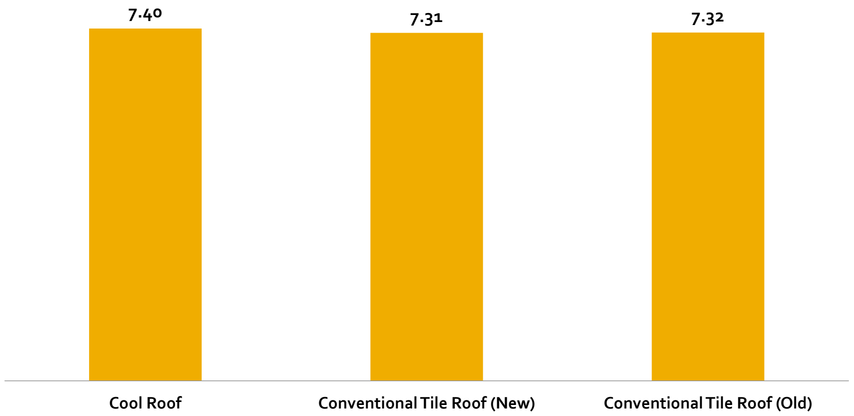


Annual Cooling Load Savings : 1.71% and 1.58%

RESULTS

Brisbane Bungalow: Annual Heating Load

Comparison of annual heating load (MWh)



SIMULATION ASSUMPTION

Tokyo Bungalow: Coating properties

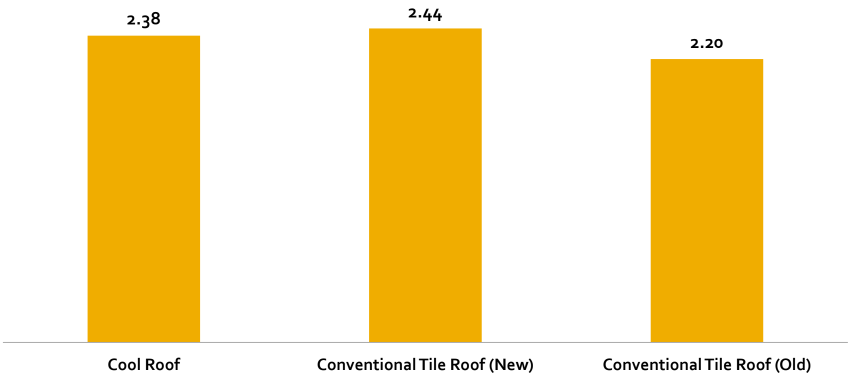
ITEMS		DESCRIPTION	E	SR
Roof Paint	A	Conventional Concrete Tile Roof (New)	0.91	0.18
	B	Conventional Concrete Tile Roof (Old)	0.91	0.19
	C	Cool Roof	0.94	0.31

Roof U-value: 0.22 W/m^2 K

RESULTS

Tokyo Bungalow: Annual Cooling Load

Comparison of annual cooling load (MWh)

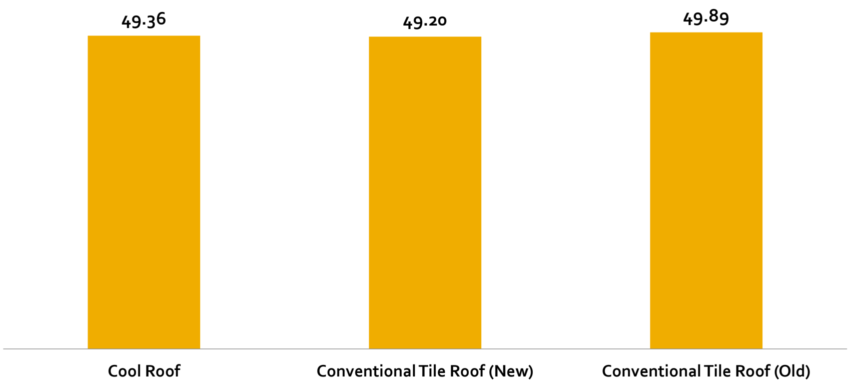


Annual Cooling Load Savings : 2.35% and -7.57%

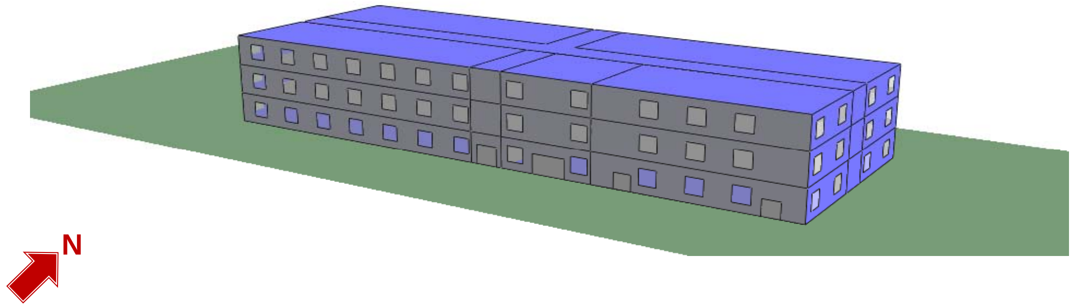
RESULTS

Tokyo Bungalow: Annual Heating Load

Comparison of annual heating load (MWh)



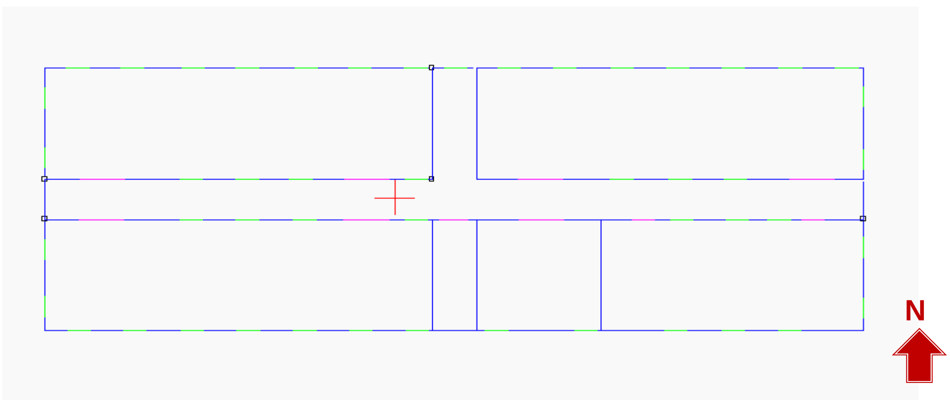
3-storey industrial building



SIMULATION MODEL

Simplified Floor Plans

- The building thermal zones were modified into Simple Zones based on the occupancy types and ACMV systems



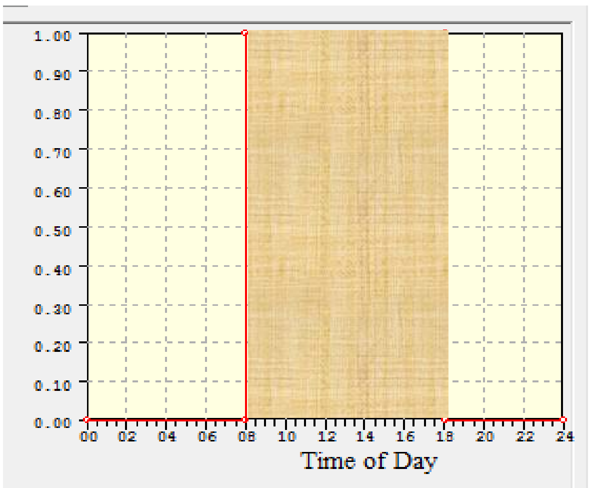
SIMULATION ASSUMPTION

Building Envelope

BUILDING ELEMENT	DESCRIPTION
Glazing	6mm clear glazing with U-value 5.69W/m²K, SC 0.85
Floor	RC slab
Wall Construction	Brick wall with plaster on both sides with light color paint
Roof	Flat Roof with insulation with Case A– with conventional roof (New) Case B– with conventional roof (Old) Case C– with cool roof

SIMULATION ASSUMPTION

Occupancy Schedules



Weekday

Weekend Off

SIMULATION ASSUMPTION
Internal Heat Gain

	People load	Lighting power density	Equipment power density	HVAC
	person	W/m²	W/m²	
workshop	15	15	25	AC
office	15	15	16	AC
corridor	4	12	0	NV
staircase	/	12	0	NV
lift&loading	30.6	12	0	AC

SIMULATION ASSUMPTION
Singapore Industrial: Coating properties

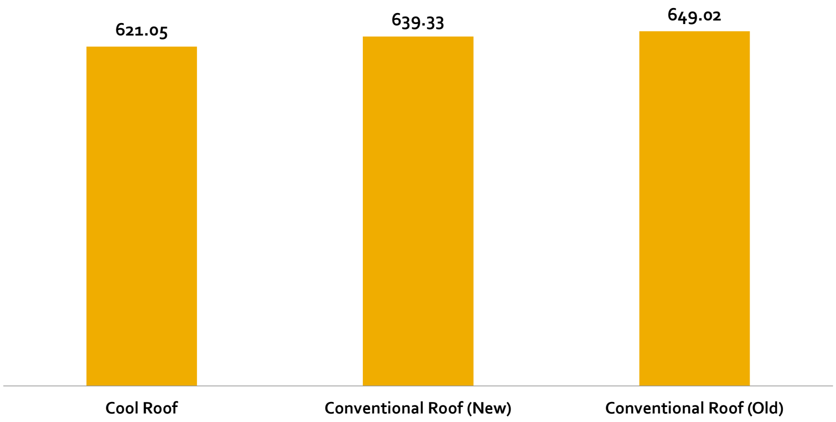
ITEMS		DESCRIPTION	E	SR
Roof Paint	A	Conventional bare concrete (New)	0.90	0.51
	B	Conventional bare concrete (Old)	0.90	0.38
	C	Cool Roof	0.89	0.76

Roof U-value: 1.2 W/m^2 K

RESULTS

Singapore Industrial: Annual Cooling Load

Comparison of annual cooling load (MWh)



Annual Cooling Load Savings : 2.94% and 4.5%

SIMULATION ASSUMPTION

Brisbane Industrial: Coating properties

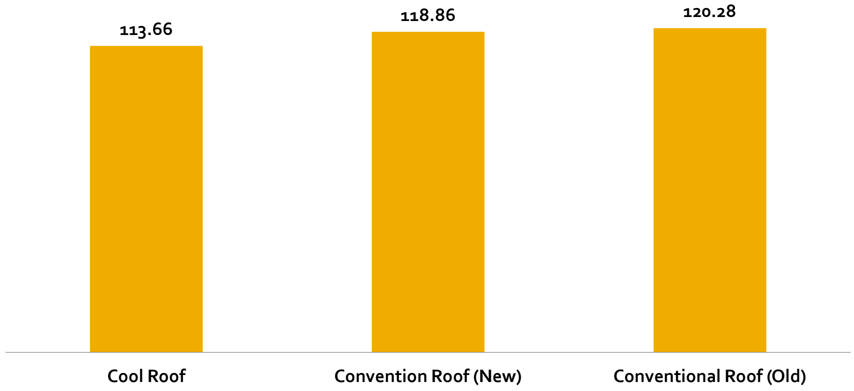
ITEMS		DESCRIPTION	E	SR
Roof Paint	**A**	Conventional Roof (New)	0.04	0.61
	B	Conventional Roof (Old)	0.04	0.53
	C	Cool Roof	0.85	0.71

Roof U-value: 0.37 W/m^2 K

RESULTS

Brisbane Industrial: Annual Cooling Load

Comparison of annual cooling load (MWh)

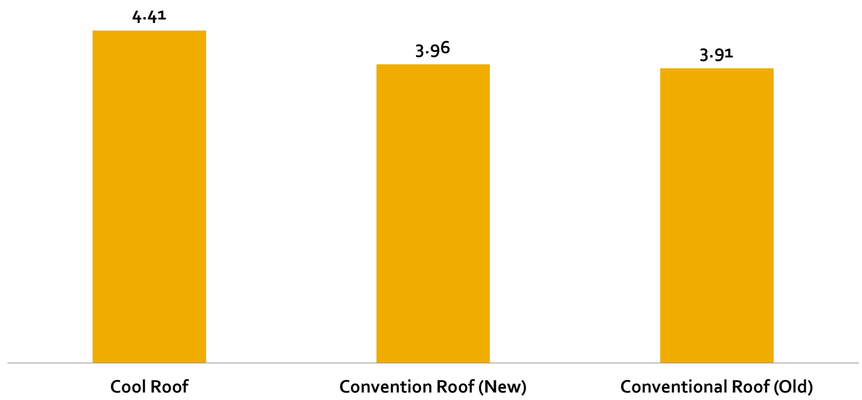


Annual Cooling Load Savings : 4.57% and 5.82%

RESULTS

Brisbane Industrial: Annual Heating Load

Comparison of annual heating load (MWh)



SIMULATION ASSUMPTION

Tokyo Industrial: Coating properties

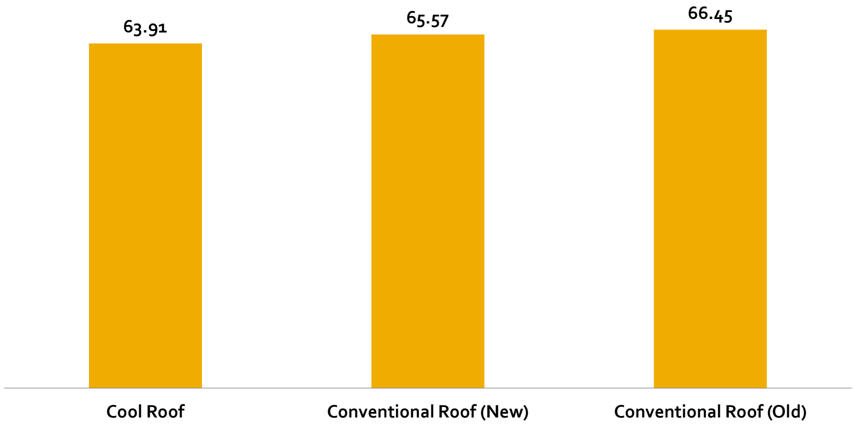
ITEMS		DESCRIPTION	E	SR
Roof Paint	A	Conventional Roof (New)	0.9	0.51
	B	Conventional Roof (Old)	0.9	0.38
	C	Cool Roof	0.89	0.76

Roof U-value: 0.4 W/m^2 K

RESULTS

Tokyo Industrial: Annual Cooling Load

Comparison of annual cooling load (MWh)

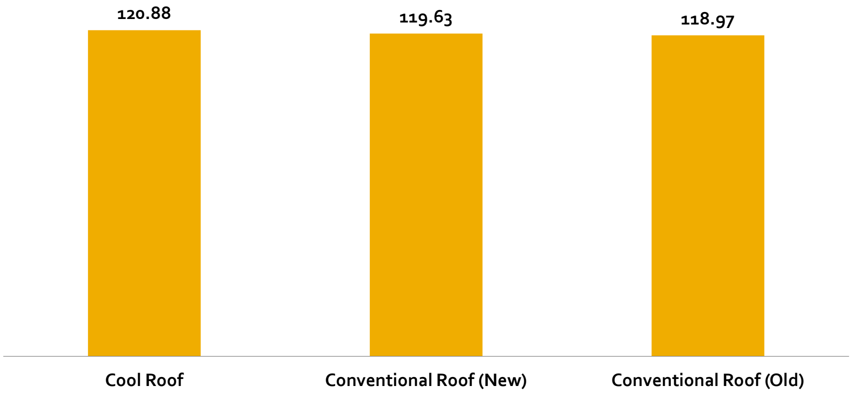


Annual Cooling Load Savings : 2.59% and 3.98%

RESULTS

Tokyo Industrial: Annual Heating Load

Comparison of annual heating load (MWh)



APPENDIX C – Survey Responses in full

Analysis of Findings

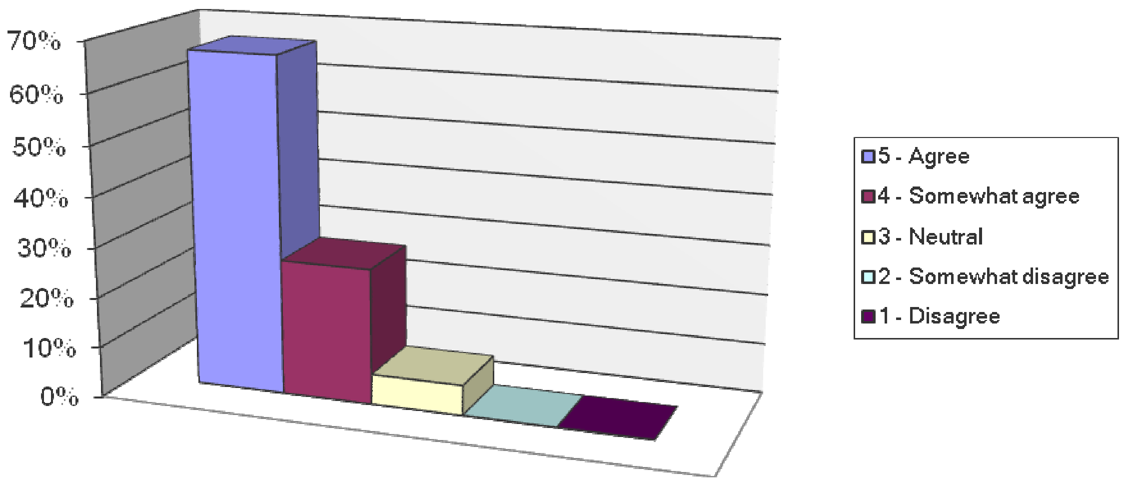
Awareness

- **Question 1a - Do you agree that Cool Roofs play a role as an energy efficiency measure in buildings?**

Most respondents agreed that Cool Roofs do play such a role.

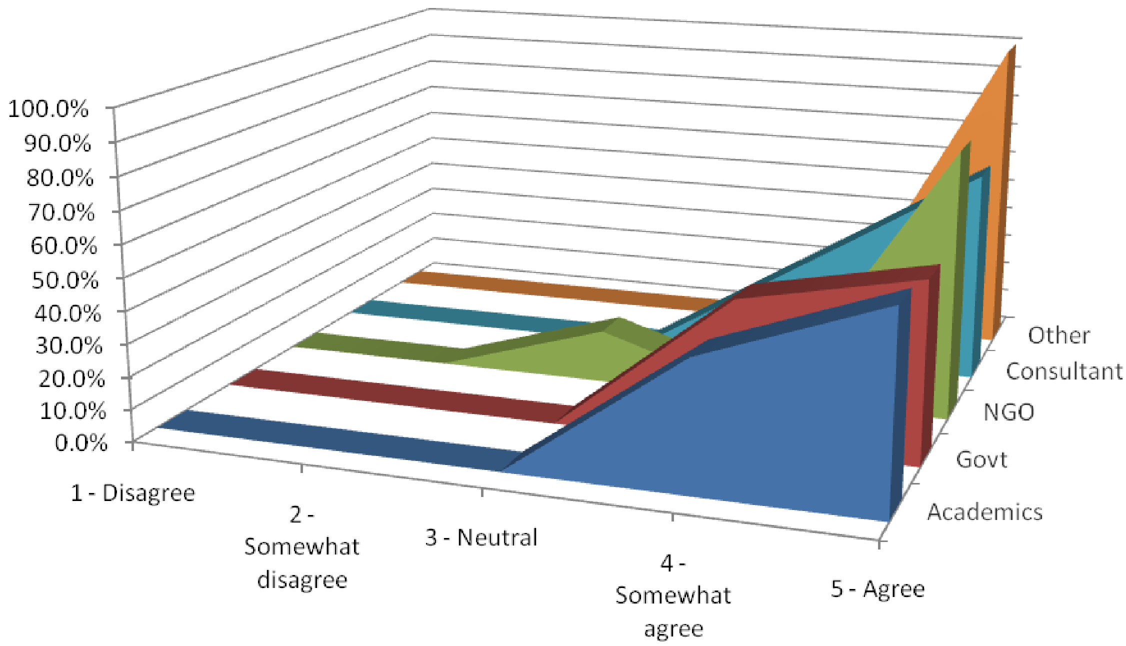
Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree
0	0	6%	27%	67%

Do you agree that cool roofs play a role as an energy efficiency measure in buildings?



Professionally speaking, the majority of respondents from each group seemed to agree with the majority.

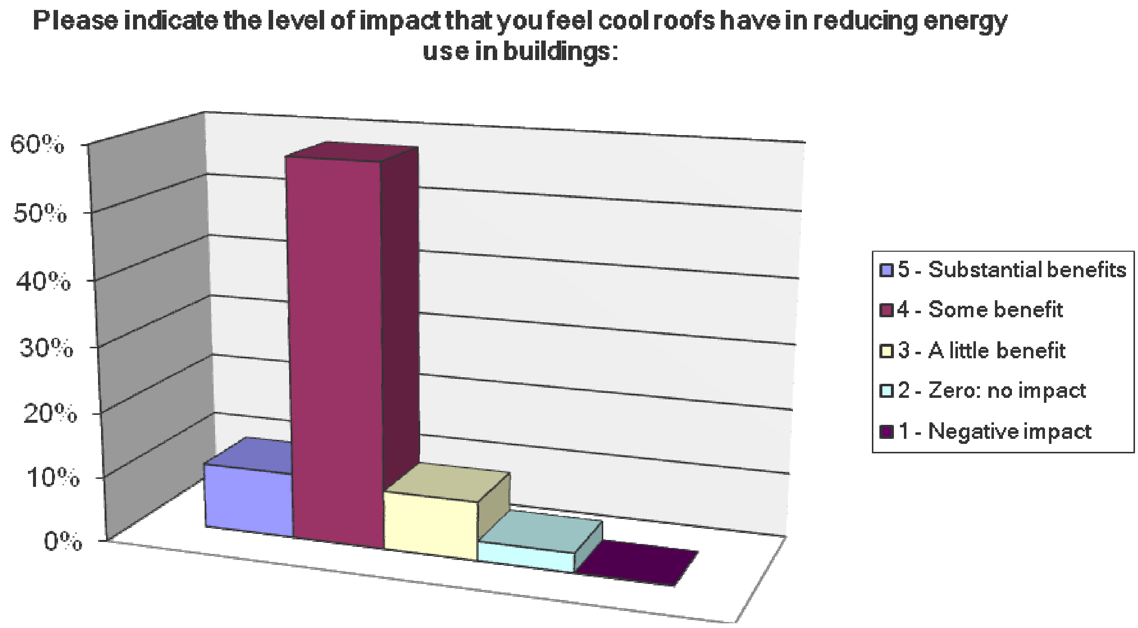
	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree
Academics	0.0%	0.0%	0.0%	40.0%	60.0%
Govt	0.0%	0.0%	0.0%	44.4%	55.6%
NGO	0.0%	0.0%	16.7%	0.0%	83.3%
Consultant	0.0%	0.0%	0.0%	33.3%	66.7%
Other	0.0%	0.0%	0.0%	0.0%	100.0%



- **Question 1b - Please indicate the level of impact that you feel Cool Roofs have in reducing energy use in buildings:**

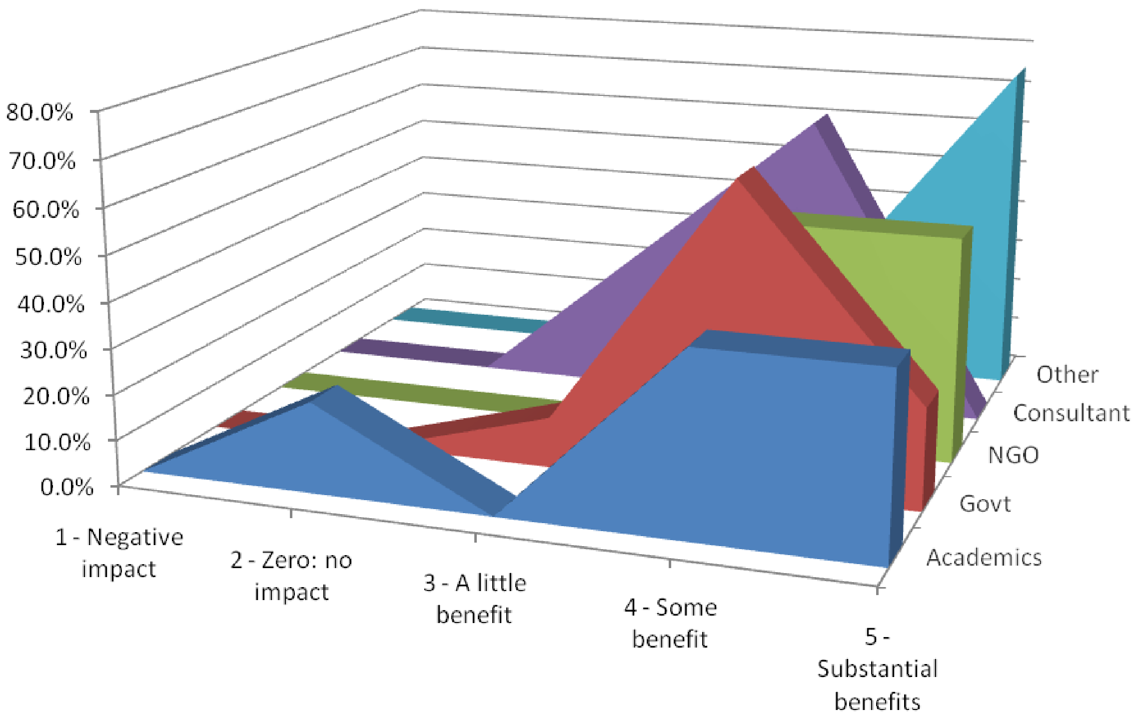
Most respondents felt that Cool Roofs had some benefit in this respect, although only 10% went as far as saying that impact was substantial.

Negative impact	Zero: no impact	A little benefit	Some benefit	Substantial benefits
0	3%	9%	58%	10%



Professionally, only academics felt that Cool Roofs had no impact on reducing energy use.

	Negative impact	Zero: no impact	A little benefit	Some benefit	Substantial benefits
Academics	0.0%	20.0%	0.0%	40.0%	40.0%
Govt	0.0%	0.0%	11.1%	66.7%	22.2%
NGO	0.0%	0.0%	0.0%	50.0%	50.0%
Consultant	0.0%	0.0%	33.3%	66.7%	0.0%
Other	0.0%	0.0%	0.0%	25.0%	75.0%

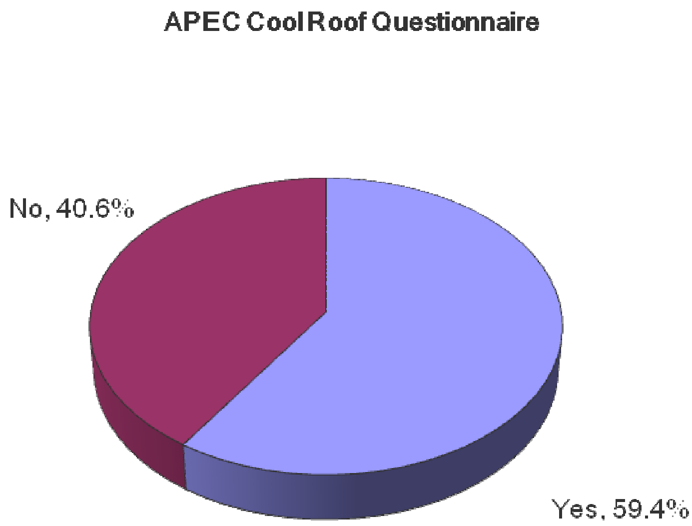


Initiatives

- **Question 2a - Are you aware of any initiatives by your government (national or regional/local) which promote the implementation of Cool Roofs?**

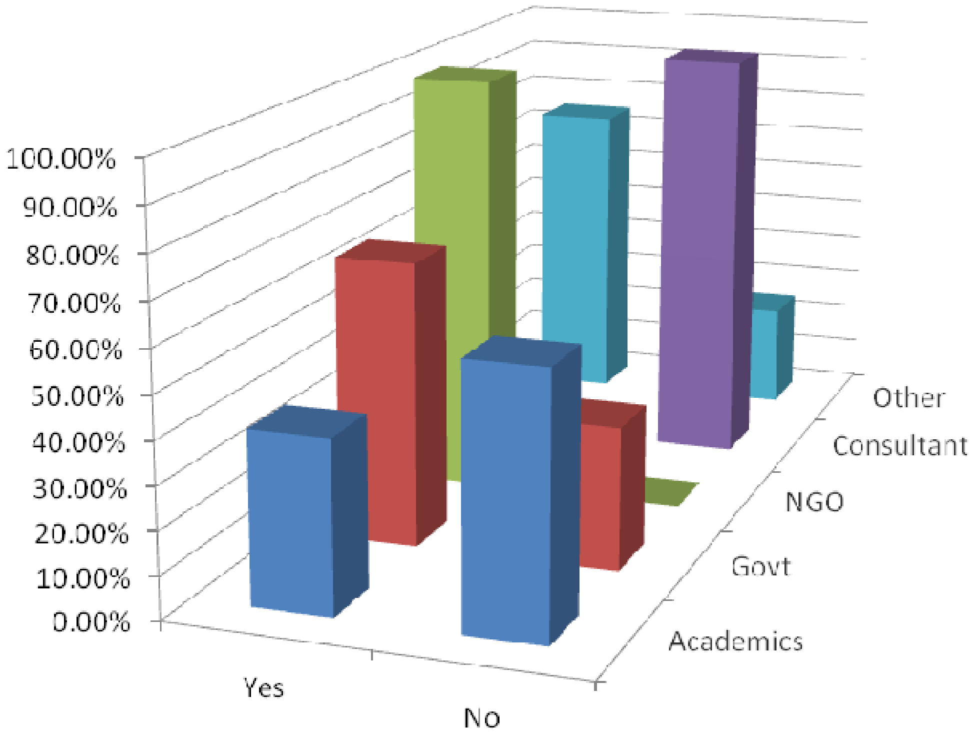
More than half respondents were aware of government initiatives to promote Cool Roofs.

Yes	59.4%
No	40.6%



Interestingly, 100% of respondents from Non-governmental organisations were aware of Govt initatives, whereas only two thirds of Government respondents were aware. No respondents from the Consultants group were aware of any such initiatives.

	Yes	No
Academics	40.00%	60.00%
Govt	66.67%	33.33%
NGO	100.00%	0.00%
Consultant	0.00%	100.00%
Other	75.00%	25.00%



<u>Question 2b</u> - If Yes, please provide further details on the initiatives below:

Further issues raised were:

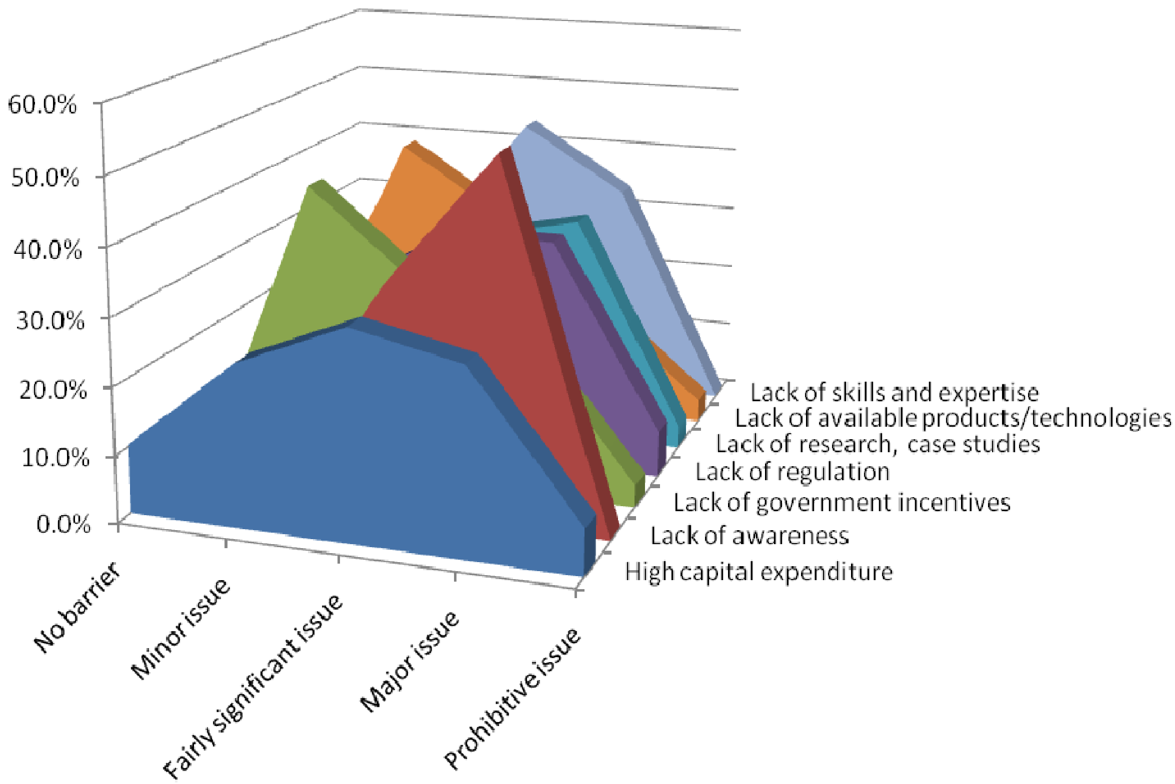
- Green Mark Scheme [Singapore]
- Because Cool Roof has an impact to RTTV. The standard of RTTV is one of system requirement in building regulation (Building Energy Code) [Thailand]
- The ministry of interior Chinese Taipei of and Taipei city government do a lot of efforts to promote the Cool Roof technology. [Chinese Taipei]
- National program on Cool Roofs. [Greece]
- Singapore's Building & Construction Authority (BCA) has the Green Mark (GM) Scheme that encourages sustainable building practices [Singapore]
- Energy Star, CA Title 24, and many more state and local initiatives [USA]
- It is the Energy Smart Communities Initiative (ESCI) COOL ROOF DEMONSTRATIONS (SB-3). [Japan]
- US Department of Energy announced a mandate last year to implement Cool Roof technologies in all new public buildings, roof replacements, and roofing retrofits as long as the energy savings justify the cost of the replacement (extension of Obama's Executive Order to reduce government GHG emissions by 28%). [USA]
- National level : The Ministry of Energy and Mineral Resources; under Directorate General New, Renewable Energy and Energy Conservation, under Directorate of Energy Conservation, under Sub Directorate of Clean and Efficient Energy Technology Implementation Provincial Level at Special Region of Jakarta: Building Regulation and Supervision Agency [Indonesia]
- You will get more detailed info on the US, but California and other states have utility incentives and code requirements, and the US Dept of Energy has directed that all re-roofing projects in its own buildings use Cool Roofing. The EPA Energy Star website has more info - see http://yosemite.epa.gov/gw/heatisland.nsf/e678cbc3b2529eda85256d510072e374/89cac94d99bbd4ae8525720b006719be!OpenDocument [USA]
- Federal legislation [is] being considered. [There is] research by [the] California Energy Commission. [It is] included in some state and local building codes. [USA]
- Local Government of Quezon City provided for ordinance on green buildings [The Philippines]
- OSAKA Prefecture initiatives (compile action on going), Tokyo Prefecture monitor works and those of [the] Ministry of the Environment have finished. [Japan]
- ASHRAE 90.1, California Title 24, US EPA/DOE Energy Star, DOE directive on Cool Roofs [USA]
- NPark[s] provide subsidy for constructing green roof [Singapore]

Possible Barriers

- **Question 3a - What do you consider are the current barriers to the implementation of Cool Roofs? (Multiple answers)**

Lack of awareness seemed to be the most likely barrier to implementation.

Answer Options	No barrier	Minor issue	Fairly significant issue	Major issue	Prohibitive issue
High capital expenditure	10.3%	24.1%	31.0%	27.6%	6.9%
Lack of awareness	6.7%	6.7%	33.3%	53.3%	0.0%
Lack of government incentives	0.0%	43.3%	30.0%	23.3%	3.3%
Lack of regulation	0.0%	24.1%	34.5%	34.5%	6.9%
Lack of research, case studies	13.8%	17.2%	31.0%	34.5%	3.4%
Lack of available products/technologies	6.9%	41.4%	31.0%	17.2%	3.4%
Lack of skills and expertise	0.0%	23.3%	43.3%	33.3%	0.0%

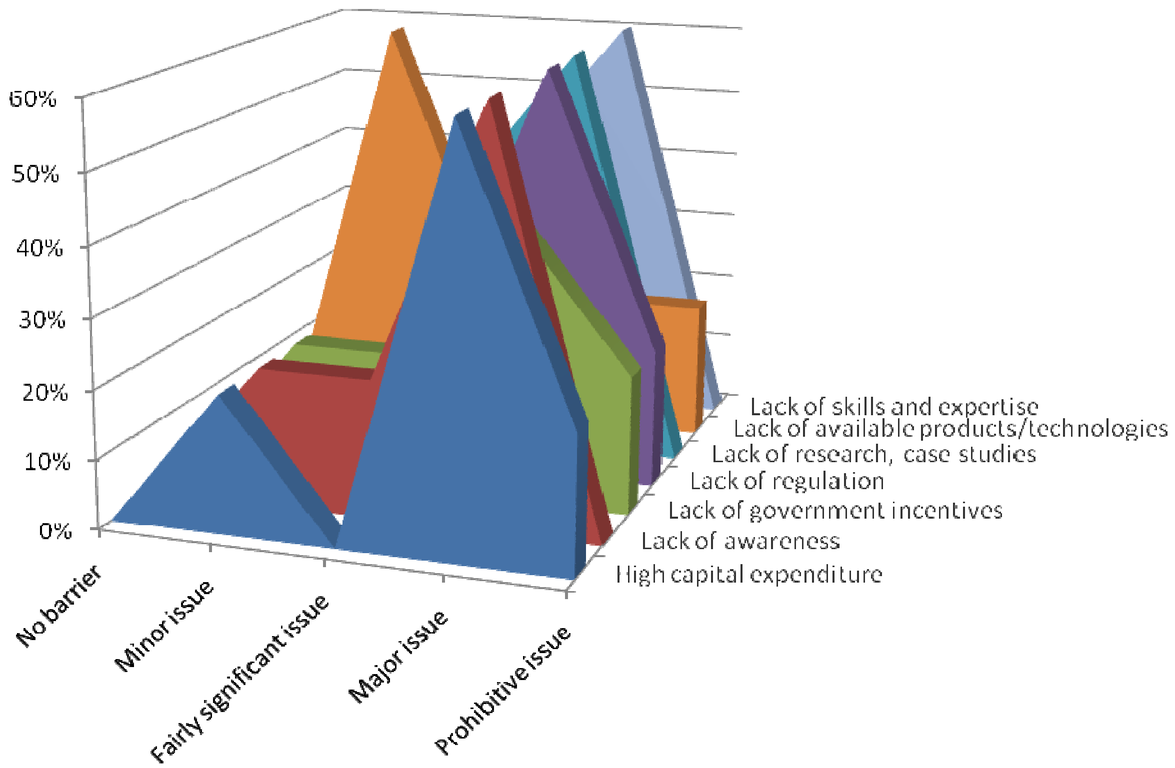


What is interesting in this circumstance is the responses of each of the professional groups:

Academics

The lack of available products and technologies was a minor issue, however the other potential barriers were mostly considered to be major issues:

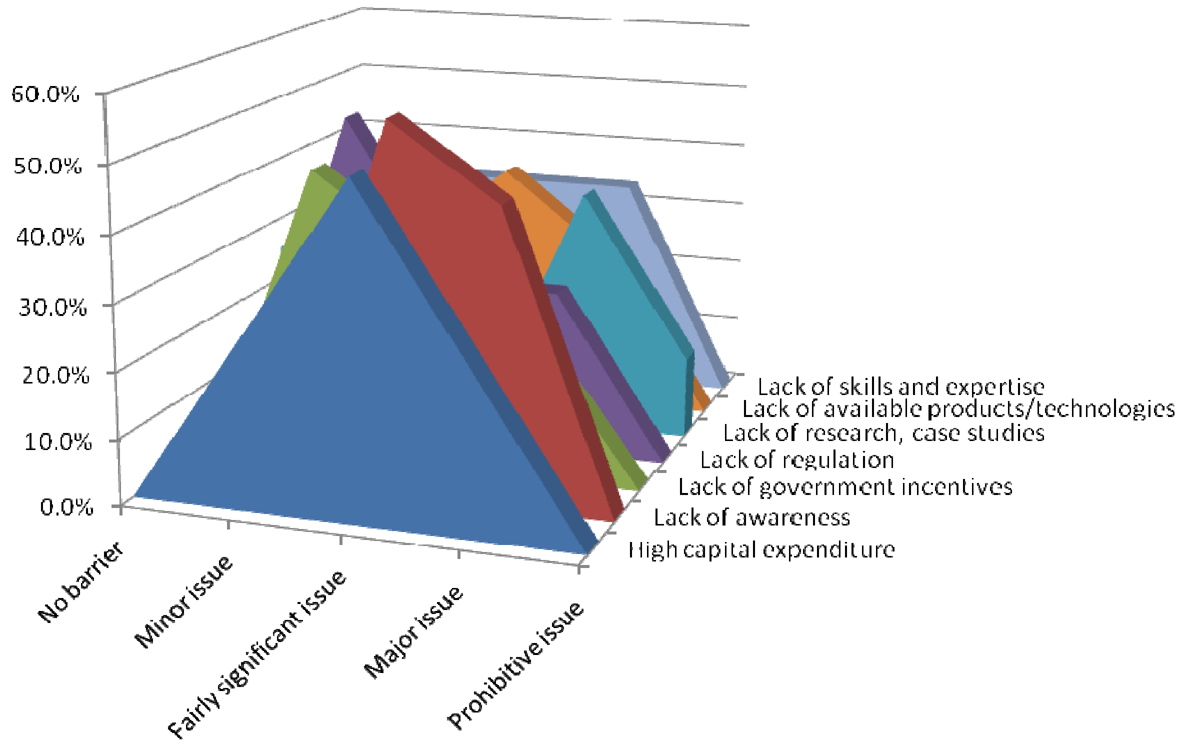
Answer Options	No barrier	Minor issue	Fairly significant issue	Major issue	Prohibitive issue
High capital expenditure	0%	20%	0%	60%	20%
Lack of awareness	0%	20%	20%	60%	0%
Lack of government incentives	0%	20%	20%	40%	20%
Lack of regulation	0%	0%	20%	60%	20%
Lack of research, case studies	0%	0%	40%	60%	0%
Lack of available products/technologies	0%	60%	20%	20%	20%
Lack of skills and expertise	0%	0%	40%	60%	0%



Government

In contrast, respondents from Government agencies and departments felt that any lack of government incentive or regulation should not be such a significant barrier, suggesting that capital expenditure and lack of awareness were the real issues. Only the lack of research and case studies was felt to be a prohibitive issue.

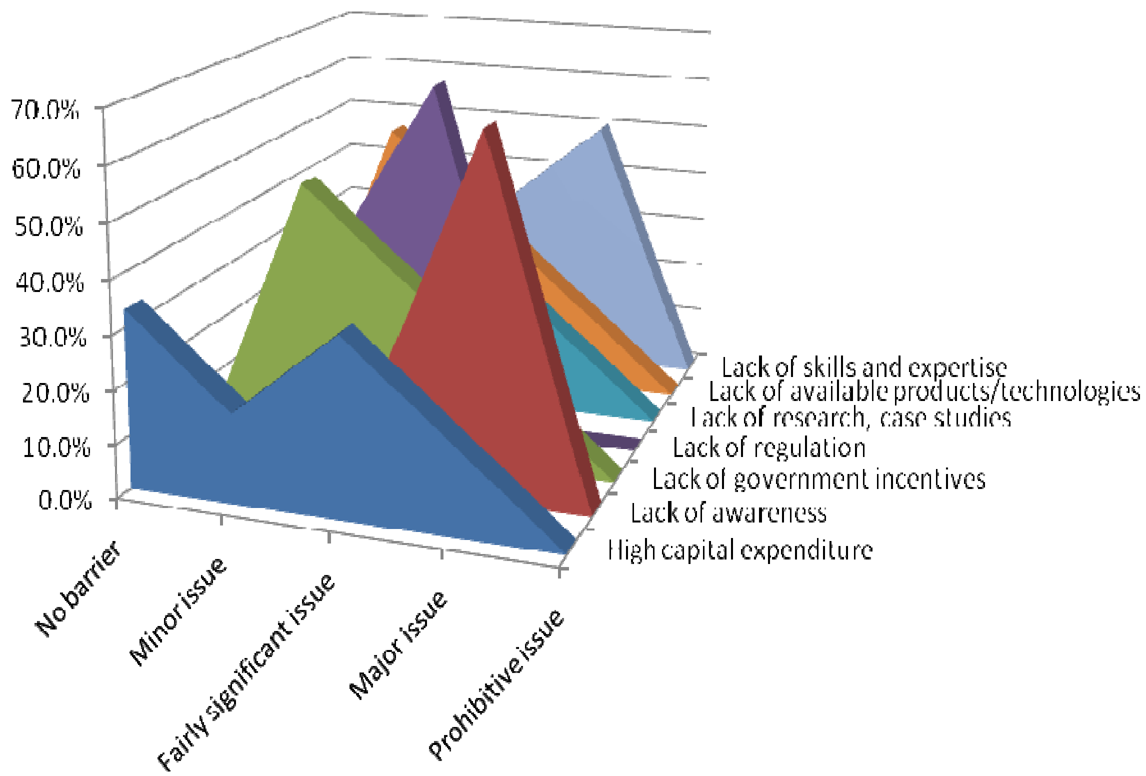
Answer Options	No barrier	Minor issue	Fairly significant issue	Major issue	Prohibitive issue
High capital expenditure	0.0%	25.0%	50.0%	25.0%	0.0%
Lack of awareness	0.0%	0.0%	55.6%	44.4%	0.0%
Lack of government incentives	0.0%	44.4%	33.3%	22.2%	0.0%
Lack of regulation	0.0%	50.0%	25.0%	25.0%	0.0%
Lack of research, case studies	25.0%	25.0%	0.0%	37.5%	12.5%
Lack of available products/technologies	12.5%	25.0%	37.5%	25.0%	0.0%
Lack of skills and expertise	0.0%	33.3%	33.3%	33.3%	0.0%



Non-Governmental Organisations

Respondents from Non-Governmental Organisations placed greater emphasis on lack of awareness and necessary skills as the main barriers, followed by a lack of regulation. None of the suggested barriers were viewed as prohibitive.

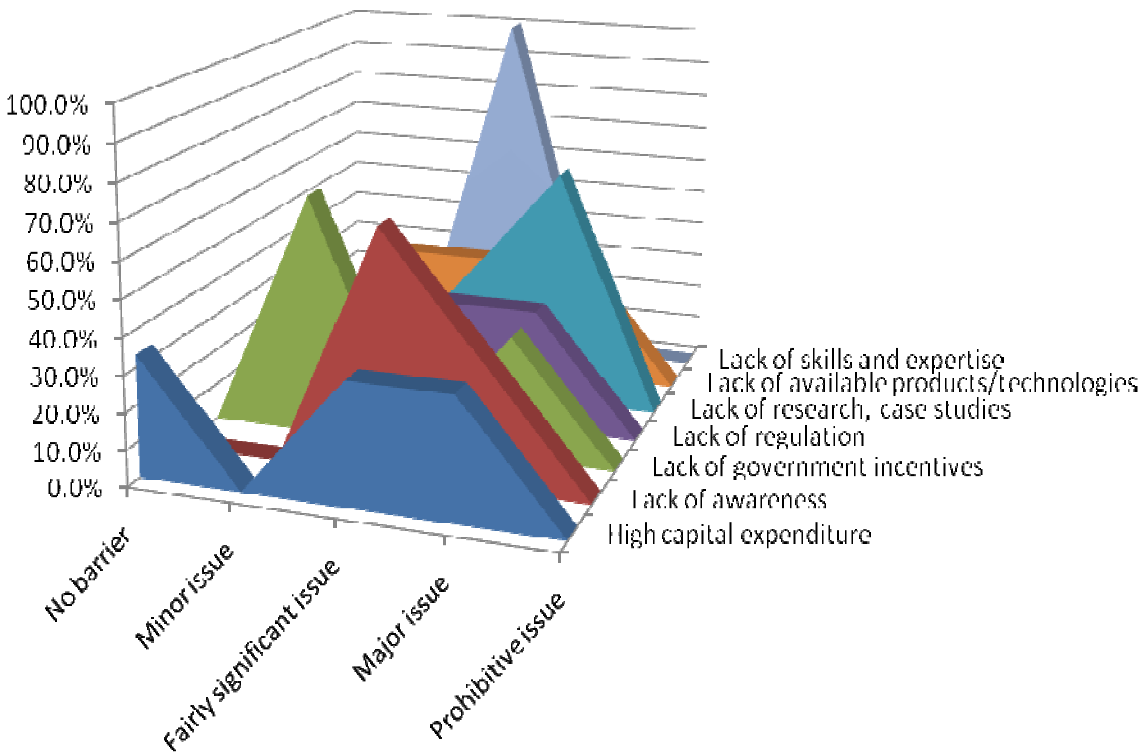
Answer Options	No barrier	Minor issue	Fairly significant issue	Major issue	Prohibitive issue
High capital expenditure	33.3%	16.7%	33.3%	16.7%	0.0%
Lack of awareness	16.7%	0.0%	16.7%	66.7%	0.0%
Lack of government incentives	0.0%	50.0%	33.3%	16.7%	0.0%
Lack of regulation	0.0%	33.3%	66.7%	0.0%	0.0%
Lack of research, case studies	16.7%	33.3%	33.3%	16.7%	0.0%
Lack of available products/technologies	0.0%	50.0%	33.3%	16.7%	0.0%
Lack of skills and expertise	0.0%	16.7%	33.3%	50.0%	0.0%



<u>Consultants</u>

From the consultants' perspective, the biggest barrier is the lack of research. Lack of government incentive was a minor issue. None of the potential barriers was felt to be prohibitive. All agreed that the lack of skills and expertise was a fairly significant issue.

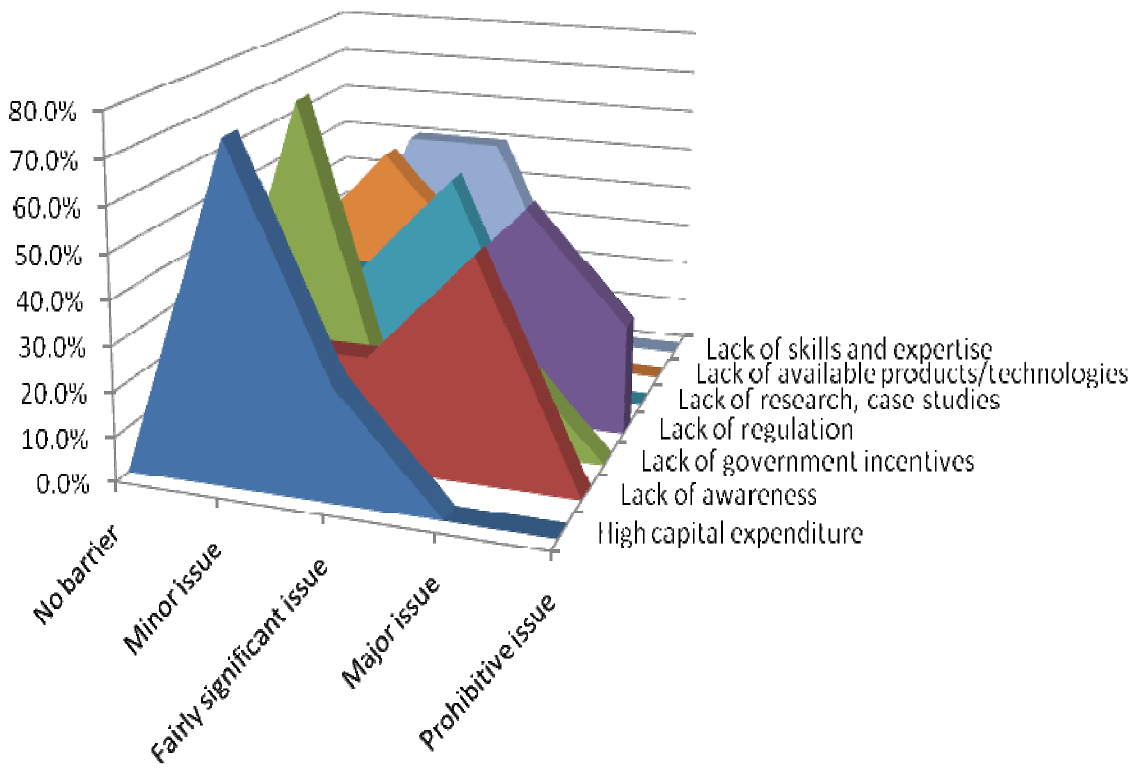
Answer Options	No barrier	Minor issue	Fairly significant issue	Major issue	Prohibitive issue
High capital expenditure	33.3%	0.0%	33.3%	33.3%	0.0%
Lack of awareness	0.0%	0.0%	66.7%	33.3%	0.0%
Lack of government incentives	0.0%	66.7%	0.0%	33.3%	0.0%
Lack of regulation	0.0%	33.3%	33.3%	33.3%	0.0%
Lack of research, case studies	0.0%	0.0%	33.3%	66.7%	0.0%
Lack of available products/technologies	0.0%	33.3%	33.3%	33.3%	0.0%
Lack of skills and expertise	0.0%	0.0%	100.0%	0.0%	0.0%



Other

Respondents from the last category felt very strongly that high capital expenditure and lack of government incentives were minor issues compared to lack of awareness and regulation, indicating a suggestion for the stick over the carrot.

Answer Options	**No barrier**	**Minor issue**	**Fairly significant issue**	**Major issue**	**Prohibitive issue**
High capital expenditure	0.0%	75.0%	25.0%	0.0%	0.0%
Lack of awareness	0.0%	25.0%	25.0%	50.0%	0.0%
Lack of government incentives	0.0%	75.0%	0.0%	25.0%	0.0%
Lack of regulation	0.0%	0.0%	25.0%	50.0%	25.0%
Lack of research, case studies	25.0%	25.0%	50.0%	0.0%	0.0%
Lack of available products/technologies	25.0%	50.0%	25.0%	0.0%	0.0%
Lack of skills and expertise	0.0%	50.0%	50.0%	0.0%	0.0%



- **Question 3b - Please use space below for any barriers, potential or existing, of which you are aware that are not listed above, or any additional comments you may have**:

Further issues raised were:

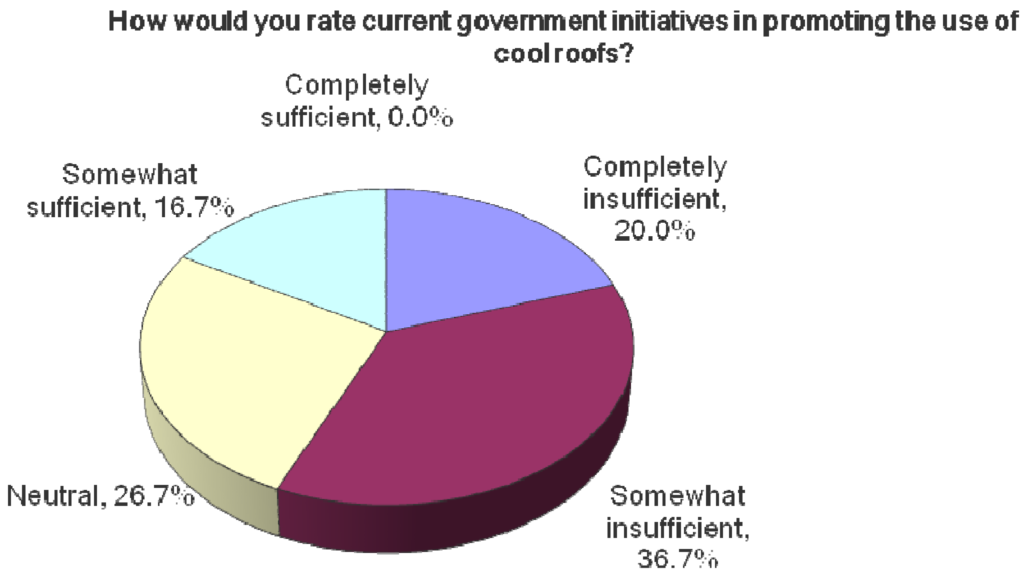
- Capital expenditure and lack of government incentives are a more serious issue for steep sloped roofs. [USA]
- Lack of awareness and technologies from SMEs. [Thailand]
- Lack of substantial data with standardization and its public information. [Japan]
- In the U.S, the Cool Roof provisions in most building energy efficiency standards outside of California are too lax. We also need better cool options for asphalt shingle roofs, the dominant residential product in this country. [USA]
- I think the main barrier is the users are not confident with technology. More successful cases have to be disseminated. [Thailand]
- Need [for] more well-labelled Cool Roofing products and awareness of the benefits among roofing product salesmen and roof installers." [USA]
- Other system to consider e.g. roof garden. Ratio to wall is small in Singapore, therefore less focus on roof. Current system can easily meet the U-value requirement therefore designer[s]/owner[s] do not see the need to install Cool Roof. [Singapore]
- Insufficient supporting findings on the actual benefits vs. conventional insulation systems already adopted in the industry. Cost-benefit analysis is somewhat lacking. Another barrier is lack of roofing products/systems rating systems for reflectivity etc. [Singapore]

Government Support

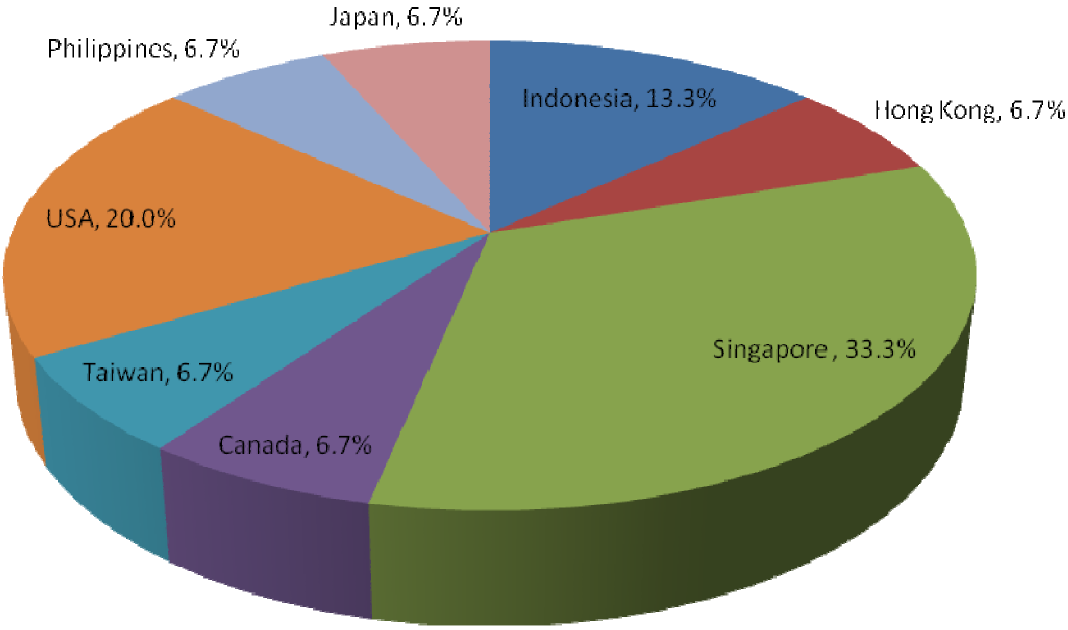
- **Question 4a - How would you rate current government initiatives in promoting the use of Cool Roofs?**

A mixed feeling was generated on this issue, dependent on the country of origin of the respondent; however no-one felt the initiatives were completely insufficient.

Answer Options	Response
Completely insufficient	20.0%
Somewhat insufficient	36.7%
Neutral	26.7%
Somewhat sufficient	16.7%
Completely sufficient	0.0%



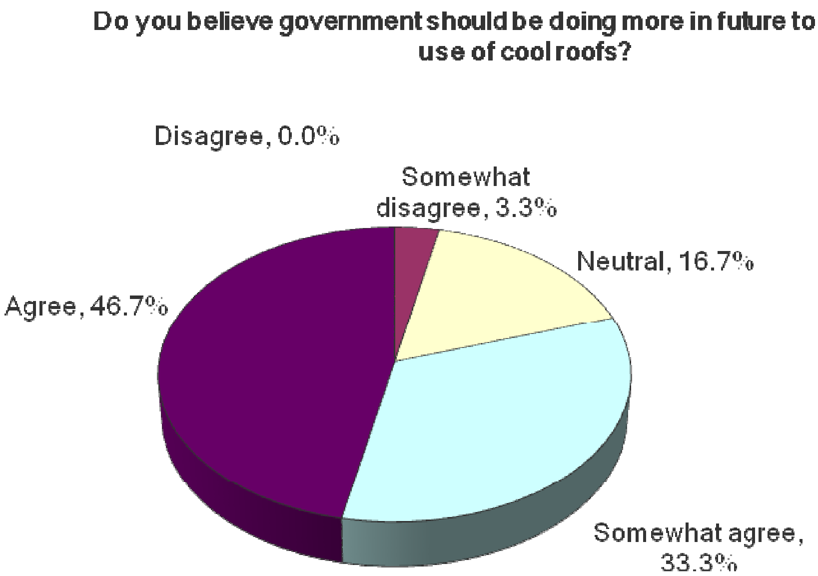
Of those who felt their government's initiatives were insufficient, the geographical spread was as follows:



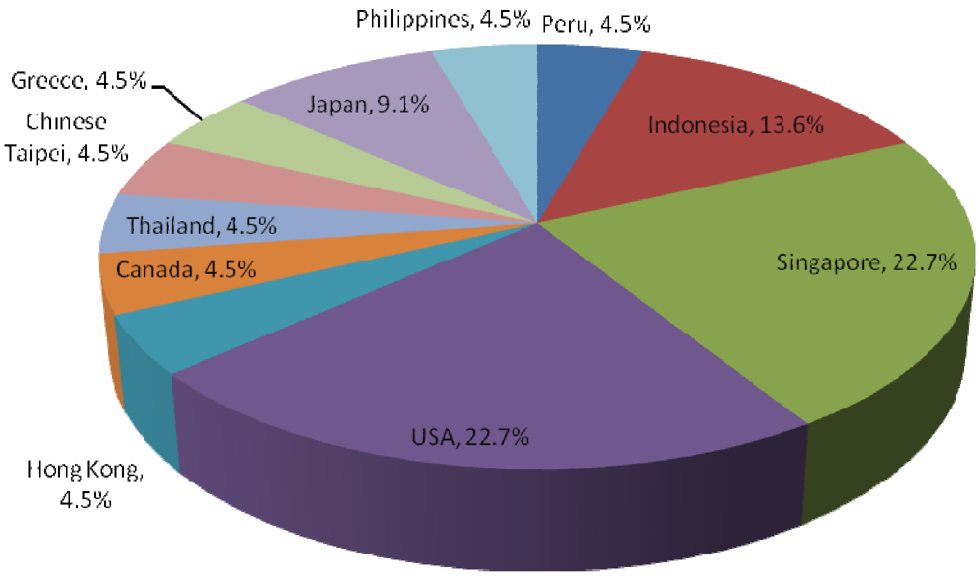
- **Question 4b - Do you believe government should be doing more in future to support the use of Cool Roofs?**

The Majority of respondents felt that their governments should be doing more to promote Cool Roofs.

Answer Options	Response
Disagree	0.0%
Somewhat disagree	3.3%
Neutral	16.7%
Somewhat agree	33.3%
Agree	46.7%



Of those that did agree to any extent, the geographical spread was as follows:



- **Question 4c – Any additional comments:**

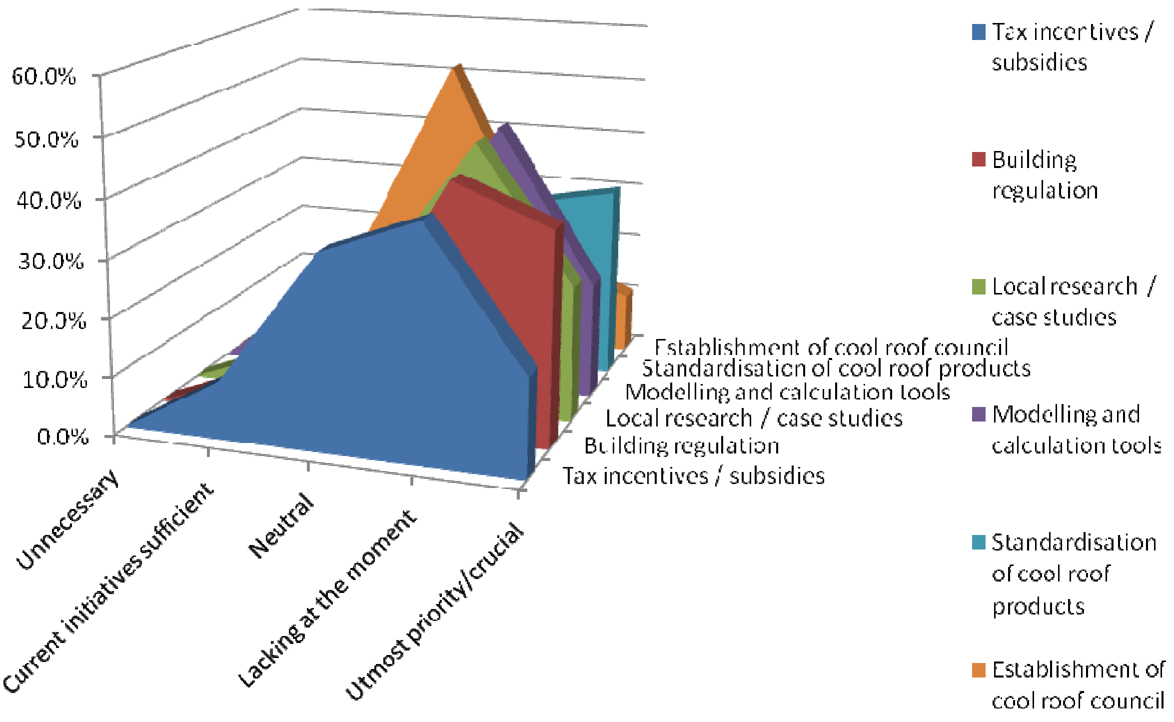
Additional comments were as follows:

- Buildings in Taipei city are closely adjacent, so the light pollution also must be considered. [Chinese Taipei]
- Due to the recent energy crisis caused by big earthquake, Government is ready for promoting incentive program in Cool Roof. [Japan]
- There are many good government initiatives, but the Cool Roof requirements in building energy efficiency standards are in most places too lax. [USA]
- Greater conclusive evidence of the costs and benefits of Cool Roofs is required. [Australia]
- As an EE measure, Cool Roofs should be economically viable by itself rather than with government incentives. [Singapore]
- Immediate alternatives are readily available in the market. Use of white or light coloured coatings, insulation systems, roof gardens, etc. for users to choose from. [Singapore]

Promotion and Encouragement

- **Question 5a - In your opinion, what should be done to further promote and encourage the use of Cool Roofs in your country? (Multiple answers)**

	Unnecessary	Current initiatives sufficient	Neutral	Lacking at the moment	Utmost priority/crucial
Tax incentives / subsidies	0.0%	10.0%	33.3%	40.0%	16.7%
Building regulation	0.0%	6.7%	13.3%	43.3%	36.7%
Local research / case studies	0.0%	6.7%	23.3%	46.7%	23.3%
Modelling and calculation tools	0.0%	13.3%	20.0%	46.7%	20.0%
Standardisation of Cool Roof products	0.0%	13.3%	23.3%	30.0%	33.3%
Establishment of Cool Roof council	3.4%	17.2%	51.7%	17.2%	10.3%

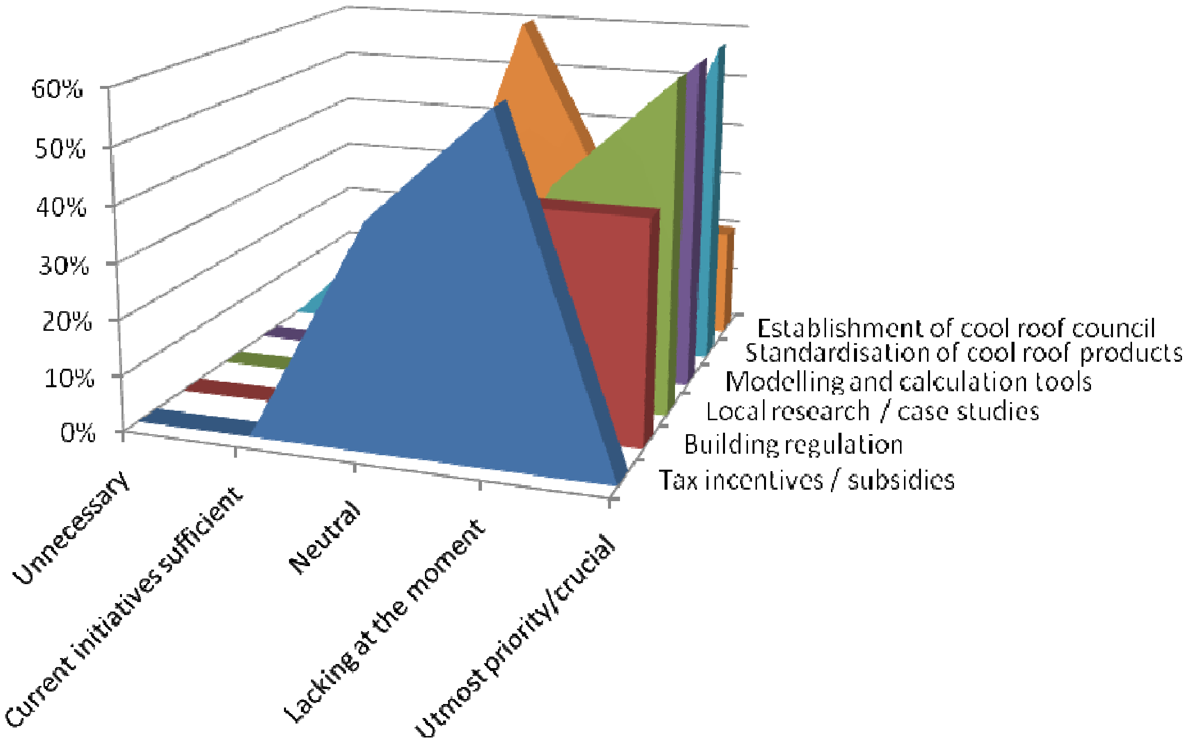


Again, the response from each professional group is interesting in this circumstance:

Academics

Overall, this group felt that most of the suggestions were lacking to some degree. The establishment of a Cool Roof council was not seen as an urgent matter.

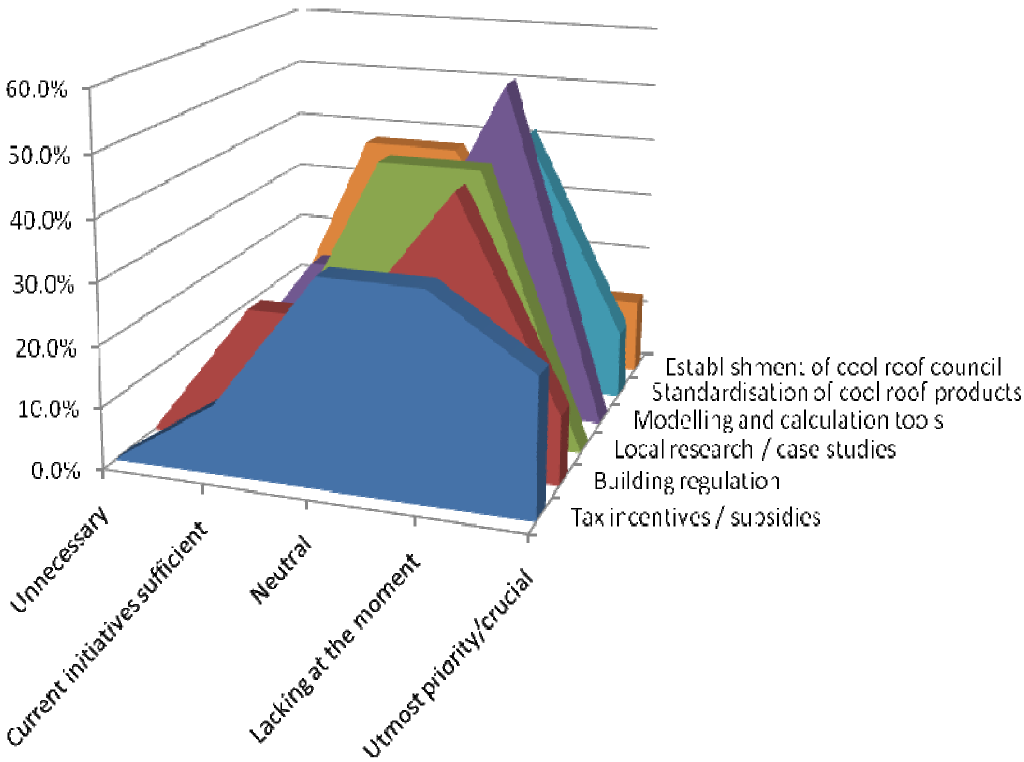
Answer Options	Unnecessary	Current initiatives sufficient	Neutral	Lacking at the moment	Utmost priority/crucial
Tax incentives / subsidies	0%	0%	40%	60%	0%
Building regulation	0%	0%	20%	40%	40%
Local research / case studies	0%	0%	0%	40%	60%
Modelling and calculation tools	0%	0%	0%	40%	60%
Standardisation of Cool Roof products	0%	20%	20%	0%	60%
Establishment of Cool Roof council	0%	0%	60%	20%	20%



<u>Government</u>

Respondents from Government had a wide range of opinions on this issue. The promotion of Cool Roofs through modelling and calculation tools was felt to be most lacking. Again, the establishment of a Cool Roof rating council was not seen as a priority by most.

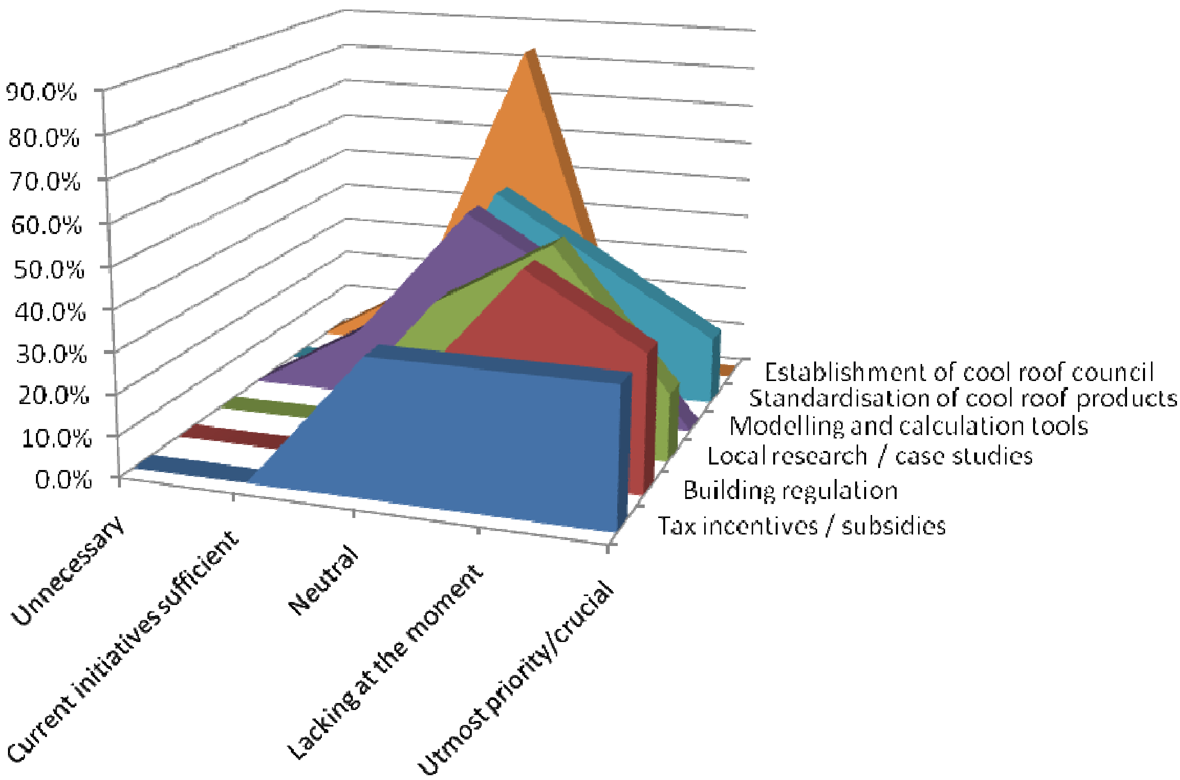
Answer Options	Unnecessary	Current initiatives sufficient	Neutral	Lacking at the moment	Utmost priority/crucial
Tax incentives / subsidies	0.0%	11.1%	33.3%	33.3%	22.2%
Building regulation	0.0%	22.2%	22.2%	44.4%	11.1%
Local research / case studies	0.0%	11.1%	44.4%	44.4%	0.0%
Modelling and calculation tools	0.0%	22.2%	22.2%	55.6%	0.0%
Standardisation of Cool Roof products	0.0%	22.2%	22.2%	44.4%	11.1%
Establishment of Cool Roof council	0.0%	37.5%	37.5%	12.5%	12.5%



Non-Governmental Organisations

For respondents from NGO's, the most pressing issues were a lack of promotion through incentives and subsidies; building regulations; and research. Again, the establishment of a Cool Roof rating council was not seen as a priority by most.

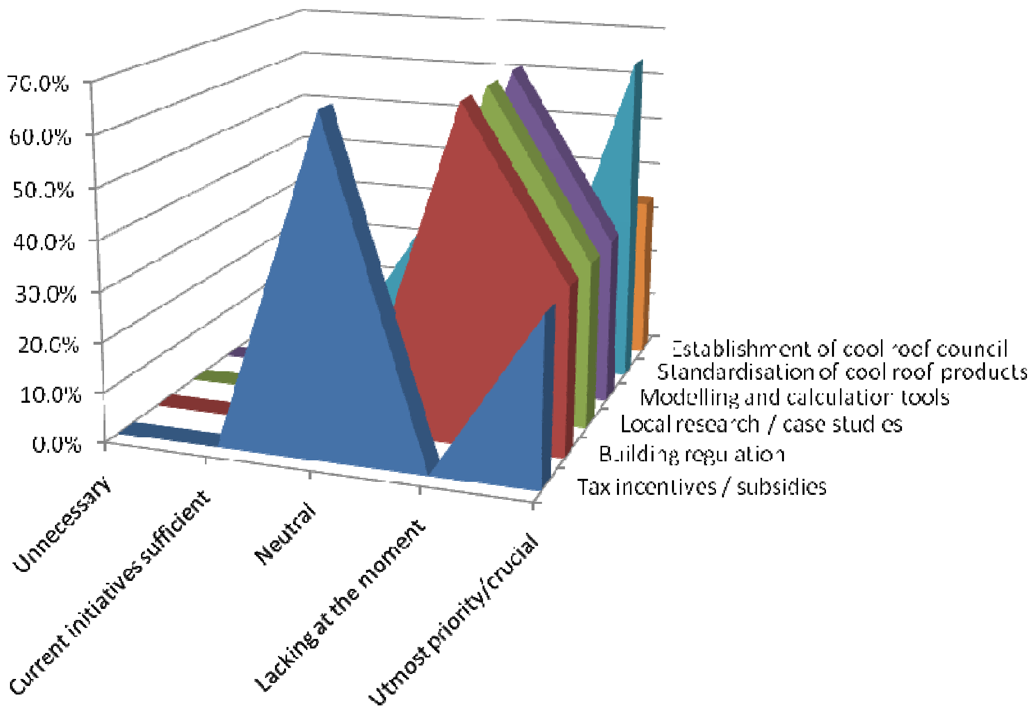
Answer Options	**Unnecessary**	**Current initiatives sufficient**	**Neutral**	**Lacking at the moment**	**Utmost priority/crucial**
Tax incentives / subsidies	0.0%	0.0%	33.3%	33.3%	33.3%
Building regulation	0.0%	0.0%	16.7%	50.0%	33.3%
Local research / case studies	0.0%	0.0%	33.3%	50.0%	16.7%
Modelling and calculation tools	0.0%	16.7%	50.0%	33.3%	0.0%
Standardisation of Cool Roof products	0.0%	0.0%	50.0%	33.3%	16.7%
Establishment of Cool Roof council	0.0%	16.7%	83.3%	0.0%	0.0%


90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Unnecessary
Current initiatives sufficient
Neutral
Lacking at the moment
Utmost priority/crucial
Establishment of cool roof council
Standardisation of cool roof products
Modelling and calculation tools
Local research / case studies
Building regulation
Tax incentives / subsidies

Consultants

The respondents from this group were unanimous in the view that promotion through building regulation, research and modelling/calculation tools was crucially lacking. Standardisation of products was also a key issue, whereas promotion through tax incentives and subsidies was not. Most felt that the establishment of a Cool Roof council was a necessary issue.

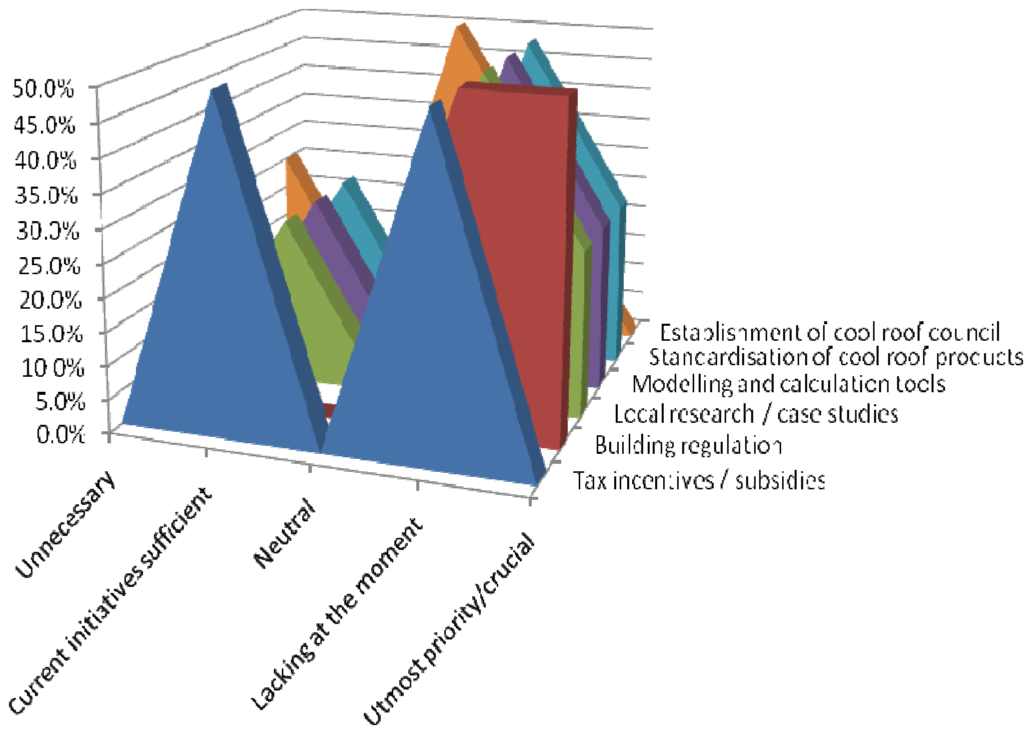
Answer Options	Unnecessary	Current initiatives sufficient	Neutral	Lacking at the moment	Utmost priority/crucial
Tax incentives / subsidies	0.0%	0.0%	66.7%	0.0%	33.3%
Building regulation	0.0%	0.0%	0.0%	66.7%	33.3%
Local research / case studies	0.0%	0.0%	0.0%	66.7%	33.3%
Modelling and calculation tools	0.0%	0.0%	0.0%	66.7%	33.3%
Standardisation of Cool Roof products	0.0%	0.0%	33.3%	0.0%	66.7%
Establishment of Cool Roof council	0.0%	0.0%	33.3%	33.3%	33.3%



Others

The majority of respondents in this category felt that most lacking was prmotion through building regulation, research, modelling/calculation tools and standardisation of products. Opinion was divided on the matter of tax subsidies and incentives. Once more, the establishment of a Cool Roof council was not a priority for most.

Answer Options	**Unnecessary**	**Current initiatives sufficient**	**Neutral**	**Lacking at the moment**	**Utmost priority/crucial**
Tax incentives / subsidies	0.0%	50.0%	0.0%	50.0%	0.0%
Building regulation	0.0%	0.0%	0.0%	50.0%	50.0%
Local research / case studies	0.0%	25.0%	0.0%	50.0%	25.0%
Modelling and calculation tools	0.0%	25.0%	0.0%	50.0%	25.0%
Standardisation of Cool Roof products	0.0%	25.0%	0.0%	50.0%	25.0%
Establishment of Cool Roof council	25.0%	0.0%	50.0%	25.0%	0.0%



- **Question 5b – Any additional comments:**

Additional comments were as follows:

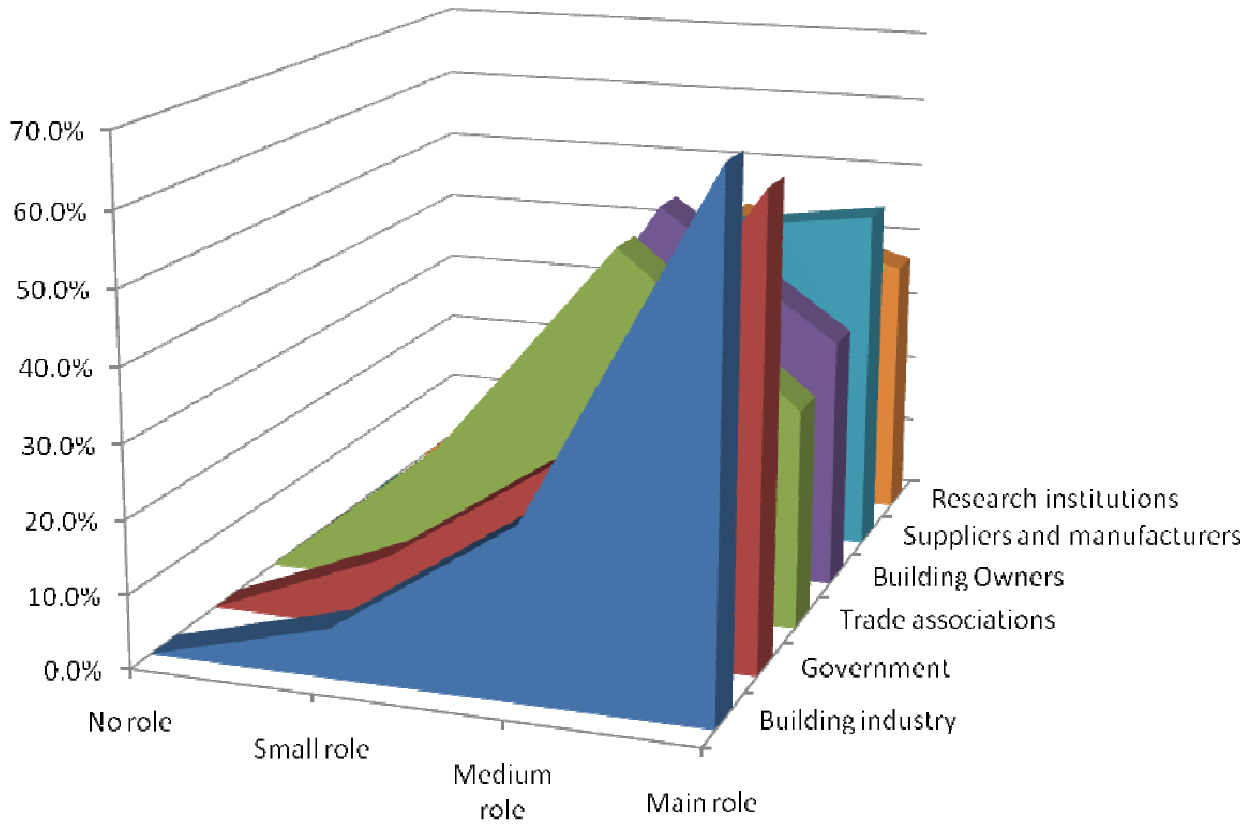
- The U.S. already has a Cool Roof rating council. We could benefit from stronger Cool Roof requirements in building energy efficiency standards; incentives/subsidies for Cool Roofing products other than asphalt shingles & metal (already provided); and research into the city-cooling (heat island mitigation) and climate cooling (negative radiative forcing) benefits of Cool Roofs. [USA]
- So far many incentive measures have been implemented but they are not fix[ed] only for Cool Roofs. BEC in building regulation have been identified in system performance [as] not prescriptive. [Thailand]
- More work [is] needed to move the market for Cool Roofing in sloped roofs; flat-roof (commercial) systems [are] fairly well developed but need to be mandated through codes and other means. [USA]
- For council on Cool Roof [this] would have to be set up by the industry. [Singapore]

Responsibility for Implementation

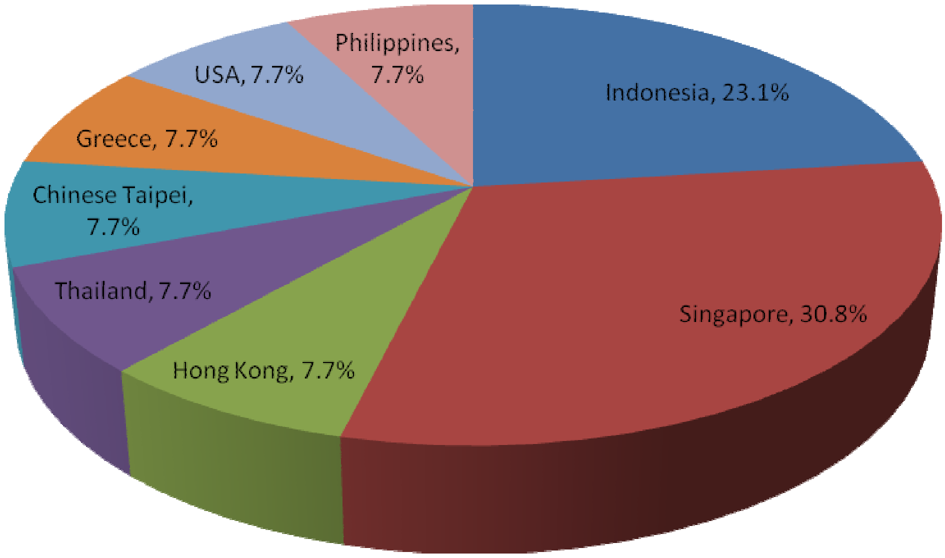
- **Question 6a - What level of responsibility should the following take in encouraging the implementation of Cool Roofs in your country? (Multiple answers)**

The prevailing view was that governments and the building industry should take the main role in encouraging the implementation of Cool Roofs.

Answer Options	No role	Small role	Medium role	Main role
Building industry	0.0%	6.7%	23.3%	70.0%
Government	0.0%	10.0%	26.7%	63.3%
Trade associations	0.0%	20.0%	50.0%	30.0%
Building Owners	0.0%	13.8%	51.7%	34.5%
Suppliers and manufacturers	0.0%	6.9%	44.8%	48.3%
Research institutions	0.0%	20.0%	43.3%	36.7%



The prevalent view above was most vociferous in the following economies – the following chart shows the country of origin of those who felt that Govt and the Building Industry should take the main role:

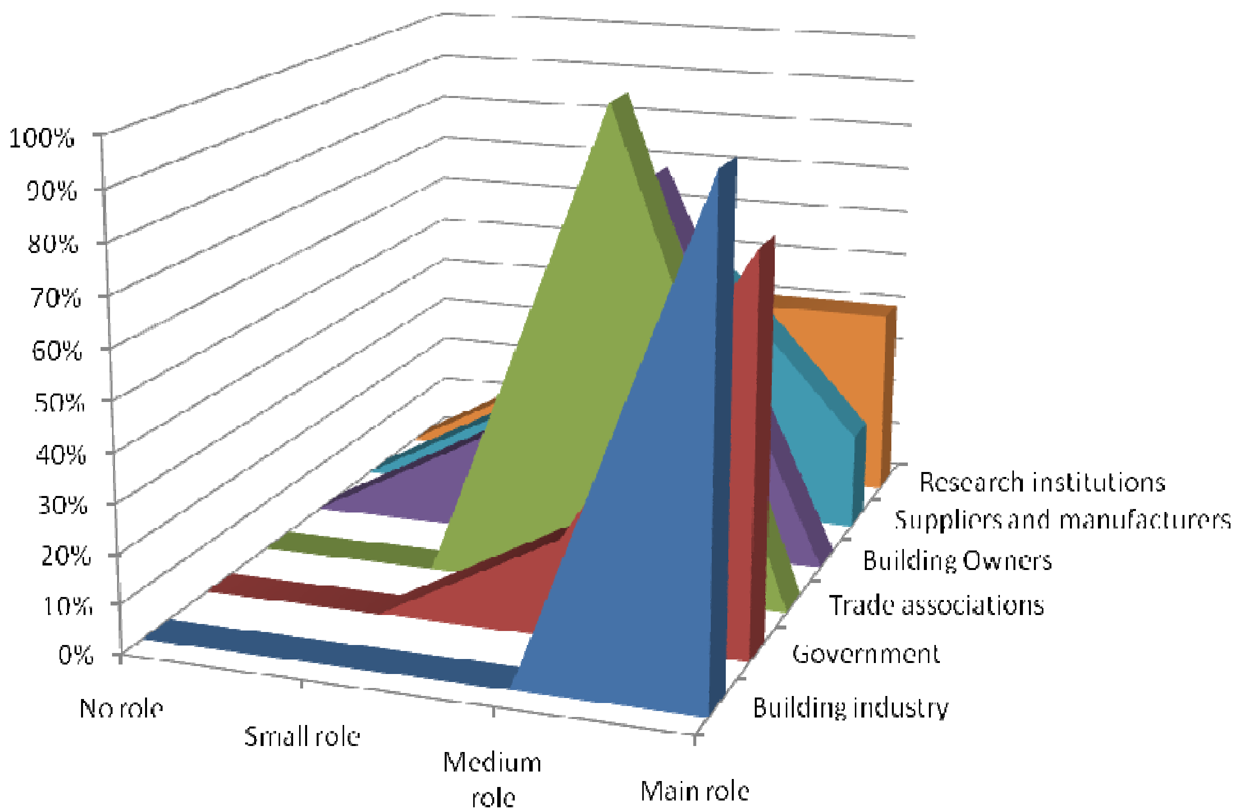


For the most part, the same view was reflected in the individual professional groups:

Academics

This group felt that each party should take some responsibility for encouraging implementation of Cool Roofs, but that the building Industry and Government should take the main roles.

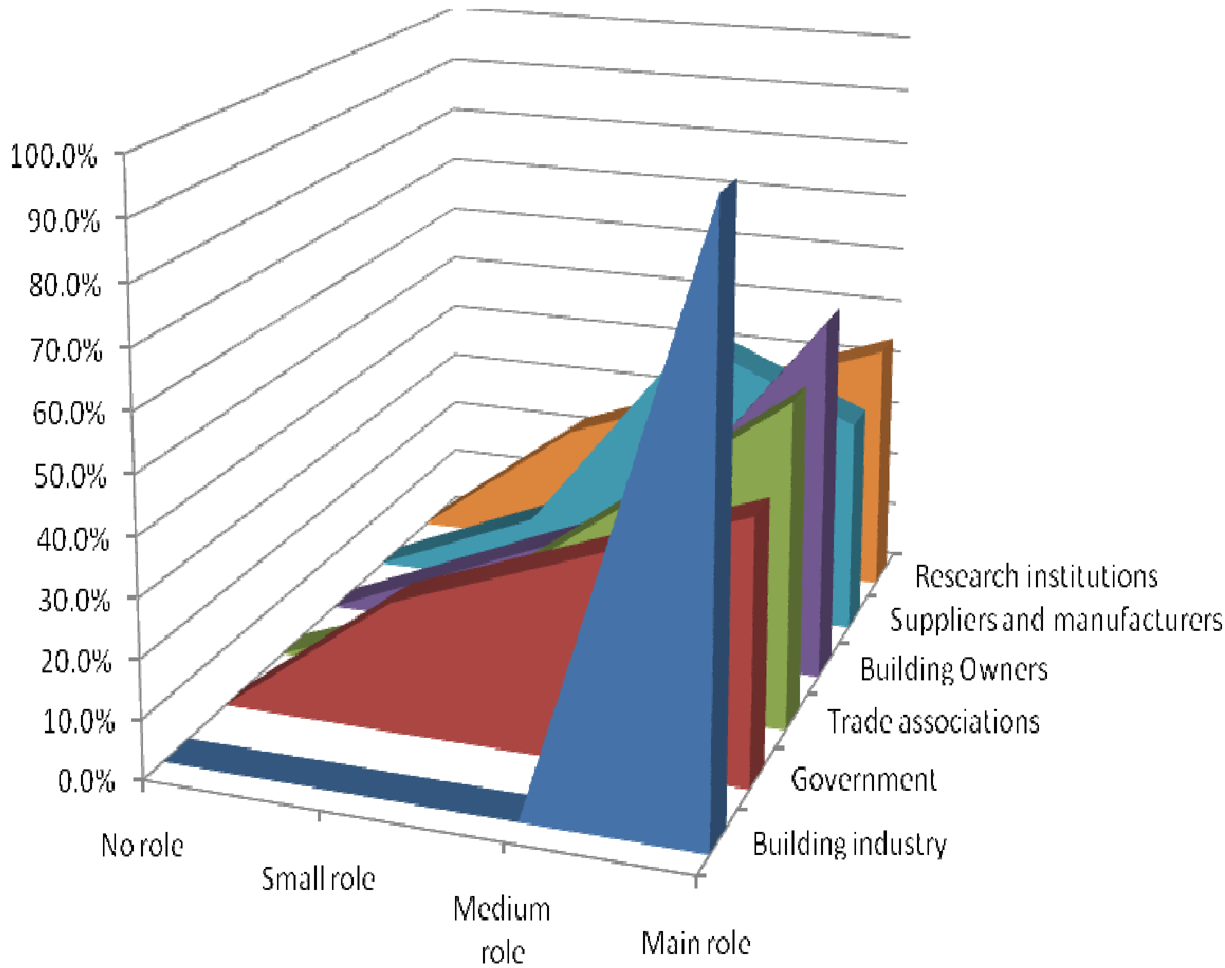
Answer Options	No role	Small role	Medium role	Main role
Building industry	0%	0%	0%	100%
Government	0%	0%	20%	80%
Trade associations	0%	0%	100%	0%
Building Owners	0%	20%	80%	0%
Suppliers and manufacturers	0%	20%	60%	20%
Research institutions	0%	20%	40%	40%



Government

Respondents from government felt that most responsibility lay with the Building industry, followed by Building Owners and Trade Associations. Opinion was divided on the role of Government.

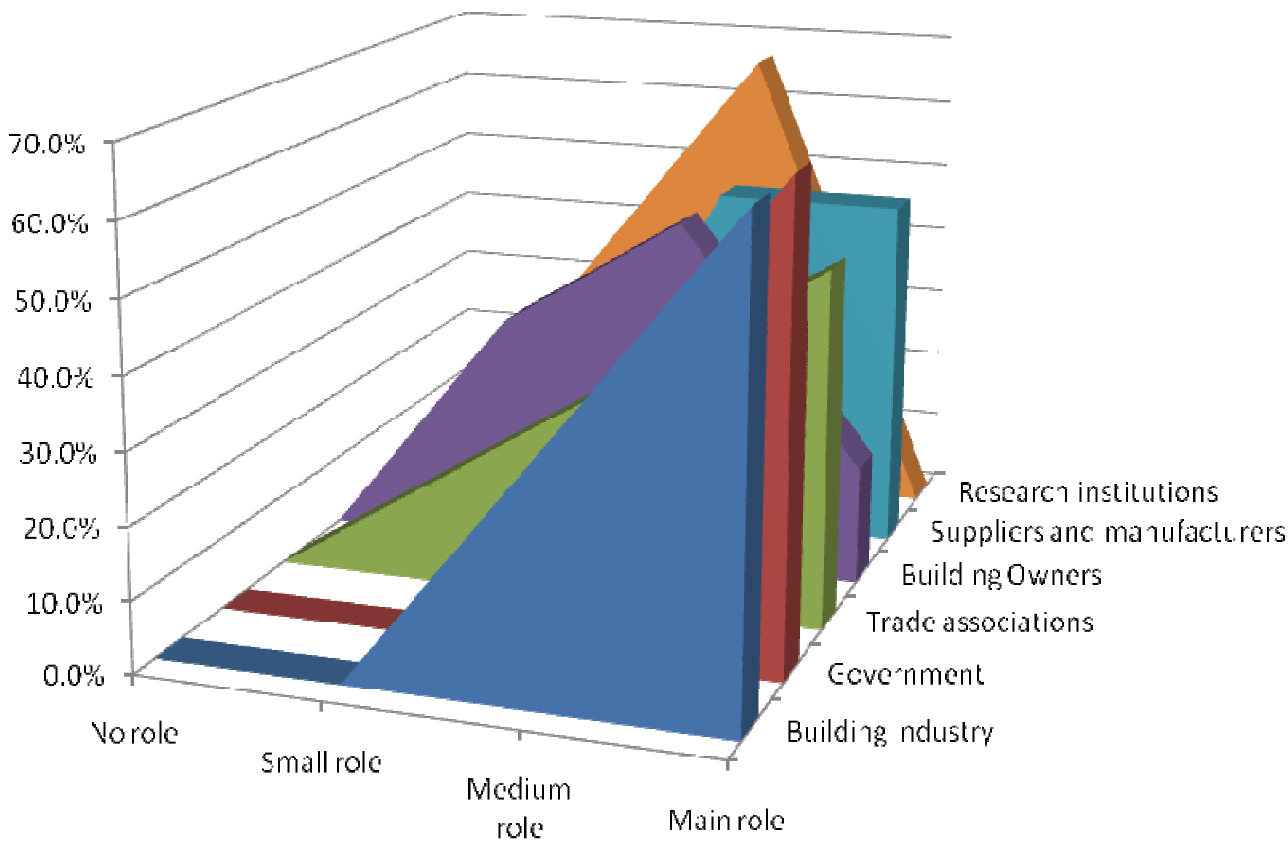
Answer Options	No role	Small role	Medium role	Main role
Building industry	0.0%	0.0%	0.0%	100.0%
Government	0.0%	22.2%	33.3%	44.4%
Trade associations	0.0%	11.1%	33.3%	55.6%
Building Owners	0.0%	12.5%	25.0%	62.5%
Suppliers and manufacturers	0.0%	12.5%	50.0%	37.5%
Research institutions	0.0%	22.2%	33.3%	44.4%



Non-Governmental Organisations

Those in non-governmental organisations felt that the main responsibility lay with the Building Industry and Government. Opinion was divided over who else should take key roles.

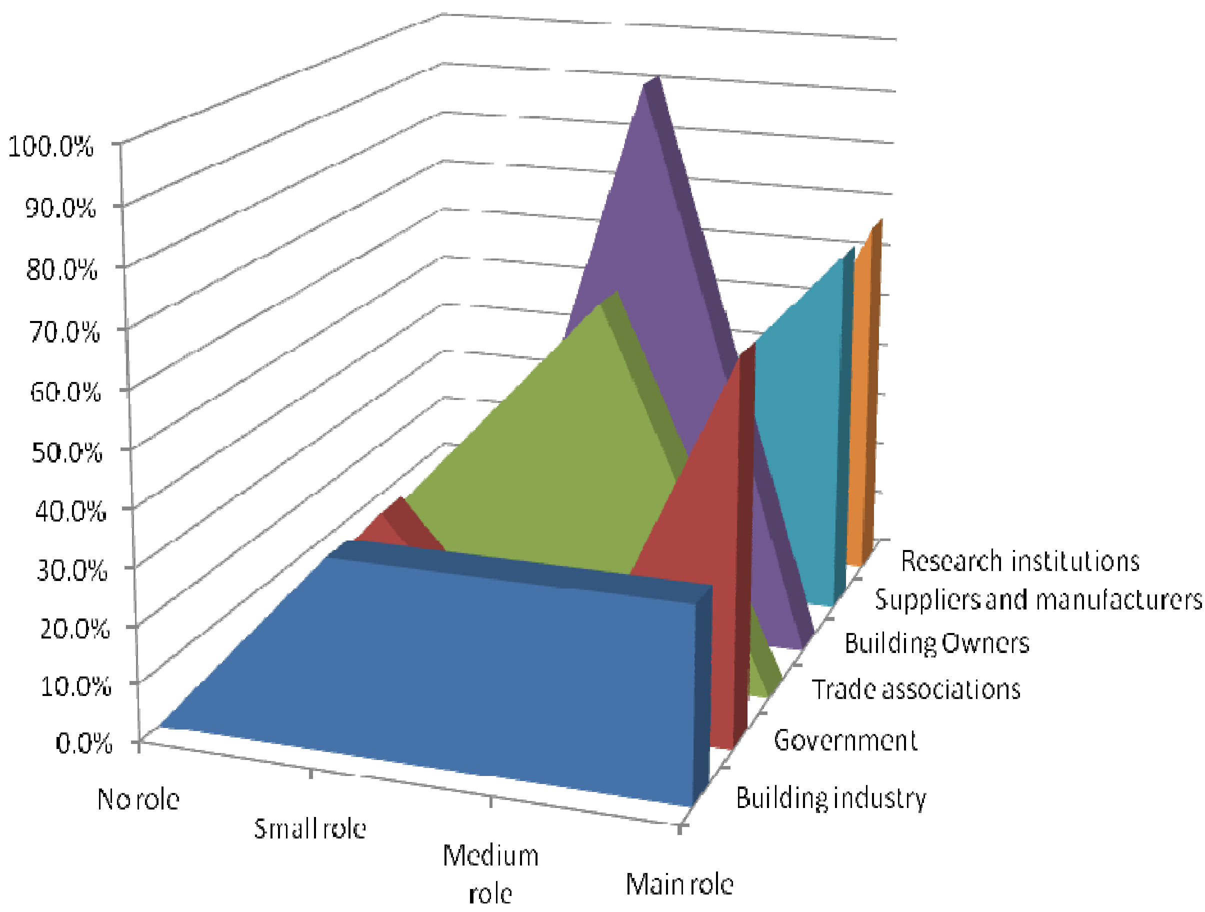
Answer Options	No role	Small role	Medium role	Main role
Building industry	0.0%	0.0%	33.3%	66.7%
Government	0.0%	0.0%	33.3%	66.7%
Trade associations	0.0%	16.7%	33.3%	50.0%
Building Owners	0.0%	33.3%	50.0%	16.7%
Suppliers and manufacturers	0.0%	0.0%	50.0%	50.0%
Research institutions	0.0%	33.3%	66.7%	0.0%



Consultants

The majority of consultants felt that the main roles should be taken by Government, along with the product suppliers/manufacturers as well as research institutions.

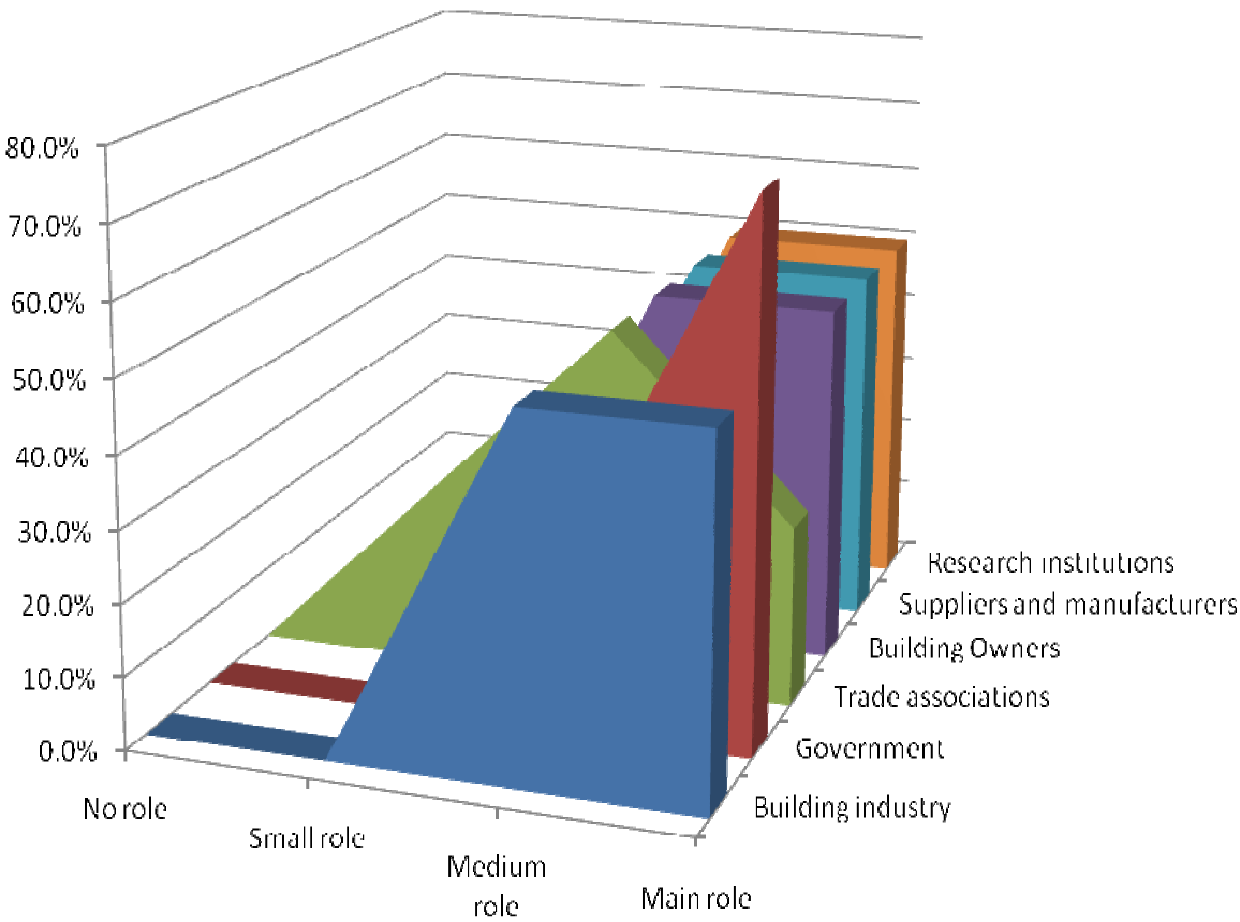
Answer Options	No role	Small role	Medium role	Main role
Building industry	0.0%	33.3%	33.3%	33.3%
Government	0.0%	33.3%	0.0%	66.7%
Trade associations	0.0%	33.3%	66.7%	0.0%
Building Owners	0.0%	0.0%	100.0%	0.0%
Suppliers and manufacturers	0.0%	0.0%	33.3%	66.7%
Research institutions	0.0%	33.3%	0.0%	66.7%



Other

Respondents from this group felt that all parties should take some role, but that government should take the lead.

Answer Options	No role	Small role	Medium role	Main role
Building industry	0.0%	0.0%	50.0%	50.0%
Government	0.0%	0.0%	25.0%	75.0%
Trade associations	0.0%	25.0%	50.0%	25.0%
Building Owners	0.0%	0.0%	50.0%	50.0%
Suppliers and manufacturers	0.0%	0.0%	50.0%	50.0%
Research institutions	0.0%	0.0%	50.0%	50.0%



- **Question 6b - Any additional comments:**

Additional comments were as follows:

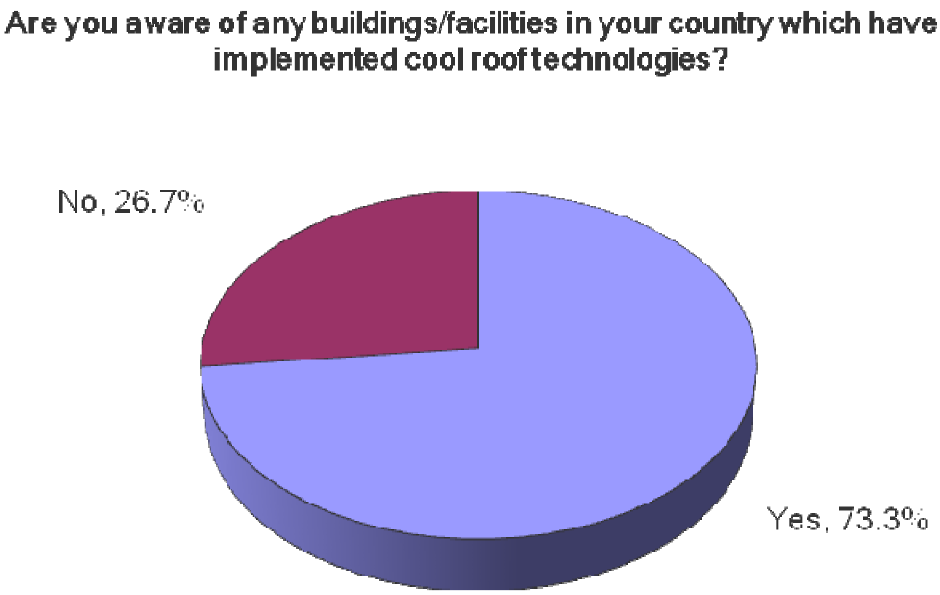
- Role of suppliers & manufacturers should be measured as they would push such initiatives as it is to their advantage. [Singapore]
- Architects and speciality consultants should also adopt a main role to educate and develop the awareness to building owners/users. [Singapore]

4.7 Existing Cool Roofs

- **Question 7a - Are you aware of any buildings/facilities in your country which have implemented Cool Roof technologies?**

The majority of respondents were aware of buildings or facilities within their country which have implemented Cool Roof technologies.

Yes	73.3%
No	26.7%



- **Question 7b - please provide further details below and links to any pages or contacts if possible:**

  The data for such projects as provided was as follows;

- New York City's Cool Roof Initiative has installed over 1 million square feet of Cool Roofs. [USA

- http://www.hiperroof.com/page/home.html [Thailand]

  Google translated version: http://translate.google.com.sg/translate?js=n&prev=_t&hl=en&ie=UTF-8&layout=2&eotf=1&sl=th&tl=en&u=http%3A%2F%2Fwww.hiperroof.com%2Fpage%2Fhome.html

- T-Car industry`s factory Roof, A-brewery`s factory Roof. [Japan]

- Demonstrat[ion] [of] projects in Japan: http://www.env.go.jp/policy/etv/s05_c1.html#03 [Japan]

  Google translated version:
  http://translate.google.com.sg/translate?js=n&prev=_t&hl=en&ie=UTF-8&layout=2&eotf=1&sl=ja&tl=en&u=http%3A%2F%2Fwww.env.go.jp%2Fpolicy%2Fetv%2Fs05_c1.html%2303

- There are many white roofs on commercial buildings, especially in the U.S. SW and SE. [USA]

- Mostly Cool Roof technology implemented in Jakarta only limited on green roof and roof plantation. One example is the project in Springhill group. [Indonesia]

- Some of government buildings and commercial buildings in Taipei city have been implemented Cool Roof technologies. [Chinese Taipei]

- http://eetd.lbl.gov/HeatIsland/PROJECTS/DEMO [USA]

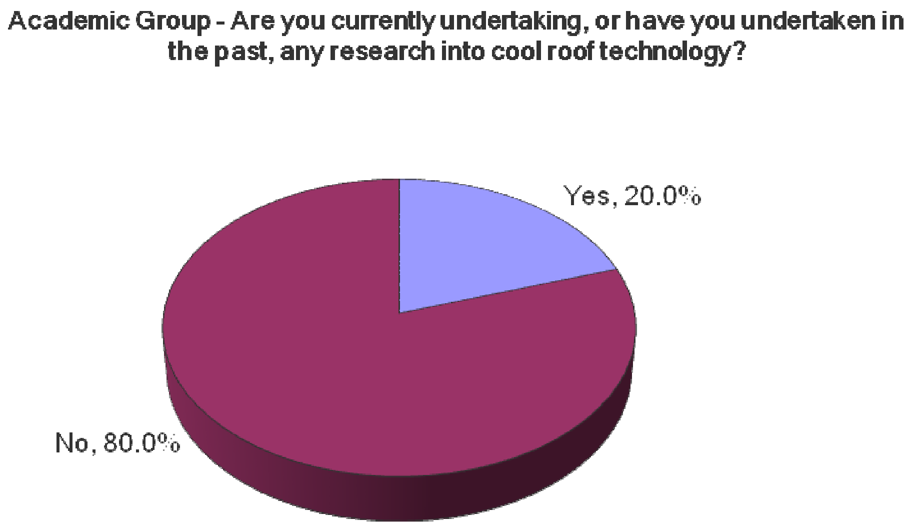
Group 1 – Academia

Research

- **Question 8a - Are you currently undertaking, or have you undertaken in the past, any research into Cool Roof technology?**

Only 20% of respondents from Group 1 – Academia said they were or had been involved in any research into Cool Roof technology.

Yes	20.0%
No	80.0%



- **Question 8b - Which department are you involved in and how many people are involved in the research?**

Those who responded in the affirmative stated the National University of Singapore as their institution.

- **Question 8c - Which areas of Cool Roof research have you focused on? (e.g. material, energy modelling, policy etc.)**

The area they stated to have focused on was the measurement of the reflectance, conductance, surface temperature reduction, cooling [and] energy saving modeling etc.

- **Question 8d - Please provide further details on your research below, with links to any pages if possible:**

They did not provide any links or further details.

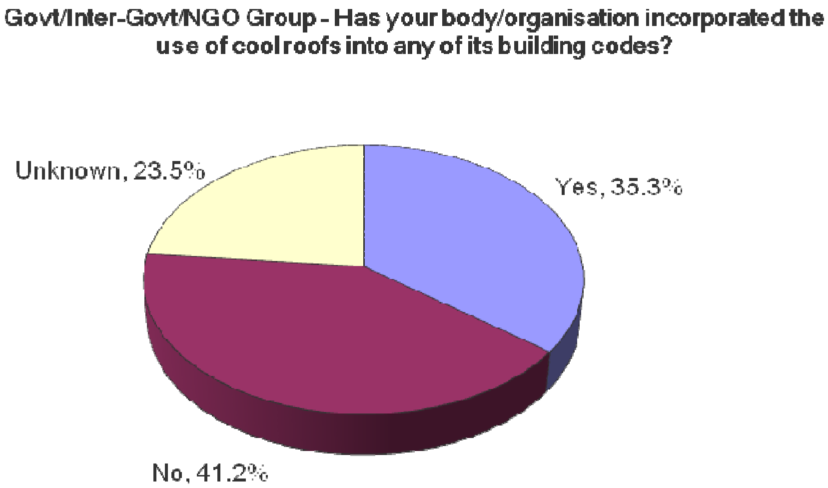
Group 2 – Government / Inter-governmental Organisation / Non-governmental Organisation / Trade Association

Incorporation

- **Question 8a - Has your body/organisation incorporated the use of Cool Roofs into any of its building codes?**

The response to this question was mixed:

Yes	35.3%
No	41.2%
Unknown	23.5%



- **Question 8b - Please provide further details below with links to any pages or documents if possible:**

Further details were provided as follows:

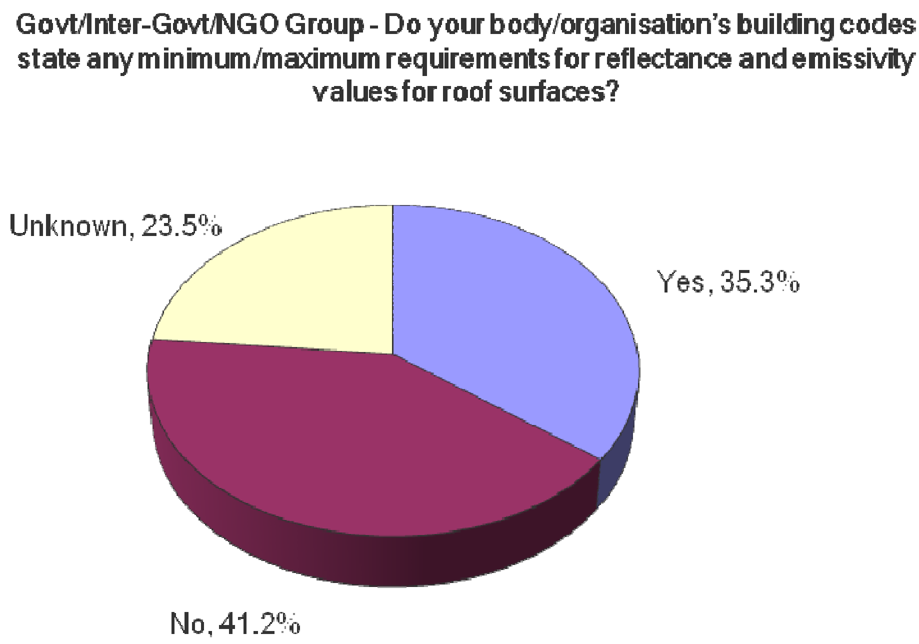
- Standards and guidelines: YES [Canada]
- One of the aims of DANIDA project is developing and establishing Energy Efficiency standards and codes in Indonesia. Various energy efficiency technology will be implemented in 8 pilot projects [Indonesia]
- As [previously] mentioned, the BEC have been identified in system performance, so Cool Roof is one EE material that has been informed to the users. [Thailand]
- For our US code development advocacy activities we continue to support Cool Roofs. [USA]
- None of the several organizations that I'm associated with have building codes. [USA]

Building Codes

- **Question 9a - Do your body/organisation's building codes state any minimum/maximum requirements for reflectance and emissivity values for roof surfaces?**

The responses to this question are identical to the previous question, leading to the conclusion that where the incorporation of Cool Roof into a body's building codes was known to exist it included maximum and minimum requirements for reflectance and emissivity values for the roof surfaces.

Yes	35.3%
No	41.2%
Unknown	23.5%



- **Question 9b - Please provide further details below with links to any pages or documents if possible:**

Further information was provided as follows:

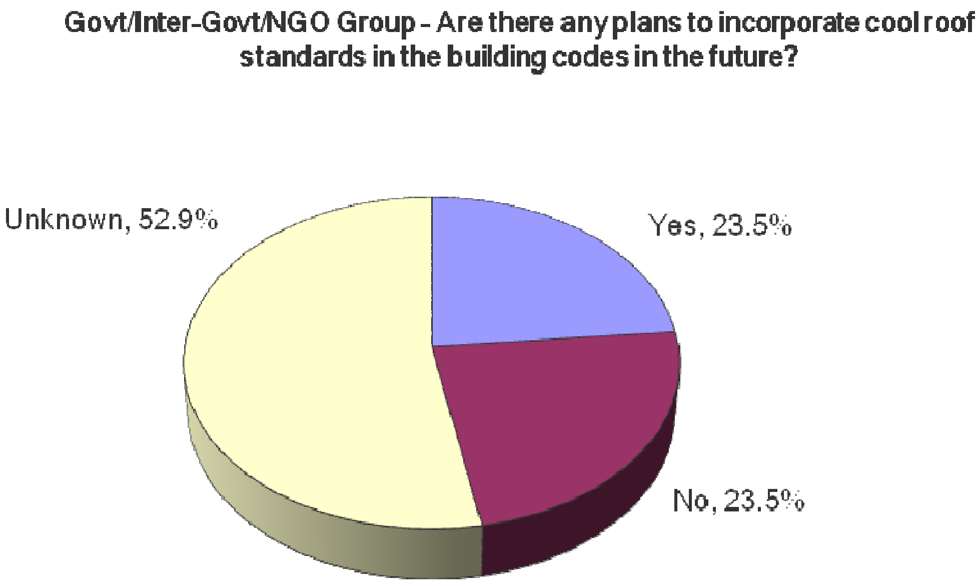
- The minimum albedo is 0.3 for Greenship Certification Indonesia Standard for Building envelope (SNI 03-6389:2010):
  Max. Thermal Transmittance (W/m2.K) < 50 kg/m2 roof -- Ur max 0.4 50 - 230 kg/m2 roof -- Ur max 0.8 > 230 kg/m2 roof -- Ur max 1.2
  Equivalent Temperature Difference of Roof (TDeq) < 50 kg/m2 roof -- TDeq 24 50 - 230 kg/m2 roof -- TDeq 20 > 230 kg/m2 roof -- TDeq 16 50
  [Indonesia]
- So far it is under consideration [but] the enforcement is not effective. [Thailand]

Future Plans

- **Question 10a - Are there any plans to incorporate Cool Roof standards in the building codes in the future?**

This question prompted a higher level of uncertainty:

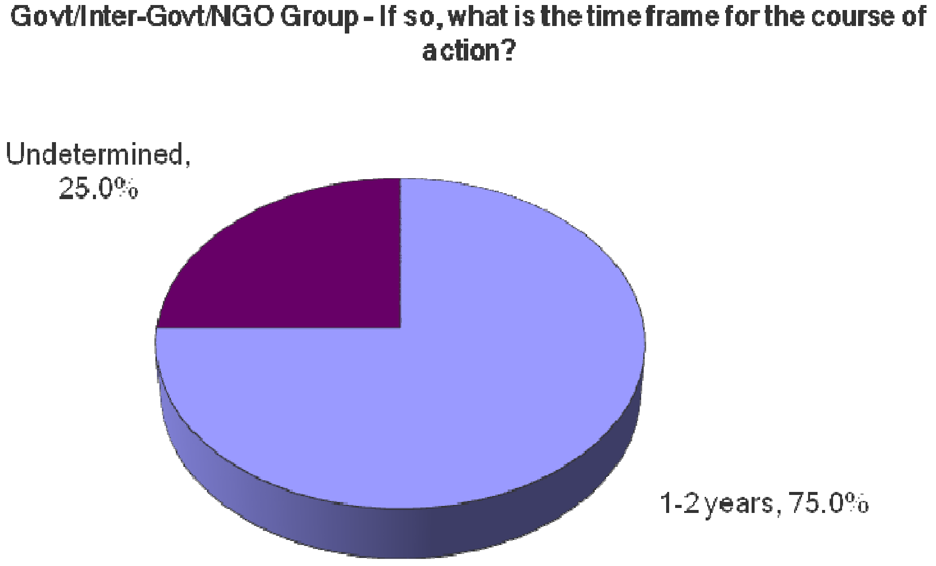
Yes	23.5%
No	23.5%
Unknown	52.9%



- **Question 10b - What is the time frame for the course of action?**

For those responded in the affirmative, 75% specified a short time frame for incorporation, whereas 25% stated it was undetermined:

1-2 years	75.0%
3-5 years	0.0%
6-10 years	0.0%
10+ years	0.0%
Undetermined	25.0%



Group 7 – Consultant (e.g. Architect, Engineer, Designer, Building Professional)

Use of Cool Roofs

- **Question 8a - Have you specified the implementation of Cool Roofs for any of your buildings or projects?**

None of the respondents stated that they had specified the implementation of Cool Roofs for any of their projects or buildings.

Group 8 – Other

Experience

- **Question 8 - If you have any direct experience with Cool Roofs, either through research, policy, use or manufacture and have any comments you would like to share, please feel free to add them below:**

The only comment in this section was as follows:

It is necessary paying [sic] respect for each country`s landscape [and] culture when [a] trader introduce[s] colours. [Japan]

General Comments

- **If you have any other comments on the application and/or implementation of Cool Roofs, please feel free to add them below:**

The additional comments were as follows:

- We would not put Cool Roof [as] standard in the BEC directly because we set BEC standard in system performance. However, in parallel to make it more effective we set the standard of some EE material and equipment that we think they have [a] significant impact [on] energy conservation. [Thailand]
- Hope the APEC, together with industry, will raise awareness for Cool Roofs implementation to enhance energy savings. [Singapore]
- I reside and work predominantly in the US and specifically California. We have significant Cool Roof achievements in flat roofs in the US and are still working through hurdles with adoption of steep Cool Roof products. [USA]
- Japan has been making superior performance building materials using the performance evaluation method, and promoted the comprehensive improvement of the residential environment. I think, in the ASEAN region, climate, culture, lifestyle and architectural styles vary in each country, so regulations and standards must be established by each country taking into account such variations. [Japan]
- [A] worldwide information exchange is essential in building reliable product standard[s]. Many discussions should be made with CRRC to make mutual understandings in rating coating colours vs. heat reflectant effect. [Japan]

Conclusions from the survey

Most participants agreed that Cool Roofs play a role as an energy efficiency measure in buildings and had some impact upon reducing energy use.

The main barriers to Cool Roof implementation were thought to be a lack of awareness on the subject, leading to a lack of the skills and expertise necessary, together with little or no regulation or research on the topic. A lack of valid case studies to back up scientific data was also cited, as well as cost-benefit analyses.

In addition, despite a wide variety of products on the CRRC website, it was felt that, certainly in the USA where the predominant domestic roof covering is shingles, there was a lack of product choice in terms of Cool Roof shingles.

The general view was that government initiatives for promoting Cool Roofs are currently lacking and that governments should be doing more in this regard. Lax building energy efficiency standards were cited as one of the main issues in jurisdictions outside of California.

Most felt that promotion through building regulations was the most vital initiative currently lacking. Also cited were a lack of tax incentives/subsidies, research/case studies and modelling/calculation tools.

The establishment of Cool Roof Councils was for the most part not seen as a key ingredient by most respondents, the success of the CRRC notwithstanding – many respondents felt that other matters were more of a priority and might be more effective, such as requirements for Cool Roof standards through building regulations and codes.

Most felt that on the whole, the main responsibility for encouraging implementation of Cool Roofs in the various economies should rest with the Building Industries and Governments in each respective economy. However, all respondents felt that each stakeholder should take some form of responsibility and that it was not solely industry and government who were the drivers. There was also a call for architects and speciality consultants to take a key role in promoting the use of Cool Roof to clients.

In order to further promote Cool Roofs on a global scale, it was suggested that the establishment of a worldwide information exchange would help to build reliable product standards.

The recent earthquake in Japan has left the Government in a position where it is ready to introduce an incentive program to promote Cool Roofs, both through necessity in terms of energy efficiency, and opportunity due to the sheer scale of rebuilding required.

Some economies such as Chinese Taipei have installed Cool Roof products on some public building, but to date no clear mandate or requirement exists. For most South East Asian economies, mitigation of solar gain through roofs is limited to green roofs and roof plantations.

APPENDIX D – Original Survey Questionnaire

Page 1

- **Introduction**

Cool Roofs are roofing systems that have been designed to reflect the sun's energy from roof surfaces, thereby reducing the heat transfer into the buildings and reducing the cooling energy loads therein.

The extent of Cool Roof implementation varies considerably between different eies and geographic regions. The reasons for this also vary; for example, lack of awareness, incentives or institutions to drive forward use of Cool Roofs. The objective of this survey is thus: to better understand the current state of Cool Roof policy, industry and applications from different stakeholders' perspectives across different regions.

This survey, commissioned by Building System & Diagnostics (BSD) on behalf of the Asia-Pacific Economic Cooperation group (APEC), will form part of a research study into the application of Cool Roofs across the APEC economies.

Responses to this survey will be strictly confidential, will not be redistributed and will only be used as part of informing the study.

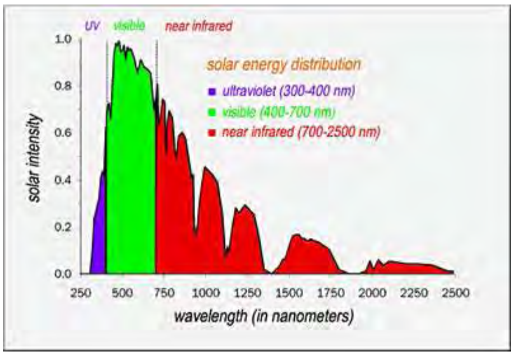
There are no more than 12 questions in total and it should only take a few minutes to complete.

Page 2

- **Cool Roofs**

Cool Roofs are roof products made from highly reflective and emissive materials that can significantly reduce the temperature of the roof and subsequently transfer of heat through the roof. To understand how Cool Roof works, it is essential to understand the scientific properties of Cool Roof, i.e. solar reflectance and thermal emittance.

Solar energy intensity varies over wavelengths from about 250 to 2500 nanometres. White or light coloured Cool Roof products reflect visible wavelengths. Coloured Cool Roof products reflect in the infrared energy range:

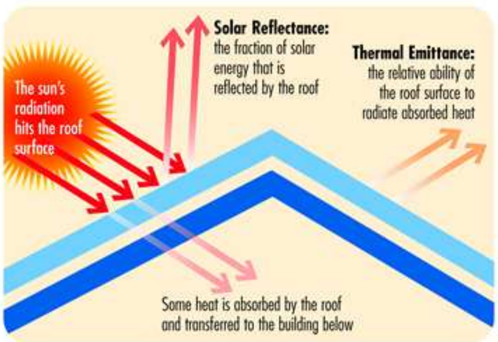


Source: Lawrence Berkeley National Laboratory[6]

On a hot, summer, sunny day, a black roof that reflects 5 percent of the sun's energy and emits more than 90 percent of the heat it absorbs can reach 180°F (82°C).

A metal roof will reflect the majority of the sun's energy while releasing about 25 percent of the heat that it absorbs and can warm to 160°F (71°C).

A Cool Roof will reflect and emit the majority of the sun's energy and reach a peak temperature of 120°F (49°C):



Source: Cool Roof Rating Council[2]

Page 3

- **Personal Information**

Please provide the following information:

- Name
- Email
- Organisation
- Designation
- Country

Page 4

- **Question 1**

Do you agree that Cool Roofs play a role as an energy efficiency measure in buildings?

1) Disagree
2) Somewhat disagree
3) Neutral
4) Somewhat agree
5) Agree

Please indicate the level of impact that you feel Cool Roofs have in reducing energy use in buildings:

1) Negative impact
2) Zero: no impact
3) A little benefit
4) Some benefit
5) Substantial benefits

Please provide further comments to support, if any:

Page 5

- **Question 2**

Are you aware of any initiatives by your government (national or regional/local) which promote the implementation of Cool Roofs?

- Yes
- No

If Yes, please provide further details on the initiatives below:

Page 6

- **Question 3**

What do you consider are the current barriers to the implementation of Cool Roofs? Please rate each in terms of the significance as a barrier: 1 being no barrier and 5 being a prohibitive issue:

- High capital expenditure
- Lack of awareness
- Lack of government incentives (e.g. tax subsidies)
- Lack of regulation
- Lack of research, case studies
- Lack of available products/technologies
- Lack of skills and expertise

1) No barrier (not an issue)
2) Minor issue
3) Fairly significant issue
4) Major issue
5) Prohibitive issue (irresolvable barrier)

Please use space below for any barriers, potential or existing, of which you are aware that are not listed above, or any additional comments you may have:

Page 7

- **Question 4**

How would you rate current government initiatives in promoting the use of Cool Roofs?

1) Completely insufficient
2) Somewhat insufficient
3) Neutral
4) Somewhat sufficient
5) Completely sufficient

Do you believe government should be doing more in future to support the use of Cool Roofs?

1) Disagree
2) Somewhat disagree
3) Neutral
4) Somewhat agree
5) Agree

Please add any additional comments below:

Page 8

- **Question 5**

In your opinion, what should be done to further promote and encourage the use of Cool Roofs in your country? Please rate in terms of priority and effectiveness:

- Tax incentives / subsidies
- Building regulation
- Local research / case studies
- Modelling and calculation tools
- Standardisation of Cool Roof products
- Establishment of Cool Roof council

1) Unnecessary: initiatives should be removed
2) Current initiatives already sufficient
3) Neutral
4) Lacking at the moment: should consider improving
5) Utmost priority/crucial: should establish asap

Please add any additional comments below:

Page 9

- **Question 6**

What level of responsibility should the following take in encouraging the implementation of Cool Roofs in your country?

- Building industry
- Government
- Trade associations
- Building Owners
- Suppliers and manufacturers
- Research institutions

1) No role
2) Small role
3) Medium role
4) Main role

Please add any additional comments below:

Page 10

- **Question 7**

Are you aware of any buildings/facilities in your country which have implemented Cool Roof technologies?

Yes
No

If Yes, please provide further details below and links to any pages or contacts if possible:

Page 11

- **Question Logic Split**

Please select the industry you best represent

1) Academia
2) Government
3) Intergovernmental Organisation (e.g. United Nations, World Bank)
4) Trade Association
5) Non-governmental Organisation / Think Tank
6) Building Owner
7) Building Tenant
8) Cool Roof Supplier / Manufacturer
9) Cool Roof Installer
10) Consultant (e.g. Architect, Engineer, Designer, Building Professional)
11) Other (please specify)

Page 12 - G1 - Academia

- **Question 8**

Are you currently undertaking, or have you undertaken in the past, any research into Cool Roof technology?

- Yes
- No

If yes, which department are you involved in and how many people are involved in the research?

Which areas of Cool Roof research have you focused on? (e.g. material, energy modelling, policy etc.)

Please provide further details on your research below, with links to any pages if possible:

<u>Page 13 - G2 - Government, Inter-Governmental Organisation, Trade Assoc, Non-Governmental Organisation</u>

- **Question 8**

Has your body/organisation incorporated the use of Cool Roofs into any of its building codes?

Yes
No

If yes, please provide further details below with links to any pages or documents if possible:

<u>Page 14</u>

- **Question 9**

Do your body/organisation's building codes state any minimum/maximum requirements for reflectance and emissivity values for roof surfaces?

- Yes
- No

If yes, please provide further details below with links to any pages or documents if possible:

<u>Page 15</u>

- **Question 10**

Are there any plans to incorporate Cool Roof standards in the building codes in the future?

- Yes
- No

If so, what is the time frame for the course of action?

- 1-2 years
- 3-5 years
- 6-10 years
- 10+ years
- Undetermined

Page 16 - G3 - Cool Roof Supplier/Manufacturer

- **Question 8**

Do you manufacture or supply Cool Roof products?

- Yes
- No

If so, do you employ any testing methods for your Cool Roof products?

- Yes
- No

If yes, please give details below:

Page 17 - G4 – Cool Roof Installer

- **Question 8**

Have you installed any Cool Roof technology on any of your projects?

- Yes
- No

If so, please give details of the type of project and product used:

Page 18 - G5&7 - Building Owner / Consultant (Building Professional, Architect, Designer, Engineer etc.)

- **Question 8**

Have you specified the implementation of Cool Roofs for any of your buildings or projects?

- Yes
- No

If so, please give details of the type of project and product used:

From your experience, would you say such use has been worthwhile?

- Yes
- No

Please give any details and reasons for your response:

Page 19 - G6 – Building Tenant

- **Question 8**

Has any Cool Roof technology been installed on any of the buildings you have occupied?

- Yes
- No

If so, from your experience, would you say such use has been worthwhile?

- Yes
- No

Please give any details and reasons for your response:

Page 20 - G8 - Other

- **Question 8**

If you have any direct experience with Cool Roofs, either through research, policy, use or manufacture and have any comments you would like to share, please feel free to add them below:

Page 21 - G4,5,6&7

- **Question 9**

How would you evaluate the energy efficient properties of the Cool Roof materials that you have used?

- Excellent
- Good
- OK
- Poor
- Very Poor

How would you evaluate the energy efficient performance of Cool Roofs that you have used?

- Excellent
- Good
- OK
- Poor
- Very Poor

Page 22

- **Comments**

If you have any other comments on the application and/or implementation of Cool Roofs, please feel free to add them below:

End of survey

APPENDIX D - Summary of Existing Cool Roof Policies

Below is a short summation of each standard.

CALIFORNIA

California Green Building Standards Code (CALGreen)

On January 12, 2010, the California Building Standards Commission unanimously adopted the first state-wide mandatory Green Buildings Standards Code under the name CALGreen. The standard will take effect January 2011. These regulations are intended to reduce state-wide greenhouse gas emissions, energy consumption, and water use. Compliance will be enforced by government agencies, and will cover buildings of all occupancy types. It will be integrated into existing California building codes and regulations.

State jurisdictions have the option to adopt Tier 1 or Tier 2 of the green code, if they want to be considered a California green community. Tier 1 meets the Savings by Design, Healthcare Modelling Procedures requirements. Tier 2 exceeds the Savings by Design requirements by a minimum of 15%. Both tiers specify Cool Roof requirements.

The CALGreen Code[124] Cool Roofing specifications can be viewed in section A4.106.5, starting on page 67, and under the Heat Island effect: Cool Roof (section A5.106.11.2), page 104. Exceptions are provided for roof constructions that have a thermal mass over the roof membrane with a weight of at least 25 lb/ft^2.

Tier 1 Cool Roof Requirements					
Roof Slope	Roof Weight	Climate Zone	Minimum		
			3-year SR	Thermal Emittance	SRI
≤ 2:12	N/A	13 & 15	0.55	0.75	64
> 2:12	< 5 lbs/ft^2	10 - 15	0.20	0.75	16
	≥ 5 lbs/ft^2	1 - 6	0.15	0.75	10
Tier 2 Cool Roof Requirements					
≤ 2:12	N/A	2, 4, 6 - 15	0.65	0.85	78
> 2:12	N/A	2, 4, 6 - 15	0.23	0.85	20

Section A5.205.3.9, page 112, states exceptions for roofing products not certified shall assume the following default reflectance/emittance values: Asphalt shingles = 0.08 / 0.75 All other roofing products = 0.10 / 0.75

The CALGreen Code also sets VOC content limits for roof coatings (Table 4.504.3 and 5.504.4.3), as well as VOC limits for sealants and adhesives (Table 4.504.2 and 5.504.4.1). Section A5.205.3.9.4 of the code details liquid applied coating specifications.

[124] http://www.documents.dgs.ca.gov/bsc/CALGreen/2010_CA_Green_Bldg.pdf

You can learn more from the California Building Standards Commission website at http://www.bsc.ca.gov/default.htm.

California 2008 Building Energy Efficiency Standards for Residential and Non-residential Buildings (California Title 24)

Section 10-113 – Certification and Labelling of Roofing Product Reflectance and Emittance

This section establishes rules for implementing labelling and certification requirements relating to reflectance and emittance for roofing products for showing compliance with Sections 141, 142, 143(a)1, 149(b)1B, 151(f)12, 152(b)1H, and 152(b)2 of Title 24, California Code of Regulations, Part 6. This section also provides for designation of the Cool Roof Rating Council (CRRC) as the supervisory entity responsible for administering the state's certification program for roofing products, provided CRRC meets specified criteria.

(a) **Labelling Requirements.**

Every roofing product installed in construction to take compliance credit or meet the Prescriptive requirements for reflectance and emittance under Sections 141, 142, 143(a)1, 149(b)1B, 151(f)12, 152(b)1H or 152(b)2 shall have a clearly visible packaging label that lists the emittance and the initial and 3-year aged reflectance tested in accordance with CRRC-1.

Packaging for liquid-applied roof coatings shall state the product meets the requirements specified in Section 118(i) 4.

(b) **Certification Requirements.**

Every roofing product installed in construction to take compliance credit or meet the Prescriptive requirements for reflectance and emittance under Sections 141, 142, 143(a)1, 149(b)1B, 151(f)12, 152(b)1H or 152(b)2 shall be certified by CRRC or another supervisory entity approved by the Commission pursuant to Section 10-113(c).

Section 118 – Mandatory Requirements for Insulation and Roofing Products

(i) **Roofing Products Solar Reflectance and Thermal Emittance.**

1. In order to meet the requirements of Sections 141, 142, 143(a)1, 149(b)1B, 151(f)12, 152(b)1H or 152(b)2, a roofing product's thermal emittance and 3-year aged solar reflectance shall be certified and labelled according to the requirements of Section 10-113.

EXCEPTION to Section 118(i)1: Roofing products that are not certified according to Section 10-113 shall assume the following default aged reflectance/emittance values:

A. For asphalt shingles, 0.08/0.75

B. For all other roofing products, 0.10/0.75

2. If CRRC testing for 3-year aged reflectance is not available for any roofing products, the 3-year aged value shall be derived from the CRRC initial value using the equation R_{aged} = [0.2+0.7[$\rho_{initial}$-0.2], Where $\rho_{initial}$ = the initial Solar Reflectance.

3. Solar Reflectance Index (SRI), calculated as specified by ASTM E 1980-01, may be used as an alternative to thermal emittance and 3-year aged solar reflectance when complying with the requirements of Sections 141, 142, 143(a)1, 149(b)1B, 151(f)12, 152(b)1H.,or 152(b)2. SRI calculations shall be based on moderate wind velocity of 2-6 meters per second. The SRI shall be calculated based on the 3-year aged reflectance value of the roofing products.

4. Liquid applied roof coatings applied to low-sloped roofs in the field as the top surface of a roof covering shall:

A. Be applied across the entire roof surface to meet the dry mil thickness or coverage recommended by the coating manufacturer, taking into consideration the substrate on which the coating is applied, and
B. Meet the minimum performance requirements listed in TABLE 118-B or the minimum performance requirements of ASTM C836, D3468, D6083, or D6694, whichever are appropriate to the coating material.

EXCEPTION 1 to Section 118(i)4B: Aluminium-pigmented asphalt roof coatings shall meet the requirements of ASTM D2824 or ASTM D6848 and be installed as specified by ASTM D3805.

EXCEPTION 2 to Section 118(i)4B: Cement-based roof coatings shall contain a minimum of 20 percent cement and shall meet the requirements of ASTM C1583, ASTM D822, and ASTM D5870.

Section 143 – Prescriptive Requirements for Building Envelopes

A building complies with this section by being designed with and having constructed and installed either (1) envelope components that comply with each of the requirements in Subsection (a) for each individual component and the requirements of Subsection (c) where they apply, or (2) an envelope that complies with the overall requirements in Subsection (b) and the requirements of Subsection (c) where they apply. When making calculations under Subsection (a) or (b), all of the rules listed in Section 141(c)1, 4, and 5 shall apply.

(a) **Envelope Component Approach.**

1. **Exterior roofs and ceilings.** Exterior roofs and ceilings shall:

A. Roofs. All roofing products shall meet the requirements of Section 118 and the applicable requirements of Subsections i through iii:

i. Non-residential buildings with low-sloped roofs in climate zones 2-15 shall have a minimum 3-year aged solar reflectance of 0.55 and a minimum thermal emittance of 0.75, or a minimum aged SRI of 64.

EXCEPTION 1 TO SECTION 143(a)1Ai: Wood-framed roofs in climate zones 3 and 5 are exempt from the minimum requirements for solar reflectance and thermal emittance or SRI if the roof assembly has a U-factor of 0.039 or lower.

EXCEPTION 2 TO SECTION 143(a)1Ai: Metal building roofs in climate zones 3 and 5 are exempt from the minimum requirements for solar reflectance and thermal emittance or SRI if the roof assembly has a U-factor of 0.048 or lower.

EXCEPTION 3 TO SECTION 143(a)1Ai: Roof area covered by building integrated photovoltaic panels and building integrated solar thermal panels are not required to meet the minimum requirements for solar reflectance and thermal emittance or SRI.

EXCEPTION 4 TO SECTION 143(a)1Ai: Roof constructions that have thermal mass over the roof membrane with a weight of at least 25 lb/ft^2.

ii. Non-residential steep-sloped roofs with roofing products that have a roof weight of less than 5 pounds per square foot in climate zones 2-16 shall have a minimum 3-year aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16. Steep-sloped roofing products that have a roof weight of 5 pounds per square foot or more in climate zones 1 through 16 shall have a minimum 3-year aged reflectance of 0.15 and a minimum emittance of 0.75, or a minimum SRI of 10.

iii. High-rise residential buildings and hotels and motels with low-sloped roofs in climate zones 10, 11, 13, 14, and 15 shall have a minimum 3-year aged solar reflectance of 0.55 and a minimum thermal emittance of 0.75, or a minimum SRI of 64.

As of January 1, 2010, updates to California's Energy Efficiency Standards are in effect, superseding the 2005 Standards. Section 118(i) includes updated minimum reflectance and emittance requirements for Cool Roofs, which are limited to certain climate zones.

Other relevant updates include:

The use of minimum SRI (Solar Reflectance Index) values as an alternative to reflectance and emittance values.

- The use of three-year aged data for reflectance values.
- Default roof emittance and reflectance values assumed for products not certified by the CRRC.
- Distinct requirements for steep-slope (greater than 2:12) non-residential roofs and for residential roofs.
- Less stringent requirements for steep-slope roofs with a minimum surface weight 5 lbs / ft^2.

The full text of the code is available at the California Energy Commission website at http://www.energy.ca.gov/title24/.

California Summary

Roof Type	Solar Reflectance	Thermal Emittance	SRI
Low-slope non-residential	> 0.55	> 0.75	> 64
Steep-slope non-residential	> 0.20	> 0.75	> 16
Low-slope residential	> 0.55	> 0.75	> 64
Steep-slope residential	> 0.20	> 0.75	> 16

All values after three years ageing.

Tables 143 A-C are on the following pages:

Table 143A

TABLE143-A – PRESCRIPTIVE ENVELOPE CRITERIA FOR NONRESIDENTIAL BUILDINGS (INCLUDING RELOCATABLE PUBLIC SCHOOL BUILDINGS WHERE MANUFACTURER CERTIFIES USE ONLY IN SPECIFIC CLIMATE ZONE; NOT INCLUDING HIGH-RISE RESIDENTIAL BUILDINGS AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS)

			Climate Zone															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Roofs/Ceilings	Metal Building		0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
	Wood Framed and Other		0.049	0.039	0.039	0.039	0.049	0.075	0.067	0.067	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Roofing Products	Low-sloped	Aged Reflectance	NR	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	NR
		Emittance	NR	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	NR
	Steep Sloped (less than 5 lb/ft²)	Aged Reflectance	NR	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
		Emittance	NR	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
	Steep Sloped (5 lb/ft² or more)	Aged Reflectance	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
		Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Walls	Metal Building		0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
	Metal-framed		0.098	0.062	0.082	0.062	0.062	0.098	0.098	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
	Mass Light		0.196	0.170	0.278	0.227	0.44	0.44	0.44	0.44	0.44	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Mass Heavy		0.253	0.650	0.650	0.650	0.650	0.690	0.690	0.690	0.690	0.650	0.184	0.253	0.211	0.184	0.184	0.160
	Wood-framed and Other		0.102	0.059	0.110	0.059	0.102	0.110	0.110	0.102	0.059	0.059	0.059	0.059	0.059	0.059	0.042	0.059
Floors/Soffits	Mass		0.092	0.092	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.092	0.092	0.092	0.092	0.092	0.058
	Other		0.048	0.039	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.039	0.071	0.071	0.039	0.039	0.039
Windows	U-factor		0.47	0.47	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.47	0.47	0.47	0.47	0.47	0.47	0.47
	RSHG North	0-10% WWR	0.72	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.72
		10-20% WWR	0.49	0.51	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.51	0.51	0.51	0.51	0.51	0.51	0.49
		20-30% WWR	0.47	0.47	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.47	0.47	0.47	0.47	0.47	0.47	0.47
		30-40% WWR	0.47	0.47	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.47	0.47	0.47	0.47	0.40	0.40	0.47
	RSHG Non-North	0-10% WWR	0.49	0.47	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.47	0.47	0.47	0.47	0.46	0.46	0.49
		10-20% WWR	0.43	0.36	0.55	0.55	0.55	0.61	0.61	0.61	0.61	0.36	0.36	0.36	0.36	0.36	0.36	0.43
		20-30% WWR	0.43	0.36	0.41	0.41	0.41	0.39	0.39	0.39	0.39	0.36	0.36	0.36	0.36	0.36	0.36	0.43
		30-40% WWR	0.43	0.31	0.41	0.41	0.41	0.34	0.34	0.34	0.34	0.31	0.31	0.31	0.31	0.31	0.31	0.43
Doors, U-factor	Non-Swinging		0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
	Swinging		0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Skylight	U-factor	Glass, curb	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
		Glass, no curb	0.68	0.68	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.68	0.68	0.68	0.68	0.68	0.68	0.68
		Plastic	1.04	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.04
	SHGC	Glass, 0-2%	NR	0.46	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.46	0.46	0.46	0.46	0.46	0.46	NR
		Glass, 2.1-5%	NR	0.36	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.36	0.36	0.36	0.36	0.36	0.36	NR
		Plastic, 0-2%	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
		Plastic, 2.1-5%	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57

Notes:

1. Mass, Light walls are defined as having a heat capacity greater than or equal to 7.0 Btu/h-ft2 and less than 15.0 Btu/h-ft2. Heavy mass walls are defined as having a heat capacity greater than or equal to 15.0 Btu/h-ft2.
2. No skylight SHGC requirements are defined for climate zones 1 and 16. A climate zone without a requirement is designated as "NR".

Table 143B

TABLE 143-B – PRESCRIPTIVE ENVELOPE CRITERIA FOR HIGH-RISE RESIDENTIAL BUILDINGS AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS

			Climate Zone															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Roofs/Ceilings	Metal Building		0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
	Wood Framed and Other		0.034	0.028	0.039	0.028	0.039	0.039	0.039	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Roofing Products	Low-sloped	Aged Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.55	0.55	NR	0.55	0.55	0.55	NR
		Emittance	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.75	0.75	NR	0.75	0.75	0.75	NR
Walls	Metal Building		0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.057	0.057	0.057	0.057	0.057
	Metal-framed		0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105
	Mass Light		0.170	0.170	0.170	0.170	0.170	0.227	0.227	0.227	0.196	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Mass Heavy		0.160	0.160	0.160	0.184	0.211	0.690	0.690	0.690	0.690	0.690	0.184	0.253	0.211	0.184	0.184	0.160
	Wood-framed and Other		0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.042	0.059	0.059	0.042	0.042	0.042
Floors/Soffits	Mass		0.045	0.045	0.058	0.058	0.058	0.069	0.092	0.092	0.092	0.069	0.058	0.058	0.058	0.045	0.058	0.037
	Other		0.034	0.034	0.039	0.039	0.039	0.039	0.071	0.039	0.039	0.039	0.039	0.039	0.039	0.034	0.039	0.034
Windows	U-factor		0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
	RSHG North	0-10% WWR	0.68	0.49	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.49	0.49	0.49	0.49	0.47	0.47	0.68
		10-20% WWR	0.68	0.49	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.49	0.49	0.49	0.49	0.43	0.43	0.68
		20-30% WWR	0.47	0.40	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.40	0.40	0.40	0.40	0.43	0.43	0.47
		30-40% WWR	0.47	0.40	0.55	0.55	0.55	0.61	0.61	0.61	0.61	0.40	0.40	0.40	0.40	0.41	0.41	0.47
	RSHG Non-North	0-10% WWR	0.46	0.36	0.41	0.41	0.41	0.47	0.47	0.47	0.47	0.36	0.36	0.36	0.36	0.36	0.36	0.46
		10-20% WWR	0.46	0.36	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.36	0.36	0.36	0.36	0.31	0.31	0.46
		20-30% WWR	0.36	0.31	0.31	0.31	0.31	0.36	0.36	0.36	0.36	0.31	0.31	0.31	0.31	0.26	0.26	0.36
		30-40% WWR	0.30	0.26	0.26	0.26	0.26	0.31	0.31	0.31	0.31	0.26	0.26	0.26	0.26	0.26	0.26	0.30
Doors, U-factor	Non-Swinging		0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
	Swinging		0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Skylight	U-factor	Glass, curb	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
		Glass, no curb	0.68	0.68	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.68	0.68	0.68	0.68	0.68	0.68	0.68
		Plastic	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
	SHGC	Glass, 0-2%	0.46	0.46	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.46	0.46	0.46	0.46	0.46	0.46	0.46
		Glass, 2.1-5%	0.36	0.32	0.32	0.32	0.32	0.40	0.40	0.40	0.40	0.32	0.32	0.32	0.32	0.31	0.31	0.36
		Plastic, 0-2%	0.69	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
		Plastic, 2.1-5%	0.55	0.34	0.39	0.39	0.39	0.57	0.57	0.57	0.57	0.34	0.34	0.34	0.34	0.27	0.27	0.55

Notes:
1. Mass, Light walls are defined as having a heat capacity greater than or equal to 7.0 Btu/h-ft2 and less than 15.0 Btu/h-ft2. Heavy mass walls are defined as having a heat capacity greater than or equal to 15.0 Btu/h-ft2.

Table 143C

TABLE 143-C PRESCRIPTIVE ENVELOPE CRITERIA FOR RELOCATABLE PUBLIC SCHOOL BUILDINGS WHERE MANUFACTURER CERTIFIES USE IN ALL CLIMATE ZONES

		ALL CLIMATE ZONES
Roof/Ceiling U-factor		
Metal Building		0.048
Wood-framed and other		0.039
Roofing Products – Aged Reflectance/Emittance		
Low-Sloped		0.55/0.75
Steep-Sloped – Less than 5 lb/ft^2		0.20/0.75
5 lb/ft^2 or more		0.15/0.75
Wall U-factor		
Wood frame		0.059
Metal frame		0.062
Metal building		0.057
Mass/7.0≤ HC		0.170
Other		0.059
Floor/Soffit U-factor		
Wood-Framed and Other		0.048
Windows		
U-factor		0.47
Relative solar heat gain		
0-10% WWR		0.36
11-20% WWR		0.31
21-30% WWR		0.26
31-40% WWR		0.26
Doors, U-factor	Non-Swinging	0.50
	Swinging	0.70
Skylights		
U-factor	Glass w/Curb	0.99
	Glass wo/Curb	0.57
	Plastic w/Curb	0.87
SHGC Glass	0-2%	0.46
	2.1-5%	0.36
SHGC Plastic	0-2%	0.69
	2.1-5%	0.57
Note: Construction assembly U-factors shall be calculated in accordance with Reference Joint Appendix JA4.		

CHICAGO COOL ROOFS PROGRAM[125]

COOL ROOFS…how they benefit you and the environment

The roof system of a building is an area where significant heat gain occurs, in particular on relatively flat exposures to the sun's position during the warmest period of the day. Dark coloured roof surfaces can also contribute significantly to the urban heat island effect and smog formation, leading to increased air pollution. Reflective, light coloured "Cool" roofs can not only help reduce cooling costs, but can also have a positive environmental impact by reducing the urban heat island effect. Light coloured roof materials and coatings are advantageous over dark colours because of their ability to reflect and radiate energy away from the roof. Here are a few additional Cool Roof benefits:

- Reduce cooling costs
- Reduce contribution to Urban Heat Island effect
- Increase life cycle of roof
- Reduce maintenance of roof
- Improve occupancy comfort level

How a Cool Roof Is Defined…

Cool Roofs are characterized by their ability to reflect and radiate a high percentage of the sun's solar flux. This helps prevent the transmittance of heat into the building and the heating of its surroundings, known as "heat island" effect. Cool Roofs have been confirmed to be up to 60° degrees Fahrenheit cooler than conventional dark coloured roofs.

- Heat Flux: the direct and diffused radiation from the sun received at ground level
- Solar Reflectance: an index between 0 and 1 that expresses the fraction of solar flux that is reflected from the material. The higher the value the more solar energy that is reflected
- Thermal Emittance: is the ratio between 0 and 1 that indicates the energy radiated by a material compared to the energy radiated by a black body at the same temperature. The higher the value the more energy that is radiated away from the material

Cool Roof Grants Program

Building Type	Initial Reflectance		Rebate (per square foot)	
	Low Slope[126]	Medium Slope[127]		Soy–based coating
Residential	> 0.65	> 0.25	$ 0.50	$ 0.70
Commercial	> 0.65	> 0.25	$ 0.55	$ 0.75
Industrial	> 0.65	> 0.25	$ 0.60	$ 0.80

[125] http://www.chicago-roofer.com/Website%20images_files/Roofing/downloads/CoolRoofsGrantsProgramDescription.pdf

[126] Low Slope Roof: A roof with a surface slope between 0 in 12 and 2 in 12 (0 inch rise in a 12 inch run and 2 inch rise in a 12 inch run) as defined in the Chicago Building Code Section 13 (18-13-303.2.1)

[127] Medium Slope Roof: A roof with a surface slope over 2 in 12 and up to and including 5 in 12 (over a 2 inch rise in a 12 inch run up to and including a 5 inch rise in a 12 inch run) as defined in the Chicago Building Code Section 13 (18-13-303.2.2)

- To qualify for a low slope grant, the roof slope must meet the slope requirements as specified above and have a roof material or coating system with initial solar reflectance greater than or equal to 0.65, as rated by the Cool Roofs Rating Council or Energy Star
- To qualify for medium slope grant, the roof slope must meet the medium slope requirements and include roof materials or roof coatings with initial solar reflectance greater than or equal to 0.25, as rated by the Cool Roofs Rating Council or Energy Star

INTERNATIONAL GREEN CONSTRUCTION CODE[128]

The Sustainable Building Technology Council (SBTC) is in the process of producing a first draft of the International Green Construction Code (IgCC). A draft for public comment is scheduled to be released in March 2010, and public comments will be due in May 2010. Version 4 of the IgCC draft states that 75% of the roof surface of buildings located in climate zones 1-3 shall be covered with a combination of vegetative roofing, solar collectors, and Cool Roofing. In order to qualify as a Cool Roof, values for solar reflectance and thermal emittance must be determined by an independent laboratory accredited by the CRRC or other nationally recognized accreditation programs. SRI values may be used as long as the value is determined using ASTM E1980 with a convection coefficient of 2.1 Btu/h-ft^2 (12 W/m^2*k) tested in accordance with the CRRC-1 Standard. The minimum solar reflectance, thermal emittance, and SRI values for Cool Roofs can be found in the table below and more details can be found in section 404.3.1 of the draft.

Roof Slope	Minimum		
	Aged Solar Reflectance	Aged Thermal Emittance	Aged SRI
< 2:12	0.55	0.75	60
> 2:12	0.30	0.75	25

Source: IgCC 4th Version of First Draft

128 http://www.iccsafe.org/cs/IGCC/Pages/default.aspx

ASHRAE

Proposed Standard 189.1 (Approved for Publication)[129]

In December 2009, Standard 189.1 (Standard for the Design of High Performance, Green Buildings Except Low-Rise Residential Buildings) was approved for publication by the Boards of Directors of ASHRAE, IES and USGBC. This standard will provide a uniform, comprehensive code for green buildings. The proposed code requires an initial SRI of 78 for low-slope roofs and initial SRI of 29 for steep-slope roofs, with some exceptions. It applies to climate zones 1- 3 (South and Southwest areas)[130].

Publication is expected in February 2010. ASHRAE has launched a website to track this standard: http://www.ashrae.org/greenstandard

Standard 90.1 Update 2010[131]

ASHRAE and IES are working to strengthen the requirements in ANSI / ASHRAE / IESNA Standard 90.1 (Energy Standard for Buildings Except Low-Rise Residential Buildings) which provides minimum requirements for the energy-efficient design of non-residential buildings. ASHRAE's goal for the 2010 standard is 30% energy savings over the 2004 version. The proposed standard contains new mandatory prescriptive requirements for Cool Roofs, including a minimum three-year aged reflectance of 0.55, and a minimum aged emittance of 0.75. The 2010 standard is expected to be released in fall 2010.

UNITED STATES DEPARTMENT OF ENERGY / ENVIRONMENTAL PROTECTION AGENCY ENERGY STAR[132]

ENERGY STAR Requirements

ENERGY STAR qualified roof products must meet minimum initial and aged solar reflectance values. Emissivity is not currently a requirement for energy star qualification. However, starting December 31, 2007, EPA will post emissivity values for all products on the energy star Qualified Products List to assist consumers in their purchasing decision. Longer term, EPA plans to revisit the possibility of adding an emissivity component to the energy star specification.

[129] http://www.ashrae.org/publications/page/927
[130] http://spc189.ashraepcs.org/
[131] http://www.ashrae.org/education/page/1834
[132] http://www.energystar.gov/

Specifications for ENERGY STAR Qualified Roofs			
Type	**Characteristic**	**Property**	**Performance Specification**
Low-Slope	Energy Efficiency	Initial Solar Reflectance	≥ 0.65.
		Maintenance of Solar Reflectance	≥ 0.50 three years after installation under normal conditions.
Steep-Slope*	Energy Efficiency	Initial Solar Reflectance	≥ 0.25.
		Maintenance of Solar Reflectance	≥ 0.15 three years after installation under normal conditions.
Each company's roof product warranty for reflective roof products must be equal in all material respects to the product warranty offered by the same company for comparable non-reflective roof membrane products. A company that sells only reflective roof products must offer a warranty that is equal in all material respects to the standard industry warranty for comparable non-reflective roof products.			

* slope greater than 2:12 inches

DOE Cool Roof Calculator[133]

The Cool Roof Calculator is an interactive tool developed by Oak Ridge national Laboratories (ORNL) for the Department of Energy (DOE) to assist commercial building owners and managers estimate the maximum effect of solar radiation control on energy needs for a building under a low-slope roof. The calculator directly gives two methods to improve a roof to save the same amount of costs for energy.

The first method is to install a reflective roof: the calculator allows quick comparison of the energy cost differences between a reflective and non-reflective roof for over 243 cities in the United States.

The second method is to add more insulation to the roof: the calculator shows how much insulation is required to add to save the same amount of money using a reflective roof.

The Cool Roof Calculator is available on-line in two versions: A *Standard Calculator* for facilities with uniform utility rates and a *Peak Demand Calculator* for facilities with peak demand charges in addition to standard rates.

The Cool Roof Calculator site also contains links to detailed information about the methodology used to develop the calculator and useful guides for determining the reflectivity of various roof surfaces.

[133] http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm

GREEN SEAL STANDARD GS-11[134]

3.8. Reflective Roof Coatings.

Reflective roof coatings shall meet the following requirements:

3.8.1. Physical Properties. The product shall meet the requirements in ASTM D6083-05e1 Standard Specification for Liquid Applied Acrylic Coating Used in Roofing.

3.8.2. Solar Reflectance. The product shall meet the requirements as listed below as determined by ASTM C1549-04 Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer or ASTM E1918-06 Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field.

Characteristic	**Performance Specification**[135]	
	Low-Slope Roofs	**Steep-Slope Roofs**
Initial Solar Reflectance	$\geq$ 0.65	$\geq$ 0.25
Maintenance of Solar Reflectance[136]	$\geq$ 0.50	$\geq$ 0.15

3.8.3. Thermal Emittance. The product shall have a thermal emittance of 80% or more as determined by ASTM C1371-04a Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers.

3.9. Alternative Performance Requirements. Alternatively, a product can demonstrate adequate performance through using another scientifically validated test method under controlled and reproducible laboratory conditions if accompanied by justification for the method modification and documented in sufficient detail.

COOL ROOF RATING COUNCIL (CRRC)[137]

The predominant Cool Roof organization is the CRRC. The CRRC is the body assigned by the California stature as the referee for determination of a Cool Roof. The CRRC administers a Rating Program in which companies can label roof surface products with radiative property values. The CRRC does not set a minimum definition for "cool", the CRRC simply lists the measured radiative property values on their Directory. Any roofing product can be tested as long as it is in compliance with the Product Rating Program Manual (CRRC-1). A product's placement on the Directory does not mean that the product is "cool" as defined by any particular code body or program.

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134 http://www.greenseal.org/Portals/0/Documents/Standards/GS-11/GS-11_Paints_and_Coatings_Standard.pdf

135 Low-slope roofs are surfaces with a slope of 2:12 inches or less and Steep-slope roofs are surfaces with a slope of greater than 2:12 inches as determined by ASTM E1918-06 Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field.

136 Three years after installation under normal conditions.

137 http://www.coolroofs.org/

All radiative property testing is conducted by accredited testing laboratories. Solar reflectance can be measured in accordance with ASTM test methods C1549, E1918, E903 and CRRC-1 Method #1: Test Method for Certain Variegated Products. Thermal emittance is measured in accordance with ASTM C1371. For aged ratings, product samples are exposed for three years at the CRRC Approved Test Farm. Product ratings are verified periodically through the CRRC's Random Testing Program.

EUROPEAN COOL ROOF COUNCIL (EU-CRC)[138]

The CRRC is no longer the only Cool Roof Council on the block. The European Union has started its own Cool Roofs Council (EU-CRC) under the guidance of Hashem Akbari, ex-officio CRRC Board member and founding member of the CRRC. The stated goals of the EU-CRC are to:

•Support policy development by improving understanding of the actual and potential contributions by Cool Roofs to heating and cooling consumption in the EU.
•Remove market barriers and simplify the procedures for the integration of Cool Roofs in construction.
•Change the behaviour of decision-makers and stakeholders to improve acceptance of Cool Roofing technologies.
•Promote the development of innovative legislation, codes, permits and standards concerning Cool Roofs.

The EU-CRC is also in the process of developing its own database of Cool Roofing products which currently includes over 100 products from six companies in Germany, Greece and Italy. The minimum requirements to be listed in the database will be determined by a combination of factors including the product performance with respect to the roof slope and the effects of aging on the materials. In addition to creating this database, the EU-CRC is working to identify the potential policy issues and opportunities for introducing Cool Roof technology in the EU based on lessons learned from the introduction of Cool Roofing standards in the United States.

The CRRC is looking forward to working with our counterpart in the European Union to promote the adoption of Cool Roofing products around the world. To learn more visit http://coolroofs-eu.eu/.

Building Codes Assistance Project

The Building Codes Assistance Project (BCAP) at the Alliance to Save Energy recently launched its new Online Code Environment & Advocacy Network (OCEAN) website. OCEAN is an interactive, Web-based resource designed to share lessons learned, best practices, educational resources and key facts as they relate to building energy code adoption and implementation. You can visit BCAP's new website at http://bcap-ocean.org/ or go directly to the new state code status page http://bcap-ocean.org/code-status.

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[138] http://coolroofs-eu-crc.eu/

TEST METHOD STANDARDS

The only test methods used for Cool Roofs are ASTM standards. The Cool Roof Ratings Council has a test method; Test Method 1 which simply refers to ASTM C1371. Underwriters Laboratories is n accredited test lab for the ASTM and CRRC standards.

ASTM Standards for Cool Roofs

ASTM E1980-01: ***Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces*** **(Withdrawn 2010, no replacement)** (Comm. D08.18 / Vol.)[139]

E1980 is the reference standard for the California Energy Efficient Building Code.

Withdrawn Rationale:

This practice covers the calculation of the Solar Reflectance Index (SRI) of horizontal and low-sloped opaque surfaces at standard conditions. The method is intended to calculate SRI for surfaces with emissivity greater than 0.1.

Formerly under the jurisdiction of Committee D08 on Roofing and Waterproofing, this practice was withdrawn in January 2010 in accordance with section 10.5.3.1 of the Regulations Governing ASTM Technical Committees, which requires that standards shall be updated by the end of the eighth year since the last approval date.

1. Scope

1.1 This practice covers the calculation of the Solar Reflectance Index (SRI) of horizontal and low-sloped opaque surfaces at standard conditions. The method is intended to calculate SRI for surfaces with emissivity greater than 0.1.

ASTM E1918 - 06: ***Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field*** (Comm. D08.18 / Vol. 04.04)[140]

Significance and Use

Solar reflectance is an important factor affecting surface and near-surface ambient air temperature. Surfaces with low solar reflectance (typically 30 % or lower), absorb a high fraction of the incoming solar energy which is either conducted into buildings or convected to air (leading to higher air temperatures). Use of materials with high solar reflectance may result in lower air-conditioning energy

139 http://www.astm.org/Standards/E1980.htm
140 http://www.astm.org/Standards/E1918.htm

use and cooler cities and communities. The test method described here measures the solar reflectance of surfaces in the field.

1. Scope

1.1 This test method covers the measurement of solar reflectance of various horizontal and low-sloped surfaces and materials in the field, using a pyranometer. The test method is intended for use when the sun angle to the normal from a surface is less than 45.

ASTM C1549 - 09: *Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer* (Comm. C16.30 / Vol. 04.06)[141]

Significance and Use

The temperatures of opaque surfaces exposed to solar radiation are generally higher than the adjacent air temperatures. In the case of roofs or walls enclosing conditioned spaces, increased inward heat flows result. In the case of equipment or storage containers exposed to the sun, increased operating temperatures usually result. The extent to which solar radiation affects surface temperatures depends on the solar reflectance of the exposed surface. A solar reflectance of 1.0 (100 % reflected) would mean no effect on surface temperature while a solar reflectance of 0 (none reflected, all absorbed) would result in the maximum effect. Coatings of specific solar reflectance are used to change the temperature of surfaces exposed to sunlight. Coatings and surface finishes are commonly specified in terms of solar reflectance. The initial (clean) solar reflectance must be maintained during the life of the coating or finish to have the expected thermal performance.

The test method provides a means for periodic testing of surfaces in the field or in the laboratory. Monitor changes in solar reflectance due to aging and exposure, or both, with this test method.

This test method is used to measure the solar reflectance of a flat opaque surface. The precision of the average of several measurements is usually governed by the variability of reflectances on the surface being tested.

Use the solar reflectance that is determined by this method to calculate the solar energy absorbed by an opaque surface as shown in Eq 1.

1. Scope

1.1 This test method covers a technique for determining the solar reflectance of flat opaque materials in a laboratory or in the field using a commercial portable solar reflectometer. The purpose of the test method is to provide solar reflectance data required to evaluate temperatures and heat flows across surfaces exposed to solar radiation.

141 http://www.astm.org/Standards/C1549.htm

1.2 This test method does not supplant Test Method E903 which measures solar reflectance over the wavelength range 250 to 2500 nm using integrating spheres. The portable solar reflectometer is calibrated using specimens of known solar reflectance to determine solar reflectance from measurements at four wavelengths in the solar spectrum: 380 nm, 500 nm, 650 nm, and 1220 nm. This technique is supported by comparison of reflectometer measurements with measurements obtained using Test Method E903. This test method is applicable to specimens of materials having both specular and diffuse optical properties. It is particularly suited to the measurement of the solar reflectance of opaque materials.

ASTM C1371 - 04a: *Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers* (Comm. C16.30 / Vol. 04.06)[142]

1. Scope

1.1 This test method covers a technique for determination of the emittance of typical materials using a portable differential thermopile emissometer. The purpose of the test method is to provide a comparative means of quantifying the emittance of opaque, highly thermally conductive materials near room temperature as a parameter in evaluating temperatures, heat flows, and derived thermal resistances of materials.

1.2 This test method does not supplant Test Method C 835, which is an absolute method for determination of total hemispherical emittance, or Test Method E 408, which includes two comparative methods for determination of total normal emittance. Because of the unique construction of the portable emissometer, it can be calibrated to measure the total hemispherical emittance. This is supported by comparison of emissometer measurements with those of Test Method C 835.

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[142] http://www.astm.org/Standards/C1371.htm

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