Abolin Co.

Cool and Photocatalytic Benefits at the Service of Public Health and the Environment

“Art arises when the secret vision of the artist and the manifestation of nature agree to find new shapes”

Contents

1. Cool Materials Technology

Prescribing the use of cool construction materials in building energy-efficiency standards and in urban environment best practices promotes the cost-effective use of cool construction materials to save energy, reduce peak power demand, and improve air quality. Another option is to credit, rather than prescribe, the use of such materials. This can allow more flexibility in building design for example, permitting the use of less energy-efficient components (e.g., larger windows) in a building that has energy-saving cool roofs. Such credits are energy neutral, but may still reduce peak power demand and improve air quality. They may also reduce the first cost of a building.

a) Cool roof standards, building codes, rating, and labelling in the U.S

• ASHRAE Standard 90.1-2007 prescribes cool materials for low-sloped roofs on nonresidential buildings in some U.S. climates.

• ASHRAE Standards 90.1-2004 and 90.1-2001 offer credits for cool materials for low sloped roofs on nonresidential buildings in some U.S. climates.

• ASHRAE Standard 90.2-2004 offers credits for cool materials for all roofs on residential buildings in some U.S. climate zones.

• The 2008 California Title 24 Standards prescribe cool materials for roofs on residential and nonresidential buildings in some California climate zones.

• The 2005 California Title 24 Standards prescribe cool materials for low-sloped roofs on nonresidential buildings in all California climate zones (but one coastal region) and offers credits for steep-sloped roofs on residential and nonresidential buildings in all California climate zones.

• The 2003 International Energy Conservation Code allows commercial buildings to comply by satisfying the requirements of ASHRAE Standard 90.1, which at the time that IECC 2003 was written offered cool-roof credits.

• The Chicago, IL Energy Conservation Code prescribes a minimum solar reflectance and thermal emittance for low-sloped roofs.

• The 2004 Florida Building Code prescribes cool materials for all roofs on non residential buildings that are essentially the same as those in ASHRAE Standard 90.1- 2004.

• Hawaii. In 2001, 2002, and 2005, respectively, the counties of Honolulu, Kauai, and Maui adopted cool-roof credits for commercial and high-rise residential buildings based on ASHRAE Standard 90.1-1999.

• U.S. EPA ENERGY STAR™ Label. The U.S. EPA currently requires that low-sloped roofing products have initial and three-year-aged solar reflectances not less than 0.65 and 0.50, respectively. Steep-sloped roofing products must have initial and three-year-aged solar reflectances not less than 0.25 and 0.15, respectively.

• LEED Green Building Rating System. The Leadership in Energy and Environmental Design (LEED) Green Building Rating System assigns one rating point for the use of a cool roof in its Sustainable Sites Credit.

• Green Guide for Health Care: The Green Guide for Health Care is a best practices guide for healthy and sustainable building design, construction, and operations for the healthcare industry.

b) Cool Roofs in Other Countries

Cool Roof Energy Saving Potentials. Cool roofs offer significant cooling energy savings in buildings with air conditioning and improve comfort in buildings without air conditioning. Akbari et al. (2005) have calculated the effect of cool roofs on the annual cooling energy use of a prototypical house for most cooling-dominant cities around the world. The savings estimates are based on an increase in roof solar reflectance to 0.3 (typical cool roof) from 0.1 (typical hot roof).

Table 1 shows cooling degree days based on 18°C (CDD18) and potential cooling energy savings in kWh per year for a house with a roof area of 100 m2. The savings can be linearly adjusted for houses with larger or smaller roof areas. They also can be linearly scaled for a smaller or greater change in the roof's solar reflectance. The savings range from approximately 170 kWh/year for mild climates to over 700 kWh/year for very hot climates. At US$0.10/kWh, the economical value of cooling energy savings ranges from US$0.25-1.00/year per m^2 of roof area. Assuming a 20 year life for a roof and a discount rate of 3%, the present value of the 20 year savings will be $3.70 to $14.90 per m2 of roof area. In most countries, these savings may equal or exceed the cost premium (if any) for the cool roof. For houses that are not air conditioned, cool-colored roofing materials offer comfort, typically at very reasonable costs. Assuming an emission rate of 750 g CO_2 per kWh of electricity savings, the annual CO2 savings ranges from 1.9 – 7.5 kg/m2 of roof area.

We have also calculated the effect of cool roofs on the annual cooling energy use of a prototypical office building for the same cooling-dominant cities around the world. The prototype may not necessarily be representative of the stock of office buildings in all countries.

Table 2 shows potential cooling energy savings in kWh per year for a house with 100 m^2 of roof area. The savings range from approximately 500 kWh/year for mild climates to over 1000 kWh/year for very hot climates. At $0.10/kWh electricity price, the savings range from $0.50- 1.00 per m2 of roof area. Assuming a 20 year life for a roof and a discount rate of 3%, the present value of the 20 year savings will be $7.40 to $14.90 per m^2 of roof area. In most countries, these savings may equal or exceed the cost premium (if any) for the cool roof. For offices that are not air conditioned, white roofing materials offer comfort, typically at very reasonable costs. The annual CO_2 savings ranges from 3.8 – 7.5 kg/m^2 of roof area.

c) Cool roof standards, building codes, rating, and labelling in Other Countries

The European Union (particularly its southern countries that require significant summertime cooling) also offer significant opportunities. In February 2009, the EU Cool Roof Council (EU-CRC) organized its first meeting to promote and provide support for installation of cool roofs in Europe.

Four countries (Greece, UK, Germany, Italy) adopted initiatives to promote CR, and Greece has adopted CR standards The Greek temporary national standard for cool materials currently requires that low-sloped roofing products have initial and three-year-aged solar reflectances not less than 0.65 and 0.50, respectively. Steep-sloped roofing products must have initial and three-year-aged solar reflectances not less than 0.25 and 0.15, respectively. In the same standard there are also technical directives about the use of cool pavements.

In Brazil the "One Degree Less" movement (ODL 2009), pioneered in Brazil, has adopted cool roofs and heat island mitigation as its first practical program to combat global warming.

Other developed (e.g., Australia) and developing countries in Middle East and Africa offer significant opportunities for installing white roofs to save energy and cool the globe.

Table 1. Annual cooling energy savings (kWh) by installing a cool roof (increasing roof's solar reflectance by 0.20) for a typical 100m² house.

Country	City	CDD18	Sav-	Country	City	CDD18	Savings
Albania	Tirana	715	208	Morocco	Rabat-Sale	606	187
Algeria	Alger/Dar-El-Beida	899	244	Mozambique	Maputo	2,085	477
Argentina	Buenos Aires/Ezeiza	693	203	Pakistan	Karachi Airport	3,136	683
Australia	Sydney/K Smith	678	201	Panama	Howard AFB	3,638	782
Bahamas	Nassau	2,511	561	Paraguay	Asun-	2,218	503
Bermuda	St Georges/Kindley	1,802	421	Peru	Lima-Callao/Chavez	906	245
Bolivia	Trinidad	2,879	633	Philippines	Manila Airport	3,438	743
Brazil	Belo Horizonte	1,702	402	Puerto Rico	San Juan/Isla Verde	3,369	729
	Brasilia	1,353	333	Saudi Arabia	Dhahran	3,340	723
	Rio de Janeiro	2,360	531		Medina	3,691	793
	Sao Paulo	1,187	301		Riyadh	3,304	717
Brunei	Brunei Airport	3,516	758	Senegal	Dakar/Yoff	2,445	548
China	Beijing (Peking)	840	233	Singapore	Singapore/Changi	3,647	784
	Shanghai/Hong qiao	1,129	289	Spain	Barcelona	533	172
Cuba	Havana/Casa Blanca	2,700	598		Madrid	886	241
Cyprus	Akrotiri	1,139	291	Syria	Damascus Airport	1,074	278
Dominican Republic	Santo Domingo	3,053	667	Taiwan	Taipei	2,204	500
Egypt	Aswan	3,187	693	Tajikistan	Dusanbe	1,081	280
	Cairo	1,833	427	Tanzania	Dar es Salaam	2,922	641
France	Nice	545	175	Thailand	Bangkok	3,962	846
Greece	Athenai/Hellenikon	1,030	270		Chiang Mau	3,140	684
Hong Kong	Royal Observatory	2,136	487	Tunisia	Tunis/El Aouina	1,102	284
India	Bombay/Santa Cruz	3,386	733	Turkey	Istanbul/Yesilkoy	567	179
	Calcutta/Dum Dum	3,211	698	Turkmenis-	Ashkhabad	1,442	351
	New Delhi/Safdarjung	2,881	633	United States	Phoenix	2,579	574
Indonesia	Djakarta/Halimperda	3,390	733		Burbank/Hollywood	920	248
Italy	Palermo/Punta Raisi	1,058	275		Sacramento	743	213
	Roma/Fiumicino	621	189		Washing-	930	250
Jamaica	Kingston/Manley	3,656	785		Miami	2,516	561
	Montego Bay/Sangster	3,112	679		Atlanta	1,104	284
Japan	Kyoto	1,084	280		Honolulu, Oahu	2,651	588
	Osaka	1,180	299		New Or-	1,627	387
	Tokyo	938	251		Memphis	1,324	327
Jordan	Amman	1,063	276		Dallas-Ft Worth	1,519	366
Kenya	Nairobi Airport	566	179	Uruguay	Montevi-	595	184
Korea	Seoul	746	214	Venezuela	Caracas/Mai quetia	3,331	722
Libya	Tripoli/Idris	1,686	399	Vietnam	Saigon (Ho Chi	3,745	803
Madagascar	Antananarivo/I vato	701	205	Zimbabwe	Harare Airport	775	219
Malaysia	Kuala Lumpur	3,475	750				
Mexico	Chihuahua	1,058	275				
	Mexico City	245	115				
	Acapulco/Alvarez	3,623	779				

CDD18 is cooling-degree-days base on 18 °C.

Table 2. Annual cooling energy savings (kWh) per 100 m² of roof area by installing a cool roof (increasing roof’s solar reflectance by 0.40) for a typical office building.

Country	City	CDD18	Savings	Country	City	CDD18	Savings
Albania	Tirana	715	603	Morocco	Rabat-Sale	606	586
Algeria	Alger/Dar-El-Beida	899	633	Mozambique	Maputo	2,085	825
Argentina	Buenos Aires/Ezeiza	693	600	Pakistan	Karachi Airport	3,136	995
Australia	Sydney/K Smith	678	597	Panama	Howard AFB	3,638	1076
Bahamas	Nassau	2,511	894	Paraguay	Asuncion/Stroessner	2,218	847
Bermuda	St Georges/Kindley	1,802	779	Peru	Lima-Callao/Chavez	906	634
Bolivia	Trinidad	2,879	953	Philippines	Manila Airport	3,438	1044
Brazil	Belo Horizonte	1,702	763	Puerto Rico	San Juan/Isla Verde	3,369	1033
	Brasilia	1,353	707	Saudi Arabia	Dhahran	3,340	1028
	Rio de Janeiro	2,360	870		Medina	3,691	1085
	Sao Paulo	1,187	680		Riyadh	3,304	1022
Brunei	Brunei Airport	3,516	1056	Senegal	Dakar/Yoff	2,445	883
China	Beijing (Peking)	840	624	Singapore	Singapore/Changi	3,647	1078
	Shanghai/Hong qiao	1,129	670	Spain	Barcelona	533	574
Cuba	Havana/Casa Blanca	2,700	925		Madrid	886	631
Cyprus	Akrotiri	1,139	672	Syria	Damascus Airport	1,074	662
Dominican Republic	Santo Domingo	3,053	982	Taiwan	Taipei	2,204	844
Egypt	Aswan	3,187	1003	Tajikistan	Dusanbe	1,081	663
	Cairo	1,833	784	Tanzania	Dar es Salaam	2,922	960
France	Nice	545	576	Thailand	Bangkok	3,962	1129
Greece	Athenai/Hellenikon	1,030	654		Chiang Mau	3,140	996
Hong Kong	Royal Observatory	2,136	833	Tunisia	Tunis/El Aouina	1,102	666
India	Bombay/Santa Cruz	3,386	1035	Turkey	Istanbul/Yesilkoy	567	580
	Calcutta/Dum Dum	3,211	1007	Turkmenis-	Ashkhabad	1,442	721
	New Del-	2,881	954	United	Phoenix	2,579	905
Indonesia	Djakarta/Halimperda	3,390	1036		Burbank/Hollywood	920	637
Italy	Palermo/Punta Raisi	1,058	659		Sacramento	743	608
	Roma/Fiumicino	621	588		Washington/National	930	638
Jamaica	Kingston/Manley	3,656	1079		Miami	2,516	895
	Montego	3,112	991		Atlanta	1,104	666
Japan	Kyoto	1,084	663		Honolulu, Oahu	2,651	917
	Osaka	1,180	679		New Or-	1,627	751
	Tokyo	938	640		Memphis	1,324	702
Jordan	Amman	1,063	660		Dallas-Ft Worth	1,519	734
Kenya	Nairobi Airport	566	579	Uruguay	Montevi-	595	584
Korea	Seoul	746	608	Venezuela	Caracas/Mai quetia	3,331	1027
Libya	Tripoli/Idris	1,686	761	Vietnam	Saigon (Ho Chi Minh)	3,745	1094
Madagascar	Antananarivo/I vato	701	601	Zimbabwe	Harare Airport	775	613
Malaysia	Kuala Lumpur	3,475	1050				
Mexico	Chihuahua	1,058	659				
	Mexico City	245	527				
	Acapulco/Alvarez	3,623	1074				

CDD18 is cooling-degree-days base on 18 °C.

d) Cool Pavements

Current pavement construction standards do not account for the solar reflectance of pavements. However, the maximum temperature of a pavement and the diurnal range of pavement temperature is an important consideration in design of a pavement. Laboratory tests have demonstrated that cooler pavements have a longer life time (Pomerantz and Akbari 1998; Pomerantz et al. 1997).

LEED Green Building Rating System. The Leadership in Energy and Environmental Design (LEED) Green Building Rating System assigns one rating point for the use of cool pavements in its Sustainable Sites Credit. LEED Version 2.2 (2005) uses Solar Reflectance Index (SRI), rather than solar reflectance, thermal emittance, or Energy-Star™ compliance, to qualify a cool pavement. SRI is a relative index of the steady-state temperature of a roof’s surface on a typical summer afternoon (ASTM 1980). LEED requires a cool pavement to have a minimum SRI 29.

2. Photocatalytic materials technology

Heterogeneous photocatalytic oxidation (PCO) has shown to be a promising air purifying technology in outdoor conditions using TiO2 as photocatalyst activated with UV light. Also to indoor air quality more and more attention is paid because of the very important role it plays on human health, and it can be influenced by many factors like ventilation system, building materials, furniture, cooking, and outdoor pollutants.

In the last several years, a growing body of scientific evidence has indicated that the air within homes and other buildings can be more seriously polluted than the outdoor air in even the largest and most industrialized cities. Other research indicates that people spend approximately 90 percent of their time indoors. Thus, for many people, the risks to health may be greater due to exposure to air pollution indoors than outdoors.

Majority of people live, work and recreate in densely populated environments, which facilitate to a greater extend their susceptibility to different pathogens. The threat of getting sick has health related and psychological issues. It reduces the well-being of the population as well as has a strong economical impact due to absenteeism and reduced productivity.

In addition, people who may be exposed to indoor air pollutants for the longest periods of time are often those most susceptible to the effects of indoor air pollution. Such groups include the young, the elderly, and the chronically ill, especially those suffering from respiratory or cardiovascular disease.

Poor indoor and outdoor air quality can be a contributing factor to health problems as well as damaging ecosystems, biodiversity and valued habitats. The adverse health effects from short and long-term exposure to air pollution range from premature deaths caused by heart and lung disease to worsening of asthmatic conditions, which often leads to a reduced quality of life and increased costs of hospital admissions. Despite improvements over recent decades, air pollution is still expected to reduce life expectancy. There are also clear links between air pollutants and the sources of greenhouse gases that cause climate change.

Key facts

- Air pollution is a major environmental risk to health. By reducing air pollution levels, we can help countries reduce the global burden of disease from respiratory infections, heart disease, and lung cancer.
- The lower the levels of air pollution in a city, the better respiratory (both long- and short-term), and cardiovascular health of the population will be.
- Indoor air pollution is estimated to cause approximately 2 million premature deaths mostly in developing countries. Almost half of these deaths are due to pneumonia in children under 5 years of age.
- Urban outdoor air pollution is estimated to cause 1.3 million deaths worldwide per year. Those living in middle-income countries disproportionately experience this burden.

- Exposure to air pollutants is largely beyond the control of individuals and requires action by public authorities at the national, regional and even international levels

a) Air quality standards

In response, the European Union has developed an extensive body of legislation which establishes health based standards and objectives for a number of pollutants in air. These standards and objectives are summarised in the table 3 below. These apply over differing periods of time because the observed health impacts associated with the various pollutants occur over different exposure times.

The US EPA Office of Air Quality Planning and Standards (OAQPS) has set National Ambient Air Quality Standards for six principal pollutants, which are called "criteria" pollutants. They are listed below in Table 4.. Units of measure for the standards are parts per million (ppm) by volume, parts per billion (ppb - 1 part in 1,000,000,000) by volume, milligrams per cubic meter of air (mg/m3), and micrograms per cubic meter of air (µg/m3).

Table 3. European Union standards related to air quality

Pollutant	*Concentration*	*Averaging period*	*Legal nature*	*Permitted exceedences each year*
Fine articles (PM2.5)	25 µg/m3***	1 year	Target value entered into force 1.1.2010 Limit value enters into force 1.1.2015	n/a
Sulphur dioxide (SO2)	350 µg/m3	1 hour	Limit value entered into force 1.1.2005	24
	125 µg/m3	24 hours	Limit value entered into force 1.1.2005	3
Nitrogen dioxide (NO2)	200 µg/m3	1 hour	Limit value entered into force 1.1.2010	18
	40 µg/m3	1 year	Limit value entered into force 1.1.2010*	n/a
PM10	50 µg/m3	24 hours	Limit value entered into force 1.1.2005**	35
	40 µg/m3	1 year	Limit value entered into force 1.1.2005**	n/a
Lead (Pb)	0.5 µg/m3	1 year	Limit value entered into force 1.1.2005 (or 1.1.2010 in the immediate vicinity of specific, notified industrial sources; and a 1.0 µg/m3 limit value applied from 1.1.2005 to 31.12.2009)	n/a
Carbon monoxide (CO)	10 mg/m3	Maximum daily 8 hour mean	Limit value entered into force 1.1.2005	n/a
Benzene	5 µg/m3	1 year	Limit value entered into force 1.1.2010**	n/a
Ozone	120 µg/m3	Maximum daily 8 hour mean	Target value entered into force 1.1.2010	25 days averaged over 3 years

Arsenic (As)	6 ng/m3	1 year	Target value enters into force 31.12.2012	n/a
Cadmium (Cd)	5 ng/m3	1 year	Target value enters into force 31.12.2012	n/a
Nickel (Ni)	20 ng/m3	1 year	Target value enters into force 31.12.2012	n/a
Polycyclic Aromatic Hydrocarbons	1 ng/m3 (expressed as concentration of Benzo(a)pyrene)	1 year	Target value enters into force 31.12.2012	n/a

Table 4. US National Ambient Air Quality Standards

	Primary Standards		Secondary Standards	
Pollutant	**Level**	**Averaging Time**	**Level**	**Averaging Time**
Carbon Monoxide	9 ppm (10 mg/m³)	8-hour	None	
	35 ppm (40 mg/m³)	1-hour		
Lead	0.15 µg/m³	Rolling 3-Month Average	Same as Primary	
Nitrogen Dioxide	53 ppb	Annual (Arithmetic Average)	Same as Primary	
	100 ppb	1-hour	None	
Particulate Matter (PM_{10})	150 µg/m³	24-hour	Same as Primary	
Particulate Matter ($PM_{2.5}$)	15.0 µg/m³	Annual (Arithmetic Average)	Same as Primary	
	35 µg/m³	24-hour	Same as Primary	
Ozone	0.075 ppm (2008 std)	8-hour http://www.epa.gov/air/criteria.html - 8	Same as Primary	
	0.08 ppm (1997 std)	8-hour	Same as Primary	
	0.12 ppm	1-hour	Same as Primary	
Sulfur Dioxide	0.03 ppm (1971 std)	Annual (Arithmetic Average)	0.5 ppm	3-hour
	0.14 ppm (1971 std)	24-hour		
	75 ppb	1-hour	None	

b) Assessing health risks of indoor air pollution

1. Introduction

Indoor exposure to air pollutants may occur in both private and public indoor environments such as homes, offices, schools and transport systems. Some indoor air pollutants come from the outside, but most are released inside the building, for example when cleaning or when burning fuel for cooking and heating. Furniture and construction materials can also emit pollutants. Dampness and lack of ventilation may further increase indoor air pollution.

Because indoor air can contain a mixture of many different pollutants, it is very difficult to assess the associated risks to health. Moreover, there is no such thing as a "typical indoor environment".

This opinion considers how health risks of indoor air pollutants are currently evaluated and how they should be assessed in the future, taking into account simultaneous exposure to multiple pollutants and particularly vulnerable groups of population such as children, pregnant women and elderly people.

2. What are the main factors in indoor air quality?

Certain chemicals from household products and home appliances are known to irritate the eyes, nose and throat. However, for many chemicals present in indoor air information is lacking on possible health effects of long term exposure, such as cancer or reproductive effects. Radon occurs naturally in parts of Europe. It can get inside buildings and may lead to lung cancer. Suspended particles can cause harmful effects on health, particularly on the respiratory system. Microbes, such as moulds and viruses, can contribute to the development of asthma and allergies. Pets and pests such as dust mites, cockroaches, and mice, are important indoor sources of allergens. Low humidity causes eye irritation, dryness of the skin and the nose, and rashes, while high humidity fosters the growth of moulds and dust mites. Insufficient ventilation, one of the most important factors in poor indoor air quality, may affect health and work performance.

3. How can scientists determine whether indoor air pollutants pose a health risk?

To determine whether pollutants may cause health effects, it is necessary to consider four aspects:

- Toxicity of pollutants and their concentrations in indoor air. Indoor air can for instance contain organic compounds, particles, or microbes that may cause allergies or other health effects.
- Exposure. People are mainly exposed to air pollutants when breathing but may also be exposed via other routes, such as dust ingestion. Since exposures can vary, even very low and very high exposures should be considered and not only average ones.
- Exposure-response relationships. To assess the risk posed by a given pollutant, it is important to know how the body responds to different concentrations in air. Health effects observed in people who have been exposed to pollutants at work are valuable in determining the risks posed by a particular pollutant. However, such findings may not be directly applicable to the general public.
- Risk characterisation. In the final step of the risk assessment process, all the collected scientific evidence is analysed to determine the probability that a specific pollutant will cause illness.

4. Are certain people more vulnerable than others to indoor air pollution?

Population groups that are potentially more vulnerable than others to indoor air pollution are children, pregnant women, elderly people, and people suffering from cardiovascular or respiratory diseases. Depending on their age, children may be more vulnerable than adults to certain toxic substances, like lead and tobacco smoke. Even at low levels, air pollutants may disrupt the development of their lungs, cause cough, bronchitis and other respiratory diseases, and make asthma worse. Factors other than age and presence of cardiovascular or respiratory diseases that may render some people more vulnerable are genetic traits, lifestyle, nutrition and other health problems.

5. Why are the combined effects of indoor air pollutants hard to measure?

Like outdoor air, indoor air contains a complex mixture of pollutants (chemical substances, allergens and microbes) from different sources that changes with time. Findings on the health effects of single air pollutants cannot necessarily be extended to mixtures. Indeed, different chemicals may interact with each other and cause more (or less) harmful effects than the sum of the effects caused by each chemical separately. Very little is known about the combined effects of indoor air pollutants.

Risk assessments which take into account the combined exposure and cumulative effects of the pollutants in indoor air are seldom possible. Nonetheless, the possibility of combined effects should be considered in the risk assessment taking a case-by-case approach.

7. What household chemicals and products can pollute indoor air?

Certain paints emit chemicals. Several household consumer products emit chemicals into air, for instance cleaning products, floor care products, furniture and household fabrics, air fresheners, glues, paints, paint strippers, personal care products, printed matter, electronic equipment, candles and incense.

Some studies show a link between the use of consumer products and adverse health effects. However, it is not clear to what extent pollutants are responsible for the observed effects because other factors may also contribute to them.

A recent study investigated the emissions of chemicals from a large number of different consumer products. Although typical levels in indoor air were in most cases acceptable, in some occasions, accepted limits were exceeded.

8. Why is dampness in buildings a health concern?

Humidity promotes the growth of moulds. The majority of the health effects linked to dampness and moisture of buildings are those of the respiratory system. They range from irritation of mucous membranes, respiratory symptoms, and infections to diseases such as asthma and allergy. However, it is still not known precisely how dampness leads to these symptoms and which are the main substances responsible.

Humidity problems in buildings may originate from leaks, condensation, or the ground. Excess humidity promotes the growth of micro-organisms such as moulds and bacteria that lead to release of pollutants into indoor air. Inadequate ventilation may increase humidity and the levels of pollutants.

9. Conclusions and recommendations

Assessing the health risks of indoor air pollution is very difficult as indoor air may contain over 900 chemicals, particles and biological materials with potential health effects. Factors like ventilation, cleaning conditions, building characteristics, products used in households, cultural habits, climate and outdoor environment all influence indoor air quality.

- Indoor air pollutants of particular concern are carbon monoxide, formaldehyde, benzene, nitrogen oxides, naphthalene, environmental tobacco smoke, radon, lead and organophosphate pesticides.
- All possible routes of exposure should be considered.
- All relevant sources known to contribute to indoor air pollution should be evaluated.

3. Benefits of using cool roofs and pavements

A cool roof reflects and emits the sun’s energy as light back to the sky instead of allowing it to enter the building below as heat. In many climate zones, a cool roof can substantially reduce the cooling load of the building, providing several direct benefits to the building owner and occupants:

• increased occupant comfort, especially during hot summer months

• reduced air conditioning use, resulting in energy savings typically of 10-30%1, and

• decreased roof maintenance costs due to longer roof life.

In addition to these well known benefits to the building owner, cool roofs benefit the environment and public health in far more ways. As recognition of these benefits has become more widespread, cool roof requirements are appearing in building energy codes and green building programs across the nation.

Climate Change Mitigation

Cool roofs directly reduce green house gas emissions by conserving electricity for air conditioning therefore emitting less CO2 from power plants. Cool roofs and pavements also cool the world independently of avoided carbon emissions, simply by reflecting the sun’s energy as light back to the atmosphere, thereby mitigating global warming. A Lawrence Berkeley National Laboratory study found that world-wide reflective roofing will produce a global cooling effect equivalent to offsetting 24 gigatons of CO2 over the lifetime of the roofs. This equates to $600 billion in savings from CO2 emissions reduction.

Urban Heat Island Mitigation

Cities can be 2° to 8°F warmer than surrounding areas due to dark materials, including roofs and pavements, which absorb the sun’s light energy as heat during the day and release it at night as heat. This phenomenon removes the opportunity for air to cool down at night and results in higher temperatures being maintained longer. By immediately reflecting solar radiation back into the atmosphere and reemitting some portion of it as infrared light, cool roofs result in cooler air temperatures for the surrounding urban environment during hot summer months.

Reduced Smog

Cool roofs and pavements, through mitigation of the urban heat island effect and reduction of ambient air temperatures, in turn improve air quality. Smog is created by photochemical reactions of air pollutants and these reactions increase at higher temperatures. Therefore, by reducing the air temperature, cool roofs and pavements decrease the rate of smog formation.

Public Health Benefits

Lower ambient air temperatures and the subsequent improved air quality also result in a reduction in heat-related and smog-related health issues, including heat stroke and asthma.

Peak Energy Savings and Grid Stability

Because cool roofs reduce air-conditioning use during the day's hottest periods, the associated energy savings occur when the demand for electricity is at its peak. Therefore, use of cool roofs reduces the stress on the energy grid during hot summer months and helps avoid shortages that can cause blackouts or brownouts. In addition, for building owners that pay for their energy based on the time of use, they save energy when it is at its most expensive – and hence, save more money

4. Benefits of using Photocatalytic materials

Construction materials with photocatalytic properties have the potential for removing nitrogen oxides (NOx), volatile organic compounds (VOCs) and bacteria in critical areas such as building's interior and/or, consequently, for reducing concentrations of toxic and irritating ozone, a key constituent of smog that forms in urban spaces. Photocatalytic construction materials mainly deal with coatings, concretes and transparent or translucent sols which can provide several direct benefits to the building owner and occupants:

- Improves indoor and outdoor air quality
- Decrease organic smells and bacteria loads in critical areas such as hospitals

Climate Change Mitigation

Photocatalysis contributes in fighting all potential greenhouse gases, as photo-catalysed reactions are able to transform or destroy almost all well-mixed, long lived greenhouse gases - CO2, CH4, N2O, CFC-12 and CFC-11 and also short-lived climate forcers like VOCs, NOx, BC and soot that have an important contribution to climate change.

Reduced Smog

The use of photocatalytic construction materials in wide city scale can contribute in the decomposition of nitrous and sulfuric oxides that are significant factors in smog.

Public Health Benefits

Indoor and outdoor air quality can be improved significant, in terms of bacteria and air pollutants - such as Volatile Organic Compounds, carbon monoxide, formaldehyde, benzene - elimination and as a consequence a better quality of life can be achieved. The use of the photocatalytic technology in critical areas such as Hospitals can help public health professionals also to control better the issue of hospitals infections.

5. Cool Barrier Technology and LEED Rating System

Over the past several years, a number of green building rating systems have been developed to help measure a building's impact on the environment, and encourage design techniques to reduce that impact. The LEED® (Leadership in Energy and Environmental Design) Green Building Rating System, developed by the US Green Building Council, is one of the most widely used building rating systems in the US. Abolin Co. manufactures several products that help reduce a building's overall impact on the environment, and thus can contribute to a project's ability to earn points toward LEED certification.
Abolin Co, recognizes that no product by itself is LEED certified, and that no product can guarantee a specific number of points for LEED certification.

LEED® SYSTEM

- Sustainable Sites (SS)

Credit 7.1: Heat Island Effect - Non-Roof
Intent
This credit is intended to reduce the heat island effect (developed areas that absorb and hold heat) caused by site hardscapes such as roads, parking lots, walkways, sidewalks and courtyards.

- Sustainable Sites (SS)

Sustainable Sites 7.2 – Heat Island Effect – Roof
Intent
1. This credit is intended to reduce the heat island effect
2. Minimize impact on microclimate and habitats

- Materials & Resources Credits 5.1 & 5.2

Regional Materials - 10% Extracted, Processed & Manufactured Regionally
Regional Materials - 20% Extracted, Processed & Manufactured Regionally
Intent
Encourage use of materials that are extracted and manufactured regionally, within 500 miles of the project location, thus reducing environmental impact caused by transportation of materials.

- Indoor Environmental Quality Credit 4.2

Low-Emitting Materials: Paints and Coatings
Intent
Reduce indoor air contaminants that can be harmful to occupants and installers.

- Innovation in Design Credits 1.1 - 1.4

Low-Emitting Materials: Paints and Coatings
Intent
To allow additional points to be awarded for exceptional performance above the LEED NC requirements, or for innovative performance in Green Building categories not addressed by the LEED NC rating system.

ABOLIN Co. PRODUCTS

- Potential Solutions using Abolin Co Products

Abolin Co, r with a Solar Reflectance Index (SRI) value of at least 29 comply with this LEED requirement.

Abolin Co, products typically used in these types of applications include: Cool Barrier Pavements (Blocks and Tiles), Cool Barrier Bicycle Lines Coat, Heavy Duty Road **Potential Points: 1**

- Potential Solutions using Abolin Co Products

Abolin Co, roof coatings with SRI 78 for a slope less than 2:12 (low-sloped roof) and SRI 29 for a slope more than 2:12 (steep-sloped roof) comply with this LEED requirement.

Abolin Co, products typically used in these types of applications include: Cool Barrier Roof Optimum, Cool Barrier Roof, Cool Barrier Façade, Cool Barrier 2k Top Coat, Cool Barrier Roof SLV, Active Cool, Cool Barrier Roof CEM. **Potential Points: 1**

- Potential Solutions using Abolin Co Products

Abolin Co, operates 2 manufacturing plants to meet regional demand of much of our market. Typically, between 20 and 80% of the raw material volume by weight is extracted locally to our manufacturing plants. Contribution of Abolin Co products toward these credits is determined by the project location.
Potential Points: 1

- Potential Solutions using Abolin Co Products

Paints, coatings and primers with Volatile Organic Compound (VOC) content* that is less than 50 g/L comply with this LEED requirement.

Abolin Co, products typically used in these types of applications include: Cool Barrier Roof Optimum, Cool Barrier Roof, Cool Barrier Façade, Cool Barrier Roof SLV, Active Cool, Cool Barrier Roof CEM. Cool Barrier Epoxy Hydroprimer. **Potential Points: 1**

- Potential Solutions using Abolin Co Products

Abolin Co Active Cool coating has the unique propertiesof contributing to cooling load reduction and air pollution mitigation at the same time. This coating can reduce the amount of cleansers and water required to keep the building clean, reduces the need for cooling energy and purifies the air by the meaning of air pollution decomposition. **Potential Points: 4**

6. Cool Barrier Technology and Green Label Singapore

Cool Barrier Roof and Façade are characterised as Low Emitting elastomeric coatings by the Green Label Singapore Council. The verification procedure was performed for the named scope by TUV PSB SINGAPORE. In the following tables you can check the advanced environmental performances in terms of coatings formulations.

Table 1 : The Formaldehyde results for “COOL BARRIER FACADE”.

Test	Result
Formaldehyde Content	Not Detecteda

a – The method detection limit was 0.1%.

Table 2 : The Elemental results for “COOL BARRIER FACADE”.

Test	Result
Mercury	Not Detectedb
Lead	Not Detectedb
Cadmium	Not Detectedb
Chromium	Not Detectedb

b – The method detection limit was 0.01%.

Table 3 : The Flash Point results for “COOL BARRIER FACADE”.

Test	Result
Flash point @61OC	No Flash

Table 4 : The Volatile Organic Compound (VOC) content for “COOL BARRIER FACADE”.

Test	Result
VOC Content	7.1 g/L

c - Volatile organic compound (VOC) means any organic compound having an initial boiling point less than or equal to 250°C measured at a standard pressure of 101,3kPa.

Table 5 : The analytical results for “COOL BARRIER FACADE”.

Test	Result
Halogenated solvent	Not Detectedd
Epichlorohydrin	Not Detectedd
Aromatic solvent	Not Detectede

Table 6 : The Formaldehyde results for “COOL BARRIER ROOF”.

Test	Result
Formaldehyde Content	Not Detecteda

a – The method detection limit was 0.1%.

Table 7 : The Elemental results for “COOL BARRIER ROOF”.

Test	Result
Mercury	Not Detectedb
Lead	Not Detectedb
Cadmium	Not Detectedb
Chromium	Not Detectedb

b – The method detection limit was 0.01%.

Table 8 : The Flash Point results for “COOL BARRIER ROOF”.

Test	Result
Flash point @61OC	No Flash

Table 9 : The Volatile Organic Compound (VOC) content for “COOL BARRIER ROOF”.

Test	Result
VOC Content	7.4 g/L

c - Volatile organic compound (VOC) means any organic compound having an initial boiling point less than or equal to 250°C measured at a standard pressure of 101,3kPa.

Table 10 : The analytical results for “COOL BARRIER ROOF”.

Test	Result
Halogenated solvent	Not Detectedd
Epichlorohydrin	Not Detectedd
Aromatic solvent	Not Detectede

7. Cool Barrier Technology and US ENERGY STAR

"ABOLIN Co ("ENERGY STAR Partner") joins in partnership with the US Environmental Protection Agency (EPA) and the Department of Energy (DOE) in one or more areas, ENERGY STAR Partner recognizes ENERGY STAR as a broad partnership designed to promote buildings, products, homes, and industrial facilities that use less energy while providing the same or better performance than conventional designs. ENERGY STAR Partner agrees to use the partnership and the ENERGY STAR mark to promote energy efficiency as an easy and desirable option for organizations and consumers to prevent pollution, protect the global environment, and save on energy bills. ENERGY STAR Partner agrees that it is important to build and maintain the meaning of the ENERGY STAR mark as a trustworthy symbol that makes it easy to make a change for the better".

Partnership Agreement between ENERGY STAR® and ABOLIN Co an ENERGY STAR® Partner

Energy Star-Efficiency Specifications for Roof Products: Roof products that may be applied to either low-slope or steep-slope roofs, such as roof coatings and single-ply membranes, must meet the ENERGY STAR low and Steep slope requirements provided in Table 1 & 2 below.

Table 1 – Specifications for Low-Slope Roof Products	
Characteristic	**Performance Specification**
Energy Efficiency Levels	
Initial Solar Reflectance	Greater than or equal to 0.65.
Maintenance of Solar Reflectance	Greater than or equal to 0.50 three years after installation undernormal conditions.
Table 2 – Specifications for Steep-Slope Roof Products	
Characteristic	**Performance Specification**
Energy Efficiency Levels	
Initial Solar Reflectance	Greater than or equal to 0.25.
Maintenance of Solar Reflectance	Greater than or equal to 0.15 three years after installation under normal conditions.

Abolin Co Roof Products in US Energy Star Roof product List April 2011: Table Below

Company Name	Brand	Model	Initial Solar Reflectance	Solar Reflectance after 3 years	Initial Emissivity
Abolin Co.	Cool Barrier	Facade White	0.89	0.85	0.90
Abolin Co.	Cool Barrier	010	0.43	0.42	0.89
Abolin Co.	Cool Barrier	011	0.64	0.61	0.88
Abolin Co.	Cool Barrier	012	0.70	0.66	0.88
Abolin Co.	Cool Barrier	013	0.82	0.77	0.86
Abolin Co.	Cool Barrier	014	0.83	0.79	0.86
Abolin Co.	Cool Barrier	015	0.84	0.80	0.87
Abolin Co.	Cool Barrier	016	0.79	0.75	0.87
Abolin Co.	Cool Barrier	017	0.66	0.60	0.86
Abolin Co.	Cool Barrier	018	0.39	0.35	0.89
Abolin Co.	Cool Barrier	019	0.86	0.83	0.88
Abolin Co.	Cool Barrier	020	0.80	0.78	0.89
Abolin Co.	Cool Barrier	021	0.77	0.74	0.89
Abolin Co.	Cool Barrier	022	0.74	0.70	0.89
Abolin Co.	Cool Barrier	023	0.60	0.55	0.89
Abolin Co.	Cool Barrier	024	0.29	0.29	0.91
Abolin Co.	Cool Barrier	025	0.70	0.68	0.90
Abolin Co.	Cool Barrier	001	0.73	0.71	0.87
Abolin Co.	Cool Barrier	002	0.84	0.82	0.86
Abolin Co.	Cool Barrier	003	0.87	0.85	0.88
Abolin Co.	Cool Barrier	004	0.45	0.43	0.90
Abolin Co.	Cool Barrier	005	0.75	0.68	0.87
Abolin Co.	Cool Barrier	006	0.76	0.71	0.86
Abolin Co.	Cool Barrier	007	0.42	0.41	0.89
Abolin Co.	Cool Barrier	008	0.62	0.60	0.89
Abolin Co.	Cool Barrier	009	0.74	0.70	0.87
Abolin Co.	Cool Barrier	Roof White	0.89	0.83	0.89

8. Cool Barrier Technology and ASHRAE

About ASHRAE

ASHRAE, American Society of Heating, Refrigerating and Air-Conditioning Engineers, founded in 1894, is an international organization of over 50,000 persons. ASHRAE fulfills its mission of advancing heating, ventilation, air conditioning and refrigeration to serve humanity and promote a sustainable world through research, standards writing, publishing and continuing education.

Building Codes and Regulations

ASHRAE 189.1-2009 Standard for the Design of High Performance, Green Buildings—A minimum of 75% of the entire roof surface shall be covered with products that comply with one or more of the following: a. have a minimum initial SRI of 78 for a low-sloped roof (a slope less than or equal to 2:12) and a minimum initial SRI of 29 for a steep-sloped roof (a slope of more than 2:12). b. comply with the criteria for US EPA's ENERGY STAR® Program Requirements for Roof Products—Eligibility Criteria. Certain allowances and exceptions may apply

Potential Solutions using Abolin Co Products

Abolin Co, products typically used in these types of applications include: Cool Barrier Roof Optimum, Cool Barrier Roof, Cool Barrier Façade White and Colours, Cool Barrier 2k Top Coat, Cool Barrier Roof SLV, Active Cool, Cool Barrier Roof CEM.

9. References

For the preparation of this Handbook a lot of references, web resources and technical articles were used. Hereby we refer some of most important.

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