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Albedo Effect and Energy Efficiency of Cities

Aniceto Zaragoza Ramírez[1] and César Bartolomé Muñoz[2]
[1]Polytechnic University of Madrid
[2]Spanish Cement Association
Spain

1. Introduction

The United Nations, by means of the Intergovernmental Panel on Climate Change (IPCC), establishes in the Fourth Assessment Report, Working Group I, that warming of the climate system is unequivocal and that most of the observed increment in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.

European Union considers that the average surface temperature of the Earth should not be exceeded in more than 2ºC with respect to preindustrial levels in order to avoid negative consequences of global warming. With this purpose, CO_2 concentration should be kept below 450 ppmv.

The International Energy Agency (IEA) predicts an important increment of primary energy demand until 2030. The electricity generation sector expects that world's demand gets duplicated, which would mean the installation of new plants up to an additional global capacity of 5,000 GWe. This huge increment of the demand, together with other economic factors, will give fossil fuels (coal, gas and oil) a key role within the energy field.

The IPCC Third and Fourth Assessment Reports state that no individual measure by itself will be able to reduce the necessary amount of greenhouse gases emissions, but a global approach will be required. In this context, energy efficiency is considered the most relevant measure to achieve the objectives.

Despite energy efficiency shows the highest potential as a mitigation measure, the influence of the albedo of cities on global warming is not mentioned in IPCC reports, focusing on other aspects such as: thermal envelope, heating systems, co-generation and efficiency lighting systems, which are also of paramount importance, but no as powerful as albedo effect.

2. Albedo effect

2.1 Background

Looking backwards into History, we can fix the first human energy revolution when human beings abandoned the caves where they lived and set up stable settlements where new houses were built. Inside caves, the temperature was almost constant independently from the external temperature and acclimatization needs were negligible. However, new houses required new measures to keep their temperature acceptable for life.

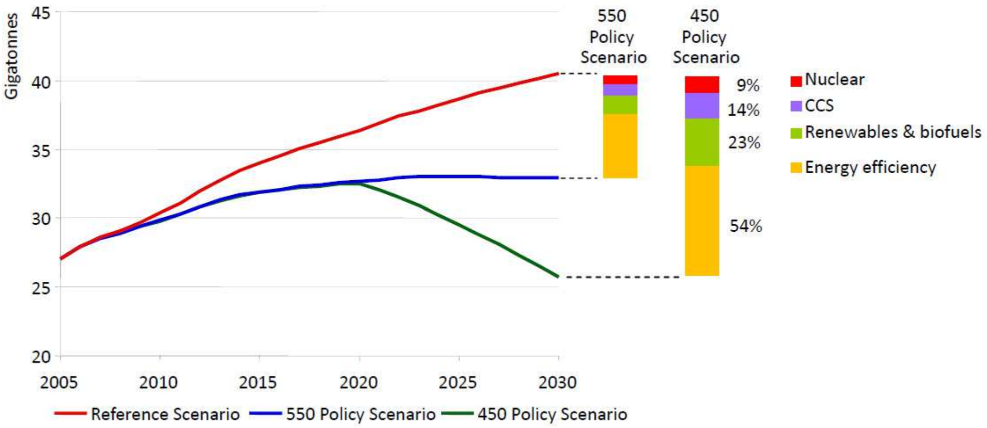


Fig. 1. Reductions in energy-related CO_2 emissions in different climate-policy scenarios (*Source: International Energy Agency, 2010*)

Fires were lighted inside houses during winter in order to protect themselves against cold. However, no air conditioning system was available for summer and our ancestors resorted to passive measures: increasing the width of walls and painting facades in light colours.

The construction of white buildings is a simple and economical bioclimatic measure to save energy, since they reflect a higher amount of solar radiation and, therefore, these buildings are cooler in summer. On the other hand, these houses are not able to absorb solar energy during winter time and they have a greater demand of heat. For this reason, we only find this kind of buildings within latitudes where solar radiation reaches a minimum value.

Fig. 2. White buildings in a town in the South of Spain

Although this value is not scientifically fixed, the experience has established that these measures are effective within latitudes under 40º, both in the north and south hemispheres, where the Earth radiation is, on average, over 225 W/m^2.

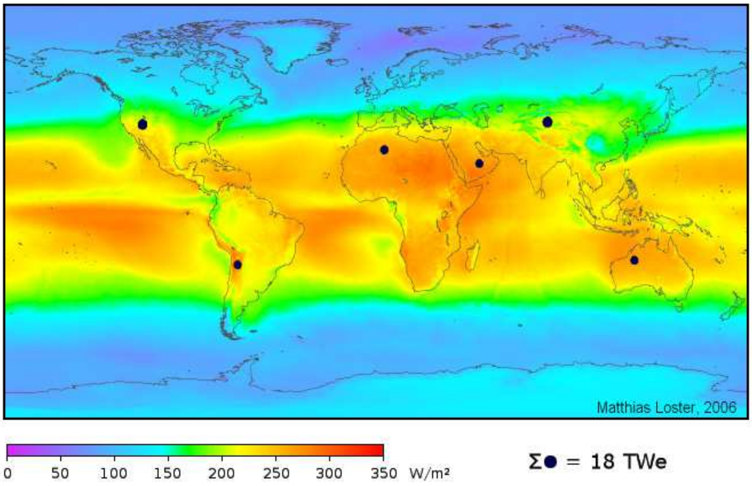


Fig. 3. Solar radiation intensity (Source: http://www.ez2c.de/ml/solar_land_area)

This portion of the planet includes ¾ parts of World's population and, in consequence, these measures would have a large impact not only in developed societies, but also in developing countries from Asia or South America, where the demand of energy will become more and more important in the near future.

2.2 Earth radiation and albedo

The atmosphere of the Earth is fully transparent to visible light, but much less to infrared radiation. This is the reason why almost 58% of solar light that our planet receives reaches its surface, from which 50% is absorbed by the Earth. The rest of the radiation coming from the Sun is absorbed by the atmosphere (20% approx.), reflected by clouds (22% approx.) or reflected by Earth's surface (8% approx.).

The energy absorbed by the Earth makes it getting warm and then emitting this heat as infrared radiation, which heats up the atmosphere until it reaches a temperature at which the energy flows entering and leaving the Earth are balanced.

The presence in the Earth's atmosphere of water vapour, methane, CO_2 and other greenhouse gases, which are nearly impermeable to infrared radiation, keep the energy emitted in such a way, increasing the equilibrium temperature in comparison with the temperature in the absence of these gases. This effect is desirable, since otherwise the temperature of the Earth would be too low (-18 or -19ºC) for life. However, the excessive concentration of GHG has resulted into an unusual increment of atmospheric temperature and consequently into a climate change that will modify rain distribution around the Earth, will increase the frequency of extreme atmospheric phenomena and will cause more floods, droughts and hurricanes.

The first approach from the international community to face this problem consisted of reducing the emission of GHG so that the infrared radiation emitted by the Earth is not

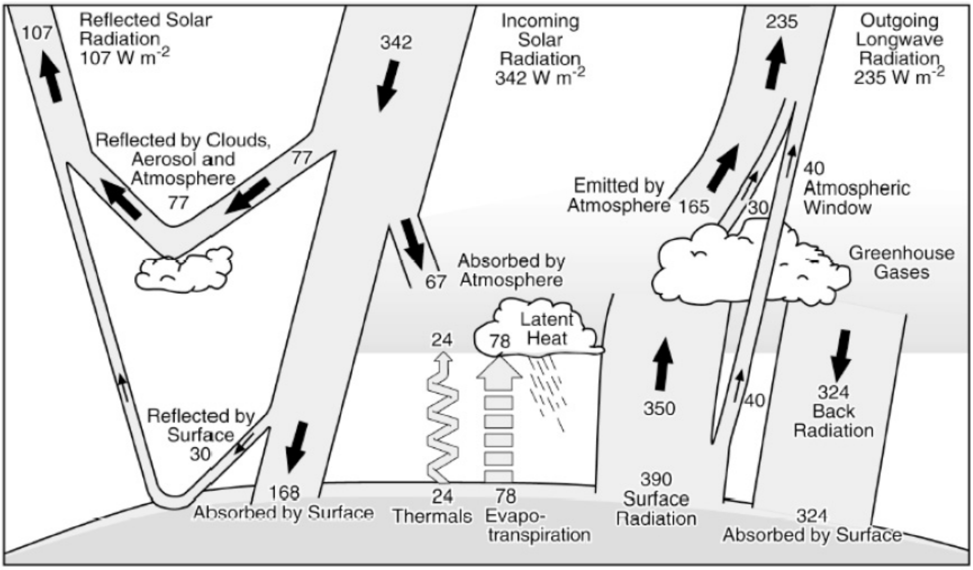


Fig. 4. Earth radiation Budget (Source: Kiehl and Trenberth, 1997)

retained in the atmosphere. Nevertheless, there exist other fields that have not been exploited yet, at least at a global scale, whose influence on global warming would be relevant. Increasing the reflectivity of the Earth's surface would decrease the absorption of solar energy, thus, emitting less infrared radiation and cooling the atmosphere. This action is cheap and means no significant changes in production processes, thus, permitting an immediate and fast deployment.

Earth's surface naturally reflects approximately 8% (not considering the poles) (Kiehl and Trenberth, 1997) of the total solar energy it receives. This reflection is conditioned by the colour of the surface: the lighter the more energy it reflects and vice versa.

The albedo or reflection coefficient is the diffuse reflectivity or reflecting power of a surface. It is defined as the ratio of reflected radiation from the surface to incident radiation upon it. A surface that absorbs all the energy it receives (black surface) has an albedo of 0, whereas a perfect reflector (white surface) has an albedo of 1.

Typical albedo of different kind of surfaces and materials are shown in table 1:

Surface	**Albedo**	**Surface**	**Albedo**
Fresh snow	81 - 88 %	Old snow	65 – 81 %
Ice	30 – 50 %	Rock	20 – 25 %
Woodland	5 – 15 %	Exposed soil	35 %
Oceans	5 – 10 %	Concrete	15 -25 %
Asphalt	2 – 10 %		

Table 1. Typical albedo values of different kind of surfaces and materials *(Source: European Concrete Paving Association, 2009)*

On average, the albedo of the planet is 0.35. That is to say 35% of all the solar energy is reflected while 65% is absorbed. However, it must be pointed out that polar ice, with its high albedo plays an important role in maintaining this balance. Should the polar ice melt, the average albedo of the Earth will fall because the oceans will absorb more heat than the ice.

Humans act on Earth's surface, mainly by means of construction works, usually decreasing its albedo. Pavements and building's roofs are the most exposed surfaces to solar radiation among typical construction works and they must become the objective of any measure aiming at increasing energy efficiency by means of the application of the albedo effect. In this sense, there exist at the moment construction materials that are lighter than the natural surface of the Earth. Its utilization would increase the global albedo, reducing, this way, the amount of solar energy absorbed by our planet.

Asphalt albedo ranges from about 0.05 to 0.20 (Akbari and Thayer, 2007), depending on the age and makeup of the asphalt. Its albedo typically increases somewhat as its colour fades with age. A typical concrete has an albedo of about 0.35 to 0.40 when constructed; these values can decrease to about 0.25 to 0.30 with normal usage. With the incorporation of slag or white cement, a concrete pavement can exhibit albedo readings as high as 0.70. As shown in Figure 5, concrete has a significantly higher albedo than asphalt, either new or old. In fact, concrete usually has a higher albedo than almost every other material that is typical to urban areas, including grass, trees, coloured paint, brick/stone and most roofs.

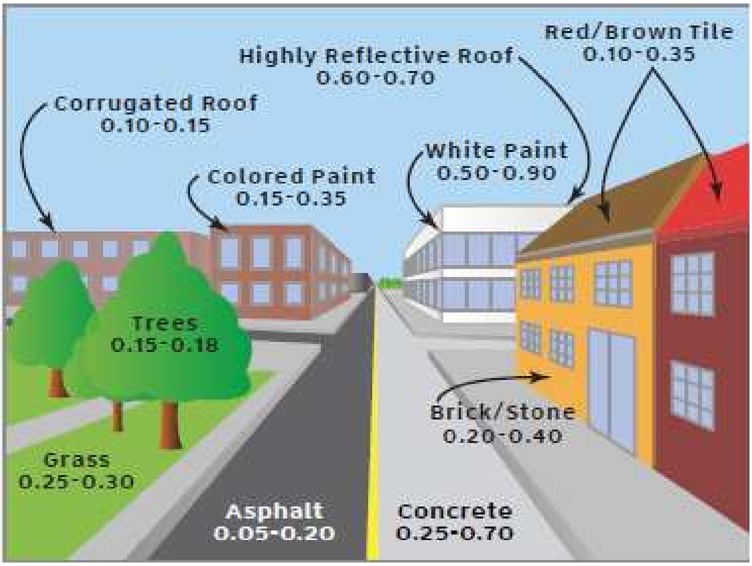


Fig. 5. Albedo ranges of various surfaces typical to urban areas *(Source: NASA, Akbari and Thayer, 2007)*

3. Influence of albedo on global warming

As previously mentioned, the albedo effect has a significant influence on climate change since approximately 50% of the solar radiation reaches the Earth's surface, where it will be either absorbed or reflected, depending on its albedo. The more radiation the Earth absorbs, the hotter it becomes, favouring global warming.

Nonetheless, this global warming effect can be slowed down by applying our knowledge, namely by providing more reflective surfaces.

The "Heat Island Group", a research group from Berkeley, California, compared the albedo effect and the influence of the concentration of atmospheric CO_2 on the net radiation power responsible for global warming. They calculated that an increase by one percent of the albedo of a surface corresponds to a reduction in radiation of 1.27 W/m^2. This reduction in radiation has the effect of slowing global warming. Their calculations indicate that delay in warming is equivalent to a reduction in CO_2 emissions of 2.5 kg per m^2 of the Earth's surface.

According to these results, the potential of this measure would be at the same level as increasing renewable energies up to 20% of the energy mix or implementing CCS technologies in power and industrial plants. Additionally, the cost of this measure would be much more economical. As construction works are continuously being carried out around the World, especially in developing countries where the deficit of infrastructures is considerable, this measure could be easily applied either by using lighter construction materials or by painting surfaces in white or other light colours. Whereas the latter means an extra cost from paint, the former could be deployed at the same price or even cheaper.

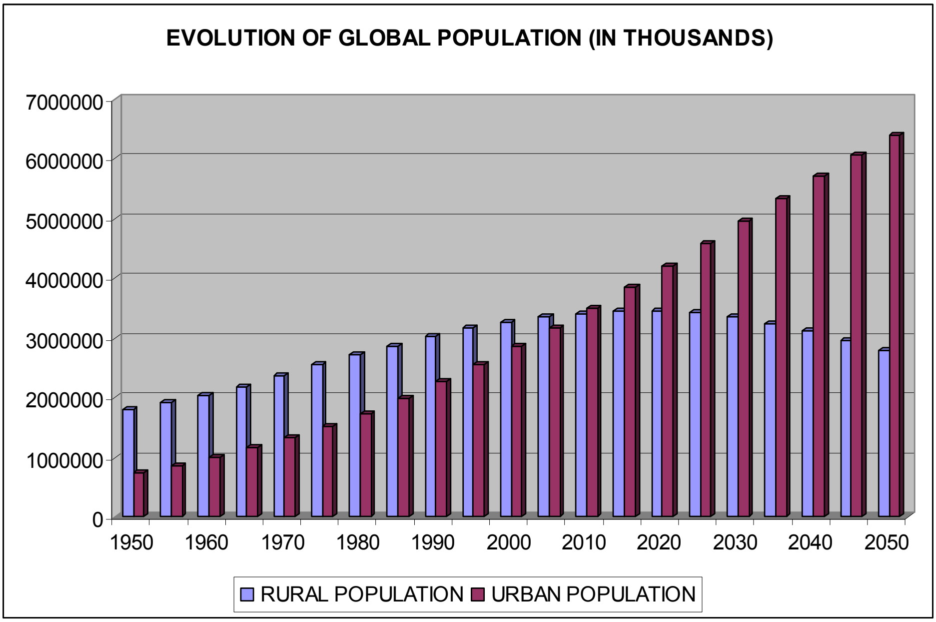


Fig. 6. Past and future evolution of worldwide population (Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2006 Revision and World Urbanization Prospects: The 2007 Revision)

4. The albedo and the cities

4.1 Energy demand of cities and buildings

World's population has had a steady trend to urban concentration from the last century. In 1900, the ratio of people who lived in cities represented the 10% of global population, whereas in 2007 United Nations estimated that urban population already exceeded rural people. Projections predict the same trend for the future and, therefore, present situation of cities will worsen and new problems will arise.

One of the main difficulties that cities will have to face in the future is the energy supply. Despite only representing 2 percent of the world's surface area, cities are responsible for 75 percent of the world's energy consumption. London, for example, requires a staggering 125 times its own area in resources to sustain itself (New Scientist, 2009)

London's population is around 7.4 million, so it is nowhere near megacity status yet, but according to the Tyndall Centre, it already consumes more energy than Ireland (and the same amount as Greece or Portugal) (New Scientist, 2009).

A great amount of this energy consumed by cities comes from residential uses, mainly from acclimatization of buildings.

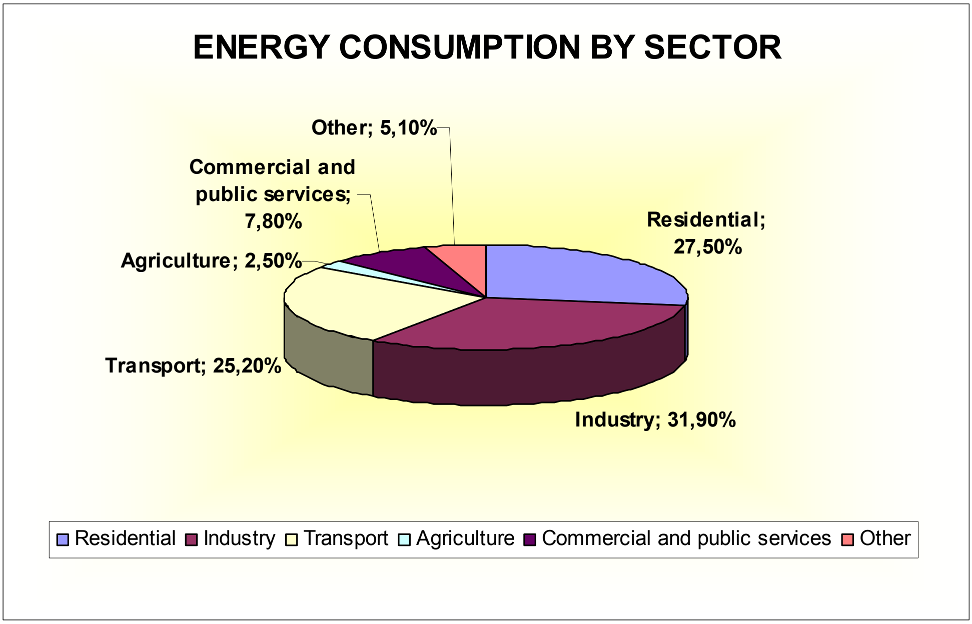


Fig. 7. World's energy consumption by sector *(Source: International Energy Agency, 2009)*

For this reason, it is essential to adopt measures aiming at reducing energy consumption of buildings within cities. Thermal insulation systems are continuously improving, electrical appliances are becoming more and more efficient and the utilization of energy-efficient light bulbs is increasing.

However, there exist measures that are not being considered and whose impact would be much higher than the impact of traditional solutions. Cement and concrete are in the core of these innovative measures, since they can increase the reflectivity of cities, helping to reduce the ambient temperature and, in consequence, the air conditioning needs.

4.2 Urban heat islands

An urban heat island (UHI) is a metropolitan area which is significantly warmer than its surrounding rural areas. This effect is more noticeable during the night than during the day and it is more apparent when the winds are weak. Seasonally, UHI is seen in both summer and winter.

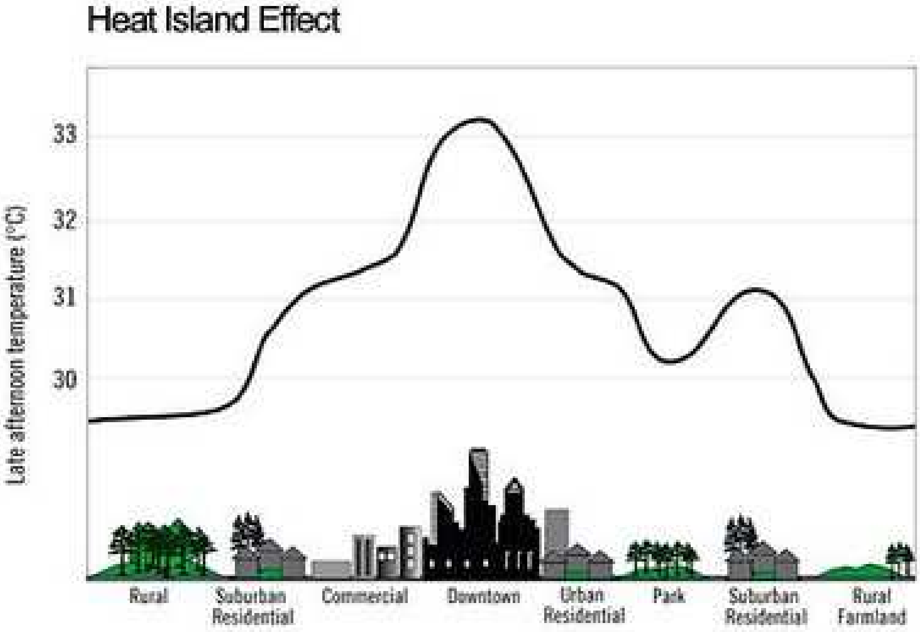


Fig. 8. Distribution of temperatures due to urban heat island effect (European Concrete Paving Association, 2009)

In the case of Madrid (Spain), two meteorological stations were chosen: one in the city centre, near Retiro Park, and another in Barajas, where the airport is placed. The distance between both stations is less than 15 kilometres, but the difference of temperatures reaches 8ºC. Although Madrid is a dense city where this effect is deeper, it can also be noticed in any other city where building concentration and dark pavements produce this effect.

There are several causes for urban heat islands. The main reason is the modification of the environment by human being, introducing new materials that absorb more heat than natural ones. The solar radiation absorbed by the urban construction materials highly affects the temperature distribution inside cities. The thermo physical properties of these materials, especially the albedo and the infrared emissivity, have an important impact in their

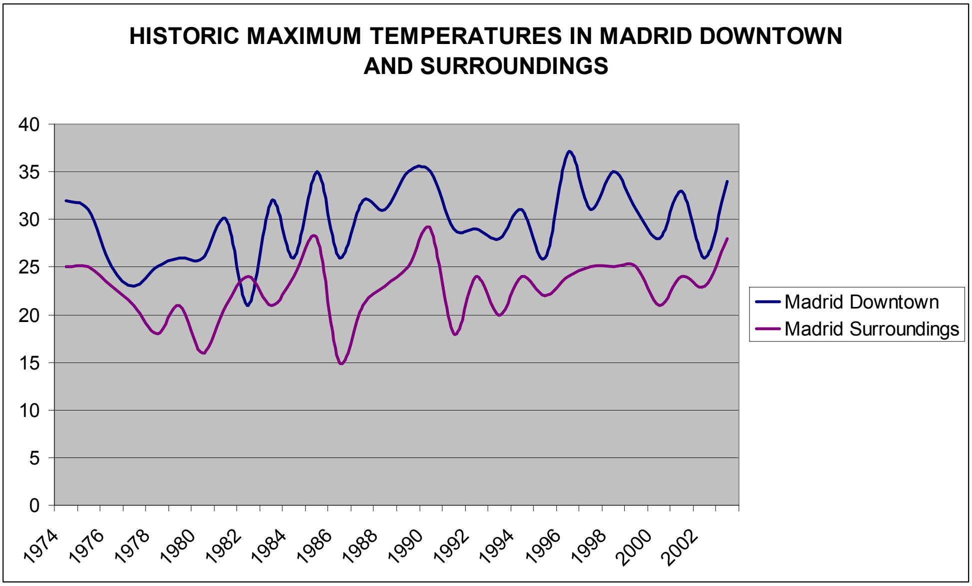


Fig. 9. Maximum average temperatures in Madrid downtown and surroundings (Source: Agencia Estatal de Meteorología, Spain)

energetic balance. Pavements are quantitatively important urban components in what is referred to the horizontal surface exposed to solar radiation (20% of the urban ground approximately) (Rose et al., 2003) and generally they have a high absorptivity and a high thermal capacity. These characteristics made significant contributions to the urban heat island effect, particularly in arid climates with high radiation levels.

This effect can be easily appreciated in a thermal photography that gives the temperature of any surface (see figure 10)

The heat absorbed during the day coming from solar radiation is emitted at night to the relatively cold night sky. The result is the increment of the average temperature within cities in approximately 5°C, which has a negative effect, mainly during summer time and in those areas where the air conditioning needs are high. The immediate result will be a dramatic rise of the demand of energy.

4.3 Strategy for cities

Increasing the albedo of the Earth's surface has a positive effect against global warming independently of the place where this increment is achieved. However, the effect of lightening the surfaces inside cities is much higher due to the indirect effect on urban heat islands and on acclimatization needs. For this reason, it must be in cities where greater efforts must be made in order to take advantage of this powerful tool.

Light roofs and facades have a direct effect on energy demand of buildings. When receiving solar radiation, these buildings reflect more light and, therefore, absorb less energy, thus,

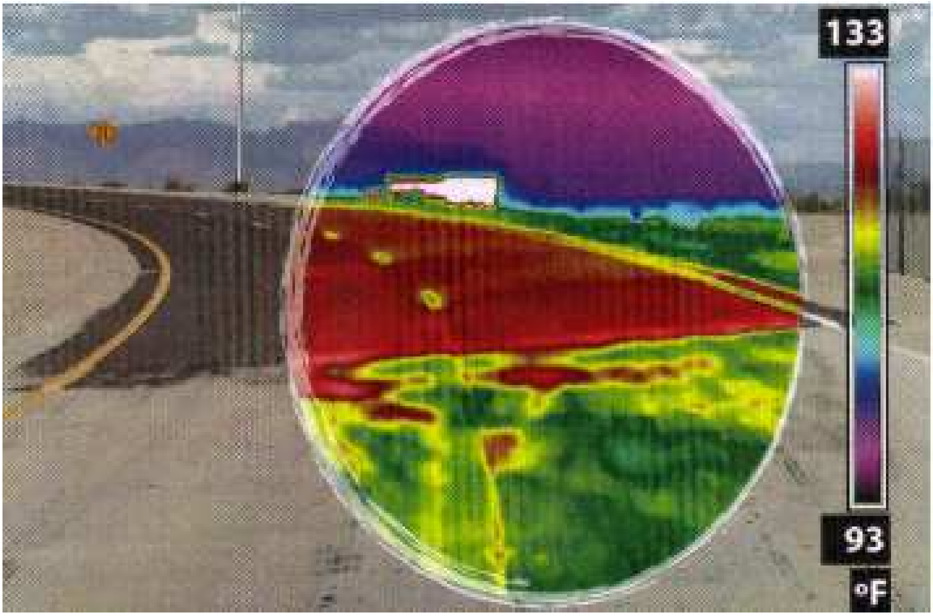


Fig. 10. Temperatures distribution on top of surfaces built by human being (Source: "Concrete roads: a smart and sustainable choice", European Concrete Paving Association, 2009)

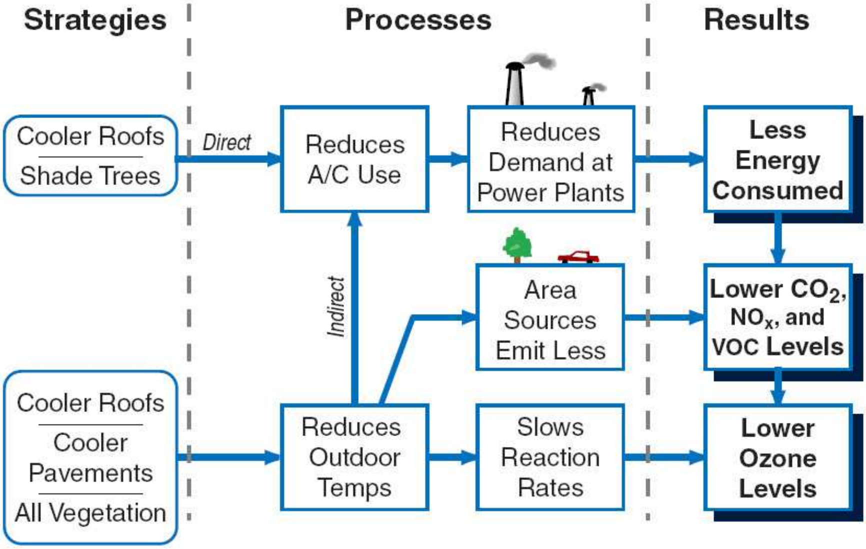


Fig. 11. Direct and direct effects of increasing the albedo of cities (*Source: H. Akbari, 2009*)

reducing the inner temperature. As a result of this, the energy demand for acclimatization purposes of the building also decreases.

Additionally, pavements can also be lighter, which means increasing the global albedo of the Earth and reflecting a higher amount of solar energy into the space.

Both measures have an indirect effect in cities. Higher albedo means less energy absorption, which helps to combat urban heat islands, reducing the ambient temperature and the energy consumption for air conditioning.

There are more advantages coming from the increase of albedo, which is not only accompanied with lower surface temperatures and lower energy use, but also with lower CO_2, NOx, VOC and ozone levels. Besides, the probability of smog formation decreases 5% for every 0.25°C fall in daily maximum temperatures above 21°C.

5. Quantification of albedo effect

5.1 Potential of global albedo effect

The most important human action on environments is, with high probability, road construction. Transport has become one of the principal activities of human being and road transport represents 85% of this activity. The consequence has been the construction of more than 30 million kilometres of roads (International Road Federation, 2006), of which 20.3 million kilometres are paved. There are other constructions that also modify the Earth's surface: railways, dams, airports, etc, but their magnitude is far from road construction. This is the reason why the quantification is only focused on roads.

The principal material used in road pavement construction is asphalt, to the point that more than 95% of roads worldwide are built with this material. As the albedo of asphalt ranges between 5 and 10% (European Concrete Paving Association, 2009), whereas the albedo of exposed soil can be fixed in 35% (European Concrete Paving Association, 2009), the result is an absolute reduction of 25% in the albedo of the surface occupied by the road. Although it has not been quantified, researches carried out in Berkeley have proved that this action have a significant impact on global warming.

Lightening asphalt or substituting it by other lighter materials (i.e. concrete) would have the contrary effect. This action would not only reduce the global albedo of the planet but it would increase it in those areas where road runs along forests or other surfaces with medium albedo values.

Assuming an average width for paved roads of 10 metres, we can estimate the influence of lightening road pavements on global warming by the application of the following equation:

$$TER = \Delta A \times ER \times ES$$

where:

ΔA = Increment of Earth albedo by asphalt-concrete substitution in roads
ER = Equivalent reduction in CO_2 emissions per m^2 per 1% increment of albedo
ES= Earth surface
ΔA can be calculated by the application of the equation:

$$\Delta A = \frac{PS}{ES} \times \Delta NA$$

where:
PS = Total paved surface
ΔNA = Difference in albedo between asphalt and concrete

The results of the calculation are shown in table 2:

PARAMETER	VALUE	SOURCE
Total length of paved roads	20,301,039 km	IRF Statistics, 2006
Average width of roads	10 m	Estimated
Total paved surface	203,104 km^2	Calculated
Earth's surface	510,072,000 km^2	Wikipedia http://en.wikipedia.org/wiki/Earth
Ratio paved surface/total surface	0.04 %	Calculated
Albedo of asphalt	10%	EUPAVE, 2010
Albedo of concrete	25%	EUPAVE, 2010
Difference in albedo between asphalt and concrete	15%	Calculated
Increment of Earth albedo by asphalt-concrete substitution in roads	0,006 %	Calculated
Equivalent reduction in CO$_2$ emissions per m^2 per 1% increment of albedo	2.5 kg/m^2	Heat Island Group, 2009
Total equivalent reduction by asphalt-concrete substitution	7.6 GTn CO$_2$	Calculated

Table 2. Calculation of global albedo effect estimated in equivalent CO$_2$ emissions

The potential reduction of atmosphere temperature thanks to the substitution of road asphalt by lighter materials is equivalent to withdrawing from the atmosphere 7.6 G tons, which represents 25% of total emissions of CO$_2$ in 2010 (International Energy Agency, 2010)

Obviously, it is not feasible to lighten all paved roads around the World, since the cost of this action is unaffordable. However, this result should make the society focus on the implementation of this measure. In this sense, new roads and preservation works should become a powerful tool against global warming.

5.2 Potential of albedo effect inside cities

Quantifying the effect of an increment of the albedo inside cities is much more complicated than quantifying the global effect coming from lightening road pavements, mainly due to indirect effects. The principal benefit of increasing the albedo of cities comes from the partial elimination of heat islands, which is difficult to evaluate.

However, recent researches (Lawrence Berkeley National Laboratory in California, 2009) suggest that urban areas cover between 1.2 to 2.4% of the Earth's land mass. Paved areas in 100 of the world's largest cities cover an area of about 525 billion m^2. By using lighter pavements and roofs, it is possible to increase the albedo of urban surfaces in the world's top 100 cities up to 15%. The goal is to positively impact energy use, as well as to reduce smog formation, CO_2 levels, and ultimately, global warming.

Typical reflectivity of roof fabric is low, especially in residential sector. The average albedo of roofs can be estimated between 10 and 25%. It is possible to increase the albedo of roofs either by using new lighter materials or by placing a white covering on top of current roofs. In case these measures are applied, reflectivity of roofs is estimated to reach 55-60%, which means an absolute increment of 30%. Regarding pavements, long term albedo could be increased in a 10%.

A study carried out in the United States (Rose et al. 2003) estimated that the total surface occupied by roofs in urban areas is 20% and it can reach up to 25% in dense cities. The same study establishes that the percentage of paved surfaces ranges between 29 and 44%. Since the ratio of surface for vegetation purposes in American areas exceeds the world's average, it can be stated that the ratio of urban surface occupied either by roofs or by pavements is 20 and 40% respectively.

The distribution of surfaces by type inside cities is shown in table 3:

Vegetation	28 %
Roofs	20 %
Pavements	40 %
Other	12%

Table 3. Distribution of surfaces by type inside cities (Source: Rose et al. 2003, partially modified)

Assuming previous figures, an absolute increment of 0.10 in the reflectivity of albedo inside cities can be achieved (see table 4)

	Potential increment of albedo	**Surface ratio**	**Total increment**
Roof	0,30	20%	0,06
Pavement	0,10	40%	0,04
Total			0,10

Table 4. Increment of global albedo of cities due to the increment of roofs and pavements reflectivity

So far, assessing the influence of a 10% increment of albedo of cities has been extremely complicated because numerical models could only use a minimum square grid of 250 km sideway for the evaluation. Computational developments now permit reducing the size of the grid up to 50-100 km and even less for urban areas. These powerful models predict a fall of global temperature of 0,03 ºC under these assumptions (H. Akbari, 2009):

1. Urban areas (2% of total Earth's surface) are perfectly white (albedo equal to 1).
2. The rest of the Earth's surface (98%) maintained its natural albedo.

In case the first assumption is changed and, instead of a perfect reflectivity, a 10% increment of the albedo is considered, the reduction of the global temperature would be 0,01 ºC annually (H. Akbari, 2009). Taking into account that United Nations predict an increment of global temperature of 3ºC in the next 60 years (0,05 ºC per year), the conclusion is that substituting current roof and asphalt pavements by cool roofs and concrete pavements would slow down global warming by 20%.

World's current rate of CO_2 emissions is about 30 G tons/year (International Energy Agency, 2010). World's rate of CO_2 emissions averaged over next 60 years is estimated at 50 G tons/year (International Energy Agency, 2008). Hence, the 20% delay in global warming is worth 10 G ton CO_2 annually.

5.3 Economic impact

Although economic evaluation of certain measures is always difficult because of the volatility of prices, net potential savings coming from the direct effect on buildings (cooling energy savings minus heating energy penalties) have been estimated in excess of one billion Euros only in United States (H. Akbari, 2007).

Additionally, partial elimination of heat islands would make cities cooler and would improve the quality of air, thus indirectly reducing the consumption of energy for air conditioning (Taha 2002, Taha 2001, Taha et al. 2000, Rosenfeld et al. 1998; Akbari et al. 2001, Pomerantz et al. 1999). Savings of energy and better quality of air would mean a 2 billion Euros profit per year only in United States.

At the moment, the price of a CO_2 ton in European emissions market is around 13 €. This price is relatively low due to the current economic and financial crisis. However, it is estimated to rise up to 30 € in the short term. Substituting asphalt by lighter materials in world's paved roads would have the same effect as abating 7,6 G tons of CO_2 per year (calculated in this report). Global effect on cities, direct and indirect effect would be equivalent to abating 10 G tons annually (H. Akbari, 2009). The estimated cost (emissions trading) of both effects in the middle term could reach 528 billion Euros.

6. Conclusions

Results presented in this report show the social and environmental advantages of increasing the reflectivity of roofs and pavements inside cities and in interurban roads. Actually, the potential benefits of this measure are much higher than other actions that are considered as a priority by United Nations and other international organizations.

Increasing urban albedo in a 10% would allow saving up to 3 billion Euros in electricity only in the United States (H. Akbari, 2009) thanks to direct effects and also to the elimination of urban heat islands. Additionally, its influence on global temperature could slow down global warming up to 45%(calculated in this report), which would have an equivalent economic saving of more than 500 billion Euros per year during the next 60 years.

Obviously, it is not possible to reach these figures in the short term. Increasing the reflectivity of roofs means placing white materials on top of current buildings and using innovative solutions for new buildings. In the same way, increasing the albedo of pavements means covering all asphalt pavements with other construction materials, mainly concrete (whitetopping) and building new pavements of cities with concrete.

Besides, the actual effect of increasing reflectivity of construction works is not precisely defined. For this reason, it is essential to perform research and demonstration projects to deeply study and evaluate the differences between traditional and new cities with cool roofs and pavements, quantifying potential benefits and profits.

Increasing the reflectivity of urban areas and also of interurban paved roads might have the same effect as the rest of measures considered for combating global warming all together: energy efficiency of industrial processes, CCS technologies, nuclear power plants, renewable sources of energy, etc. This is the reason why increasing albedo of construction materials should be included as a mitigation measure in IPCC reports.

7. References

"Combat Global Warming", pavements4life.com, American Concrete Pavement Association, 2007.

"Energy efficiency in buildings, transforming the market", World Business Council for Sustainable Development, Switzerland, 2009.

European Directive 2002/91/CE: "Directive on the Energy Performance of Buildings"

"Energy Technology Perspectives: Scenarios & strategy to 2050", International Energy Agency, OECD/IEA, Paris, 2010

H. Akbari, S. Menon and A. Rosenfeld, *"Global cooling: effect of urban albedo on global temperature"*, 2nd PALENC Conference and 28th AIVC Conference on Building Low energy Cooling and Advance Ventilation Technologies in the 21st Century, 2007.

H. Akbari and R. Levinson, *"Status of cool roofs standards in the united States"*, 2nd PALENC Conference and 28th AIVC Conference on Building Low energy Cooling and Advance Ventilation Technologies in the 21st Century, 2007.

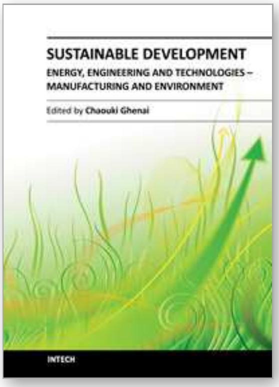
H. Akbari, *"Global Cooling: increasing worldwide urban albedo to offset CO_2"*, Fifth Annual California Climate Change Conference, Sacramento, CA, 2009.

H. Akbari, M. Pomerantz and H. Taha, "Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas", Solar Energy, vol. 70, N.3, Great Britain, 2001.

I. Ben Hamadi, P. Pouezat and A. Bastienne, "The IRF World Road Statistics", International Road Federation, Switzerland, 2006.

L. Rens, *"Concrete roads: a smart and sustainable choice",* European Concrete Paving Association, Brussels, 2009.

"Technology Roadmap: Energy efficient buildings: heating and cooling equipment", International Energy Agency, France, 2009.



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The technological advancement of our civilization has created a consumer society expanding faster than the planet's resources allow, with our resource and energy needs rising exponentially in the past century. Securing the future of the human race will require an improved understanding of the environment as well as of technological solutions, mindsets and behaviors in line with modes of development that the ecosphere of our planet can support. Some experts see the only solution in a global deflation of the currently unsustainable exploitation of resources. However, sustainable development offers an approach that would be practical to fuse with the managerial strategies and assessment tools for policy and decision makers at the regional planning level. Environmentalists, architects, engineers, policy makers and economists will have to work together in order to ensure that planning and development can meet our society's present needs without compromising the security of future generations.

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Unit 405, Office Block, Hotel Equatorial Shanghai
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Phone: +86-21-62489820
Fax: +86-21-62489821