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Case Study

Reducing urban heat island effects: A systematic review to achieve energy consumption balance

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Considering the current energy consumption worldwide, it has become increasingly important to study the effects of urban heat island on energy consumption in order to improve the environment. This paper investigates the impact of Urban Heat Island (UHI) on energy consumption and also determines which factors can directly affect energy use in the city. The UHI current knowledge and literature are reviewed, as well as how UHI can affect energy consumption. This paper explores literally the conceptual framework of confliction between population and urban structure, which produce UHI intensity and affected energy consumption balance. It is then discussed how these two factors can be affected and gives implication to the city and then, focuses on whether actions should be taken for balancing adaptation and mitigation UHI effects. It will be concluded by making the three important strategies to minimise the impact of UHI on energy consumption: providing an appropriate landscape, using appropriate materials on external surfaces of buildings and urban areas and promoting natural ventilation.

Key words: Energy consumption, quality of life, urban heat island, urban temperature.

INTRODUCTION

Urban development has serious effects on the global environmental quality, including the quality of air, increase in temperature and traffic congestion. Building itself is related to global changes in the increase of urban temperatures, the rate of energy consumption, the increased use of raw materials, pollution and the production of waste, conversion of agricultural to developed land, loss of biodiversity and water shortages (Santamouris et al., 2001). It is clear that urban areas without high climatic quality use more energy for air conditioning in summer and even more electricity for lighting. Moreover, discomfort and inconvenience to the urban population due to high temperatures, wind tunnel effects in streets and unusual wind turbulence due to incorrectly designed high rise buildings is very common (Bitan, 1992).

This trend toward urbanisation can be interpreted as the process of regional socioeconomic self-organisation, which is induced by various opportunities that cities provide for their inhabitants (Kikegawa et al., 2006). However, with the concentration of anthropogenic actives-ties into urban areas, a climatic environmental problem, the "urban heat island", has emerged. An urban heat island is a climatic phenomenon in which urban areas have higher air temperature than their rural surroundings as a result of anthropogenic modifications of land surfaces, significant energy use and its consequent generation of waste heat. Thus, this might prove to be an unsustainable factor that leads to excessive energy use for cooling and putting the urban population at great risk for morbidity and mortality.

According to the above perspective and considering that rapid and huge population growth is expected in the near future, it becomes increasingly important to apply heat island mitigation strategies in order to reduce energy consumption and improve the quality of life.

Thus, this paper investigates the primary factors of urban heat island formation, such as population, which significantly affects energy consumption. Then, according to the Oke's heat island parametric model that shows that

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Abbreviation: UHI, Urban Heat Island.

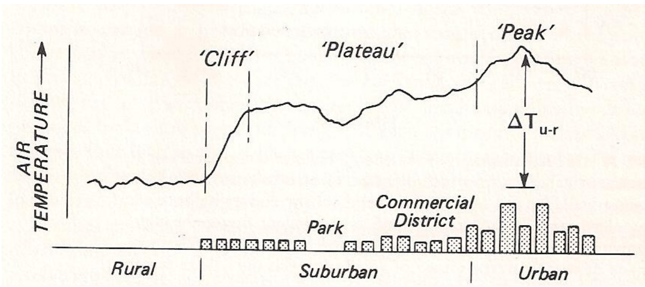

Figure 1. Generalized cross-section of a typical Urban heat Island (Oke, 1987).

higher population increases density and urban temperature in urban areas, population and UHI intensity are directly related and lead to maximum energy consumption for heating and cooling buildings (Oke, 1987). In addition, rapid urbanisation and density growth cause UHI due to urban factors such as air pollution, anthropogenic heat, urban geometry, surface waterproofing and thermal properties of fabric that increase the energy loads for cooling buildings and peak electricity loads. For energy saving, therefore, this paper suggests two strategies at two different scales: macro-scale and micro-scale; the combination of both strategies provides the best possible energy saving solution.

URBAN HEAT ISLAND PHENOMENON AND ENERGY CONSUMPTION

The urban heat island effects in hot climates exacerbate energy consumption for cooling in summer. UHI effects are due to meteorological and urbanisation factors that increase urban temperature and the corresponding electricity demand in an urban area. The following two sections present how UHIs form and factors that increase UHI intensity; in next section, analysis of the process of increasing energy consumption in Figure 4, shows that there is a correlation between UHI and energy consumption.

Urban heat island

The majority of cities are sources of heat and pollution and the thermal structure of the atmosphere above them is affected by the "heat island" effect. A heat island is best visualised as a dome of stagnant warm air over the heavily built-up areas of cities (Emmanuel, 2005). The heat that is absorbed during the day by the buildings, roads and other constructions in an urban area is re-emitted after sunset, creating high temperature differences between urban and rural areas (Asimakopoulos et al., 2001). The exact form and size of this phenomenon varies in time and space as a result of meteorological, regional and urban characteristics (Oke, 1987). Therefore, urban heat island morphology is greatly influenced by the unique character of each city. As seen in Figure 1, Oke (1987) stated that in a larger city with a cloudless sky and light winds just after sunset, the boundary between the rural and the urban areas exhibits a steep temperature gradient to the urban heat island and then the rest of the urban area appears as a "plateau" of warm air with a steady but weaker horizontal gradient of increasing temperature towards the city centre. In Figure 1, the uniformity of the "plateau" is interrupted by the influence of distinct intra-urban land-uses such as parks, lakes and open areas (cool) and commercial, industrial or dense building areas (warm).

In metropolitan areas, the urban core shows a final "peak" in the urban heat island where the urban maximum temperature is found. The difference between this value and the background rural temperature defines the "urban heat island intensity" (ΔT_{u-r}). The intensity of the heat island is mainly determined by the thermal balance of the urban region and can result in a temperature difference of up to 10 degrees (Asimakopoulos et al., 2001). As shown in Figure 2, the heat island intensity varies in a recognisable way through the day under ideal weather conditions. At night, stored heat is released slowly from the urban surface, contrary to the rapid heat escape from rural surfaces. Thus, the urban heat island intensity peaks several hours after sunset when rural surfaces (and consequently surface air temperatures) have cooled yet urban surfaces remain warm. After sunrise, rural areas warm more quickly than urban areas (Figure 2b). If the difference in heating rates is great enough, rural air temperatures may equal or exceed urban temperatures. This reduces the urban heat island intensity to a daytime minimum (Figure 2c) and may even generate an *urban cool island*.

The heat island phenomenon may occur during the day or during the night. Givoni (1998) mentioned that the largest elevations of the urban temperatures occur during clear and still-air nights. Under these conditions, temperature elevations of about 3 - 5℃ are common, but elevations of about 8 - 10℃ were also observed.

Today, the majority of cities are around 2℃ warmer than rural areas and commercial and high density residential areas are hotter by 5 to 7℃ (Bonan, 2002). There are some main parameters which influence the temperature increase in cities and play significant role on it. Therefore, urban heat island is caused by different factors that can be divided into two types: (1) meteorological factors, such as cloud cover, wind speed and humidity; (2) city parameters, such as city and population size, anthropogenic heat and urban canyon.

According to Landsberg (1981), a heat island is present in every town and city and is the most obvious climatic manifestation of urbanisation. Clearly higher urban temperatures seriously impact the electricity demand for air conditioning in buildings and increase smog production, as well as contribute to increased emission of

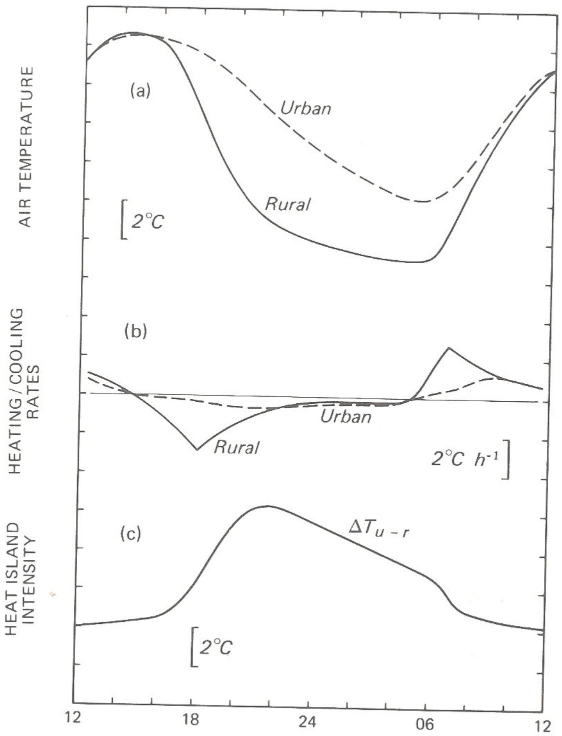

Figure 2. Typical temporal variation of Urban and Rural. (2a) Air temperature, (2b) Cooling/Warming rates and (2c) The resulting heat Island intensity under Ideal weather conditions (Oke, 1982).

pollutants from power plants, including sulphur dioxide, carbon monoxide, nitrous oxides and suspended particulates (Asimakopoulos et al., 2001).

Considering heavy construction, urban heat islands are a result of many factors, the most important of which are summarised by Oke et al. (1991):

(a) Canyon radiative geometry contributes to decreasing the long-wave radiation loss from street canyons as a result of the complex exchange between buildings and the screened skyline. Infrared radiation is emitted from various buildings and street surfaces within the canyons. Buildings replace a fraction of the cold sky hemisphere with much warmer surfaces, which receive a high portion of the infrared radiation emitted from the ground and radiate back an even greater amount.
(b) Thermal properties of materials may increase heat storage in the fabric of the city during the daytime and release the stored heat into the urban atmosphere after sunset. Furthermore, the replacement of natural soil or vegetation by materials, such as concrete and asphalt, typically used in cities reduces the potential to decrease ambient temperature through evaporation and plant transpiration.
(c) Anthropogenic heat is released by the combustion of fuels from either mobile or stationary sources, as well as by animal metabolism.
(d) The urban greenhouse effect contributes to the increase in the incoming long-wave radiation from the polluted urban atmosphere. This extra radiative input to the city reduces the net radiative drain.
(e) Canyon radiative geometry decreases the effective albedo of the system because of the multiple reflections of short-wave radiation by the canyon surfaces.
(f) The reduction of evaporating surfaces in the city puts more energy into sensible heat and less into latent heat.
(g) There is reduced turbulent transfer of heat within streets.

Asimakopoulos et al. (2001) also mention that humans are capable of influencing the climate through many types of human activities and changes in ground cover (deforestation) or on the surface of the earth (building, highways); this is also important on a local scale because they modify the albedo, surface roughness and thermal and moisture behaviour.

Correlation between urban heat island and energy consumption

Urban areas throughout the world have increased in size during recent decades. Omer (2008) stated that about 50% of the world's population and approximately 7.6% in more developed countries are urban dwellers. Even though there is evidence to suggest that, in many 'advanced' industrialised countries, there has been a reversal in the rural-to-urban shift of populations; virtually all population growth expected between 2000 and 2030 will be concentrated in urban areas of the world. With an expected annual growth of 1.8%, the world's urban population will double in 38 years. UNPD (2000) stated that accelerating urbanization would be caused by intensive increases in the urban populations in developing countries in Asia and other areas and that more than 90% of the increase in the world population during this period (2 billion persons) would be unevenly concentrated in those urban regions. Population shifts, urban and suburban growth, changes in land use and production and dispersal of anthropogenic emissions and pollutants interact with regional climate as well as the frequency and intensity of specific weather events (Saaroni et al., 2000; Taha, 1997; Sailor, 1994; Roth et al., 1989; Oke, 1982; Landsberg, 1981). Moreover, as urbanisation increases throughout the world, cities are growing in number, population and complexity. Today, it is well accepted that urbanisation leads to a high increase in energy usage (Asimakopoulos et al., 2001). Heat islands develop in areas that contain a high percenttage of non-reflective, water-resistant surfaces and a low percentage of vegetated and moisture trapping surfaces. In particular, materials such as stone, concrete and asphalt tend to trap heat at the surface (Landsberg, 1981; Oke, 1982; Quattrochi et al., 2000) and a lack of

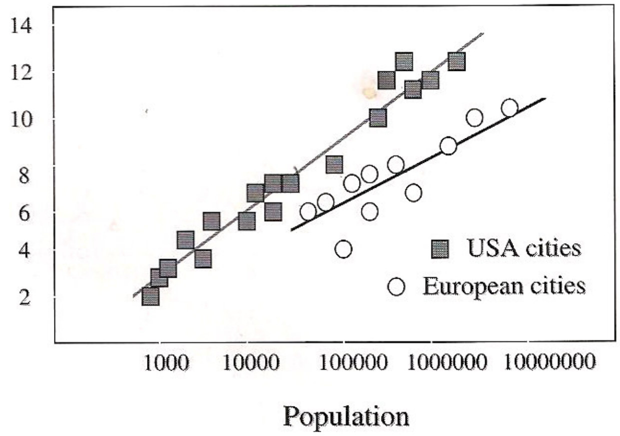

Figure 3. The maximum difference between Urban and Rural temperature for US and European cities (Oke, 1982).

vegetation reduces heat lost due to evapotranspiration (Lougeay et al., 1996). The addition of anthropogenic heat and pollutants into the urban atmosphere further contributes to the intensity of the UHI effect (Taha, 1997). Urban centres tend to have higher energy demands than surrounding areas as a result of their high population density. Though the heat island effect reduces the need for heating in the winter, this is outweighed by the increased demand for air-conditioning during the summer months (Landsberg, 1981), which in turn causes increased local and regional air pollution through fossil-fuel burning electric power generation. The pollution created by emissions from power generation increases absorption of radiation in the boundary layer (Oke, 1982) and contributes to the creation of inversion layers. Inversion layers prevent rising air from cooling at the normal rate and slow the dispersion of pollutants produced in urban areas (Sahashi et al., 2004).

Consequently, urban heat islands not only impact the comfort and health of the inhabitants but also the energy consumption for heating or cooling buildings.

Conceptual framework: Energy consumption balance

As discussed previously, "urban heat islands" form as a result of many factors, which include population and urban construction. The population interacts with its environment in a complex manner. To understand and simplify the complexity, some models have been developed. Oke (1982) has correlated the heat island intensity to the size of the city. Using population (P) as a surrogate of city size, ΔT_{u-r} is found to be proportional to log P. Oke (1982) remarks that the production of urban warm temperature has a direct relationship with urban population. This is because the density of built-up area and the production of anthropogenic heat sources, such as public transportation, automobiles and industrial activities, develop with population growth. Oke (1987) further explains that the ideal case with calm winds and cloudless skies that generates the maximum heat island ($\Delta T_{u-r(\max)}$) varies with log P for many North American and European settlements (Figure 3). As shown, the expected heat island intensity for a city of one million inhabitants is close to 8 K in Europe and 12 K in the US. Oke (1982) believes that the higher values for the American cities are because the centres of North American cities have taller buildings and higher densities than typical European cities.

Based on the above data for North American cities, Oke (1987) suggested the following formula to calculate the heat island intensity near sunset under cloudless skies as a function of the population and the regional wind speed:

$$\Delta T_{u-r} = P^{0.25} \Big/ (4U)^{0.5} \tag{1}$$

where ΔT_{u-r} is the heat island intensity in K, P is the population and U is the regional (non-urban) wind speed in m/s at a height of 10 m.

Oke (1987) stated that urban/rural thermal differences are obliterated with very strong winds. The form of equation (1) does not easily allow the critical wind speed at which this happens in a given city to be identified. Based on observation, it appears that this value is approximately 9 m/s (measured at a height of 10 m at a rural site) in a city with one million inhabitants and about 5 and 2 m/s for populations of 100,000 and 10,000, respectively. On the other hand, Bonan (2002) stated that the relationship between urban heat island intensity and population for North America and Europe as the following:

$$\Delta T = 5.21 Log10(P) - 11.24$$ North America

$$\Delta T = 3.02 Log10(P) - 3.29$$ Europe

where ΔT is the maximum difference between urban and rural areas and P is population.

The preceding two models highlight the role of population in urban heat island formation. Oke's model demonstrates how urban warm temperatures are directly related to urban population; Bonan's model achieves the same purpose.

Other statistical data show that the amount of energy consumed by cities for heating and cooling offices and residential buildings has increased significantly in the last two decades. Santamouris (2001) reported that an increase of the urban population by 1% increases the

Table 1. Patterns of commercial energy consumption (Emmanuel, 1995).

Activity	Energy consumption (% of total country needs)		
	US	U.K.	Sri Lanka
Industries	41.2	32.0	9.9
Transportation	21.0	18.0	16.4
Building energy needs	28.0	48.0	67.0
Agriculture/other	7.7	2.0	6.7

energy consumption by 2.2%, that is, the rate of change in energy use is twice the rate of change in urbanisation. On the other hand, Emmanuel (2005) believes that urban design influences energy needs for transportation and building energy use.

Emmanuel (1995) has shown the rate of energy consumption of three countries, US, U.K. and Sri Lanka, in Table 1. A comparison of energy-use patterns between a developed country like the US and a developing country like Sri Lanka shows that transportation and activities within buildings consume a considerable share of energy in both cases.

These data clearly show the impact of urbanisation on energy use. Increased urban temperatures have a direct effect on building energy consumption during the summer and winter periods. In fact, during the summer, higher urban temperatures increase the electricity demand for cooling and increase the production of carbon dioxide and other pollutants, while higher temperatures may reduce the heating load of buildings during the winter period (Asimakopoulos et al., 2001).

Although many factors are cited as causes for the increase in consumption, it is generally agreed that urbanisation in the region is the primary cause, particularly in areas where increasing income has resulted in greater demand for transportation and home appliances and especially space-conditioning devices (de Dear and Fountain, 1994).

Numerous studies have been performed to show that increasing the urban temperature directly increases energy consumption. For instance, heat island studies in Singapore show a possible increase in the urban temperature close to 1°C (Tso, 1994). Some studies on Tokyo metropolitan areas conclude that, between 1965 and 1975, the cooling load of existing buildings increased on average 10 - 20% because of the heat island phenomenon (Ojima, 1991).

Therefore, it can be concluded that an increasing population in the city culminates in urban construction and anthropogenic heat, which leads to raised temperatures and generates an urban heat island that provides a warm air canopy over the city. Consequently, it causes signifycantly increased energy consumption to heat and cool buildings. This process is summarised in Figure 4.

As shown in Figure 4, rapid urbanisation is causing urban heat islands as a result of several factors. Oke (1981) incorporated these causes into the following five categories (not rank ordered), each of which represents changes to the pre-urban environment brought about by urbanisation:

(1) Air pollution
(2) Anthropogenic heat
(3) Surface "waterproofing"
(4) Thermal properties of fabric
(5) Surface geometry.

Air pollution results from the emission of particulates, water vapour and carbon dioxide from industrial, domestic and automobile combustion processes. These atmospheric "pollutants" change the urban net all-wave radiation budget by reducing the incident flux of short-wave (that is, solar) radiation, re-emitting long-wave (that is, infrared) radiation from the urban surface downward where it is retained by the ground and absorbing long-wave radiation from the urban surface, which effectively warms the ambient air (Oke, 1987).

Anthropogenic heat discharge in a city also contributes to the urban heat island effect. Sources of anthropogenic heat include space heating, manufacturing, transportation and lighting.

Human and animal metabolisms are also considered sources of artificial heat (Peterson, 1973). Heat from these sources warms the urban atmosphere by conduction, convection and radiation. The contribution of anthropogenic heat to the urban energy balance is largely a function of latitude and season of the year. In a temperate city, for example, anthropogenic heat flux may be a significant component of the energy balance in winter, yet a negligible component in summer.

Surface "waterproofing", refers to the predominance of impermeable surfaces in urban areas. Buildings and paved streets quickly shed precipitation into catchment basins, which creates an evaporation deficit in the city. Conversely, in rural areas, exposed soils and natural vegetation retain water that leads to evapotranspirational cooling. During the day, urban surface cover enhances sensible heat transfer and suppresses latent heat flux, whereas moist rural surface suppress sensible heat transfer and enhance latent heat flux.

The fourth factor contributing to the formation of urban heat islands relates to the thermal properties of the urban fabric. The heat capacity and consequently the thermal inertia, of urban construction materials, such as concrete

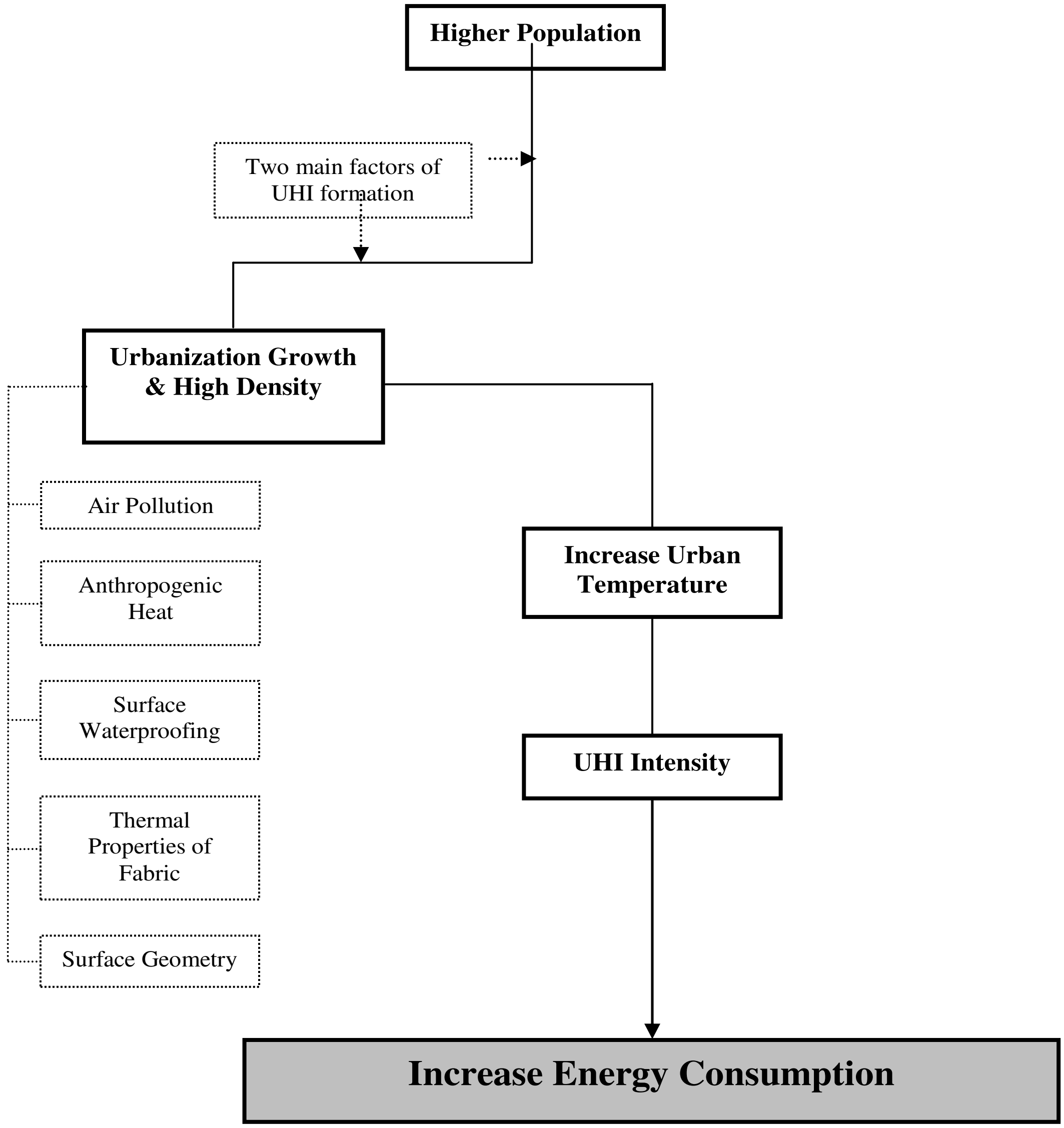

Figure 4. The process of increasing energy consumption.

and asphalt, is greater than that of natural materials found in rural environments. A greater heat capacity means that urban materials absorb and retain more solar radiation than do rural soils and vegetation. At night, this stored heat is released slowly from the urban surface, contrary to the rapid heat escape from rural surfaces.

The complex geometry of urban surfaces influences air temperatures in two ways. First, increased friction created by a rough urban surface (as compared to a smooth rural surface) reduces horizontal airflow in the city. Mean annual wind speeds within cities are approximately 30 – 40% lower than mean annual wind speeds in the countryside (Lee, 1984). Warm air stagnates in the urban canyons unless ventilated by cool rural air.

Lower wind speeds in the city also inhibit evaporation cooling. Second, the complex geometry of the urban surface changes the urban radiation budget. During the day, vertical canyon walls trap (that is, reflect and absorb) short-wave radiation. Night-time losses of infrared energy are also retarded due to the decreased sky view below roof level. Rural surfaces, on the other hand, are comparatively smooth and therefore experience greater nocturnal radiative flux divergence than complex urban surfaces.

Consequently, higher ambient temperature significantly impacts energy consumption by increasing the energy loads to cool buildings; high ambient temperatures increase peak electricity loads.

These models should be further developed and it is essential to build up specific concepts to complement the general ones. Both the general and the specific models

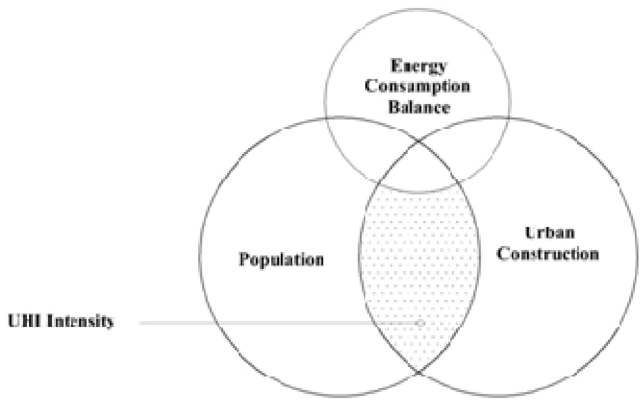

Figure 5. Conflict between population and Urban construction, provision UHI and its effect on energy consumption balance.

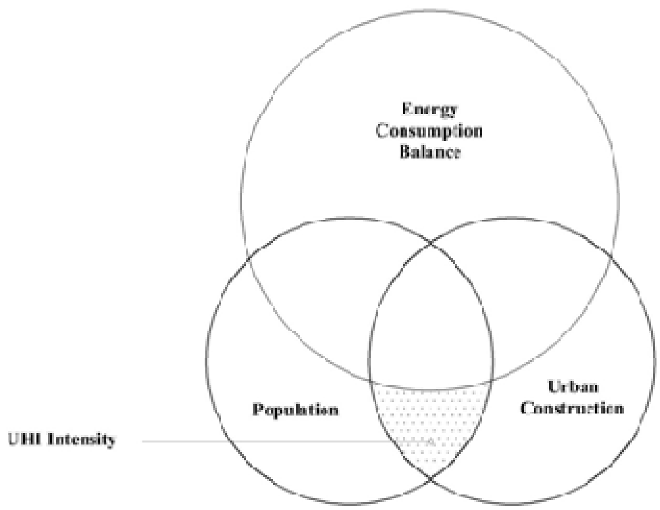

Figure 6. Mitigation of UHI has direct effect on energy consumption balance.

should be considered to be integral parts of a complete framework.

This paper highlights energy consumption, population and urban construction as the key components. The rising population causes higher density, more construction in cities, higher urban temperature and finally an urban heat island (Figure 4). Compiling the three key components into a specific model is meaningful in reducing urban heat island effects and achieving energy consumption balance. The conflict between these three key components is presented in the model shown in Figures 5 and 6.

In Figure 5, the shaded area represents the urban heat island intensity. A greater conflict between population and urban construction factors causes higher UHI intensity. With increasing UHI intensity, energy consumption loses its balance, while Figure 6 shows that by mitigating UHI effects, energy consumption balance can be achieved.

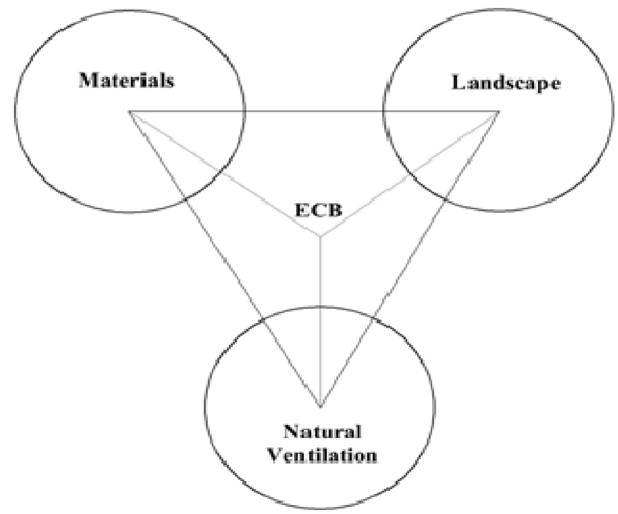

Figure 7. Achieve energy consumption balance by providing balance with vegetation covers, natural ventilation and high Albedo materials.

This process can be described in the following way:

$$UHI \downarrow = ECB$$
$$UHI \downarrow = P \downarrow + UC \downarrow$$
$$P \downarrow + UC \downarrow = ECB$$

where

UHI is the urban heat island ($\downarrow$ decrease), ECB is the energy consumption balance, P is the population, UC is urban construction.

Therefore, by decreasing population and urban construction, mitigation of UHI effects is achievable. Although decreasing the population requires long term planning, an optimal and realistic solution is to focus on urban construction factors, such as natural ventilation, surface materials and landscape or vegetation covers to decrease UHI intensity and create energy consumption balance.

$$ECB = MEC + LEC + NVEC$$

$$MEC = LEC = NVEC$$

where

MEC is the amount of reflectivity and emissivity of surface materials, LEC is the amount of appropriate landscape or vegetation covers; NVEC is the appropriate amount of wind introduced into a built environment;

An appropriate solution is adequate vegetation, natural ventilation and high albedo materials, which results in an acceptable impact on energy consumption balance. Under such circumstances, a balanced urban environment can be created (Figure 7). This means that adding natural ventilation, vegetation covers and high albedo and high emissivity materials in urban areas can reduce UHI effects and balance energy consumption. This will be described in the next section.

ACHIEVING ENERGY CONSUMPTION BALANCE BY REDUCING THE URBAN HEAT ISLAND EFFECT

The continuous increase in urbanisation combined with degradation of the urban climate leads to higher energy consumption. The reduction of the energy consumption of urban buildings by combining techniques to improve the thermal quality of the ambient urban environment with the use of up-to-date alternative passive heating, cooling and lighting techniques can partly decrease these kinds of environmental problems.

Asimakopoulos et al. (2001) stated that some of the factors that usually have a negative effect on the low-energy consumption include the design and construction of urban buildings:

(a) The layout of the basic road network with a specific orientation. This layout affects the buildings on either side of the road, giving them an orientation that, in most cases, is not suitable for implementing solar and energy-saving techniques.
(b) The relationship between the height of a building and the width of the road, which causes overshadowing and thus prevents access to direct sunlight in living spaces.
(c) The relationship between plot frontage and depth, which can determine how many internal spaces, will have a southern aspect.
(d) Densely built urban centres, which result in the obstruction of airflow and sunlight by the walls of tall buildings.
(e) A lack of greenery that has been replaced by concrete and tarmac;
(f) Overshadowing caused by adjacent buildings and other landscape features, which is difficult to avoid.
(g) Building regulations and codes that in most cases determine the dimensions of a building and thus its geometrical form and its position on the plot.

It also must be noted that higher temperature and less intensive winds are causes of urban heat island effects. In addition, inappropriate orientation, high density and shading can directly affect UHI formation. If proper interventions are implemented in urban design, better climate conditions will be achieved when serious overheating problems occur. A large number of air-conditioning appliances leads to increased cooling loads during the summer and to over-consumption of electric energy, which also increase peak energy demand and creates failures in the energy transport network.

Energy saving techniques that can be applied in a building includes two kinds of strategies that can be divided into urban elements (macro scale) and building elements (micro scale) strategies. The first strategy includes the energy conservation methods, which involve application of some strategies in urban areas, while the second method includes strategies for buildings. This paper focuses on three main strategies in each scale, which are categorised in Figure 8.

The combination of these two categories will provide the best possible energy saving solution. According to the above considerations these strategies are described in the following sections.

Providing appropriate landscape

Providing an appropriate landscape in urban and building scales can contribute to energy consumption reduction. The impact of an appropriate landscape around a building on energy consumption and surrounding temperature regime is very important. Landscaping the surrounding area is a basic criterion to improving the external climatic conditions. As mentioned by Asimakopoulos et al. (2001), shading from trees can

(1) Significantly decrease the energy required for cooling.
(2) Decrease the rate of heat convection inside buildings because of shaded surfaces that have a lower temperature.
(3) Decrease the radiation exchange of the wall with the sky.

Sailor (1994) considers that the low evaporative heat flux in cities is the most significant factor in the development of an urban heat island. When vegetation is placed on urban surfaces, thermal balances can shift to new conditions that are closer to the cooler conditions of rural areas. It is estimated that 1460 kg of water is evaporated from an average tree during a sunny summer day, which consumes about 860 MJ of energy; this offers a cooling effect outside a building that is equal to five average air conditioners (Santamouris, 2001). In addition, water surfaces and wind channelling through natural or artificial barriers reduce the effect of solar radiation in summer, while in winter they shelter the building.

Furthermore, to reduce energy consumption, various types of trees and vegetation, as well as bodies of water, in different parts of the city and buildings must be considered.

Therefore, this paper recommends using green spaces in vertical and horizontal layers.

Vertical green spaces

Green spaces in some parts of buildings and city that provide natural ventilation or appropriate landscapes in different layers or floors of buildings with a multiuse

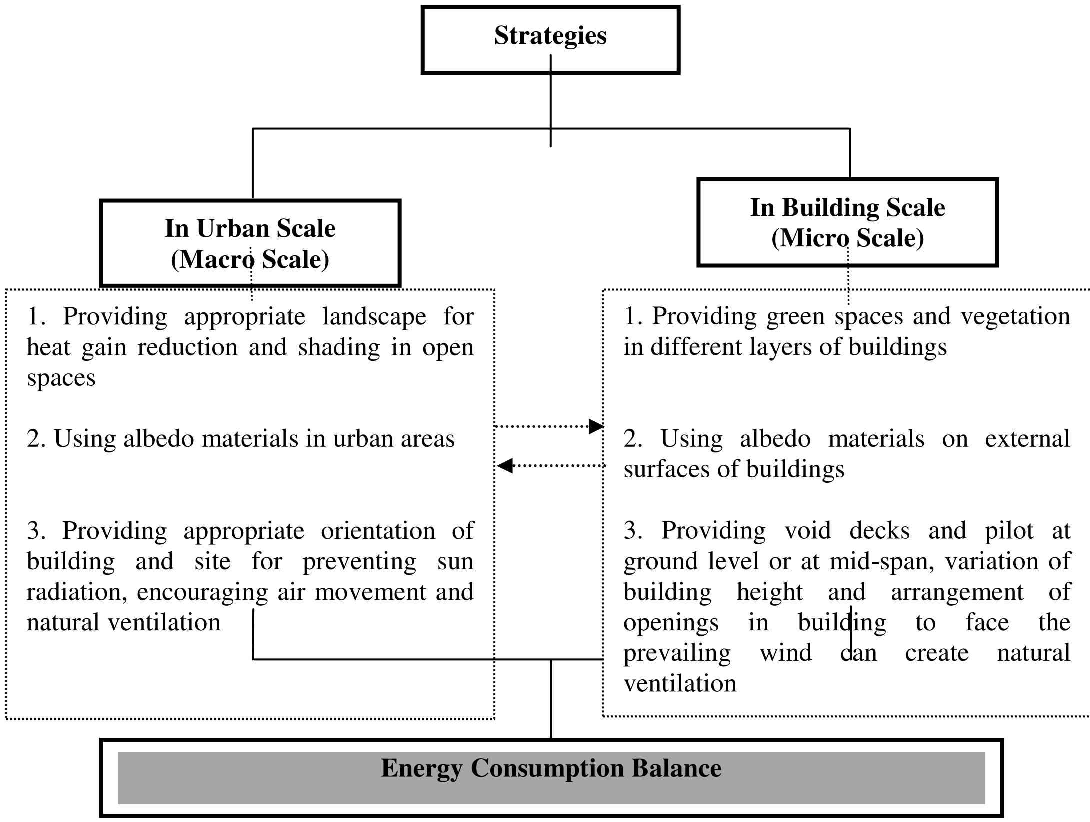

Figure 8. Categorizing different strategies for energy consumption reduction.

function can significantly decrease the energy required to cool buildings.

Horizontal green spaces

Green spaces on roofs absorb heat, decrease the tendency towards thermal air movement and filter air movement. Through the daily dew and evaporation cycle, plants on vertical and horizontal surfaces are able to cool cities during hot summer months. In the process of evapotranspiration, plants use heat energy from their surroundings when evaporating water.

Using appropriate materials on external surfaces of the buildings and urban areas

An increase in the surface albedo has a direct impact on the energy balance of a building. Large-scale changes in urban albedo may have important indirect effects at a city scale. Cities and urban areas in general are characterised by a relatively reduced effective albedo as a result of two mechanisms (Santamouris, 2001):

(1) Darker buildings and urban surfaces absorb solar radiation.
(2) Multiple reflections inside urban canyons significantly reduce the effective albedo.

As Asimakopoulos et al. (2001) stated, numerous studies have been performed to evaluate the direct effects of albedo change and demonstrate the benefits of using reflective surfaces. In all cases, the roof temperatures are significantly reduced, but the degree to which the cooling load decreases depends on the structure of the roof and on the overall thermal balance of the building. Surface materials with a high albedo index to solar radiation reduce the amount of energy absorbed through building envelopes and urban structures and keep the surface cooler. Sites and urban areas materials can be divided into pavement materials, roof materials and building envelopes.

Therefore, this paper recommends using reflective materials in urban areas to reduce heat island effects and improve the urban environment.

Using high albedo materials on building surfaces

A material with high albedo can reduce the solar heat gain during the daytime. The surface temperature of the material is lower than that of a material with low albedo. Because the urban ambient temperature is associated with the surface temperatures of the building façade, lower surface temperature can obviously decrease the ambient air temperature and eventually contribute to better urban thermal environment.

Using white pavement instead of asphalt

Asphalt temperature can reach 63°C and white pavements only reaches 45°C (Santamouris, 2001). Lower surface temperatures contribute to decreasing the temperature of the ambient air because the heat-convection intensity from a cooler surface is lower. Such temperature reductions have a significant impact on cooling energy consumption in urban areas.

Using cool roofs

Cool roofs reduce building heat-gain, create savings 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 demand for electric power, reduce resulting air pollution and greenhouse gas emissions, provide energy savings and mitigate urban heat island effects.

Promoting natural ventilation

Natural ventilation is the most effective passive cooling technique that can provide cooling during both day and night, while night ventilation is a very effective strategy in hot climates (Asimakopoulos et al. 2001). Some strategies for urban areas and buildings can provide natural ventilation and save energy. Therefore, this paper recommends some strategies to achieve this aim:

1. Natural ventilation by arranging the openings in buildings to face the prevailing wind can provide efficient natural ventilation and create a healthy indoor air quality.
2. Natural ventilation by ventilated roofs eliminates overheating.
3. Variation in building height can create better wind at higher levels if differences in building heights between rows are significant.
4. Building orientation with adequate gaps is useful for good airflow.
5. Increasing building permeability by providing void decks or pilots at ground level or at mid-span.

CONCLUSIONS

There is strong scientific evidence that the average temperature of the earth's surface is rising because of increased energy consumption. Global warming has a major impact on human life and the built environment. Therefore, an effort must be made to reduce energy use and to promote green energies, particularly in the building sector. Energy balance can be achieved by minimising energy demand, rational energy use, recovering heat and using more green energies. This paper was a step towards achieving that goal. The adoption of green or sustainable approaches to the way in which society is run is seen as an important strategy in finding a solution to the energy problem. As discussed in this paper, one of the most important factors that increases energy use is the formation of urban heat islands. Therefore, this paper considers the effects of UHI and by recognising them, proposes beneficial solutions that can lead to energy consumption balance.

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