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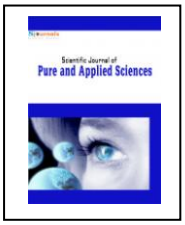

Original article

Solutions for urban climate modification and their effects on energy usage in Tehran (Capital of Iran)

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ABSTRACT

It has been proved that urbanization and urban development has a significant effect on climate. Urban climate is totally different from the suburbs. Manipulation in urban areas intensifies this effect or alleviates it. This paper reviews the previous reports and papers on these effects concisely. A set of international studies prove that urban alteration has a significant impact on energy usage in buildings. Precise studies on this issue are being performed in scientific communities all over the world which have been addressed in this paper. Nowadays, researchers and governors are interested in decreasing the negative effects of overheated summers. Summer urban heat island in Iran leads to more heat strokes, heat exhaustions and building cooling demand. On the contrary, Urban Heat Island (UHI) results in less building heating demand, less frostbite and cold weather related diseases. Therefore, during the urban planning process, the related issues with urban climate must be considered.

1. Introduction

One of the most prominent effects of urbanization on urban climate is increase in urban air temperature. This phenomenon is called UHI. A set of differences between urban and rural areas result in UHI. Some of these

differences are thermal properties of materials, building type and height and the rate of air pollution. These characteristics trap more sun radiation during the day in urban context and increase the urban air temperature consequently. During the night, thermal energy is released and makes the urban districts warmer.

In addition, less evapotranspiration in urban areas leads to less latent heat release and reduction of its cooling effect consequently. Besides, cities are sources of thermal energy which originates in high rate of energy usage in them. The whole energy is used in buildings and transportation finally appears as thermal energy. A comprehensive and accurate planning is necessary which considers all of the factors specifically factors related to climatic changes. UHI in a unique city has its own temporal and spatial characteristics. However, its effect is more intense after sunset all over the world (Oke, 1992, 132).

During July 2000, average dailytemperature difference between Tehran city and its surrounding rural areas reached 12°C on some days. (Shahmohamadi, Cubasch, Sodoudi, & Che-Ani, 2012, 289;Ranjbar, Saadati, 2005, 63)have done extensive research on UHI effect in Tehran using climatic data between 1956 and 1995.

Table 1

Maximum and minimum temperature changes in Tehran Ranjbar (Saadati, 2005).

Maximum Temperature Changes			Minimum Temperature Changes			
Difference	**VARAMIN**	**MEHRABAD**	**Difference**	**VARAMIN**	**MEHRABAD**	**Month**
F=D-E	E	D	C=A-B	B	A	
0.68	-1.08	-0.40	1.04	0.80	1.84	January
0.12	-2.88	-1.68	1.68	-0.44	1.24	February
1.72	-3.00	-1.28	1.80	-0.28	1.52	March
0.68	-1.20	1.88	2.76	0.80	3.56	April
-0.12	-1.08	-0.12	1.16	0.36	1.52	May
-0.80	0.88	0.08	1.56	0.92	2.48	June
-0.84	1.52	0.68	0.16	1.36	2.96	July
-0.48	0.76	0.28	1.72	1.00	2.72	August
0.16	-0.2	0.04	3.08	-0.12	2.96	September
-0.04	-1.04	-1.08	3.28	0.04	2.32	October
0.28	1.28	1.58	2.52	2.12	4.64	November
1.40	-2.28	-0.88	2.12	0.80	2.92	December
0.36	-0.52	-0.16	1.96	0.64	2.60	Annual Ave

Analysis of above data indicates that Tehran has the most severe UHI effect in Septembers. It should be noted that in some cities Urban Cool Island (UCI) occurs allegedly called an oasis. The cities that use irrigation systems in dried-hot climate usually are cooler than their suburb areas (Grimond, 2007).

This paper discusses about UHI which happens in most cities and it doesn't cover UCI.

Although the main objective of this paper is to explore the effect of urbanization on energy usage, but its impact on human health should take into account. While summer UHI mitigation can reduce deaths from heatstroke, it should be noted that UHI effect reduction can decrease the urban air temperature in winter and leads to increase the rate of death from frostbite consequently. In Iran, deaths from frostbite are much more than deaths form heatstroke and heat exhaustion.

2. Modifying factors

Efforts to modify the urban climate occur in micro-scale too. UHI is an urban (Macro) scale phenomenon and usually employed strategies in order to modify the urban climate encompass the modifications of whole parts in a city such as streets. In a physical or local scale, these modifications include the alteration of surfaces' characteristics (cool and green roofs, cool sidewalks and roads), increase of per capita green space, tree plantation and establishment of parks. Meanwhile, the urban geometry and anthropogenic heat should take in to consideration too.

Several studies show the effect of anthropogenic heat on urban climate (Coutts, Beringer, & Tapper, 2007, 479; Ichinose, Shimodozono, & Hanaki, 1999, 3899; Kłysik, 1996, 3401; Taha, 1997, 100).

Ichinose (1999)conducted a comprehensive research about the anthropogenic heat released by human activities in Tokyo-Japan. Their research proves that in the regions with the highest rate of anthropogenic heat, the air temperature is 1.5°C higher than their surrounding areas. This effect is more severe in winter time than summer time.

Taha(1997) investigated several U.S. cities, Canada and Europe and his analysis indicate that the anthropogenic heat released in city centers in cold climates is more severe than city centers in other climates. But it is negligible in suburbs. It has been estimated that increase of 2 to 3°C in temperature may be due to human activities.

In another study (Sadeghinia, 2012, 95) has located the hot spots in Tehran city. Compared with land use map, it is clear that hot spots are located in the regions with higher rate of human activities; Central, Sothern and western parts of Tehran where the most industrial and commercial centers exist.

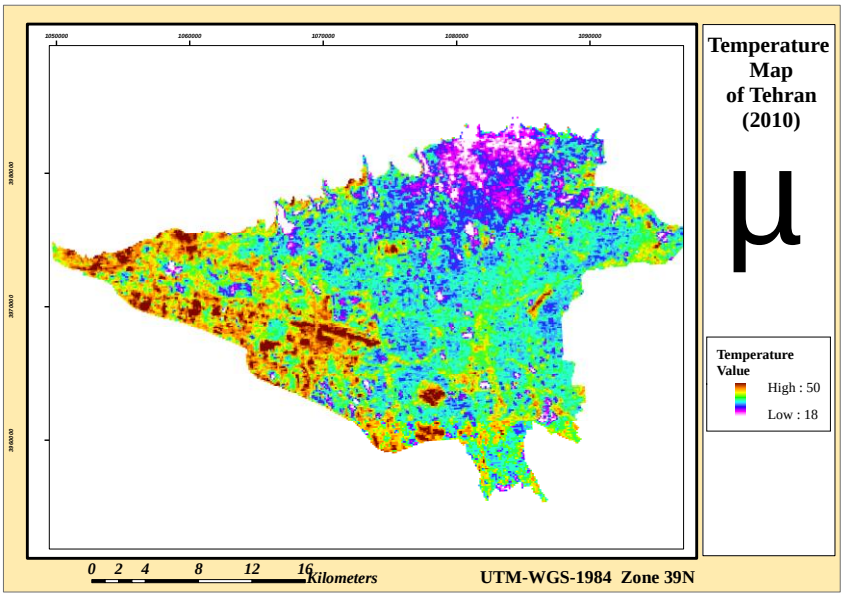

Fig. 1. Hot and cool spots in Tehran city.

The highest rate of thermal release exists in central, western and southern part of Tehran.Although there are some solitary hot spaces, but there is a pattern in released heat which originates in aggregation of residential and non-residential buildings, type of clustering and their density. It should be noted that in dense areas with narrow streets and high-rise buildings on both sides (urban canyons), anthropogenic heat constitutes a major part of UHI and the rate of energy saving depends on the intensity of UHI.

In the future, it is very likely that the energy consumption is much lower than today. This is due largely to regulations and laws that have to be imposed to prevent major climatic changes. These rules include restrictions on the energy distribution and law enforcement in order to produce energy in buildings and make them self-sufficient. These regulations probably change the release patterns of anthropogenic heat.

It is necessary to mention that generating electricity without carbonic compounds also has been a significant change.

The reason is that producing energy with or without carbon dioxidewill ultimately end with heat release. So it is better to produce carbon-free energy and keep the environment clean.

Manipulation in albedo of roofs influences the energy balance of surfaces and their surrounding areas. Similar case happens to other urban materials such as sidewalks and parking lots. Materials with higher albedo mitigate the UHI effect. High rate of material permeability associated with high albedo value improves the evaporation cooling effect which results in higher rate of UHI mitigation.Roads and sidewalks with high albedo materials can reflect the light and contribute in improvement of nocturnal lighting system in urban environment. Another strategy in order to mitigate the UHI is using greenery systems(Akbari & Rose, 2001, 18; Emmanuel, 2005, 1600; Huang, Akbari, & Taha, 1990; Rosenfeld et al., 1995, 256; Santamouris et al., 2001, 214; Shahidan, 2011, 168;

Shashua-Bar & Hoffman, 2000, 227; Solecki et al., 2005, 39). Plants and trees improve the weather effectively. They cast shadow and decrease the air temperature through evapotranspiration. Finally, one of the key factors in disturbing the energy balance between rural and urban areas is that the urban areas tend to reduce the long-wavelength radiation during the nights. The main reason for this phenomenon is reduction of sky view factor in urban areas.

The direction of streets also has an impact on local wind speed. Sky view factor and direction of streets are two factors that should take into account during urban planning phase.

3. Energy usage

3.1. The effect of UHI on energy usage in urban areas

Generally, the urban heat island phenomenon is expected to make greater use of cooling energy in summers and reduce energy demand for heat in winters. The literature confirms this phenomenon. In England, temperature data were used as input for a building energy simulation software (Kolokotroni, Zhang, & Watkins, 2007, 102). This simulator examined the cooling and heating load of official buildings equipped with air-conditioned systems in 24 different locations in London city. The results show that the cooling load of urban areas is 25 percent higher than cooling load of rural areas during a year. Also, the annual heating load required for urban areas falls to 22 percent in a comparison with rural areas. In Overall, it can be claimed that UHI effect increases the cooling load of buildings in summertime. For official buildings without HVAC systems, the UHI effect leads to net energy saving in wintertime, though the residents have to tolerate the high air temperature in summers.

3.2. The effect of environmental manipulation on energy saving

There are several strategies in order to change the urban climate and consequently have a significant impact on per capita energy consumption. The climatic changes affect the rate of energy consumption through two ways: The direct effect which includes the improvement of energy consumption in a single building e.g. using cool roofs in buildings, while the indirect effect includes the modification of energy consumption through macro-scale projects such as changing the sky view factor and the modification of streets direction in urban areas.

Synnefa et al (2007, 1167) investigated the direct effect of cool roofs on thermal load of buildings and thermal comfort of residents in various climates. The study (investigation of27 cities all over the world)revealed that mitigation of summer cooling load compensates the need for heating load demand in wintertime in terms of energy usage.

Akbari et al (2005, 756) obtained significant results through simulations which investigated the effect of appropriate strategies on UHI. These strategies include using cool roofs, the cultivation of trees and shrubs, high albedo sidewalks and urban greenery system. The researchers conducted the simulations for 240 locations in US and arranged and recorded the data in terms of cooling and heating energy demand respectively. Consequently, they predicted the rate of energy saving for different land uses (residential, official and commercial buildings). Based on the results obtained, there will be a significant rate of energy saving, if the mitigation strategies be performed. For all land uses, more than 75 percent of energy saving is obtained through cool roofs and tree shading.

4. Future way

The literature proves that both UHI and mitigation strategies has the potential to affect the rate of energy usage; although this effect needs to be investigated and analyzed comprehensively and deeply. The analysis of correlation between energy usage and air temperature (Ta) shows that this correlation is much more complicated than what has been imagined previously. For instance, it can't be claimed that the rate of energy usage reduces with increasing of air temperature; as the higher outdoor air temperature may lead to higher indoor Ta and need for more ventilation. Urban energy usage is a very complicated phenomenon; for example, one of the reasons behind using HVAC systems in buildings is noise and air pollution produced by vehicles.

Urban traffic produces the different types of pollution which results in closing the whole openings in a building by residents in order to avoid harmful side effects. Consequently they use air conditioning systems in

order to approach to thermal comfort standards. Therefore, this paper suggests employing some strategies like using lightweight electrical vehicles in order to reduce the air and noise pollution.

This strategy supports the use of natural ventilation instead of air conditioning and mitigate the UHI effect significantly. Large scale and rapid modification of the urban environment to reduce urban heat island intensity in Tehran is not possible; although many small changes can have a significant overall impact.

5. Conclusion

The urban climate is different from rural climate. This paper focused on general condition related to UHI. In this condition, the city center has a higher average air temperature than the suburbs. Modification of urban environment affects this difference significantly. Different types of manipulations have been mentioned in this paper. International studies show that the impact of urban environment manipulation is significant on the rate of energy usage; governors and decision makers are interested in mitigation of Summer UHI, although, all aspects should be considered carefully. Summer UHI in Tehran results in more cooling energy demand and more heatstroke and heat exhaustion. On the other hand, UHI leads to less heating energy demand and lower rate of death caused by frostbite. Therefore, decision makers should consider both negative and positive aspects.

In the case of Tehran, it can be claimed that UHI has a negative effect on the rate of energy usage, human health and thermal comfort of citizens annually. Comprehensive studies are running in Iran which not only considers the issues related to energy saving, but also they consider technical and social aspects too. Before taking any fundamental action to mitigate the UHI effect, the results of these studies should be analyzed in order to avoid the short-term decisions which results in negative consequences.

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