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Impacts of city-block-scale countermeasures against urban heat-island phenomena upon a building's energy-consumption for air-conditioning

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Abstract

This study quantifies the possible impacts of urban heat-island countermeasures upon buildings' energy use during summer in Tokyo metropolis. Considering the dependency of the buildings air temperature upon the local urban canopy structure, Tokyo urban canopies were classified in the city-block-scale using the sky-view factor (svf). Then, a multi-scale model system describing the interaction between buildings' energy use and urban meteorological conditions was applied to each classified canopy.

In terms of urban warming alleviation and cooling energy saving, simulations suggested that the reduction in the air-conditioning anthropogenic heat could be the most effective measure in office buildings' canopies, and that vegetative fraction increase on the side walls of buildings in residential canopies. Both measures indicated daily and spatially averaged decreases in near-ground summer air temperature of 0.2–1.2 °C. The simulations also sug-

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gested these temperature decreases could result in the buildings' cooling energy-savings of 4–40%, indicating remarkable savings in residential canopies. These temperature drops and energy savings tended to increase with the decrease of the svf of urban canopies.

Keywords: Urban heat-island; Mitigation measures; Urban canopy model; Building energy-simulation; Urban energy conservation

1. Introduction

The 21st century will be the century of cities, when more than half of the world's population will inhabit urban environments. The global urban population, which in 2000 accounted for some 47% of the world's 6.1 billion population, has been forecasted to increase and to reach to 60% of the future world's population of 8.1 billion by 2030 [1]. It has been also predicted that the accelerating urbanization would be caused by intensive increases in the urban populations in the developing countries of Asia and other areas, and that more than 90% of the increase in the world's population during this period (2 billion persons) would unevenly concentrate in those urban regions [1].

This trend toward urbanization can be interpreted as a process of regional socio-economic self-organization, induced by various opportunities that cities give their inhabitants. However, with the concentration of the anthropogenic activities into urban areas, a climatic environmental problem, so called as 'urban heat-island', has emerged. Urban heat-island means a climatic phenomenon in which urban areas have higher air temperature than their rural surroundings as results of anthropogenic modifications of land surfaces, intensive use of energy, and its consequent generation of waste heat. In recent years, the importance of the heat island has been recognized not only in terms of urban climatology but also from the viewpoint of its negative environmental effects in summer, such as the deterioration of the pedestrian-level thermal comfort and the acceleration of photochemical air pollution [2]. Moreover, the heat island causes the increase in building energy demand for cooling in summer. This bad effect will not only result in additional generation of waste heat, but also bring about the increase in fossil fuel consumption. On the other hand, in a previous study [3], the opinion has also been expressed that higher temperatures in the heat island lead to cuts in energy demand for heating in winter, and so would contribute to reduced urban energy demands on an annual basis. However, low-latitude cities in the developing countries of Asia and Africa, which are expected to experience rapid and huge population increase in the near future, have little energy demand for heating. Therefore, there is a high risk that urban heat islands will induce unchecked increases in fossil-fuel consumption for cooling and its consequent increases in the anthropogenic CO_2 emission, which could become the major cause of the global climate change.

According to the above perspective, heat-island mitigation strategies should be examined as means to reduce urban-scale energy consumption and the ensuing CO_2 emission from a global standpoint. However, the previous studies addressing