4.6 COMPARISON OF ENERGY IMPACT OF HEAT ISLAND REDUCTION STRATEGIES BETWEEN TOKYO AND HUSTON.

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1. Introduction.

Elevated summertime temperatures in urban "heat islands" increase cooling-energy use and accelerate the formation of urban smog. Except in the city core areas, summer heat islands are created mainly by the lack of vegetation and by the high solar radiation absorptance by urban surfaces. Also, cities with high building density like Tokyo, anthropogenic heat release from buildings is an important factor in the modified urban heat balance and one of the main causes of the urban heat island. Urban trees and high-albedo surfaces can offset or reverse the heat-island effect. The albedo of a city may be increased at minimal cost if high-albedo surfaces are chosen to replace darker materials during routine maintenance of roofs and roads. Incentive programs, product labeling, and standards could promote the use of high-albedo materials for building and roads. Similar incentive-based programs need to be developed for urban trees. Quantitative evaluation method of these measures is needed for investigating promotional policies for mitigating heat island.

In an earlier report, we summarized our efforts to calculate the annual energy savings, peak power avoidance and annual CO_2 reduction of Heat Island Reduction (HIR) strategies in Baton Rouge, Sacramento, Salt Lake City, Chicago, and Houston (Konopacki and Akbari, 2000, 2002). Akbari and Konopacki (2003) extended the methodology and developed summary tables to estimate the energy saving potentials of HIR stragtegies for any US cities. In this report, we extend these analyses to Tokyo, Japan and compare the results with earlier calculations for Houston. The analysis focuses on four major building types that offer the greatest potential savings: single-family residence, multi-family residence (in Tokyo only), office and retail store (in Houston only).

In this study, we followed the same methodology used to analysis the five cities. The methodology consisted of (1) defining prototypical buildings for each city; (2) simulating or table estimating the base heating- and cooling-energy use for each prototype; (3) simulating the energy effects of reflective roofs for each prototype; (4) estimating the total roof area for each prototype by metropolitans or cities, and (5) estimating energy savings by metropolitan or citywide regions.

The 2000 population of Metropolitan Statistical Area of Huston is 4,715,407 by U.S. Census Bureau, Census 2000. And that of 23 Wards area of Tokyo is 8,134,688 by Statistics Bureau of Japan, 2000 Population Census.

2. Typical Weather Data for Chicago and Houston.

Local full-year hourly weather data are required as input to the DOE-2 simulation program. For Houston, we used the Typical Meteorological Years (TMY) format. for Tokyo, we used Expanded AMeDAS (EA) Weather Data by Architectural Institute of Japan (Akasaka et. al. 2003). It is important to remark that TMY and WYEC2 formats represent typical rather than extreme weather

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conditions. TMY format is derived from observation data of 1961 to 1990. EA data is derived from data of 1981 to 1995.

Cooling-degree-days (base 18.3 °C) for Houston and Tokyo are 1,560 and 860 °C-day, and Heating -degree-days are 860 and 1680 °C-day.

The monthly-mean air temperature and relative humidity of the standard weather data for Tokyo and Houston are in Figure 1. Climates of both cities are relatively similar in summer, although Tokyo is colder and drier than Houston in winter.

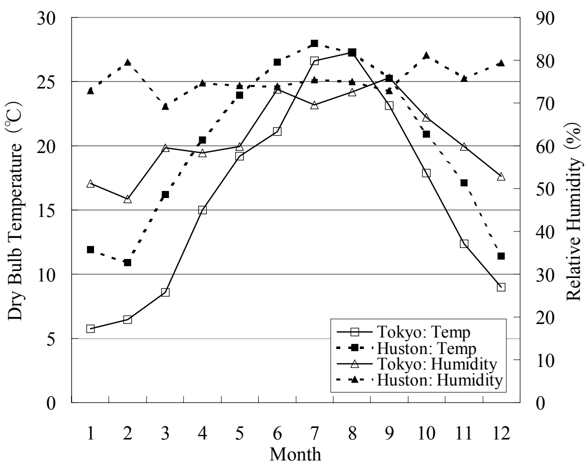

Figure 1. Monthly-mean dry-bulb temperature and relative humidity of Tokyo and Houston.

3. Building Prototypes.

Four major building prototypes have been selected for investigation in this paper ; single-family residence, multi-family residence (in Tokyo only), office and retail store (in Houston only).

For Houston, prototypes developed in Akbari and Konopacki and Akbari (2003) were used in this study. The single-family residence was modeled as a ranch-style building with a detached garage. Exterior dimensions were 12.2m by 12.2m with a total conditioned floor area of 149m^2.

The office was modeled as a rectangular building with four perimeter zones and a core zone. The exterior dimensions were 21.3m by 21.3m with total conditioned floor area of 455m^2.

The retail store was modeled as a rectangular building with a single zone, as part of a strip mall with other buildings on two sides. The exterior dimensions were 27.4m by 27.4m with a total conditioned floor area of 752m^2.

For Tokyo, prototypes from several studies were used. The single-family residence model was from standard residence prototype of Architectural Institute of Japan (Udagawa, 1985). The model was two story, five bedrooms or storage rooms. Exterior dimensions were 8.6m by 7.3m with a total conditioned floor area of 71m^2.

The multi-family residence model was referred from a study of Nagase et.al. (2001). The model was four stories, eight family-units building. Exterior dimensions were 13.9m by 12.6m. Total area per unit was 80 m^2, and a total conditioned floor area per unit was 63.2m^2.

The office model was based on a research project of Central Research Institute of Electric Power Industry (Suzuki et. al. 1995). It was seven stories building with exterior dimension of 25.6m by 17.8m. Total conditioned floor area was 2,323 m^2.

4. Estimated Energy Use and Savings.

Reflected roof savings was estimated using tables in Akbari and Konopacki (2003). The table values for heating-degree-days and cooling-degree-days were averaged. The modified cases had a roof albedo of 0.5 for residence and 0.6 for commercial buildings, and base case had a low-albedo roof of 0.2. All buildings in Tokyo were assumed to be air-conditioned by electricity. Building statistics and estimated values in Houston and Tokyo are showed on Table-1 and Table-2.

For Tokyo residential building of pre-1980 and post-1980, electricity savings are estimated at 196 and 104 kWh/100m^2, respectively. For Tokyo office buildings, the savings is estimated at 675 kWh/100m^2. For Houston buildings, savings values are more than double than that of Tokyo.

The data for the total commercial and residential air-conditioned roof areas in Houston were obtained from a detailed analysis of stock of buildings in the U.S. (Konopacki *et al.*, 1997). Also, GIS data on buildings in Tokyo 1991 was provided by Bureau of City Planning, Tokyo Metropolitan Government. Total floor area and air-conditioned roof area was analyzed from the GIS data. In Houston, air-conditioned roof area of residence, office, and retail store were 114.0, 7.7, and 10.6 km^2. In Tokyo, the area of single-family residence, multi-family residence, and office were 45.7, 24.7, and 22.5 km^2.

We used 1998 Japan's Bureau of Statistics data to obtain information on the are of residential buildings in Tokyo. 30% or 48% of the residential buildings were post 1980 construction in 1990 or 1997, respectively, Since GIS data of Tokyo is 1991, we choose 30% for post 1980 construction in Tokyo. For office buildings, we use pre 1980 construction data for all buildings.

From above data, citywide savings in Tokyo is estimated to be 63 and 14 GWh for pre-1980 and post-1980 single-family residential buildings, respectively, and 152 GWh for office buildings. Total reduction is estimated at 271 GWh and this figure is less than half of 680 GWh, estimation of Houson. Smaller roof areas due to higher building stories in Tokyo, compared to those of Houston, is the prime reason for smaller value of citywide savings in Tokyo.

Table-1. Building statistics and estimated citywide savings for cool roofs in Houston.

	Residene		Office		Retail Store	
Item	Pre-1980	1980+	Pre-1980	1980+	Pre-1980	1980+
Total Roof Area [km^2]	105.9	35.7	4.7	3.0	10.4	2.2
Conditioned Roof Area [km^2] AC & Gas	73.3	28.8	4.5	2.5	8.4	1.8
AC & HP	7.2	4.7	0.2	0.4	0.4	0.0
Estimated cool roofs electoricity savings [kWh/100m^2] AC & Gas	579	228	790	229	1064	315
AC & HP	500	213	768	220	1050	315
Estimated citywide cool roofs electricity savings [GWh] AC & Gas	424	66	35	6	89	6
AC & HP	36	10	2	1	5	0
Estimated cool roofs electoricity peak demand reduction [W/100m^2]	352	157	385	98	386	124
Estimated citywide cool roofs electoricity peak demand reduction [MW]	283	53	18	3	34	2

Table-2. Building statistics and estimated citywide savings for cool roofs in Tokyo.

Item	Single Family Residene		Multi Family Residene		Office
	Pre-1980	1980+	Pre-1980	1980+	
Total Roof Area [km^2]	46.1	19.7	24.0	10.3	22.5
Conditioned Roof Area [km^2]	32.0	13.7	17.3	7.4	22.5
Estimated cool roofs electoricity savings [$kWh/100m^2$]	196	104	196	104	675
Estimated citywide cool roofs electricity savings [GWh]	63	14	34	8	152
Estimated cool roofs electoricity peak demand reduction [$W/100m^2$]	350	156	350	156	390
Estimated citiwide cool roofs electoricity peak demand reduction [MW]	112	21	60	12	88

5. Conclusion

Citywide energy savings of Tokyo by cool roof is estimated at 60 % smaller than that of Houston, although total conditioned roof area of Tokyo is 22% smaller. That is mainly because of difference of city-structure and number of building stories.

This estimation is based on building prototypes for Houston. Simulating the base heating- and cooling-energy using Tokyo building prototype is not included in this paper, and that is needed further investigation.

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