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Measures to Mitigate Urban Heat Islands

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1 Introduction

The "Outline of the Policy Framework to Reduce Urban Heat Island Effects", which was laid down in March 2004, stipulates that lifestyles must be reformed as part of measures to mitigate urban heat islands. One of these measures is the promotion of the wearing of light clothing in summer. For instance, with the Kyoto Protocol now taking effect, the Ministry of the Environment encouraged its staff members to participate in the "Cool Biz" dress code campaign by not wearing neckties or jackets in summer beginning in June 2005. This enabled the temperature of its air-conditioned workplaces to be kept at 28°C. In addition, an annual event dubbed the "Grand Water Sprinkling Campaign" was carried out across the country on August 10. Urban heat island mitigation measures are making steady headway. Aside from lifestyle issues, however, another perspective from which to debate urban planning itself is necessary.

Japan's approaches to the urban heat island effect trace their origins to the 1980s, when it became a topic of study in the field of physical science, including meteorology and geography. That is where most early progress was made. In the 1990s, the phenomenon also became a research topic in engineering fields such as architecture and civil engineering, which addressed urban heat and energy problems. Study of the urban heat island effect from an urban planning perspective thus began[1]. Political approaches, meanwhile, have also made significant headway over recent years, playing catch-up with more-established approaches. When the Ministry of the Environment defined "the urban heat island effect as air pollution" in August 2001, mitigation measures suddenly emerged as a political issue. In response, the Cabinet decided in March 2002 to "set up a general task force comprising the ministries concerned and draw up guidelines to implement comprehensive approaches to urban heat island mitigation" in accordance with the "Three-Year Program for Promoting Deregulation (Revised)." The Ministry of the Environment, the Ministry of Land, Infrastructure and Transport, the Ministry of Economy, Trade and Industry, and the Cabinet Secretariat subsequently established the Inter-Ministry Coordination Committee to Mitigate Urban Heat Islands (hereinafter "the Liaison Council") in September 2002. This was followed by the establishment of the "Outline of the Policy Framework to Reduce Urban Heat Island Effects" in March 2004.

The "Guideline of Measures to Prevent Global Warming" was laid down in 2002. It aims to "promote global warming mitigation measures in order to achieve a 6% reduction in greenhouse gas emissions." One of these measures concerns the "promotion of comprehensive approaches to the urban heat island effect."

The "Basic Policies for Urban Renaissance," adopted by the Cabinet in July 2002, frames urban heat island mitigation measures as a means to revitalize urban areas. Heat island mitigation measures have thus become a major political issue from an urban renewal perspective.

The urban heat island effect was thus originally studied in the fields of physical science and engineering, from which various preventive policies gradually developed. It is too complex a problem to be solved by a single ministry, as is acknowledged in the establishment of the Liaison

Council. Furthermore, it is an interdisciplinary subject that involves meteorology, geography, architecture, civil engineering and the like. A range of studies is underway to elucidate the effect, develop and implement mitigation measures, and so on. There is a pressing need to mobilize a wide range of findings from these studies to come up with comprehensive mitigation measures.

This article explores urban heat island mitigation measures primarily from the perspective of urban planning.

2 The Urban heat island effect

Urbanization involves concentration of population, loss of natural surface, and expansion of living space above and below ground. All of these factors alter the balance of radiation, heat, and water, generating a climate typical of urban areas[2].

The urban heat island effect is a phenomenon whereby cities become warmer than the surrounding suburbs. In other words, there is a temperature difference between cities and the areas surrounding them. The effect was first observed in London and other European cities in the 1830s, followed by big cities such as New York and Chicago in the USA. The phenomenon is now becoming a major problem in Asia as well. Indeed, the urban heat island effect exists wherever there are large cities. While elimination of the phenomenon is not feasible, the key issue is how best to mitigate it. A variety of factors, such as surface cover, anthropogenic heat release, and urban characteristics including geographic features and climatic conditions interact with one another to create the effect. Its generating mechanism is complex and yet to be fully elucidated. Currently, therefore, each mitigation measure, such as energy-saving technologies and greenification, is being separately implemented[3].

Under these circumstances, elucidation of each contributing phenomenon to establish a scientific background and development of quantitative assessment techniques are imperative.

2-1 Status and causes of the urban heat island effect

(1) Status of the urban heat island effect

(i) Long-term upward trend in average temperatures

The third Intergovernmental Panel on Climate Change (IPCC) report*1 points out that average global temperature rose by some 0.6°C during the 20th century. Six big cities in Japan (Sapporo, Sendai, Tokyo, Nagoya, Kyoto, and Fukuoka) have seen average temperature rises of 2-3°C. The urban heat island effect has been more pronounced in these cities than have changes due to global warming.

(ii) Sweltering nights and rising daytime temperatures

Temperatures are on the rise, particularly in big cities. In fact, the temperature now stays above 30°C for longer, over a larger area (see the upper and middle color maps on the front cover and Figure 1). Accordingly, the number of sweltering nights is increasing.

(2) Causes of the urban heat island effect

The following four factors are the major causes of the urban heat island effect[5] (see Figure 2).

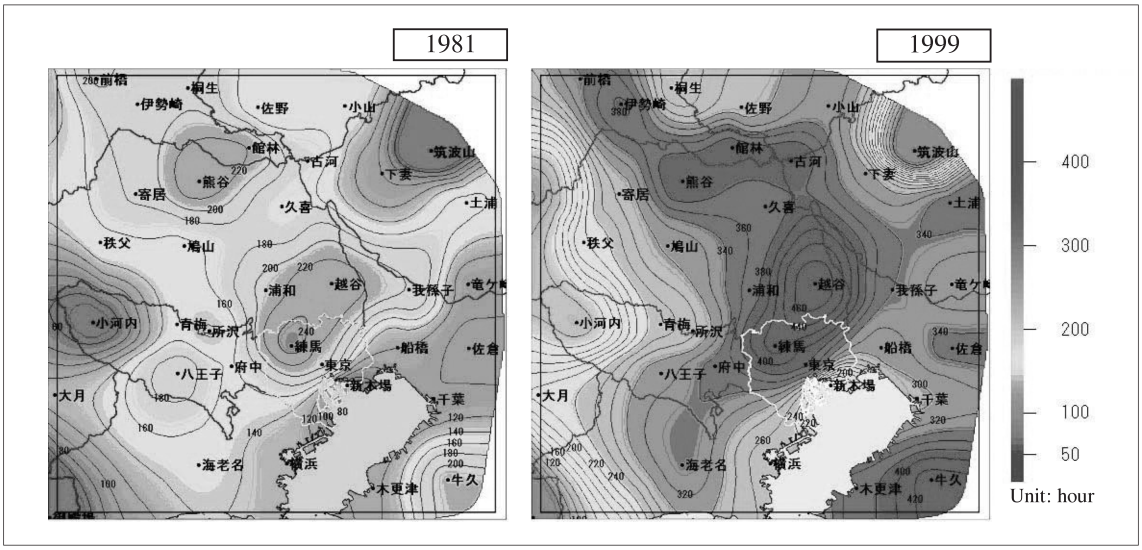
(i) Increased anthropogenic heat release
- Heat release resulting from energy consumption in urban areas

(ii) Changes in surface cover
- Reduced surface evapotranspiration capacity due to less green area
- The heat storage effect of construction materials such as concrete and asphalt

(iii) Urban structure
- Heat stagnation due to densely packed buildings
- Expansion of urban areas

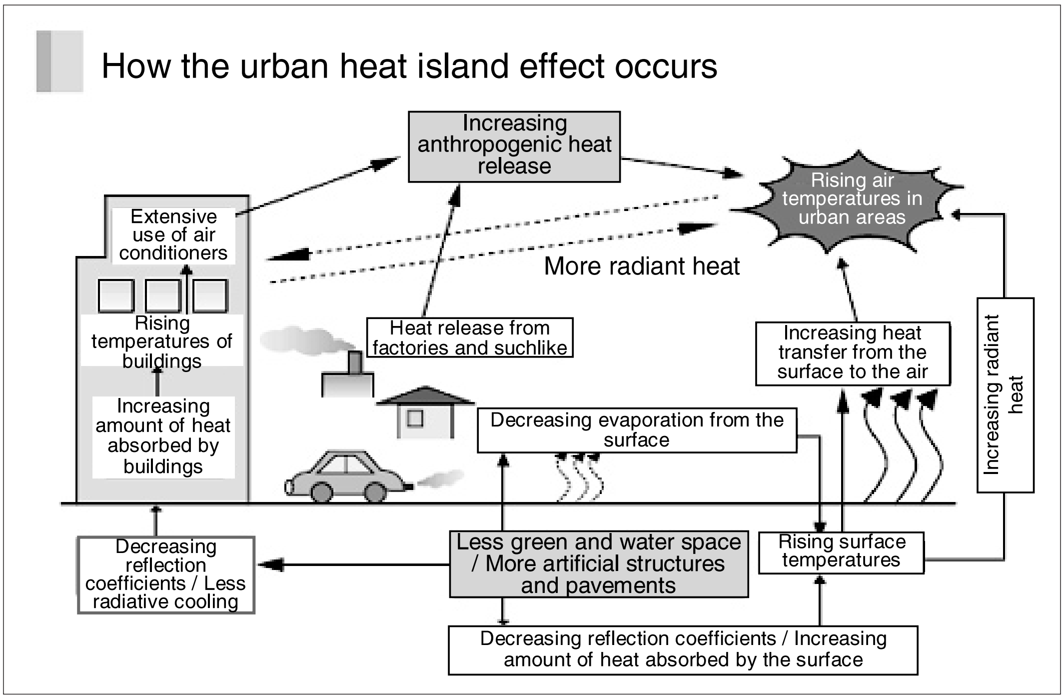
(iv) Other
- The greenhouse effects of fine-particulate air pollution in the urban atmosphere

Figure 1 : Distribution of cumulative hours with temperatures above 30°C (Tokyo) (see the color maps on the front cover)



Based on data provided by AMeDAS (July to September in 1981 and 1999). Cumulative hours with temperatures above 30°C are tabulated, and their distribution is shown by means of an isochrone. Source: Reference[4]

Figure 2 : Causes of the urban heat island effect



Source: Reference[6]

2-2 *Impacts of the urban heat island effect*

(1) Summer impacts

Urban areas are becoming uncomfortable places to live because of higher temperatures during daytime and an increasing number of sweltering nights. Higher temperatures boost demand for air conditioning, resulting in increased energy consumption. They also contribute to localized torrential downpours and the production of photochemical oxidants.

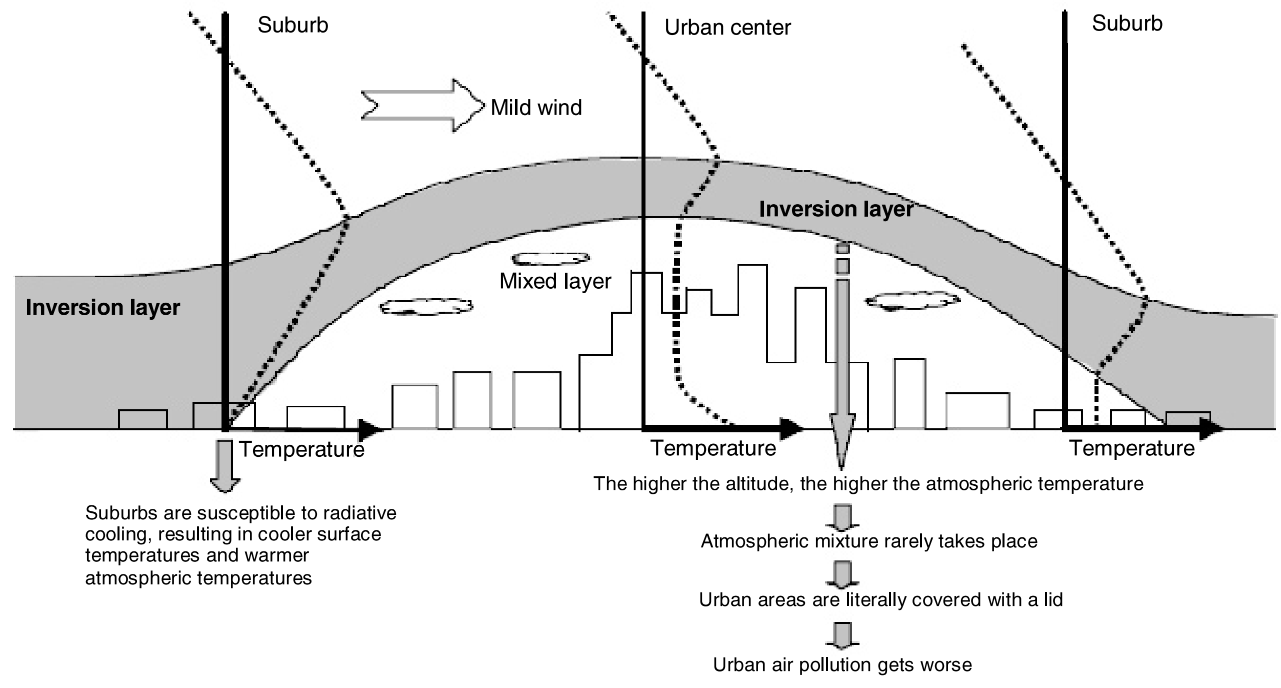
(2) Winter impacts

Inversion layers*3 form by radiative cooling*2 on clear, calm winter nights. Ascending air currents created by warm urban areas are trapped under inversion layers, forming mixed layers (dust domes*4) that exacerbate air pollution (see Figure 3).

(3) Other

Changes in surface cover cause decreased evaporation, making urban areas drier.

Figure 3 : Atmospheric conditions inside and outside urban areas in winter (when inversion layers are formed)



Source: Reference[4]

3 Measures to mitigate urban heat islands

3-1 Status of urban heat island mitigation measures

Since 2000, local governments made remarkable strides in implementing systematic approaches to urban heat island mitigation measures. Typical systems aim primarily to promote the greening of urban areas by mandating the promotion of greening, subsidizing the cost of greening, and incentivizing rooftop greening by granting higher floor-area ratios to buildings that implement it.

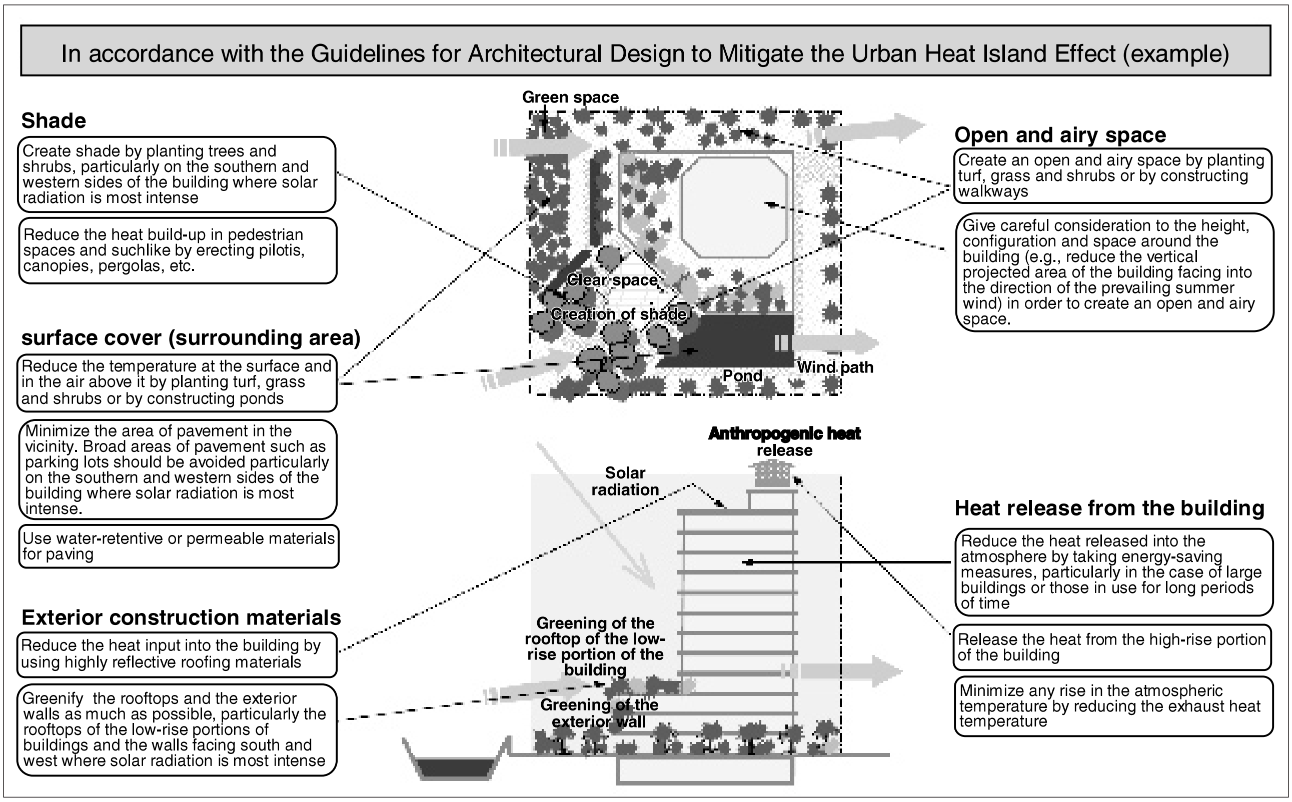
At the government level, in March 2002 the Cabinet decided to create guidelines for urban heat island mitigation measures in accordance with the "Three-Year Program for Promoting Deregulation (Revised)." Establishment of the Liaison Council in September 2002 was followed by the March 2004 adoption of the "Outline of the Policy Framework to Reduce Urban Heat Island Effects."

In line with the policy outline, in July 2004 the Ministry of Land, Infrastructure and Transport laid down "Guidelines for Architectural Design to Mitigate the Urban Heat Island Effect", encouraging building owners to adopt proactive mitigation measures (see Figure 4.). In July 2005, the CASBEE-HI system to assess the overall environmental performance of buildings was completed. CASBEE-HI is a tool for evaluating the effects of mitigation measures. It maintains a comfortable thermal environment in pedestrian spaces and other areas inside buildings. It uses a five-level rating system to assess the environmental performance of buildings by evaluating reduction of thermal impacts on their surroundings.

In December 2004, the Urban Renaissance Headquarters of the Cabinet Secretariat (headed by the Prime Minister) adopted the eighth Urban Renaissance Project: "Development of Measures against Global Warming and Heat Islands through Urban Renaissance Projects". Accordingly, "model areas for measures to mitigate global warming and urban heat islands" (see below) were selected in April 2005.

With the Kyoto Protocol taking effect in February 2005, the "Measures and Policies to Achieve the Goal" stipulated in April 2005 in the "Plan for Meeting Japan's Commitments under the Kyoto Protocol" specifies that "CO_2 emissions must be reduced by improving the thermal environment through urban heat island mitigation

Figure 4 : Issues to be considered when designing buildings



Source: Reference[7]

measures such as greening."

3-2 Major urban heat island mitigation measures

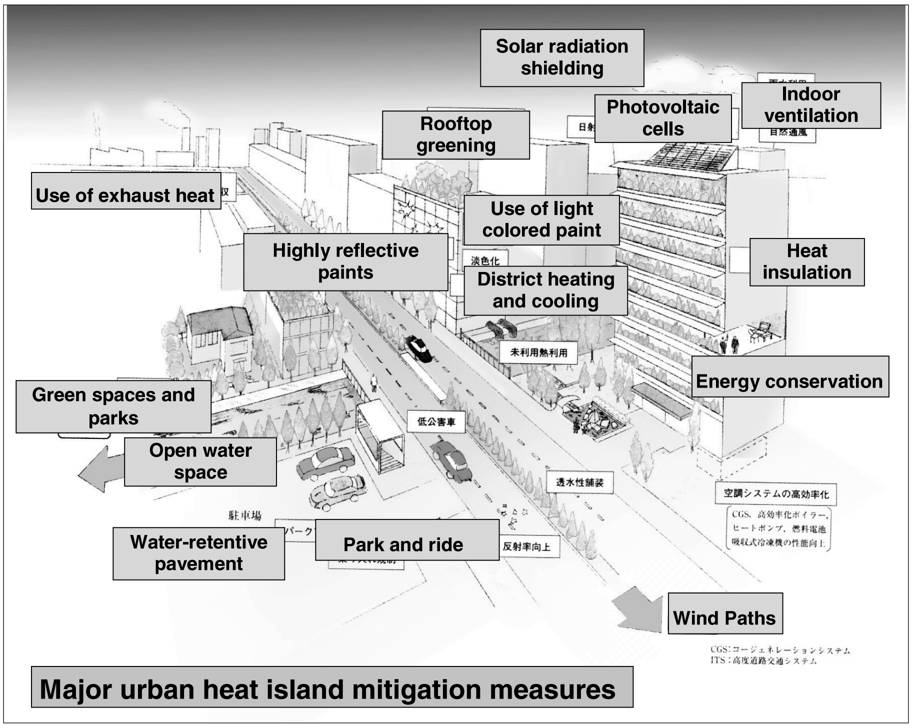
The "Outline of the Policy Framework to Reduce Urban Heat Island Effects" focuses on the following. (i) Reduction of anthropogenic heat release through urban activities, (ii) improvement of artificial urban surface covers, (iii) improvement of urban structure such as the placement and orientation of buildings, and (iv) enhancement of lifestyles. In particular, campaigns to encourage light clothing in summer and to reduce idling of automobile engines are both promoted as lifestyle improvements, i.e., measures closely related to social and economic activities.

The urban heat island effect in summer varies by city according to unique characteristics such as geography. Mitigation measures to be used are therefore left to the discretion of local governments. A variety of organizations and individuals, such as the central government, prefectural governments, municipalities, and business owners, administer the measures, which vary in scale and period (the time needed to produce) results[8]. There are both long-term citywide measures and measures suited for implementation in a relatively short time. Improving surface cover is effective in reducing the amount of heat storage and thus the incidence of sweltering nights. Reduction of exhaust heat contributes to the lowering of maximum daytime temperatures. Given this diversity of factors, the central government should create a framework within which mitigation measures can be tailor-made to suit the needs of each city. Table 1 summarizes the range of mitigation measures that are considered most effective.

These include the greening of building rooftops and walls, adoption of water-retentive construction materials, application of light colored paint to exterior walls, use of reflective roofing materials, central control of building exhaust heat at the regional level, maintenance and improvement of parks and green spaces, construction of large-scale greenbelts, and reorientation of industrial/commercial facilities in light of prevailing wind direction.

These measures grow in scale and scope as

Figure 5 : Urban heat island mitigation measures



Source: Prepared by Toshiaki Ichinose, the National Institute for Environmental Studies, based on Reference[6]

Table 1 : Categories of urban heat island mitigation measures

Description	Scale	Period	Degree of Effect		Administered by
			Sweltering nights	Rise in daytime temperatures	
(1) Reduction in anthropogenic heat release (reduction and substitution)					
(i) Improvement in the efficiency of energy-using products					
Office automation equipment and electric consumer appliances	Individuals	Short term	B	B	Individuals, business institutions, local governments
(ii) Improvement in the efficiency of air conditioning systems					
Refrigerators and heat source equipmen	Buildings	Short term	B	B	Individuals, business institutions, local governments
(iii) Optimal operation of air conditioning systems					
Proper placement of outdoor units	Buildings	Short term	B	B	Individuals, business institutions, local governments
Use of cooling towers	Buildings	Short to medium term	—	A	Individuals, business institutions, local governments
Voluntary restraints on nighttime operations	Buildings	Short term	A	—	Individuals, business institutions, local governments
(iv) Improvement in the heat insulation and thermo-shield of buildings					
High-performance heat insulation materials (interior heat insulating materials)	Buildings	Short to medium term	C	C	Individuals, business institutions, local governments
High-performance heat insulation and thermo-shield materials (exterior heat insulating materials)	Buildings	Short to medium term	A	D	Individuals, business institutions, local governments
(v) Greening of buildings and adoption of water-retentive materials					
Greening of buildings and adoption of water-retentive materials (Exterior heat insulating materials)	Buildings	Short to medium term	A	A	Individuals, business institutions, local governments
(vi) Improvement in the reflectivity of walls and roofing materials					
Light colored walls and highly reflective roofing materials	Buildings	Short term	A	A	Individuals, business institutions, local governments

Description	Scale	Period	Degree of Effect		Administered by
			Sweltering nights	Rise in daytime temperatures	
(vii) Introduction of traffic-control measures					
Traffic demand management and introduction of low emission vehicles	Cities	Medium to long term	B	C	Individuals, business institutions, local governments
Promotion of alternatives such as bicycles	Wards	Short to medium term	B	C	Individuals, business institutions, local governments
(viii) Introduction of district heating and cooling					
Central control of exhaust heat from buildings (at the regional level)	City blocks	Medium term	A	A	Business institutions, local governments
(ix) Use of untapped energy					
Use of sea, river and ground water	Wards	Medium to long term	B	B	Business institutions, local governments
Use of exhaust heat from urban facilities					
Use of exhaust heat from industrial plants, subways, buildings, power plants, substations, etc.	City blocks	Medium term	B	B	Business institutions, local governments
Recovery of energy from waste materials					
Waste power generation and heat supply	Wards	Medium term	B	B	Local governments
(x) Use of natural energy					
Photovoltaic generation	Buildings to cities	Short to medium and long term	B	B	Individuals, business institutions, local governments
Use of solar heat	Buildings to cities	Short to medium and long term	B	B	Individuals, business institutions, local governments
(2) Improvement of artificial surface covers (reduction of sensible heat transfer and expansion of latent heat transfer)					
(i) Improvement in the reflectivity and water-retentivity of paving materials					
Adoption of colored and permeable paving materials	Cities	Short term	B	B	Local governments
(ii) Greening					
Maintenance and improvement of parks and green spaces	Wards to cities	Medium to long term	A	A	Business institutions, local governments
Greening of streets	Wards to cities	Medium term	B	B	Local governments
Greening of dwellings	Individuals	Short term	B	B	Individuals, business institutions, local governments
(iii) Greening of buildings and adoption of water-retentive materials (reduction of sensible heat)					
Greening of buildings and adoption of water-retentive materials	Buildings	Short to medium term	A	A	Individuals, business institutions, local governments
(iv) Open water spaces					
Conversion of small rivers into open channels and construction of ponds in parks	Wards to cities	Medium to long term	B	A	Local governments
(3) Improvement of urban structure (improvement and integration of advection currents)					
(i) Improvement of the orientation of buildings					
Improvement of orientations of buildings and roads, and effective use of wind or water paths	City blocks to cities	Medium to long term	B	B	Local governments
(ii) Improvement of land use					
Construction of large-scale parks and green spaces, and reorientation of industrial or commercial facilities	Cities	Long term	A	A	Local governments
(iii) Creation of eco-energy cities					
Cascade use of energy, and organic integration of energy use in industrial and private sectors	Wards to cities	Medium to long term	B	B	Local governments
(iv) Creation of a recycling-based society					
Effective use of energy and resources, and creation of eco-friendly cities based on recycling	Wards to cities	Long term	B	B	Local governments

Note) Degree of effectiveness: A (very effective), B (effective), C (somewhat effective), D (counter effective) Source: Reference[4] they develop from (1) reduction in anthropogenic heat release to (2) improvement of artificial surface covers and (3) improvement of urban structure. Accordingly, their possible effects grow and so do their costs, with responsibility for their implementation shifting from individuals to government. Urban heat island mitigation measures should therefore be designed within the overall framework of urban planning.

3-3 The potential of "wind paths"

The concept of "wind path" design, a common mitigation measure that deserves further attention, is explained as follows.

(1) A "wind path" along the river

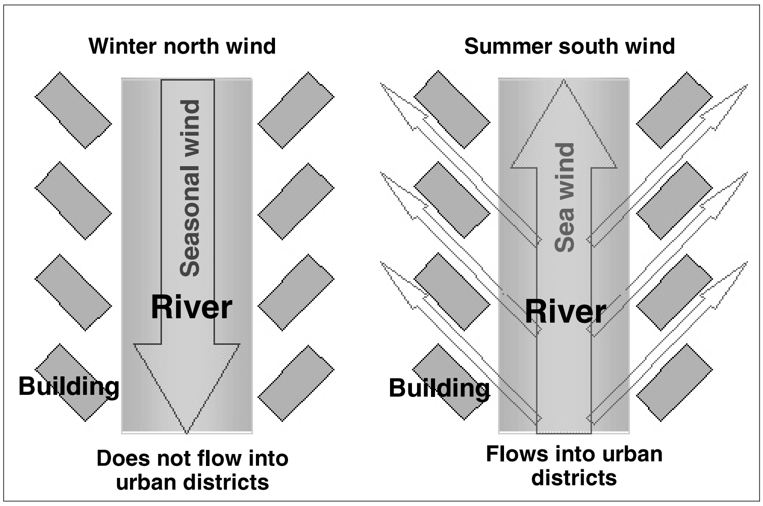
Winds that blow along paths are locally circulating winds such as those blowing from sea to land or from mountains to valleys. "Wind paths" (i) bring in cool air from the sea, lowering daytime urban temperatures, (ii) bring in cool air currents that flow down mountain slopes and valleys, cooling hot urban air at night, and (iii) help alleviate air pollution by bringing in generally cleaner sea winds and cool air currents[9].

Rivers are particularly useful in bringing in sea winds. The fact that a rivers can serve as "wind paths" is now being incorporated into urban design. For example, wind tunnel experiments have been conducted to investigate how effects such as vapor pressure and relative humidity on buildings adjacent to rivers vary when the orientation of the buildings is changed[8].

When buildings are positioned parallel to a river, they interfere with the air flowing along the river, preventing it from finding its way into urban districts. Positioning buildings perpendicular to the river, effectively channels air flow into these districts. When buildings are positioned at a 45°-degree angle to the river, however, they produce two contrasting effects, depending on the direction of wind flow along the river (see Figure 6). If the buildings align with the wind, they channel it in, while if they align against the wind, they deflect its movement. The orientation of buildings shown in Figure 6 channels a cool sea wind from the south into an urban district during the day in summer, while deflecting a cold seasonal wind from the north in winter. These experimental results show that seasonal winds can work in two beneficial ways. A project to put this concept into practice is underway in Tokyo's Shinagawa Ward (see below).

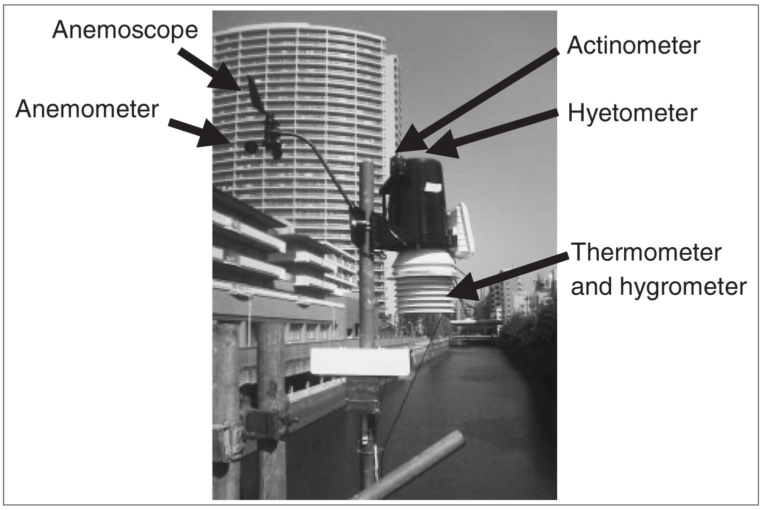
In large oceanfront cities like Tokyo, Nagoya, and Osaka, the wind usually blows from the sea towards the land because the surface of the land is warmer than the surface of the sea. Urban planning for cities, especially major oceanfront cities should therefore take advantage of sea winds flowing in along rivers ("wind paths").

Figure 6 : Illustration of a "wind path" along the river



Source: Prepared by STFC based on Reference[8]

Figure 7 : Meteorological equipment installed along the Meguro River (taken by the author at 14:24 on July 28, 2005)



A shot taken in the direction of Tokyo Bay (The anemoscope shows the direction of the bay)

This option is expected to play a major role in urban heat island mitigation in the future.

(2) Exploration of "wind paths" along the Tokyo waterfront

As described above, most of Japan's big cities are located on waterfronts, where the sea wind that flows from them could lower air temperature in summer. There are, however, no statistical techniques available to forecast this flow and predict its effects. As a result, urban planning does not yet take into account such winds. A group under the Ministry of Land, Infrastructure and Transport led by the National Institute for Land and Infrastructure Management therefore conducted a two-week large-scale survey at the end of July 2005 to explore ways in which "wind paths" can mitigate the urban heat island effect. The survey is part of a three-year general technology development project launched in 2004 by the Ministry of Land, Infrastructure and Transport. Led by Professor Toshio Ojima at the School of Science and Engineering, Waseda University, the project is called the "Development of Management Techniques for Thermal Environments in Urban Space." The project measured wind direction, speed, temperature, and relative humidity at some 200 sites in four areas: near Tokyo Station, the Shiodome/Shinbashi district in Minato Ward, the Shinagawa district, and the Osaki/Meguro River district in Shinagawa Ward. The project also observed changes in wind direction and the effects of altitude on temperature (see Figure 7). The collected data are being compared with those obtained through simulations carried out on supercomputers to analyze the influence of high-rise buildings, streets, parks, and rivers on local wind flow and temperature. One of the key objectives of this analysis is to verify the area of thermal impacts associated with skyscrapers in the Shiodome district, where the so-called "Tokyo Wall[*5]" is located. The survey results are expected to contribute to improvements in urban heat island mitigation measures such as greening and urban development.

4 Urban heat island mitigation measures from the perspective of urban planning

With such a range of accumulated findings and such a variety of developed technologies, many measures to mitigate urban heat islands have now been put into practice. These include rooftop greening, exterior wall greening, water-retentive pavement, and thermo-shield pavement. These sporadic measures, including "water sprinkling," may be effective in temporarily lowering urban temperatures, but they provide no lasting solution to the urban heat island effect. It is imperative that regional mitigation measures be simultaneously implemented in order to produce satisfactory results. Urban redevelopment and renewal, however, involve a complex consensus-building process, both socially and institutionally. In this context, the model-area projects discussed below deserve particular attention.

4-1 Model areas for measures to mitigate global warming and urban heat islands

In April 2005, the government designated 10 cities and 13 areas as model areas in which intensive environmental and energy-saving measures will be implemented to mitigate the urban heat island effect.

These "model areas for measures to mitigate global warming and urban heat islands" (hereinafter, "model areas") were designated based on the following objectives.

(i) Incorporate environmental and

Table 2 : Model areas for measures to mitigate global warming and urban heat islands

Prefecture	Model Areas	Description of Major Approaches
Hokkaido	Sapporo urban area	Creation of an energy network using snow ice cryogenic energy, biomass energy and natural gas cogeneration in addition to the development of old factory sites and the construction of an underpass beneath the Sapporo Station road
	Muroran oceanfront area	Construction of wind power generation facilities on an oceanfront area including a land readjustment project district, and intensive promotion of photovoltaic power generation systems for new residential housing in newly developed residential areas
Tokyo	Tokyo urban center	Introduction of an urban waste heat supply system using untapped energy sources (such as sewage), and implementation of global warming and urban heat island mitigation measures by the public and private sectors (such as rooftop greening, water-retentive pavement, and water sprinkling)
	Shinjuku district	Incorporation of environmental considerations into redevelopment projects (including improved heat insulation of buildings and rooftop greening) and the creation of a thermal environment improvement concept, with Shinjuku Gyoen at its center
	Osaki/Meguro district	Creation of wind paths along the Meguro River, development of environmental consideration guidelines (including the promotion of water-retentive pavement and green spaces), and implementation of district-wide approaches
	Shinagawa Station district	Examination of environmental symbiosis models (including wind paths) in developing the Shinagawa Station district (a priority district for an urban and residential environment development project), and promotion of energy-saving measures and rooftop greening among large-scale condominiums
Kanagawa	Yokohama urban area and Kanazawa district	Application of a multi-level park system to promote large-scale greening, water-retentive pavement, water sprinkling, and production of eco-energy (from natural energy, waste and biomass) to create a network supplying power and heat to businesses and dwellings
Aichi	Nagoya Station, Fushimi and Sakae districts	Introduction of district heating and cooling, and use of untapped energy sources in addition to the implementation of urban renewal projects in urban emergency redevelopment areas in order to roll out global warming and urban heat island mitigation measures
Osaka	Osaka Station, Nakanoshima and Midosuji districts	Introduction of district heating and cooling, and use of untapped energy sources (river water) in addition to the implementation of urban renewal projects in urban emergency redevelopment areas, and construction of parks and green spaces along with expansion of a railroad network to roll out global warming and urban heat island mitigation measures (capitalizing on the characteristics of Osaka, a "capital" of water resources)
	Dainichi district (Moriguchi City)	Construction of photovoltaic power generation facilities and promotion of water-retentive pavement and water sprinkling in addition to the implementation of large-scale development of old factory sites in urban emergency redevelopment areas
	Ibaraki City, Minoh City and Saito district	Promotion of a car-sharing program, new energy sources (such as photovoltaic power generation) and greening in addition to a large-scale community development project
Kochi	Susaki urban area	Construction of photovoltaic and wind power generation facilities in addition to the implementation of projects for tsunami escape routes and land readjustment, intensive construction of photovoltaic power generation facilities at old waste disposal sites and public facilities, and promotion of local lumber for use in housing and public buildings along with reforestation programs
Fukuoka	Kokura (Kitakyushu City), Kurosaki and Dokaiwan oceanfront area	Promotion of environmentally friendly housing, wind paths and district heating and cooling systems, and effective use of energy produced by adjacent factories in parallel with the redevelopment of idle land owned by companies in partnership with operating factories; promotion of global warming measures by taking advantage of existing industrial infrastructure and integrating these measures into a community planning package

* Model areas include 10 cities and 13 areas

Source: Reference[10]

energy-saving measures into urban renewal initiatives and designate urban emergency redevelopment areas and areas of concentrated urban activities as model areas in which pioneering approaches will be adopted

(ii) Systematically concentrate environmental and energy-saving measures that contribute to the alleviation of global warming and to the urban heat island effect as well as community planning measures in model areas within a certain time frame to produce maximum effect, thereby redeveloping an economically and environmentally viable city and helping achieve the Kyoto Protocol target

(iii) Concentrate measures administered by ministries, local governments, and the private sector on "model areas" to make steady progress in mitigating the urban heat island effect

In particular, the model areas must each meet the following three criteria. (i) Systematic and concentrated approaches involving cooperation and partnership among the central government, local governments, and the private sector are underway, (ii) pioneering approaches using underutilized materials/resources and mobilizing advanced technology/expertise are underway, and (iii) the approaches now underway are expected to effectively reduce environmental burdens.

The following section presents an overview of the approaches adopted by the Tokyo Metropolitan Government, including measures taken for Osaki/Meguro River district and other designated model areas (see Table 2).

4-2 Promotion of measures to mitigate urban heat islands in Tokyo

The Tokyo Metropolitan Government produced a "Thermal Environment Map" in April 2005. This map shows the atmospheric impact (thermal loading) of anthropogenic heat release and surface cover conditions. These factors cause the urban heat island effect in Tokyo's 23 wards (see the lower color map on the front cover). Efforts are now underway to implement mitigation measures designed to suit the characteristics of each area. The map categorizes these areas into five types according to thermal environment characteristics such as anthropogenic heat release and surface cover conditions, plotting them on a 500-m ×500-m grid. In particular, Type I (high-density commercial areas) and Type II (high-density residential areas), whose atmospheric impacts are relatively large, are designated by different colors according to their amount of thermal loading. On the basis of this map, four areas are designated as "areas for the implementation of urban heat island effect mitigation measures" (hereinafter, "designated areas") (see Table 3 and Figure 8).

The criteria used in designating these areas are: (i) areas whose atmospheric impact (thermal loading) is relatively large according to the Thermal Environment Map (i.e., high-density commercial and residential areas), (ii) urban emergency redevelopment areas that can attract environmentally friendly development by the private sector, and (iii) areas in which a wide range of development can be expected and where urban planning should be systematically introduced (with urban heat island mitigation measures incorporated in advance). In these designated areas, water-retentive pavement, the greening of exterior walls, and the planting of lawns on school grounds will all be promoted as part of urban renewal. The private sector will also be encouraged to take part in these developments.

In July 2005, the Tokyo Metropolitan Government developed the "Guidelines for Urban Heat Island Mitigation Measures" to encourage private businesses and the Tokyo public to develop mitigation measures according to the thermal environment in which they operate or live. These guidelines comprise (i) the Thermal Environment Map, (ii) an area-specific mitigation measures menu and (iii) a building-specific mitigation measures menu.

With the designated areas adopted as model areas by the central government, the Tokyo Metropolitan Government then set up the "urban Heat Island Mitigation Measures Designated Areas Council" in July 2005 to undertake concerted efforts to implement the program. This involves collaboration with the central government and all parties concerned, including private businesses.

4-3 Approaches to reduce environmental load through use of the Meguro River in the Osaki Station district

In July 2002, the Osaki Station district (60 ha), located in Tokyo's Shinagawa Ward was designated an urban emergency redevelopment area based on the Urban Renaissance Special Measures Law. Community-planning efforts are now underway, with the private sector (local developers, stakeholders, and others) playing a leading role. In April 2005, an area of 1,100 ha, including the Osaki Station district, was designated a national model area (see Table 2, 3 and Figure 8).

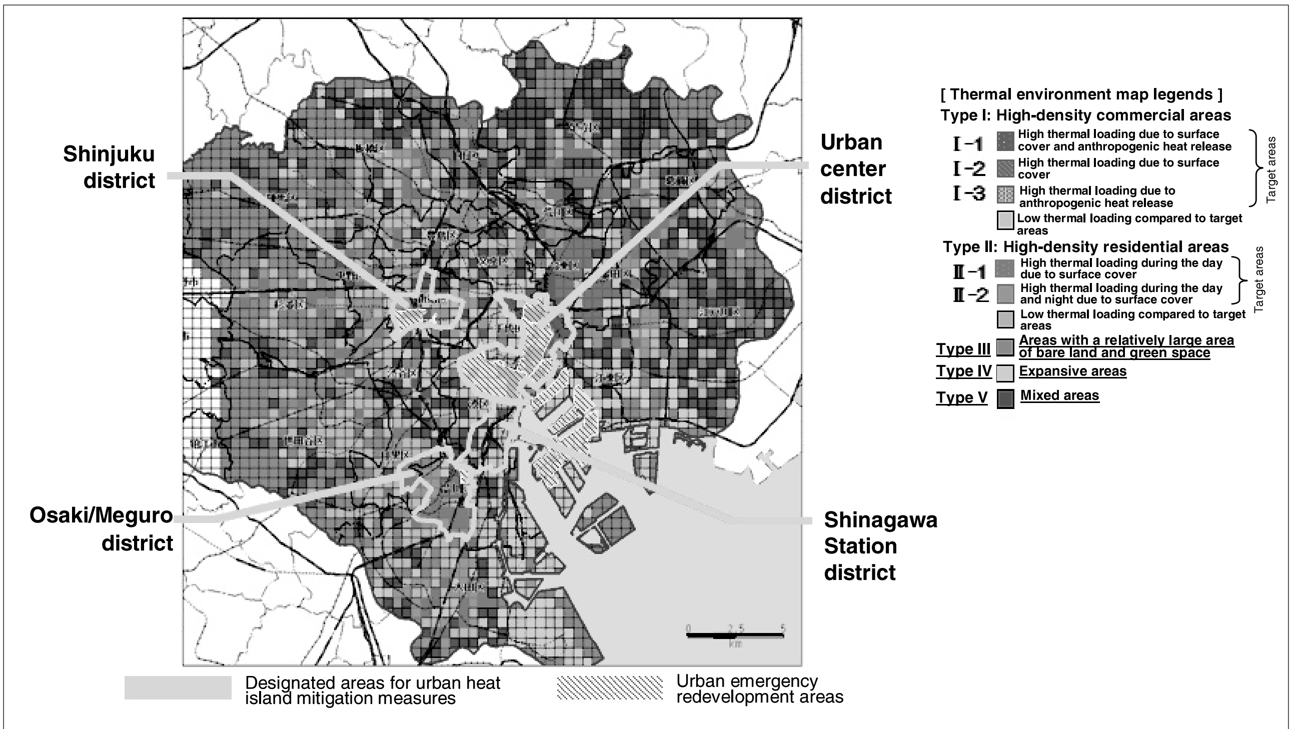
Based on their previous experience with community planning, all parties concerned, including local companies and redevelopment organizations that have development projects in

Table 3 : Overview of designated areas (Tokyo)

District	Characteristics	Description
Urban center (measures for high-density commercial areas), about 1600 ha	A substantial amount of heat is released from office buildings and artificial surface covers such as asphalt, leading to higher temperatures during the day and night	Urban emergency redevelopment areas (districts around Tokyo Station and Yurakucho Station, Akihabara, Kanda, loop road 2-Shinbashi, Akasaka, Roppongi, part of the Tokyo waterfront area), Iidabashi, Jimbocho, Nihonbashi (eastern district), and others
Shinjuku district (measures for high-density commercial areas), about 600 ha	A substantial amount of heat is released from housing, office buildings and artificial surface covers such as asphalt, leading to higher temperatures during the day and night	Urban emergency redevelopment areas (Shinjuku Station district, loop road 4-Shinjuku Tomihisa Street), Kita-shinjuku, Hyakunincho, Takadanobaba, Tomihisacho, and others
Osaki / Meguro District (measures for high-density residential areas), about 1,100 ha	A substantial amount of heat is released from the surface, leading to higher temperatures during the night (sweltering nights); a high-density residential area	Urban emergency redevelopment areas (Osaki Station district), and priority areas for disaster-resistant community planning (Rinshi-no-mori district and Ebara), Ooimachi, and others
Shinagawa Station district (introduction of measures through development projects), about 600 ha	A wide range of development is expected to take place, and systematic urban planning should therefore be adopted, with urban heat island mitigation measures incorporated	Areas designated as "urban and residential development priority areas" through the "general urban renewal project" administered by the Ministry of Land, Infrastructure and Transport

Source: Prepared by STFC based on Reference[11]

Figure 8 : Thermal environment map and designated areas for urban heat island effect mitigation measures. (see the color map on the front cover)



Source: Reference[12]

the Osaki Station district, the Shinagawa City, and elsewhere, jointly established the “Osaki Station District Emergency Redevelopment Area Community Planning Circle” (hereinafter, the “Community Planning Circle”). Established in February 2003, its aims are to formulate a shared vision of a future community and to push ahead with strategic community planning in line with the Urban Renaissance Special Measures Law. The Community Planning Circle developed with the “Osaki Station District Urban Renewal Vision” (hereinafter, the “Urban Renewal Vision”) in November 2004. This included a plan to “make use of the Meguro River as an environmental resource” (see Figure 9).

Global warming and urban heat island mitigation measures are key elements of urban renewal in the Osaki Station district. The overall plan is to utilize the Meguro River (one of the main geographical features of the district) as part of the area’s environmental resources, with particular emphasis on the following.

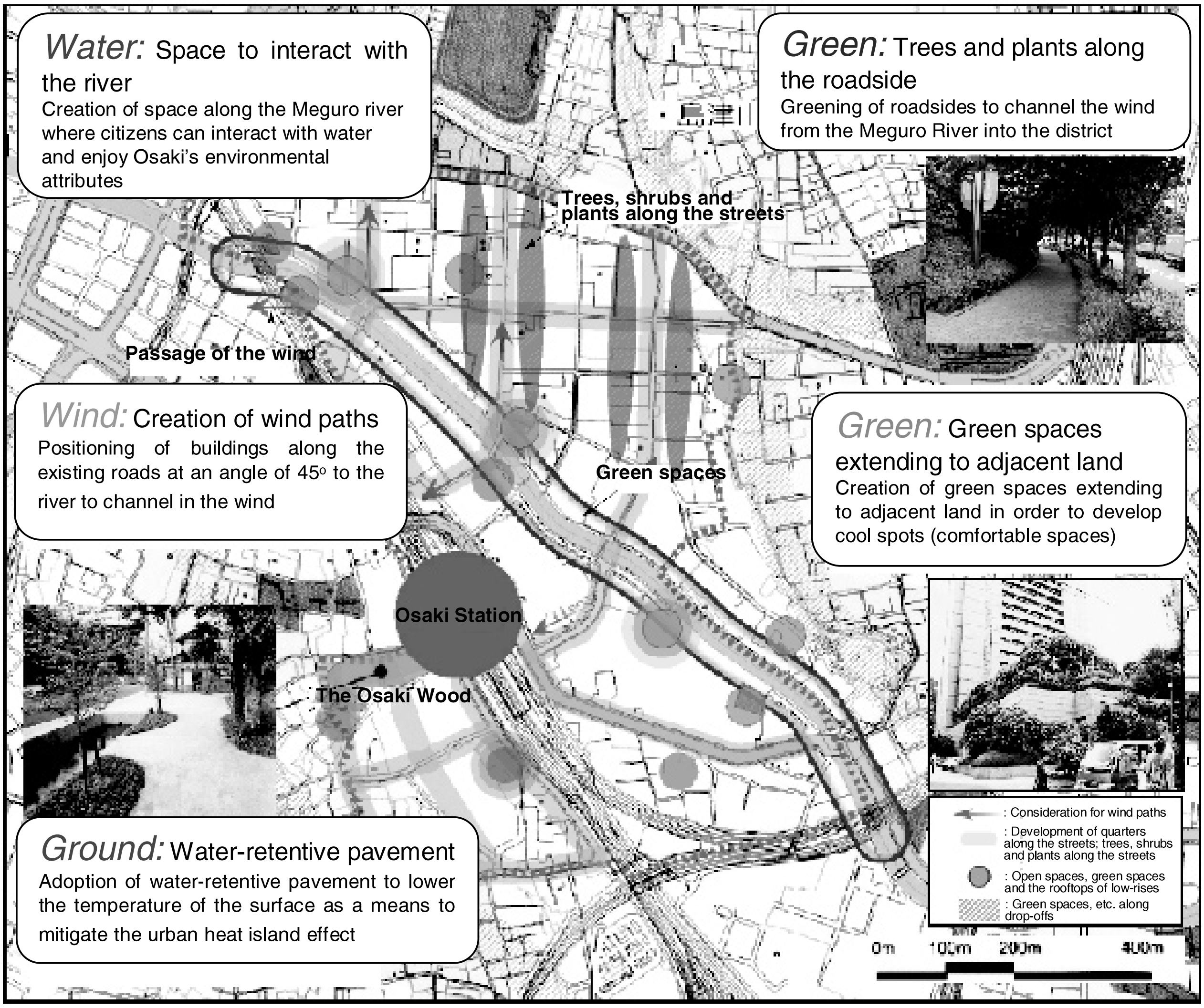
(i) Creation of a community centered on the Meguro River that gives due consideration to urban heat island mitigation measures, including the development of wind paths

(ii) Construction of riverfront parks, etc. along the Meguro River to create a community where citizens can enjoy and interact with the water and construction of river walls, open spaces and bridges to provide citizens with opportunities to interact with the river

(iii) Development of “Environment-conscious guidelines” based on a shared awareness of environmental conservation to support concerted efforts

(iv) Application of the guidelines to development projects in order to reduce

Figure 9 : Network of water, green spaces and wind paths along the Meguro River



Source: Reference[13]

the environmental load of urban heat island effects and to enhance the potential of the district

In response to this agenda, a voluntary proposal called the "Osaki Station District Environmental-conscious Guidelines" was set forth in July 2005 to carry out joint environmental measures, i.e., urban heat island mitigation measures. These guidelines encourage local developers to undertake environmental measures based on a shared awareness of environmental conservation. An "Environment-conscious Manual" was also prepared in order to present examples of the sort of environmentally conscious measures envisaged by the guidelines.

In Shinagawa Ward, the concept of a "wind path" is being put into practice. As part of the Osaki Station district's community planning, a project has been specifically authorized whereby buildings will be constructed along the Meguro River, all facing upstream at an angle of 45°. The project takes advantage of existing ward roads that extend from the river at similar angles (see Figure 9).

5 Urban heat island mitigation measures in other countries

(1) "Wind paths" in Freiburg, Germany

Freiburg is located at the east end of the Rhine River Valley, where a lack of wind often leads to thermal stress (heat impacting human health) in summer and air pollution in winter. In this area, the prevailing wind blows up the valley (behind the city) during the day and down the valley during the night. The nighttime wind, generated by radiative cooling in the mountain forests and pastures, cools as it flows down the streams. When channeled into the city, it is effective in alleviating thermal stress and air pollution. The street pattern has therefore been laid out in order to bring in cool air currents at night and the cool north wind during the day, while blocking the strong southwest wind that prevails in spring and autumn[8].

Although observations show that the temperature has been rising in European cities over recent years, the heat wave that struck the region in 2003 was considered a very unusual phenomenon. Public awareness of the urban heat island effect is thus not as prevalent in Europe as it is in Japan[14].

The creation of "wind paths" in Freiburg and other inland cities in Germany instead is primarily a means to alleviate air pollution in low-wind conditions or when surface inversion layers form*6.

(2) Urban heat island mitigation measures in the U.S.

In 1997, the Environmental Production Agency (EPA) instituted the "Heat Island Reduction Initiative" (HIRI) in the wake of the heat wave that struck Chicago in July 1995, resulting in a death toll of over 700 people[15]. As part of this initiative, the "Urban Heat Island Pilot Project" (UHIPP) was launched in 1998 to investigate the heat island effect, raise public awareness of the issue, and quantify the effects of mitigation measures[16]. Subsequently, five cities have been selected for inclusion: Baton Rouge, Louisiana; Chicago, Illinois; Houston, Texas; Sacramento, California; and Salt Lake City, Utah.

(3) The Cheonggyecheon restoration project in Korea

A large-scale river restoration project underway in the heart of Seoul is attracting worldwide attention[17]. The Cheonggyecheon, an 11 km-long tributary that joins the Han River, was converted into a culvert in the 1950s, with an elevated road constructed on top. Due to its age and increasing environmental concerns, however, the Seoul Metropolitan Government demolished and removed a 5.8-km section of the elevated road in July 2003 to restore the river to its natural state. The project was completed in October 2005. As a river restoration project of this magnitude is unprecedented, the potential environmental benefits, including alleviation of air pollution due to lower traffic volume and decreased summer temperatures in the area alongside the river, will produce valuable data (see the lower color photo on the front cover, and Figures 10 and 11).

Figure 10 : Before restoration (the Tondemun district in June 2003)

Source: Reference[18]

Figure 11 : Westward view from the rooftop of a building adjacent to the Cheonggyecheon near the Tondemun (August 2005) (see the color photo on the front cover)

Source: Taken by Kumi Kataoka, the National Institute for Environmental Studies

6 Recommendations on measures to mitigate urban heat islands

There is growing awareness that the urban heat island effect (local warming) and global warming have much in common in terms of their mitigation measures. In fact, they are both caused by the mass consumption of energy and resources and share some key mitigation measures: (i) energy and resource saving in buildings, (ii) energy-saving traffic systems, (iii) restoration of green spaces, and (iv) improvement of urban airflow.

The Tokyo Metropolitan Government is focusing on energy-saving measures in an effort to create an energy-efficient city. It takes account of both the urban heat island phenomenon and global warming as the "twin warmings" responsible. Underlying this action is the realization that energy-saving measures such as a reduction in energy consumption contribute to alleviating both global warming through reduction of CO_2 emissions and the urban heat island effect through reduction of exhaust heat.

As noted above, the urban heat island effect exists wherever there are large cities. Tokyo and many other major cities in Japan, carried out urban development after World War II in an unsystematic way, giving little consideration given to possible impacts on urban climate. The result is an urban system based on mass production and consumption that causes a variety of problems. For example, the incidence of heat stroke is on the rise due to higher daytime temperatures, and sweltering nights have become so frequent and uncomfortable as to be intolerable. Urban heat island mitigation measures must be adopted when planning further development in these cities.

(1) Approaches from the perspective of urban planning

Urban heat island mitigation measures must involve not only individual measures based on environmental technologies but also specific measures to improve infrastructure such as roads, rivers, parks and green spaces. For example, measures such as the development of "wind paths" that use locally circulating winds for urban ventilation should be incorporated into land use and urban planning in a systematic and comprehensive manner. In this context, the Cheonggyecheon restoration project in Seoul City is noteworthy. In short, urban heat island mitigation measures need to be incorporated into urban planning master plans from the outset.

In cooperation with local residents and corporations, local governments are strongly expected to play a leading role in facilitating mitigation measures and incorporating them into urban renewal projects that are already underway. Local policies should also reflect the policies and measures promoted by central government. In particular, relevant information should be shared with all parties who have a common appreciation of the mitigation measures needed. With large numbers of buildings constructed during Japan's period of high economic growth requiring replacement soon, this time of urban renewal in many cities provides a golden opportunity to implement urban heat island mitigation measures.

(2) Elucidation of the mechanisms of the urban heat island effect and mitigation measures

(i) Enhanced monitoring to elucidate the urban heat island effect

The urban heat island effect is the product of a variety of factors such as changes in land use and anthropogenic heat release. Both the thermal and the natural characteristics of relevant areas concerned should be studied, and area-specific approaches should be adopted to carry out effective mitigation measures within the framework of urban planning.

The coverage provided by the observation and monitoring stations of the Automated Meteorological Data Acquisition System (AMeDAS) of the Japan Meteorological Agency is considered insufficient to keep track of the regional characteristics of large, densely-populated cities and their surroundings. A better monitoring system based on high-density meteorological observation is necessary. AMeDAS monitors precipitation at about 1,300 sites across the country, one for approximately every 17km², Some 850 sites, one for approximately every 21km², are used to monitor wind direction and speed, temperature, and hours of sunshine as well as precipitation. These monitoring sites, however, are not evenly distributed across the country. In fact, there are only 10 such sites in Tokyo, not including outlying islands, and only 5 in the 23 Tokyo wards. In 2002, therefore, the Tokyo Metropolitan Government began installing monitoring equipment at 120 sites in the 23 wards in order to obtain highly precise, high-density meteorological data, such as temperature and relative humidity. This is a means to elucidate the mechanisms responsible for the urban heat island effect. Other government-designated cities should also create high-density meteorological monitoring systems of this sort.

The type of measurement survey conducted this summer (2005) along the Tokyo waterfront area should also be implemented this winter and again next year, and in other cities as well.

(ii) Development of simulation techniques to assess mitigation measures

Simulation plays a vital role in forecasting the urban heat island effect. The development of techniques to simulate the effects of prospective mitigation measures is therefore imperative so that they can be implemented in a comprehensive and systematic manner.

Efforts are underway to develop simulation techniques for the urban thermal environment. They should be integrated with simulation results obtained from other research areas in order to predict the effects of mitigation measures and to develop effective alternatives. Such techniques would enable the accurate assessment of the effects of mitigation measures such as wind paths, air cooling by green spaces, rooftop greening, water-retentive pavement, and thermo-shield pavement.

(iii) Development of comprehensive techniques to assess urban heat island mitigation measures

A system to assess the effectiveness of urban heat island mitigation measures should be put in place to prevent urban development projects such as urban renewal from exacerbating the heat island effect. This entails the development of techniques to assess the effectiveness of urban heat island mitigation measures.

Urban heat island mitigation measures already in place are assessed with the effects of each individual element of the technology quantified separately. There is still a need for comprehensive techniques to assess the overall effects of mitigation measures on entire cities. For example, buildings are the most important elements of cities and require the development of appropriate mitigation measures in order to reduce the urban heat island effect on a city-wide basis. However, the current assessment system is designed only to assess buildings on an individual basis. As new buildings sprout up in rapid succession, they should instead be assessed on a group, block or district basis. There is thus a need to develop standards for comprehensive assessment.

(3) From research to policy implementation

Priorities for implementing urban heat island mitigation measures must be set. Priority has commonly been given to measures that are readily available, but there is a growing need to adopt long-term, large-scale measures. The short-term, small-scale measures now being implemented are not always delivering the hoped-for results.

The use of “wind paths”, a typical long-term measure designed to channel locally circulating winds into urban areas, is shifting from a research and investigation phase to an implementation phase, both in Japan and abroad. Under these circumstances, the current efforts to apply scientific findings by creating “wind paths” from the Meguro River in the Osaki Station district and to use the orientation of buildings near the river to influence wind flow are unprecedented and praiseworthy contributions to community planning.

A variety of mitigation measures should first be applied to the model areas in order to accumulate data on their effects. These areas can then serve as useful examples to other areas in Japan and to rapidly urbanizing cities throughout Asia.

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Glossary

*1 IPCC (Intergovernmental Panel on Climate Change)
IPCC is a UN organization jointly established by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) to provide a scientific basis for global warming mitigation measures by using the latest findings on global climate change.

*2 Radiative cooling
A phenomenon whereby the radiation of infrared rays back into space cools down the air and the surface

*3 Inversion layer
An atmospheric layer in which the usual temperature gradient, with warm air below cold air, is reversed

*4 Dust dome
A phenomenon whereby air pollutants are trapped in a dome-shaped layer near the surface

*5 Tokyo Wall
This refers to a wall of skyscrapers in the Tokyo waterfront area that collectively blocks the sea wind, thereby exacerbating the urban heat island effect.

*6 Surface Inversion Layers
Surface inversion layers are formed when the surface temperature drops due to radiative cooling, cooling the air above it such that the higher the altitude, the higher the air temperature.

References

[1] The Science Council of Japan. Recommendations on the Analysis of the Urban Heat Island Effect from the Viewpoint of Architecture and Urban Environment Study, 2003. (Japanese) :
http://www.scj.go.jp/ja/info/kohyo/pdf/kohyo-18-t996-38.pdf

[2] Yamashita, S. "Heat Island". Environment Climatology. Yoshino, M. and Fukuoka, Y., ed. University of Tokyo Press, 2003. (Japanese)

[3] Nemoto, M. and Kobayashi, H. Trends in the Studies of Heat Island Mitigation Technology : Analysis from the Viewpoint of Energy Use. Science & Technology Trends Quarterly Review. No. 17, 2002. (Japanese)

[4] The Ministry of the Environment. Report on the Analysis of the Urban Heat Island Effect and its Mitigation Measures: 2000 (Expanded Edition), 2001. (Japanese) :
http://www.env.go.jp/air/report/h14-01/index.html

[5] Saka, S. Development of Urban Space Forming Technology Contributing to Urban Heat Island Mitigation Measures. The National Institute for Land and Infrastructure Management, 2004. (Japanese):
http://www.nilim.go.jp/japanese/report/lect

ure/kouenkai2004/image/saka1.pdf

[6] The Ministry of the Environment. For the Promotion of Urban Heat Island Mitigation Measures (Brochure), 2000. (Japanese) : http://www.env.go.jp/air/life/heat_island/panf01.pdf

[7] The Ministry of Land, Infrastructure and Transport. (Japanese) : http://www.mlit.go.jp/kisha/kisha05/07/070719_2/05.pdf

[8] Ichinose, T. "Urban Planning and Wind Paths". Environment Climatology. Yoshino, M. and Fukuoka, Y., ed. University of Tokyo Press, 2003. (Japanese)

[9] The Science Council of Japan. The Paradigm Changeover of Metropolis Policies Emphasizing the Quality of Life (Proclamation), 2005. (Japanese): http://www.scj.go.jp/ja/info/kohyo/pdf/kohyo-19-s1025.pdf

[10] Secretariat of the Urban Renaissance Headquarters, Cabinet Secretariat. (Japanese): http://www.kantei.go.jp/jp/singi/tosisaisei/siryou/0411tiiki.pdf

[11] The Tokyo Metropolitan Government. (Japanese): http://www.metro.tokyo.jp/INET/OSHIRASE/2005/04/20f4b100.htm

[12] The Tokyo Metropolitan Government. (Japanese): http://www2.kankyo.metro.tokyo.jp/heat/maperia.html

[13] The Shinagawa City (Tokyo). (Japanese) : http://www2.city.shinagawa.tokyo.jp/jigyo/05/bijyon_s.pdf

[14] Iwamura, K. Case Study: (b) Germany. IBEC. No. 138, 2003. (Japanese)

[15] The Environmental Protection Agency (U.S.) : http://www.epa.gov/heatisland/index.html

[16] Urano, A. and Morikawa, Y. Case Study: (a) The United States. IBEC. No. 138, 2003. (Japanese)

[17] Seoul City: http://japanese.seoul.go.kr/chungaehome/seoul/main.htm

[18] Seoul City: http://japanese.seoul.go.kr/chungaehome/seoul/sub_htm/4sub_03.htm

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