*Special Issue:*

# Sustainable Cities and Regions

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## Preface

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Important changes in the quality of the urban environment have occurred in the last few decades. Despite the progress achieved in controlling local air and water pollution, urban areas show increasing signs of environmental stress. Major concerns for cities are the quality of air and water quality, heat island conditions and traffic congestion. Open spaces and green areas are under continuous threat due to more competitive uses for limited land resources. The quality of life in cities is also affected by the deterioration of buildings and infrastructure and the degradation of the urban landscape. Beyond their immediate environment, cities also absorb increasing amounts of resources and produce increasing amounts of emissions and waste, causing significant burdens on the regional and global environment. These problems are warning signs of a more deep-seated crisis, and call for a rethinking of current models of organization and urban development.

Urban environmental problems are often viewed as local problems, since the high concentration of people and activities in cities is the cause of heavy pressures on the local environment. However, urban environmental problems are closely linked with regional and global problems by their common causes and interdependent effects. As cities deplete local resources and increase their dependence on imported global resources, they become more vulnerable to the effects of global environmental change. Yet at the same time, the disproportionately strong influence that urban areas have on the global environment also ensure that implementation of measures to improve these areas can have significantly beneficial effects on the regional and global environment. This means that urban planning must deal simultaneously with both local and global environmental problems, such as global climate change.

This century is projected to be the century of the environment. The future of human beings is dependent on the actions we take on behalf of the environment. An adequate response to these environmental concerns requires a new concept of how cities can become more symbiotic with the local and global environment in the future. In order to develop such a concept, four authors report on their research in the areas of urban planning and global/local environmental problems in this special issue.

# Global Warming Countermeasures and City Planning

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## 1. Global warming countermeasure trends in Japan

In December 1997, COP3 (3rd Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change) adopted the Kyoto Protocol, in which Japan pledged to reduce its greenhouse gas emissions 6% compared to 1990 levels by 2012. In October 1998, Japan enacted the Act on Promotion of Global Warming Countermeasures and legally established the Kyoto Protocol Target Achievement Plan as the necessary plan to realize its pledge in the Kyoto Protocol. The actual plan was created in April 2005, and was completely revised in March 2008.

In June 2008, the Act on Promotion of Global Warming Countermeasures was revised to promote cuts in greenhouse gas emissions and the preservation and strengthening of absorption of these gases by local governments. The revisions required that prefectures and cities of a certain size or larger (referred to below as specially designated cities) to create plans to limit greenhouse gas emissions in their area (referred to below as an implementation plan), and to tie these plans to the city plan.

Furthermore, in July 2008, the Cabinet Secretariat's Urban Renaissance Headquarters designated certain cities as "eco model cities" and started to promote the spread of more-environmentally-suited cities throughout Japan.

In this paper, I look at the relationship between efforts concerning global warming countermeasures and city planning and the state of creating Low-Carbon City Development Guidelines that are expected to be completed in March (2010) and will act as guidelines for concrete effects to create low-carbon cities.

## 2. Global warning countermeasure trends in the field of city planning

### (1) Kyoto Protocol Target Achievement Plan

In order to realize dramatic reductions in greenhouse gas emissions, both individual measures for each sector (such as hybrid cars, energy efficient home electric appliances, and well-insulated houses) and a revolution in not only the structure of cities and local communities, but also social and economic systems are necessary. Looking at the population density of Japanese cities and per capita $CO_2$ emissions in the transportation sector reveals that there is a strong correlation between a compact urban structure with high population density and a decline in $CO_2$ emissions in the transportation sector (figure 1). In addition, it is important to use the opportunity provided by development efforts throughout a city to increase the efficiency of energy use, which includes efforts such as introducing new types of energy. In the Kyoto Protocol Target Achievement Plan, which was fully revised in March 2008, the following measures were considered methods to create "(a) a low-carbon urban/regional structure and a social and economic system"

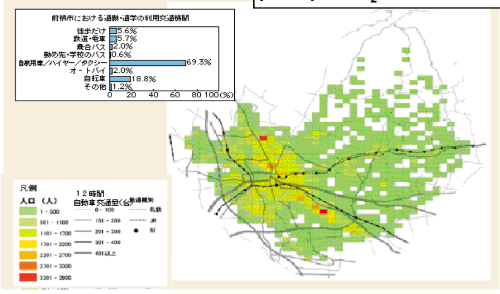
**Creation of a low-carbon urban/regional structure and a social and economic system**
(excerpt from the Kyoto Protocol Target Achievement Plan)

- Promote comprehensive urban and regional transportation systems in order to realize a compact city structure
- Intensively introduce facilities that employ multiple types of new energies into regions, cities, and buildings
- Use opportunities such as urban development to promote leading measures that can be expected to dramatically reduce $CO_2$ emissions throughout the area at the city and regional level through public-private cooperation
- Promote the area use of energy through partnerships between various buildings at the city and regional level and operate and manage energy for the whole area

- **Using Maebashi-shi and Kochi-shi, which have about the same area and population, as examples, Maebashi-shi with extensive low-density urban areas is highly dependent on cars. Comparing per-capita $CO_2$ emissions for the passenger transportation sector, the figure for Maebashi-shi is 1.21 tons, around 40% greater than the 0.87 tons for Kochi-shi**

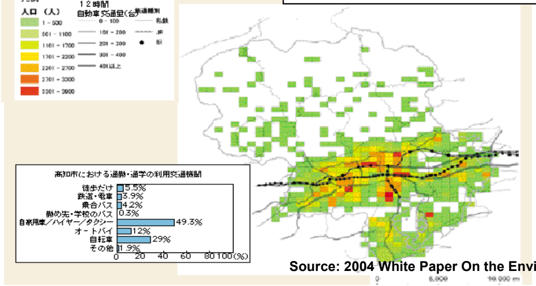
- **Maebashi-shy** · **Percentage of habitable land = 85%**

**per-capita $CO_2$ emissions = 1.21 tons**



- **Kochi-shy** · **Percentage of habitable land = 39%**

**per-capita $CO_2$ emissions = 0.87 tons**



**Source: 2004 White Paper On the Environment**

*** Per-capita $CO_2$ emissions for the passenger transportation sector**

- **Transformation of the city structure has a major impact on the form of transportation, causing a shift to transportation modes centered on public transportation that have low $CO_2$ emissions per distanced travel and promoting walking and the use of bicycles.**
- **Shift to a compact city structure also creates the conditions conductive to transforming the city's energy system into a low-carbon one that is more efficient.**

**Reference: Mamoru Taniguchi, Time Series Analysis of Car $Co_2$ Emissions From A City Structure Perspective, Toshi-Keikakau-Ronbunshu No. 43-3, October 2008**

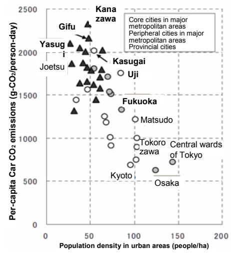



Figure 1

## (2) Revision to the Act on Promotion of Global Warming Countermeasures and city plans

Revisions were made to the Act on Promotion of Global Warming Countermeasures in June 2008, which included requiring prefectures, ordinance-designated cities, core cities, and specially designated cities to create a new implementation plan that "establishes measures with various objectives including reducing emissions of greenhouse gases according to the natural and social conditions of that area". Revisions also mandated that the following items be examined in the new implementation plan; in June 2009, the Ministry of the Environment created a manual for local governments that indicated the ministry's thoughts on creating this plan.

### Mandatory items to be examined in the new implementation plan

- Promotion of the use of natural energy such as solar power and wind power
- Promotion of activities by businesses and residents to limit greenhouse gases emissions
- Increase in the use and convenience of public transportation, preservation of existing green areas and introduction of greenery in cities, and the development of and improvements to the local environment that would contribute to various efforts including cutting greenhouse gas emissions
- Promotion of reductions in the production of waste material and other measures to create a recycling-based society

The revisions also required that consideration be given to tying the implementation plan to the city plan.

### Act on Promotion of Global Warming Countermeasures, Article 20.3.4

In order to promote global warming countermeasures, prefectures, designated cities, etc. shall take into consideration efforts aimed at reducing greenhouse gas emissions through coordination with the local government's implementation plan by harmonizing these goals with those of the city plan, agricultural promotion zone plan, and other measures related to efforts to limit the emission of greenhouse gases.

### (3) Eco model cities

Based on an awareness that it is necessary to make fundamental changes in lifestyles and social structures, such as cities and transportation (systems), in order to create a low-carbon society, efforts have been made to select leading cities that implement low-carbon urban development through a comprehensive approach as eco model cities, and these efforts have been centered on the Cabinet Secretariat's Urban Renaissance Headquarters. During the application period, which ran from April 11 to May 21, 2008, 82 municipalities from throughout Japan applied for the designation, and 13 were selected.

**Approach and criteria for selecting eco model cities**

Requirements of proposals
- Include concrete measures to effectively reduce greenhouse gases
- Exhibit a comprehensive approach that can be used throughout Japan
- Exhibit a future image of an attractive city and region

Proposal perspective
(1) Dramatic reduction in greenhouse gases
(2) Initiative and ability to act as model
(3) Regional adaptability
(4) Implementable
(5) Sustainable

Selection criteria and perspective
(1) Dramatic reduction in greenhouse gases
(2) Initiative and ability to act as model
(3) Regional adaptability
(4) Implementable
(5) Sustainable
* The smaller the city, the greater the focus on the initiative and model-traits is

**Selection Results**

**Selected in July 2008**

| | |
|---|---|
| Major cities: | Yokohama-shi, Kita-Kyushu-shi |
| Core provincial cities: | Obihiro-shi, Toyama-shi |
| Small cities, towns, villages: | Shimokawa-cho (Hokkaido), Minamata-shi |

**Selected February 2009**

Candidate cities were selected in July 2008, and the final selection was made in January after an action plan was created

| | |
|---|---|
| Major cities: | Kyoto-shi, Sakai-shi |
| Core provincial cities: | Iida-shi, Toyota-shi |
| Small cities, towns, villages: | Yusuhara-cho (Kochi), Miyakojima-shi |
| Tokyo wards: | Chiyoda-ku |

## 3. Examination of Low-Carbon City Development Guidelines

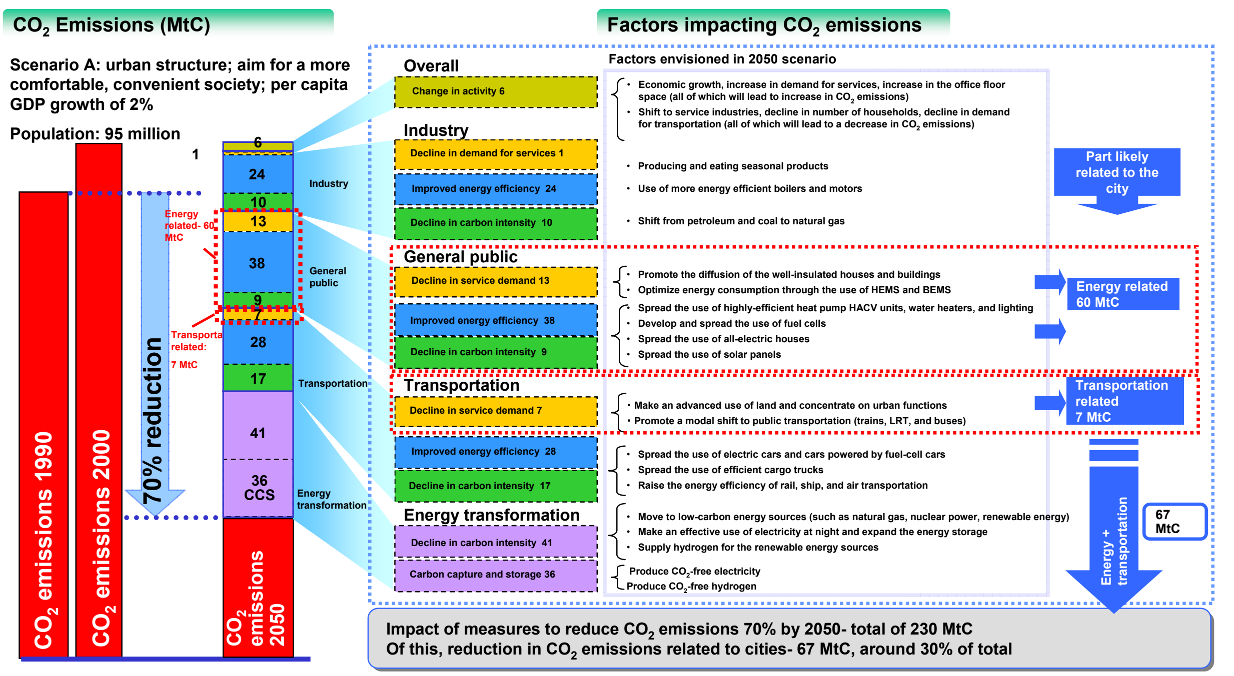
The city plan is a mechanism to comprehensively examine the ideal form of a city from various perspectives, including society, economy, and environment, and to realize this ideal form. It is also necessary that global warming countermeasures be examined. Measures must also be developed from a long-term perspective taking into consideration the distinguishing characteristics of the city including the surrounding natural environment, the city structure, and form of greenhouse emissions, which is related to the scale of commerce and industry, population density, land use, and the state and use of public transportation of the particular city, and to build up measures.

However, reductions in greenhouse gases have mainly been promoted through sector-specific countermeasures, such as hybrid cars, energy-efficient home electronic appliances, and well-insulated housing, and there has been insufficient consideration from a city perspective such as forming a compact city structure and making area-wide use of energy. Staff of local governments, who operate the various systems related to the city plan, have not been provided with a systematic explanation of how to create low-carbon cities. Therefore, efforts are being made to establish Low-Carbon City Development Guidelines to be used when local governments develop city plans and measures based on these plans, and the guidelines will achieve two objectives–(1) indicate items that should be considered in order to create a low-carbon city, and the basic philosophy on efforts and various other issues such as how to promote countermeasures, and (2) provide both methods to ascertain the benefits of the measures and related data. These guidelines are envisioned to be used in various situations including the following: (1) conducting city-wide examinations of low-carbon city planning at various times such as when revising the city's master plan; (2) considering how to create a low-carbon city when promoting various efforts such as redevelopment projects, and the construction of facilities included in the master plan; (3) examining city development measures when creating the new implementation plan; (4) analyzing the impact of measures to create a low-carbon city. While adaptation measures are not covered this time, they are extremely important from a perspective of responding to global warming, and they will be a topic for future examination.

When conducting an examination, a determination is made regarding the fields that should be targeted by city measures (figure 2). In addition to areas such as energy, transportation, and city structure, which are the sources of many $CO_2$ emission, focus is on the area of greenery, which includes increasing $CO_2$ absorption sources and using land in a manner that preserves greenery from a perspective of reducing the use of land for city purposes that generate $CO_2$ emissions. After that, the basic philosophy (figure 3) and effective measures (figure 4) are organized. To the extent that benefits can be calculated and based on the assumption that the measures are thought to contribute to reductions in $CO_2$ emission function sufficiently, the following calculations were made in order to determine what the possible greatest reductions in $CO_2$ emissions would be in the above three fields through measures within the city plan.

Using the case of the Sendai metropolitan area, reductions in $CO_2$ emissions in the fields of transportation, city structure, and energy were calculated assuming the development of measures to create a compact city structure.

Regarding the population distribution, the population in 2050 was estimated based on a scenario using existing research[1], and it is assumed that people were induced to concentrate in the city center and core areas. It is also assumed that various transportation measures were implemented: hardware related measures include building railroads (airport access line and subways) and roads (car-only roads and roads appearing in the city plan), and transportation demand management (TDM) related measures include increasing the frequency of trains, creating new city bus routes such as a loop line and core routes and restructuring branch lines. As a result, it would possible to reduce $CO_2$ emissions 24% compared to the cur-




Source: Examination of the Possibility of 70% Reduction in Greenhouse Gases (revised June 2008)

Figure 2

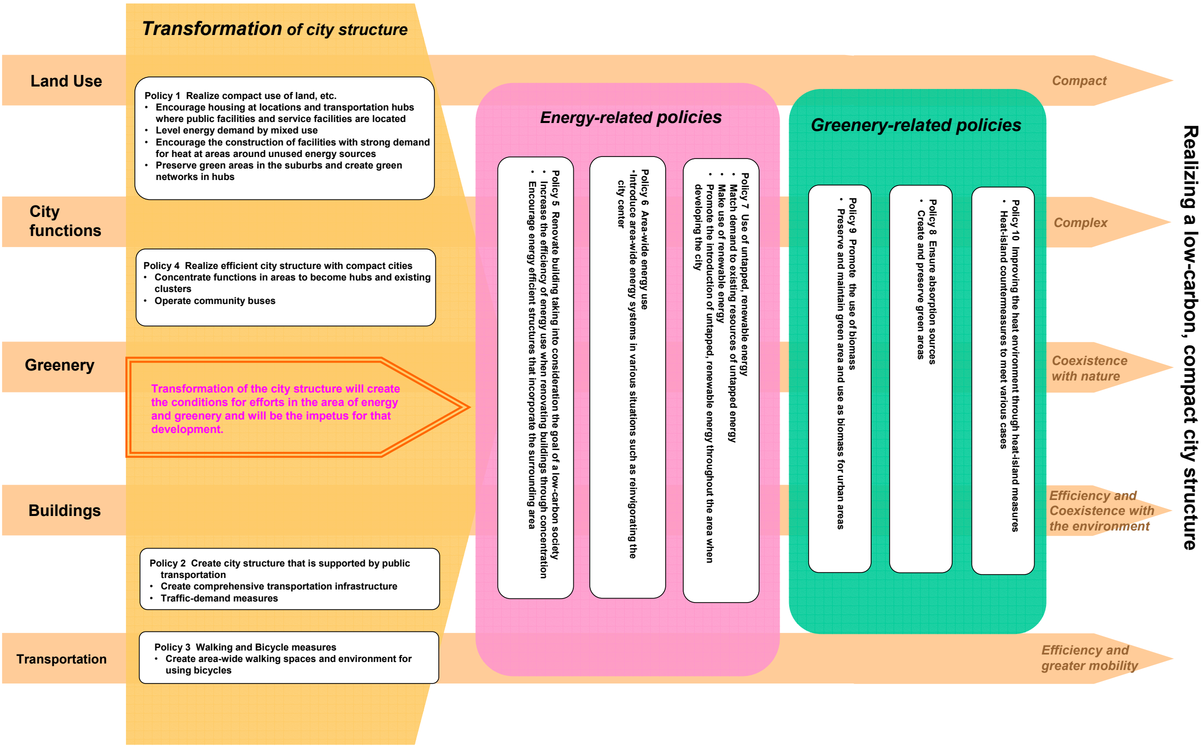



Figure 3

## Policies for Creating a Low-Carbon City

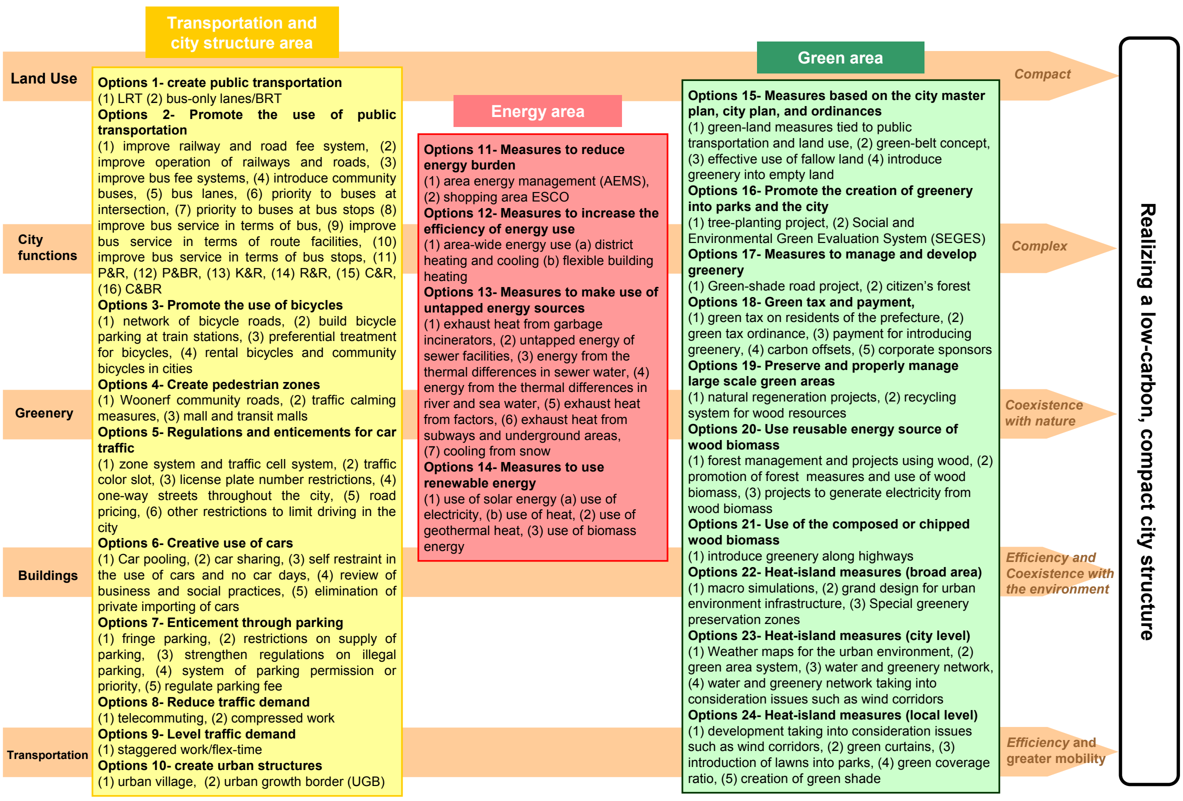



Figure 4

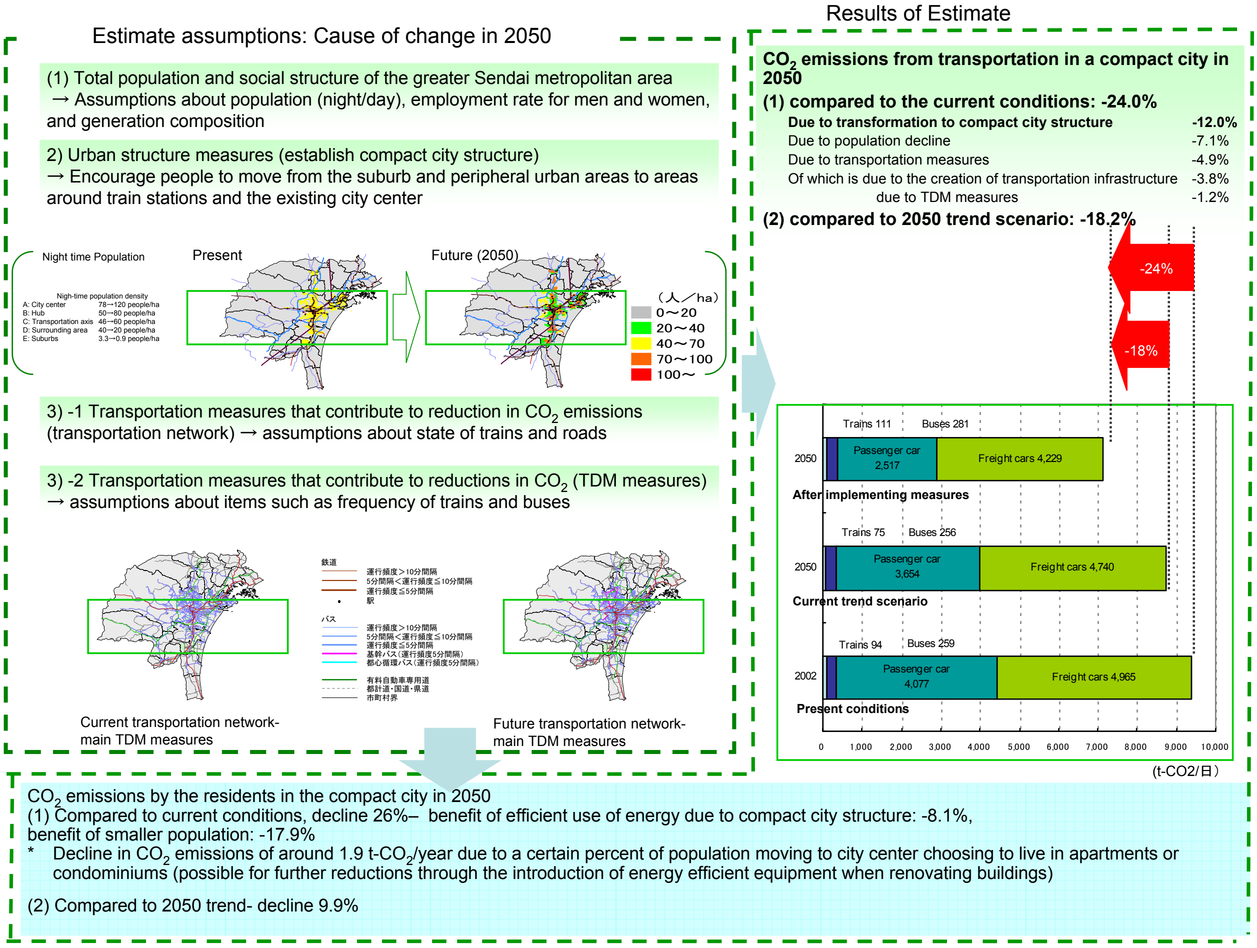



Figure 5

rent level and 18% compared to the trend scenario for 2050.

In addition, assuming that a certain percentage of the population enticed to move into the city center or hubs chose to live in apartments or condominiums instead of detached houses, $CO_2$ emissions would decline 26% compared to the current level and 10% compared to the 2050 trend scenario (figure 5).

In the area of energy, a trial calculation was made for Otemachi, Marunouchi, and Yurakucho (Daimaru) areas of Chiyodu-ku, Tokyo, assuming that business floor space is the same as that for 2025, and energy measures are implemented for the whole area. It was assumed that measures included those for individual buildings, expanded district heating and cooling, introduction of large-scale cogeneration facilities, introduction of waste water heat system, use of exhaust heat from incineration plants, and the introduction of renewable energy. Assuming the total floor space increases 50% through 2025 and the $CO_2$ emission coefficient for electric power improves 16%[2], $CO_2$ emissions would decline 15% compared to the current level and at most 40% compared to the case in which no measures are implemented (figure 6).

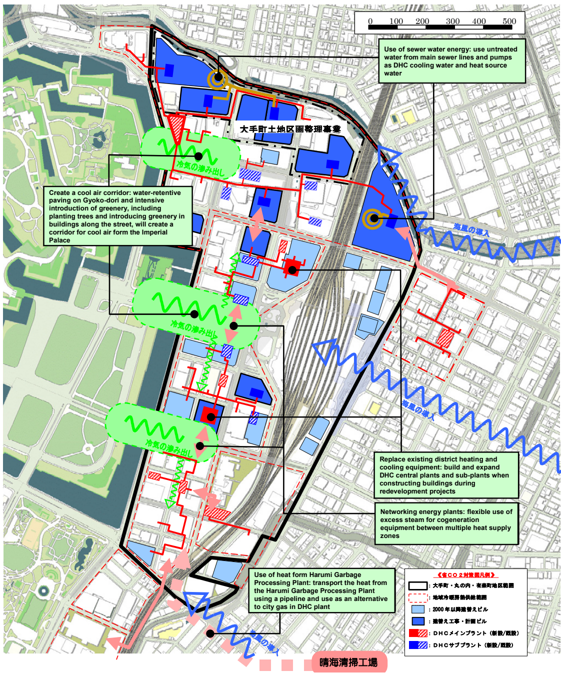
In the field of land use to preserve greenery, the greater Tokyo metropolitan area and Oita-shi were used as cases, and a trial calculation was made assuming absorption sources increased through the creation of new green areas and the preservation of existing ones. In terms of creating new green areas, assuming there is an increase in the green coverage ratio for urban areas and a certain percentage of fallow agricultural land is planted with greenery such as trees and, in terms of preservation, there is an increase in absorption sources through forest management[3], the amount of $CO_2$ absorbed in both the greater Tokyo metropolitan area and Oita-shi would increase 200% (figure 7). The guidelines will reflect other data including the results of other case studies and are expected to be created in March 2010.

**notes:**

1. The following are assumption for 2050: 2050 Japan Low-Carbon Society: Examination of the Possibility of 70% Reduction in Greenhouse Gases (created in February 2007 and revised in June 2008) and the night population declines 18% and the working population falls 13% based on estimates by the National Institute of Population and

Social Security Research.

2. Assumption based on the 2000 actual emissions coefficient (average) for Tokyo Electric Power Company.
3. Absorption volume was set based on the report by Japan to the United Nations Framework Convention on Climate Change (new tree planning, forest management, and regeneration of plants based on article 3.3 and 3.4 or the Kyoto Protocol)




* Source for building area data: Summary of Otemachi, Marunouchi, Yurakucho Zone Redevelopment Project Council (pamphlet) September 2002/December 2006

Trial calculation assumptions (2025): Cause of change
Scope: area 120 ha, 104 buildings
Future conditions:
Building floor space: 600 ha (2000) → 900 ha (2025)
* the building floor space in 2025 is assumed to be half current buildings and half new buildings (2-fold increase in floor space), which is 1.5 times the figure for 2000
Improvement in $CO_2$ emissions coefficient for the electric system: 0.334 (2000) → 0.28 (2025)
* An increase in the coefficient for Tokyo Electric Power Company of 516% compared to the actual figure for 2000 (average)
$CO_2$ reduction measures options-

- Individual building measures: 50% of the buildings in the area (on a floor space basis) are renovated improving energy efficiency
- Area-wide measures on the region and city level
  - Area use of energy
    - Improvement in refrigeration efficiency
      - Total efficiency improves to 1.05 (2025) from 0.75 (2000) through expanded use of existing district heating and cooling
      - Connections between district heating and cooling pumps: networking
- Introduction of large cogeneration plants: introduction of system to use sewer heat
- Introduction of roof-top greenery
  - Use of roof-top greenery on redeveloped buildings throughout the area by concentrating heat source equipment (cooling towers)
- Introduction of renewable energy
  - Installation of roof-top solar panels
  - Use of food waste from local restaurants as biogas to generate fuel for the district heating and cooling plants
- Transportation of heat from the incineration of garbage at the Harumi Garbage Processing Plant
  - Use of heat source for the district heating and cooling pump

| | Type of measure | Details | Reduction in consumption | Comparison | t-CO₂/year |
|---|---|---|---|---|---|
| 2000 | Base line | | | | 532, 187 |
| 2005 | Increase in floor space | | — | — | 798, 280 |
| | Electric system measures | Improvement in emissions coefficient | 98, 042 | 28. 2% | 700, 237 |
| Area $CO_2$ Reduction Measures →41% reduction in $CO_2$ emissions | Individual building measures | Redeveloped building | 109, 336 | 31. 4% | 590, 902 |
| | Energy-area use | Improve efficiency of refrigeration | 45, 796 | 13. 2% | 545, 106 |
| | | Large-scale cogeneration | 28, 793 | 8. 3% | 516, 313 |
| | Introduction of roof-top greenery | Redevelopment building, etc. | 9, 373 | 2. 7% | 506, 939 |
| | Introduction of renewable energy | Solar panels | 13, 110 | 3. 8% | 493, 829 |
| | | Garbage biomass | 4, 873 | 1. 4% | 488, 956 |
| | Exhaust heat from Harumi Garbage Processing Plant | | 38, 903 | 11. 2% | 450, 053 |
| | Total reductions | | 348, 227 | 100% | |

15% reduction compared to current state

40% reduction compared to no measures

Figure 6

## Assumptions for estimates

• Target
Greater Tokyo metropolitan area (existing city areas and suburban development areas)

• Cause of change
Calculate reduction in $CO_2$ emission from the following perspective

**a. Create green areas**

Assume the green coverage ratio is 30% in urban areas (current 9% in the greater Tokyo metropolitan area), with 50% accounted for by trees. Assume that 50% of the agricultural land in the area around Tokyo (suburban development areas and adjustment areas) projected to go fallow is planted with trees (currently around 18,000 ha in the greater Tokyo metropolitan area)

**b. Preserve green area**

Improve function as an absorption source by properly managing forests in the area around Tokyo

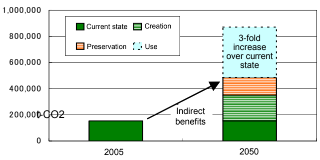
*** Indirect benefit**
**Make use of the green areas, etc.**

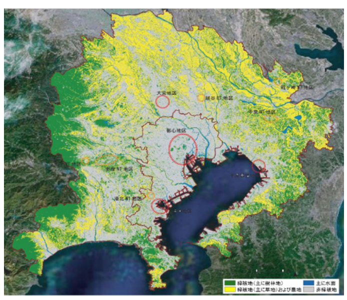
## Results

Increase the volume absorbed and reduced around 3 fold compared to the current state through “creation” and “preservation” of the green land.

**Expected $CO_2$ absorption**

- Create green areas in the city : 9.81t-CO2/ha·year
- Plant new forest areas : 13.57t-CO2/ha·year
- Increase from support for forest maintenance : 6.53t-CO2/ha·year
- Forest maintenance (current level) : 3.00t-CO2/ha·year



3 fold increase over current level

| | Area (ha) | Source units (t-CO2/ha/yr) | Reduction (t-CO2/yr) |
|---|---|---|---|
| 【Current state】 | | | |
| Trees in current city areas | 9,000 | 9.81 | 153,022 |
| Trees in suburban development zones | 20,720 | 3.00 | |
| Introduction of roof-top greenery | 64 | 40.00 | |
| 【Creation】 | | | |
| Create urban green areas in existing urban areas | 8,565 | 9.81 | 197,872 |
| Create new areas with trees in suburban development zones | 6,660 | 13.57 | |
| Introduction of roof-top greenery | 587 | 40.00 | |
| 【Preservation】 | | | |
| Properly manage forest areas in the suburban development areas | 20,720 | 6.53 | 135,302 |

**Items that can be expected to reduce CO2 emissions in an indirect manner**
Use biomass generated through the proper management of forested areas as wood pellets and bio-ethanol
Reduce heating and cooling burden by introducing roof-top greenery

Figure 7

# Efforts to Create a Low-Carbon City in Chiyoda-ku

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## Introduction

Chiyoda-ku (one of the 23 wards of central Tokyo) is the political and economic center of Japan, and is the location of many administrative functions.

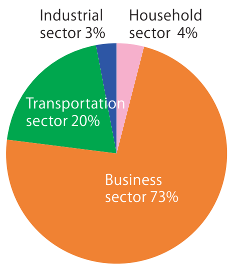
On the other hand, the ward possesses a rich natural environment with water and greenery, centered on the Imperial Palace. The ward encompasses an area of 11.64 km$^2$ and has a population of 46,000; however the daytime population is 850,000, around twenty times larger than the number of residents.

A breakdown of Chiyoda-ku's $CO_2$ emissions by sector reveals that 73% of emissions are generated by the business sector, particularly offices. In terms of energy sources, around 69% of $CO_2$ emissions are due to the use of electricity.

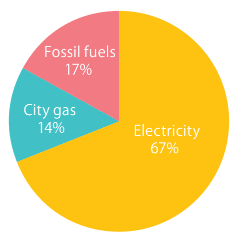
It is projected that the business floor area will increase and $CO_2$ emissions will grow as economic activity expands and city functions are updated. (In 2005, the business floor area was 2,019.5 ha, which was 23% greater than that in 1990. Total $CO_2$ emissions in 2005 for the ward were 2.803 million tons, 13% larger than the 2.49 million tons in 1990. In addition, BAU emissions are forecast to increase approximately 33% to 3.311 million tons by 2020). $CO_2$ omissions for the ward will continue to increase if no measures are implemented.

Therefore, the ward enacted a Chiyoda-ku Global Warming Countermeasure Ordinance in December 2007 in order to balance the economy and environment and to promote global warming countermeasures.

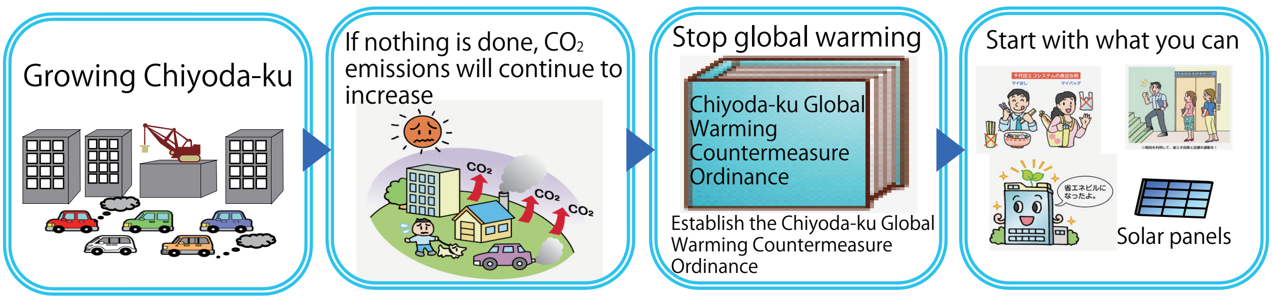
The ordinance was the first of its kind for a local government in Japan and includes a medium-term goal of reducing $CO_2$ emission 25% by 2020 compared to 1990 levels.




Chiyoda-ku $CO_2$ Emissions by Sector (2005)



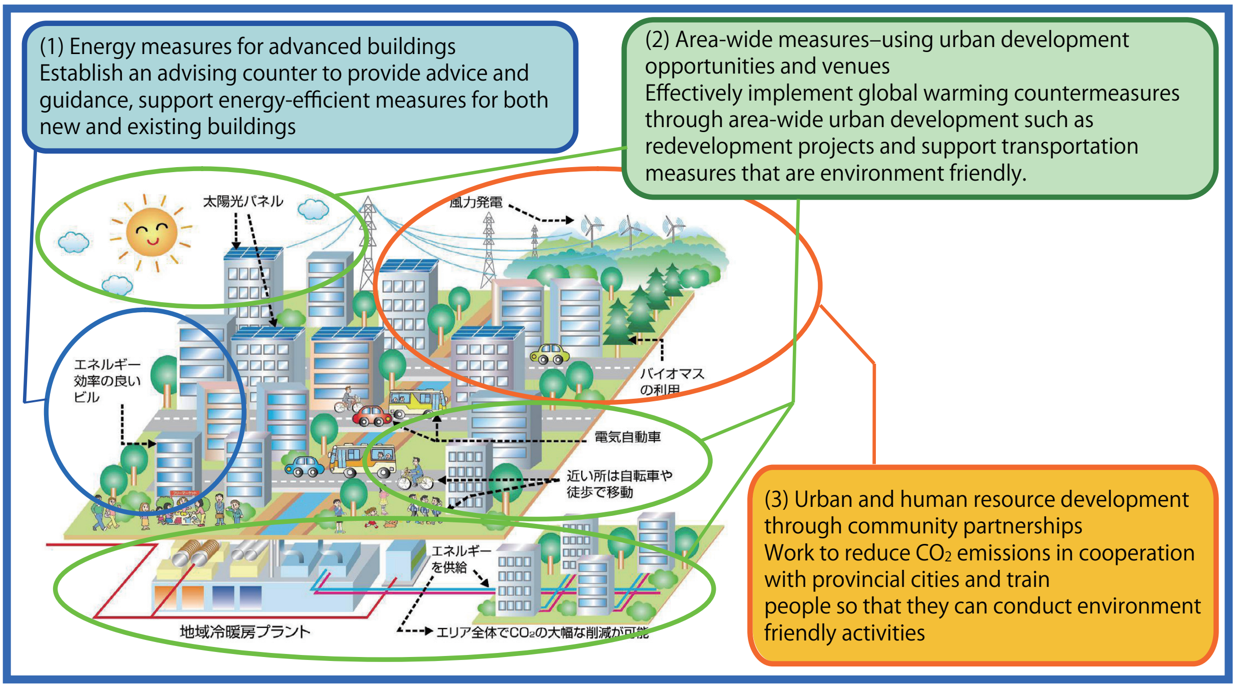

Chiyoda-ku $CO_2$ Emissions by Energy Source (2005)




## Three pillars for creating a low-carbon city

Three policies form the core of Chiyoda-ku's efforts to create a low-carbon city.

The first policy is "energy measures for advanced buildings," which refer to measures aimed at raising the energy efficiency of buildings. The second one is "area-wide measures–using urban development opportunities and venues", area-wide measures for the whole ward which make use of the unique characteristics of the local area, namely the high concentration of businesses. The third policy is "urban and human resource development through community partnerships", which includes measures to create a low-carbon city center




and reinvigorate the local area through partnerships with the community and measures to develop human resources who will undertake environment friendly activities through numerous efforts including the Chiyoda-ku Eco System (CES) and environmental education.

**(1) Energy measures for advanced buildings**

Measures targeting buildings (both new and existing buildings), a source of $CO_2$ emissions, will be promoted with the goal of achieving several objectives including introducing renewable energy and rationalizing energy use in and raising the energy efficiency.

In terms of new buildings, the central government's Act on the Rational Use of Energy and the Tokyo Metropolitan Ordinance on Environmental Preservation require stronger global warming countermeasures. Within Chiyoda-ku, there are plans to create a building environmental plan system (tentative name) for small- and medium-size buildings as one step toward implementing the required countermeasures. The system requires that when a new building is constructed, a plan covering various issues be submitted, and these issues include not only reducing the building's heat burden through improved insulation for exterior walls and windows and the use of greenery, but also cutting energy consumption through more efficient facilities, including heating, air conditioning, and ventilation (HVAC) equipment, lighting, and water heaters, and promoting the use of renewable energy such as electricity generated from solar panels. This system will lead to the construction of more energy-efficient buildings.

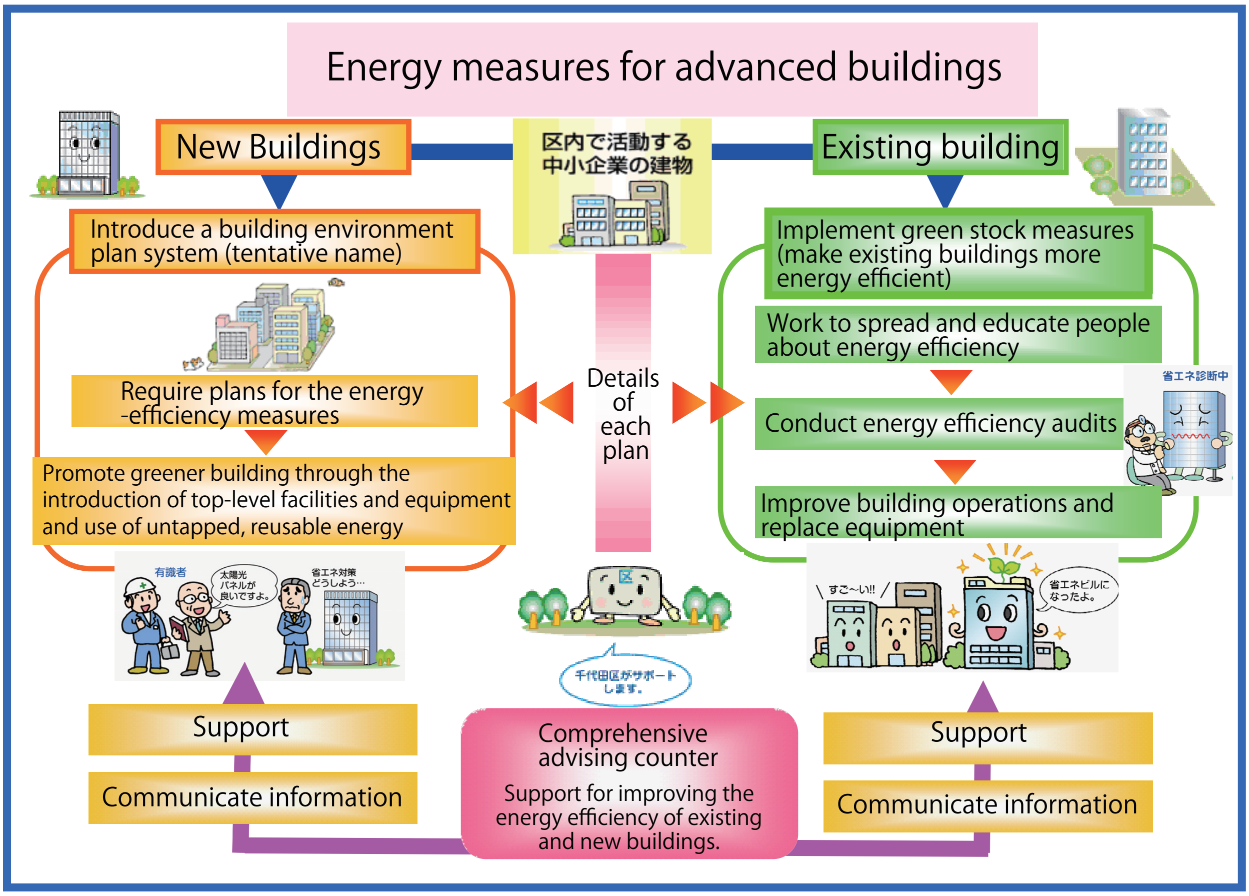
As for existing buildings, their energy efficiency will also be raised through "green stock strategies". "Green stock strategy" is a word coined from stock (existing buildings) and green (energy efficiency).

There are around 12,000 existing buildings in Chiyoda-ku, and increasing the energy efficiency of these building is the key to reducing $CO_2$ emissions for the overall ward. The green stock strategy takes two forms- one targeting individual buildings and one targeting the whole ward or particular area such as shopping districts or neighborhoods.

Currently, the Kanda-station Nishiguchi area, which is centered on a shopping district around 7 ha large bordered by two streets and includes around 260 buildings has been designated a model area. A promotion committee, centered on the shopping district association, was launched in July 2009, and energy audits are being conducted.

Improvements will be made to operations and facilities will be renovated based on the results of these audits, and there are plans to promote energy efficiency throughout the whole area by publicizing the results of these efforts.

In the future, the ward would like to reduce costs and improve efficiency through joint efforts for energy efficient renovations to buildings and joint purchasing of equipment such as HVAC equipment. In addition, the ward would like to raise awareness of greater energy efficiency and global warming countermeasures by implementing a series of green stock strategies, which will strengthen the local community.




**(2) Area-wide measures–using urban development opportunities and venues**

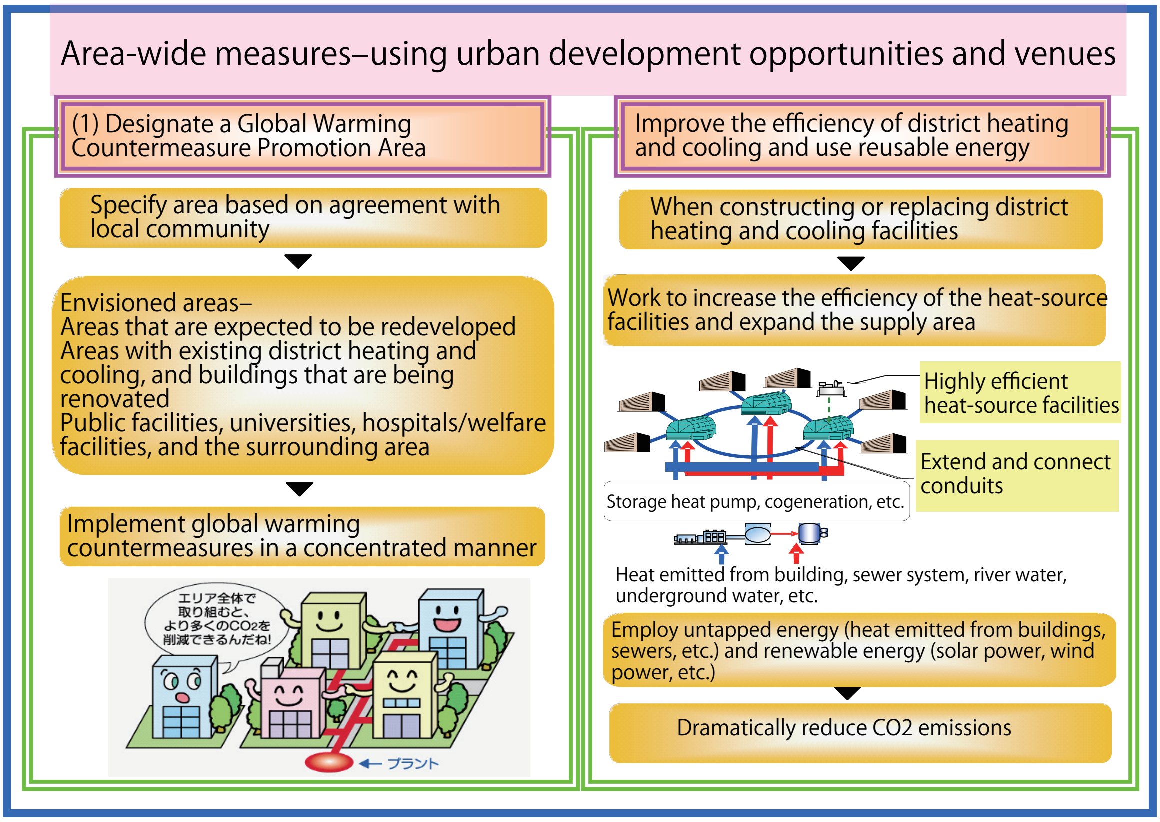
There is a large concentration of corporate headquarters and government ministries and agencies in Chiyoda-ku, and this dense concentration of administrative bodies has resulted in extremely high use of energy in a small area. Therefore, efforts are being made to raise the efficiency of energy use on various levels including particular areas and the whole ward, and area-wide global warming countermeasures will be implemented in an intensive manner.

Areas that are expected to be redeveloped, areas with existing district heating and cooling where buildings are being renovated, and similar areas are considered good locations for area-wide urban development. In consultation with businesses and local land owners, and after an agreement is reached, a community council is established, and the area is designated a Global Warming Countermeasure Promotion Area (envisioned action areas are Otemachi, Marunouchi, the Daimaru area in Yurakucho, and Kasumgaseki area). An action program that includes medium- and long-term reduction targets is created in cooperation with the local government, and the local government and businesses work together to implement the plan.

To promote area-wide use of energy, existing district heating and cooling equipment will be made more efficient, and untapped, renewable energy sources will be introduced. Chiyoda-ku has 11 district heating and cooling zones, and most of them are close to needing upgrades. Using this opportunity, efforts will be made to raise the efficiency of heat-source equipment, expand the supply area, and make the system more flexible through bypass conduits.

In addition, examinations will be made of using untapped energy sources such as exhaust heat from buildings and garbage incineration plants. A leading project related to energy efficient urban development was the project to connect the district heating and cooling conduits of the Marunouchi 1-chome district to those of the Marunouchi 2-chome, which was completed in March 2008 through cooperation between businesses, the central government, and the ward. This resulted in a 4% improvement in energy efficiency and reduction in $CO_2$ emissions.

As for area-wide heat island countermeasures, various projects are being planned. With the removal of the Tokyo Station Daimaru Department Store, a station square will be constructed, Gyoko-dori will be paved with water-retentive asphalt, in which water will be sprinkled on, and Ginkgo trees will be planted along the road. Other expected projects include constructing a wind corridor that connects the Imperial Palace to Tokyo Bay and introducing clean energy in Tokyo Station as a model project (massive solar panels will be installed on the roof of the Tokaido Shinkansen platform which will generate around 450kw of power)




### (3) Urban and human resource development through community partnerships

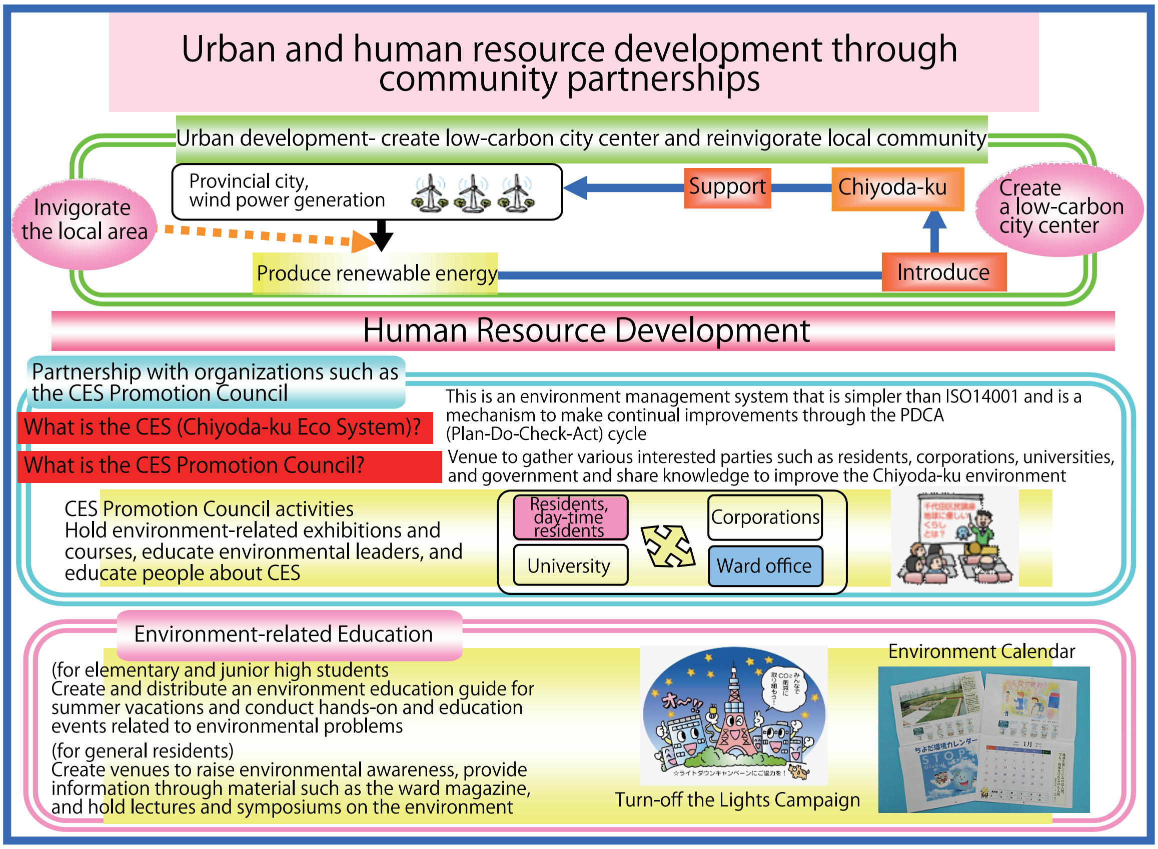
For urban development through community partnerships, efforts will be made to revitalize the local community and promote the creation of a low-carbon city through partnerships with other local governments, and these efforts will include acting as a broker of renewable energy projects, such as wind power electricity generation, for businesses located in the ward in order to realize a low-carbon local city. In December

2009, in cooperation with the Tokyo Metropolitan Government and Aomori Prefecture, Chiyoda-ku concluded an agreement for a community partnership project that will bring raw green electricity generated through various methods such as wind turbines to Chiyoda-ku from Aomori Prefecture.

As for human resource development, Chiyoda-ku established its own environment management system, the Chiyoda-ku Eco System (CES). The system makes it easy for parties such as residents, individual stores, and small- and medium-size companies to implement measures that fit their particular situation and is simpler and more economical than ISO14001. In order to promote these efforts, the CES Promotion Council, composed of residents, universities, corporations, and the ward, was founded in April 2008, and the council is working to train people to undertake various efforts such as spreading environment-friendly activities and environmental education.

Efforts are also being made to provide and disseminate information in order to promote activities to combat global warming among residents of the ward and businesses. In addition to running a series of articles related to new energy sources and energy efficiency in publications and holding events such as environment and recycling exhibitions sponsored by the ward, Chiyoda-ku is actively participating in and supporting environment related events sponsored by other organizations such as neighborhood councils.

The ward is publishing free research guides and holds hands-on classes for children. For general ward residents, various events are held including symposiums attended by environmental journalists and ward eco tours, in which participants visit parties such as wards, and corporations undertaking environment friendly activities.




## Promotional system

In order to promote global warming countermeasures, it is necessary that all parties, including the ward, residents of the ward, and businesses, fulfill their particular role. In October 2008, the ward established the Chiyoda-ku Global Warming Countermeasures Promotion Headquarters, headed by the deputy major, and the headquarters works to thoroughly educate people about basic ideas on and policies related to global warming countermeasures and to promote systematic efforts. In addition to creating a system that makes it easy for ward residents and businesses to take part in global warming countermeasures, the headquarters promotes related measures.

The Energy Efficiency Support Center (tentative name) is expected to be launched in 2010 as a comprehensive advising office and information hub regarding global warming countermeasures. In particular, the center will provide advice on making buildings more energy efficient and draw up environmental plans, conduct energy efficiency audits, provide information on subsidies for energy-efficient or new energy equipment, and accept applications and registrations.

A Global Warming Countermeasures Evaluation Committee (tentative name), composed of various parties including academics, business people, and resident representatives, will also be created in the future, and the committee will conduct various activities including ascertaining progress in implementing measures and various plans, examining and evaluating benefits, and providing advice on appropriate revisions and improvements, which will continually be reflected in measures.

## ● Conclusion

In January 2009, the central government designated Chiyoda-ku an eco model city (one of the 13 cities throughout Japan and the only ward of Tokyo), a local government that is fulfilling its role as a leader and model for realizing a low-carbon society. The ward has also been actively working on the previously mentioned global warming countermeasures.

The measures are extensive and many cannot be implemented without the understanding, action, and cooperation of residents and businesses. In order to pass on a healthy global environment to the next generation, the ward would like to marshal the wisdom and power of many people and steadily implement global warming countermeasures even if only gradually by balancing the environment with the economy.

**Reference material:**

Chiyoda Ward website: http://www.city.chiyoda.tokyo.jp/

Chiyoda-ku Global Warming Countermeasure Ordinance and Chiyoda-ku Eco Model City Plan: http://www.city.chiyoda.tokyo.jp/service/00105/d0010539.html

Eco Model Cities: http://www.kantei.go.jp/jp/singi/tiiki/080722kankyo-kouhyo.pdf

# HOW TO MITIGATE THE HEAT ISLAND PHENOMENON IN SMALL CITIES:

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## 1. Introduction

In Japan, the heat island phenomenon has become a serious urban problem. Moreover, in recent years, the heat island phenomenon has begun to affect not only large cities, but small cities as well. The outdoor thermal environment in the summer has become very disagreeable in such cities and should be improved. Improving the summer outdoor thermal environment would decrease the indoor air-conditioning load. Therefore, improvement of the summer outdoor thermal environment is important with respect to both energy savings and exhaust heat reduction.

The utilization of greenery is one method by which to improve the summer outdoor thermal environment. Compared to large cities, many small cities have more green and open spaces. Therefore, small cities are better able to use greenery as a countermeasure against the heat island phenomenon.

In this paper, the condition of urban heat island phenomenon in small cities will be described taking the case study of Tonami, Toyama, Japan and the countermeasures against heat island in a small city will be discussed. Tonami is a small city in Japan in which the urbanized area has been affected by the heat island phenomenon. Since Tonami is located on the Tonami plain, which is covered by paddy fields, the cooling effects of paddy fields could be used to mitigate the heat island phenomenon. However, the characteristics of the urban form and the cooling effects of paddy fields must be understood in order to apply cooling effects in environmental management. Therefore, the objectives of this study are (1) to examine the characteristics of the urban form and the state of heat island in the Tonami district using land cover maps and surface temperature maps and to determine appropriate observation points and (2) to clarify the degree of cooling effects by paddy fields in the Tonami urbanized area in summer.

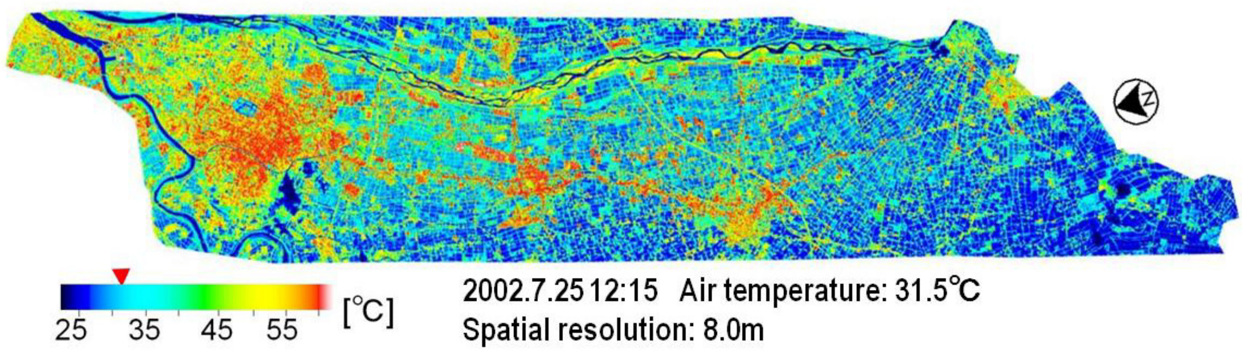


Figure 1 Surface temperature distribution of Tonami, Toyama, Japan in daytime of summer.

## 2. Characteristics of land cover distribution and outline of the thermal environment of Tonami

Observation by air-borne multi-spectral scanner (MSS) was performed in order to generate land cover maps and surface temperature maps of the Tonami district for April and July of 2002. The two observation altitudes were 6,000 m (high), which allowed observation of the entire Tonami plane, and 1,500 m (low), which allowed observation of detailed ground surface information.

In the present study, the state of heat island of the Tonami urbanized area is examined using surface temperature distribution maps. Before conducting the observations, the surface temperature distribution maps were generated using the low-altitude data collected for June, and the mean surface temperatures of each land cover in Fig. 2 were calculated (Table 1).

Among the mean surface temperatures, both the day and night temperatures were lowest in greenery areas. Compared to the air temperatures collected by the Tonami AMeDAS, the mean surface temperatures of the greenery areas were equivalent to the air temperatures during the day and during the night. The mean surface temperature of buildings was 26°C and bare areas were 16°C higher than the air temperature during the day. Whereas at night, the mean surface temperatures in these land cover types were slightly

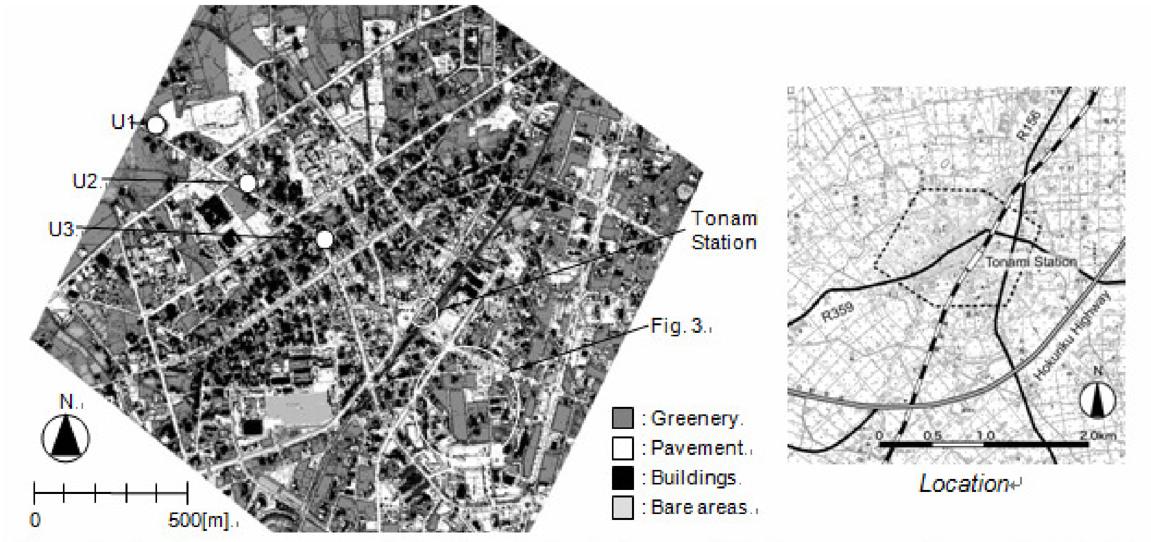


Figure 2 Land cover map around the Tonami urbanized area during the summer (Observation Point at Location U1, U2, U3 and Fig. 3

Table 1 Mean surface temperatures of each land cover in Fig. 2

| Land cover | Mean surf. temp. [℃ ] | |
|---|---|---|
| | day | night |
| Greenery | 37.4 | 26.0 |
| Pavement | 56.0 | 35.1 |
| Buildings | 58.8 | 27.4 |
| Bare areas | 48.3 | 29.0 |
| Air temperaure | 32.4 | 29.1 |

(Tonami AMeDAS)

less than the air temperature. The mean surface temperatures in pavement areas were higher than the air temperature both during the day and during the night. Both during the day and during the night, the pavement land cover type increased the air temperature.

## 3. Method for field surveys to clarify the cooling effects of paddy fields

### 3.1 Observation of the cooling effects of wind flow from the paddy fields area to the urbanized area

A field survey of the microclimate was conducted in order to determine the effects on air temperature of the wind flow from the paddy field area to the urbanized area of Tonami.

Measurements were taken around the culmination hour (day) and around sunset (night) on 3 and 10 August 2003. The weather was fine. The highest temperatures were 33°C on 3 August and 29°C on 10 August, as indicated by Tonami AMeDAS. In the present study, in order to observe the cooling effects of the paddy fields surrounding the urbanized area, observation points were positioned along the road running through from outer paddy fields area to the central urbanized area as follows: observation point U1 was positioned at the border between the urbanized area and the paddy fields area, observation point U2 was positioned 350 m nearer the central urbanized area than U1, and observation point U3 was positioned 600 m nearer the central urbanized area than U1 (Fig. 2). Low-rise wooden buildings were present on the both sides of the road, and the width of the road was 12 m. Observation of the microclimate was also conducted at a point approximately 2 km northwest of Tonami Station in order to clarify the features of the microclimate of the paddy field area surrounding the Tonami urbanized area.

At the observation points, a 0.1-mm-diameter T-type T/C and the macromolecule humidity sensor of an Assman ventilated psychrometer were positioned at an elevation of 120 cm above the ground in order to measure air temperature and humidity. A hot-wire anemometer was positioned at an elevation of 180 cm above the ground in order to measure wind speed, and an propeller vane anemometer was positioned at an elevation of 150 cm above the ground in order to measure wind direction. In addition, a photo-diode pyranometer was positioned on the ground in order to measure the solar radiation. The observations were conducted by the fixed-point observation method at two-second intervals.

### 3.2 Observation of the cooling effects of paddy fields interspersed among other types of land cover around the periphery of the urbanized area

Using the land cover map discussed in Section 2, a cluster of paddy fields interspersed with other types of land cover was extracted and was designated as the observation site. In addition, in order to clarify the effects of the paddy fields, observation points were positioned on both the windward and leeward sides of these paddy fields. This cluster of paddy fields was surrounded by middle-rise and low-rise buildings, and the land cover type at the observation points was pavement (Fig. 2 and Fig. 3).

Before observation of the cooling effects, the wind system around this site was confirmed. Both wind direction and wind speed were measured at the rooftop of a three-story building near the observation site. These winds were equated with gradient winds. The inflow points (windward side) and outflow points (leeward side) of the gradient winds at the site were determined for each wind direction. As a result, when the wind direction was from the northwest (NW), P1, P5, P6 and P8 in Fig. 3 were located on the windward side and P2 and P3 were located on the leeward side, and when the wind direction was from the northeast (NE), P2, P3, P4, P5 and P7 were located on the windward side and P1 was located on the leeward side. There were multiple windward-side points at the site. Thus, the air temperature at the one leeward-side point was compared to the temperatures at multiple windward-side points.

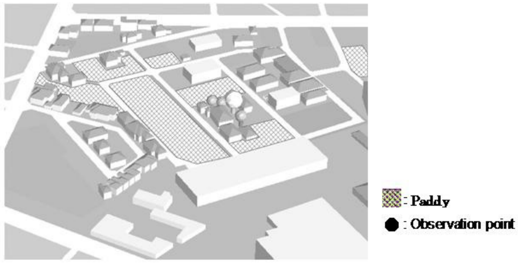


Figure 3 Observation site.

Measurements were taken around the culmination hour (day) and around sunset (night) on 4 and 7 August 2003. The weather was fine. The highest temperatures were 32ºC on 4 August and 33ºC on 7 August, as indicated by Tonami AMeDAS. Eight observation points were positioned around the paddy fields. The measuring instruments described in Section 3.3 were positioned at the observation points. The observations were conducted by the fixed-point observation method at two-second intervals.

## 4. Results

### 4.1 Cooling effects of the wind flow from the paddy fields area to the urbanized area

The weather on 3 August was clear, and the wind direction in the paddy fields area was stable W or NW until 19.00. The weather on 10 August was fine, and the solar radiation showed sharp fluctuation. The wind direction in the paddy fields area was not stable during the day and was mainly NW or NE, and the wind direction was stable during the night and was N or NE.

In order to analyze the relationship between air temperature and wind, the mean values for 10-minute intervals were calculated. The mean solar radiation indicates the trend of solar radiation during each interval. In addition, in order to clarify the relationship between temperature and wind speed, the mean air temperature was calculated for each 10-minute interval and wind speed range (below 1 m/s, over 1 m/s and below 2 m/s, and over 2 m/s). In addition, the data for the wind directions of NW and NE were considered in the analysis because the primary wind direction is NW or NE in this region during summer.

First, the wind direction data collected at the observation points in the urbanized area were sorted according to wind direction in the paddy fields area. As a result, when the wind direction was NW in the paddy fields area, the wind direction at all observation points in the urbanized area were along the road from the paddy fields area. When wind direction was NE in the paddy field area, the wind directions at U1 and U2 were not stable, and that of U3 was stable NW.

For the mean air temperatures during the observation, the air temperatures in the urbanized area were approximately 1.2ºC to 2.7ºC higher than in the paddy fields area. On 3 August, when the wind direction was stable along the road, the air temperatures increased towards the center of the city. On 10 August, however, the air temperature at U2 was 0.3ºC higher than at U3 during both the day and the night, and the air temperatures at U2 and U3 were identical.

The mean air temperature differences for 10-minute intervals between the paddy fields area and the urbanized area for three wind speed ranges when the wind direction was NW and NE on 10 August are shown in Fig. 4. When the wind direction was NW in paddy fields area, the air temperatures increased toward the center of the city, for all but one period of data. This trend was applied to 3 August, for all but one period of data. When the wind direction was NE in the paddy field area, the air temperature at U2 was the highest until 17.30, and increased toward the center of the city after 17.30. Factors other than air inflow were thought to affect the air temperature because the wind speed was low after 17.30. In addition, the radiation condition was thought to have appeared because there were no waste heat sources near the observation points. Therefore, there was a large sensible heat flux toward the center of the city. The increased wind speed was thought to have brought the air from near the ground level and higher levels. In this survey, the relationship between the air temperatures at U2 and U3 reversed according to the wind direction in paddy fields area, indicating that the inflow of lower-temperature air in the paddy fields area affected the air temperature at the observation points in the urbanized area when the wind direction was NW.

The differences in mean air temperatures between 10-minute intervals for the wind speed range of below 1 m/s, and other wind speed ranges, at three observation points in the urbanized area on 3 August when the wind direction in the paddy fields area was NW, are shown in Fig. 5. During the day, when the wind speed increased, the air temperature decreased, and the maximum decrease was 1.0ºC at U2, comparing wind speeds range of below 1 m/s and over 2 m/s. The air temperature reduction during the night tended to be smaller than that during the day. Summarizing the above results, the decrease in air temperature in the urbanized area was shown to have occurred due to the inflow of air from the paddy fields area along the road.

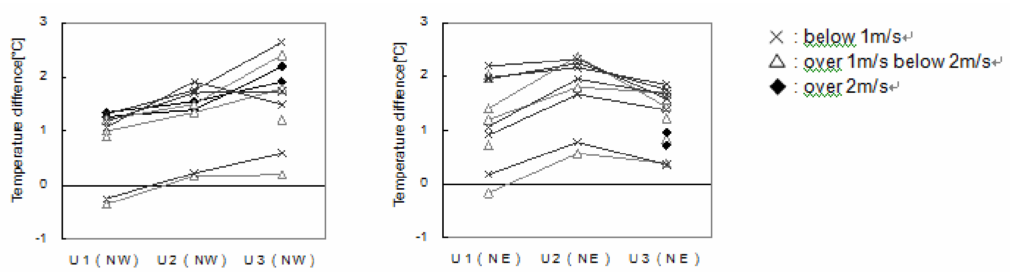


Figure 4 Mean air temperature differences for 10-minute intervals between the paddy fields area and the urbanized area for three wind speed ranges on 10 August.

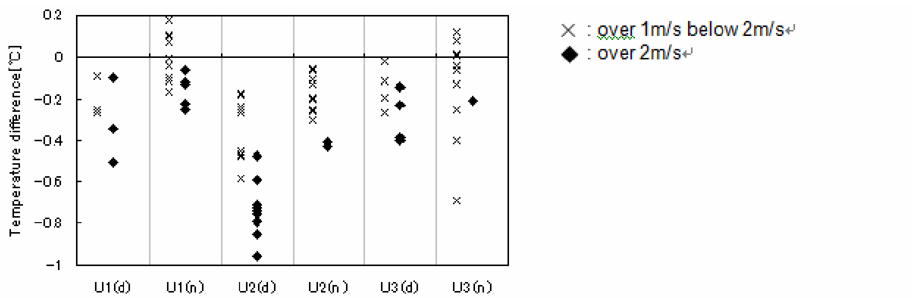


Figure 5 Differences mean air temperatures between 10-minute intervals for the wind speed range of below 1 m/s, and other wind speed ranges, at three observation points in the urebanized area when the wind direction was NW (3 August)

### 4.2Cooling effects of the paddy fields interspersed with other types of land cover in the urbanized area

The solar radiation fluctuated sharply during the observation period. Therefore, in order to analyze the relationship between the air temperature and wind speed, the mean values for 10-minute intervals were calculated. The mean solar radiation indicates the solar radiation trend at each term. In order to clarify the relationship between temperature and wind speed, the mean air temperature was calculated for each

10-minute interval and each wind speed range (below 1 m/s, over 1 m/s and below 2 m/s, and over 2 m/s). The direction of the gradient wind was NW on 4 August and NE on 7 August. Thus, P2 and P3 were located on the leeward side on 4 August, and P1 was located on the leeward side on 7 August.

The differences in mean air temperature during the observation period between the windward and leeward sides when P1, P2 or P3 was located on the leeward side are shown in Fig. 6. All three observation points showed low mean air temperatures, and the differences were approximately 1.5ºC during the day.

The distribution of mean air temperature values for 10-minute intervals of P1 and P2 when the wind direction was NW or NE are shown in Fig. 7. On 4 August, the air temperature at P2, on the leeward side, was lower than that at P1. However, on 7 August, the air temperature at P1, on the leeward side, was lower than that at P2. In this survey, the relationship between the air temperatures at P1 and P2 reversed according to the wind direction. Therefore, the inflow of the air from the paddy fields affected the air temperature on the leeward side. The mean air temperatures for 10-minute intervals for three the wind speed at P2 when P2 was located on the leeward side during the day are shown in Fig. 8. When the wind speed increased, the air temperature decreased, and the maximum decrease was 0.6ºC, comparing the mean wind speeds range of below 1 m/s (mean value is 0.7 m/s) and over 2 m/s (mean value is 3.2 m/s). When the solar radiation was low, the differences in air temperature were reduced. In addition, the maximum decrease was 0.6ºC at P1 and 0.3ºC at P3 during the day. The air temperature reduction during the night tended to be smaller than that during the day.

Summarizing the above results, around the paddy fields that are interspersed among other types of land cover in the urbanized area, the air temperature on the leeward side was lower than on the windward sides and when the wind speed increased, the air temperature decreased on the leeward side.

## 5. Conclusions

In the present study, in order to mitigate the heat island phenomenon in the Tonami urbanized area, the characteristics of urban form and the state of the heat island of Tonami district were examined and field surveys were conducted so as to clarify the degree of the cooling effect of paddy fields in Tonami urbanized

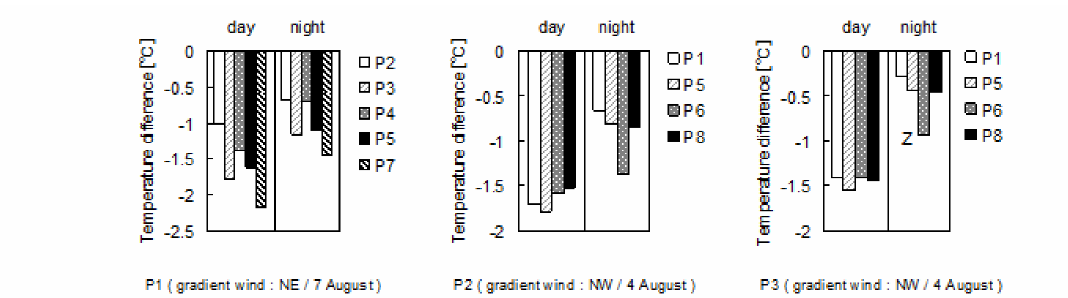


Figure 6 Differences in mean air temperature during the observation period between the windward and leeward sides when P1, P2, or P3 was located on the leeward side.

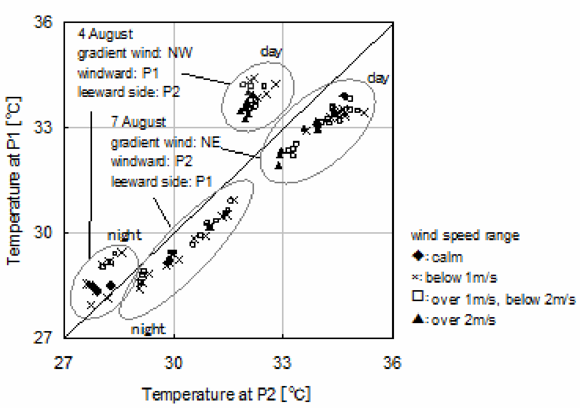


Figure 7 Distribution of mean air temperature values for 10-minute intervals of P1 and P2 when the wind direction was NW or NE.

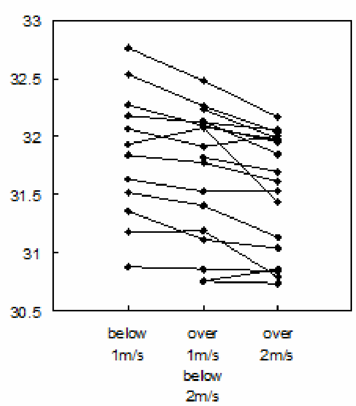


Figure 8 Mean aire temperatures for 10-minute intervals for three wind speed ranges at P2 when P2 was located on the leeward side during the day.

area during summer. The findings of the present study are as follows:
1) The forms of the paddy fields were classified as either extensive paddy fields surrounding the urbanized area or small paddy fields interspersed among other types of land cover in the urbanized area.
2) During the day, as the wind speed increased, the air temperature was decreased by the air from the outer paddy fields, and the maximum value was 1.0ºC at 350 m inside the edge of the urbanized area on the road running through from the outer paddy fields area to the central urbanized area.
3) Around the paddy fields interspersed with other types of land cover around the periphery of the urbanized area, the mean air temperatures on the leeward side were lower than on the windward side, and the differences between the windward and leeward sides were approximately 1.5ºC during the day. When the wind speed increased, the air temperature decreased by a maximum of 0.6ºC, comparing the mean wind speeds of approximately 1 m/s and 3 m/s, as measured on the leeward side of the paddy fields.

These results have implications for urban planning and design. This study investigated only small and moderately large paddy fields, and studies should be undertaken to determine the optimum size of green open spaces (i.e. the point of diminishing returns). The results of this study support the commonly-held opinion that there should be many green open spaces distributed throughout urban areas, and streets should open onto these spaces as much as possible. Streets should also be oriented with prevailing winds that occur during the hottest weather in summer.

Besides, it is well stated that the mixture of urban and rural landscapes is a key feature of Asian cities. Many of small cities in Japan are surrounded by agricultural land, mainly paddy fields, and there are many of paddy fields even in city area. The mixture of urban land use and paddy fields can be observed everywhere in small and local cities in Japan. The results of this study indicate such mixture would alleviate heat island problems.

The 21st century is projected to be the century of the environment. The future of human beings is dependent on the actions we will take on behalf of the environment at the beginning of the next century. Responding to such concern on the environment, “controlled mixture of urban and rural landscapes” should be considered as a workable concept for the future. Vegetated open spaces in urban fringe areas, including agricultural lands, are known to have many ecological functions. They may provide habitats for wildlife, become recreational spaces such as allotment gardens and aesthetically pleasuring gardens, and maintain comfortable living environment, as indicated by the results of this study.

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# ANALYSIS OF THE COOLING EFFECT OF URBAN GREENERY IN SUBSTANTIAL URBAN AREA USING 3-D CAD

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Tokyo Institute of Technology

## 1. Introduction

Changes in land cover conditions and the increasing amount of anthropogenic heat released into the outdoor spaces aggravates the outdoor thermal environment in urban areas and increases energy consumption. And, in turn, the increased energy consumption further aggravates the outdoor thermal environment. Therefore, a countermeasure against the heat environment problems must be implemented to break this vicious cycle. In the past, the cooling effect of greenery was the focus of numerous studies. However, it is not clear whether urban greenery is effective in a variety of urban spaces.

Recently, studies have examined the cooling effect of greenery in urban areas broadly using remote sensing and GIS-based modeling. However, these studies were difficult to evaluate in three-dimensions. In addition, a few studies have tried to model the outdoor thermal environment of substantial urban areas using three-dimensional numerical simulations. Unfortunately, the vast quantity and variety of urban greenery could not be evaluated accurately in these simulations.

This study uses a different approach to evaluate the cooling effect of urban greenery on the outdoor thermal environment. The urban element information for a substantial urban area is collected precisely and broadly, and is used to generate a three-dimensional CAD model, to which material data and physical properties were added. Then, a numerical simulation is conducted to determine the cooling effect of urban greenery. This approach is verified through a case study on the center of Tokyo, which contains various urban structures and greenery.

## 2. Method for generating a 3D-CAD model for the evaluation of outdoor thermal environment

First, the building and ground composition materials were considered and a region was selected for evaluation. Then, building form and material data were collected for the substantial urban area. These data were then used to develop a three-dimensional CAD model, to which material data and physical properties were added.

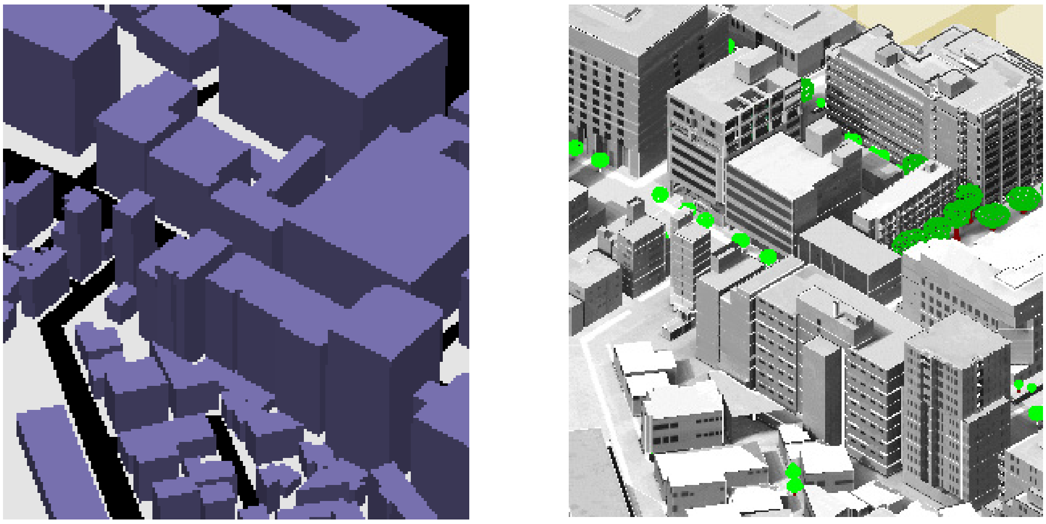

Figure 1 GIS based model and generating model

## 3. Calculation of the surface temperature distribution using numerical simulation

By evaluating each urban block in which the land cover and the land use are similar, the impact to the urban thermal environment can be evaluated. Therefore, the three-dimensional CAD model was next divided into urban blocks. The surface temperature distribution for each block was calculated using a numerical simulation system.

A cluster analysis was first performed on the building site, floor number, and the building-to-land ratio as a variable. The urban blocks were assigned according to the cluster analysis, land use, and building structures. Then, the urban blocks and the border buildings were determined.

This study used the numerical simulation system which was developed by authors to evaluate the effects of spatial forms and materials on the outdoor thermal environment.[1)] The composition and flow of the simulation program are described below:

(1) Building structures and tree shapes are drawn using the all-purpose 3D-CAD software
(2) Material data are selected from the database
(3) The 3D-CAD model generated by this process is then transformed into a “mesh model,” which is used to calculate radiative heat transfer and the surface heat balance
(4) The heat balance and one-dimensional heat conduction are determined for each mesh. Solar and atmospheric radiation are calculated from the sky factor of each mesh. The convective heat transfer calculation assumes that there are no air temperature or wind velocity distributions in the outdoor space. The weather data used for this calculation uses the vertical quantity of total solar radiation, air temperature, relative humidity, wind velocity, and cloud coverage. This study assumed a clear sky day in summer, Tokyo.

Three indices were used to evaluate the outdoor thermal environment:[1)]

(1) Surface temperature distribution determined by the 3D-CAD model

The CAD model allows for the observation of the surface temperature distribution from almost any viewpoint and at various times to fully evaluate the effects of specific spatial forms and materials.

(2) MRT distribution at a height of 1.5 m

The MRT (Mean Radiant Temperature) is the weighted average of the radiant interactions in a given space. A 1.5 m-high MRT distribution was used as an index to evaluate the thermal comfort of outdoor living.

(3) HIP (Heat Island Potential)

HIP(Heat Island Potential) which was proposed by the authors is the expressed by Equation (a). The HIP is an index of the sensible heat flow rate on all surfaces in an urban block. In this equation, HIP is the heat island potential (° C), Ts is the temperature of the microscope surface (° C), Ta is the air temperature (° C), and dS is the area of the microscope surface expressed in urban blocks ($m^2$).

$$HIP\,[^{\circ}C]=\frac{\int_{all\ surfaces}(T_s-T_a)\,dS}{A} \qquad \text{(a)}$$

## 4. Numerical simulation results

An example of the surface temperature distribution for the entire evaluation area, as shown in Fig. 2. At 10:00, the surface temperature of a wooden house's roof increased to approximately 20 degrees higher than the air temperature. This can be explained by the roof material’s small heat capacity. Other materials of low solar reflectivity were also approximately 20 degrees higher than the air temperature. On the other hand, the surface temperatures of commercial/business building roofs were nearly 10 degrees higher than the air temperature due to their large heat capacity. The surface temperature of the park block was less than 10 degrees higher than the air temperature.

At 12:00, the surface temperatures of the ground and roofs were 20 to 30 degrees higher than the air temperature for the entire area. However, the park block covered with turf grass and trees was only 10 degrees higher than the air temperature. The wall temperatures of high-density buildings were approximately equivalent to the air temperature because of lower quantity of direct solar radiation.

At 15:00, the surface temperature on the west side of the buildings rose due to the location of the sun. However, the surface temperature of buildings with numerous windows did not increase because of the indoor air conditioning. The surface temperatures of buildings that had tall buildings on their west side decreased to the air temperature due to the effect of the shadow.

At 20:00, the surface temperatures of commercial/businesses and warehouse blocks were 10 degrees

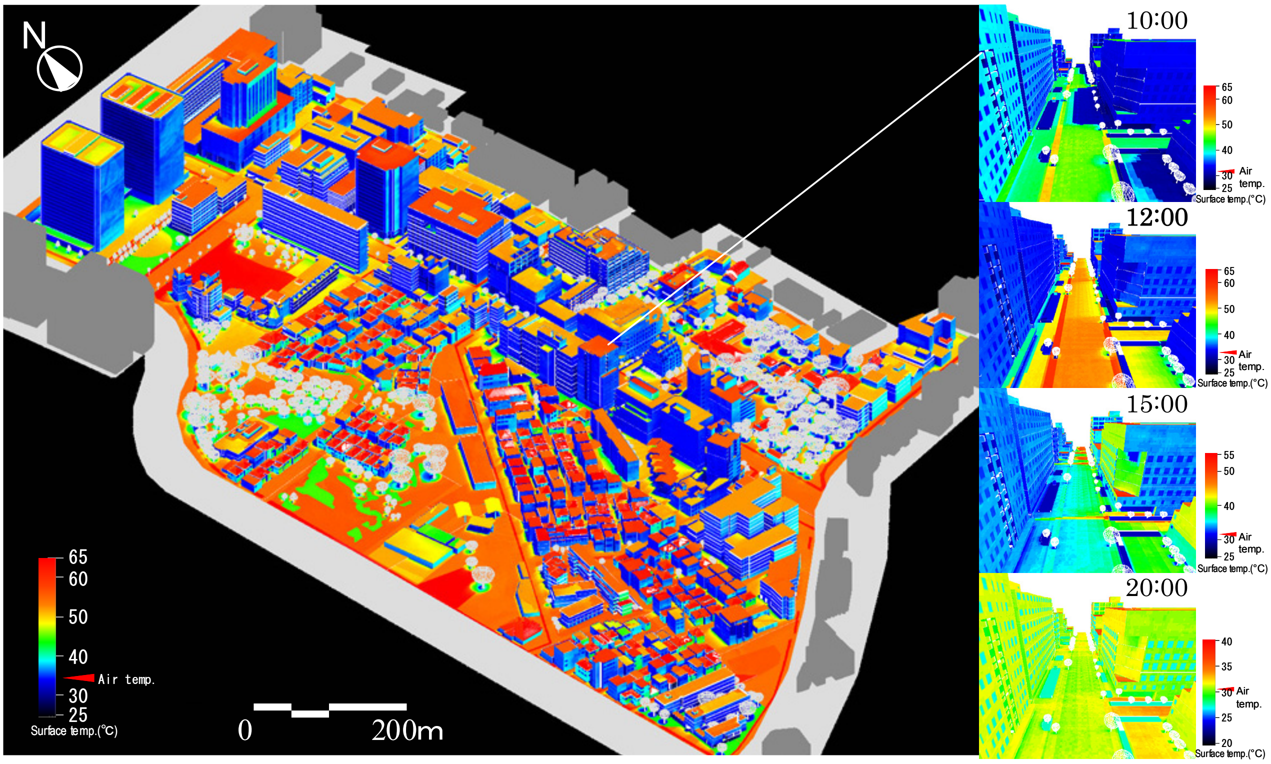


Figure 2 Surface temperature distribution for the entire area (12:00)

higher than the air temperature. The main reason for this characteristic is the large heat capacity of the component materials. On the other hand, the surface temperature of the park block decreased approximately air temperature due to radiational cooling. The effect of the setting sun on the surface temperature distribution was evident across the entire evaluation area.

Fig. 3 shows the relationship between the HIP and the vegetation cover ratio at specific times of the day. Before dawn, the wooden housing block and the park block were approximately 0° C or less. At this point, a clear correlation between the HIP and vegetation cover ratio was not clear.

At 12:00, the correlation between the HIP and the vegetation cover ratio were evident. The differences in the HIP values decrease as the vegetation cover ratio increases. At 15:00, the HIP values of the wooden housing block became lower than for the RC building block. And correlation between the HIP and vegetation cover ratio was also evident in this time frame. At 20:00, the HIP distribution was similar to that at 15:00, with values between 5 and 10 lower than 15:00 in most blocks.

## 5. Conclusions

The simulation performed in this paper provided a number of insights into the urban effect of greenery on the outdoor thermal environment. First, urban elements were collected using both existing data and field investigations. And an accurate three-dimensional CAD model was developed to analyze the outdoor thermal environment in a substantial urban area. Material and physical property data were also included in the model.

The outdoor thermal environment and cooling effect of urban greenery were studied using a numerical simulation system. The simulation revealed that a correlation exists between the HIP and vegetation cover ratio during the daytime. Building structures and materials strongly affected their surface temperatures. The setting sun also played a role on building surface temperature distributions in the evening hours.

Urban blocks with 10% or less vegetation cover ratios have little open space. The cooling effect of vegetation affected part of the block. Therefore, planting trees with large crowns, as well as rooftop vegetation, is effective. On the other hand, urban blocks having 20% vegetation cover ratios include various species of vegetation and rich open spaces. Surface temperatures in these blocks were dependent upon the species of vegetation. However, many of these blocks include high buildings that cause high HIP values into the

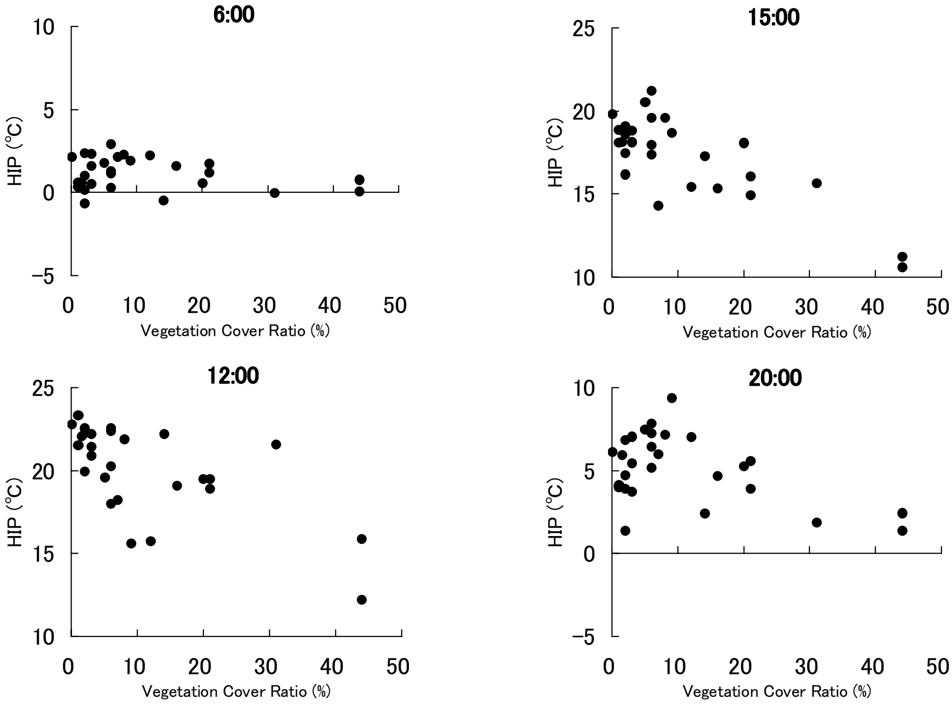

Figure 3 Relationship between the HIP and the vegetation cover ratio

night. Therefore, it would be advantageous to combine various species of vegetation and to limit the height of buildings. Urban blocks with 30% or higher vegetation cover ratios were all park blocks. HIP values for these blocks were low compared with other urban blocks during the day. However, the surface temperature of arid soil increases during the daytime, so it would be effective plant turf grass or trees.

## References

1) A. Hoyano, T. Asawa, K. Nakaohkubo 2004.12, Environmental design tool by combining outdoor thermal environment simulation with 3D-CAD, AIJ journal of technology and design NO.20, pp. 195-198.