APEC
Low Carbon Model Town (LCMT) Project
Tianjin Yujiapu Feasibility Study

Final Report

October, 2011

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Contents

1. Background

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Key points

- The APEC economies accounts for more than 40 percent of the world's population and 60 percent of the world's energy consumption. With rapid urbanization expected to continue into the future, measures to reduce carbon dioxide emissions are urgently needed.
- The APEC Low Carbon Model Town (LCMT) projects promote reduced carbon dioxide emissions in cities in every economy in the APEC region.

1.1 What is the APEC LCMT Project?

The APEC economies accounts for about 40 percent of the world's population. The population is increasingly concentrated in cities. Its energy consumption accounts for more than 60 percent of world consumption. Energy consumption in Asia in particular has been on an upward trend in concert with rising economic power and rapid urbanization. Greenhouse gas emissions have also been increasing, and countermeasures are urgently required.

On the other hand, even in developed economies in the APEC region, there are some cities where basic infrastructure such as water and sewer services and electric power are inadequate. Urban structures include every type from major cities to rural villages.

In order to promote a shift to low carbon cities based on various issues specific to every economy, it is important to construct low carbon concepts for urban areas and set low carbon strategies accordingly. In APEC economies where urbanization is advanced, guidelines in accordance with a national low carbon strategy are being set, and the study of shifting to low carbon strategies on a city-by-city basis is progressing.

In Japan, for example, "Low-Carbon Urban Development Guidelines" were set in 2010. They give directions on urban development based on low carbon development concepts and indicate methods for calculating reductions in CO_2 emissions (CO_2 mitigation).

In emerging and developing economies in the APEC region, there are every economies where upgrading of social infrastructure has not kept pace with rapid development during the recent years. They do not necessarily possess the methods and technologies needed to move towards low carbon development. Moreover, social and economic conditions differ greatly from those in industrialized economies where the study of low carbon development in cities is advanced. Therefore it is difficult to apply the strategies developed in industrialized economies to developing economies as-is (without modifications).

The purpose of the APEC LCMT project is to promote low carbon development in cities within the APEC economies through that the each national and regional government propose optimal low carbon development policies. In addition, the project will comprehensively examine low carbon development plans and methods while bearing in mind the local conditions and economies of every economy in the APEC region. This report can be used for LCMT Guidelines.

On the other hand, since urbanization might be a factor of lowering the quality of life by worsening of high density population, sanitary condition, traffic congestion and air and water pollution, addressing reduction of CO2 in cities contributes to solve these other environmental problems at the same time. It is highly expected to create a new value for the city by this APEC LCMT guideline.

1.2 Yujiapu Financial District with Regards to the APEC Low Carbon Model Town (LCMT) Project

The Yujiapu Financial District in Tianjin has been selected as Phase 1 of the APEC Low Carbon Model Town (LCMT) feasibility study project. It is being developed as a central business district (CBD) (development area of about 3,650,000 m^2, planned [daytime] population of about 500,000) and targeted for completion in 2020. Because the need for similar large-scale urban development is rising in many APEC economies, low-carbon development policies that can be applied to this type of urban development are needed.

2. Trends of CO_2 Emissions in APEC Economies

2. Trends of CO_2 Emissions in APEC Economies

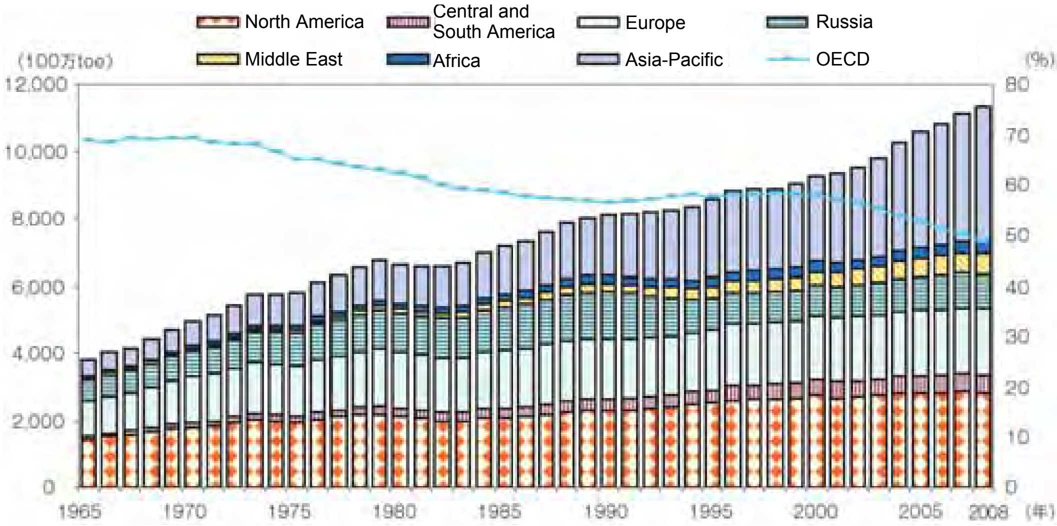
Key points

- Urbanization is advancing within APEC economies. Energy consumption is correspondingly increasing.
- Along with future economic growth mainly in emerging Asian nations, energy consumption will increase markedly.
- Factors causing CO_2 emissions to increase include population growth, lifestyle changes, increased automobile ownership, etc.
- Environmental policies are actively being pursued in China.
- Initiatives to shift to low carbon development are beginning in other cities as well.

2.1 World Energy Trends

World energy consumption (primary energy) is rising along with world economic growth. Energy consumption has risen by an annual average of about 2.6 percent from 3.8 billion tonnes of oil equivalent (toe) in 1965 to 11.3 billion toe in 2008 (see Figure 2.1.1).

As for the pace of growth, it has been slow in the Organization for Economic Co-operation and Development (OECD) nations and fast in non-OECD nations, especially in Asia-Oceania as a whole. This is not only because the developed nations typical of the OECD have experienced slower economic and population growth than developing nations, but also because their economic structures have changed and energy conservation through greater efficiency has progressed. In developing nations, on the other hand, energy consumption is increasing. The Asia-Oceania region in particular, with its remarkable economic growth, has been a major factor in increased world energy consumption. Because of this, OECD nations' share of world energy consumption has fallen by about 20 percentage points from 69 percent in 1965 to 48.8 percent in 2008 (see Figure 2.1.1).

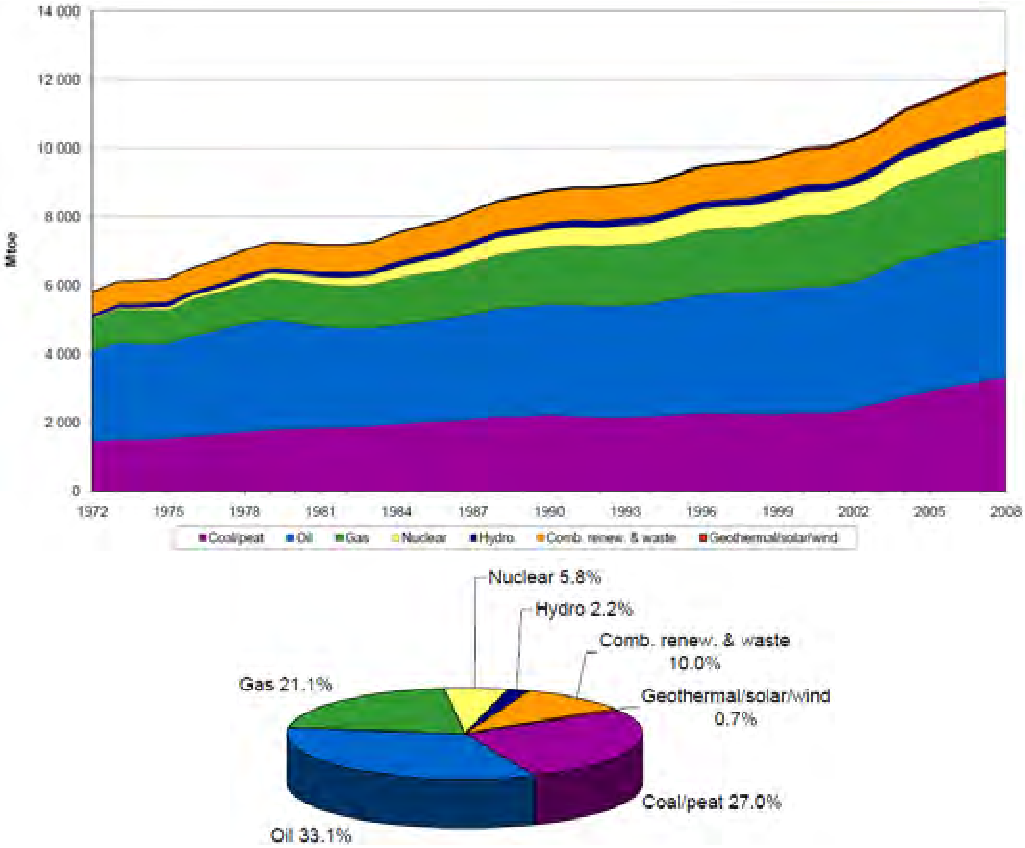


Source: BP, Statistical Review of World Energy 2009

Figure 2.1.1 Changes in World Energy Consumption (By region, primary energy)

Figure 2.1.2 shows changes in prima ry energy consumption by energy source. Oil is the major source of energ y consumption through to 2008. From 1972 to 20 08, it grew by an annual average of 1.4 p ercent. As o f 2008, it accounted for 33.1 percent of total energ y consumption. During thi s period, nuclear power and n atural gas grew remarkably as alternatives to oil. As of 2008, they respectively accounted for 5.8 percent and 21.1 percent of world energy consumption.

Coal's share of total energy showed little change. It was about 25.8 percent in 1972 and 27 percent in 2008. While green ene rgy such as geothermal, solar, wind powe r grew sharply compared with the past, its overall share remained low.

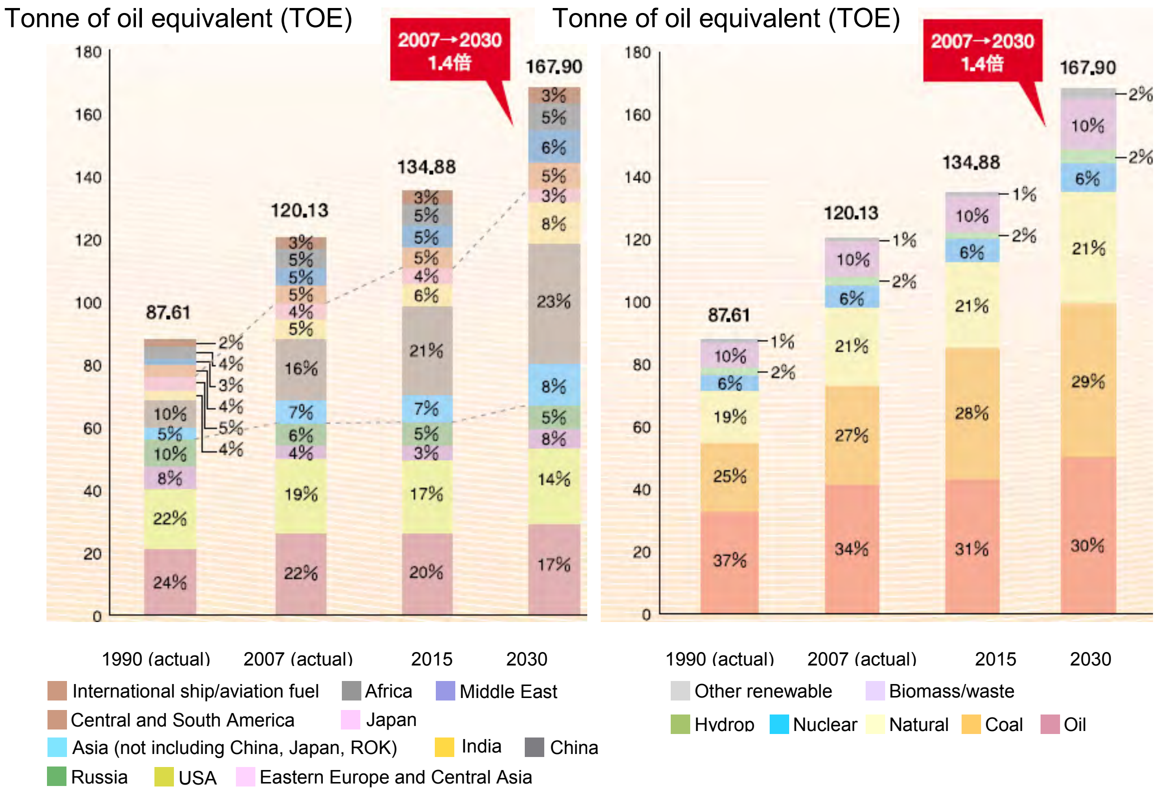


Source: IEA Statistics for 2008

Figure 2.1.2 Changes in World Primary Energy Consumption and Composition in 2008 (by type)

Turning next to future trends in energy consumption, world energy consumption in 2030 is projected to reach 1.4 times today's level. Asia will account for about half of that increased amount. In emerging nations such as China, demand for fossil fuels such as oil, coal, and natural gas is expected to further increase along with economic growth. Coal's share is forecasted to increase slightly, from 27 percent in 2007 to 29 percent in 2030. Oil's share is projected to fall by 4 percentage points; from 34 percent in 2007 to 30 percent in 2030 (see Figure 2.1.3).

At current consumption rates, world energy available supplies (reserve production ratio) are projected at 122 years for coal, but for 42 years for oil, 60 years for natural gas, and 100 years for uranium. Shifting from limited resources to renewable/untapped energy is therefore an issue.



Source: "2010 Annual Report on Energy," METI,

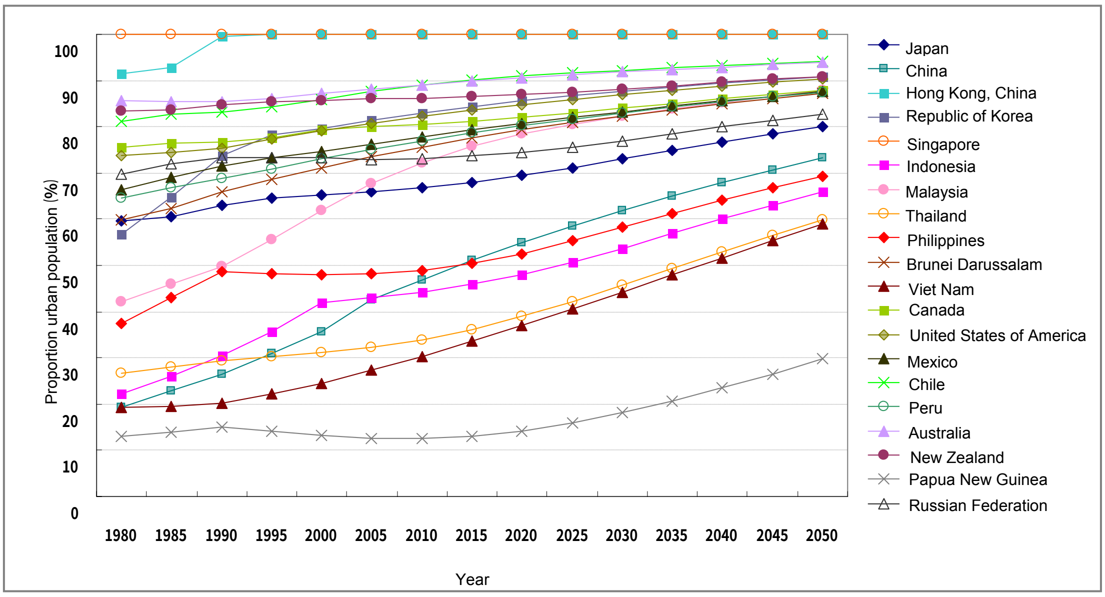
Figure 2.1.3 Projected World Demand of Energy by Region and Source

2.2 Low Carbon Development Trends in APEC economies

1) Urbanization and its Impact within APEC economies

Urbanization is advancing within APEC economies. It is progre ssing in Asia in particular. As shown in Figure 2.2.1 urbanization is proceeding rapidly in economies such as Indonesia and China.

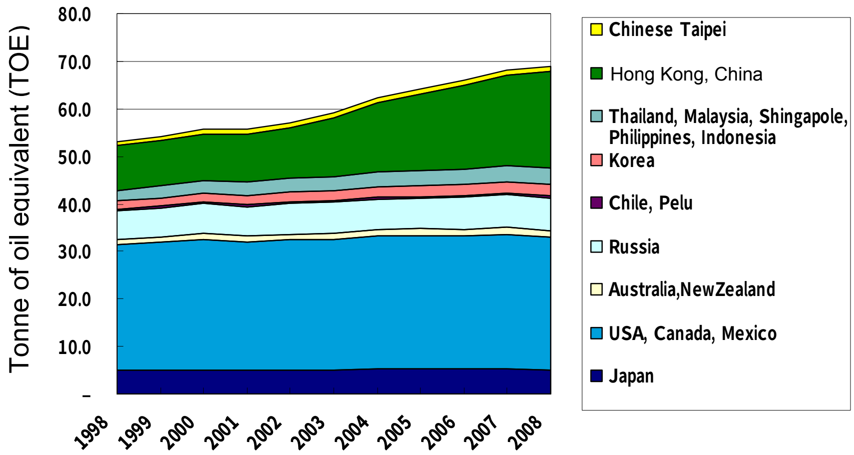
Energy consumption is expanding. Primary energy consumption in the APEC economies since 1998 has increased at an av erage annual rate of 2.7 percent. Consumption reached about 6.9 billion toe in 2008, 61.1 percent of world primary energy consumption. This is an increase from the 198 5 figure of 57.2 pe rcent (see Fi gure 2.2.2). China's energy consumption in particular has roughly doubled. Energ y consumption mainly in emerging Asian nations is expected to increase sharply in concert with high economic growth.



Source: World Urbanization Tendency 2007

Urbanization rate = (no. of people living in cities)/(total population)
No. of people living in cities: number of people living in cities as defined by each country's census
Source: UN, "World Urbanization Prospects, The 2003 Revision"

Figure 2.2.1 Changes in the Urbanization Rates of APEC Economies



Created from BP Statistical Review of World Energy, June,

Figure 2.2.2 Changes in Primary Energy Consumption of APEC Economies

Looking at urbanization rates and income levels by country, there is a tendency for the urbanization rate to rise in proportion to increases in income (see Figure 2.2.3). There is also a tendency for per capita primary energy consumption to rise (see Figure 2.2.4). As urbanization rates climb, energy consumption can be expected to rise as urban activity becomes more vigorous.

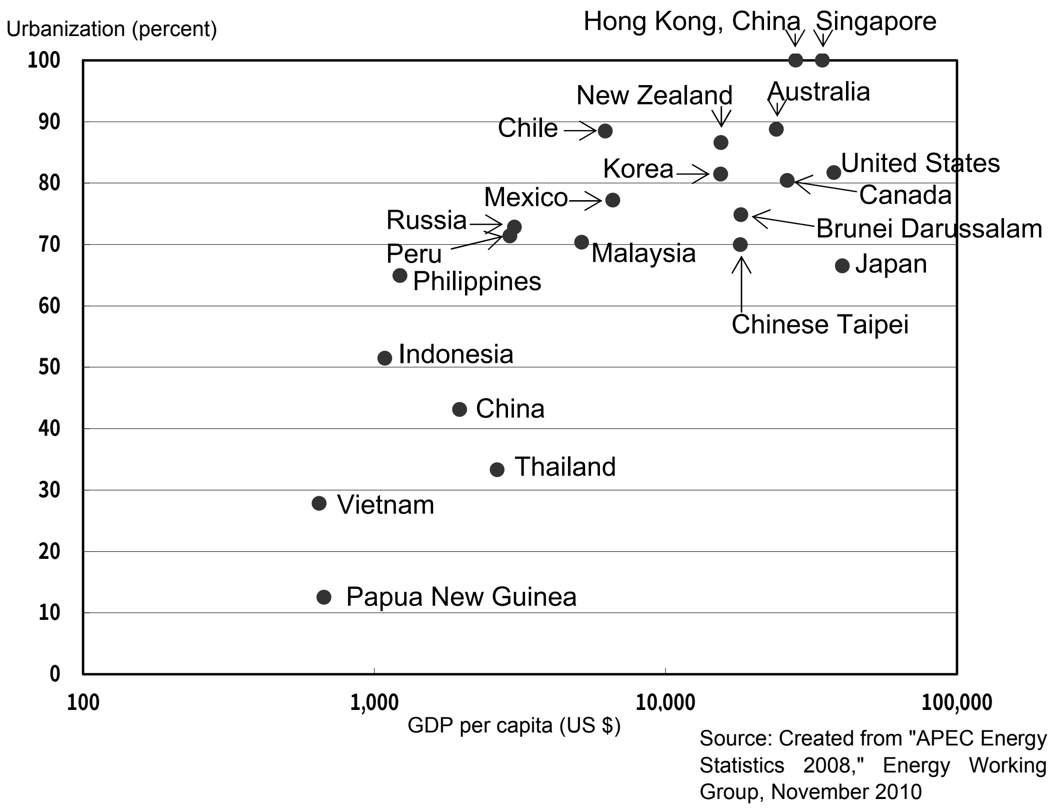
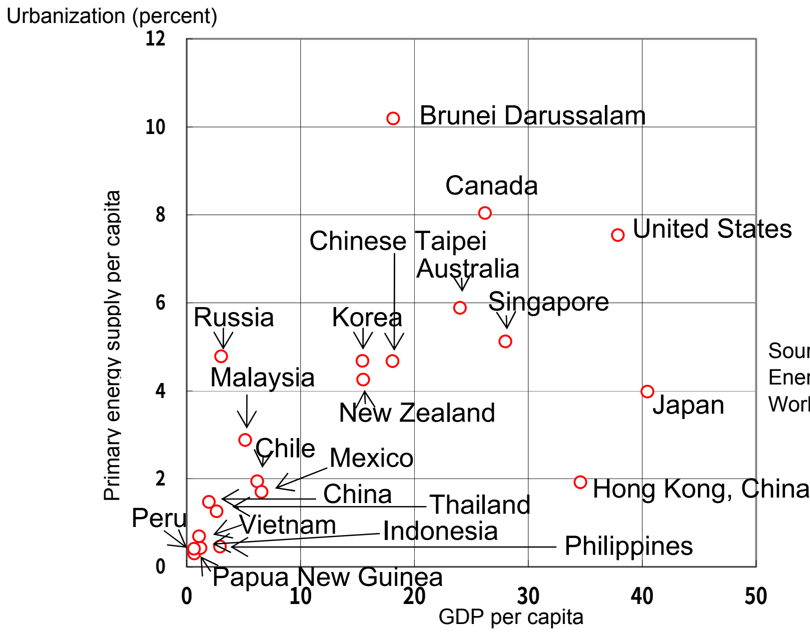


Figure 2.2.3 Urbanization and Income Levels



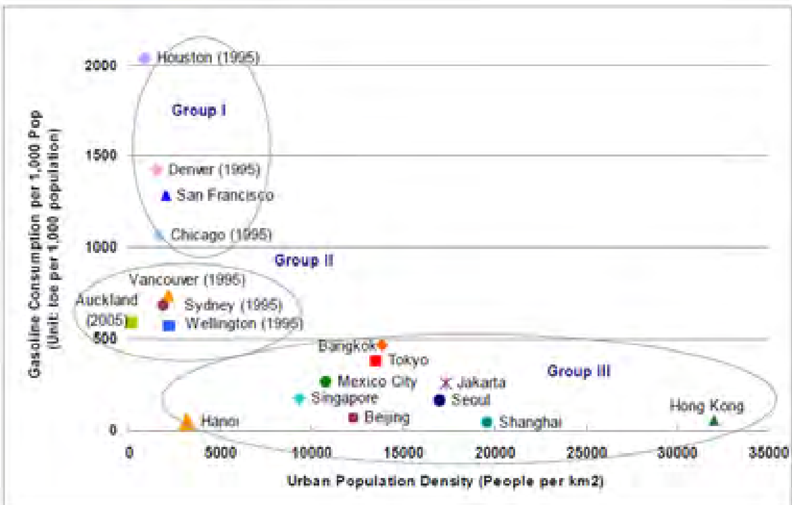
Source: Created from "APEC Energy Statistics 2008," Energy Working Group, November 2010

Figure 2.2.4 GDP per capita and Primary Energy Supply

2) CO_2 Emissions Structure in Cities

Although per capita gasoline consumption in Asian cities is lower than in North America, as income levels rise in the future, per capita CO_2 emissions are likely to increase as motorization progresses and dependence on personal automobiles in daily life increases.

Lifestyle changes accompanying economic growth also lead to changes in the urban energy demand structure and CO_2 emissions source ratios. It is necessary to study the current energy demand structure and future changes in cities where CO_2 emissions in the private and transportation sector are increasing as urbanization progresses and functions are concentrated.



Source: Urban Transport Energy Use in the APEC economies

Figure 2.2.5 Urban Population Density and Gasoline Consumption per 1,000 Persons

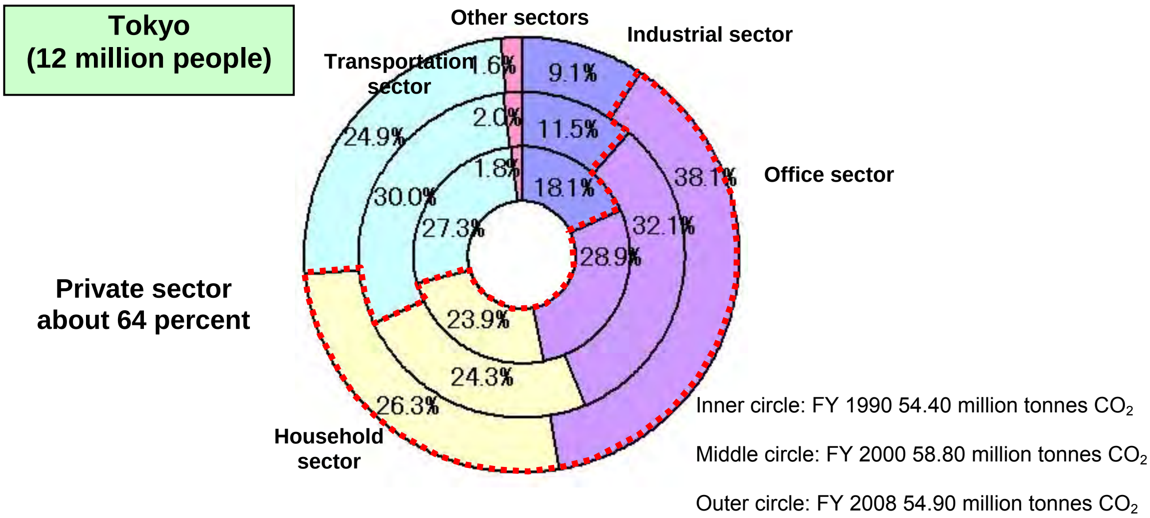


Figure 2.2.6 CO_2 Emissions in Tokyo (Source: Tokyo Metropolitan Government website)

Major causes of increased CO_2 emissions due to urbanization are as shown in Table 2.2.1. Increases in urban pop ulation and per capita CO_2 emissions in APEC economies are important causes of the increase in world CO_2 emissions.

Table 2.2.1 Causes of Increases/Reductions in CO_2 Emissions Accompanying Urbanization and Economic Growth

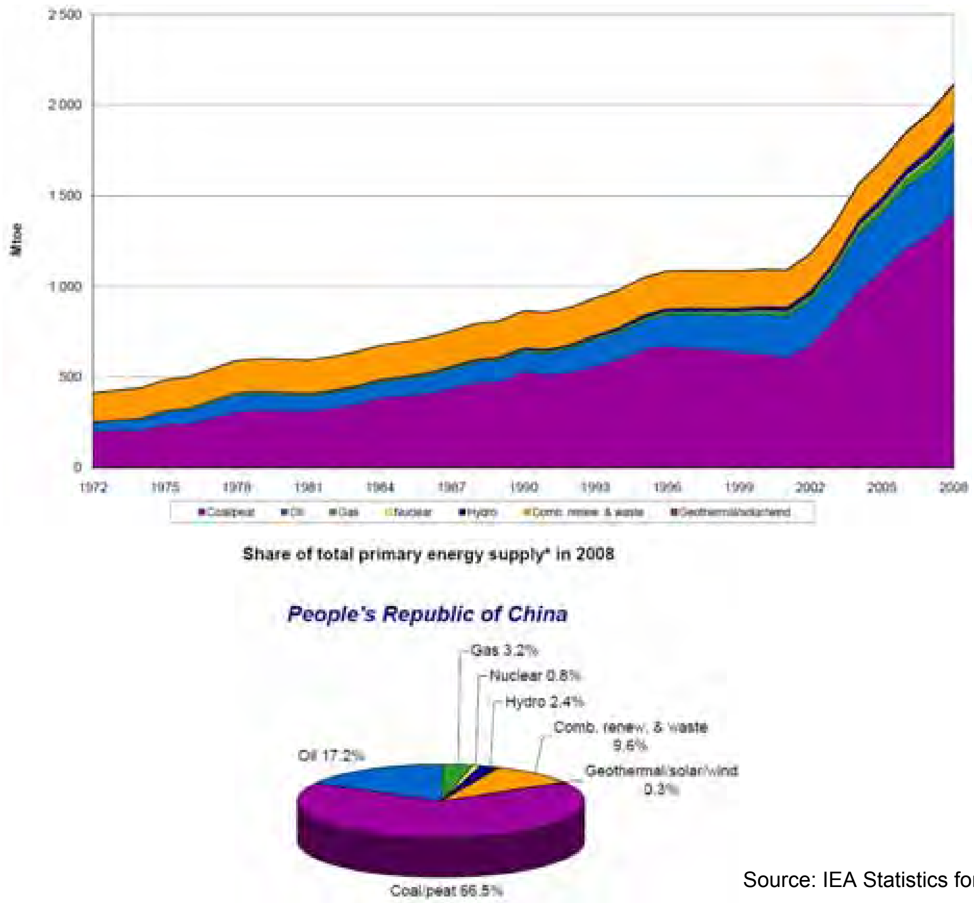
Field	Cause of Increase
Private sector (office, home)	Increased number of buildings due to population increase and economic growth
	Increased household energy consumption accompanying lifestyle changes
	Increased energy consumption in office/commercial buildings
Transportation sector	Increased automobile ownership
	Increase in the number of trucks
	Increased fuel consumption due to longer travel distances

2.3 Low Carbon Development Trends in China

1) Energy Trends in China

As a result of aggressive policies carried out by the Chinese government, the Chinese economy has achieved an average annual growth rate of more than 7 percent since the 1980s. The annual growth rate was 10 percent during the 1990s. Energy consumption has increased along with this economic growth. Figure 2.3.1 shows changes in China's primary energy supply from 1972 through to 2008. Primary energy supply has grown particularly fast since 2000. In 2008, it was about five times as high as it was in 1972. As of 2008, coal had an overwhelmingly high share of primary energy composition at 66.5 percent, followed by oil at 17.2 percent and natural gas at 9.7 percent.

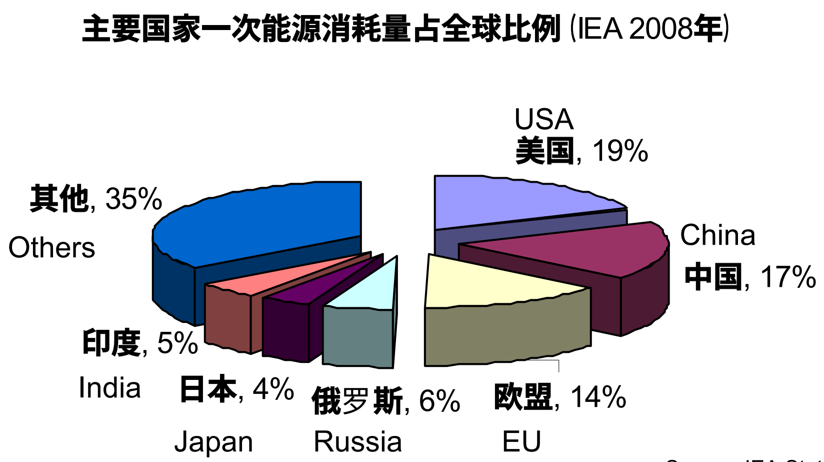
Along with the increase in energy consumption, growth in oil consumption since the beginning of 2002 has been remarkable. China is now the world's second-leading oil consuming country, only behind the United States. Since 1949, China has fostered a large-scale energy industry and developed enormous oilfields. However, declining production in its eastern oilfields and increased oil consumption due to economic growth has made China a net oil importer since 1993 and a net energy importer since 1996. Because of the scale of China's economy and the size of its population, such changes in the Chinese energy situation have had extremely large impacts on surrounding APEC economies in terms of the environment, energy supply and demand.



Source: IEA Statistics for 2008

Figure 2.3.1 Changes from 1972-2008 in China of Energy Consumption by Energy Source (Top), Share of China's Total Primary Energy Supply by Energy Source in 2008 (Bottom)

Figure 2.3.2 shows share of all the countries of the world p rimary energy consumption in 2008. China was second behind the United States at 17 percent.



Source: IEA Statistics for 2008

Figure 2.3.2 Shares of World Primary Energy Consumption

2) Environmental Policies in China

China's government has been working on policies for sustainable development since the 1990s.

China's eco-city project began in 2000. By December 2008, there were 30 eco-cities with construction permits. Of these, 20 are comprehensive eco-cities, 9 are the industrial type, and 1 is the waste processing type.

Table 2.3.1 History of Initiatives on Environmental Policy in China

1992: Signed "Rio Declaration"
August 1992: State Council announced "Ten articles on environment and development in China"
March 1994: Established "China's Agenda 21 (White Paper on China's Population, Environment, and Development in the 21st Century)"
1996: Positioned sustainable development as one of China's development strategies

Source: From materials created by Shu Ping, School of Economics, Nankai University, Tianjin, China

3) Low Carbon Goals in China

a) China's Environmental Legal System

In the 1978 revision of its Constitution, China added the provision, "The state protects and improves the environment in which people live and the ecological environment. It prevents and controls pollution and other public hazards" (Article 26). This created a basis and foundation for environmental law. In September 1979, the Environmental Protection Law of the People's Republic of China [1] was implemented. The Environmental Protection Law started the creation of a full-fledged environmental legal system in China.

The Marine Environment Protection Law of the People's Republic of China was passed in August 1982, the Law of the People's Republic of China on Prevention and Control of Water Pollution in May 1984, the Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution in September 1987, the Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste in October 1995, and the Law of the People's Republic of China on Prevention and Control of Pollution From Environmental Noise in October 1996. By the end of 1996, 12 specific laws on pollution prevention and natural resources had been passed. In a mere 20 years, an extensive environmental protection system including administrative regulations, departmental rules, local regulations, national environmental standards, local environmental standards, international treaties, and so on has been created.

[1] Law names are from: http://www.lawinfochina.com.

Table 2.3.2 China's Environmental Legal System

Legal System	Major Laws, Conditions, Standards	Passed/Revised
Constitution	Article 26, "The state protects and improves the environment in which people live…. It prevents and controls pollution and other public hazards"; Articles 9, 10, and 22	Revised 1979 Revised and implemented December 4, 1982
Basic environmental law	Environmental Protection Law of the PRC	December 26, 1989
Specific environmental laws	Marine Environment Protection Law of the PRC	August 23, 1982
	Law of the PRC on Prevention and Control of Water Pollution	May 11, 1984 Revised May 15, 1996
	Law of the PRC on the Prevention and Control of Atmospheric Pollution	September 5, 1987 Revised August 29, 1995
	Law of the PRC on the Prevention and Control of Environmental Pollution by Solid Waste	October 30, 1995
	Law of the PRC on Prevention and Control of Pollution From Environmental Noise	October 29, 1996
	Forestry Law of the PRC	September 20, 1984
	Grassland Law of the PRC	June 18, 1985
	Fisheries Law Of the PRC	January 20, 1986
	Mineral Resources Law of the PRC	March 19, 1986 Revised August 29, 1996
	Land Administration Law of the PRC	June 25, 1986 Revised December 29, 1988
	Water Law of the PRC	January 21, 1988
	Law of the PRC on the Protection of Wildlife	November 8, 1988
	Water and Soil Conservation Law of the PRC	June 29, 1991
	Law of the PRC on the Coal Industry	August 29, 1996
Administrative regulations on environmental protection	Regulation on nature reserves	October 9, 1994
	Administrative regulation on the prevention of water pollution in the Huai River watershed	August 8, 1995
	Decision of the State Council on Several Issues Concerning Environmental Protection (28 regulations through July 1997)	August 3, 1996
Departmental rules on environmental protection	Rules on application for and registration of emission of pollutants	August 14, 1992
	State Planning Commission and Ministry of Finance notification on collection of fees for emission of water pollution (120 rules through July 1997)	August 14, 1992
Local regulations on environmental protection (provinces, autonomous regions, direct-controlled municipalities, administrative-control cities, etc.)	Heilongjiang Province regulation on the prevention of industrial pollution	November 3, 1996
	Shanxi Province regulation on environmental protection	January 19, 1996
	Guangdong Province regulation on nuclear power generation and environmental protection	September 28, 1996
	Guangzhou City regulation on agriculture and environmental protection	December 3, 1996
	Dalian City regulation on environmental protection (Over 1,000 regulations through July 1997)	June 27, 1991

Source: Liang Xiushan (Assistant Professor, Environmental Management College of China), "China's Environmental Administration and Laws" Presentation Materials

b) New Trends in Environmental Policy

At the fourth meeting of the 8th National People's Congress in March 1996, the Ninth Five-Year Plan (1996–2000) and long-term targets for 2010 were announced. The new goal of achieving a sustainable society that balances economic development and environmental conservation by 2010 through fundamental change and reform in economic systems and economic growth models was established. At the same time, the "National Environmental Protection '9-5' Plan and 2010 Long Term Goals" were announced. Actual policies are as shown in Table 2.3.3.

Table 2.3.3 Major Indexes in the National Environmental Protection '9-5' Plan

Item		1995	2000
Flue dust emissions	tonnes	17.44 million	17.50 million
Industrial particle emissions	tonnes	17.31 million	17.00 million
SO_2	tonnes	23.70 million	24.60 million
COD	tonnes	22.33 million	22.00 million
Petroleum	tonnes	84,370	83,100
Cyanide compounds	tonnes	3,495	2,373
As	tonnes	27	26
Hg	tonnes	1,700	2,670
Pb	tonnes	285	270
Cd	tonnes	285	270
Hexavalent chromium	tonnes	670	618
Industrial solid wastes	tonnes	61.70 million	59,95 million
Wastewater	tonnes	35.6 billion	48 billion
Industrial wastewater	tonnes	222.5 billion	30 billion
Industrial wastewater treatment rate	percent	76.8	74
Urban wastewater treatment rate	percent	19	25
Industrial waste treatment rate	percent	74	80
Total industrial waste reuse rate	percent	40	45
Urban trash processing rate	percent	43	50
Forestation rate	percent	13.92	15.5
Nature reserve area	ha	71.85 million	100 million

Source: Liang Xiushan (Assistant Professor, Environmental Management College of China), "China's Environmental Administration and Laws" Presentation Materials

2.4 Low Carbon Technology Trends

1) Fundamental Approaches on CO_2 Reduction through Comprehensive Urban Policies

In order for entire cities to move towards low carbon emissions, the following two points must be borne in mind.

- In order for entire cities to control CO_2 emissions, scenarios for sustainable growth with high quality of life must be sketched out.
- In cities, diverse activities develop in combination. Diverse measures are available, including those linked directly to low carbon policies (installation of energy saving facilities and equipment, promotion of energy conservation, etc.) and those indirectly linked to low carbon policies (transportation measures, conservation of forests and farmland, etc.). Because such measures are interrelated, realization of the low carbon model town (LCMT) concept requires the examination of comprehensive measures (see Figure 2.4.1).

2) Policies for Low Carbon Development

Low carbon development policies can be broadly categorized as follows.

Table 2.4.1 Categories for Low Carbon Development Policies

a)	Urban structures	e)	Area energy network
b)	Buildings	f)	Untapped energy
c)	Energy management systems	g)	Renewable energy
d)	Transportation	h)	Smart grid system and others

Measure types a)–d) are on the energy demand side, measure types e)–g) are on the energy supply side, and measure h) type straddles both energy demand and supply (see Figure 2.4.2).

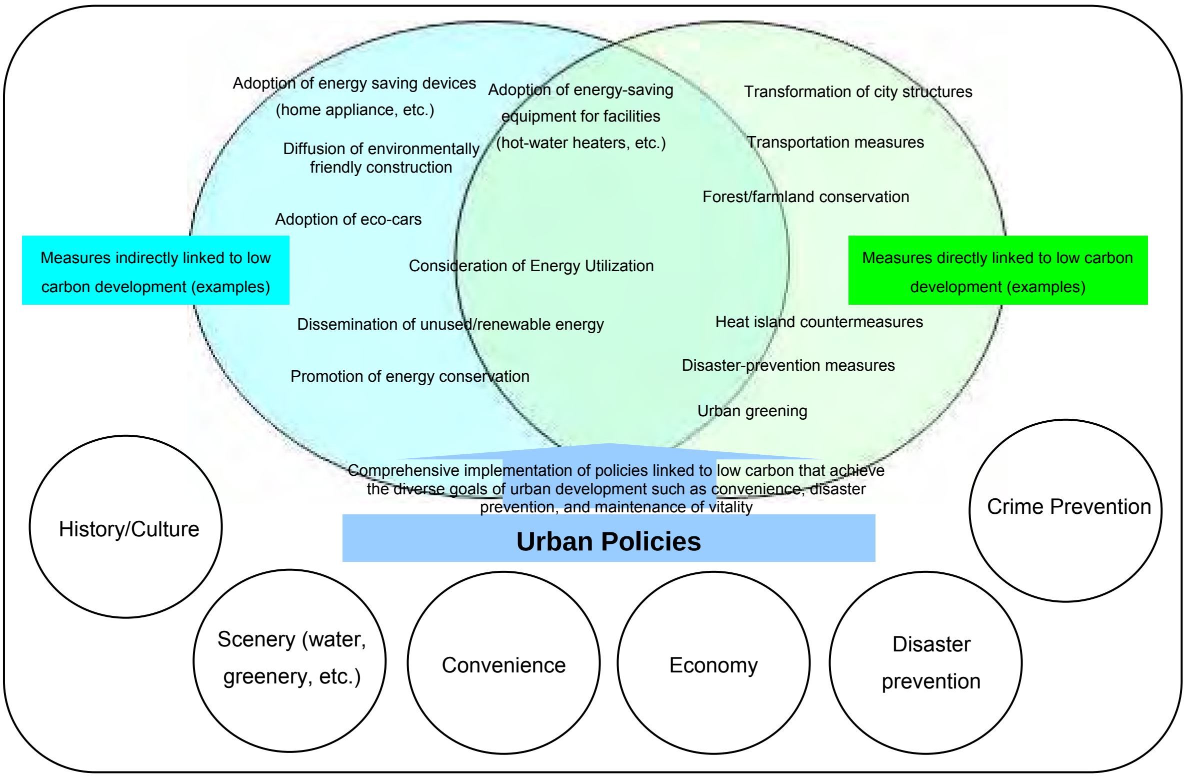


Figure 2.4.1 Policies for Low Carbon Development from the Urban Planning Perspective

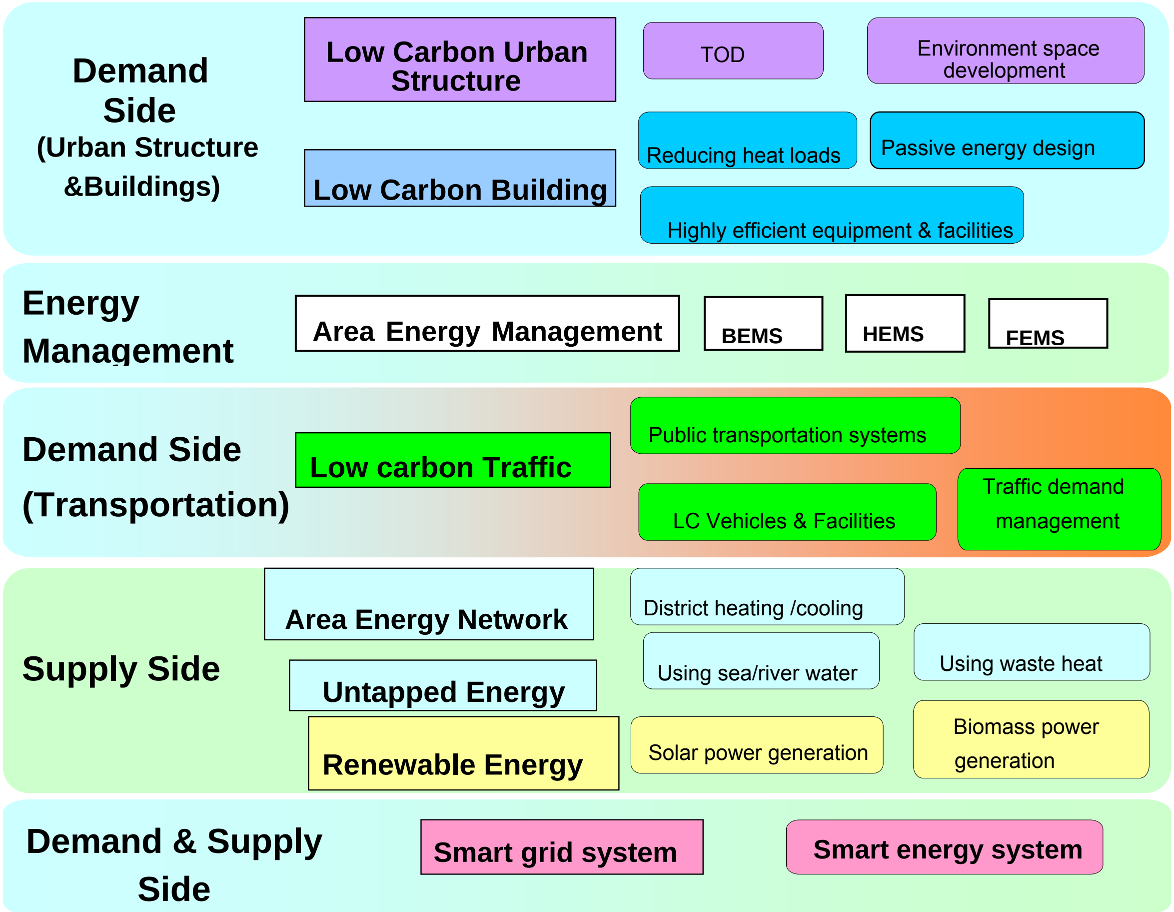


Figure 2.4.2 Low Carbon Technologies

An image of how low carbon technologies could be adopted for APEC LCMTs is shown below.

For example, if cities are divided into three types, central business districts (CBDs), housing districts, and farming districts, the following technologies could be adopted.

a) CBD: low carbon construction, local energy, untapped energy, solar, wind power generation, etc.
b) Housing districts: low-carbon housing, solar power generation, etc.
c) Farming districts: low-carbon housing, biomass power generation, etc.

Transit between cities and districts can include intercity railways, light rail transit (LRT), electric vehicles (EV), etc.

In farming districts, installation of large scale solar power and wind power generation facilities can be effective.

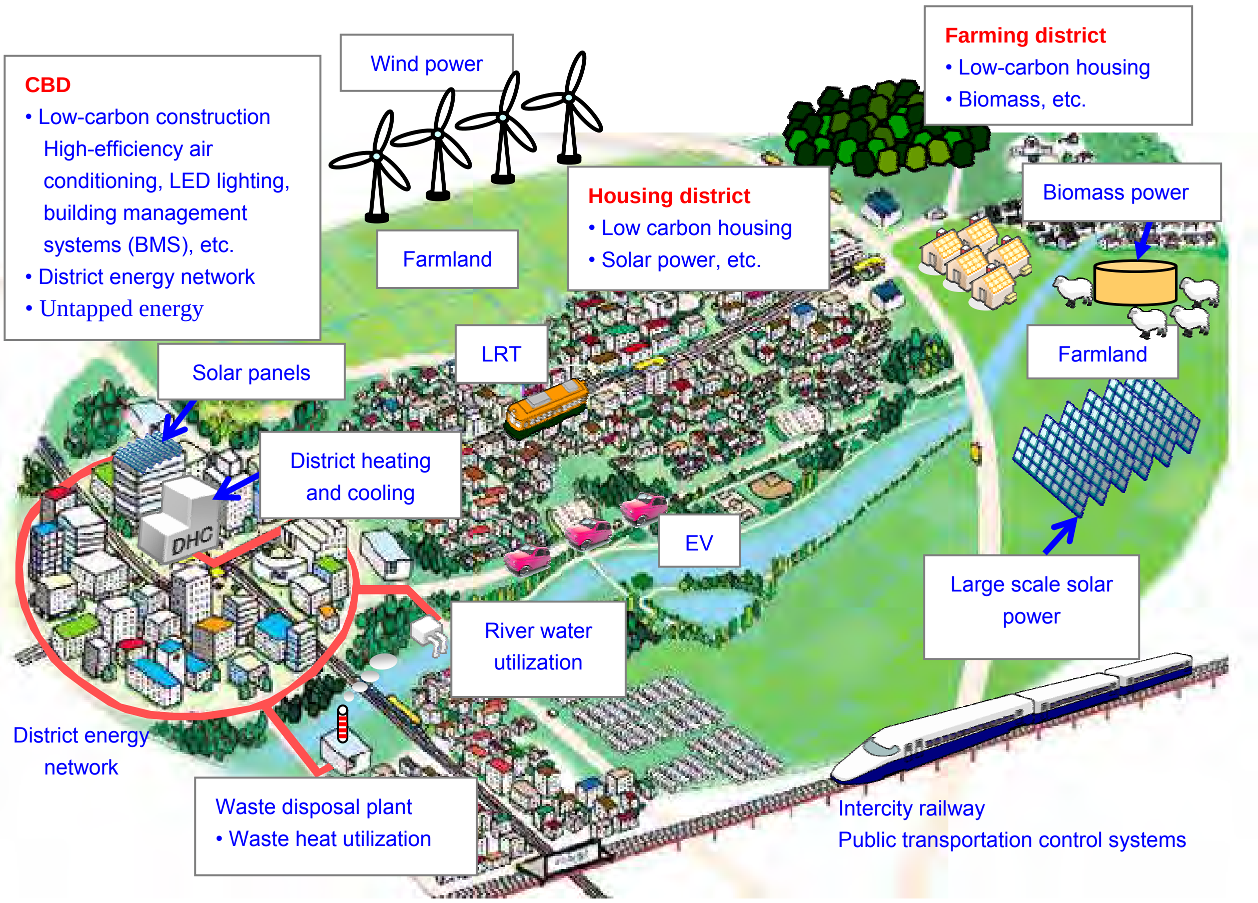


Figure 2.4.3 Comprehensive Low Carbon Policies in an APEC LCMT

2.5 Advanced Cases in Other Cities

To help set low-carbon goals for the Yujiapu Financial District, an overview of advanced cases in the world, namely, the Sino-Singapore Tianjin Eco City in China, Masdar in Abu Dhabi, and the Kashiwanoha and Kitakyushu Eco-Town in Japan is provided below.

	Sino-Singapore Tianjin Eco City, China
Environmental targets	• Twenty-two binding goals are simultaneously being pursued. • Reduced environmental impacts to be achieved by 2020 from the binding goals are as follows: o Renewable energy usage rate of at least 20% o Reclaimed (recycled) water and desalinated seawater usage rate of at least 20% o Green transportation rate of 90% o Green construction rate of 100%
Overview	• Scale of investment: 250 billion yuan (3.5 trillion yen) o Of this, the initial investment in city infrastructure, etc., is 30 billion yuan (420 billion yen) • Final planned population is 350,000 o 2010: residential population of 30,000 and working population of 15,000 o 2015: residential population 200,000, working population 100,000 o 2020: residential population 350,000, working population 150,000 • Date of completion: 2020 • Construction area: 24 million m^2 

	Masdar, Abu Dhabi
Environmental targets	• "Zero Carbon City" with no CO_2 emissions • To achieve zero CO_2 and waste emissions, automobiles will be prohibited and water recycling will be promoted.
Overview	• Total area: 6.5 km^2 • Development costs: 22 billion dollars (about 2.4 trillion yen) • Projected population: 50,000 • Scheduled completion: 2015  Artist's Rendering of Masdar Zero Carbon City Source: http://jinnou.hiciao.com/staff/img/qYzeKoqr.jpg

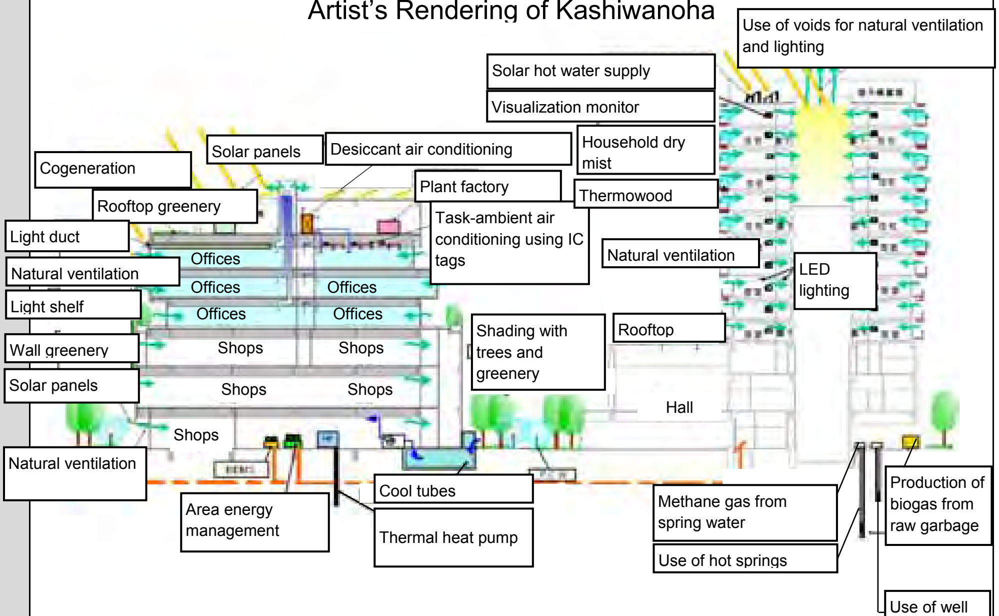
<table>
<tr><th></th><th>Kashiwanoha Eco Compact City (Chiba, Japan)</th></tr>
<tr><td>Environmental targets</td><td>

- "Efficiency and long life" in city block construction
- Urban development with rich greenery in harmony with the environment
- Reduction of at least 35% by 2030 throu gh combined use of environmental technologies
- Conservation and enhancement of green space: 40% green space
- City green space: 25%
- Bringing residents' lives in to harmony with the environment: dissemination and use of the "Eco Compact" concept

</td></tr>
<tr><td>Overview</td><td>

- In the campus city concept, harmony with the environment, biodiversity, use of natural/untapped energy, and user/regional initiatives are listed.
- The objective is to u se the low carbon green development "Eco Compact" city model to represent Japan

Artist's Rendering of Kashiwanoha



Technologies for Reducing CO_2 Emissions in Buildings

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	Kitakyushu Eco-Town (Kitakyushu, Japan)
Environmental targets	• Improved recycling • Reduction of final disposal rate • Reduction of carbon dioxide emission rate • Reduction of water resource input rate
Overview	The Eco-Town project aims to "utilize every waste product as another industry's raw material, finally resulting in zero waste (zero emissions)" as part of the creation of a recycling-oriented society. Kitakyushu has set forth the Kitakyushu Eco-Town Plan (approved by the Ministry of Economy, Trade and Industry and the Ministry of the Environment), which is based on the environmental/recycling industry. All parts of the city of Kitakyushu are engaged in actual projects. In order to promote the project, the city set forth the “Kitakyushu Eco-Town Plan”. The plan lays out the direction of basic initiatives and develops localized policies based on integrated environmental and industrial policy.

Source: Kitakyushu Eco-Town website

3. Outline of the Yujiapu Financial District

3. Outline of the Yujiapu Financial District

Key points

- The Yujiapu Financial District was announced as an implementation of APEC's Low Carbon Model Town (LCMT) project at a meeting of APEC energy ministers on June 19, 2010. As a joint Japan-China project, the Yujiapu Financial District is the first feasibility study.
- Since issues related to shifting to Low Carbon are covered in the existing master plan, this report will offer an improved proposal.

3.1 Summary of the Current Conditions in the Yujiapu District

The Yujiapu Financial District was announced as an implementation of APEC's Low Carbon Model Town (LCMT) project at a meeting of APEC energy ministers on June 19, 2010. As a joint Japan-China project, the Yujiapu Financial District is the first feasibility study.

Figure 3.1.1 Location of the Tianjin Yujiapu Financial District

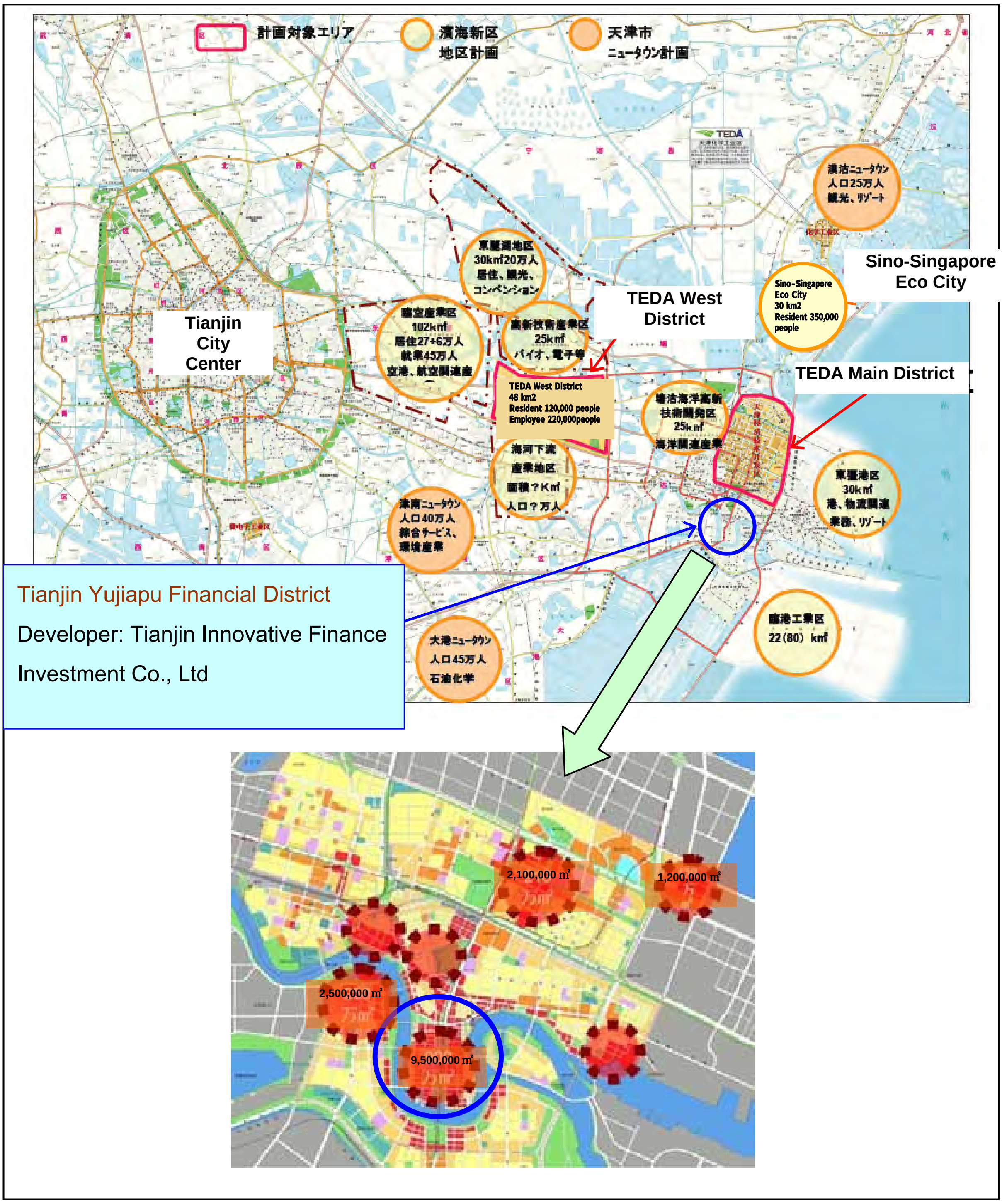


Figure 3.1.2 Location of the Yujiapu Financial District in the Tianjin Metropolitan Area

Figure 3.1.3 Artist's Rendering of the Completed District

3.2 Summary of the Existing Master Plan and Development Situation

An overview of the existing master plan for the Yujiapu Financial District is as follows.

Table 3.2.1 Overview of the Existing Master Plan

Yujiapu Financial District

- Area to be developed: about 3,850,000 m^2 (about 385 ha)
- Plan area: about 9,500,000 m^2 (about 950 ha)
- First Phase of Development
    - Site area: about 396,000 m^2 (about 40 ha)
    - Plan area: about 2,900,000 m^2 (about 290 ha)
- Planned Population
    - Daytime workers: about 500,000
    - Nighttime population: about 50,000
- Developer: Tianjin Innovative Finance Investment Co., Ltd

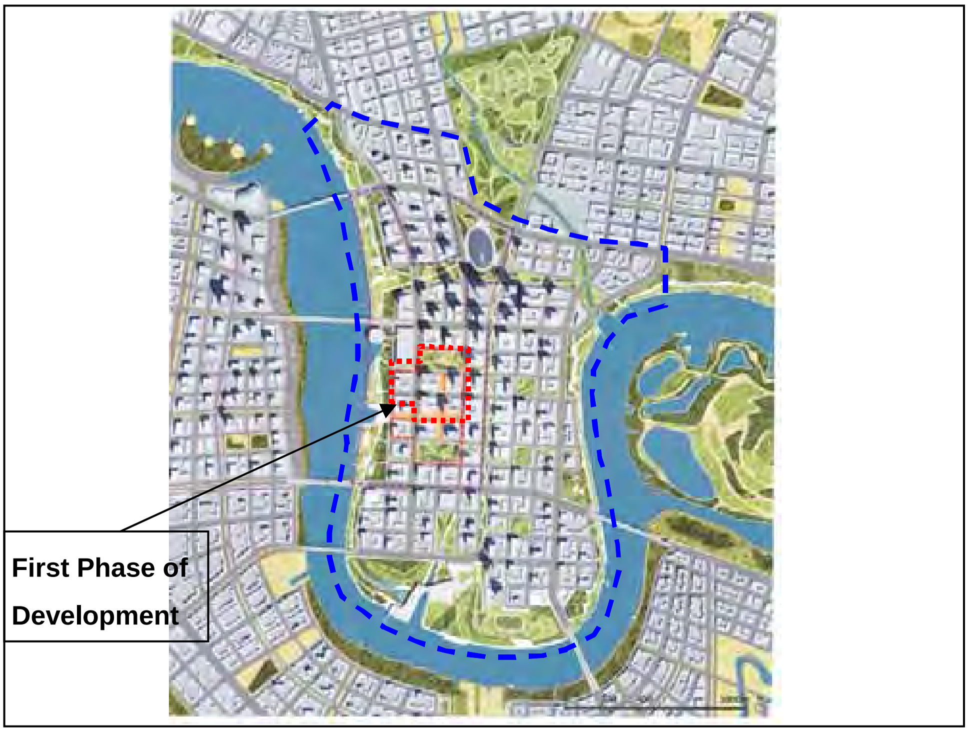


Figure 3.2.1 First Phase of Development

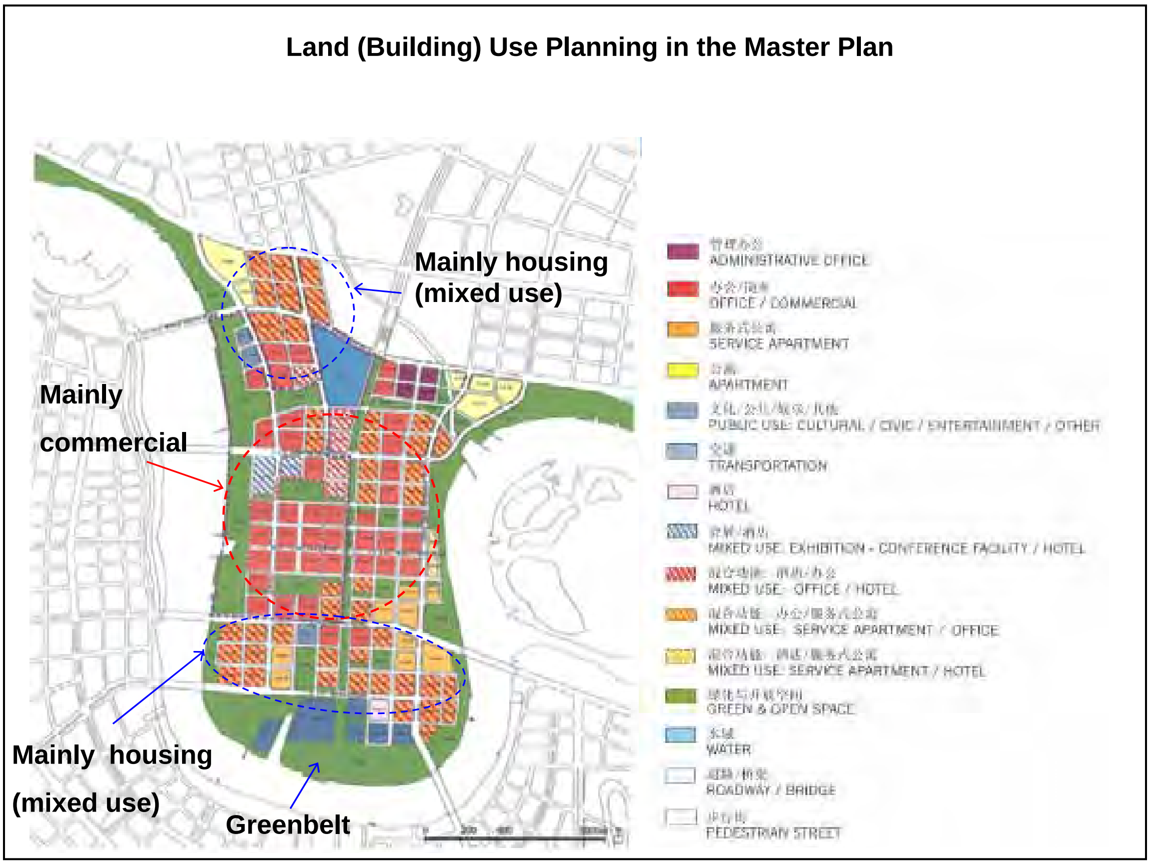


Figure 3.2.2 Land Use Plan According to the Master Plan

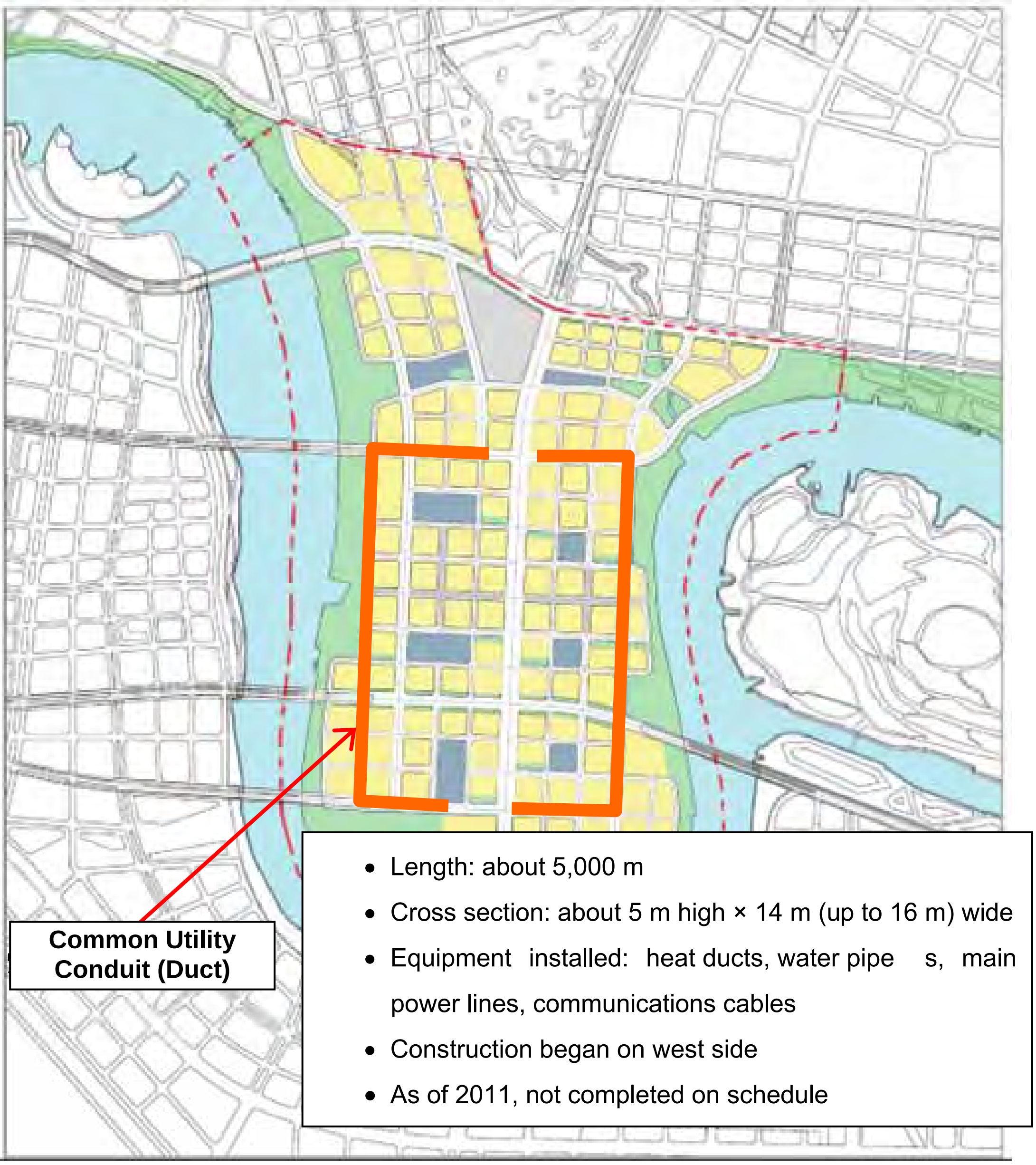


Figure 3.2.3 Common Utility Conduit (Duct) Plan

4. Building the Low Carbon Model Town (LCMT) Concept in the Yujiapu Financial District

4. Building the Low Carbon Model Town (LCMT) Concept in the Yujiapu Financial District

Key Points

- Creation of the world's first low carbon central business district (CBD)
- The Yujiapu Financial District's concept includes both load reduction and value increase
- Target figures include direct and indirect targets as well as low carbon targets
- A "hierarchical approach" is proposed as a method to lower the entire city's carbon emissions

4.1 The Significance of a Low Carbon CBD

Carrying out the feasibility study in the Yujiapu Financial District will give birth to the world's first low carbon CBD.

The goal of the Yujiapu Financial District is to achieve an internationally competitive "financial and low carbon city" that has high quality of life while having reduced environmental impacts. In that respects, there is an aim to brand the Yujiapu Financial District as a city of the future. The initiatives addressed here will be developed into methodologies for low carbon development for Chinese domestic use. Also the methodologies will be further developed for use in cities in other APEC economies.

4.2 Building the Concept

Based on the above, the low carbon CBD in the Yujiapu District will be constructed following the concepts shown below.

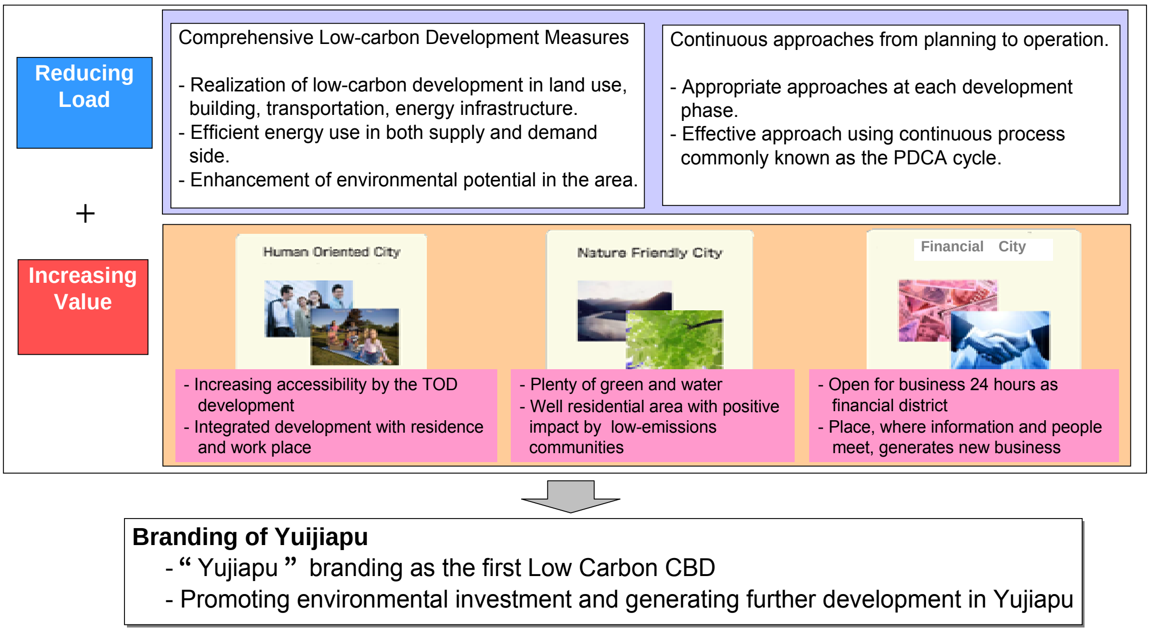


Figure 4.2.1 Concepts for Building the Low Carbon CBD in the Yujiapu District

4.3 Target Setting

The approach on setting low carbon targets and building a system of indexes is as follows.

1) Low carbon targets must be realistic (they must be both appealing and realistic)
2) Low carbon targets and indexes will comprise "Low Carbon Targets," "Direct Indexes," and "Indirect Indexes”.
3) Targets and indexes will be composed of quantifiable and vi sible categories (with some exceptions).
4) Stakeholders in the Yujiapu Financial District will jointly aim at reaching the low carbon targets and indexes and will also share data regarding them together
5) Targets and indexes will require ongoing efforts throughout the life cycle of the project

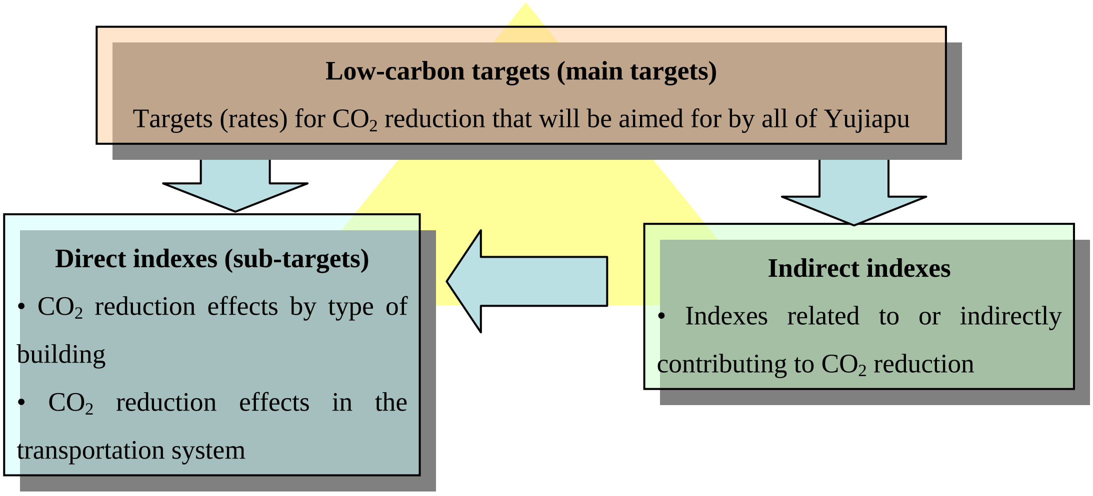


Table 4.3.1 Setting of Targets and Indexes

(1) Low carbon Targets (Main Targets)

(2) Direct Indexes (Sub Targets)：CO2 reduction effects in Buildings and Transportations — 6 Indexes

(3) Indirect Indexes : Total of 28 Indexes

L — Load Reduction (14 Indexes)

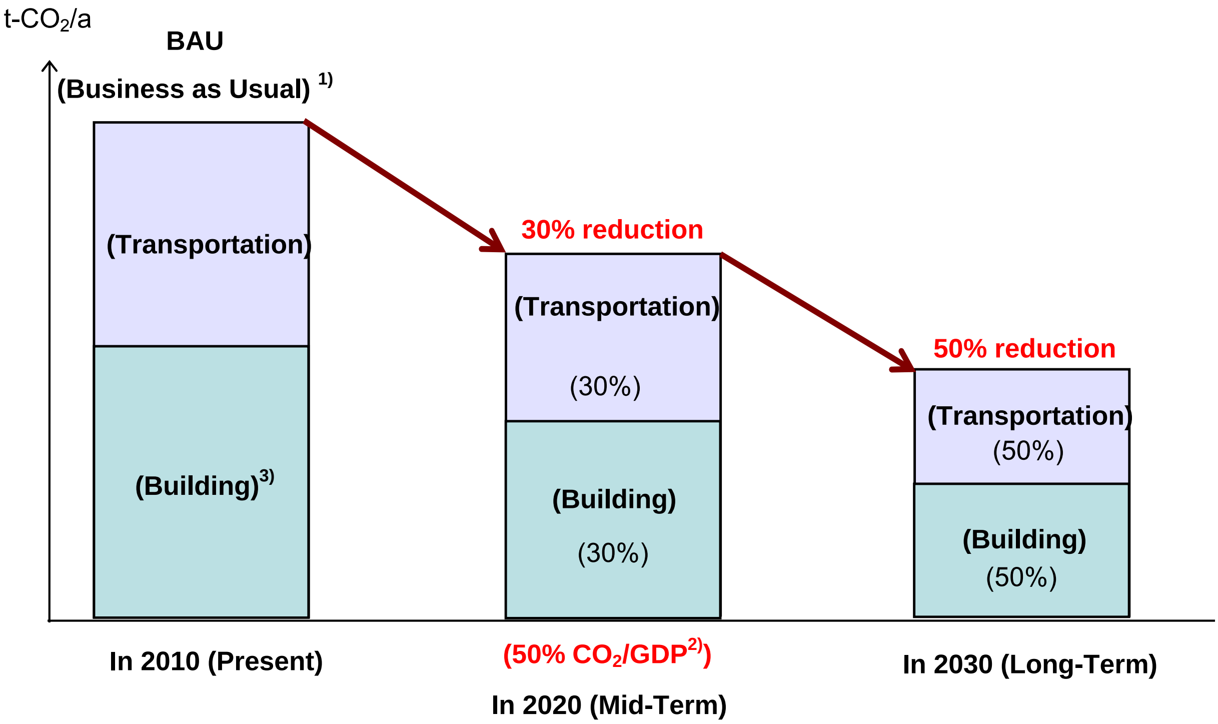
New energy	1) Area energy 2) Renewable & Untapped energy
Resource circulation	3) Water resource 4) Waste reuse, recycle
Pollution abatement	5) Atmosphere, Water, Soil

V — Value Increase (14 Indexes)

Environment	1) Greenery, Biodiversity 2) Heat Island
Transportation	3) Transportation
Business foundation as finance city	4) Safety, Security 5) Economic activity 6) Information technology

1) Low Carbon Targets (Main Targets)

- **Aiming for real reduction of approximately 50 percent**
- **In 2020 (mid-term) real reduction of approximately 30 percent (which is over 50 percent CO_2/GDP)**
- **In 2030 (long-term) real reduction of approximately 50 percent**

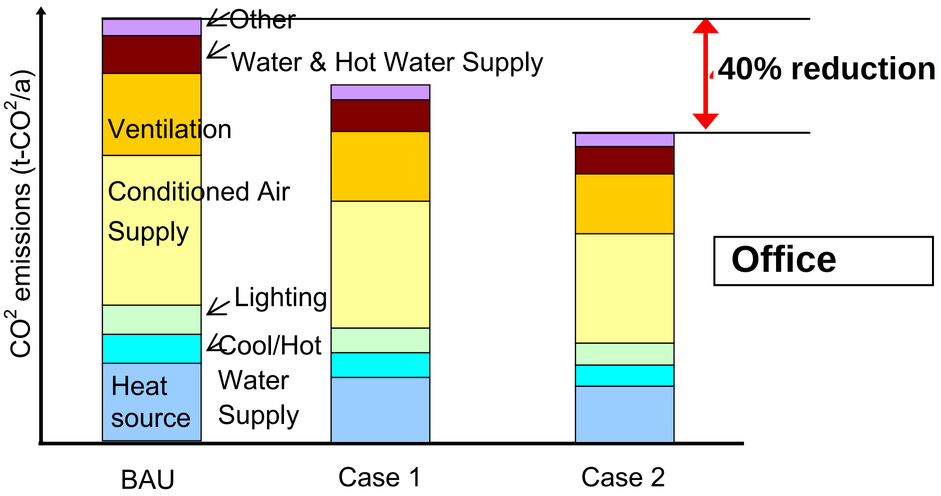


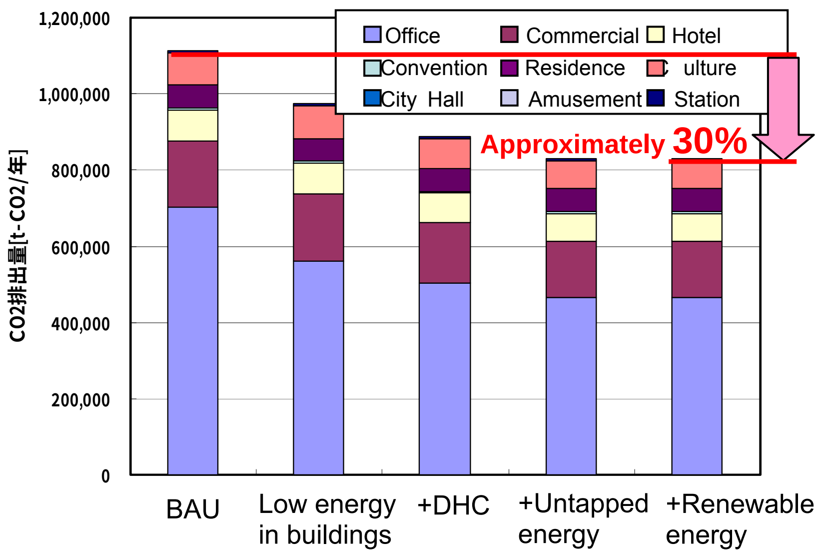
1) Standard type buildings without low carbon technologies
2) GDP growth in 2011 and 2012 in China is predicted at 9.6 percent and 9.5 percent by IMF analysis. In this CO_2 target study, GDP growth by 2020 is set at 5 percent, around half of actual growth considering the uncertainty of predictions.

Figure 4.3.1 Low Carbon Targets (Main Targets)

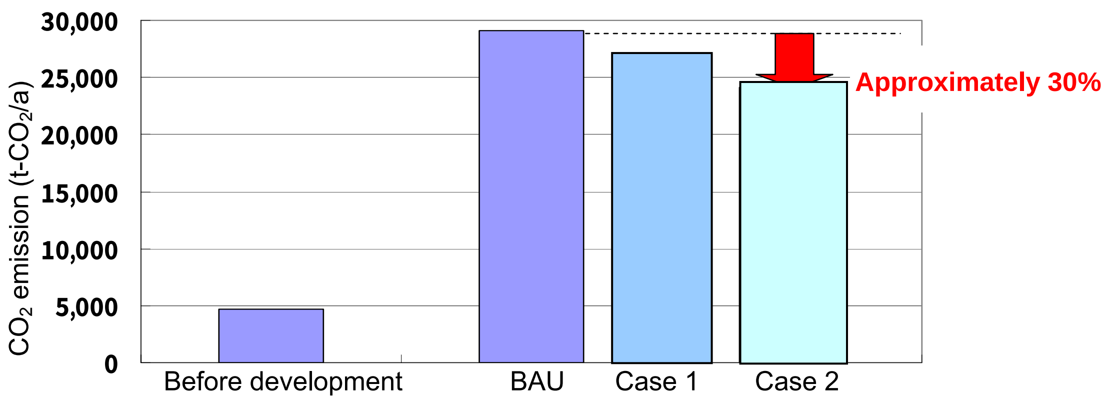
2) Direct Indexes (Sub-Targets)

a) CO_2 reduction effects by type of building (office buildings) → target: t-CO_2/year, t-CO_2/m^2, CO_2 reduction rate (percent)





b) CO_2 reduction effects in the transportation system → index: t-CO_2/year, t-CO_2/vehicle, CO_2 reduction rate (percent)



3) Indirect Indexes

a) Load Reduction

Category	Item (Reasons for Selection)	Indexes	2020	2030
New Energy	1) Area energy - Effect of intensive energy system in urban area	District Heating and Cooling (DHC) Utilization rates	50%	80%
	2) Renewable energy, - Untapped energy as CO_2 emission "Zero" energy system	Utilization rates	15%	25%
		Utilization rates	15%	25%
Resources circulation	3) Water resources - Encouraging the preservation of water resources	Gray water; recycle rates	40%	80%
		Sewage water; recycle rates	−	30%
		River water (rain water); recycle rates	15%	30%
	4) Reuse, Recycle of waste - Boosting waste reduction and preservation of water resources	Waste, kitchen waste; recycle rates	40%	80%
		Waste plastic; recycle rates	40%	80%
		Paper; recycle rates	40%	80%
		Recyclable waste; recycle rates	60%	90%
Pollution abatement	5) Pollution	Air pollution	Conforms to National Standard	Aiming for WHO standard
		Water	Conforms to National Standard	Aiming for WHO standard
		Soil	Conforms to National Standard	Aiming for WHO standard
		Chemicals	Conforms to National Standard	Aiming for RoHS standard

b) Value Increase

Category	Item (Reasons for selection)	indexes	2020	2030
Environment	1) Greenery, Biodiversity - Increase comfortableness, green scenery	Greenery coverage rate	Over 30%	Same as on the left
		Biodiversity rate	Select multiple kind of plants considering biodiversity	Same as on the left
	2) Heat Island - Improve the thermal environment	Decline of temperature	1.5 - 2.0 degree lower than BAU	
		Cool spot coverage rate	Over 40%	Over 60%
Transportation	3) Transportation - Encourage the use of public transportation systems	Modal split of public transportation	50%	80%
		Coverage rate of barrier-free design	50%	80%
		Coverage rate of 5 minutes walkable area from bus stop	50%	90%
		Accuracy of public transportation	80%	Over 90%
Business foundation as a financial center	4) Safety, Security - In order to promote investment and corporate expansion from all over the world	Surveillance camera coverage rate	50%	80%
		Traffic accident rates	Approximately the same level as advanced nations	Same as on the left
	5) Economic Activity - Assess the international competitiveness as a financial district	GDP/working person	Around 60 – 70% of average level in financial centers in developed nations	Approximately the same level as financial centers in developed nations
		Occupancy rate of finance company	Over 50%	70%
	6) Information Technology - Assess the stability of enterprise-grade information technology infrastructure	Coverage rate of optical fiber LAN	90%	100%
		Rate of data center and server downtime	Aiming for 0%	0%

Reference Project: The Sino-Singapore Tianjin Eco Region Project

1) Targets

Twenty-two binding and four nonbinding targets were set for development.

Categories		Item	Indexes	Deadline
Ecology	**Natural environment**	Air pollution	Over 310day/a realizing 2nd grade	On the same day
			155 day/a realizing 1st grade of SO_2, NO_x	On the same day
			(GB 3095-1996)	2013
		Water on the ground surface	(GB 3838-2002) Realizing the water quality of category **IV**	2020
		Realizing the standard revel of drinking water	100%	On the same day
		Realizing the standard revel of noise	100%	On the same day
		Carbon emission/GDP	150tC/million$	On the same day
		Loss of natural marshes	0%	On the same day
	Greenery	Green architecture rate	100%	On the same day
		Index of original and natur al plants	Over 0.7	On the same day
		Public green space/ person	Over 12 ㎡/person	2013
Social activity	**Lifestyle and health**	Water usage/person, day	Under 120l/person, day	2013
		Waste/person	Under 0.8kg/person, day	2013
		Green transportation rate	Over 30%	2013
			Over 90%	2020
	Infrastructure and social facilities	Recycle rate of waste	Over 60%	2013
		Number of sport s facilities within 500m walk	100%	2013
		Management revel of hazardou s waste and house waste	100%	On the same day
		Rate of barrier-free free buildings	100%	On the same day
		Coverage rate of cit y water supply piping	100%	2013
	Others	Rate of low cost house	Over 20%	2013
Economic development	**Economic development**	Renewable energy rate	Over 20%	2020
		Usage rate of new water resources	Over 50%	2020
	Concentration of technology	Number of engineer/working population	Over 50 persons	2020
	Others	Number of houses for labors	Over 50%	2013

2) Water Resource Recycling

The plan is to bring the use of unconventional water (reclaimed water, desalinated seawater) to at least 50 percent of all water use. In terms of concrete policies, a reclaimed water plant will be built, and generate reclaimed water from treated wastewater. In addition, a desalination project (investment of 140 million yuan, scale of 30,000 m^3/d) is in the planning stages.

3) Green Transportation

a) Reduction of Environmental Impact
- Reduction of demand for automobile use
- Enhanced management of emissions
- Control of pollutant emission through the diffusion of clean energy

b) Resource Conservation
- Promotion of the use of low-energy automobiles
- Setting the world's highest standards for automobile energy conservation, emissions reduction, and noise reduction

c) Increased Service Efficiency
- Connection to Tianjin International Airport with a high-speed intercity railway line to enable faster access
- Enabling access to the high-speed railway, airport, and the central coast new area within a 10 minute walking distance radius

d) Reasonable Travel Distances
- Designing the roads such that 80% of the residents' trip length are 3 km or less

e) Sustainability of the Transportation System
- Construction of a new model for urban development that contributes to low energy consumption, low pollution, effective land use, high efficiency, and high quality of services

4) Green Construction

Environmental standards have been set in the following six areas.

a) Land conservation
b) Energy conservation
c) Water conservation
d) Materials conservation and resource utilization
e) Indoor environments
f) Operations and management

The standards include mandatory and optional items. In order to receive building permits, mandatory items must be implemented.

Source: Sino-Singapore Tianjin Eco Region Project Overview, Japan Research Institute

4.4 Comprehensive and Systematic Methods for the Study of Low Carbon Development

Buildings and cities consists of complex and organizational systems. Moving to low carbon emissions through the diffusion of specific low-carbon measures is important. However, there is a limit to what can be done to lower the entire city's carbon output through individual responses.

In order to fully exploit the potential of each system in a city, quantitative evaluation by considering the operating rates of each system in addition to optimizing each system is necessary.

In order to promote low carbon, both the energy demand side and supply side must be considered. Study at the city level is possible. Even if the supply side lowers carbon emissions, overall emissions can increase if energy consumption rises on the demand side. Because of this, a "hierarchal approach" will be adopted. A hierarchal approach takes low-carbon measures for the entire city in the following order: demand side, supply side, transportation, and area energy management systems (AEMS). This mechanism contributes to a shift to low carbon development better than the implementation of individual technologies/measures does.

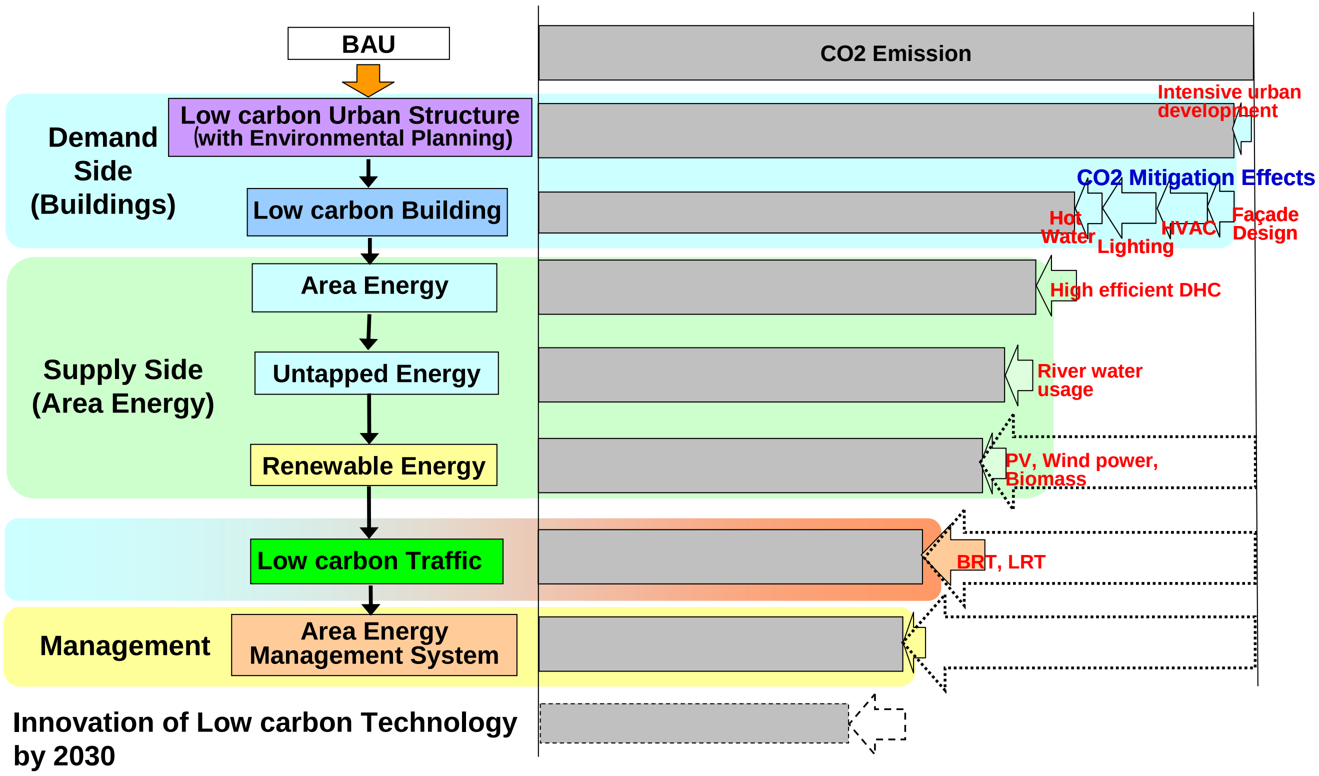


Figure 4.4.1 Hierarchical Approach

4.5 Considerations from the Characteristics of Other Financial Districts

A general characteristic of financial districts is that they are home to stock markets, central banks, headquarters of financial institutions such as securities companies and banks and commercial outlets. The streets of these financial centers are lively with the activities of industries and the business people who work there. These districts are often comprised of high-rise buildings and are positioned as central business districts (CBDs). They are also called financial districts.

Figure 4.5.1 World Financial Districts (Left: London; Right: New York)

Among the necessary conditions for financial districts are high-speed, high-capacity information networks including data centers and other systems capable of processing enormous amounts of data.

In addition, another necessary condition is an atmosphere in which business people can work comfortably with information being broadcast and streamed from all over the world. Furthermore, financial districts as whole must enhance their knowledge and international competitiveness.

The following items from "4.3 Target Setting" can address this.

Table 4.5.1 Necessary Conditions for Financial Districts

Necessary Conditions for Financial Districts	**Evaluation Indexes**
Safety/security • In order to promote investment and corporate expansion from all over the world	Degree of coverage by security cameras
	Traffic accident rate
Competitiveness • Assess the international competitiveness as a financial district	GDP per working member of population
	Occupancy rates of finance-related entities
Information technology • Assess the stability of enterprise-grade information technology infrastructure	Rate of optical LAN installation
	Rate of data center and server downtime

5. Summary of Low Carbon Measures for the Achievement of Targets

5. Summary of Low Carbon Measures for the Achievement of Targets

Key Points

- A comprehensive examination of low carbon measures is necessary in order to realize the low carbon model town (LCMT) concept.
- Low carbon measures are available on the supply side and demand side of fields such as block structuring, construction, transportation and energy
- In the Yujiapu District technologies from the building scale to the city scale will be used.

5.1 Summary of Low Carbon Measures

In cities, diverse activities develop in combination. Diverse low carbon measures are available. They include those that directly lower carbon emissions (adoption of energy-saving facilities and equipment, promotion of energy conservation, etc.) and those that have other purposes but contribute to lower carbon emissions (transportation measures, forest and farmland conservation, etc.). Because such measures interact with each other, realization of LCMTs requires the comprehensive examination of such measures.

In order to pursue low carbon development in the Yujiapu District, it is necessary to examine methods for the reduction of CO_2 emissions by gaining an understanding of the relationships among urban facilities and activities and CO_2 emissions and the distribution of environmental potential (energy sources) for CO_2 emissions and CO_2 reduction.

Methods of CO_2 reduction in this district can include a diverse set of low carbon measures through the application of appropriate facilities and activities in fields such as buildings and transportation. It is necessary to study a set of highly appropriate low carbon measures based on fundamental conditions such as district characteristics, climate, and infrastructure. Based on the hierarchical approach discussed in Section 4, the following low carbon measures can be expected.

Table 5.1.1 List of Low Carbon Measures by Category

Category	List of Low Carbon Measures
Demand side	Plan for low carbon district structure, low carbon buildings, low carbon transportation
Supply side	District energy, renewable/untapped energy
Management	Area Energy Management System (AEMS)
Supply and demand	Smart grid
Other	Consideration of environmentally friendly technologies/methods for other fields

5.2 Set of Low Carbon Methods and Technologies for the Yujiapu District

The set of low carbon methods and technologies targeted for each field in the Yujiapu District is as follows:

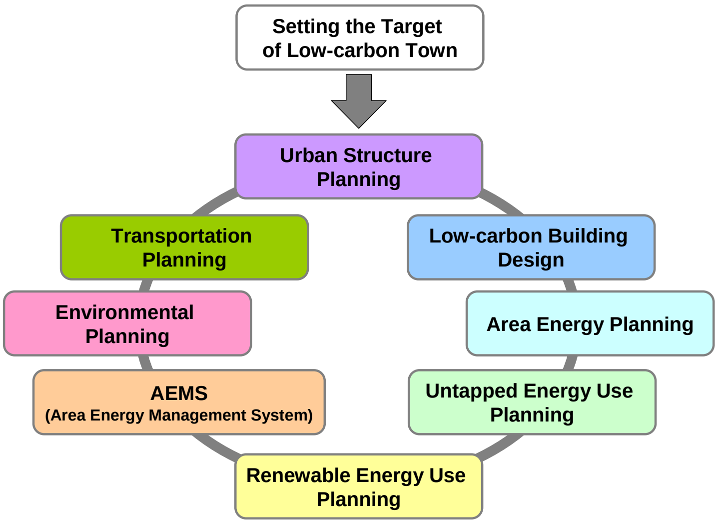


Figure 5.2.1 Fields to be Examined in the Final Report

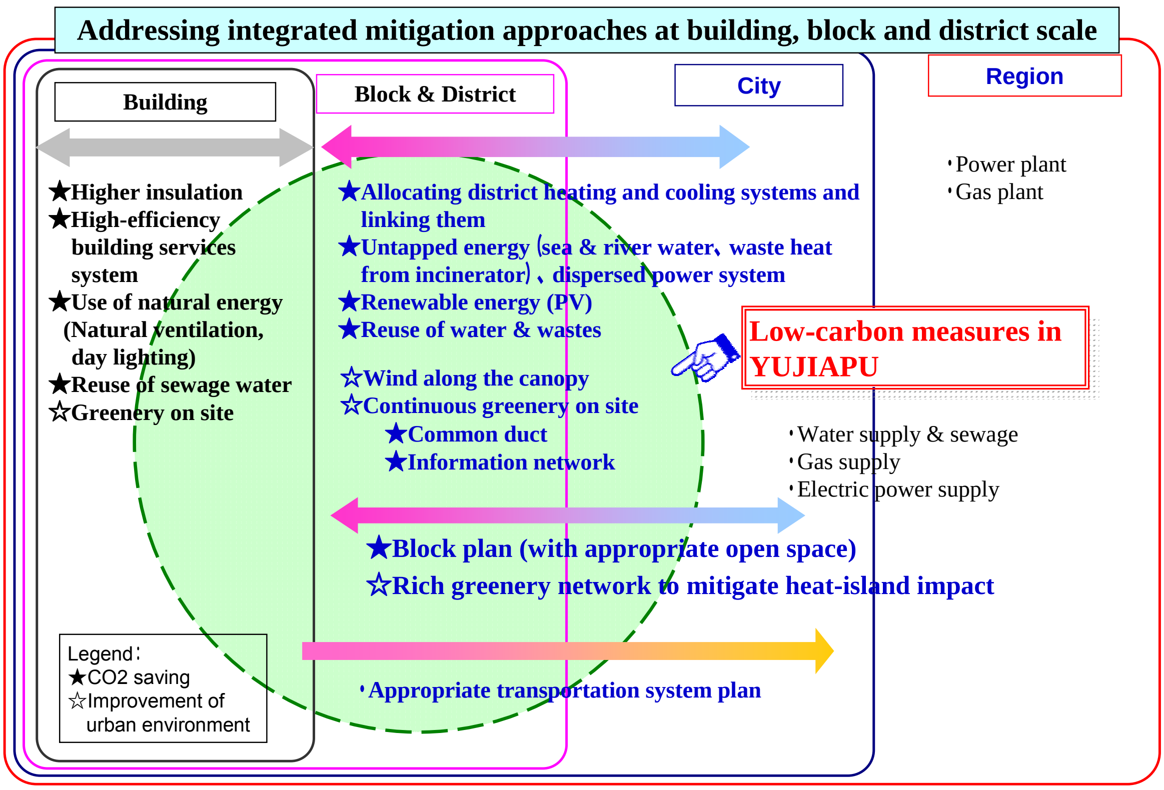


Figure 5.2.2 Methods and Technologies for Low Carbon Measures to be Examined for the Yujiapu District

6. Low-carbon Urban Structural Planning

6. Low-carbon Urban Structural Planning

Key points

- Two concepts and spatial images are shown in order to follow the existing master plan as closely as possible and function as a low-carbon city.

  Concept: Transit Oriented Development and Smart Unit Development

  Spatial image: Urban Station Core and Low-Carbon Corridor
- The idea of Transit Oriented Development (TOD) is applied to land-use planning in order to raise the modal split rate of public transportation. With the streets pattern left unchanged, high density land use is concentrated around public transportation stations and several urban functions such as business, commercial and residential, are vertically mixed. Station Cores which are considered the symbol of TOD are planned to connect stations with surrounding districts.
- In order to adapt phased development, "Smart Units" integrating layers of supply infrastructure, roads, and greenery in each development block are planned. Each smart unit is self-sustained and can be linked with another smart unit. Connection of whole smart units create smart network in all development area.
- Some streets within the district are turned into "Low-Carbon Corridors" that give priority to pedestrians and the natural environment. They become visible symbols of the Smart Units.
- Although Low-carbon Urban Structural Planning contributes to indirect CO_2 reduction, over the long term, it can contribute to the formation of a low-carbon lifestyle and the branding of Yujiapu.

6.1 Outline of methodology and project examples

1) Transit Oriented Development (TOD)

a) The idea of Transit Oriented Development

In recent years, concept of Transit Oriented Development (TOD) is considered popular in the fields of architecture and urban planning. TOD is aiming to realize urban planning and designing walk-able area surrounding train stations. This TOD system is based on the idea of moving away from car-centered urban development toward human-centered urban development.

In other words, since the idea is to plan compact cities based on offices and even homes within walking distance of public transportation stations, it is not necessary to depend on cars. As a result, the environmentally-friendly cities will be achieved with reduced CO_2 emissions. Additionally, the fact that a full range of urban services can be made available around stations, with barrier-free design making movement easy even for senior citizens is also remarkable point.

This type of compact city centered on a railway station matches social needs related to low carbon and aging societies in Japan, China, and the rest of East Asia, as well as in developed countries in Europe and elsewhere.

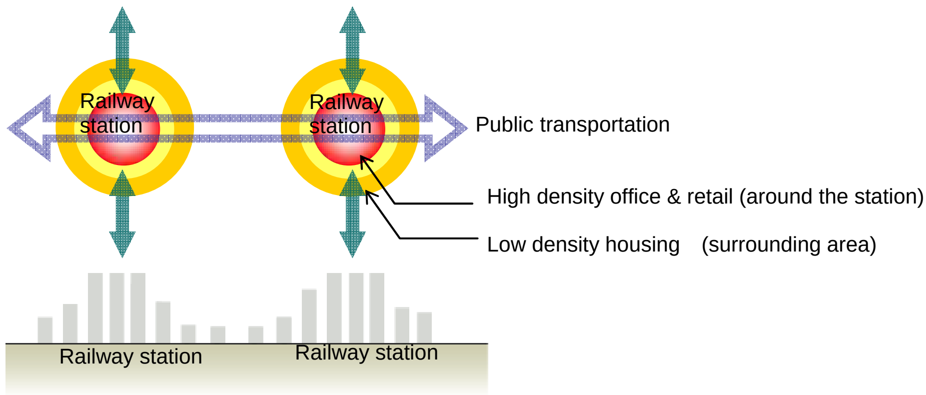


Figure 6.1.1 Transit Oriented Development (TOD) concept

b) Japanese cities centered on railway stations

In Japanese cities, especially in the metropolitan areas of large cities such as Tokyo, Osaka, and Nagoya, the modal split rate of railway is high and the rate of automobile is low compared to other countries all over the world. The map below shows the walk-able distance for pedestrians (radius 750 m) around each railway station from Osaka to Kobe. A large portion of the urban area is covered with these walk-able areas.

This is partly because railway company was trying to construct railway and development along the lines at the same time, mainly in order to promote more railway usage. The result has been that Japanese cities are the best sample of compact cities which are concentrated around railway stations.

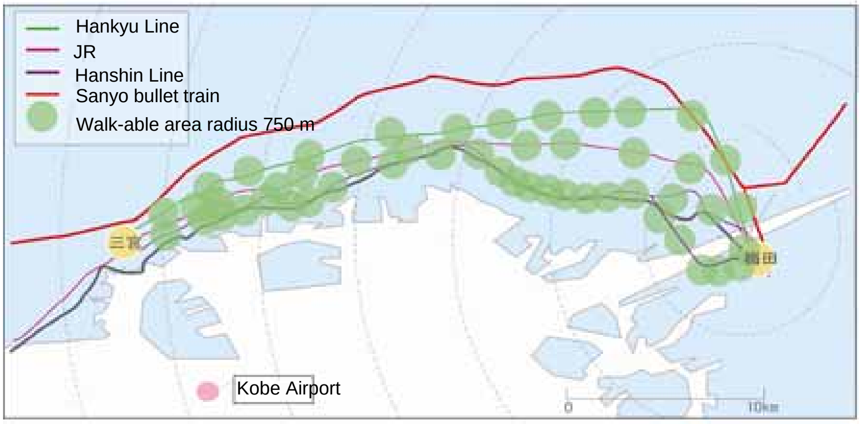


Figure 6.1.2 Walk-able areas around railway stations from Osaka to Kobe

c) More integrating with stations in Japanese cities

The necessity that passengers shall gather around railway stations make them excellent locations for commerce/business. In Japan, therefore, so-called station buildings incorporating commercial facilities have sprung up around major stations. Recently, the form of development in Japan has been "Eki-naka" (inside the station) commerce, typified by the JR Group's "ecute" and Tokyo Metro's "Echica." The reason for the popularity of the Eki-naka model is that it is overwhelmingly profitable, with revenue per square meter reaching 1.5–2 times that of commercial facilities nearby stations (including station buildings).

In addition, the idea of maximizing use of the "Eki-ue" (above the station) has also appeared, with multipurpose facilities around railway stations in large cities. Examples include the JR Group's station building complexes, such as JR Central Towers (Nagoya) Sapporo JR Towers and complexes linked with subway stations, such as Queen's Square Yokohama. This Eki-naka and Eki-ue development seems to have shifted away from priority on operating revenue to combinations of functions essential to city life, such as culture, government services, and support for childrearing, as well as commerce, offices, and hotels. They are fully developing their roles in the functioning of cities.

Table 6.1.1 Examples of Eki-naka and Eki-ue development

Facility name	Station name	Opened	Major uses
Kyoto Station Bldg.	Kyoto	1997	Hotel, department store, cultural
Queen's Square Yokohama	Minatomirai	1997	Office, hotel, commercial, cultural
JR Central Towers	Nagoya	1999	Office, hotel, department store
Izumi Garden	Tokyo	2002	Office, hotel, commercial
JR Tower	Sapporo	2003	Office, hotel, department store, cinema complex
GranTokyo	Tokyo	2007*	Office, department store
ecute Tachikawa	Tachikawa	2007	Food/drink, merchandise sale, school, clinic, daycare

*Stage 1 only; Stage 2 is scheduled for completion in 2013

■ JR Central Towers

■ ecute Shinagawa

■ Izumi Garden

Complex of offices, hotel, residential, and retail

Completed: 2002

BUA: 208,400 m^2

Stories: 2 basement

45 aboveground (tower)

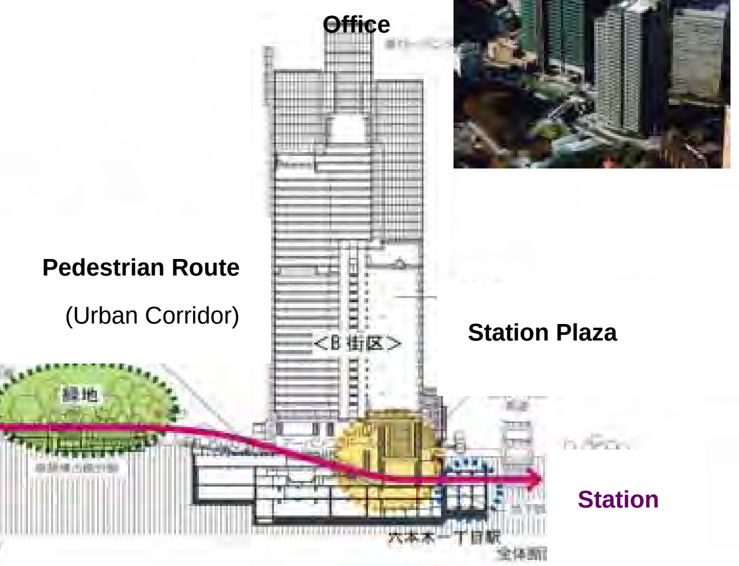
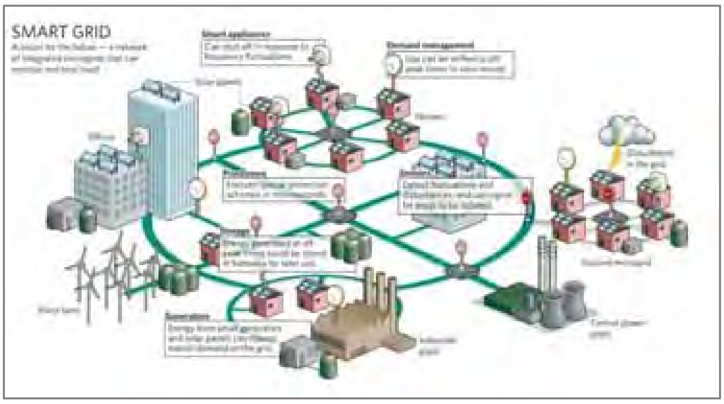


Figure 6.1.3 Example of station-complex facilities

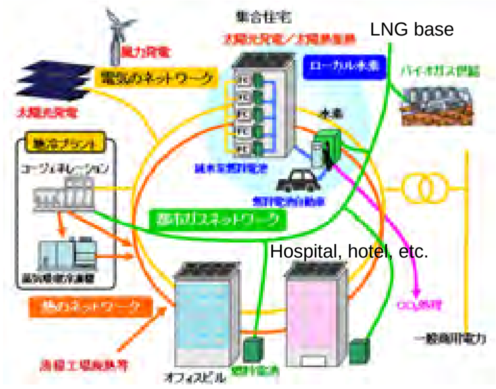
2) Smart City

a) Smart Grid, Smart Energy Network, Smart Community

In recent years, to make cities “smarter” is generally recognized for more efficient energy usage. The concepts of Smart Grids (power grids that include natural energy, and so on), Smart Energy Networks (networks that include heat as well as electricity), and Smart Communities (communities that incorporate such technologies into their lifestyles) are also being advocated.



Smart Grid concept



Smart Energy Network concept (Tokyo Gas website)

Figure 6.1.4 Smart Grid and Smart Energy Network concepts

b) Examples of smart cities around the world

There is no clear definition of a "smart city," but cities that adopt the above "smart" concepts in whole or in part are often called "smart cities." One of the world's most celebrated implementation of the smart city concept is Amsterdam Smart City in the Netherlands. On the Climate Street in the center of the city, smart meters have been placed in shops along the street in order to work towards reducing energy use. In DongTan New Town in Republic of Korea, management of parking lot use, advertising, and so on through an IT network has already been implemented on a trial basis.

Amsterdam Smart City

Dongtan New Town, Republic of Korea

Figure 6.1.5 Examples of smart cities

In Japan, some experimental smart city projects are now undergoing. First one is a smart city experiment linking three districts in Yokohama City, Kanagawa Prefecture and another is Kashiwanoha Campus City project in Chiba Prefecture which is collaborated by the private sector, public sector and university.

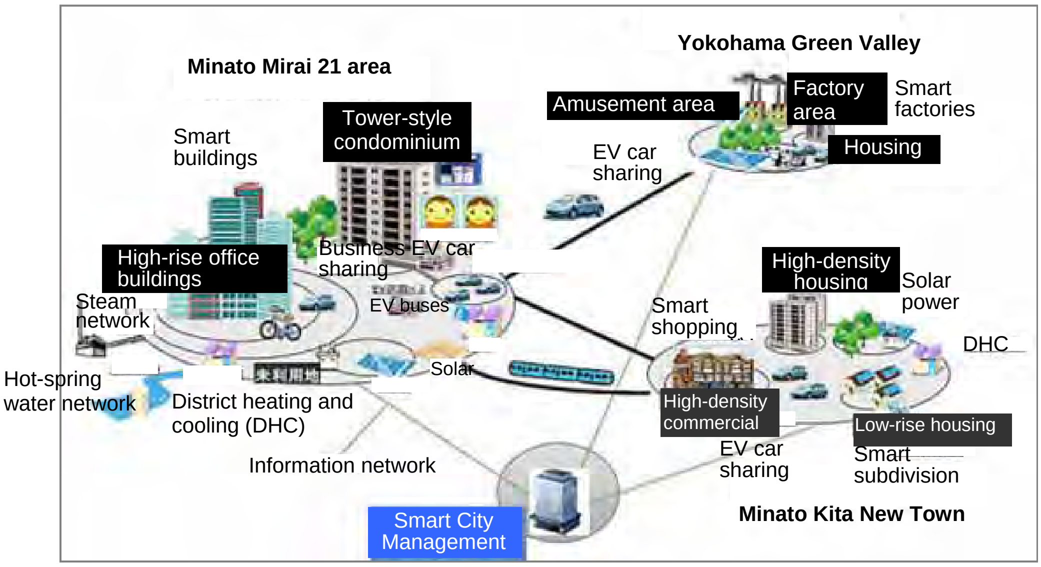


Figure 6.1.6 Experimental smart city concept in Yokohama

6.2 Examination of the adoption of low-carbon technology in this plan

1) High density, mixed-use zoning around public transportation stations

a) Concept

- Various urban functions, which are retail, restaurants, commercial, housing and livelihood supporting facilities are concentrated around public transportation stations.
- Zoning not only increases convenience for people living around stations, but also creates activity and contributes to financial condition of railway company

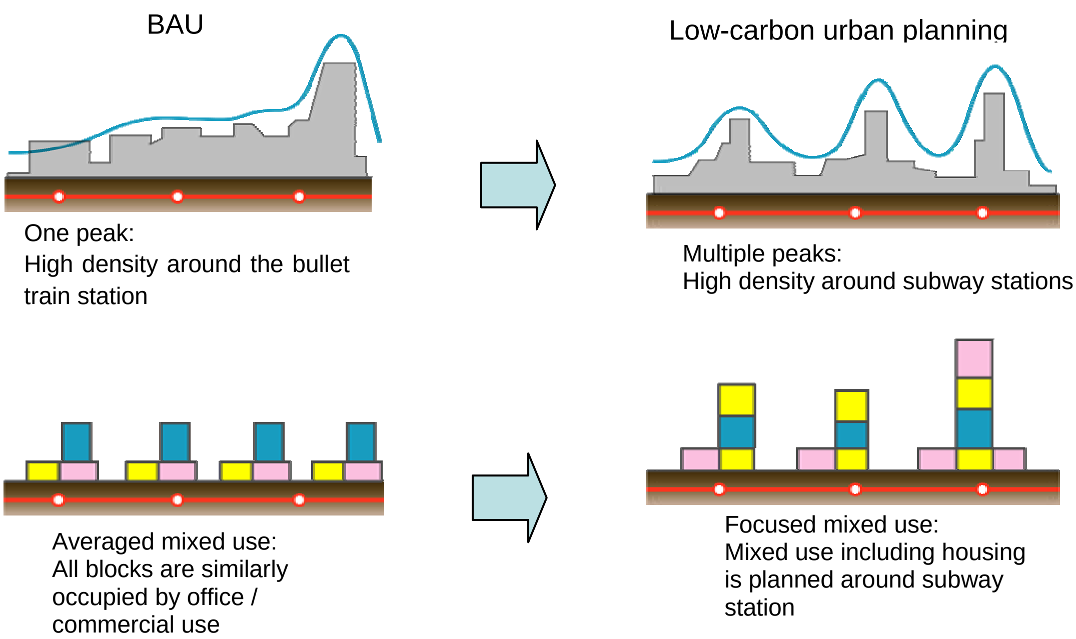
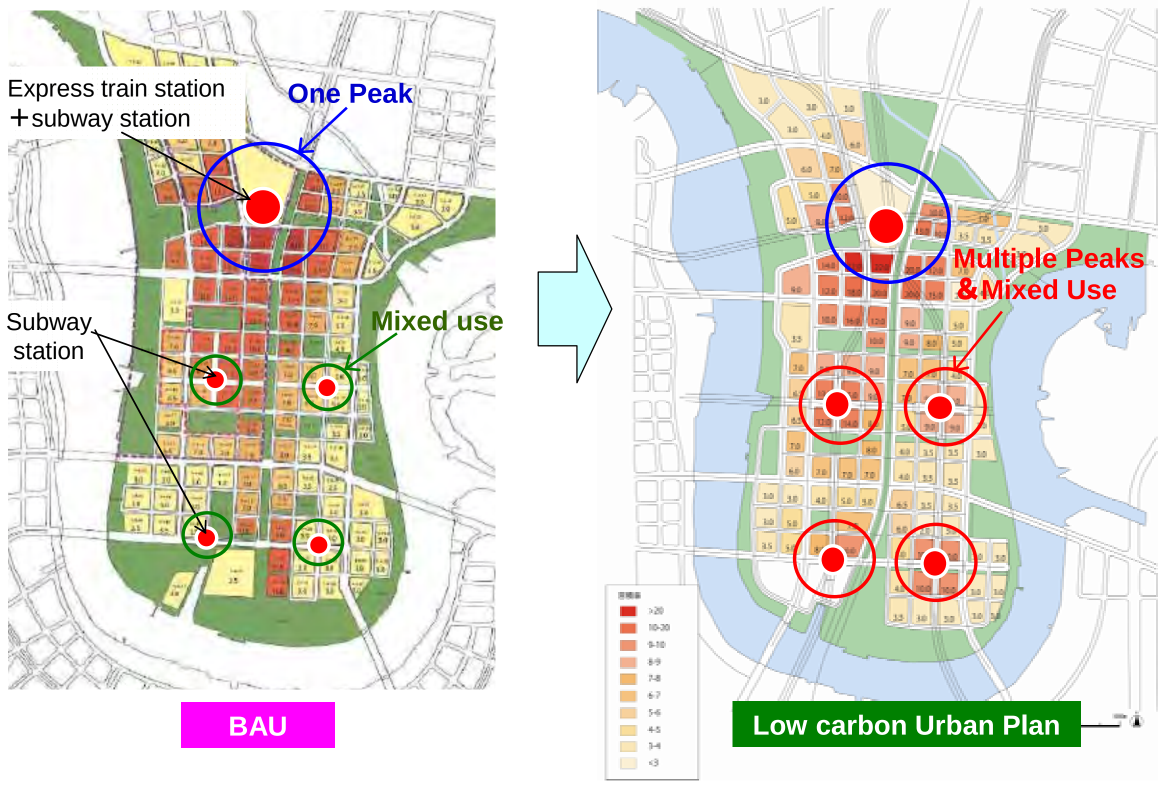
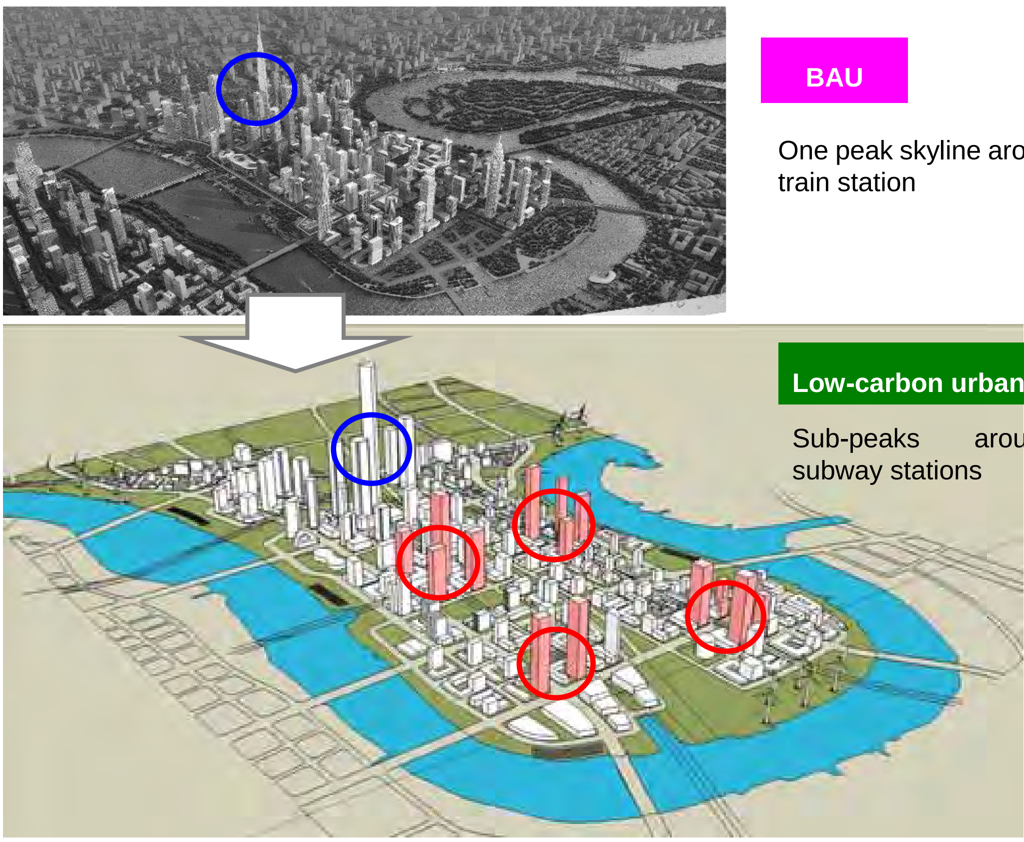


Figure 6.2.1 Idea of high-density, mixed-use zoning around public transportation stations

b) Image of adoption





BAU

One peak skyline around express train station

Low-carbon urban planning

Sub-peaks around each subway stations

Figure 6.2.2 Image of highly functional zoning around stations

2) Urban station core connecting to public transportation station

a) Concept

- Urban Station Cores which connect between subway stations and adjacent private developments are planned.
- Natural elements (light, ventilation and sound) are actively incorporated to underground space in order to reduce environmental impact.
- Station spaces are used to create a comfortable and attractive pedestrian festivity and are expected to be the focal point of pedestrian movement.

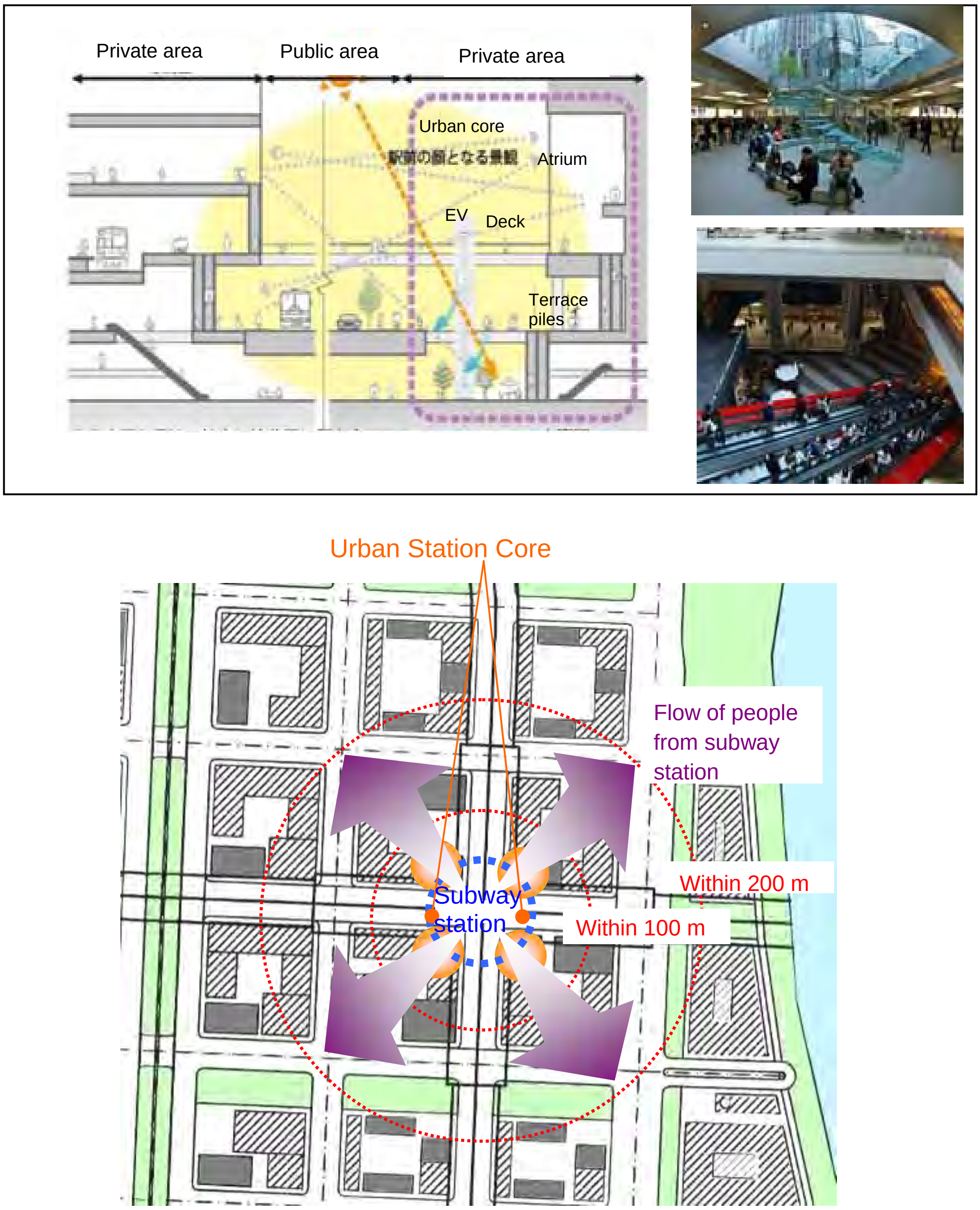


Figure 6.2.3 Concept of Urban Station Core

b) Image of adoption

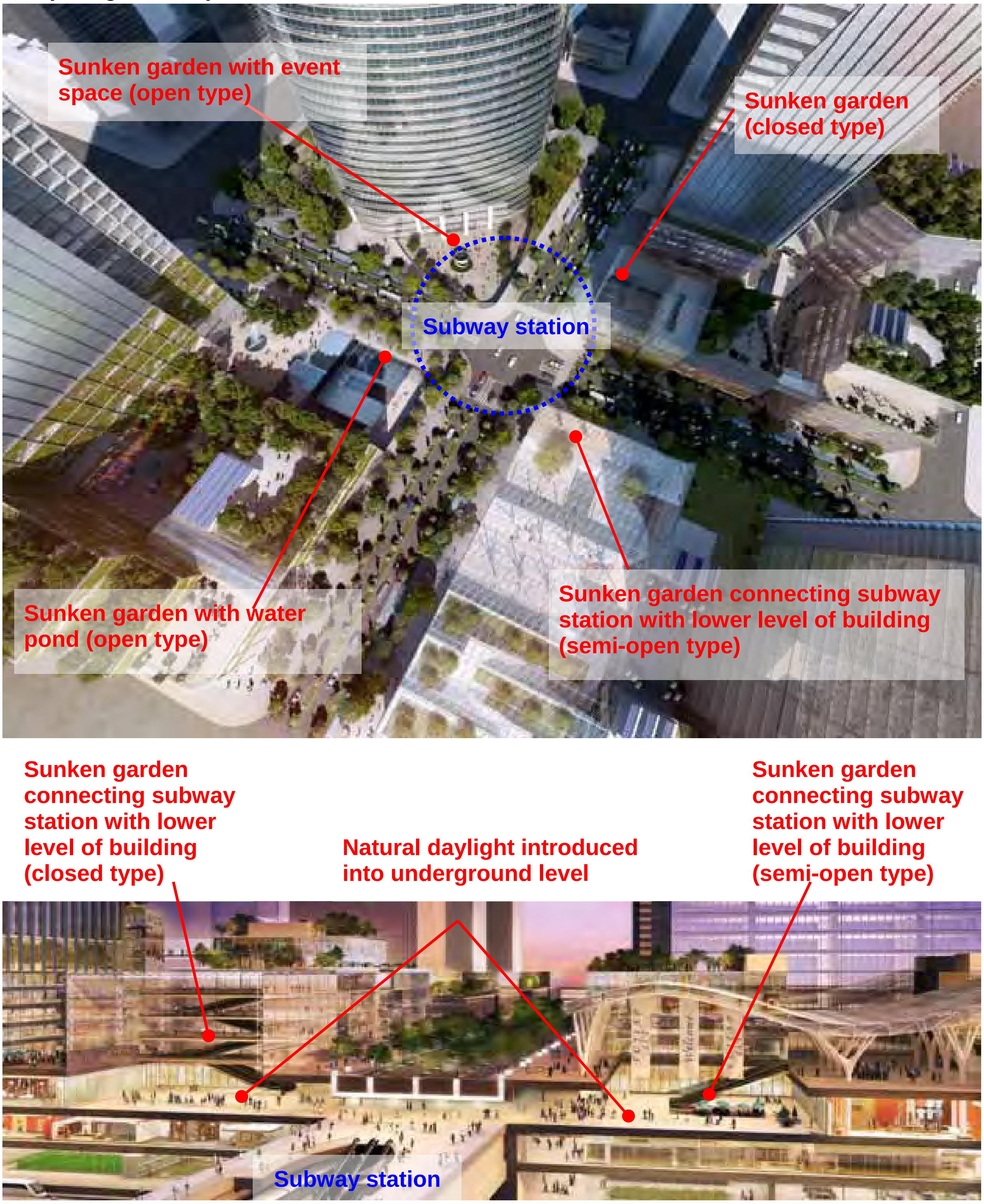


Figure 6.2.4 Image of various types of Urban Station Cores connected with subway stations

3) Smart units integrating energy, transportation and greenery

a) Concept

In conventional way of urban planning, a street plan and land use plan came first, accompanied by a greenery plan for parks, a transportation plan, a plan for energy infrastructure, and so on.

In this district, optimized energy use is premised from the initial planning stage, with the aim of creating a smarter city by integrating energy, transportation, and greenery.

Because development in this district is extremely large in scale, all infrastructures will be packed in modular units that can be connected as development progresses. This will enable phased development and the realization of a smart city during any stages. It can be likened to build a jigsaw puzzle with the smart units as the pieces.

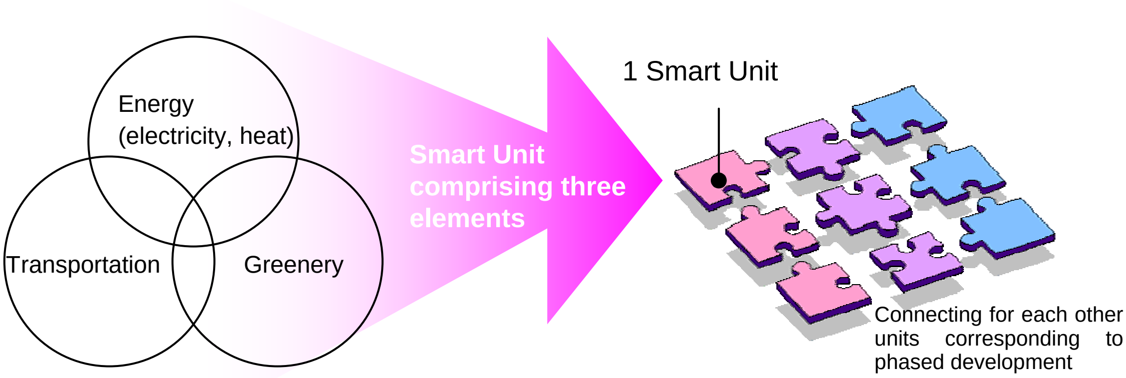


Figure 6.2.5 Smart Unit concept (1)

One smart unit (generally a DHC supply area) is considered adequate scale for sub-developers to enter into real estate business.

Energy centers such as main DHC plants are located beneath parks or other open spaces (public land), which increases overall security for the area and makes efficient use of space.

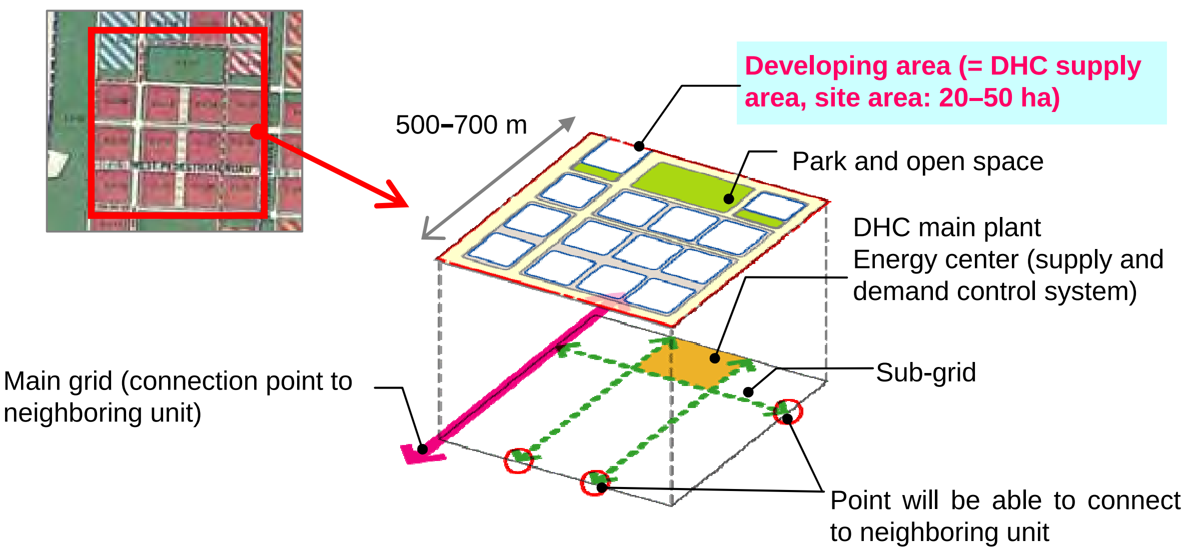
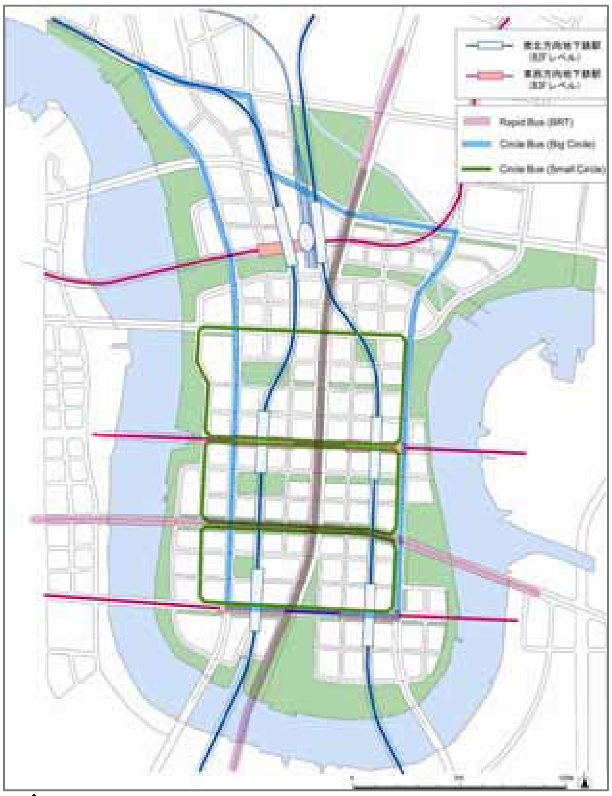


Figure 6.2.6 Smart Unit concept (2)

b) Image of adoption

◆ Smart Unit area (DHC supply area)



◆ Public transportation network

◆ Common conduit + heat network

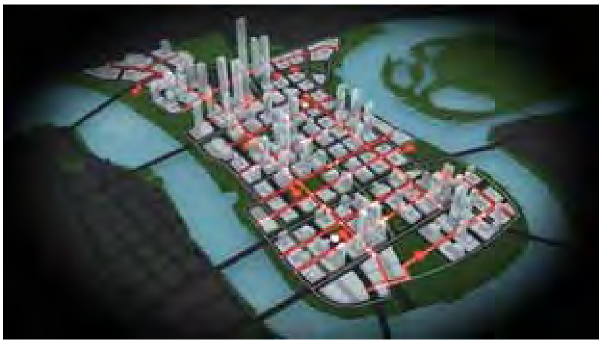
◆ Green electric power network

Figure 6.2.7 Smart Unit development image (1)

◆ Public transportation network (subway + BRT)

◆ Smart Unit area (DHC supply area)

◆ Common conduit (main line)



◆ Heat network (sub-main line)

◆ Green electric power network (sub-main line)

Figure 6.2.8 Smart Unit development image (2)

4) Low-Carbon Corridor

a) Concept

Low-Carbon Corridors which integrate energy infrastructure, transportation and tree-lined streets are located within the district, creating a cityscape that symbolizes the Low-Carbon CBD.

- Streets in the district other than main roads are planned as Low-Carbon Corridors
- A city infrastructure system integrating energy, transportation, and greenery are constructed
- Development of waterways creates wind paths and cool spots in pedestrian spaces
- Three-dimensional pedestrian spaces combining public underground walkways and sunken gardens inside of private projects, are created

Streets other than main roads with a width of 40 m are planned as Low-Carbon Corridors

Blue: 30-m wide streets
Pink: Streets with widths of 20 m or less

Figure 6.2.9 Placement of Low-Carbon Corridors

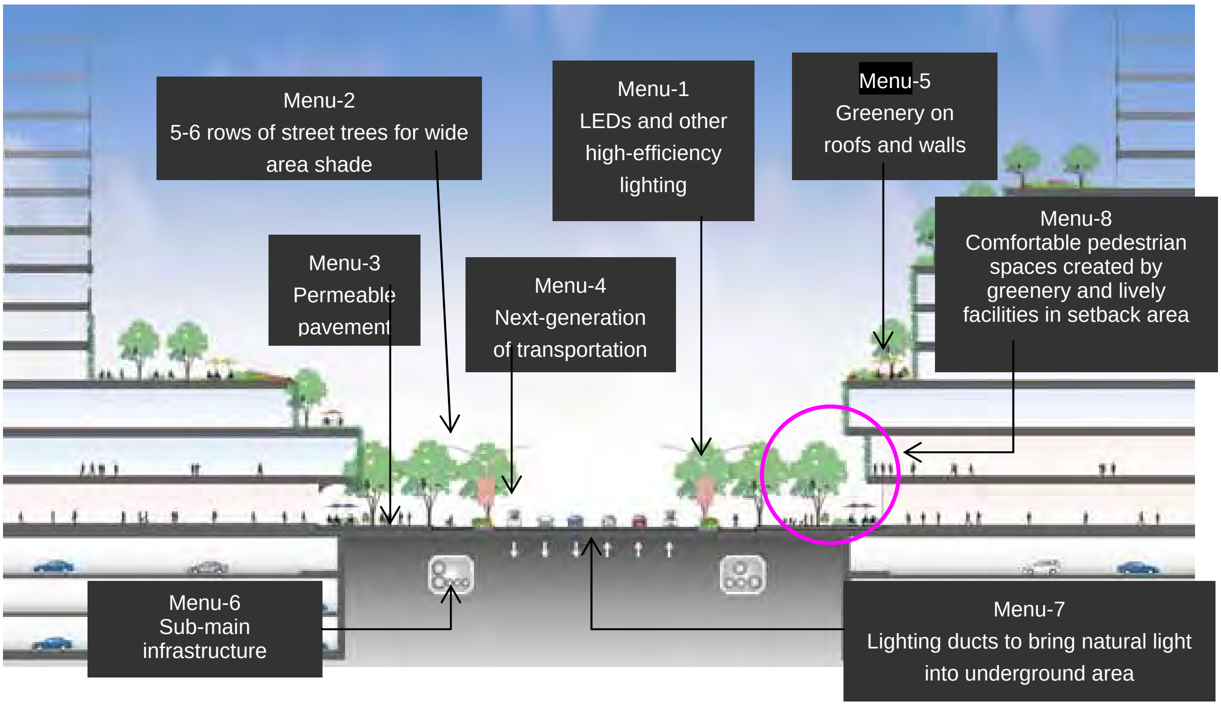


Figure 6.2.10 Basic menu for Low-Carbon Corridors

b) Image of adoption

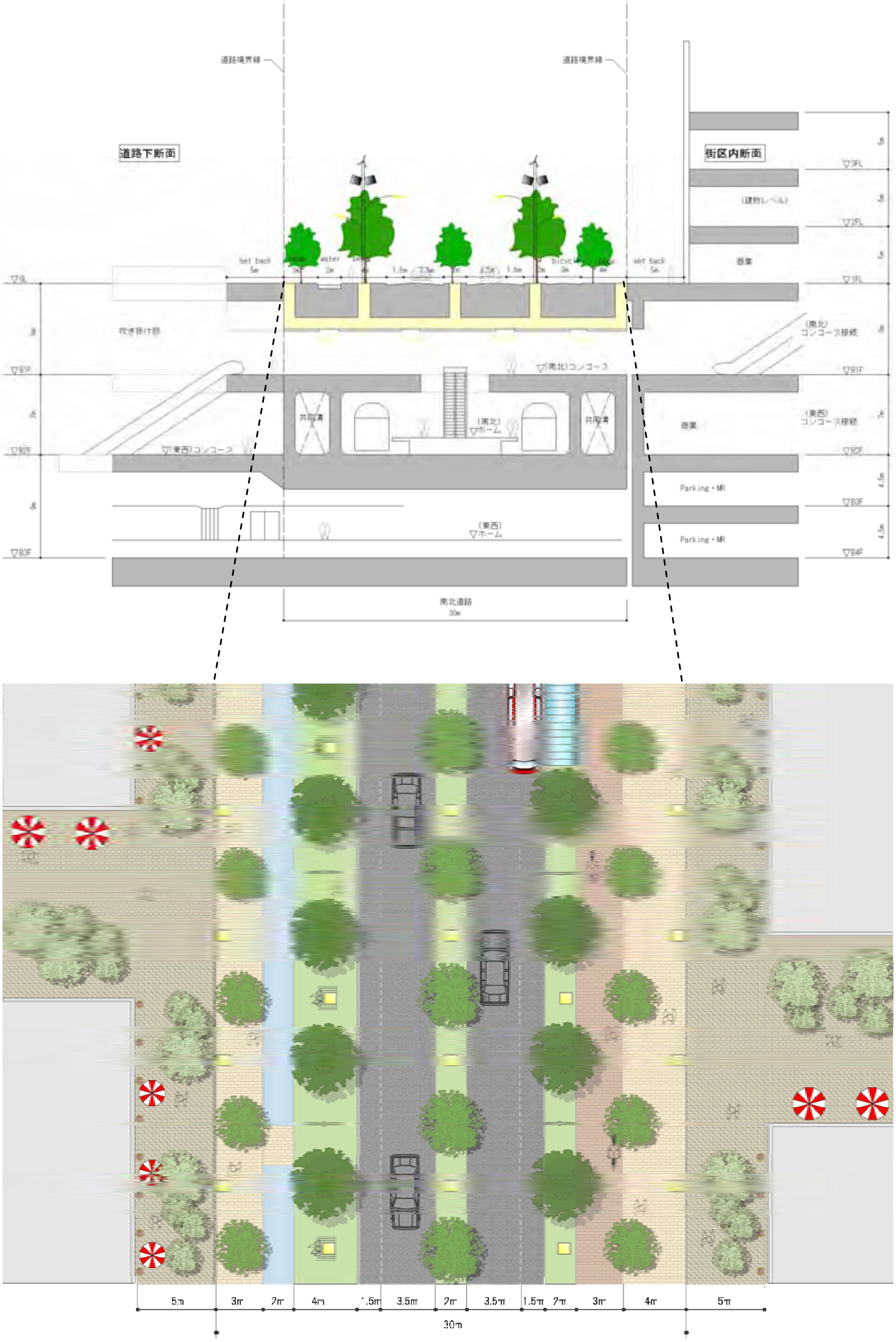


Figure 6.2.11 Image of Low-Carbon Corridor plan (in the case of 30-m width)

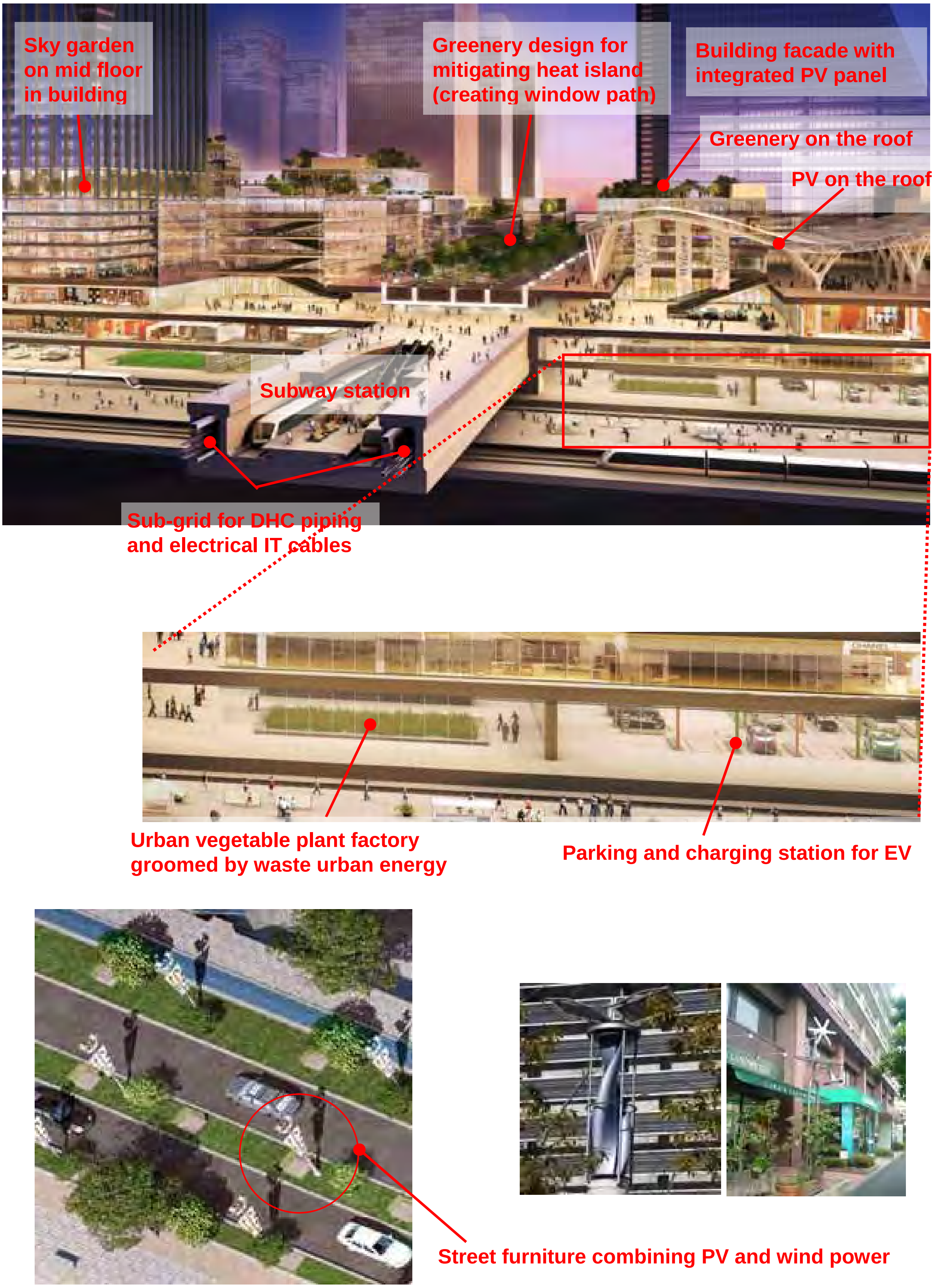
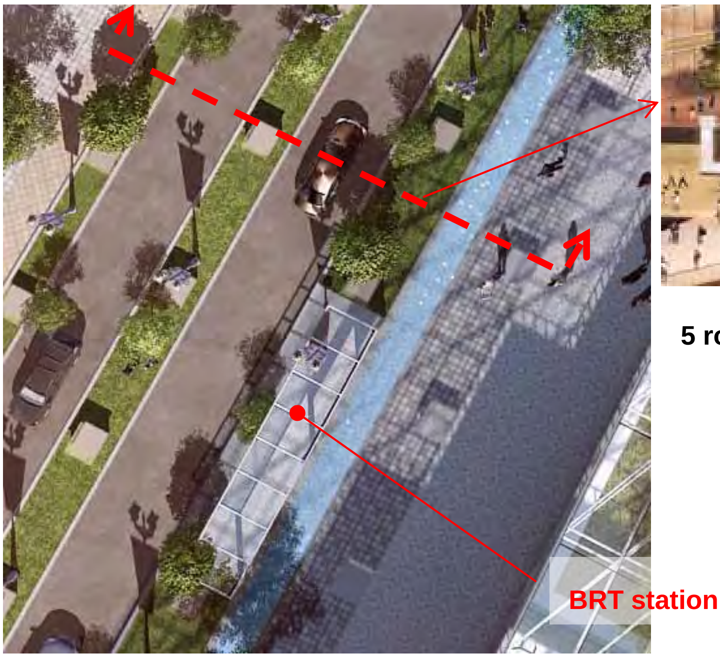


Figure 6.2.12 Image of Low-Carbon Corridor (1)



5 rows of trees and lighting ducts

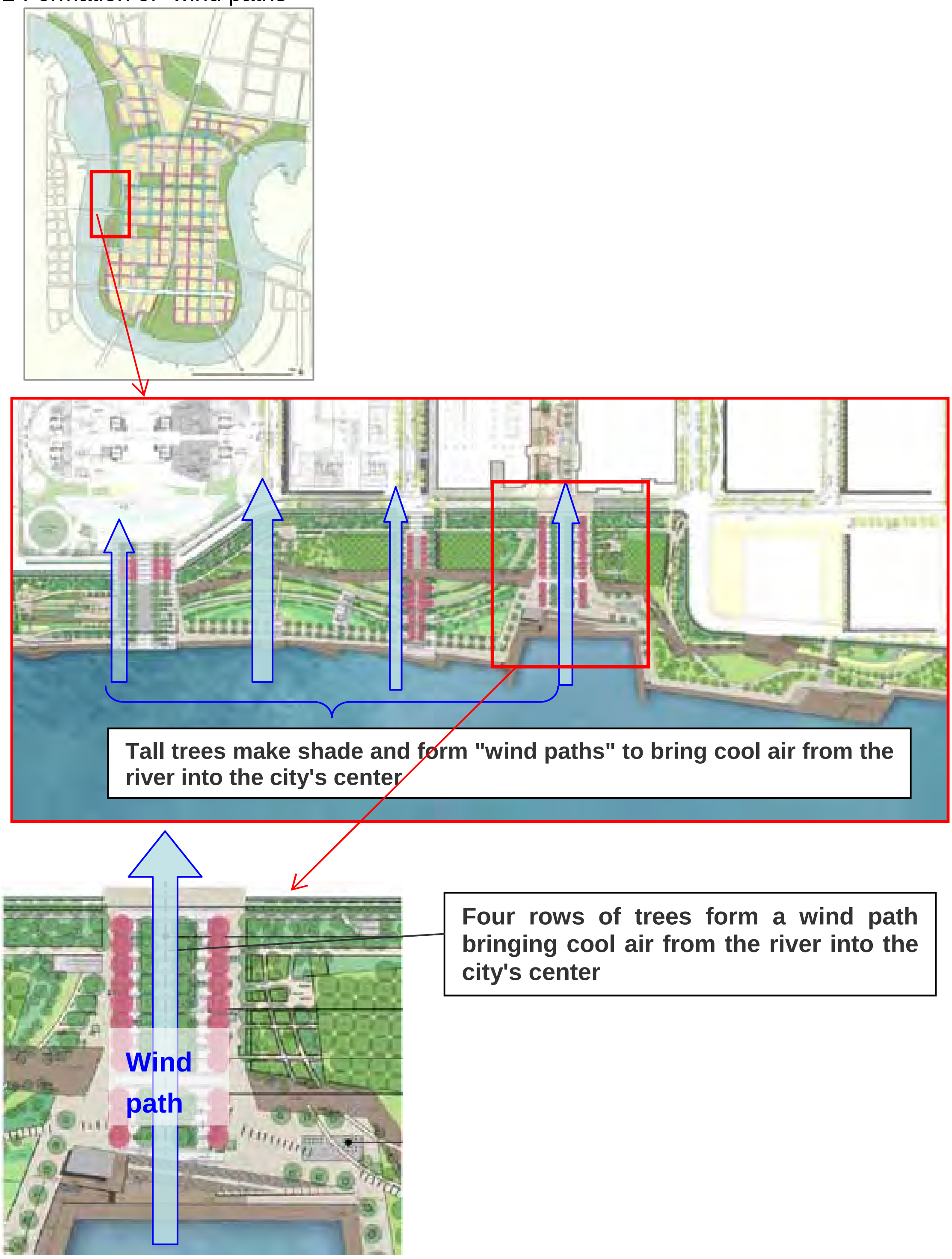
Greenery and activity in private area

Figure 6.2.13 Image of Low-Carbon Corridor (2)

<Riverside Low-Carbon Corridor>

- Linear-shaped parks along the river are planned as Riverside Low-Carbon Corridors
- Greenery are planned in order to provide comfortable pedestrian spaces, mitigate heat island effects and form comfortable heat environments.
- Landscapes in harmony with the environment are developed with integrated PV

■ Formation of "wind paths"



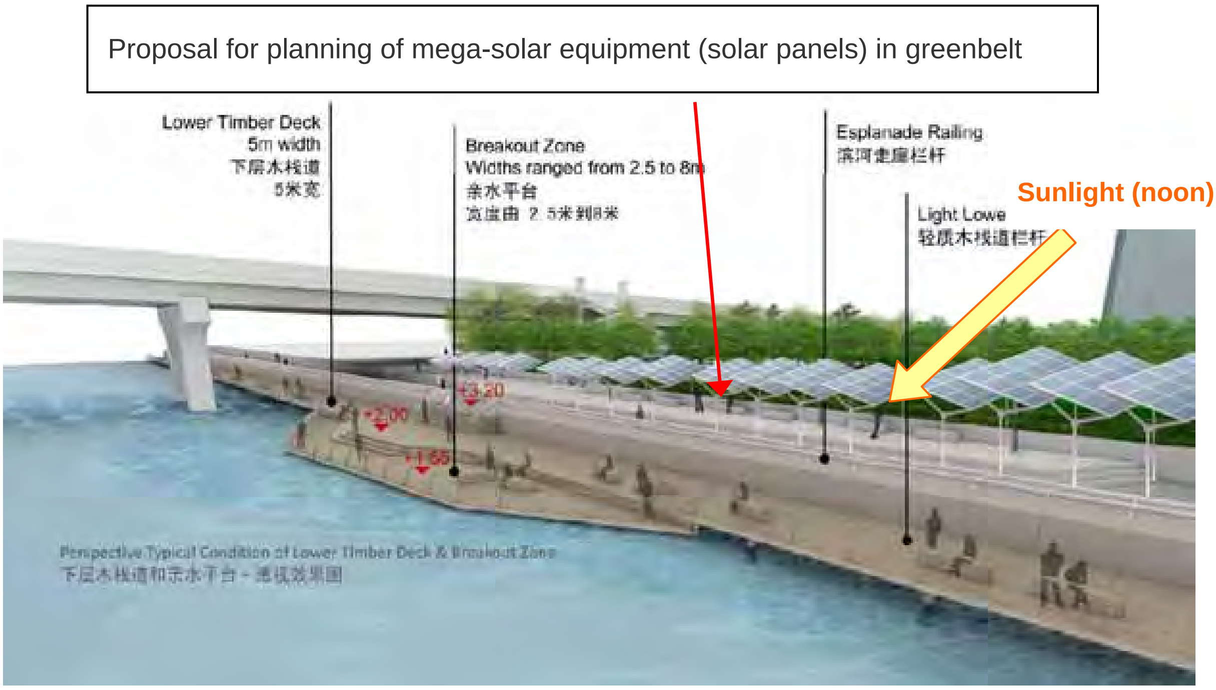
■ Planting Design for different purposes

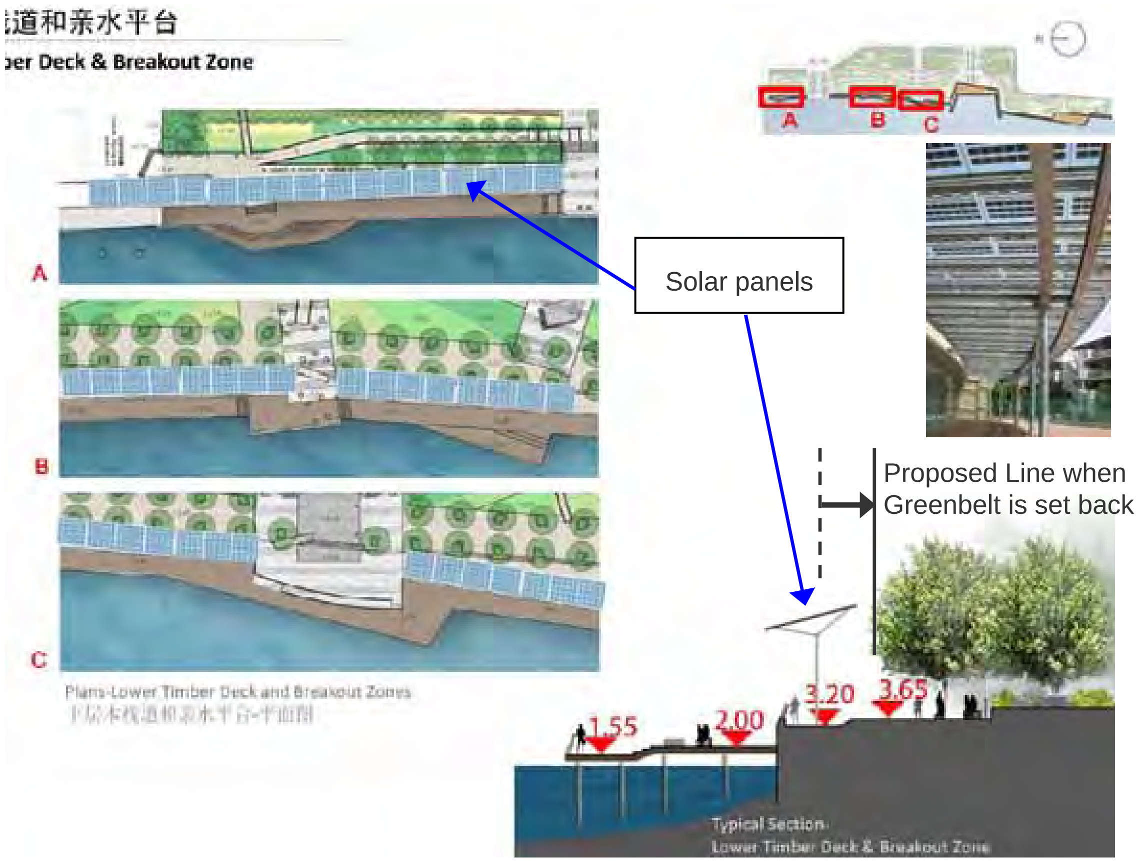
- **Eco-consciousness:**
  Diverse species suited to a cold climate with an emphasis on biodiversity
  (Examples) evergreens, deciduous conifers, etc., groundcover with mats of wild grasses, etc.

- **Improvement of warm environments:**
  Selection of tall trees with large canopies to make shade
  (Examples) Japanese zelkova, Japanese elm, Platanus, etc.

- **Landscape:**
  Selection of species to form comfortable and beautiful landscapes (biodiversity will be considered but not prioritized)

■ Mega-solar plan creating comfortable environment for the riverside pedestrian way



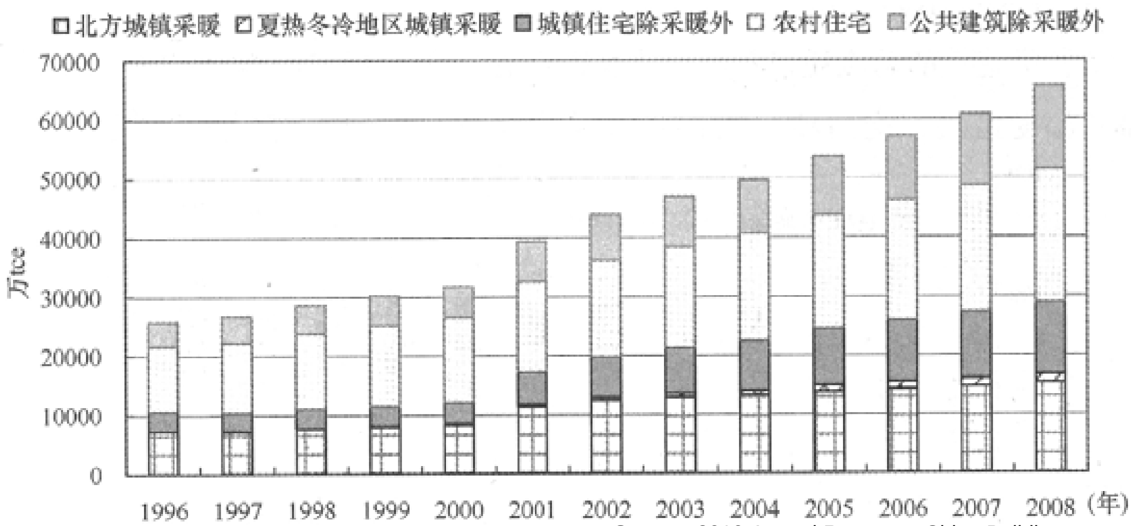


7. Design Methodology of Low Carbon Architecture

7.1 The Present Situation of Building Energy Consumption in China

China Building Energy Model (CBEM) statistics show that the building energy consumption in China increases 1.5times from 259 million TCE (Ton of Coal Equivalent) in 1996 to 655 million TCE in 2008. According to the climatic factors, economy level, building use, and different energy consumption features, the total building energy consumption could be divided into 5 parts: (1) North urban area heating, (2) heating in the hot-summer and cold-winter region, (3) urban housing energy consumption except for heating, (4) rural housing, and (5) public buildings except heating (see Figure 7.1.1). Actually, in 2008, buildings took 23% of total energy consumption and 715.8 billion kWh of electric power that made up 22% of China's total power generation. in China (Source: 2010 Annual Report on China Building Energy Efficiency)

North urban heating
heating in hot summer and cold winter region
urban housing energy except heating
rural housing
public building except heating



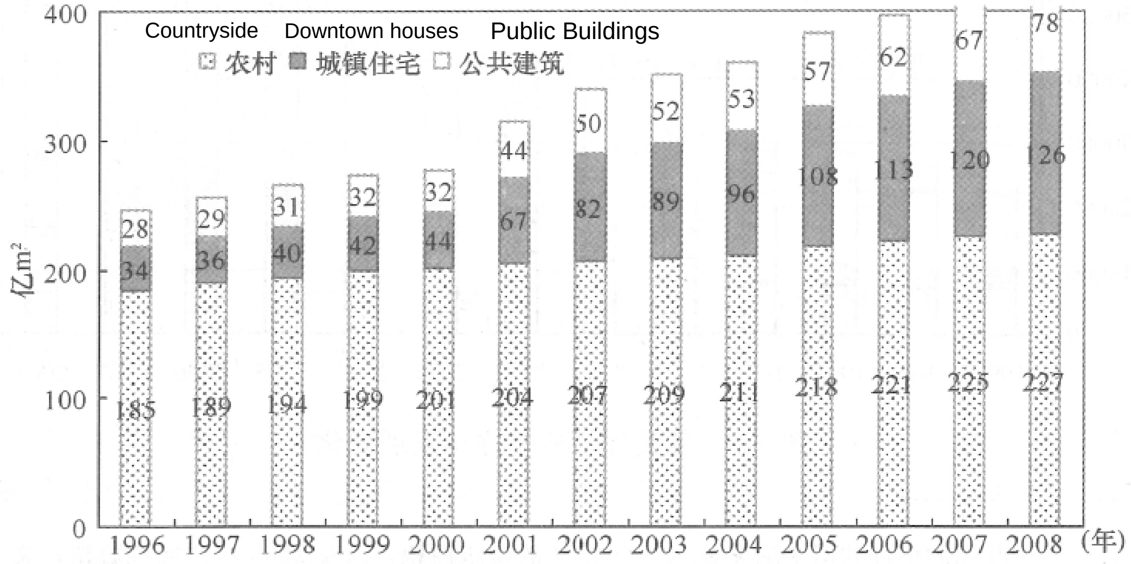
Source: 2010 Annual Report on China Building Energy Efficiency, THUBERC

Figure 7.1.1 Building Energy Consumption in China from 1996–2008

One of the two remarkable reasons for this rapid increase in building energy consumption was increase in the energy consumption per floor area. It was 10.5 kgce/(m^2·a) in 1996, and then it increased to 15.2 kgce/(m^2·a) by 2008. This was a direct result from changes in room heating, developed service qualities and the proliferation of office automation (OA) equipment. The only exception to this was the district heating energy conservation in the northern territory that was greatly reduced with energy-saving efforts between 1996 and 2008. The other reason was increasing total floor area (so was the floor area per person) in the rapidly urbanizing area. As shown in Figure 7.1.2, the total floor area of buildings in the Chinese urban area was 6.2 billion m^2 in 1996, and then it increased to 20.4 billion m^2 by

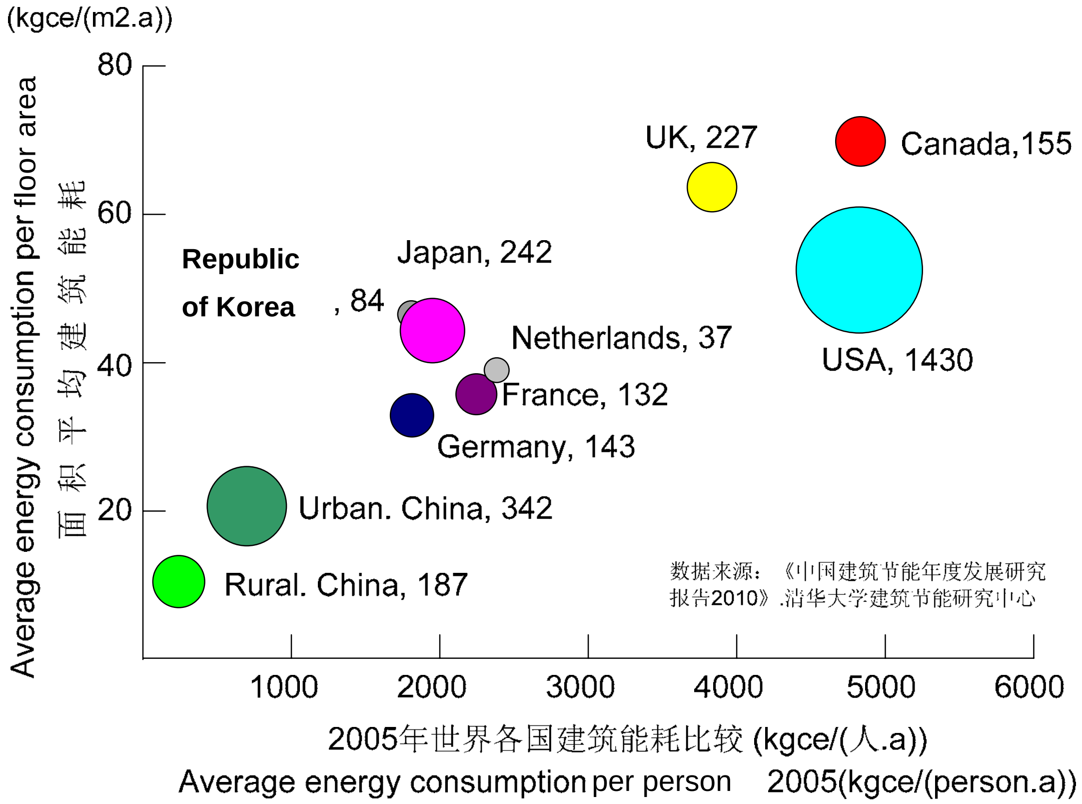
2008. The total floor area of building stocks in China was 24.7 billion m^2 by 1996, and then increased 1.7 times to 43.1 billion m^2 by 2008.

However, Chinese annual average energy consumption per total building floor area and annual average energy consumption per person in China are both much lower than that of developed countries (see Figure 7.1.3).



Source: 2010 Annual Report on China Building Energy Efficiency, THUBERC

Figure 7.1.2 The Total Floor Area of Buildings in China 1996–2008



Note: Ton of Coal Equivalent, 1 kgce = 7,000 kcal = 29.302 MJ

Figure 7.1.3 Building Energy Consumption in Various Countries 2005

1) Energy Consumption of Heating in Northern China Cities

The centralized district heating systems are generally used during winter in urban area of North China. This system provided heat to as much as 90% of buildings on a floor area basis in 2008. And its energy consumption made up 25% of national building energy consumption and 40% of urban building energy consumption.

The energy consumption of northern cities was 72 million TCE (1 TCE = 29.3076 GJ) in 1996, and then increased about 2.1 times to 153 million TCE by 2008. This rising tide was due to an increase of building floor area. However, heat energy consumption per floor area decreased from 24.3 kgce/(m^2·a) in 1996 to 17.4 kgce/(m^2·a) in 2008 through political efforts of improvement of building facade material quality and instillation of energy efficient centralized heating system.

The following are heat energy consumption characteristics of northern cities in China:

a) Energy consumption for heating per area had decreased between 1996 and 2008, because the total floor area increased of buildings grew three times while energy consumption increased to double .

b) The floor area of buildings heated with district heating systems is still increasing now.

Current district heating systems such as cogeneration systems, large boiler systems, and dispersed heating systems with smaller boilers, are adapted. These efficiency is different from each other.

c) The number of energy-efficient buildings with high quality building facade materials is increasing through a variety of low-energy schemes in recent years.

d) The billing system for heating energy still has room for improvement. It may result in excessive energy supply and loss of energy.

e) It is needed to facilitate energy efficiency awareness and promotion in the public at large.

f) Optimum heating system and higher energy conversion efficiency are the new direction for the area.

2) Energy Consumption for Housing Heating in the Hot-Summer/Cold-Winter Urban Zone Cities

China's hot-summer/cold-winter in Chinazone is an area that needs winter heating but has no district heating system. In 2008, 46 billion kWh of electric power was consumed for urban housing heating in this zone, and electric power consumption for individual heating systems was 5–10 kWh/(m^2·a) per housing floor area. In Greece, a country in same climate zone as China, power consumption per housing floor area for winter heating was 40 kWh/(m^2·a), which was much higher than that of China. This is because the heating temperature is set to 22°C for all rooms continuously in Greece, while the heating temperature is set to 14–16°C for necessary-space-and-time basis in China. The way of daily life greatly affects energy consumption.

3) Urban Housing Energy Consumption Except for Housing Heating

Chinese urban housing energy consumption except for housing heating was 34.1 million TCE in 1996 and increased 3.5-times to 120 million TCE until 2008, while energy consumption per floor area slightly decreased. Energy consumption for cooking per floor area has greatly decreased, because the cooking fuel in urban housings has been shifted from coal to city gas. The widened housing floor area per person with the developing economy also helps this trend. On the other hand, energy consumption of housing equipment come from home electrical products is greatly especially for air conditioning.

The non-heating energy consumption except for housing heating is affected from followings:

a) Increasing Total Floor Area of Buildings:

In recent years, urbanization in China has been rapidly progressing. Between 1996 and

2008, the urban population increased twice from 373 million to 607 million. Besides, total building area of urban housing increased 3.5-times in the same period.

b) Increasing Number and Operating Time of Household Electric Appliances:

The energy consumption of rapidly spreading household electric appliances keeps increasing with increasing operating time through improvement in people's daily lifestyle.

c) Lifestyles:

Nationwide economic prosperity improves service quality in households.

4) Housing Energy Consumption in Rural Area

In Chinese rural housings, energy is used for heating, cooking, lights, and household electric appliances. Energy such as coal, gases, electricity, and biomass fuels, including wood, meet these demands. Energy consumption in Chinese rural households was 245 million tce in 1996 and increased to 355 million tce until 2008 because rapidly spreading household electric appliances demand larger electrical power than ever, which reduces biomass fuel use from 55% to 38%.

5) Energy Consumption in Public Buildings for Various Purposes Other Than Heating

Electric power consumption of Chinese public buildings for any purpose other than heating is rapidly increasing nowadays compared with other types of energy. The annual energy consumption differs greatly according to the size and use and Building Spec of the building. The public buildings with a central air conditioning system whose total floor area is 20,000 m^2 or more are called "large-scale public buildings," and the buildings smaller than that are called "general public buildings." Table 7.1.1 shows the differences in these two types of public buildings in their building feature of air conditioning systems, and elevators. According to an energy consumption survey result, large-scale public buildings consume two to five times larger energy per floor area than that of general public buildings.

Table 7.1.1 The Differences in Large-Scale Public Buildings and General Public Buildings

	General Public Buildings (offices, schools, hotels, commercial facilities)	Large-Scale Public Buildings
Building Features	Smaller scale, Capable of natural ventilation	Larger scale and interior area, Glass curtain walling, Incapable of natural ventilation
Air Conditioning Systems	Fans, Packaged air conditioner, VRF	Central plant air conditioning system
Elevators	Not equipped	Equipped

Source:城市消費領域的用能特征与節能途径 P139　中国建築工業出版社）

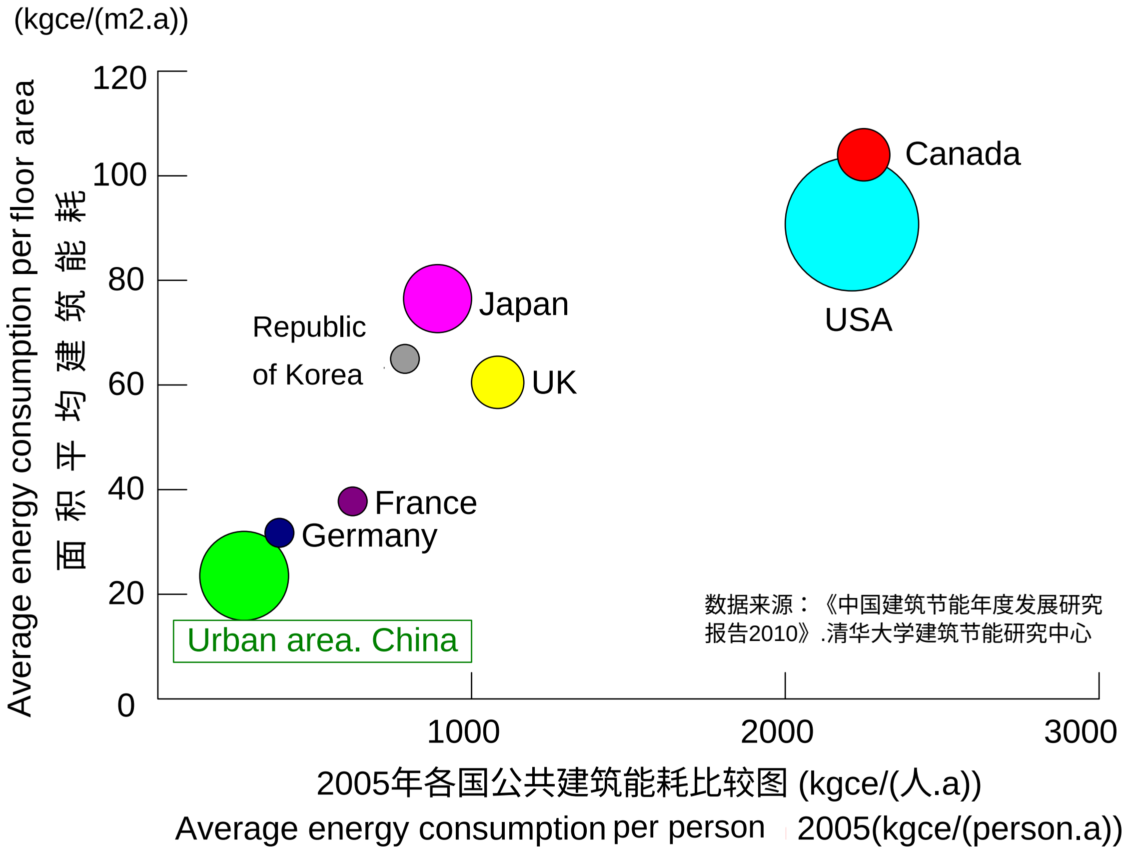


Figure 7.1.4 Energy Consumption of Public Buildings in Various Countries 2005

a) Figure 7.1.4 shows energy consumption of public buildings in the world in 2005. The horizontal axis shows energy consumption per person, the vertical axis shows energy consumption per total floor area, and the diameter of a circle is the total of the country (unit: million tce). For China, both energy consumption per capita and per total floor area are smaller than those of developed countries.

b) Large-scale public buildings that consume 100–300 kWh/(m^2·a) annually have been built after 1990. Although their total floor area is only 5% of all public buildings, their electric power consumption makes up as much as 17%.

c) Number of Large-Scale Public Buildings is continuously increasing. It is the future challenge to save energy consumption coming from them.

d) Dual Sector Model

The dual sector model is an analytical model invented by an American economist A. Lewis, in order to provide an economic explanation of developing countries' problems. It, having been made up through an analysis of the surrounding nations' situations in the 1930s, explains developing countries' economy, dividing them into a capitalist sector (modern sector) and survival sector (traditional sector). Lewis claimed that in developing countries, these two sectors can enjoy co-prosperity, and the economic development of a developing country requires a functional relationship of these two sectors.

It turned out through some research that this model can be applied to clarify the energy consumption characteristics of Chinese public buildings. Figure 7.1.5 shows them on an annual basis. The horizontal axis shows annual power consumption per total floor area, or energy use intensity (EUI), the vertical axis shows the frequency of appearance in actual energy condition surveys, that is, the number of buildings researched, and the curve is the actually measured distribution of the energy consumption of a Chinese city. This type of curve for Chinese public building energy consumption typically has two peaks, which is different from that of developed countries. Although most sample EUIs are in the range of 50–70 kWh/(m^{2}·a), some others are as much as 120–150 kWh/(m^{2}·a), that is, 1.8–2.6 times higher than that of the former one.

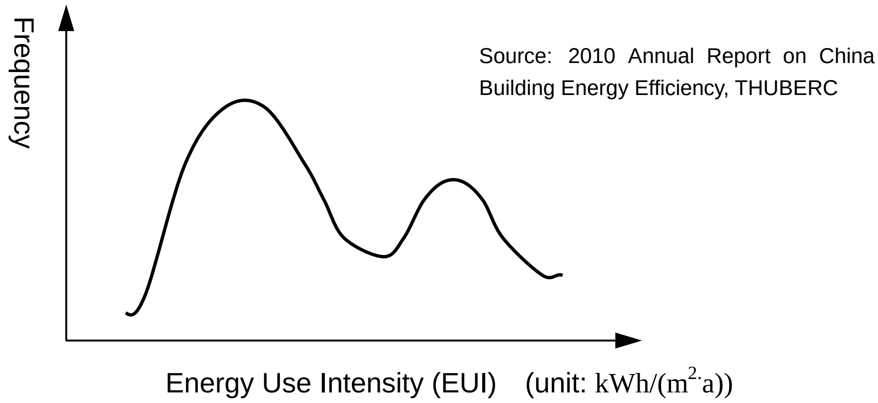


Figure 7.1.5 The Distribution of Chinese Public Building Energy Consumption

7.2 Energy-Conservation and Low-Carbon Emission Measures of Different types of Buildings

1) Office Buildings

a) Features of Energy Consumption of Chinese Office Buildings in China

The demands for new office buildings in the Chinese urban area are growing with their booming economy every year. These new office buildings' larger scale and more complex character become a focus of attention. Generally speaking, the larger an office building becomes the ampler space for other than offices, for example, shops and parking lots, are needed, which results in more structural diversity.

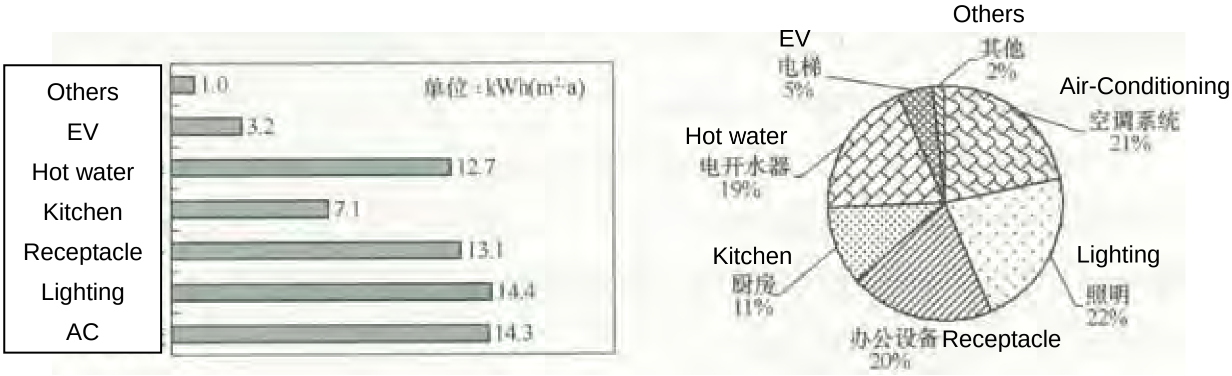
Thus, we need to know the energy consumption mechanism in office buildings to get lower carbon emissions and higher energy efficiency. Table 2.1.1 shows the energy consumption mechanism of a typical office building.

Table 2.1.1 Energy Consumption Mechanism of a Typical Office Building

Energy Usage		Main equipment of energy consumption
Item	Detail	
Energy source	Heat source	Chiller, Boiler, Chilling unit, etc.
	Auxiliaries	Pump, Fluid cooler, Primary pump, etc.
Thermal energy transport	Water-side	Secondary pump, etc.
	Air-side	Air handling unit, Fan-coil unit, etc.
Hot water	Heat source	Boiler, Recirculation pump, Electrical heater
Lighting & Receptacle	Lighting	Lighting fixture
	Receptacle	OA apparatus
Power	Ventilation	Ventilation fan in parking
	Plumbing	Lift pump, Drainage pump, Feeding pump, etc.
	EV	Elevator, Escalator, etc.
Other	Other	Transformer losses, Other power system, etc.

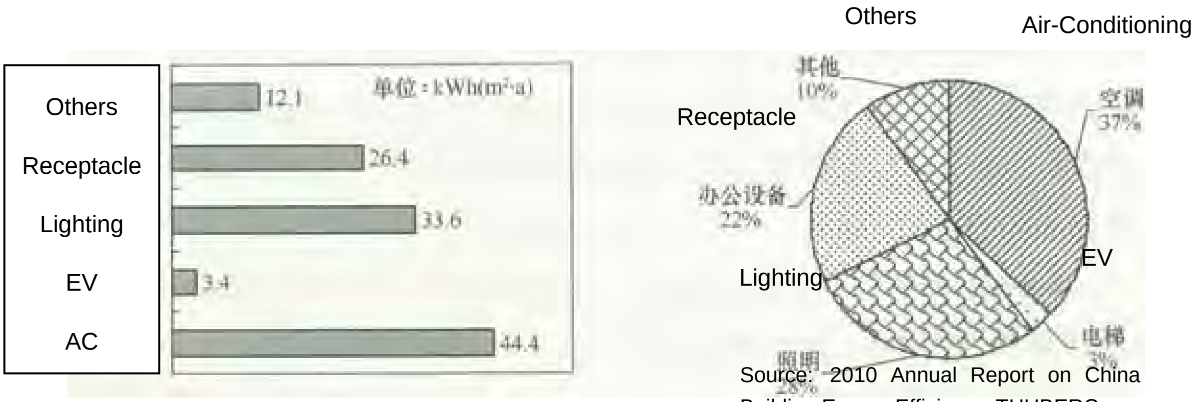
In China, all the office buildings are divided into two categories, that is, government-owned office buildings and private-owned office buildings, including rented ones. The government owned office buildings consume less energy annually than the other one because of their low staff density.

Figure 7.2.1 shows the energy consumption structure in a government office building, and 7.2.2 shows that of a private one in China. Beware that energy for winter heating is excluded from these statistics, because it greatly varies depending on the regions where the buildings are located. For example, the Northern territory, its winter temperature is strictly low has a highly efficient District Heating System (district steam/hot water infrastructure is installed), while southern regions have individual heating systems. On the other hand, weather is less affecting to all energy consumption but heating consumption. For example, if heating energy is excluded, the measurement of average energy consumption per public building floor area is almost same for both northern and southern cities. Therefore, we will find efficient energy-serving measures by finding out a structure common to energy consumption forms (other than heating energy). We found that the consumption for air conditioning, lights, and receptacle load of private-owned buildings is larger than that of government office buildings as shown in the figures below.



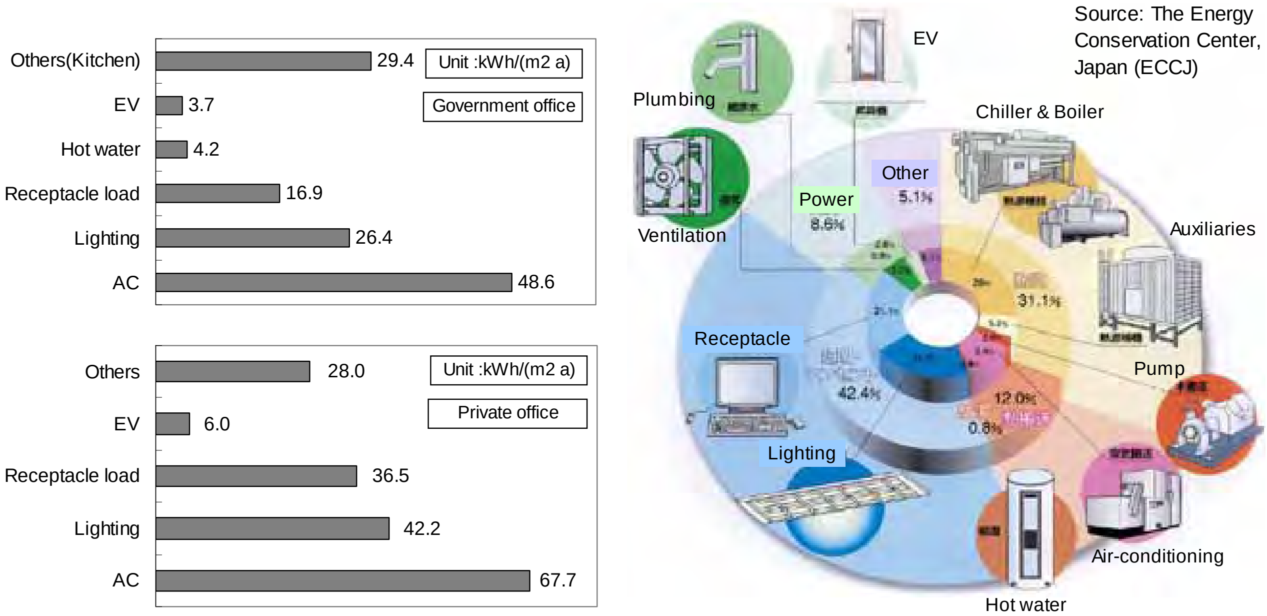
Source: 2010 Annual Report on China Building Energy Efficiency, THUBERC

Figure 7.2.1 Annual Energy Consumption Structure of a Chinese Government Office Building (Excluding Energy for Heating)



Source: 2010 Annual Report on China Building Energy Efficiency, THUBERC

Figure 7.2.2 Annual Energy Consumption Structure of a Chinese Private-Owned Office Building (Excluding Energy for Heating)



Source: The Energy Conservation Center, Japan (ECCJ)

Figure 7.2.3 Energy Consumption Structure of Japanese Government Office and Private-Owned Office Buildings for Rent

Figure 7.2.3 shows the energy consumption of Japanese government and private office buildings per floor area by energy use, on the basis of a research conducted by the Energy Conservation Center, Japan (ECCJ). One third of the total energy is excluded as room heating source energy to make the comparison with the data of China feasible. Government office buildings consume relatively less energy than private office buildings as in China, but the reason for it is different. Many Japanese government office buildings are strictly controlled their energy consumption for shorter air conditioning system's operation hour (the office's business hour), optimal room temperature, and timely switching off unneeded lights.

In comparison with Japan, although Chinese office buildings consume less energy for air conditioning, lights, and OA equipment than that in Japan, the ratio between these energy usages is the same as that of Japan on the whole.

Table 7.2.2 shows a comparison of office buildings between China and other countries. Today, the energy level consumed in Chinese large-scale public office buildings for any purpose other than room heating is roughly the same as in Europe and lower than that in Japan and the U.S.A. However, the tendency to build more large public buildings in China will open up new possibilities to increase building energy consumption in the future.

Table 7.2.2 Comparison of Energy Consumption in Office Buildings Between China and other Countries 2005 (Except for Heating)

中外办公建筑除集中采暖外能耗数据的比较

Comparison of Energy Consumption of Office Buildings Between China and Other Countries

	总能耗 Energy Consumption	总电耗 Electricity	空调系统 HVAC	照明 Lighting	办公设备 OA Machine	其他 Other	人均面积 Floor area avg
	kgce/(㎡・a)	kWh/(㎡・a)	kWh/(㎡・a)	kWh/(㎡・a)	kWh/(㎡・a)	kWh/(㎡・a)	㎡/Person
中国大型公建 Large-scale Public Building China	44	114	52.6	38.4	13.6	9.3	-
中国普通公建 General Public Building China	19.3	43.9	16.1	14.3	12.5	1.1	-
中国平均 General Public Building China	21.2	49.2	18.8	16.1	12.6	1.7	10.1
美国全国平均 Office Building on Average USA	78.4	207.5	51.5	68.8	51.6	35.6	23.3
日本全国平均 Office Building on Average Japan	69.7	168.3	25.2	143.1			11.3
韩国全国平均 Office Building on Average Korea	55.2	140	39.9	63.7	36.2	0.2	12.2
加拿大全国平均 Office Building on Average Canada	68	161.6	31.1	37.4	59.8	33.4	19.9
英国商业办公楼 Commercial Office Building UK	45	124	48	39	24	13	-

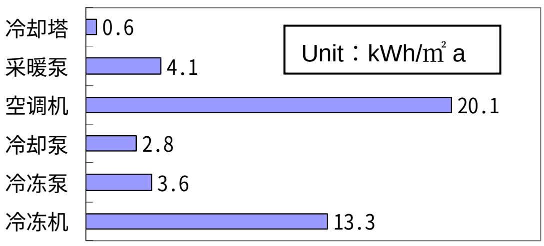
Source: 2010 Annual Report on China Building Energy Efficiency, THUBERC

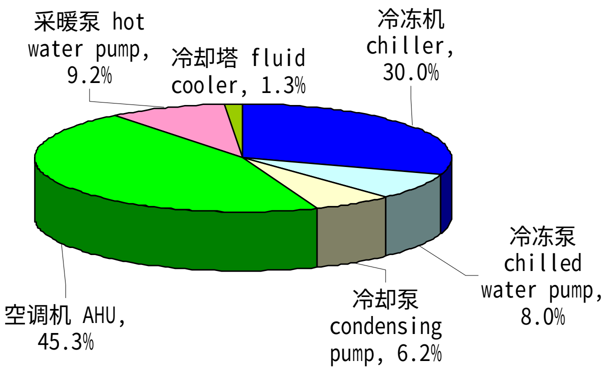
b) Key Components of Office Building Energy Consumption

The key components and characteristics of office buildings' energy consumption are as follows:

1. Air Conditioning System

An air conditioning system takes approximately 40% of the total energy for an office building. Figure 2.1.4 shows the components of annual energy consumption of a rented office building in Beijing. Because the largest part of an air conditioning system's consumption is for the chiller (30%) and air handling unit (AHU) (45.3%), if it can be cut down, an effective consumption control will be achieved. For the chiller, shorter operating hours through controlling system load and converting equipment to higher efficiency ones will do better because its power consumption primarily depends on the internal load, coefficient of performance (COP), efficient operation in partial load, and operation hours.





Source: 2010 Annual Report on China Building Energy Efficiency, THUBERC

Figure 7.2.5 Key Components of Annual Energy Consumption of a Rented Office Building in China

2. Lighting

Electric power consumption of lighting fixtures is the product of the power and the number, illumination duration, and illuminating area of the fixture. And the number of fixtures to be used is calculated from parameters, including required illumination, illuminating area, a pencil of light from a single light, coefficient of utilization, and light loss factors. Ultimately, energy efficiency of lighting can be classified into seven factors shown in Table 7.2.3. Energy saving measures appropriate to these factors will bring great energy efficiency.

Table 7.2.3 Energy-Saving and Low Carbon Emission Measures Strategy for Lighting

Item	Energy-Saving and Low Carbon Emission Measures Strategy for Lighting
Power Consumption of Lighting Fixture	Lamps with higher efficiency, Low-loss ballast
Illumination Duration	Strict control of lights-out, etc.
Required Illumination	Non-excessive illumination for the task, Primary illumination calibration
Required Illumination Area	Lights-on in only the required place, Natural lighting, Lighting duct
A Pencil of Light	Lamps with higher efficiency
Coefficient of Utilization	Interior finish with a higher reflection coefficient, Lights with higher transmittance
Light Loss Factor	Lights with a higher lumen maintenance factor, Good maintenance

3. Outlet Load (OA equipment: Receptacle)

According to <2010 Annual Report on China Building Energy Efficiency>, OA equipment in office buildings of Beijing annually consumes 6-45 $kWh/m^2 \cdot a$ per floor area. The consumption can be calculated as the product of the electric power used by the OA equipment and annual operation hours same as the lighting consumption. Increasing OA equipment power consumption from recent development of OA is one of the key factors for energy saving and lower carbon emission. Staff density per area is an affecting factor too. For example, high grade office buildings have generally higher staff densities than government buildings, thus it have larger power consumption for OA equipment per floor area. Furthermore, operation hours of OA equipment are another important factor. Supervising staff turning off their equipment when they are not at their seat to cut-off standby mode electricity is an important energy saving measure.

2) Commercial Buildings

[The Energy Consumption Characteristics of Chinese Commercial Buildings in China]

Many commercial buildings are constructed every year in China, meeting growing demands. Most of them, including department stores, supermarkets, and shopping centers, have a central air-conditioning system and consume the most energy from all Chinese public buildings. According to the statistics, the total floor area of large department stores with central air conditioning systems has reached 150 million m^2, and their annual cost for energy is excessive 22.5 billion RMB Yuan with energy consumption intensity 10–20 times higher than that of detached housings. But, from another point of view, it can be said that they have very large room for saving energy. The followings are the energy consumption-related characteristics of commercial buildings:

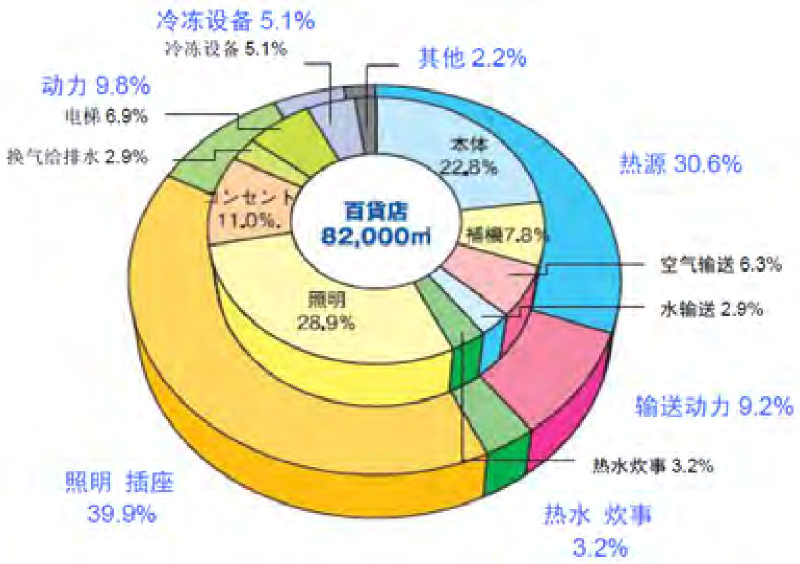
a) Their business hours are quite long, mostly twelve hours a day, 365 days a year.

b) They require external fresh air in large volumes for their high person density. The number of their guests is so unstable that the air-conditioning load is time-varying.

c) In many cases, their space is closed so that the air conditioning system avoids disturbance as much as it can, and because their interior area is large, they use mechanical ventilation to keep the interior environment comfortable. Mostly these types of buildings cool their interior through the year with much energy.

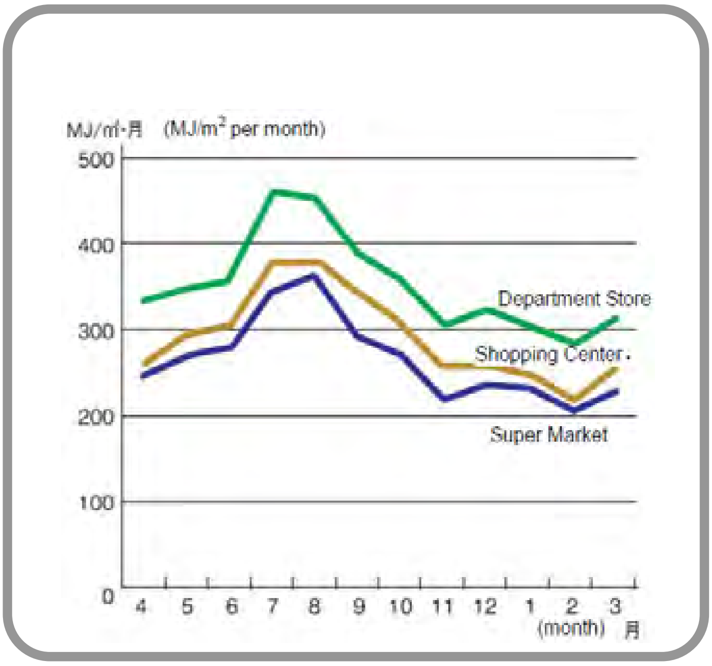
d) The large lighting load causes air-conditioning cooling load heavier.

Figure 7.2.6 shows energy consumption constituent of a typical Japanese commercial building (department store). Load for air-conditioning (for heat source and transportation) is approximately 40%, also lighting load and outlet load are about 40%. These need a sufficient action for energy saving.



Source: THE ENERGY CONSERVATION CENTER, JAPAN (ECCJ)

Figure 7.2.6 Energy Consumption Constituent of a Typical Japanese Commercial Building (Department Store)



Source: THE ENERGY CONSERVATION CENTER, JAPAN (ECCJ)

Figure 7.2.7 Tendency of Energy Consumption by Types of Commercial Buildings

3) Hotels

[Characteristics of the Energy Consumption of Hotels in China]

Hotels consume energy for air-conditioning, lighting, outlet load, hot water supply, elevator (escalator), etc. The followings are their characteristics different from other public buildings:

a) Their business hours are 24 hours a day and 365 days a year, and operation hours of each facility in a hotel are different from each other.

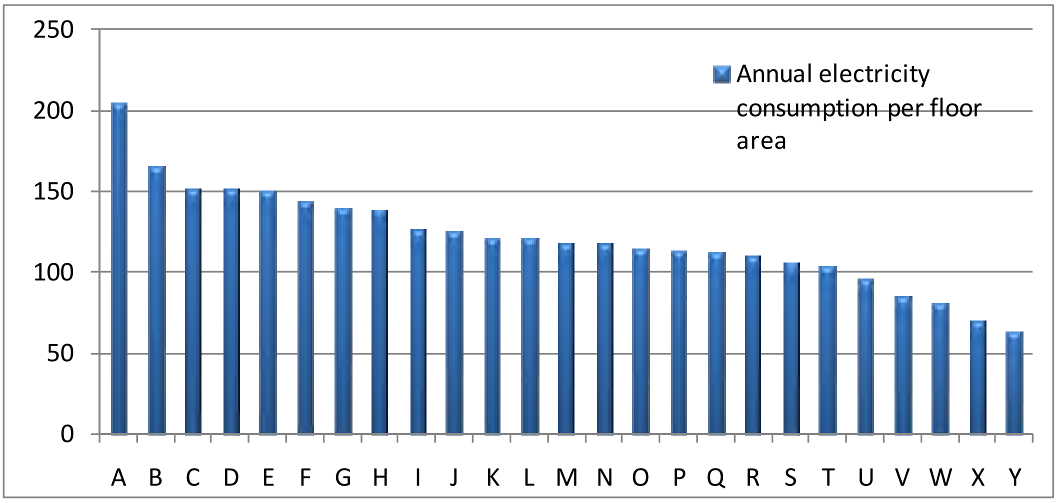
b) It is said that the air-conditioning systems in hotels are mostly in partial load condition for seasonal reasons and daily varying guest room occupancy.

c) Hotels have both all air systems used for only public space such as lobbies, banquet rooms, and meeting rooms, and fan coil units (FCU) with a central duct system used for guest rooms.

d) Hot water supply systems are operated 24 hours a day to meet heavy demands. So, circulating pumps consume much power.

e) Luxury hotels use four-pipe systems for air-conditioning to keep the inside comfortable. However, these systems may generate heat-mixing losses in seasonal changeover.

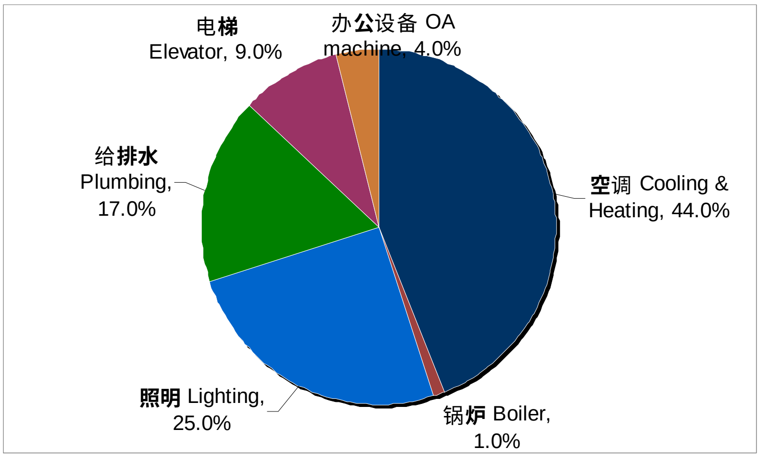
Figure 7.2.8 shows annual electric power consumption per floor area (except for heating) of hotels in Beijing, Shanghai, and Shenzhen. While there are some scatterings in the data, it is roughly between 70 kWh/(m^2·a) and 200 kWh/(m^2·a).



Source: 2010 Annual Report on China Building Energy Efficiency, THUBERC

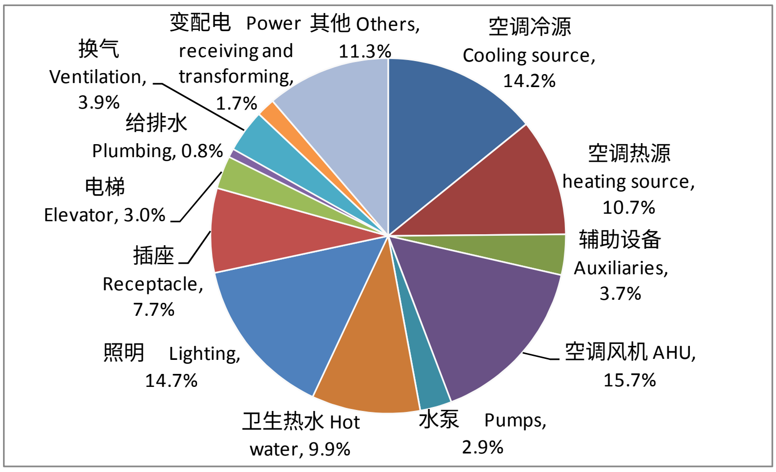
Figure 7.2.8 Annual Electric Power Consumption per Floor Area of Chinese Hotels (Except for Heating, kWh/(m^2·a))

Figure 7.2.9 shows the constituents of annual electric power consumption of representative hotels in China. Approximately 45% of all power is used for air-conditioning; roughly 30% is used for lighting and outlet; and about 17% is used for water supply (including hot water supply) and drainage; each needs energy serve measures. Figure 7.2.10 shows the constituents of annual electric power consumption of representative hotels in Japan for reference. The most, 47%, is used for air-conditioning; next, 30 % is used for lighting and outlet; and 11% is used for water supply (including hot water supply) and drainage; roughly the same ratio as that of Chinese hotels in China.



Source: 2010 Annual Report on China Building Energy Efficiency, THUBERC

Figure 7.2.9 Constituents of Annual Power Consumption of Representative Hotels in China



Source: THE ENERGY CONSERVATION CENTER, JAPAN (ECCJ)

Figure 7.2.10 Constituents of Annual Power Consumption of Representative Hotels in Japan

4) Complex Housing (Apartments)

[Characteristics of the Energy Consumption of Complex Housing in China]

Energy consumed in Chinese apartment buildings for cooking, hot water supply, home electrical products, and air-conditioning, consisting of gases (natural gas, coal gas, propane gas) as primary energy sources and electricity as secondary energy sources. All of these energies would be converted into standard coal equivalents for quantitative analyses. The results of an actual condition survey show that the energy consumption per floor area of the surveyed seven cities are all more than 10 kgce/(m^2·a), especially that of Beijing and Shanghai, both of which are over 20 kgce/(m^2·a).

Fossil fuel consumption per housing floor area tends to go up with city scale, for example, Beijing and Shanghai mark the highest level of consumption.

The average electric power consumption per floor area of northern cities is 8 kgce/(m^2·a), and that of southern cities is 11 kgce/(m^2·a), that is, 3 kgce/(m^2·a) (10 kWhE as electric power) higher than that of the former. For reference, the Chinese national average of coal consumption for power generation was 326 gce/kWh in 2008.

(Source:城市消費領域的用能特征与節能途径　中国建築工業出版社 in Chinese)

(NOTE: Tonne of Coal Equivalent, standard coal 1 kgce = 1000 gce = 7000 kcal = 29.302 MJ)

The followings are conceivable measures to achieve low-carbon housings:

a) Facilities using natural resources, such as window for natural ventilation windows, day lighting, and Heat & Cool Trench.

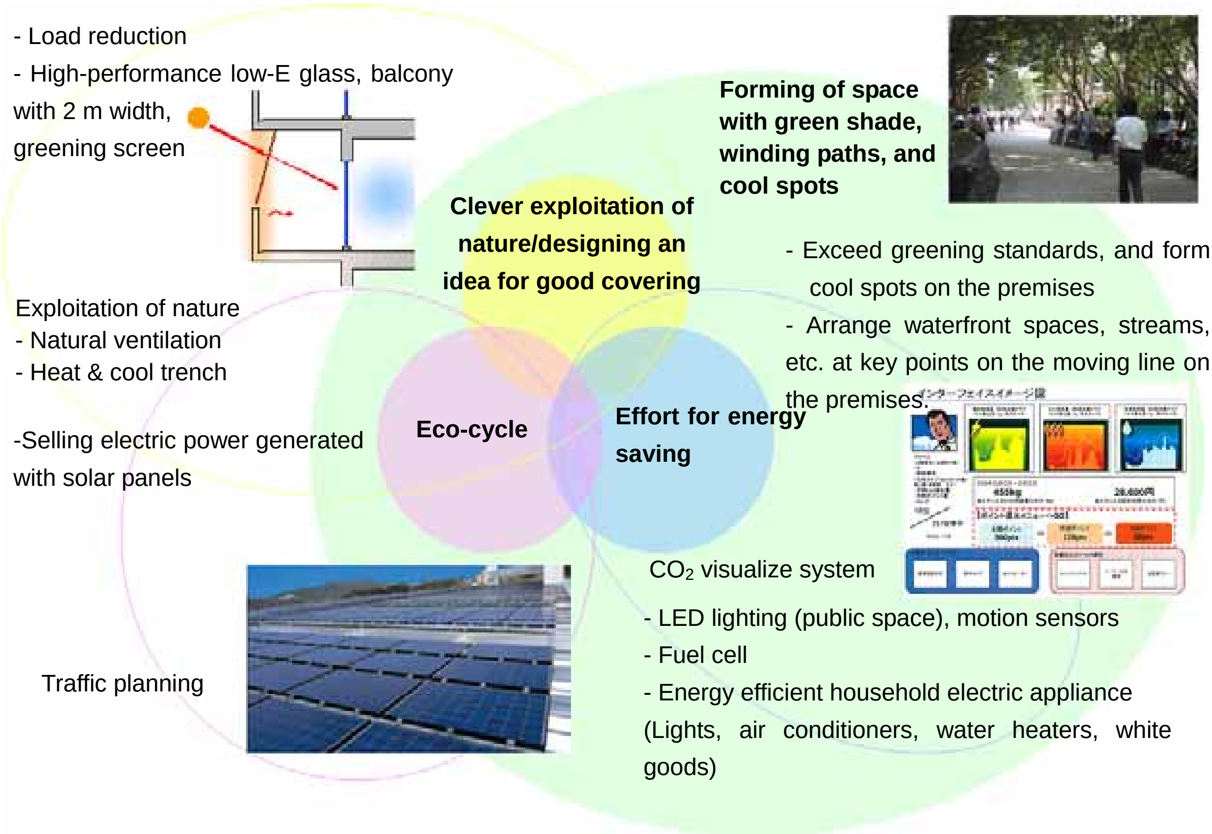
b) Heat load reduction, such as well-insulated walls, exterior insulation, sun-shading balconies, and greenery on the building facade.

c) Facilities without wasting energy, such as highly efficient heat sources, highly efficient water heating, including fuel cell water heaters for some of the housings, support for installation of energy-efficient household electric appliances, LED lightings, and motion sensors.

d) For promotion of efficient energy utilization of housing, the way of energy utilization might be visualized.

e) Installation of solar-generation panels (Optoelectronic integration)

Figure 7.2.11 shows the measures for CO_2 reduction in complex housings.



5) Low Carbon Measures by Building Use

[Low-Carbon Strategy for Buildings]

Figure 7.2.12 shows the energy consumption structure in buildings. Energy flows from city infrastructure (supply side) to buildings (consuming side). Then energy is used for air conditioning heat source, and transfer power; lighting and receptacle loads; sanitation; and elevators, etc. This supports human activities in a building by keeping the environment comfortable. Sufficient measures in both the energy supplying stage and the consuming stage are needed for carbon reduction in the construction field. The priorities of low carbon measures are, in order of precedence, load reduction, utilization of natural energy and renewable energy, adopting high efficiency equipments and systems (see Figure 7.2.13).

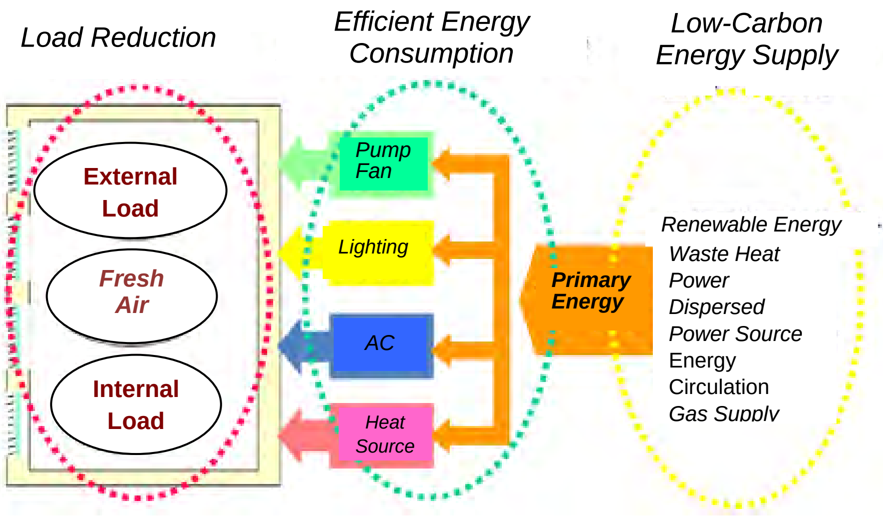


Figure 7.2.12 Energy Consumption Structure of Buildings

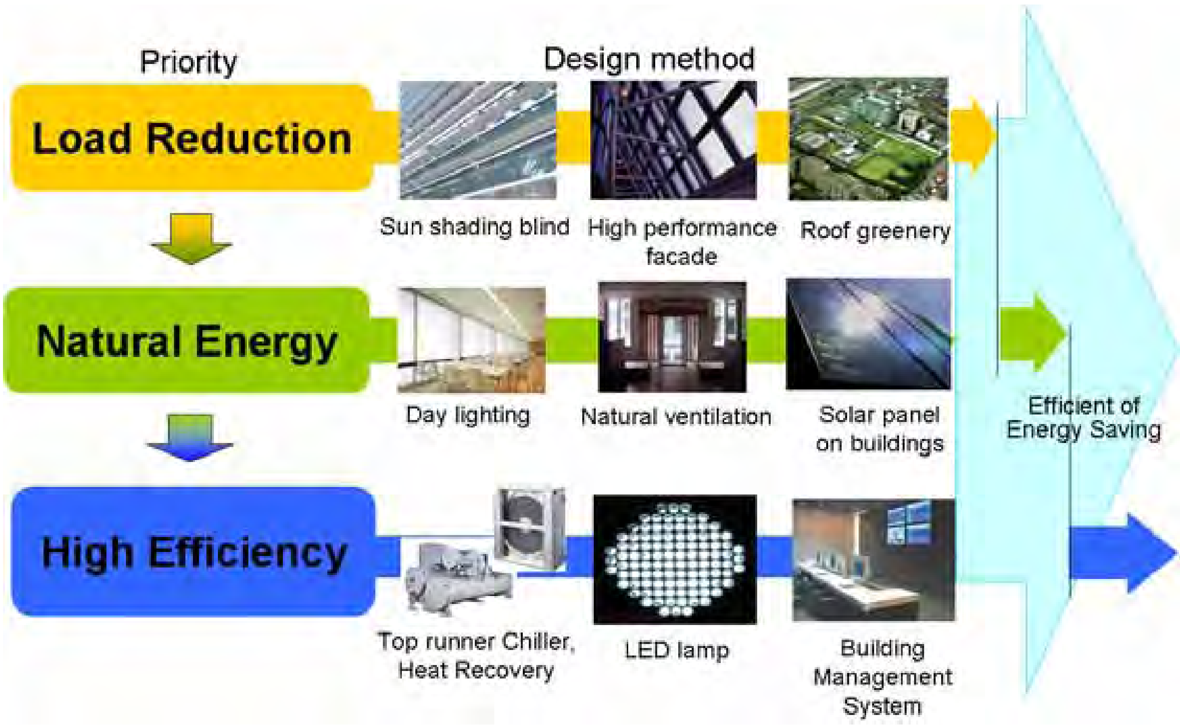
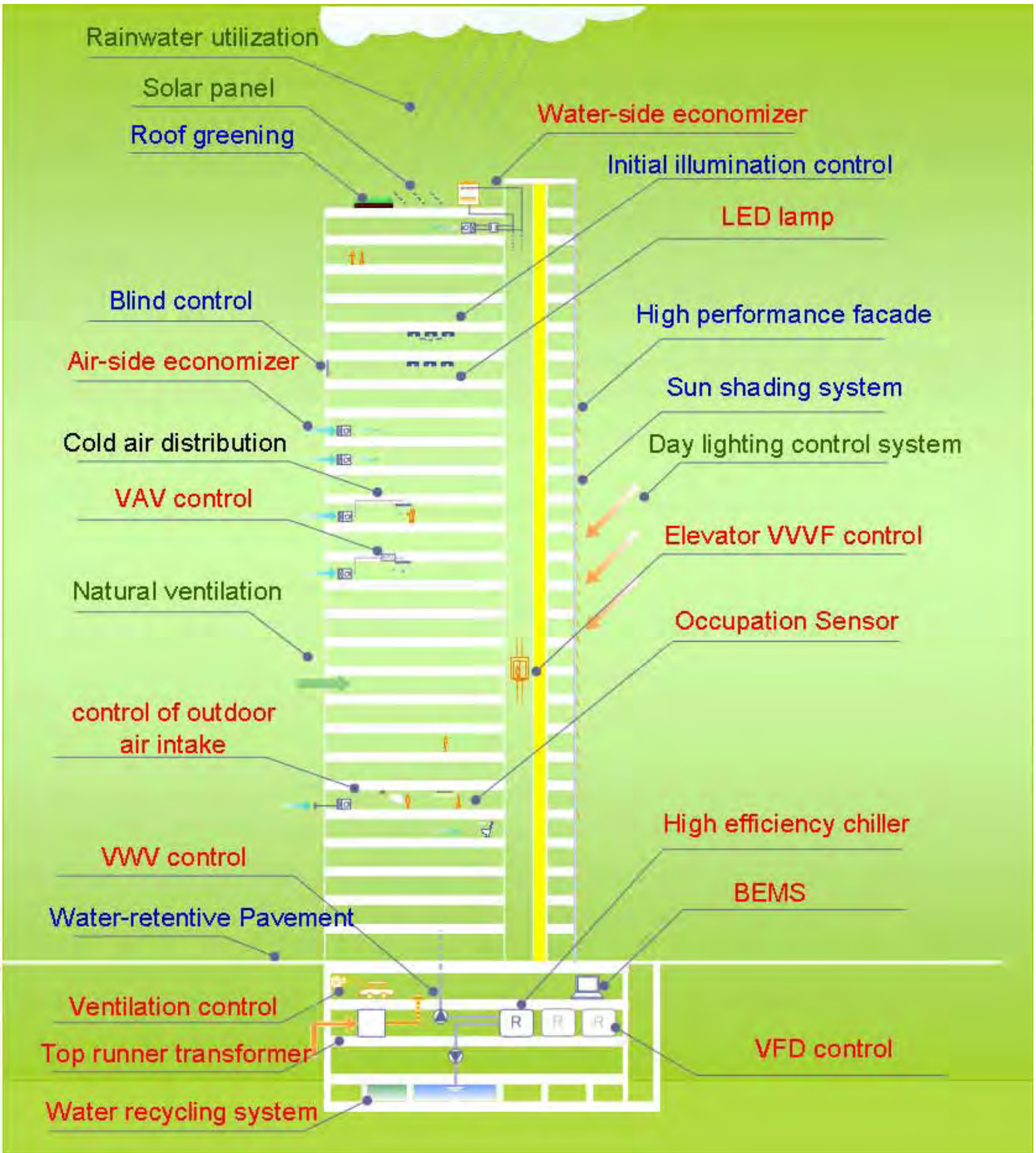


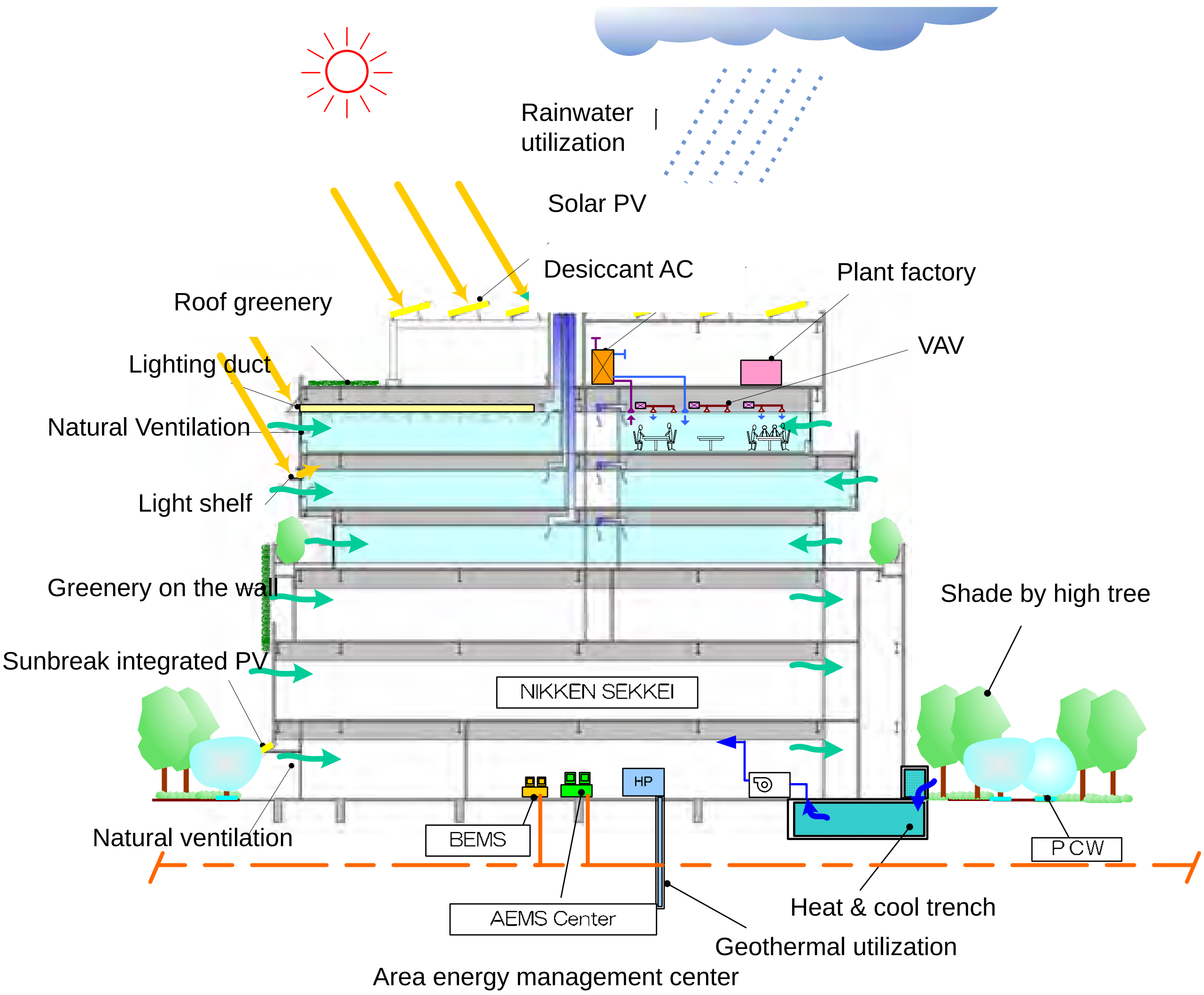
Figure 7.2.13 Action Priority for Low-Carbon Buildings

Figure 7.2.14 Conceptual Drawing of a Low-Carbon Office Building



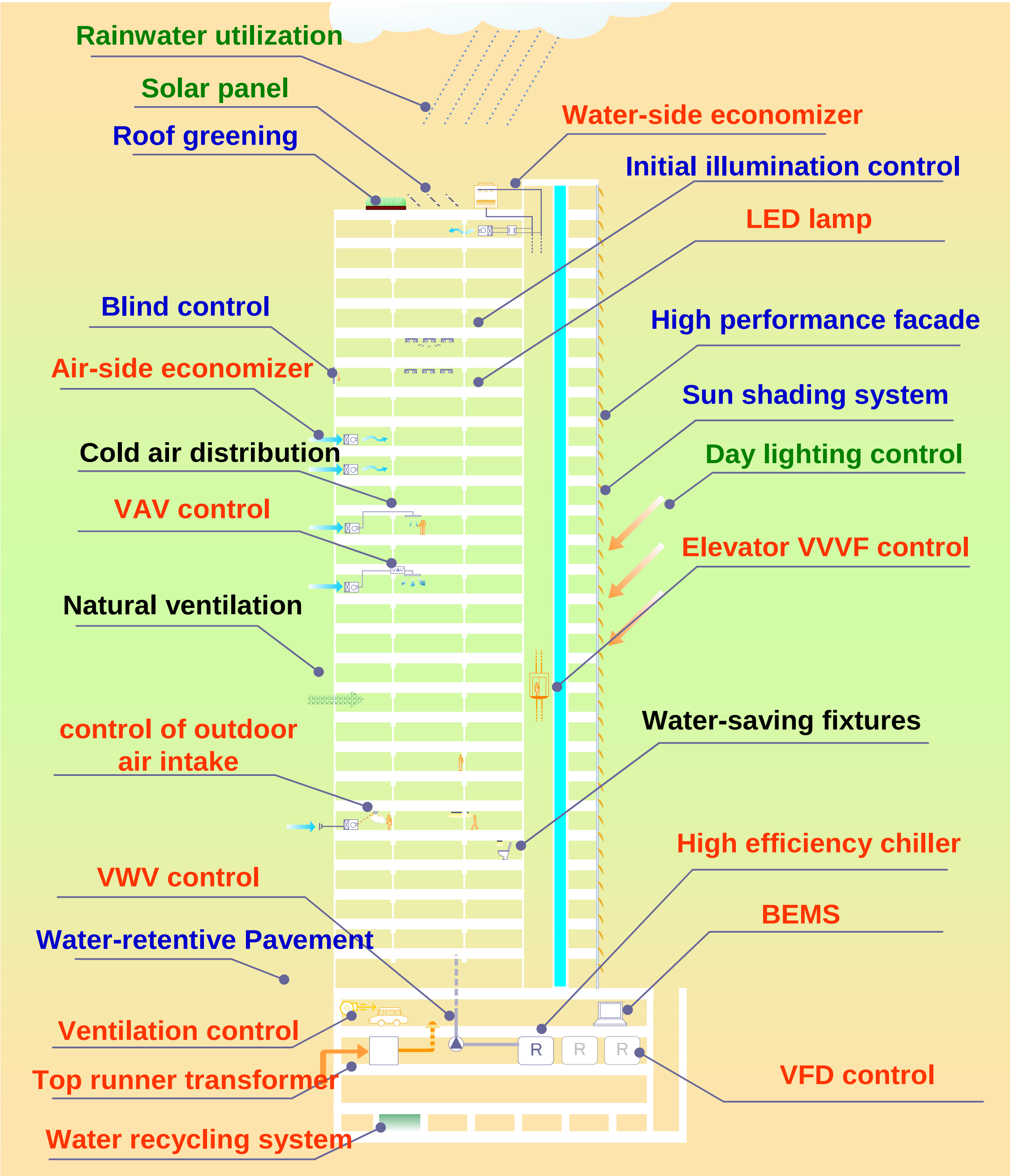
＜**Load Reduction**＞	＜**Natural Energy**＞	＜**High Tech & Efficiency**＞
Air tightness and insulation	Natural ventilation	Top-runner chiller & transformers
Sun shading system	Night purge system	Heat recovery
High performance facade	Day lighting system	VAV & VWV control
Low-E glass	Photovoltaic cells	Air & water side economizer
Double skin facade	Solar heat collector	Thermal storage system
Air-flow window	Geothermal heat pump	BEMS
Air barrier systems	Heat & cool trench	
Roof greening		

Figure 7.2.15 Conceptual Drawing of a Low-Carbon Commercial Building



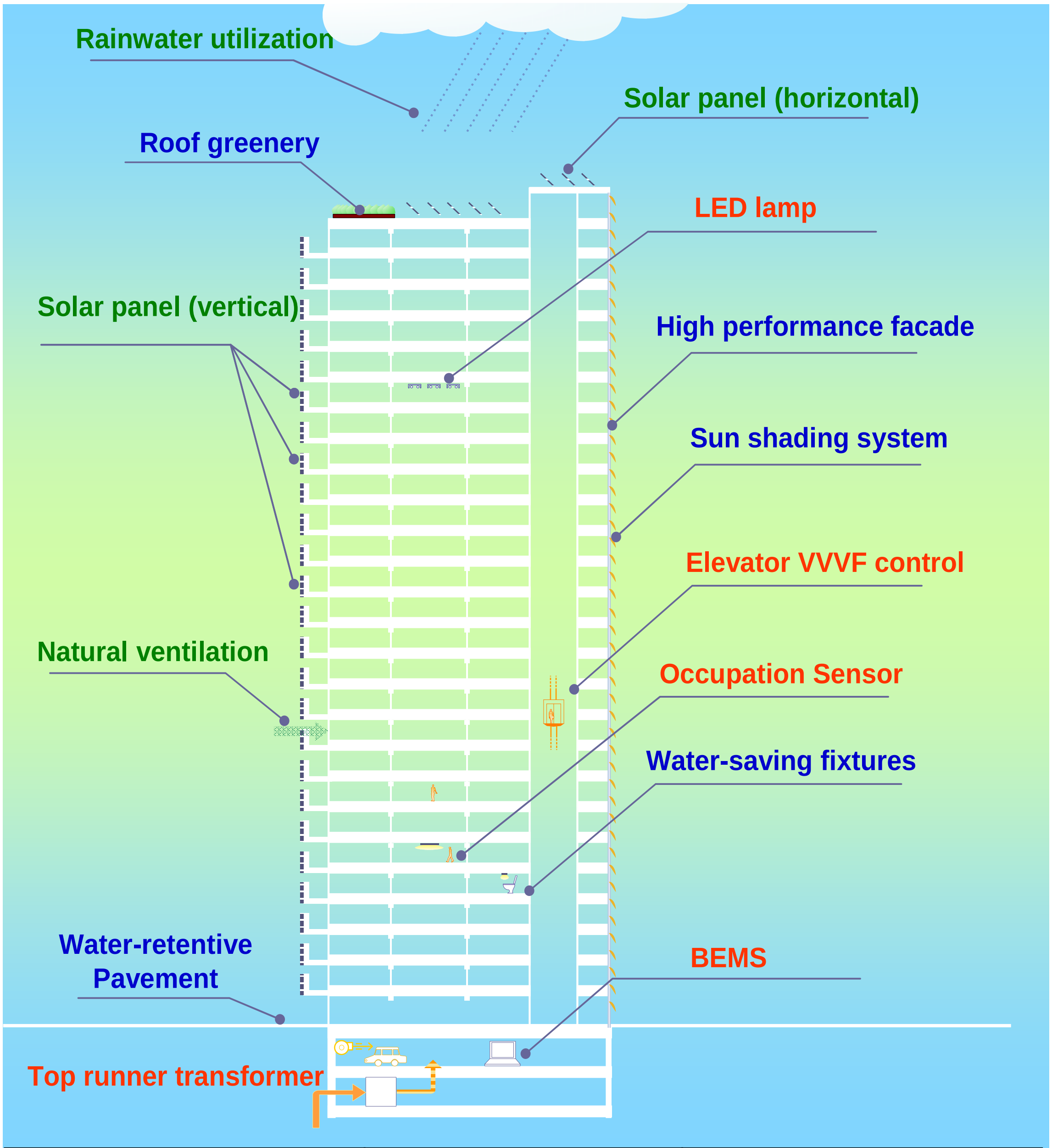
＜Load Reduction＞	＜Natural Energy＞	＜High Tech & Efficiency＞
Air tightness and insulation Sun shading system High performance facade Low-E glass Roof greening Lighting schedule program Behavior energy-saving	Natural ventilation Night purge system Day lighting system Photovoltaic cells Solar heat collector Geothermal heat pump Heat & cool trench	Top-runner chiller & transformers Heat recovery VAV & VWV control Air & water side economizer Thermal storage system BEMS

Figure 7.2.16 Conceptual Drawing of a Low-Carbon Hotel



<Load Reduction>	<Natural Energy>	<High Tech & Efficiency>
Air tightness and insulation Sun shading (louver) High performance facade Low-E glass Double skin facade Air-flow window Air barrier systems Roof greening	Natural ventilation Night purge system Day lighting Photovoltaic cells Solar heat collector Geothermal heat pump Heat & cool trench	High efficiency chillers Top-runner transformers Heat recovery VAV & VWV control Air & water side economizer LED lamp

Figure 7.2.17 Conceptual Drawing of a Low-Carbon Complex Housing



＜Load Reduction＞	＜Natural Energy＞	＜High Tech & Efficiency＞
Air tightness and insulation	Natural ventilation	Top-runner transformers
Sun shading system	Day lighting system	Heat recovery
(louver, balcony)	(Light shelf)	Heat pump water heater
High performance facade	Photovoltaic cells	High efficiency appliances
Low-E glass	(Horizontal, vertical)	LED lamps
Roof greening	Solar heat collector	Occupation sensor
		HEMS
		Garbage collection recycle

7.3 Case Study of a Low-Carbon Building

Integrated development with Environmental Consideration and Building Design

1) Building Design for Low Thermal Load

Mokuzai-kaikan in Tokyo uses carbon-neutral lumber for reducing solar radiation load and simultaneously characterizes its exterior design (see Figure 7.3.1). The Islamic Development Bank adopts slit-like windows in its double shell outer wall and installs a traditional patio inside the skyscraper (see Figure 7.3.2). The Nikken Sekkei Headquarters Building in Tokyo has an adaptive automatic controlled external venetian blind system that shifts its angles against the sunlight angles automatically. It reduces thermal gain from sun radiation, and is a part of the external design (see Figure 7.3.3).

Figure 7.3.1 Mokuzai-kaikan (Japan)

Figure 7.3.2 The Islamic Development Bank (Saudi Arabia)

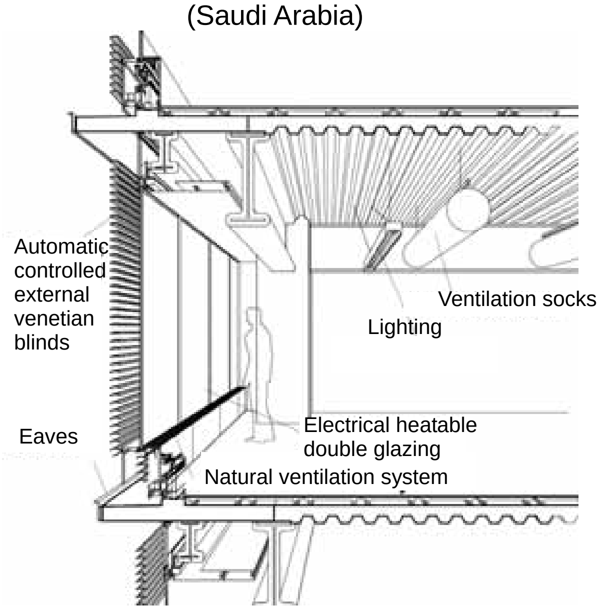


Figure 7.3.3

The Nikken Sekkei Headquarters Building

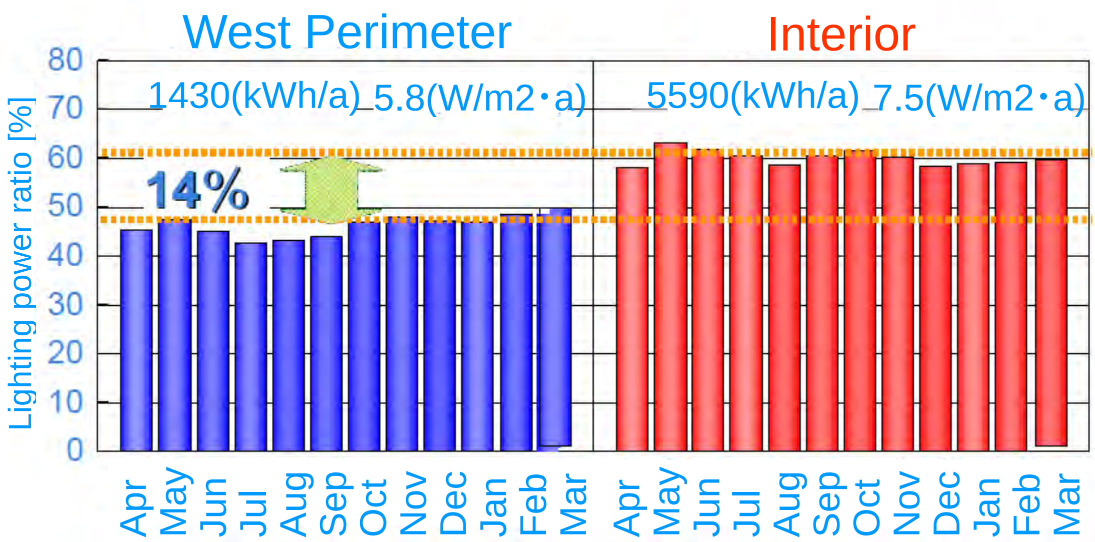


Figure 7.3.4 External Venetian Blind

Figure 7.3.4 shows reduced lighting electric power by the effect of the automatic controlled external venetian blind system. This system works as sun shades and provides natural light, reducing energy for lightings of the room perimeter area for 14% lower than that of the interior part.

2) Hybrid Design Utilizing Natural Resources

The Institute for Global Environmental Strategies (IGES, Kanagawa Pref., Japan) uses a combination of horizontal and vertical louvers to shield sun radiation from the south and southwest effectively. Furthermore, the horizontal louvers work sufficiently to take in natural light working as light shelves. And a window open/close system is designed with air flow simulation for affluent natural ventilation. By adapting the technologies mentioned above, 40% of CO_2 emission reduction is achieved.

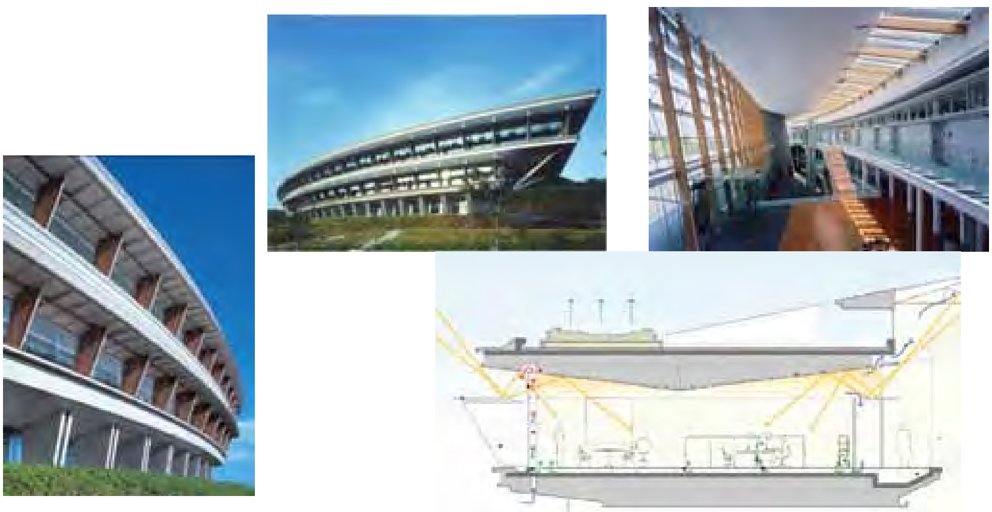


Figure 7.3.5 IGES-Designed Technologies Utilizing Natural Resources

3) Highly Efficient Natural Energy Utilization with Advanced Technology

a) Daylight (JAXA: Japan Aerospace Exploration Agency): Lighting ducts installed in the ceilings of each floor take in natural daylight deep into the interior zone to reduce 60% of lighting energy (see Figure 7.3.6).

b) Natural Ventilation (China Beijing TV Station): In the past, it was said that to actualize a natural ventilation system in skyscrapers was almost impossible. However, a stable natural ventilation system with little effect of wind direction fluctuation is realized utilizing the atrium space efficiently in this building (see Figure 7.3.7).

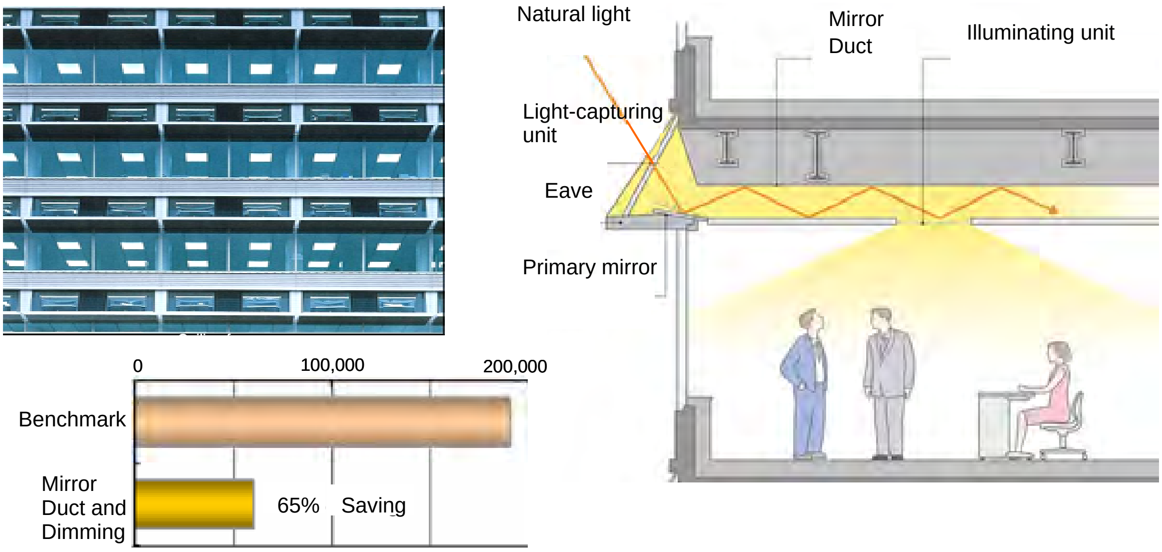


Figure 7.3.6 Lighting Duct in JAXA

Figure 7.3.7 China Beijing TV Station (Photo: Air Flow Simulation)

7.4. Prediction for Potential CO_2 Emission Reduction Level by Building Use Types Using Various Low Carbon Measures

1) Actual Energy Consumption by Building Use Types in China

The purpose of this prediction is to provide development related members with concrete low-carbon methodologies by assessing quantitatively the phased reduction potential of buildings for various uses in the Yujapu area. The reduction targets for the whole area are about 30% by 2020 and about 50% by 2030, both with reference to 2005.

Buildings' actual energy consumption was measured by use (office, commercial facility, hotel, apartment, etc.), and the results were analyzed to determine whether it can be used to define business as usual (BAU),e it was needed to clearly define CO_2 emission levels at BAU before taking any measures.

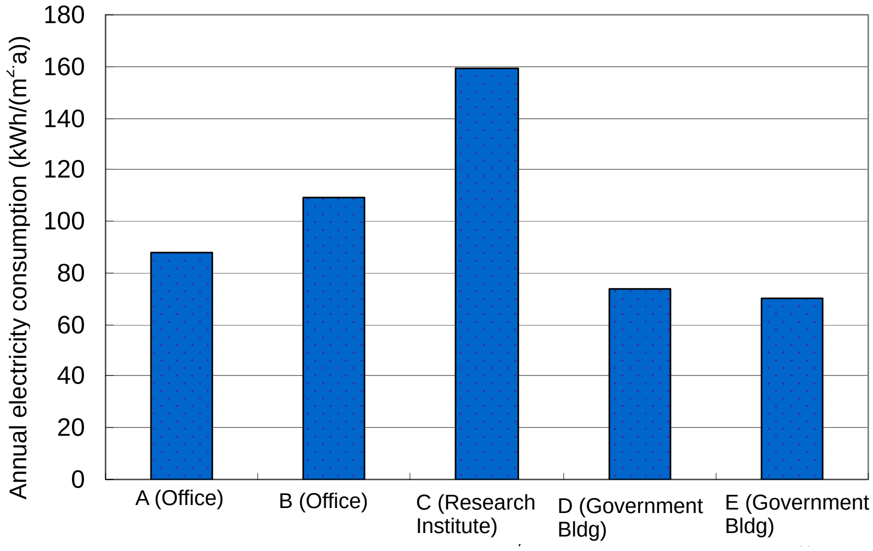


Figure 7.4.1 Actual Measurement of Annual Electric Power Consumption in Beijing, China

Figure 7.4.1 shows the actual measurement of annual electric power consumption of office buildings in Beijing. According to this data, it is not appropriate to use simply this data to define BAU for office buildings energy consumption, because there are great differences of data between 70 kWh/(m^2·a) and 160 kWh/(m^2·a) even in buildings in a same usage for office. The same thing goes for other uses, for example, commercial buildings. Explanations in the concrete are as follows:

a) The distribution curve of building energy consumption in China has two peaks, because they consume energy differently depending on several factors such as completion year, building style, operation hours, and installed equipment. For example, new buildings, especially the new large-scale public buildings, consume

1.8–2.6 times more energy than old ones, according to the energy investigations conducted by Tsinghua University, China.

b) This measurement does not tell the whole story about building energy consumption, because it usually does not include heat energy. It cannot be measured in Beijing and Tianjin where heat is generally provided through a district heating system. Buildings have no meters to measure the heat provided, because the fare for heat is billed against the floor area of the building.

c) The measurement values may be too small for normal energy consumption, because in some cases, it was actually seen that building management staff cut off required equipment such as air-conditioners for outside air processing in order to cut down running costs.

d) The measurement values may be too large for normal heating energy consumption, because in some winter cases, there is no control valve installed in the heating pipes, which means that the energy supplied could not be adjusted. It is actually seen that the residents open up their windows to release excessive heat that faulty room temperature controls brought.

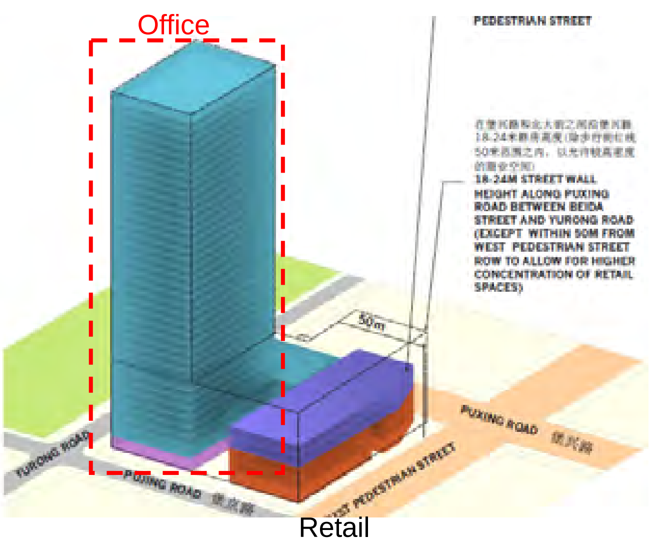
Considering these situations, BAU for building energy consumption (and CO_2 emission) is to be set as followings. First, a standard building will be set for each usage to define the scale, staff density, operation hours, and installed equipment. Then, annual energy simulation will be performed on the building, and the result of it will be set as BAU. (Standard building: a building that meets the required performance according to the related laws of 2005 or current law [Design standard for energy efficiency of public buildings GB50189-2005], but does not adopt any other energy-saving measures)

2) Setting the CO_2 Emission Level of BAU

a) Setting Conditions for Calculation to Determine BAU

An annual energy consumption simulation was performed by setting the building's scale, staff density, operation hours, and installed equipment to grasp quantitatively the CO_2 reduction effect from low carbon methodologies. Table 7.4.1 is the condition set for a model building (office, BAU). Model conditions for other usage such as commercial facilities, hotels, and apartments were also set.

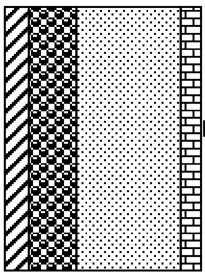
Table 7.4.1 Specifications for the Model Building (Office)

Building Type	Office	Model Building from Master Plan
(Total Floor area)	100,000 m^2	
Height	160 m	
Floors	37 Floors	
Under Floor	3 Floors	
Typical Floor area	2,500 m^2	
Structure	SRC	
Core Type	Center Core	
(Floor Height)	4.3 m (Ceiling 3 m)	

1. Window area ratio: 3 m/4.3 m ＝ 0.70

2. Exterior wall structure

Interior	Material	Thickness (mm)	Heat transmission coefficient
↓	Plasterboard	20	0.60 $W/m^2 \cdot K$
	Urethane	35	
	Concrete	150	
Exterior	Tile	10	



Exterior wall: Overall heat transmission coefficient: 0.6 (meets the design standard for energy efficiency of public buildings GB50189-2005)

Roof: Overall heat transmission coefficient: 0.513 (meets the design standard for energy efficiency of public buildings GB50189-2005)

3. Glass (GB50189-2005) SC Coefficient: 0.5

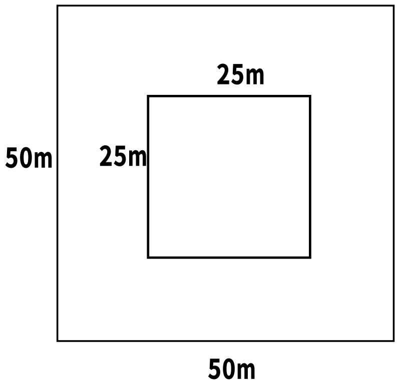
0.5 ＜ Window area ratio ＜ 0.7 Overall heat transmission: 2.0 $W/(m^2 \cdot K)$ →Limit value while the shape coefficient of the building is 0.09

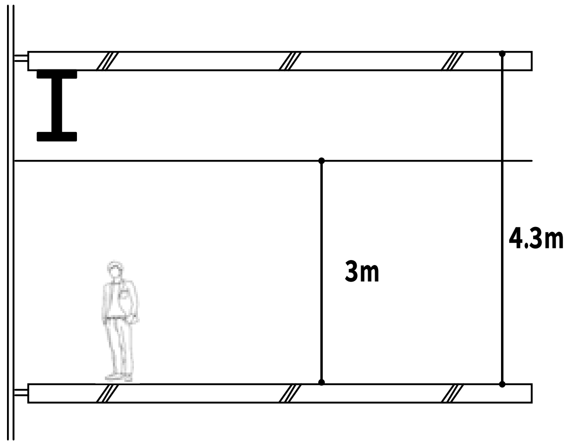
4. Construction floor plan and section view for a typical floor

Typical Floor area: 2500 m^2

Rentable ratio = 0.75

Net office area of a typical floor = 1875 m^2





5. Design conditions for air-conditioning, ventilation, heating, etc. (According to the design standard for energy efficiency of public buildings GB50189-2005)

Floor Use	夏季(Summer)		冬季(Winter)		Persons	Lighting	Conceptacle	Fresh Air
	温度 Temp.℃	相対湿度 RH %	温度 Temp. ℃	相対湿度 RH %	Person /m^2	W/m^2	W/m^2	m^3/h /person
办公室(Office)	25	50	20	40	0.15	15	40	30
大堂 (Entrance hall)	28	50	16	—	0.05	10	5	30
走廊(Corridor)	26	50	18	40	0	10	-	-

* Heat load from human body: Sensible heat + Latent heat = 102 W/m^2/person (office work)

* Operation schedule is set on the basis of the design standard for energy efficiency of public buildings GB50189-2005.

* Weather data of Tianjin City is used for weather condition.

6. HVAC and plumbing system

Heat source type: District cooling (DC) + Hot water by waste heat from local electricity power plant

(Hot and cold water heat exchanger is on the building side)

Cooling (DC): Centrifugal chiller (COP: 5.1 or more)

Heating: Hot water supply by Nanjiang Power Station’s cogeneration exhaust heat (Hot water: 70–130^{o}C)

Air conditioning type: Interior: All air type, Constant air volume control system

Perimeter: Fan coil unit (FCU)

Air supply temperature (office): 15–25^{o}C, ΔT = 10^{o}C

Chilled water: 7–12^{o}C, ΔT = 5^{o}C

Hot water (heating): 72–82 ^{o}C, ΔT = 10^{o}C

7. Simulation tool: FACES 4.36.1 (Japan)

b) Determination Results

The following are the BAU determination results.

1.CO_2 Emission for Office BAU

Figure 7.4.2 shows the breakdown of CO_2 emission for the model under BAU. Annual CO_2 emission per floor area is about 135 CO2-kg/(m^2·a) for BAU without any carbon reduction measures.

CO_2 emissions intensity for electric power is 0.7802 tCO_2/MWh (Source: 華北区域電網、「関于公布 2009 年中国区域電網基準線排放因子的公告」、中国国家発展改革委員会応対气候変化司). CO_2 emissions intensity for natural gas is 0.048 kg/MJ (Source: 「天燃气在発展低炭経済中的技術経済性分析」、《城市燃气》).

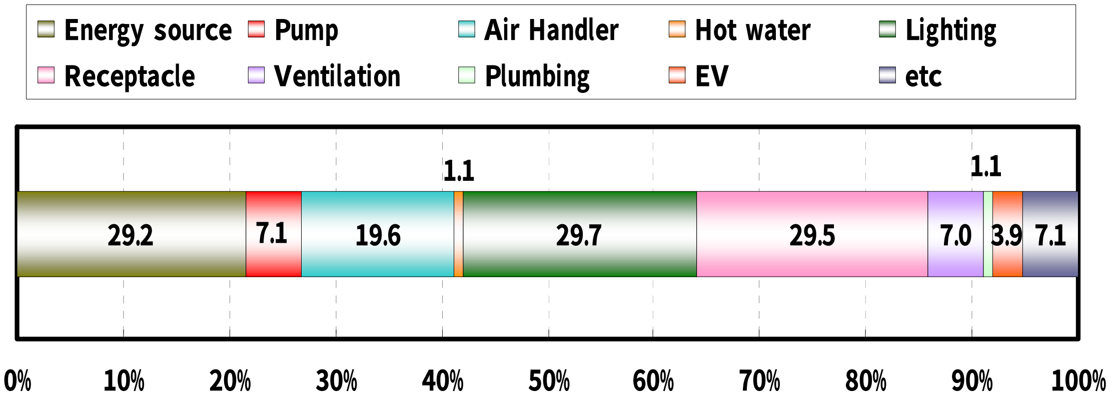
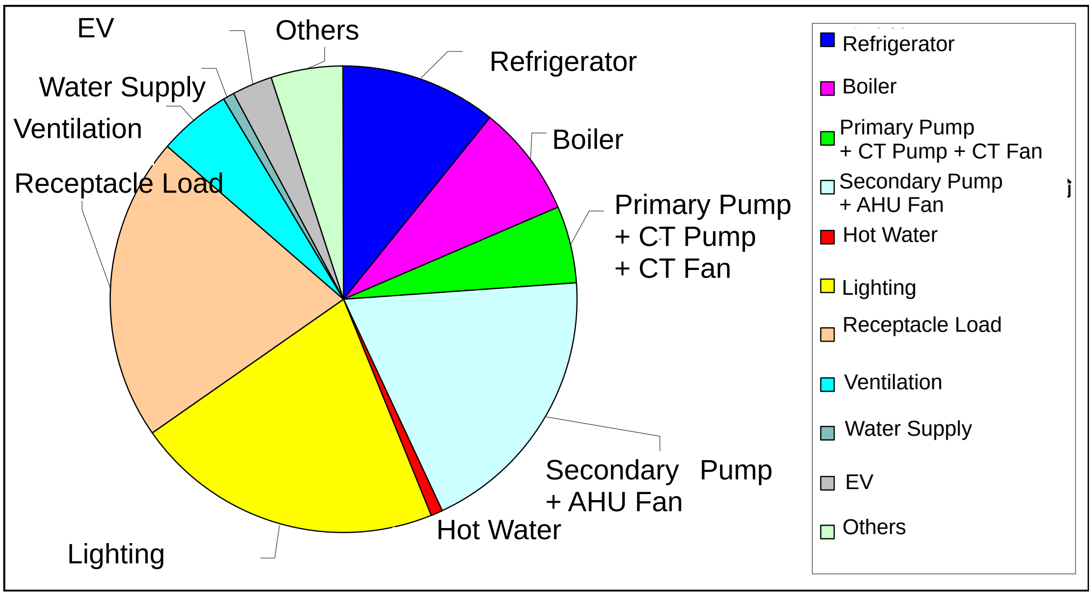


Figure 7.4.2 CO_2 Emissions of the Model Office Building (CO2-kg/(m^2·a))



Chiller	10.8%
Boiler	7.6%
Primary Pump + CT Pump + CT Fan	5.5%
Secondary Pump + AHU Fan	19.1%
Hot Water	0.8%
Lighting	21.3%
Receptacle Load	21.1%
Ventilation	5.0%
Water Supply	0.8%
EV	2.8%
Others	5.1%
Total	100.0%

[Suffix]
CT: Cooling Tower
AHU: Air Handling Unit
EV: Elevator

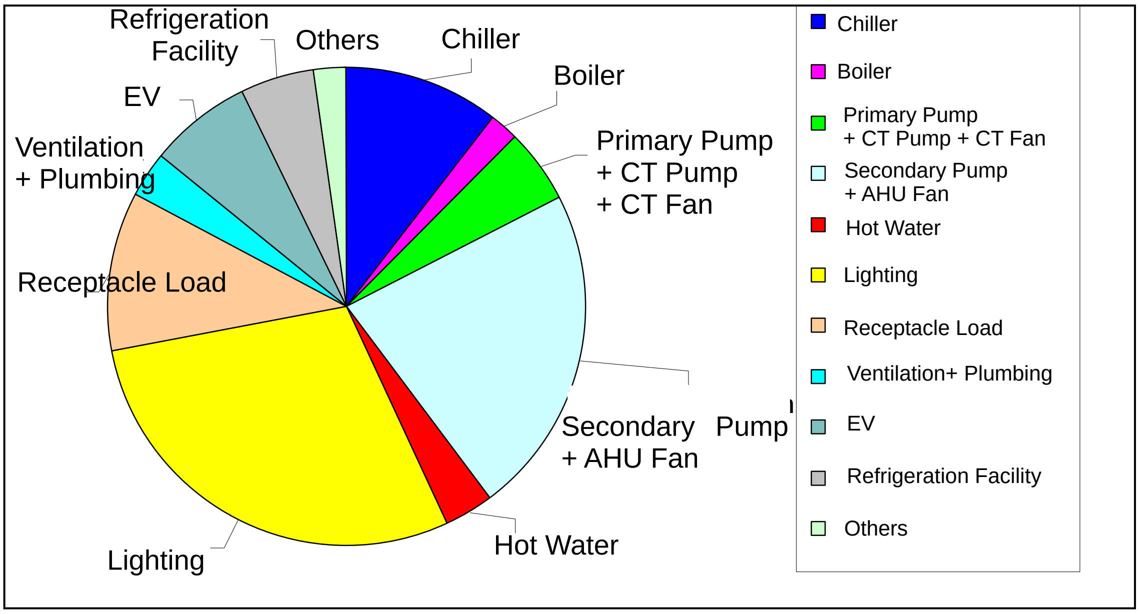
Figure 7.4.3 Primary Energy Annual Consumption Constituent Ratio of Office Building BAU

Table 7.4.2 Electricity Consumption per Total Floor Area Breakdown (Except for Heat Source)

Chiller	19.4 kWh/m^2 year
Primary Pump + CT Pump + CT Fan	9.9 kWh/m^2 year
Secondary Pump + AHU Fan	34.2 kWh/m^2 year
Hot Water	1.4 kWh/m^2 year
Lighting	38.1 kWh/m^2 year
Receptacle Load	37.8 kWh/m^2 year
Ventilation	9.0 kWh/m^2 year
Water Supply	1.4 kWh/m^2 year
EV	5.0 kWh/m^2 year
Others	9.1 kWh/m^2 year
Total	165 kWh/m^2 year

CO_2 emissions under BAU for commercial buildings and hotels are defined in same way.

2. BAU of a Commercial Building under BAU (Department Store)



Chiller	10.5%
Boiler	2.0%
Primary Pump + CT Pump + CT Fan	4.9%
Secondary Pump + AHU Fan	22.3%
Hot Water	3.2%
Lighting	28.9%
Receptacle Load	11.0%
Ventilation + Water Supply	2.9%
EV	6.9%
Refrigeration Facility	5.1%
Others	2.2%
Total	100.0%

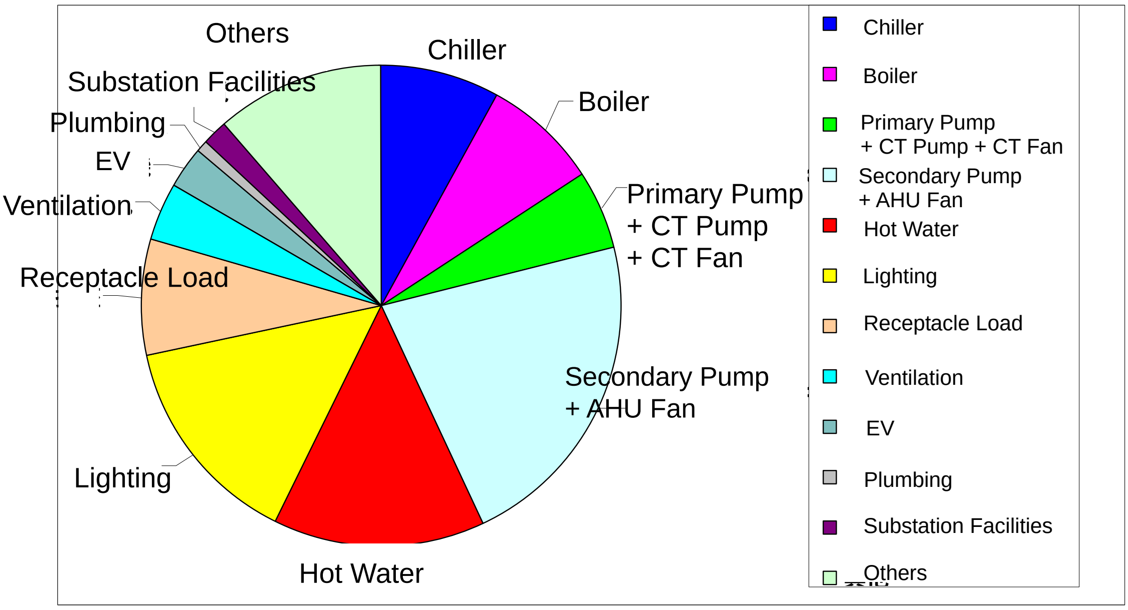
[凡例(Suffix)]
CT：冷却塔
（Cooling Tower）
AHU：空調機
（Air Handling Unit）
EV：昇降機（Elevator）

Energy Annual Consumption Ratio of Commercial Building under BAU

Table 7.4.3 Electricity Consumption per Total Floor Area Breakdown (Except for Heat Source)

Chiller	31.1	kWh/m^2 year
Primary Pump + CT Pump + CT Fan	14.5	kWh/m^2 year
Secondary Pump + AHU Fan	66.0	kWh/m^2 year
Hot Water	9.5	kWh/m^2 year
Lighting	85.4	kWh/m^2 year
Receptacle Load	32.5	kWh/m^2 year
Ventilation	8.6	kWh/m^2 year
Water Supply	20.4	kWh/m^2 year
EV	15.1	kWh/m^2 year
Others	6.5	kWh/m^2 year
Total	289	kWh/m^2 year

3. BAU for Hotels



Chiller	8.2%
Boiler	7.6%
Primary Pump + CT Pump + CT Fan	5.4%
Secondary Pump + AHU Fan	22.0%
Hot Water	14.0%
Lighting	14.7%
Receptacle Load	7.7%
Ventilation	3.7%
EV	3.0%
Water Supply	0.8%
Substation Facilities	1.7%
Others	11.3%
Total	100.0%

[Suffix]
CT: Cooling Tower
AHU: Air Handling Unit
EV: Elevator

Figure 7.4.5 Primary Energy Annual Consumption Constituent Ratio of Hotel under BAU

Table 7.4.4 Electricity Consumption per Total Floor Area Breakdown (Except for Heat Source)

Chiller	22.3 kWh/m^2 year
Primary Pump + CT Pump + CT Fan	14.6 kWh/m^2 year
Secondary Pump + AHU Fan	60.1 kWh/m^2 year
Lighting	40.1 kWh/m^2 year
Receptacle Load	21.0 kWh/m^2 year
Ventilation	10.1 kWh/m^2 year
EV	8.2 kWh/m^2 year
Water Supply	2.2 kWh/m^2 year
Substation Facilities	4.6 kWh/m^2 year
Others	30.8 kWh/m^2 year
Total	214 kWh/m^2 year

3) Prediction of CO2 Reduction Effects of Low Carbon Measures (for Office Buildings)

Low carbon strategies and measures are shown by building use types in Section 7.2.5, and low carbon measures that can be used in office buildings are shown in Figure 7.2.4 as examples. In this section, CO_2 reduction effects with more than one low carbon measure are to be assessed to validate the feasibility of CO_2 reduction target for buildings of 30% reduction by 2020.

The effects of low carbon measures were determined for the model office building introduced in section 7.4.2.1. Figure 7.4.6 shows CO_2 reduction effects from the measures adopted. It was revealed that about 40% of CO_2 reduction from BAU was to be achievable with measures combinations in the figure. Besides, 40% of reduction for commercial buildings and 30% for apartments were also determined by individual simulation. The accomplishment of the CO_2 reduction target is expected through low carbon measures based on the results when buildings are planned, designed, constructed, and used in this district.

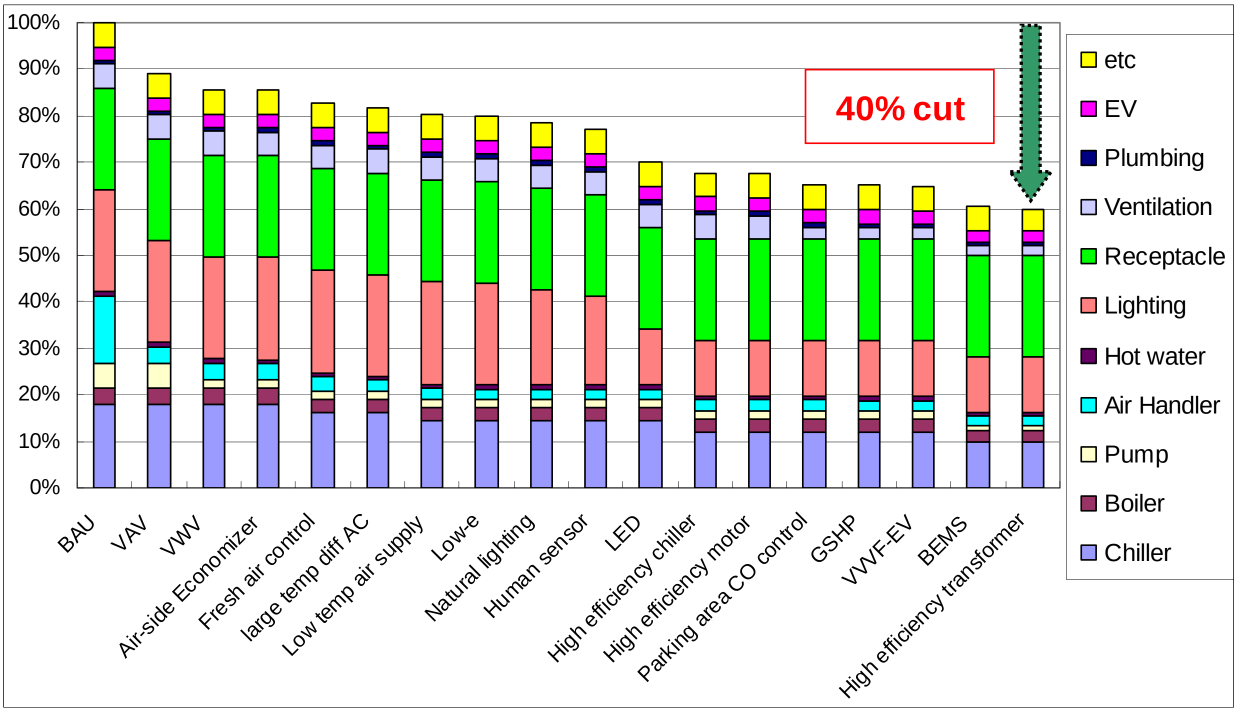


Figure 7.4.6 CO_2 Reduction Effects of Low Carbon Measures in the Model Office Building

8. Area Energy Planning

8.Area Energy Planning

Key points

- Since this development area is the high-density intensive CBD area, the area energy District Heating and Cooling (DHC) is the most effective method to be adopted under area energy planning.
- This paper introduces the outlines and examples of DHC and assumes, as the concept of air-conditioning in this development area, high-temperature water supply + cold water supply using the heat discharged from the power station in Tianjin city as usual.
- As a result of examining the heat source comparison, the availability of the heat storage system in the electric heat source can be confirmed. In addition, the possibility of adopting the cogeneration system (CHP) for this area's air-conditioning facility is high from the viewpoint of stability and efficiency of power supply.
- As the phased area energy arrangement plan, the assumed arrangement scale of the area air-conditioning facility is calculated for each development phase. In addition, if the power station function is improved in future in the mid-term and long-term phased area energy arrangement plan, shift from CHP to the electricity based heat source system can be considered
- It should be necessary to examine the usage of the untapped energy of the installation plan of the area air-conditioning facility now, not in future.

8.1 Outline and example of the introduced technology

For the large-scale, intensive, high-density area development, the method that the plant in the development area generates energy and supplies it to each building can make more contribution to low carbonization than the method that each building generates and consumes the building energy for air-conditioning and hot water because of utilizing the scale merit. Therefore, the installation plan of the area air-conditioning facility will be studied.

1) Outline of DHC

The following shows the outline of the area air-conditioning facility. It can be roughly classified into the cool heat source (cold water), hot heat source (e.g., steam, hot water), and the energy source for generation (electricity and gas).

a) Method mainly using electricity

The method that generates cold water and hot water using the turbo freezer of electricity heat source and the heat pump chiller

b) Method mainly using gas

The method that generates cold water and steam by the steam suction type freezer using heat discharged from the gas suction type freezer and cogeneration steam

c) Method using electricity and gas

The method that generates cold water and steam (hot water) combining (a) and (b) above

In addition, there is the area air-conditioning that combines untapped energy such as river water, sewage heat, and incineration plant discharged heat.

2) Example of DHC

The following is an example of the representative area air-conditioning facility in Japan.

a) Harumi Island district (electricity based district)

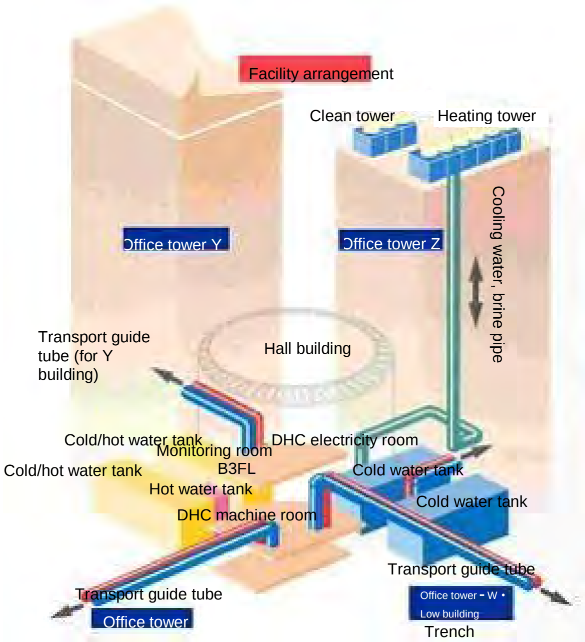


Figure 8.1.1 Outline of Harumi Island District

1. Supply start: April, 2001
2. Supplied to: 5 buildings (complex facilities of mainly office use)
3. Supply area: about 61,000 m^2
4. Total floor space to supply: about 438,000 m^2
5. Supply condition: cold water: 6°C, hot water: 47°C
6. Heat source device: cooling ability: about 77,000 MJ/h, heating ability: about 39,000 MJ/h

   Heating tower heat pump: 1445 RT × 4

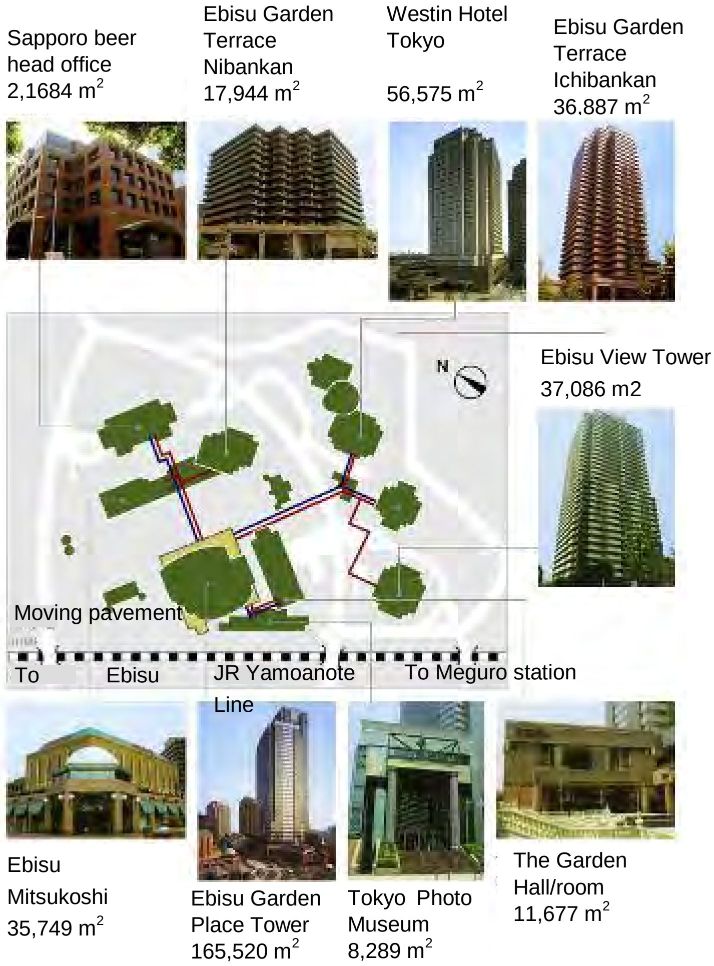
   Turbo freezer: 1180 RT × 2

   Heat collection turbo freezer: 430 RT × 2

   Water heat storage tank: 19,060 m^3

b) Ebisu district (mainly, gas)

Source: Japan Heat Supply Business Association HP



Source: Tokyo Energy Service HP

Figure 8.1.2 Outline of Ebisu District

1. Supply start: September, 1994
2. Supplied to: 9 buildings (complex application: office, merchant, hotel)
3. Supply area: about 97,000 m^2
4. Total floor space to supply: about 391,000 m^2
5. Supply condition: cold water: 7°C (partially, 8°C), steam: about 0.8 MPa
6. Heat source device: cooling ability: about 139,000 MJ/h, heating ability: about 123,000 MJ/h

Gas turbine cogeneration: Power generation capacity 1500 kW × 4

Steam generation amount: 4.45 t/h × 3 + 5.0 t/h × 1

Furnace cylinder type steam boiler : 15 t/h × 3 + 4.8 t/h × 2

Steam suction freezer: 2000 USRT × 4 + 1000 USRT × 3

c) Sapporo station north entrance redevelopment district (use of electricity and gas)

Source: Japan Heat Supply Business Association HP

Figure 8.1.3 Outline of Sapporo Station North Entrance Redevelopment District

1. Supply start: April, 1989
2. Supply area: about 220,000 m^2
3. Total floor space to supply: about 196,000 m^2
4. Supply condition: cold water: 7°C, hot water: 90°C
5. Heat source device: cooling ability: about 59,000 MJ/h, heating ability: about 82,000 MJ/h

Electric-driven turbo freezer: 785 RT × 2

Hot water suction freezer: 600 RT × 1

Steam suction freezer: 1200 RT × 1 + 1000 RT × 1

Gas suction freezer: 300 RT × 1

Steam boiler : 9.3 t/h × 2 + 2.0 t/h × 9

8.2 Examination of introducing low-carbon technology in this project site

1) Consideration of area air-conditioning facility in this project site

The area air-conditioning in this developed district can receive the heat discharged from power stations out of the developed district (Figure 8.2.1). Therefore, “cold water + high-temperature water supply” is basically considered for air-conditioning of this development district (Figure 8.2.2).

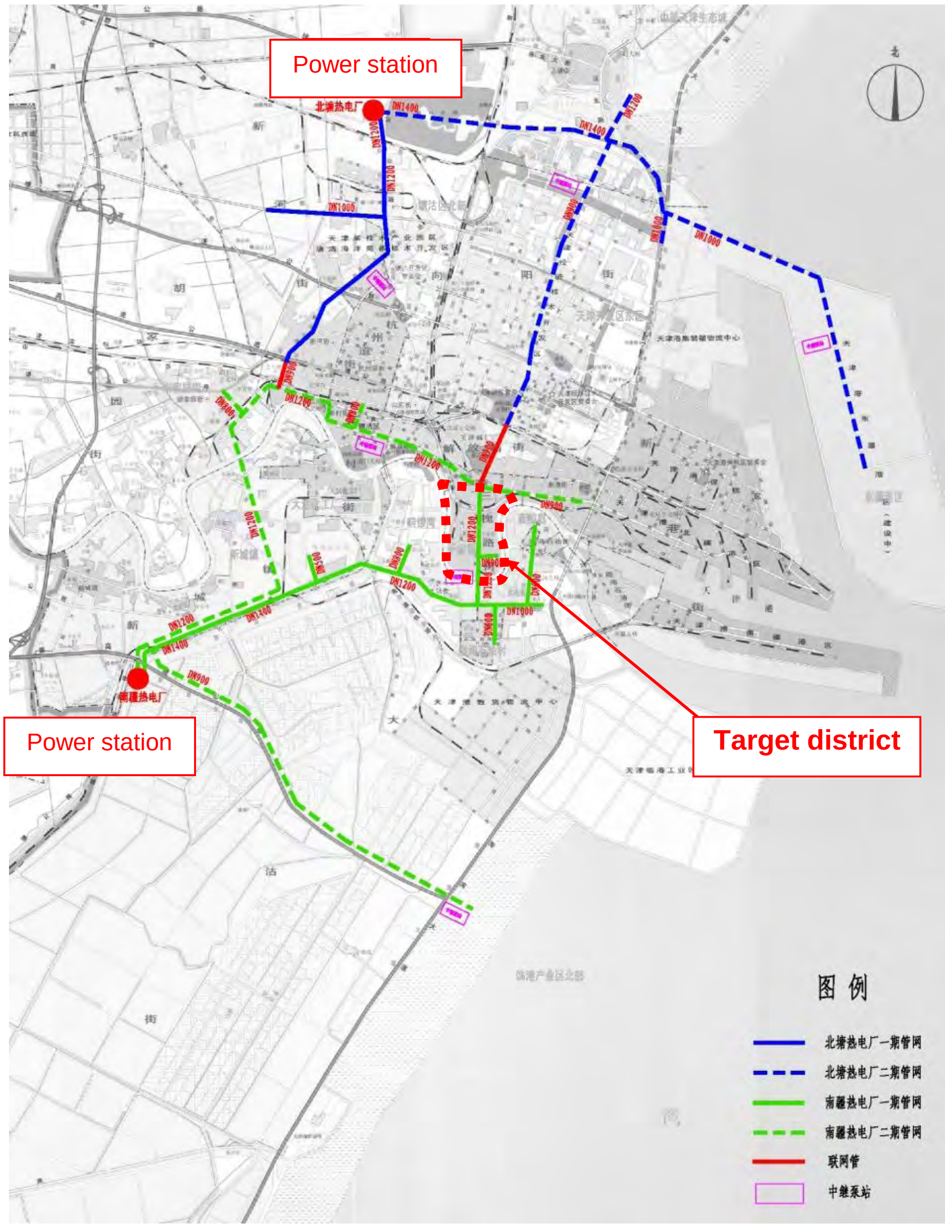


Figure 8.2.1 Plan of Discharged Heat Pipes from the Power Station

High-temperature hot water supply utilizing discharged heat from the power station is already planned in the entire Tianjin city.

↓

High-temperature hot water should be used as a warm heating source in the district.

↓

When the power station's condition is improved in which, efficiency can be improved and electricity can be stably supplied, electricity based area energy plan might be possibly adopted in this areaity is possible.

Figure 8.2.2 Flow of Consideration about an Area Air-conditioning Facility in Yujiapu

2) Location arrangement plan of an area air-conditioning facility and examination method of heat source simulation system

The followings are the location arrangement plan of the area air-conditioning facility. A total of 12 area air-conditioning facilities are planned to be installed through each development PHASE.

PHASE-1: 3 locations
PHASE-2: 4 locations
PHASE-3: 2 locations
PHASE-4: 3 locations
Total: 12 locations

Therefore, the maximum heat supply range is the total floor space: about 1,200,000 m^2 and the site area: about 200,000 m^2.

In addition, the following shows the entire flow of the heat source system simulation for the area air-conditioning facility.

"The entire flow of the heat source system simulation"

1. Arrange the building use and scales of the representative area air-conditioning district as to be a model case from the above 12 locations in DHC supply area which proposed in the last- year business, and select the model district.
(This time, STEP-1 III district is the model.)

↓

2. Assume a load of cold water, steam, and hot water in the model district (floor area by building use × load patter for each floor area (load of air-conditioning and hot water

supply))

* Extract the load pattern for each floor area.

↓

3. Assume the heat source system of the area air-conditioning facility on the basis of district load. (About 5 patterns (main use of power station discharged heat based, electricity based (2 cases), gas based, use of electricity and gas combination))

↓

4. Calculate the amount of primary energy consumption and CO_2 emissions for each system using the simulation software based on the assumed system and compare them.

↓

5. Calculate the initial cost and running cost and compare its cost performance.

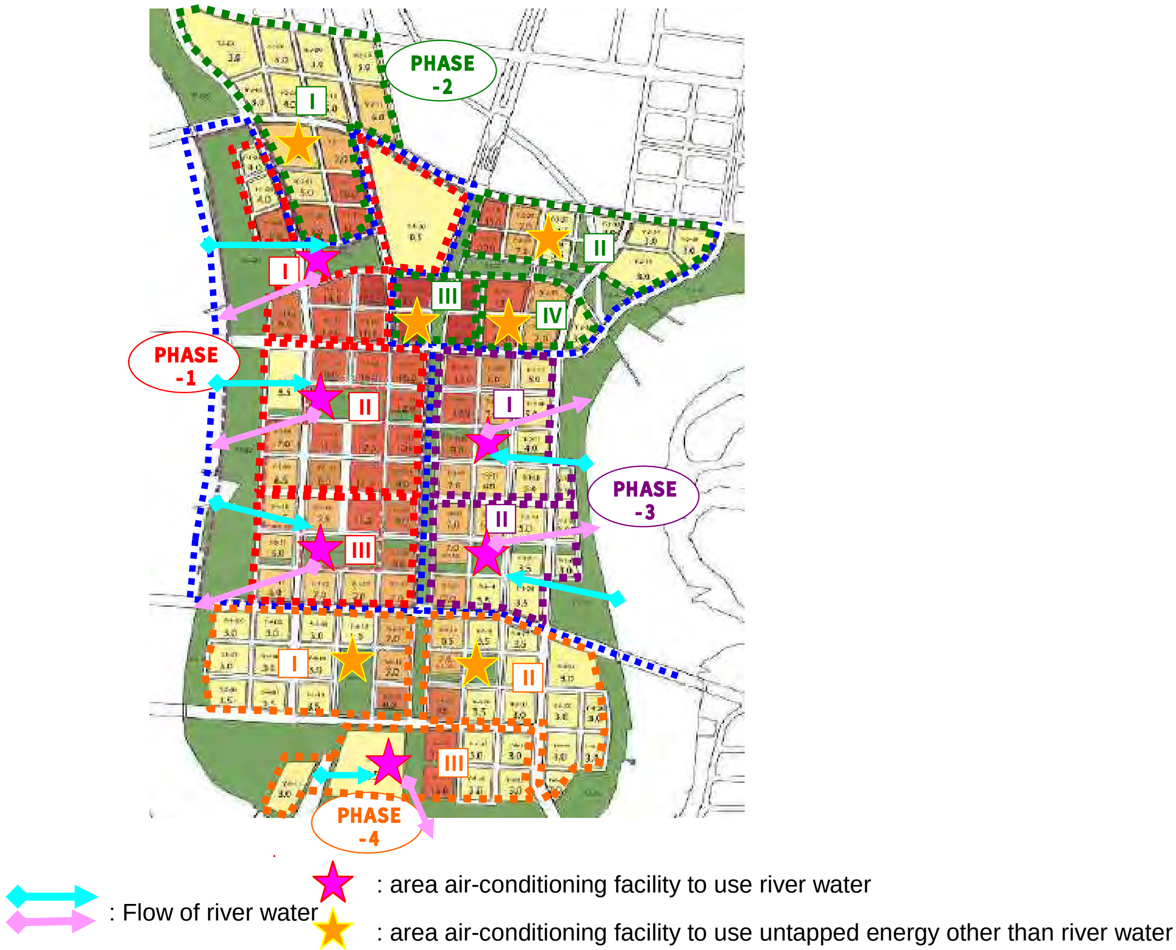


Figure 8.2.3 Arrangement Plan of the DHC Facility in the Development District

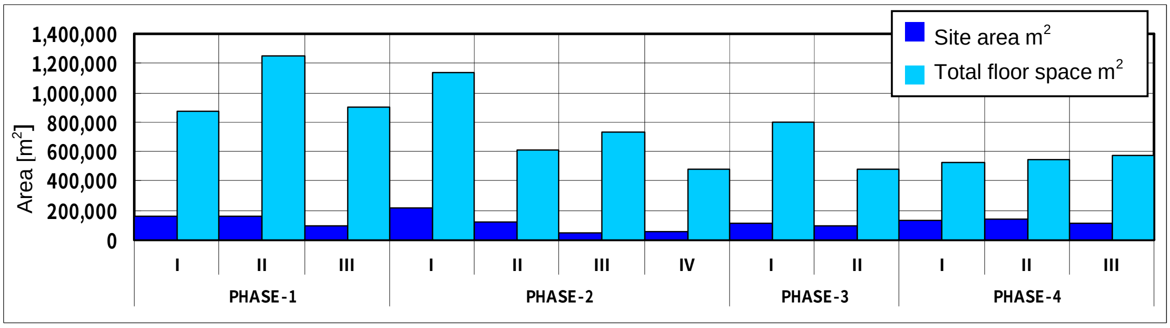


Figure 8.2.4 Supply Area of Each Area Air-Conditioning Facility

3) DHC heat source structure

The heat source structure of the area air-conditioning facility is based on the conditions below:

a) High-temperature water heat supply using power station discharged heat

b) The efficiency of power generation of current power station is not good.

c) Stability of current power supply from the power station is low.

d) It is necessary to coordinate the area air-conditioning facility plan by using the untapped energy and considering the environment.

The heat source structure plan of the area air-conditioning facility is considered as follows, based on the conditions below:

"Comparison of heat source systems"

CASE 1 (mainly using discharge heat from power station): discharge heat steam from power station + steam suction freezer (aggressive use of power station discharged heat)

CASE 2 (mainly using electricity): discharge heat steam from power station + electric turbo freezer + ice storage heat tank (according to the current Master Plan)

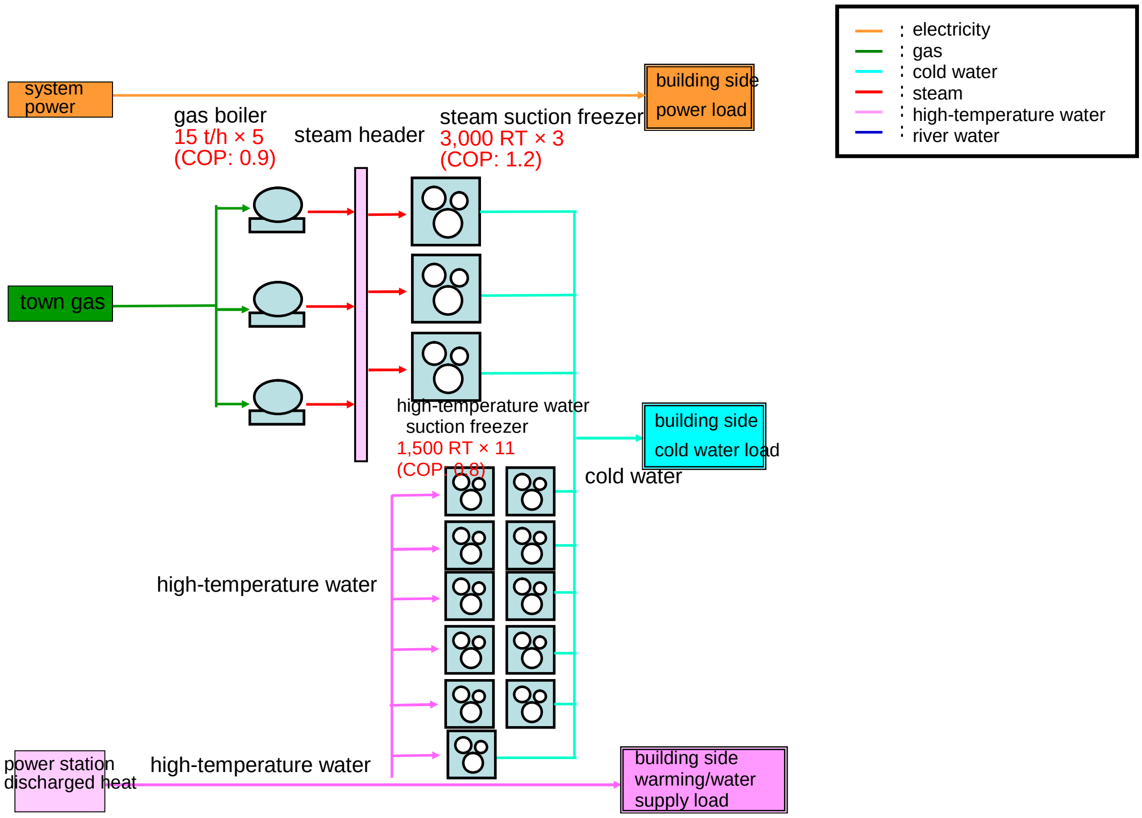
CASE 3 (mainly using electricity): discharge heat steam from power station + electric turbo freezer + Water heat storage tank (representative ice storage heat; Japanese high efficient system)

CASE 4 (mainly using gas): discharge heat steam from power station + gas cogeneration + Steam suction freezer (cogeneration intending improved electricity reliability)

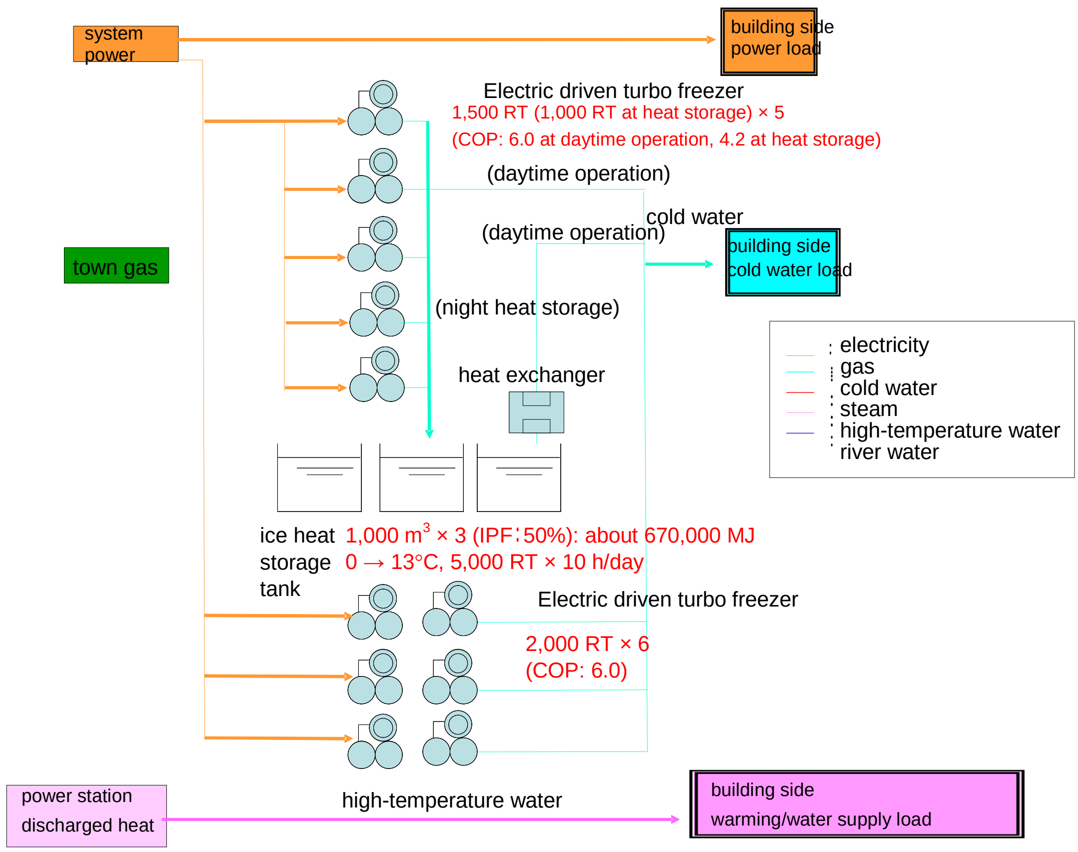
CASE 5 (using electricity and gas): discharge heat steam from power station + gas cogeneration + electric turbo freezer + Gas suction freezer + Water heat storage tank

The followings are the examples of the heat source structure based on the load estimation of the area air-conditioning facility in PHASE-1 III.

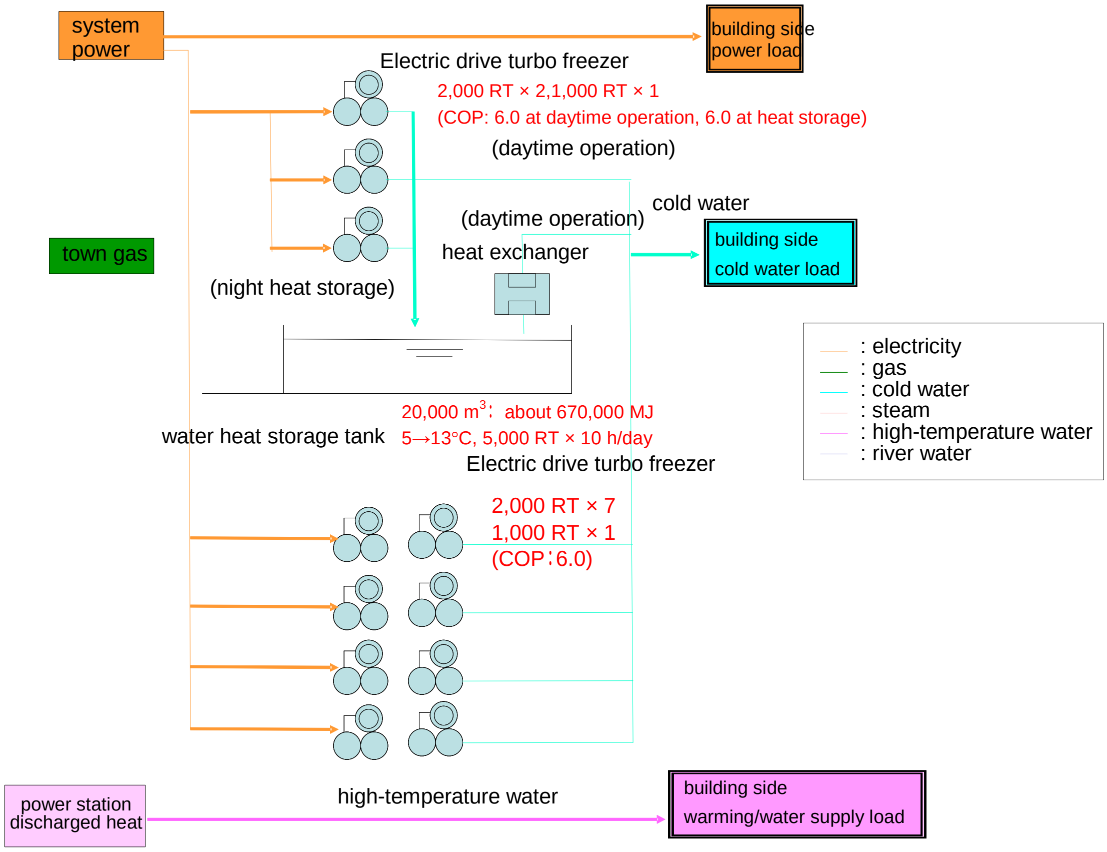
CASE 1 (power station discharged heat based): (power station discharged heat (high-temperature hot water) + steam suction freezer (cold water))



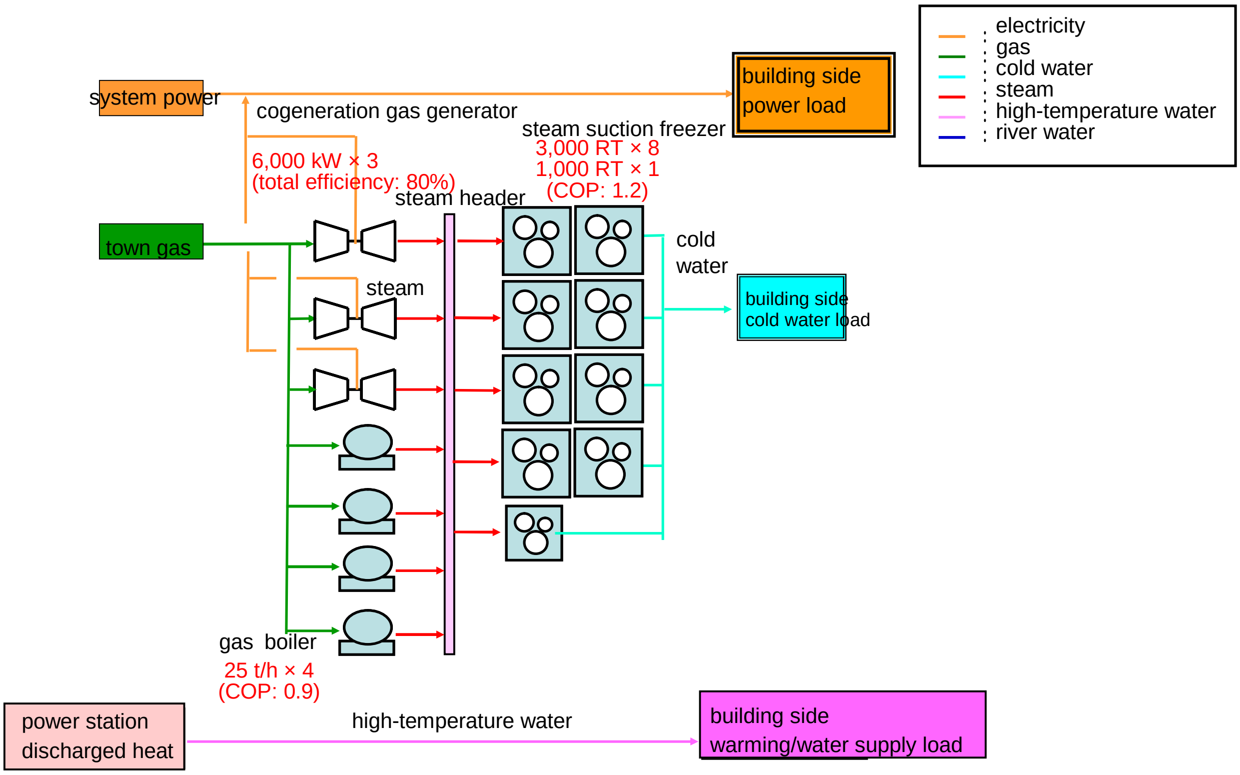
CASE 2 (electricity based – 1): (power station discharged heat (high-temperature hot water) + turbo freezer + ice storage heat tank (cold water))



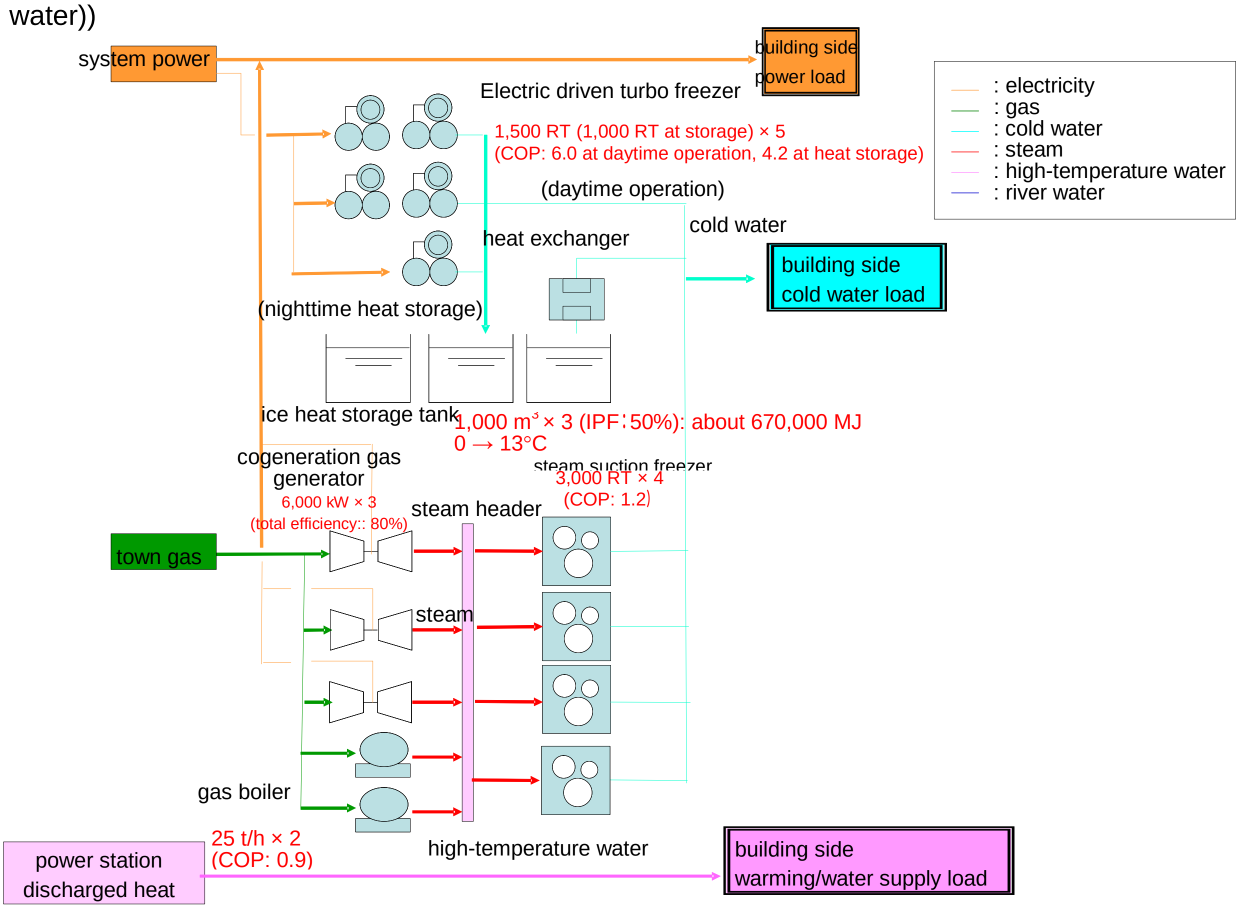
CASE 3 (electricity based – 2): (power station discharged heat (high-temperature hot water) + turbo freezer + water heat storage tank (cold water))



CASE 4 (gas based): (power station discharged heat (high-temperature hot water) + gas cogeneration + steam suction freezer (cold water))



CASE 5 (electricity and gas combination): (power station discharged heat (high-temperature hot water) + gas cogeneration + steam suction freezer + turbo freezer + ice storage heat (cold water))



8.3 Analysis of the CO_2 reduction effect

1) Outline of the assumed plan model and assumed load

The following show (a) the development site area and total floor space of buildings and (b) the ratio of building use for the model district PHASE-1 III.

Table 8.3.1 Development Site and Total Floor Space (PHASE-1 III District)

District/building NO.		District/building 1	
Outline of district and site	Site area	92,540	m^2
	Volume ratio	970	%
	Total floor space	897,638	m^2
		Floor space (m2)	Structure ratio (%)
Building use	Office	751,438	84
	Hotel	0	0
	Hospital	0	0
	Shop	89,838	10
	Sports gym	0	0
	Residence	57,104	6
	Total	898,380	100

Selection of heat supply device	District/building 1
Cooling	Cold water
Heating	Steam
Hot-Water supply	Steam

a) About unit load and load pattern of the assumed district

The values below are used for the load original unit and the load pattern for each different building use consulting with Tsinghua University. The load of the entire district is calculated by assuming that the load of the office on holidays is 30% of that on weekdays. For other building usage, the load ratio is assumed to be the same for weekdays and holidays.

Table 8.3.2 Load Original Unit Assumed by Building Use

(Before review)

* Japanese standard values are used.

Building usage	Type	Usage / Unit	Office	Shop	Residence
Max. demand	Power	Wh/m^2	50	70	30
	Cooling	Wh/m^2	100.0	140.0	40.0
	Heating	Wh/m^2	60.0	95.0	20.0
	Hot-Water supply	Wh/m^2	20.0	25.0	20.0
Annual demand	Power	$kWh/m^2/Y$	160	250	25
	Cooling	$kWh/m^2/Y$	85.0	150.0	10.0
	Heating	$kWh/m^2/Y$	40.0	45.0	25.0
	Hot-Water supply	$kWh/m^2/Y$	5.0	30.0	35.0
	Cooling	$MJ/ m^2/Y$	306.0	540.0	36.0
	Heating	$MJ/ m^2/Y$	144.0	162.0	90.0
	Hot-Water supply	$MJ/ m^2/Y$	18.0	108.0	126.0

(After review)

* Chinese standard values are used

Building usage	Type	Usage / Unit	Office	Shop	Residence
Max. demand	Power	Wh/m^2	50	70	30
	Cooling	Wh/m^2	100.0	140.0	40.0
	Heating	Wh/m^2	60.0	95.0	20.0
	Hot-Water supply	Wh/m^2	20.0	25.0	20.0
Annual demand	Power	$kWh/m^2/Y$	160	250	25
	Cooling	$kWh/m^2/Y$	85.0	120.0	
	Heating	$kWh/m^2/Y$	40.0	30.0	60.0
	Hot-Water supply	$kWh/m^2/Y$			
	Cooling	$MJ/m^2/Y$	306.0	432.0	0.0
	Heating	$MJ/m^2/Y$	144.0	108.0	216.0
	Hot-Water supply	$MJ/m^2/Y$	0.0	0.0	0.0

Chinese standard values are derived by co-working with Tsinghua University

b) About load of assumed district

The followings are the result of calculating the power, cooling, heating, and hot-water supply load patterns of the assumed district.

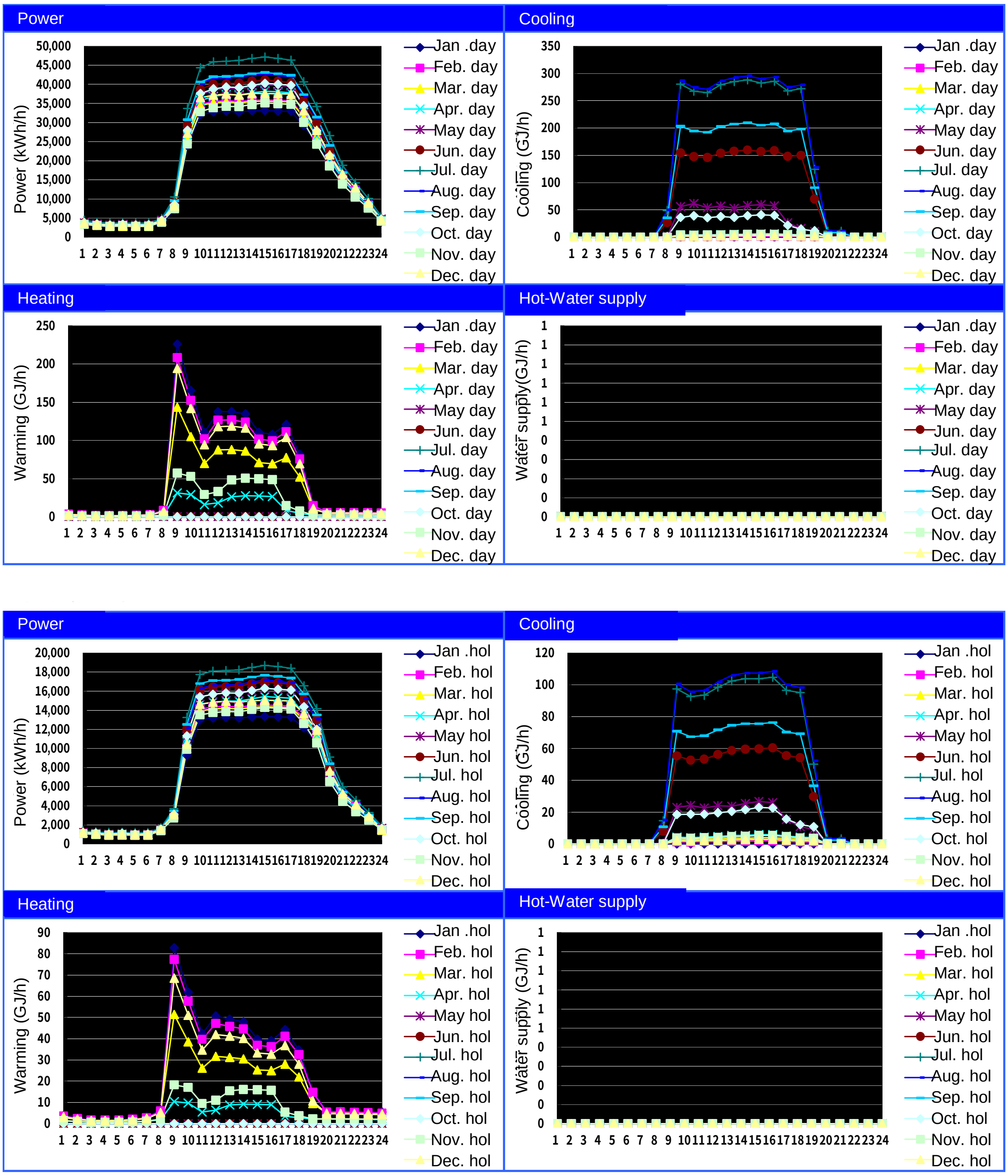


Figure 8.3.1 Assuming Electricity, Cooling, and Warming Loads by Hour and by Month (PHASE-1 III District)

2) Comparison result of heat source systems (using the Japanese electricity primary energy original coefficients (9,760 kJ/kWh))

The following shows comparion result of the annual primary energy consumption, heat source device efficiency (COP), and CO_2 emissions amount in 5 cases of the heat source systems in the model district PHASE-1 III.

Primary energy consumption value (Japan)

Power	Gas (LNG)	Gas (LPG)	Kerosene
kJ/kWh	kJ/Nm^3	kJ/kg	kJ/L
9,760	45,100	50,000	37,000

CO_2 emission factor (Japan)

Power	Gas (LNG)	Gas (LPG)	Kerosene
kg-CO_2/kWh	kg-CO_2/Nm^3	kg-CO_2/kg	kg-CO_2/L
0.425	2.08	3.00	2.49

(CO_2 emission factor for primary energy)

(kg-CO2/MJ)

	Power	Gas (LNG)
	0.044	0.046

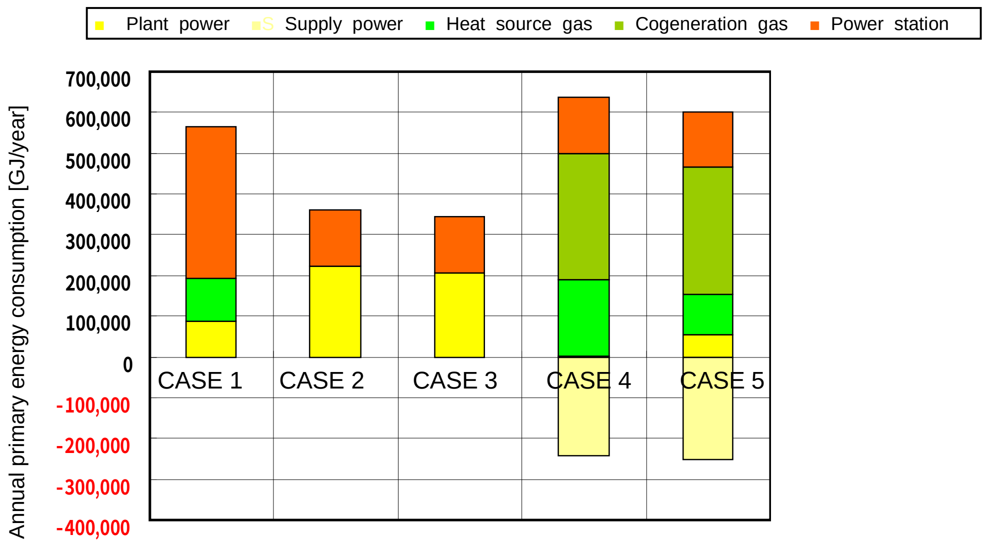


Figure 8.3.2 Results of the Comparison of the Heat Source Systems (Annual Primary Energy Consumption)

$$COP = \frac{\text{(Amount of cool heat supply [GJ/year] + Amount of electric power supply [GJ/year])}}{\text{(Power consumption in plant [GJ/year] + gas consumption in plant [GJ/year])}}$$

* This calculation does not consider the amount of warm heat supply because the plan is supposed to use discharged heat from power station.

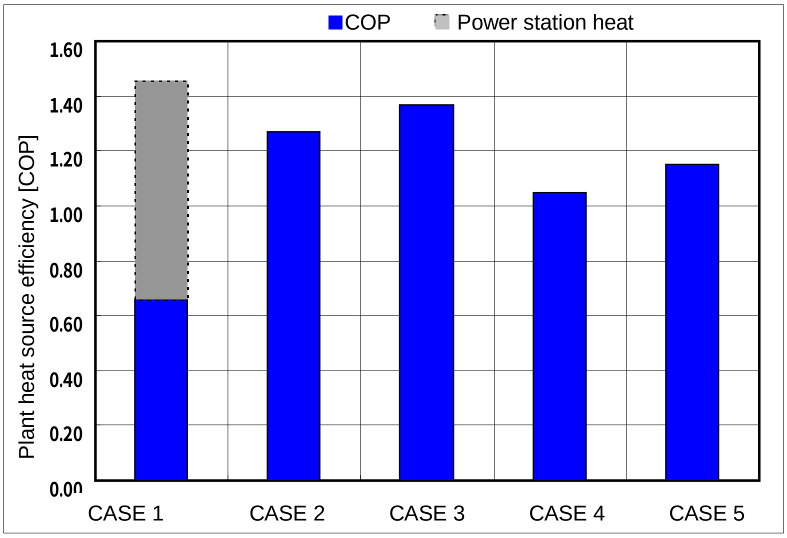


Figure 8.3.3 Results of the Comparison of the Heat Source Systems (Heat Source Device Efficiency)

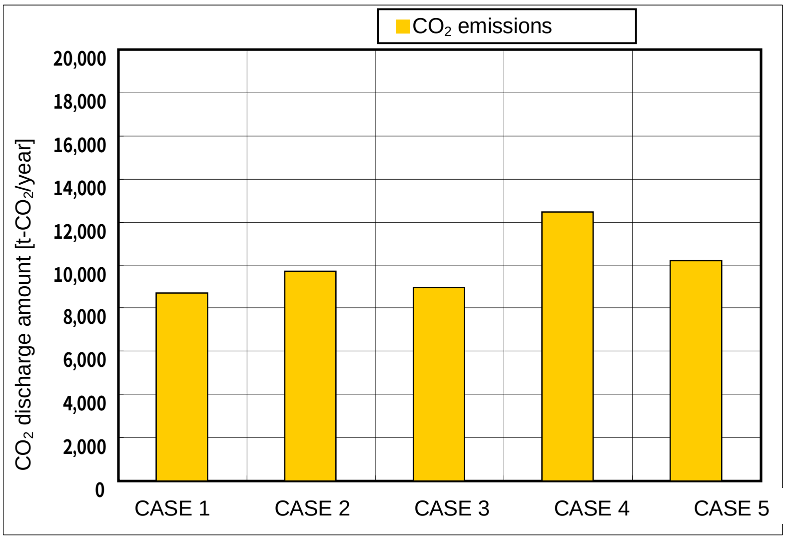


Figure 8.3.4 Results of the Comparison of the Heat Source System (CO_2 Emissions)

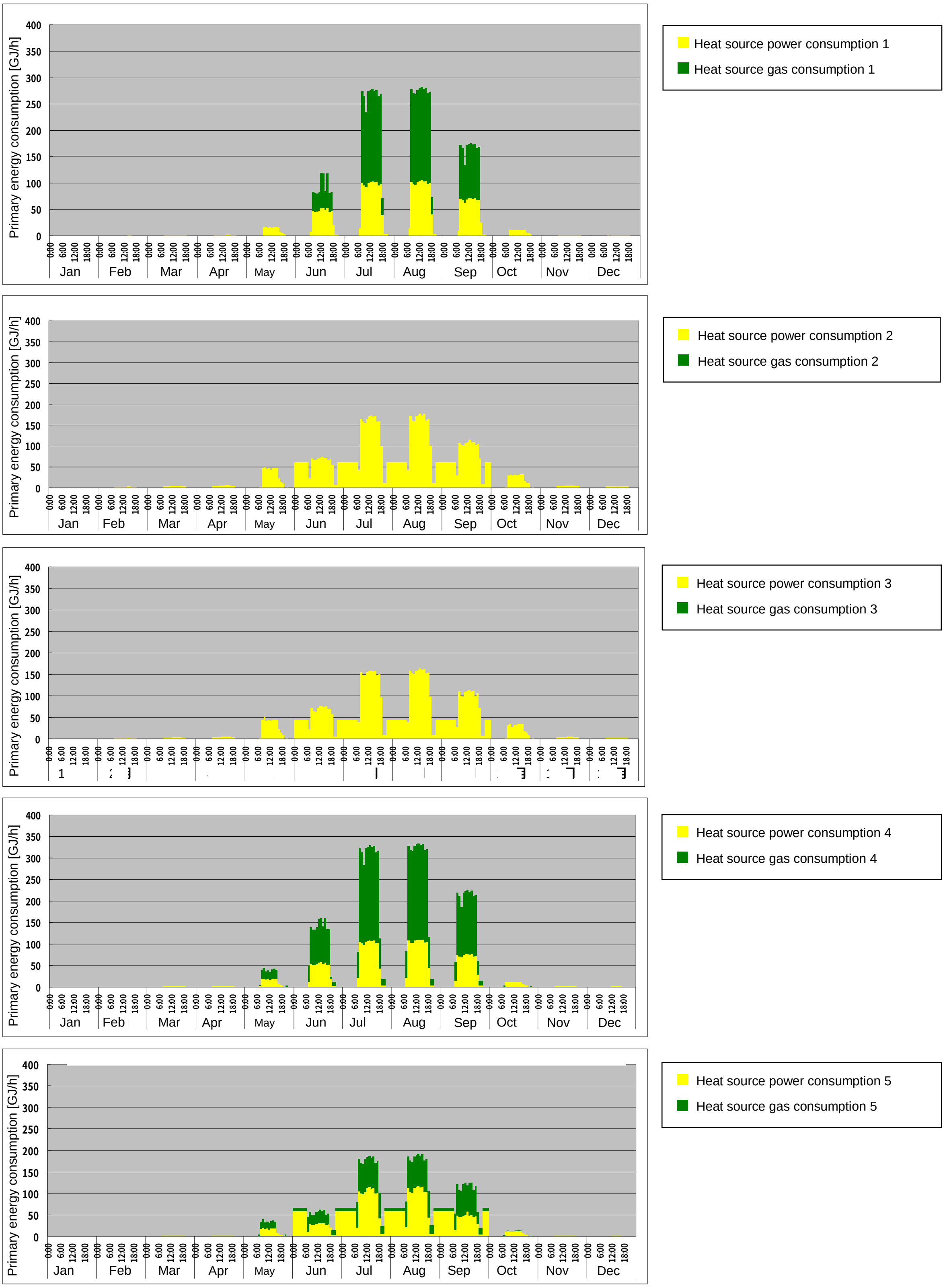


Figure 8.3.5 Consumed Primary Energy (Power, Gas) of Heat Source devices by Month and Hour (Representative of Weekdays, Case 1 to Case 5 from Top)

* Not including power and gas energy consumption of co-generation devices

3) Comparion result of heat source systems (using Chinese electricity primary energy original coefficients (12,000 kJ/kWh))

The following shows comparion result of the annual primary energy consumption, heat source device efficiency (COP), and amount of CO_2 emissions in 5 cases of the heat source systems in the model district PHASE-1 III. Since the assumed electricity primary energy original coefficients of China is larger than that of Japan, the CO_2 discharge amount of cases 4 and 5, including the cogeneration, is more advantageous than the other cases.

Primary energy consumption value (China, assumed)

Power	Gas (LNG)	Gas (LPG)	Kerosene
kJ/kWh	kJ/Nm^3	kJ/kg	kJ/L
12,000	35,500	50,000	37,000

CO2 emission factor (China, assumed)

Power	Gas (LNG)	Gas (LPG)	Kerosene
kg-CO_2/kWh	kg-CO_2/Nm^3	kg-CO_2/kg	kg-CO_2/L
0.780	1.64	3.00	2.49

(CO_2 emission factor for primary energy)
(kg-CO2/MJ)

	Power	Gas (LNG)
	0.065	0.046

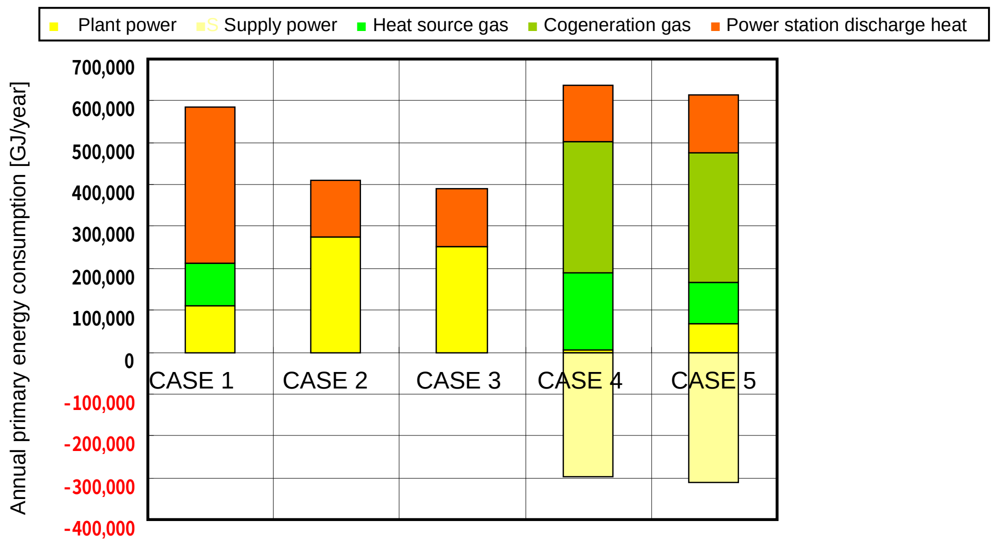


Figure 8.3.6 Results of the Comparison of the Heat Source Systems
(Annual Primary Energy Consumption)

$$\text{COP} = \frac{\text{(Amount of cool heat supply [GJ/year] + Amount of electric power supply [GJ/year])}}{\text{(Power consumption in plant [GJ/year] + gas consumption in plant [GJ/year])}}$$

* This calculation does not consider the amount of warm heat supply because the plan is supposed to use discharged heat from power station.

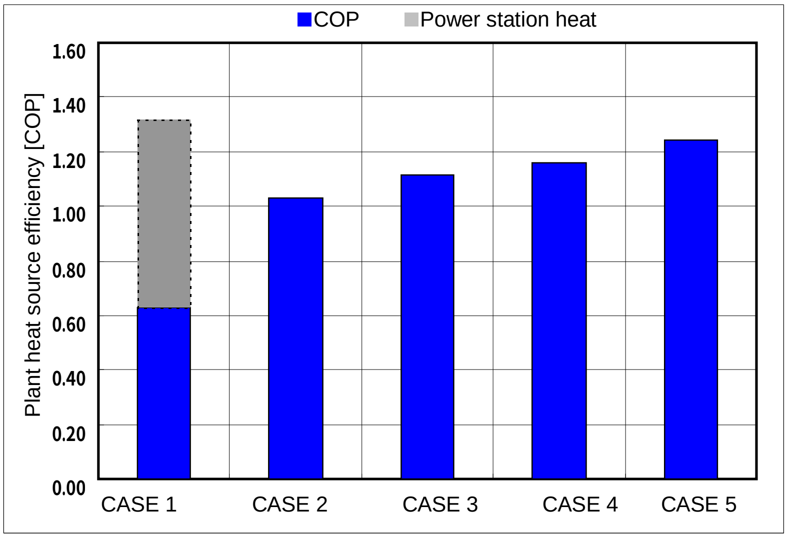


Figure 8.3.7 Results of the Comparison of the Heat Source Systems (Heat Source Device Efficiency)

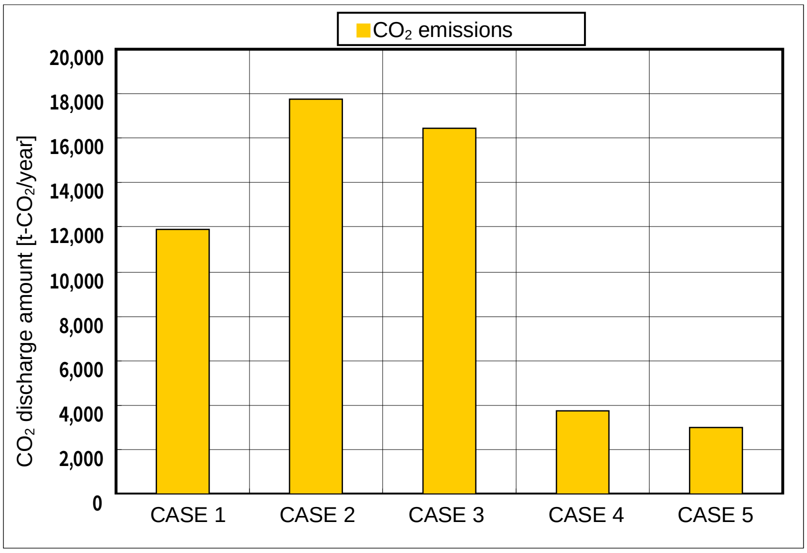


Figure 8.3.8 Results of the Comparison of the Heat Source System (CO_2 Emissions)

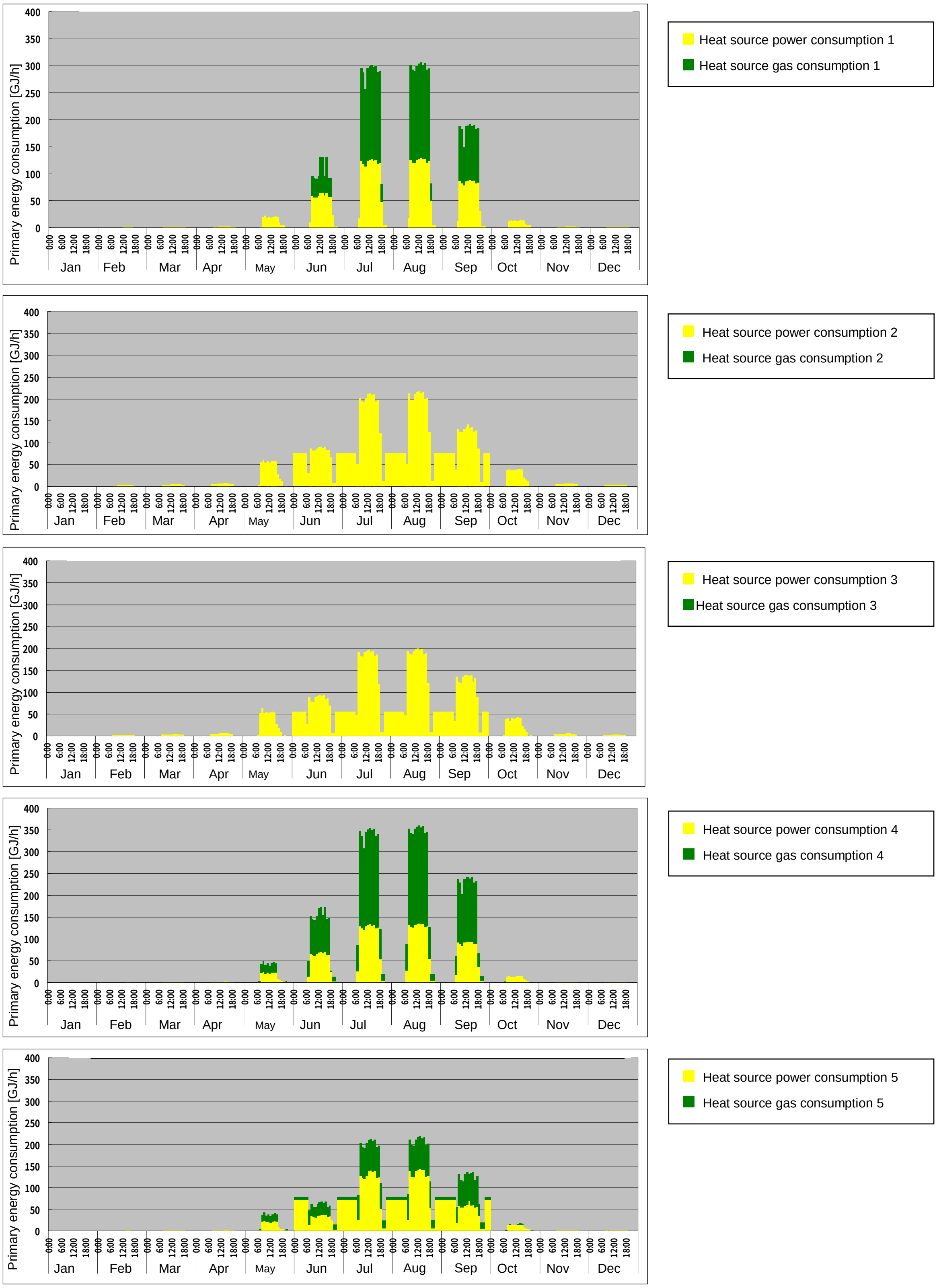


Figure 8.3.9 Consumed Primary Energy (Power, Gas) of Heat Source Devices by Month and Hour (Representative weekday, case 1 to case 5 from top)

* Not including power and gas energy consumption of co-generation devices.

8.4 About the phased area energy arrangement plan

The following is a summary of the phased area energy arrangement plan. Considering the power supply status in this development district, it is important to examine the plan of the area air-conditioning facility using the cogeneration (CHP). In addition, when the heat source of the area air-conditioning is updated since stability and efficiency of the power supply are improved in the future, the heat source facility should be reviewed. However, it is necessary to sufficiently examine the use of untapped energy for the current area air-conditioning facility plan and introduce it.

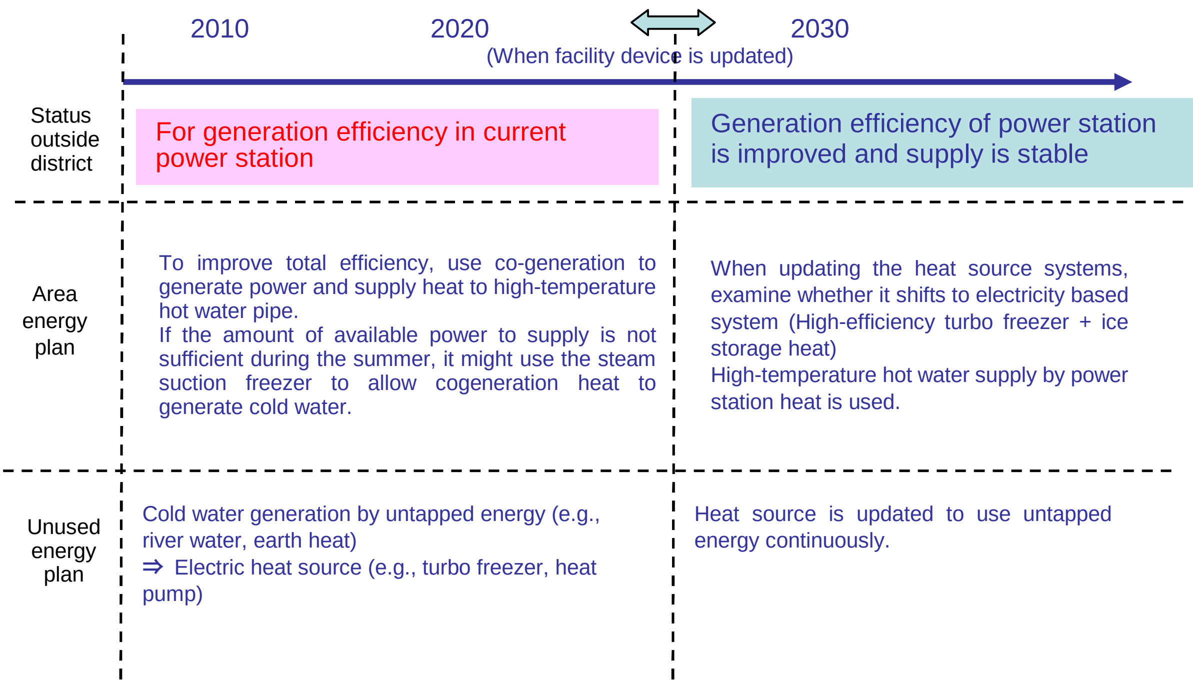


Figure 8.4.1 Consideration of a Phased Area Energy Arrangement Plan

9. Untapped Energy Use Planning

9. Untapped Energy Use Planning

[Key points]

- The paper introduces the untapped energy and examples of Japan.
  (1) Use of river water, (2) use of sewage heat, (3) use of incineration plant discharge heat, (4) use of geothermal heat, and (5) use of subway discharge heat
- The potential of using river water is high because there is a river close to this development area. In addition, the use of incineration plant discharged heat may allow the supply of high-temperature water as use of the power station discharged heat does it.
- Use of sewage heat has a close relationship with the arrangement plan of the sewage facility; therefore, it is needed to decide the adoption of it after comparing it with the use of river water. In addition, since the usage of geothermal heat and subway discharge heat is lower than the others, their priority is low.

9.1 Outline and examples of introduced technologies

The followings are introducing outline of using untapped energy and its examples in Japan.

1) Use of river water

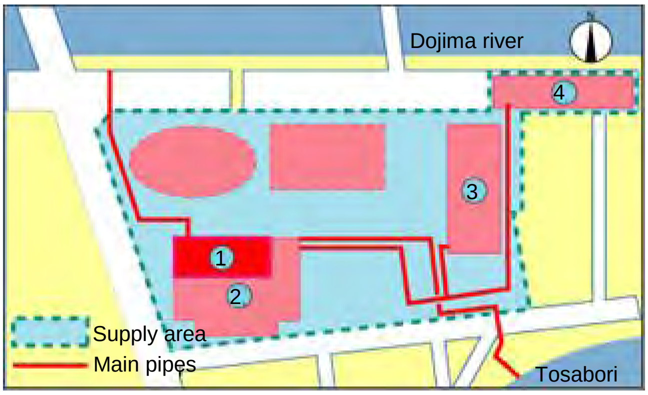
Since the temperature of river water is lower in summer and higher in winter than the air temperature, it is often used for as heat source water when systems such as heat pumps are used. In addition, it contributes to the restraint of heat islands because of no heat emitted to the atmosphere.

a) Introduction of examples

The following introduces the area air-conditioning facility using river water in Japan.

<Nakanoshima 2, 3 Chome district>

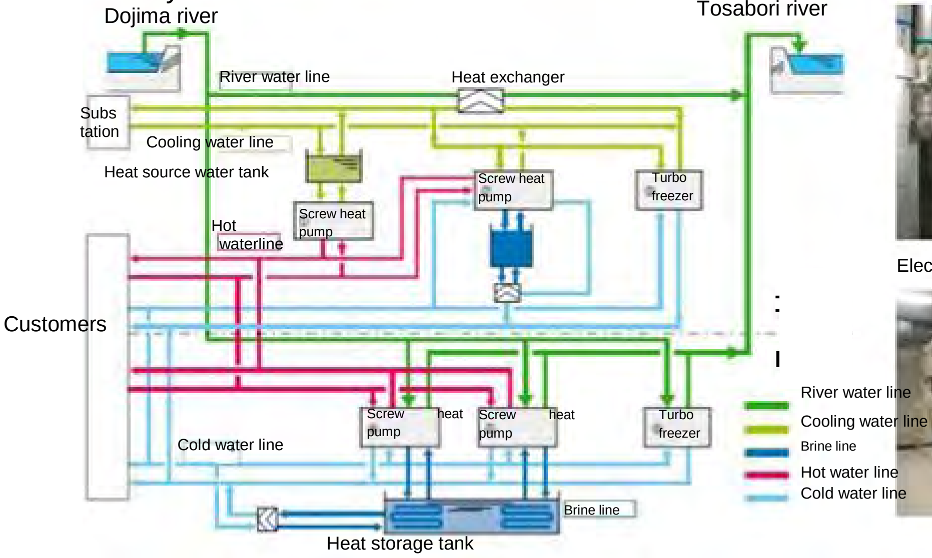
Source: Japan Heat Supply Business Association HP



Sluice gate

Source: Japan Heat Supply Business Association HP

Plant system chart



Electric driven screw heat pump (ice-maker type, heat-collection type

Electric driven turbo freezer

Source: Kanden Energy Development HP

Figure 9.1.1 Outline of Nakanoshima 2, 3 Chome District

1. Supply start: January, 2005
2. Supply area: about 25,000 m^2
3. Total floor space to supply: about 190,000 m^2
4. Supply condition: cold water: 4°C, hot water: 47°C
5. Heat source device: cooling ability: about 51,000 MJ/h, heating ability: about 47,700 MJ/h

(1st phase)
Electric driven heat pump: 838 MJ/h (heating) × 1
Heat collection type electric driven heat pump: 3,080 MJ/h (cooling) × 8
2,606 MJ/h (heating) × 8
Electric-driven turbo freezer: 5063 MJ/h × 1
Ice storage heat tank: 870 m^3
(2nd phase)
Electric driven heat pump: 5,062 MJ/h (cooling) × 1
4,187 MJ/h (heating) × 1
Electric driven heat pump: 8,640 MJ/h (cooling) × 1
13,860 MJ/h (heating) ×1
Electric-driven turbo freezer: 7,595 MJ/h × 1
Ice storage heat tank: 545 m^3

2) Sewage heat use

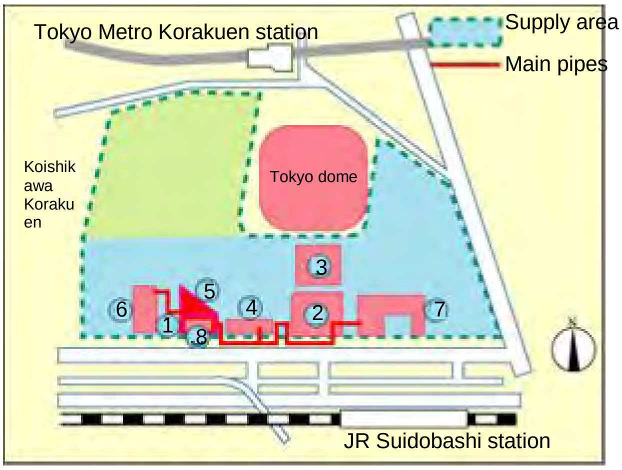
Since the sewage temperature is lower in summer and higher in winter than the air temperature as described for river water, it is used for the heat source water when systems such as heat pumps are used. It also contributes to the restraint of heat islands.

a) Introduction of examples

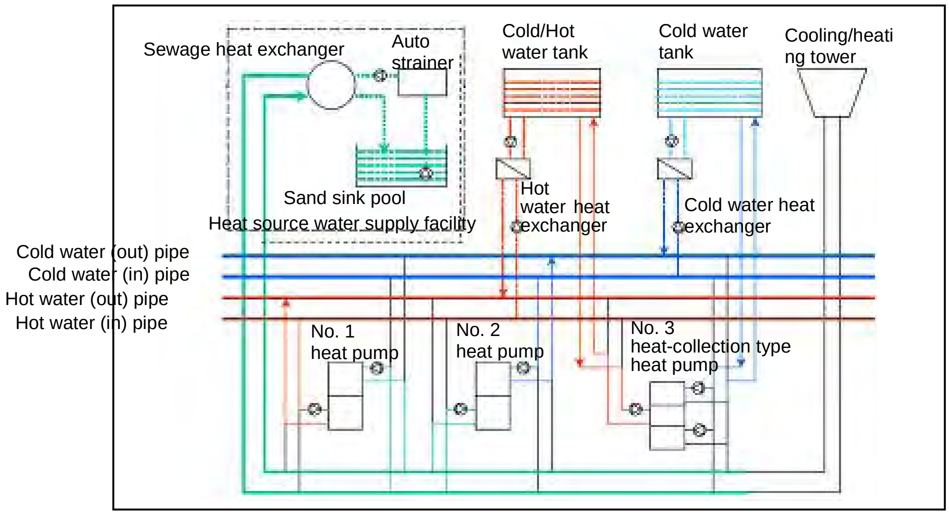
The following introduces the area air-conditioning facility using sewage in Japan.

<Koraku 1 Chome district>

Source: Japan Heat Supply Business Association HP



Source: Japan Heat Supply Business Association HP



Source: Ebara Corporation material

Figure 9.1.2 Outline of Koraku 1 Chome District

1. Supply start: July, 1994
2. Supply area: about 216,000 m^2
3. Total floor space to supply: about 242,000 m^2
4. Supply condition: cold water: 7°C, hot water: 47°C
5. Heat source device: cooling ability: about 109,000 MJ/h, heating ability: about 128,000 MJ/h

    Electric driven heat pump: 38,000 MJ/h (cooling) × 2

    46,000 MJ/h (heating) × 2

    Heat collection type electric driven heat pump: 14,000 MJ/h (cooling) × 1

    18,100 MJ/h (heating) × 1

    Water heat storage tank: 1,520 m^3

3) Use of incineration plant discharged heat

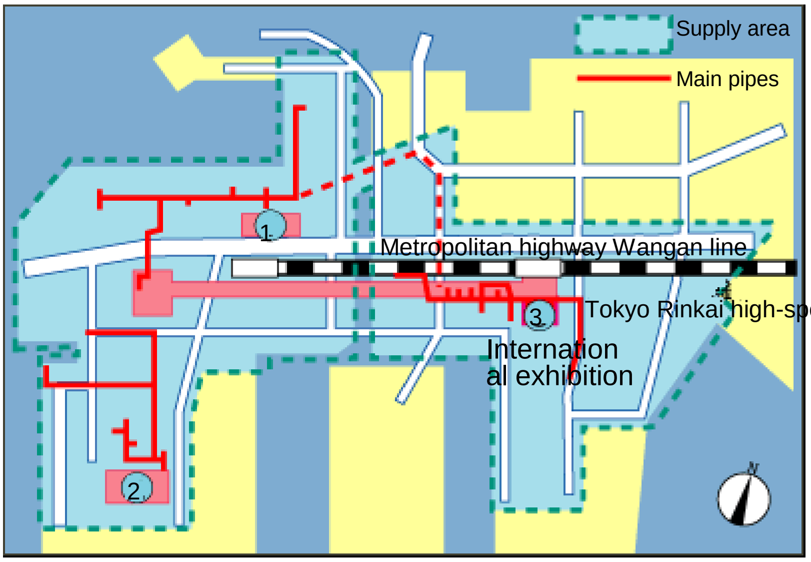
The discharged heat from the incineration plant is supplied to the area air-conditioning facility to allow the steam suction freezer to generate the cold water and to use it as a warm heat source.

a) Introduction of examples

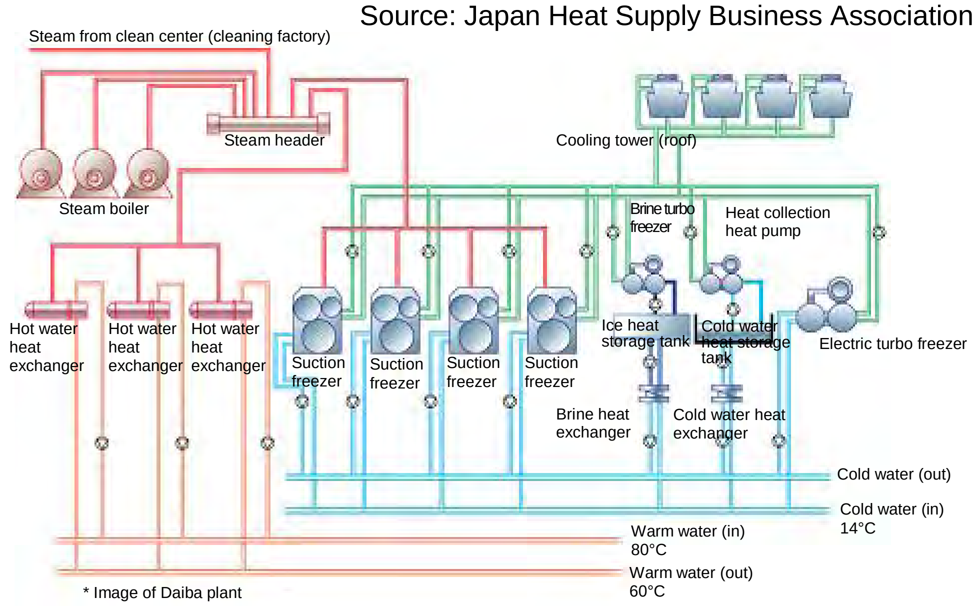
The following introduces the area air-conditioning facility using the incineration plant discharged heat in Japan.

<Ariake district area DHC facility>

Source: Japan Heat Supply Business Association HP



Source: Japan Heat Supply Business Association HP



Source: Tokyo Rinkai heat supply HP

Heat source device		Facility scale		
		Tutumi plant	Airake South plant	Qinghai South plant
Cooling/warming facility	Electric-driven turbo freezer	3,000 RT × 1	3,000 RT × 2	3,000 RT × 2
	Electric brine turbo freezer	1,200 RT × 2	1,200 RT × 2	
	Double purpose steam suction freezer	2,600 RT × 5	2,500 RT × 3 3,000 RT × 1	2,500 RT × 2
	Brine heat exchanger (ice steam heat)	1,500 RT × 2	1,5(X) RT × 2	
	Cold water heat exchanger (ice steam heat)	1,000 RT × 2	1,000 RT × 2	1,400 RT × 2 1,000 RT × 2
	Total	23,400 RT (296 GJ/h)	23,900 RT (302 GJ/h)	15,800 RT (200 GJ/h)
Warming facility	Hot water heat exchanger	50.2 GJ/h × 3 41.9 GJ/h × 1	67.0 GJ/h × 2 33.5 GJ/h × 2	62.8 GJ/h × 1 54.4 GJ/h × 1 16.7 GJ/h × 1
	Total	193 GJ/h	201 GJ/h	134 GJ/h
Heating facility	Furnace pipe warm pipe boiler	30 t/h × 3	25 t/h × 3	24 t/h × 2 14 t/h × 1
	Small flow type boiler		2.5 t/h × 10	
	Total	90 t/h (203 GJ/h)	100 t/h (226 GJ/h)	62 t/h (140 GJ/h)
Heat storage facility	Electric-driven turbo freezer for heat storage			2,800 RT × 1
	Heat collection heat pump for heat storage	800 RT × 1	600 RT × 1	
	Electric brine turbo freezer for heat storage	1,600 RT × 1	766 RT × 2	
	Total	2,400 RT	2,710 RT	2,800 RT
	Heat storage tank: Cold water tank	3,200 m^2	3,750 m^2	8,350 m^2
	Heat storage tank: Ice storage heat tank	857 m^2	712 m^2	
	Heat storage tank: Cool/hot water tank		500 m^2	550 m^2
Supply capacity	Cool heat	23,400 RT (296 GJ/h)	23,900 RT (302 GJ/h)	15,800 RT (200 GJ/h)
	Warm heat	193 GJ/h	201 GJ/h	134 GJ/h
	Total	489 GJ/h	503 GJ/h	334 GJ/h

Source: Tokyo Rinkai heat supply HP

Figure 9.1.3 Outline of Ariake District

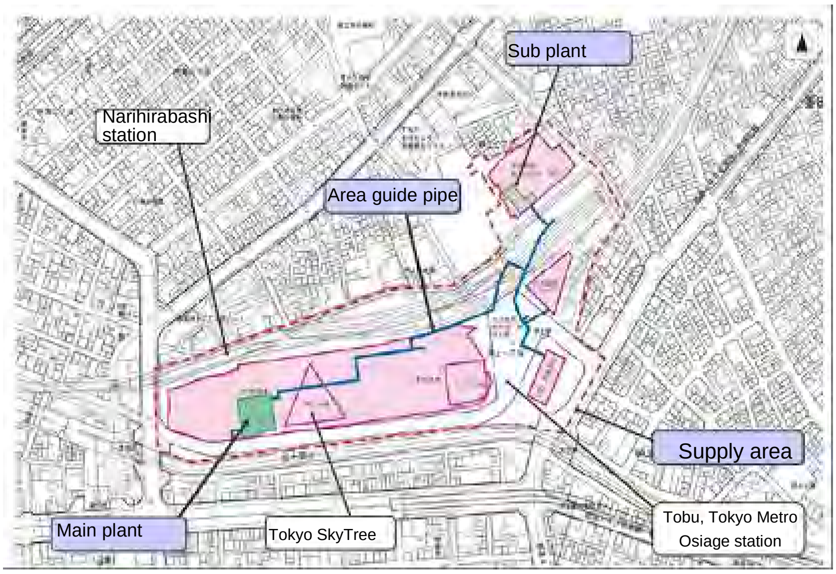
1. Supply start: October, 1995
2. Supply area: about 3,050,000 m^2
3. Total floor space to supply: about 2,142,000 m^2
4. Supply condition: cold water: 7°C, hot water: 80°C
5. Heat source device: see table above.

4) Other untapped energy

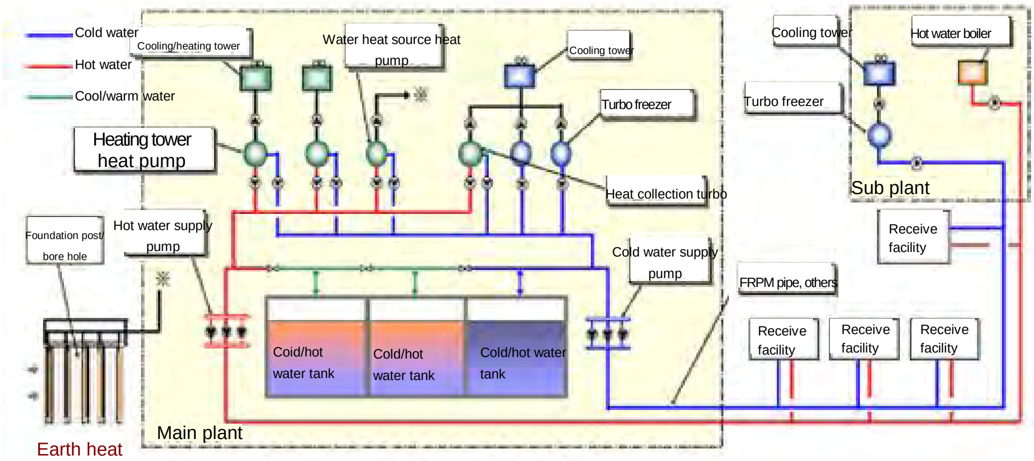
a) Geothermal heat use

Use of geothermal heat is the system that uses the water heat source heat pump to obtain heat from underground and emit it. Since the underground temperature is lower in summer and higher in winter than the air temperature, it can improve the energy consumption efficiency greatly. In addition, it contributes to the restraint of heat islands because of no heat emitted to the atmosphere. The Tokyo SkyTree district where supply from the main plant is planned to start in January, 2012, adopts the first geothermal heat using heat pump for the area air-conditioning facility in Japan. (There are many examples where each building adopts the geothermal heat use technology.)

Source: Nikken HP



Source: Tobu energy management HP



Source: Tobu energy management HP

Figure 9.1.4 Outline of Tokyo SkyTree District

1. Supply start: January, 2012 (scheduled)
2. Supply area: about 102,000 m^2
3. Total floor space to supply: about 205,000 m^2
4. Heat source device: the followings are for the main plant.

Heat pump for geothermal heat: 630 MJ/h (cooling) × 1

800 MJ/h (heating) × 1

Heating tower heat pump: 6,400 MJ/h (cooling) × 2

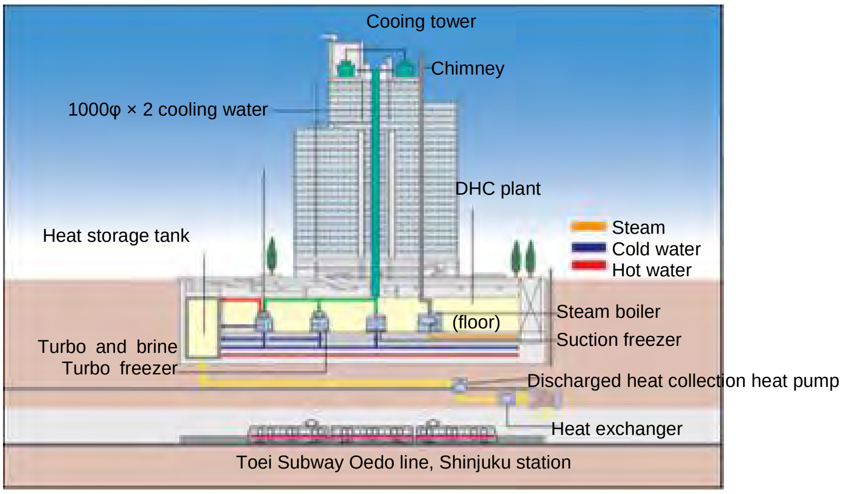
7,600 MJ/h (heating) × 2

Turbo freezer (to be expanded in future): 12,600 MJ/h (cooling) × 1

Water heat storage tank: 7,000 m^3

b) Use of Subway discharged heat

Use of subway discharged heat is the method where low-temperature discharged heat is collected and the operation efficiency of the heat source is improved. When the area air-conditioning facility uses the subway discharged heat, it is mainly adopted by the large-scale station with about 1 million users per day.



Source: Shinjuku south entrance energy service HP

Figure 9.1.5 Outline of Shinjuku South Entrance, West District

1. Supply start: October, 1995
2. Supply area: about 94,000 m^2
3. Total floor space to supply: about 383,000 m^2
4. Supply condition: cold water: 7°C, hot water: 47°C, steam: about 0.8 MPa
5. Heat source device: cooling ability: about 98,700 MJ/h, heating ability: about 111,000 MJ/h

   Heat exchanger for subway discharged heat collection: 3,180 MJ/h × 1 + 2,340 MJ/h × 2

   Water heat storage tank: 3,780 m^3

   Ice storage heat tank: 810 m^3

9.2 Study on introduction of low-carbon technology in this project site

The following evaluates the advantages of each method to use untapped energy in this project site.

1) Use of river water: The potential of using river water is high because of abundant river water close to the development district. Therefore, the area air-conditioning facility close to the rivers should use the river water. However, the quality of the water is low; therefore, it is necessary to use it after water treatment.

(Since, in the study on PHASE-1 III district, the necessary amount of river water is a maximum of 11,800 m^3/h, if the flow speed in the pipe is 3.0 m/s, two 850φ × 2 pipes are required.)

Table 9.2.1 Statistical Data on Pollution at the Boundary between the Sea and River Exceeding the Standard

Pollution index Max. concentration Multiple of standard Monitoring location

	污染指标	最大浓度值 /(mg·L^{-1})	最大超标倍数	出现站点
Mixed oxygen	溶解氧	0		龙王庙、馆陶、先锋桥、白庄桥、四女寺、第三店、吴桥、王营盘、大清集
Ammonia/nitrogen	氨氮	60.20	59.2	第三店
Potassium permanganate	高锰酸盐指数	286.8	46.8	吴桥
COD	化学需氧量	971.6	47.6	吴桥
BOD3	五日生化需氧量	333.7	82.4	吴桥
Fluoridation	氟化物	4.27	3.3	第三店
Volatile phenol	挥发酚	1.330	265.0	窦庄子南
Sulfuration	硫化物	22.50	111.5	窦庄子南
Cr (VI)	六价铬	0.072	0.4	乌龙矶
Lead	铅	0.490	8.8	窦庄子北

2) Use of sewage heat: If the sewage facility is installed close to the area air-conditioning facility in this project district, it may be adopted. However, since there is also river water available, it is necessary to compare the use of both when examining the sewage heat.

3) Use of incineration plant discharged heat: If the incineration plant is installed close to the area air-conditioning facility in this project district, it sewage heat may be adopted instead of the cogeneration discharged heat. In addition, the method to connect the power station discharged heat with the high-temperature hot water pipe is also considered.

4) Use of geothermal heat: Since the capacity of geothermal heat to be used is limited when the area air-conditioning facility adopts it, the priority of using it is low. In addition, since the heat to be used is not high temperature when the geothermal heat is used by digging, it is suitable for the heat source of hot water supply in a building (e.g., hotels and apartments with large hot water loads) not for heat source for producing cold/hot water of the area air-conditioning facility.

5) Use of subway discharged heat: Since the capacity of subway discharged heat to be used is limited when the area air-conditioning facility adopts subway discharged heat, the priority of using it is low.

9.3 Analysis of the CO_2 reduction effects

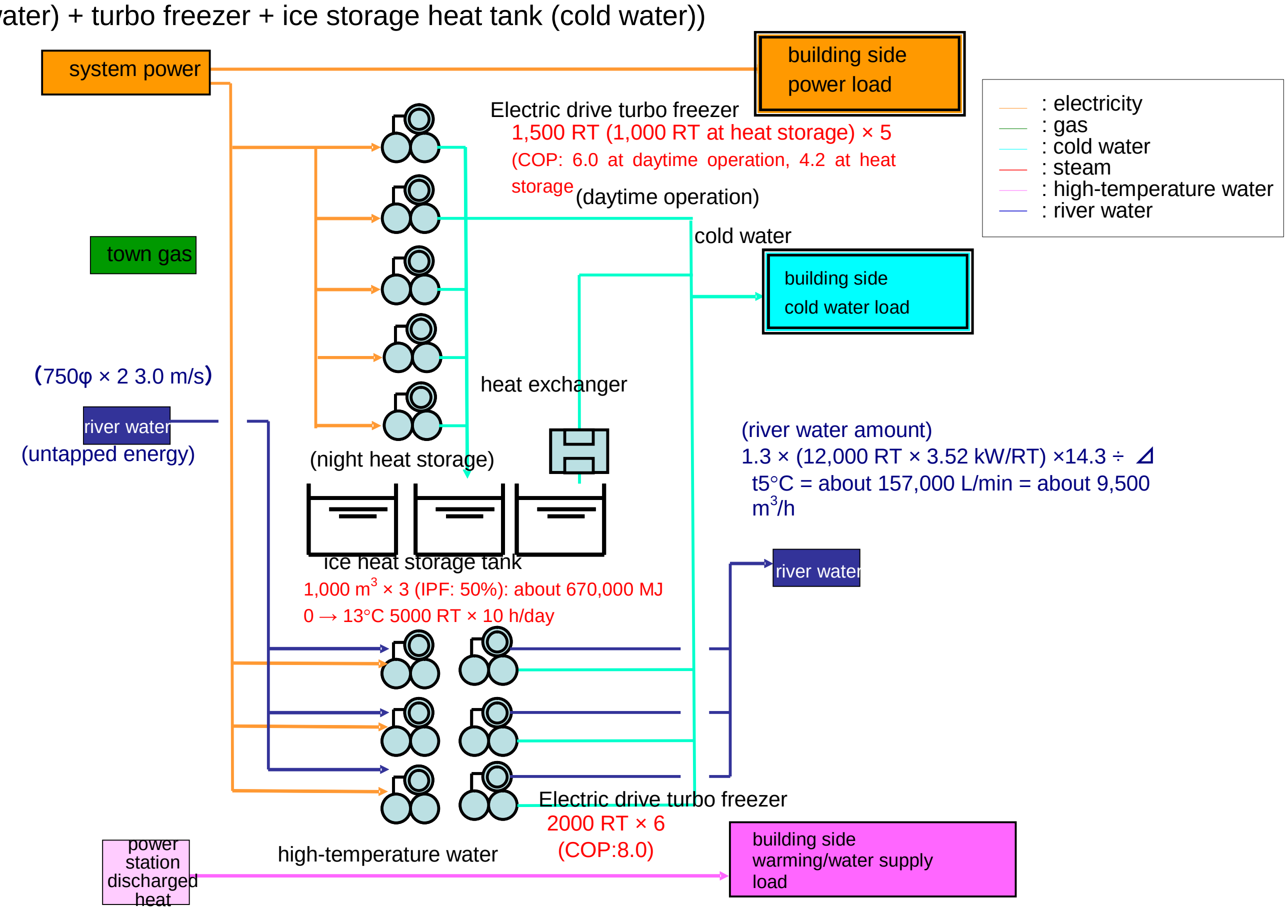
Analysis is done for CO_2 reduction of “river water use,” which is expected to have a great effect on the untapped energy plan described in section 9.2.

1) Examination condition

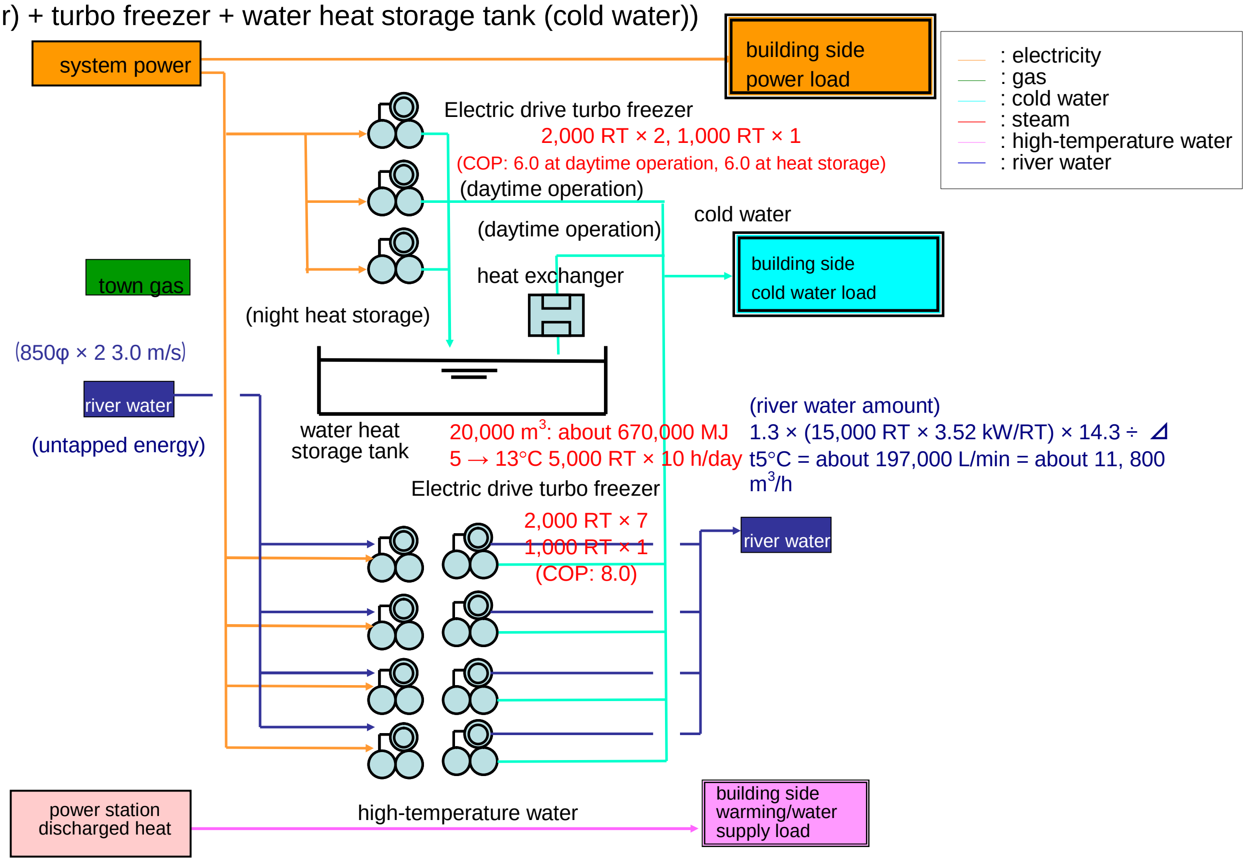
Simulation is done considering the setting where the heat source device efficiency (COP) is improved by using the river water in the heat source system in the PHASE-1 III district described in section 8.2. In addition, the heat source systems in the 3 cases below are examined.

Turbo freezer: rating COP: 6.0 → rating COP: 8.0 by using river water

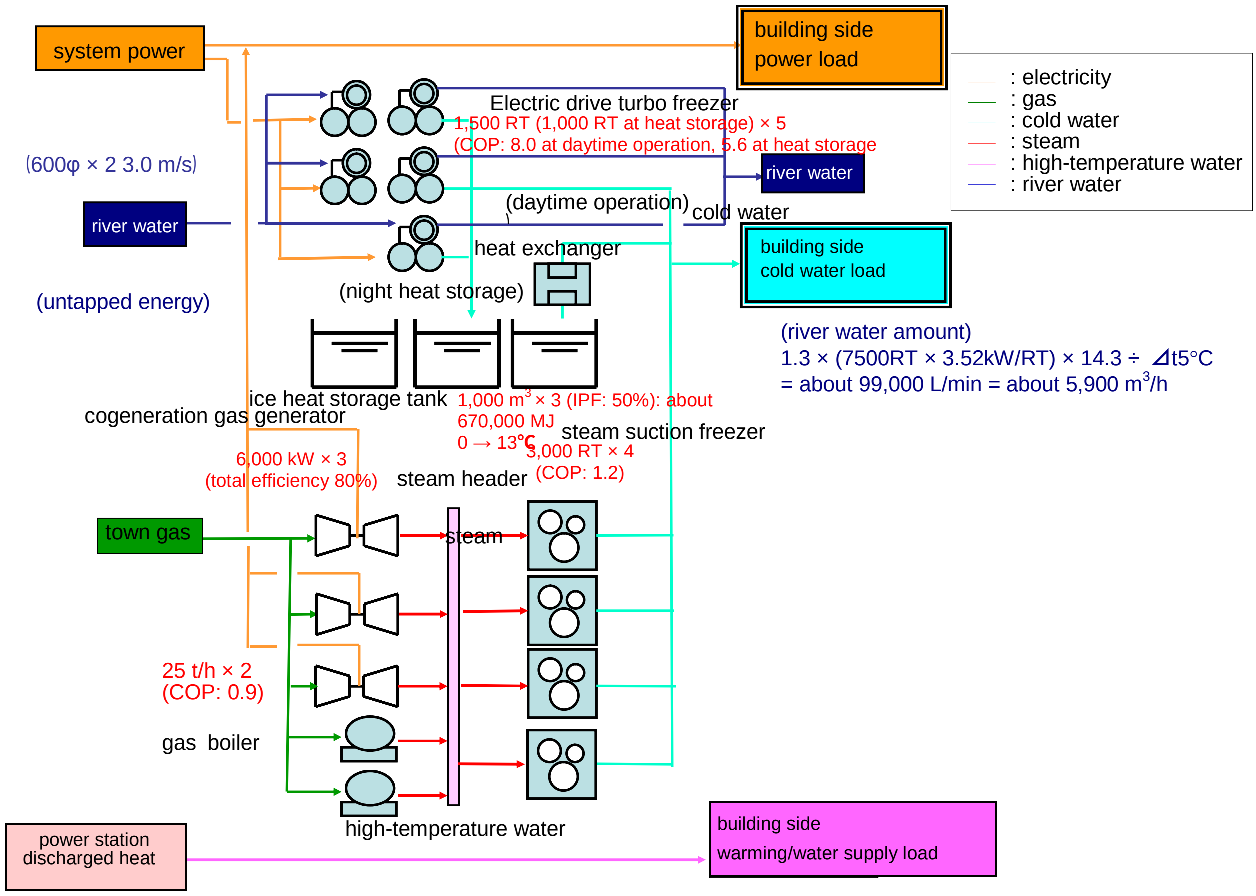
CASE 1 (mainly using electricity – 1): (power station discharged heat (high-temperature water) + turbo freezer + ice storage heat tank (cold water))



CASE 2 (mainly using electricity –2): (power station discharged heat (high-temperature water) + turbo freezer + water heat storage tank (cold water))



CASE 3 (using electricity and gas): (power station discharged heat (high-temperature water) + gas cogeneration + steam suction freezer + turbo freezer + ice heat storage (cold water))



2) Examination result

The followings are the effects when river water is used in PHASE-1 III district. The effect varies depending on the heat source system and it is known that about 10% of CO2 can be reduced in the system which uses much river water. In addition, it is necessary to make close examination of the route of the pipe to take in river water and the discharge pipe in future (Figure 9.3.1).

Table 9.3.1 Examination Results of Effect by Use of River Water (PHASE-1 III district)

	Without use of river water	With use of river water	CO_2 emissions reduction ratio [%]
	CO_2 discharge amount [t-CO2/year]		
CASE 1 (mainly using electricity) (ice heat storage system)	9,688	8,656	10.6
CASE 2 (mainly using electricity) (ice heat storage system)	8,975	7,962	11.2
CASE 3 (using electricity and gas)	10,244	9,687	5.4

* Japan electricity primary energy consumption value , CO_2 emission factor are used for calculation.

CASE A: Intake and exhaust water on each DHC

CASE B: Intake from east side and exhaust to west side of the river

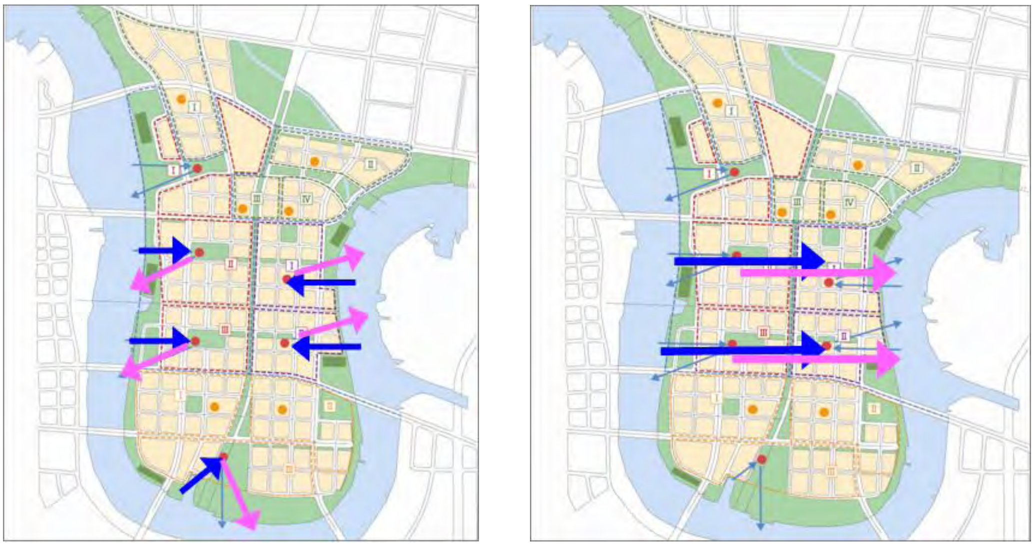


Figure 9.3.1 Examination of River Water Piping Route

9.4 The phased untapped energy plan

In the untapped energy plan described in section 9.2, the arrangement using all methods from the development stage reduces the initial cost more than the arrangement using modification in the future. In particular, judgment of what untapped energy should be used at the stage of examining the installation location of the area air-conditioning facility may change the installation location.

1) Use of river water: Installation of the area air-conditioning facility close to the river can reduce the initial cost using river water.

2) Use of sewage heat: If the sewage facility is close to the area air-conditioning facility, the initial cost of using it can be reduced. In addition, it is necessary to examine the installation location of the sewage facility.

3) Use of incineration plant discharged heat: If the incineration plant is close to the area air-conditioning facility, the initial cost of using it can be reduced. In addition, it is necessary to examine the installation location of the incineration plant.

4) Use of geothermal heat: It does not affect the location in the area air-conditioning facility greatly, but it is necessary to use geothermal heat in the site. In addition, it is suitable for the heat source of the hot water supply in a building (e.g., a big hotel or apartment with a large hot water load), not for the heat source for producing cold/hot water of the area air-conditioning facility.

5) Use of subway discharged heat: Installation of the area air-conditioning facility close to a large subway station with many users can reduce the initial cost. In addition, since the capacity of using the subway discharged heat is limited when the area air-conditioning facility adopts it, the priority of adopting it is low.

10. Renewable Energy Use Planning

10. Renewable Energy Use Planning

Key points

- This paper introduces renewable energy technology.

  (1) Photovoltaic power generation, (2) wind power generation, (3) biomass power generation, (4) solar heat power generation, and (5) geothermal power generation
- It is known that in this district, the potential of the biomass power generation is relatively high. In addition, it is also known that the large-scale photovoltaic panel installation spaces are limited because of the high-density intensive district; that is, the effects of the entire CO_2 reduction are low.
- Since the annual average wind speed is low, large-scale wind power generation is judged to be difficult and it should be installed as a monument. In addition, other technologies are considered to not contribute to CO_2 reduction greatly.
- Since the merit of the initial cost, when installing photovoltaic power generation at the first stage of the area development is low, future technology innovation is expected, and the cost will be reduced; it is possible to make step-by-step arrangements for it.

10.1 Outline and examples of introduced technologies

The concern about renewable energy becomes high rapidly in the world and measures for the introduction and enlargement of it are reinforced in each country.

To realize 3E of the basic energy policy; that is, ensuring stable energy supply (Energy Security), adaptation to environment (Environment), and Economic Efficiency, introduction and enlargement of it is urgent. The following introduces the outline and examples of it.

1) Photovoltaic

a) Kinds of photovoltaic generators

The photovoltaic technology is roughly classified into the silicon, chemical combination, and organic technologies and the solar cell below is mainly developed.

- Silicon

  Crystal type (single crystal, multi-crystal): practicable

  Thin membrane type: practicable
- Chemical combination

  CIS type: practicable

  CdTe type: practicable (no Japanese manufacturer)

Light concentrating type: under research

- Organic

Coloring matter increased sensitivity: under research

Organic thin membrane: under research

2) Wind power generation

a) Kinds of wind power generation

In recent years, the output of wind power generators has become large and the scale of the stations has become large. Windmills are roughly classified into “horizontal axis” and “vertical axis” depending on the direction of the rotation axis. In addition, they are also classified by the operation principle, into “lifting power type,” which generates high-speed rotation by using the lifting power of wings and “power resistant type,” which generates low-speed rotation by wind pressing power. The mainstream for the middle- and large-sized windmills is the 3-wing, horizontal axis, propeller type.

2.4 MW machine

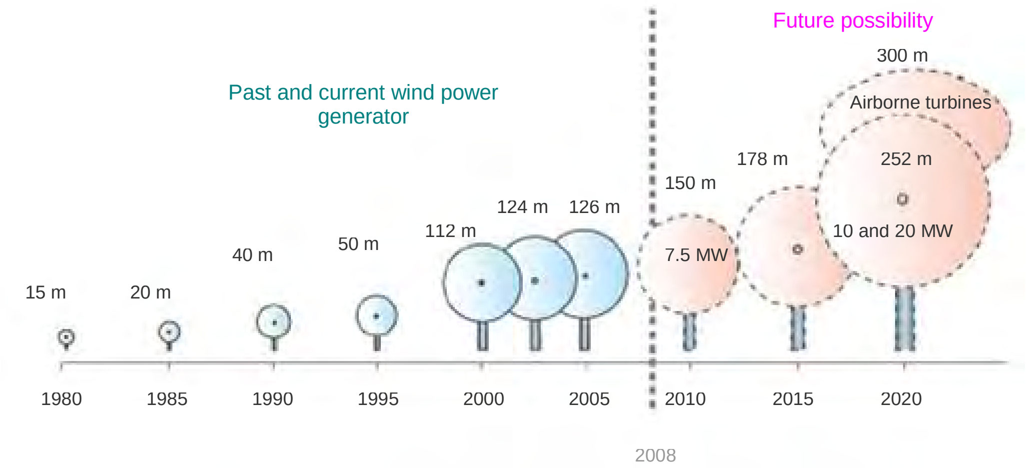
Source: Mitsubishi Heavy Industries HP (http://www.mhi.co.jp/products/detail/wind_mwt92.html)

3.0 MW machine

Source: Vestas HP (http:// http://www.vestas.com/da/vindm%C3%B811eparker.aspx)

Figure 10.1.1 Example of Propeller-Type Wind Power Generation

To acquire as much wind power energy as possible, it is important to install the windmill at a location where the wind suitable for wind power generation can be obtained. Since the power generation output per windmill increases by the enlarged windmill and the output from the entire wind farm increases by installation of multiple windmills (i.e., power generation cost can be reduced), the wind farm has become large in recent years.



Source: Prepared by "Technology Roadmap Wind energy" (2009, OECD/IEA)

Figure 10.1.2 Transition to Large-Scale Wind Power Generation in the World

b) Installation effects of large-scale wind power generation

The condition to allow installation of large-scale wind power generation is an average wind speed of about 5.5 m/s or more (Table 10.1.1). Therefore, the merit of installing large-scale wind power generation in this development district is small; that is, it is considered to be proper that only small-scale wind power generation is installed as the environment appeal.

Table 10.1.1 Condition to Allow Installation of Wind Power Generation

		Trial calculation by the Japan Wind Power Generation Association	Investigation by the Ministry of the Environment
Land	Suitable place	Wind power: 6.5 m/s or more (height: 80 m), altitude: less than 1,000 m, max. tilt angle: less than 20 degrees, within 10 km from the road with width 3 m or more	Wind power: 5.5 m/s or more (height: 80 m), altitude: less than 1,000 m, max. tilt angle: less than 20 degrees, within 10 km from the road with width 3 m or more
	Installation location	Natural park (No. 2 and No. 3 special areas, ordinary area) 500 m or more from residential area Outside of the city area Other farm, forest (not protected), wild land, shore	Natural park (No. 2 and No. 3 special areas, ordinary area) 500 m or more from residential area Outside of the city area Other farm, forest (not protected), wild land, shore
Sea	Suitable place	Wind speed: 7.5 m/s or more (height: 80 m), less than 30 km from shore	Wind speed: 6.5 m/s or more (height: 80 m), less than 30 km from shore
	Installation location	Natural park (ordinary area) Flooring type: water depth: less than 50 m Floating type water depth: 50 m or more, less than 200 m	Natural park (ordinary area) Flooring type: water depth: less than 50 m Floating type water depth: 50 m or more, less than 200 m
Conversion to wind power generation output		10 MW/km^2	10 MW/km^2

Source: "Wind power generation endowment remaining and potential and calculation of long-term introduction target and road map based on them (Ver.2.1)" (2010, Japan Wind Power Generation Association), "H21 year: Potential investigation of renewable energy introduction" (2010, Ministry of the Environment)

3) Biomass power generation

a) Kinds of biomass power generation

Various biomass resources can be used for energy and various classification methods are considered. The following classifies them into the untapped, wastes, and production resources and Table 10.1.2 shows examples of each class.

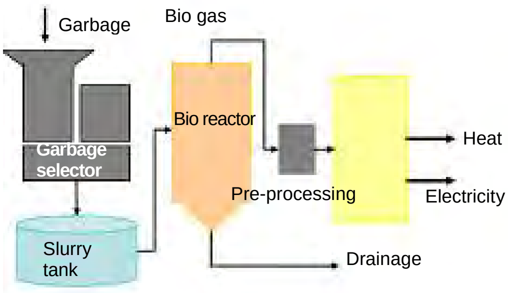
Most of biomass resources currently used for energy in Japan are the waste resources; that is, wood biomass such as sawing waste and building waste and paper making biomass such as black liquid are used.

When the waste biomass generated (e.g., in the factory) is used on the site, it is possible to collect and use it efficiently. However, for untapped resources such as forest biomass, which is distributed widely and thinly across the country, it is necessary to make the cost of collection and used technology low and enlarge the usage in the district.

Table 10.1.2 Kinds of Biomass Resources

Biomass resource	Untapped	Wood biomass	Forest biomass	Remaining wood
				Thinned wood
				Unused wood
			Others (e.g., trimmed wood)	
		Agriculture biomass	Rice farming waste	Rice straw
				paddy
			Barley straw	
			Bagasse	
			Others	
	Waste	Wood biomass	Sawing waste	
			Building waste	
		Paper making biomass	Old paper	
			Paper production sludge	
			Black liquid	
		Farm animal waste	Farm animal waste	Cow
				Pig
				Chicken
				Others
			Sewage sludge	
			Septic tank sludge	
		Food biomass	Food processing waste	
			Food sales waste	Wholesales
				Retail
			Kitchen waste	Home
				Business
			Wasted food oil	
		Others	Reclaimed land gas	
			Paper waste, fiber waste	
	Production	Wood biomass	Short-cycle culture wood	
		Grass/tree biomass	Grass	
			Water grass	
			Sea grass	
		Others	Algae	
			Sugar, starch	
			Plant oil	Palm oil
				Rape oil

Specification example of combining the kitchen garbage methane generation device and the fuel battery



Garbage processing ability	5 t/day
Bio reactor capacity	100 m^3
Bio gas generation amount	1,000 to 1,100 m^3
Methane concentration	60 to 70%
System power consumption	860 kWh/day
Power generation amount (efficiency: 40%)	2,900 kWh/day
Generator collection heat (40%)	10,251 MJ/day (245,000 kcal/day)
Installation area	420 m^2

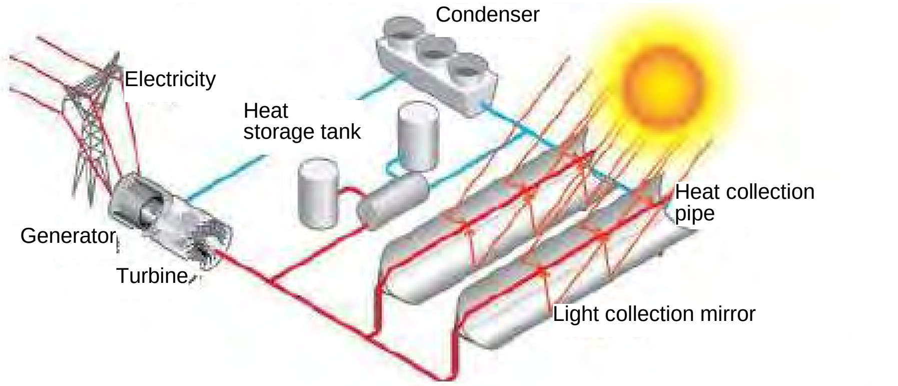
Source: New energy foundation HP

Figure 10.1.3 Specification Example of Biomass Power Generation

4) Solar heat power generation

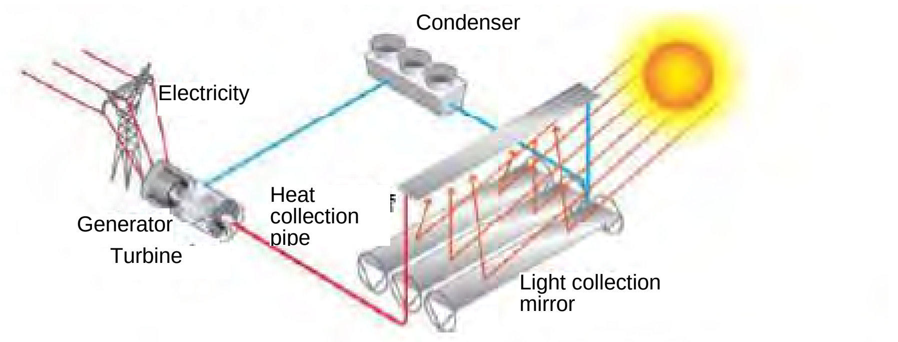
Solar heat power generation is the system that uses the steam generated by solar heat to rotate turbines for power generation. The currently used technologies are classified into 3 types:

a) Trough type



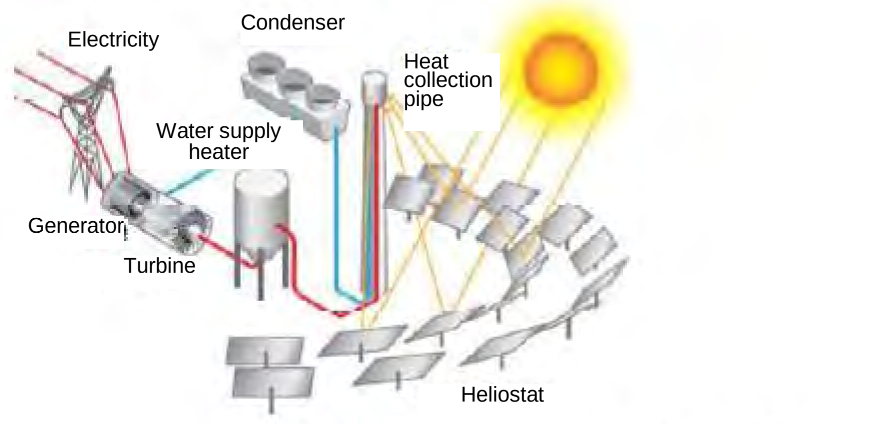
Source: DOE HP (http://www1.eere.energy.gov/solar/)

b) Fresnel type



Source: DOE HP (http://www1.eere.energy.gov/solar/)

c) Tower type



Source: DOE HP (http://www1.eere.energy.gov/solar/)

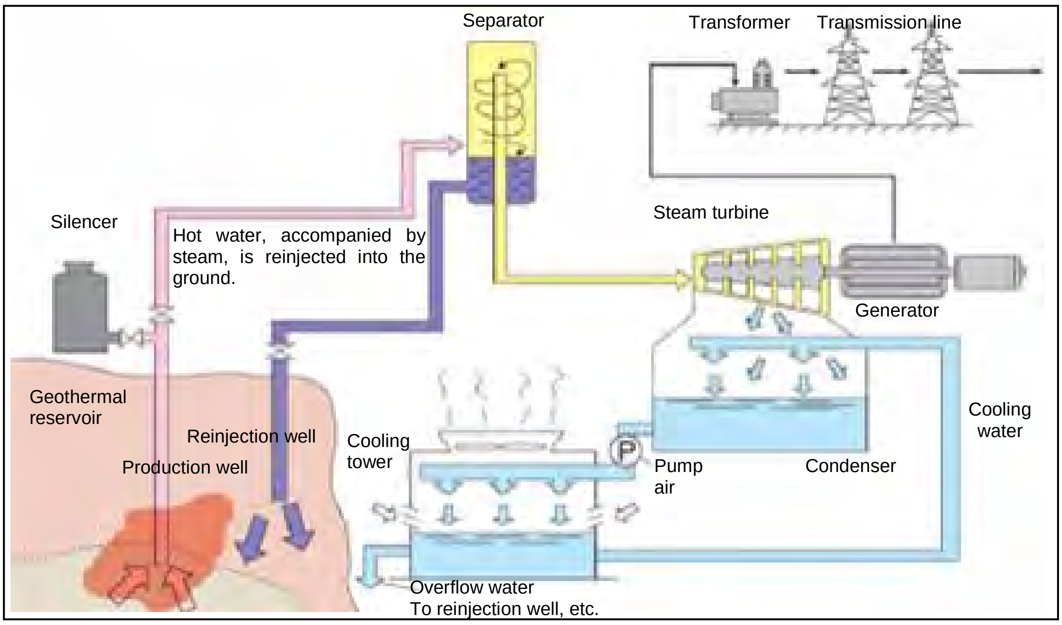
Figure 10.1.4 Examples of Solar Heat Power Generation

5) Geothermal heat and hot spring power generation

There is “magma storage” at several km to 10 km underground of the volcanic zone and it heats rocks around it with about 1,000°C. Rainwater from the ground surface penetrates into cracks of rocks for several 10 years and changes to high-temperature and high-pressure water by the heat from the magma storage, resulting in the formation of an geothermal heat storage layer. Geothermal power generation is the power generation method where a well called a “production well” is dug to the earth-heat storage layer and the hot water and steam and is pumped out and used. Geothermal power generation is not affected by the weather, and stable power supply is possible; that is, the usage ratio of the facility is about 70%.

The practical methods of geothermal power generation are the widely-used flash type and the binary type, which has become practical recently.

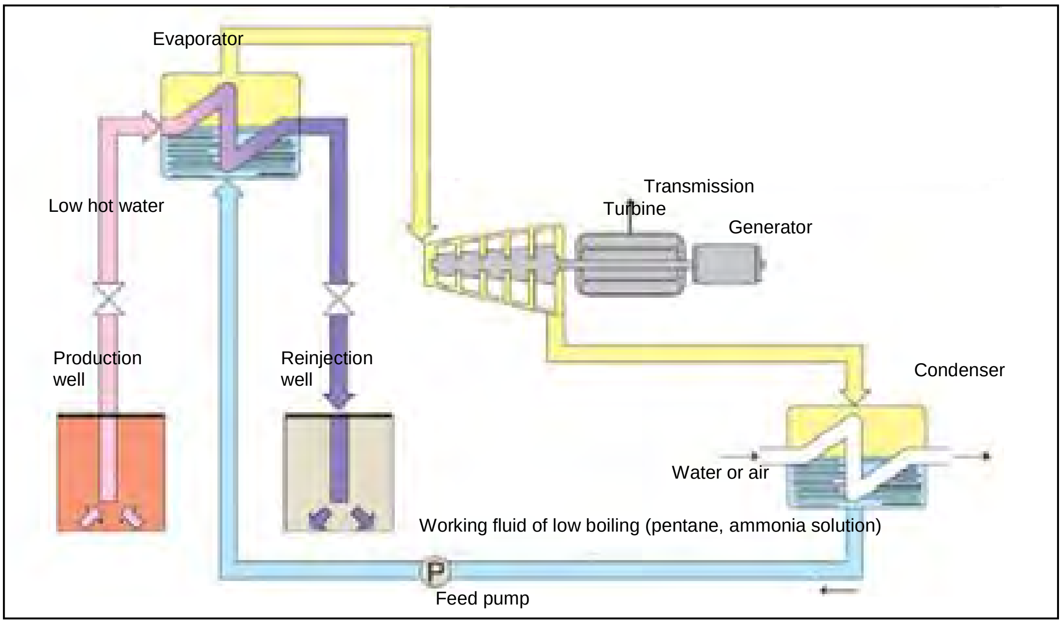
a) Single flash type (for use of high temperature of 200°C or more)



Source: “Current state of earth heat development (2008, NEDO)

b) Binary type (for use of middle temperature of 80°C or more)

Characteristic
Driving the turbine by using liquid that has a low boiling point allows power generation with the use of hot water having a low temperature, which was not possible with the steam power generation method.



Source: "Current state of earth heat development (2008, NEDO)

Figure 10.1.6 Example of Geothermal Power Generation

10.2 Study on introduction of low-carbon technologies in this project site

The following evaluates the advantage of each method of using renewable energy in this project site.

1) Photovoltaic: The installation effect is low but the merit of installation for environmental appeal is high. Since future technology innovation is expected, the phased arrangement is considered possible.

2) Wind power generation: Since the installation merit is not obtained by the average wind speed in this project site, it is considered to be proper that only small-scale wind power generation is installed as the environment appeal.

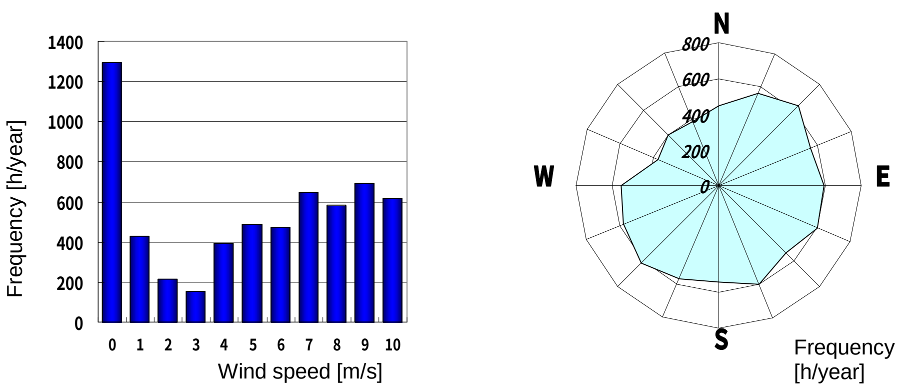


Figure 10.2.1 Distribution of Wind Speed and Wind Direction in Tianjin

3) Biomass power generation: If the incineration plant or the sewage facility is installed in this project sited, biomass power generation may be adopted and its potential is higher than that of photovoltaic power generation in this project site.

4) Solar heat power generation: Similar to photovoltaic power generation, the installation effect is low. Since future technology innovation is expected, it is considered that a comparison with photovoltaic power generation should be done to decide the adoption.

5) Geothermal power generation, hot spring power generation: The geothermal heat source is away from this project site and since there is no volcano and hot spring zone, it is difficult to adopt them.

Photovoltaic Power and Wind Power Design

PV generation
< Expected for coming innovation >

PV layout designed as landscape

PV along the road and the sidewalk

Large-scale PV panels and wind power will be located along the greenbelt around the river considering the view points from the bridges

Wind power generation
<Mainly used as a Landmark>

Large-scale wind power along the river

Along the streets in Yujiapu CBD, small wind power systems are also installed.

Figure 10.2.1 Example of Installation of Photovoltaic and Wind Power Generation in this Project Site

10.3 Analysis of the CO_2 reduction effects

Analysis is done for “photovoltaic power generation” and “biomass power generation” whose effects seem to be relatively high in this project site in the untapped energy use plan described in section 10.2.

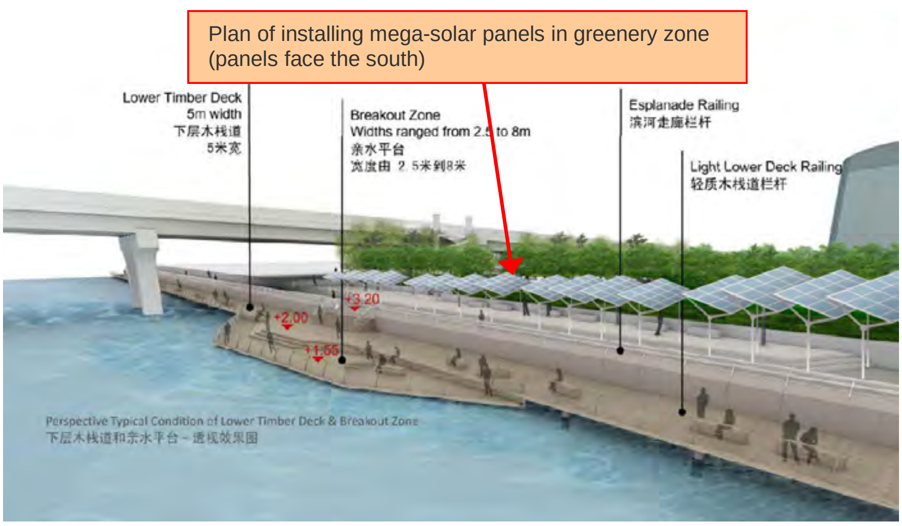
1) Installation of large-scale photovoltaic power generation

Trial calculation is done when large-scale photovoltaic power generation is installed in this project site.

1. Greenery area: about 45 ha (450,000 m^2)
2. Installation area of photovoltaic power generation: For about 30% of greenery area, about 45 ha × 30% = 13.5 ha
3. Area of photovoltaic power generation panel: 13.5 ha (135,000 m^2) ÷ 2.2 = about 61,000 m^2
4. Assumed sunlight amount (tilt angel: 30 degrees at right south): 1,400 kWh/m^2/year
5. Module conversion efficiency: 13%
6. Loss coefficient (temperature rise of cell, power conditioner, uncleanness of wiring and light receive surface): about 73%
7. Power generation amount: 1,400 kWh/m^2/ year × 13% × 73% × 61,000 m^2 = 8,104,460 kWh/year
   → 80,801 GJ/year (primary energy)
8. Reduction effect: 80,801 GJ/year ÷ 15,962,282 GJ/year = about 0.51% (for Japanese original units)

2) Installation of large-scale photovoltaic power generation

The plan to install large-scale photovoltaic power generation along the riverbanks in this project site is considered. Figure 10.3.2 shows the plan of installing the photovoltaic panels.



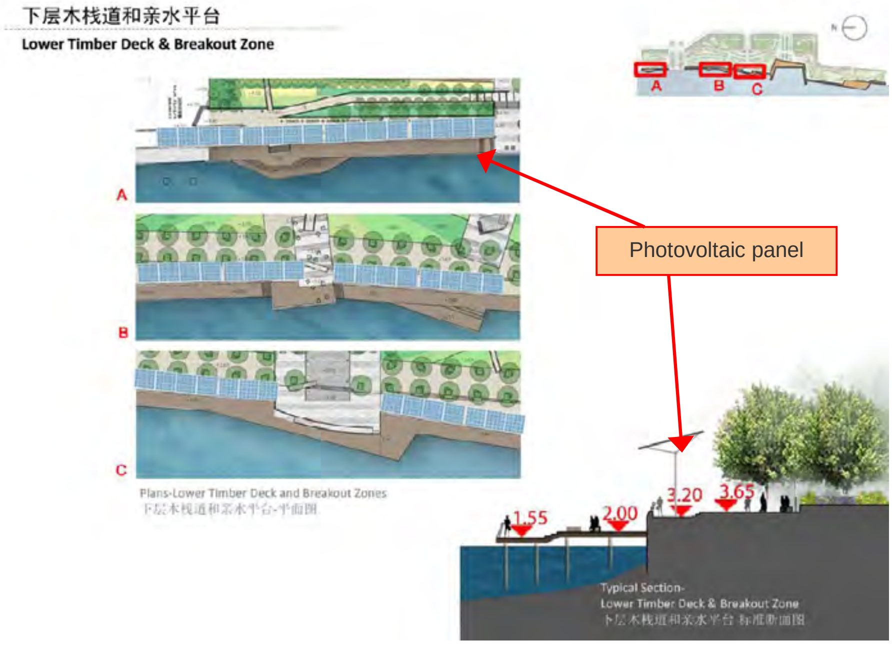


Figure 10.3.2 Example of Installing Photovoltaic Panels

3) The effects of installing biomass power generation

Since this development district is the CBD district mainly including offices, the sewage sludge and home/business kitchen garbage are considered to be the biomass resources. Therefore, the trial calculation is done for the effect of the biomass power generation by the home/business kitchen garbage.

1. Garbage discharge amount:

	Shop	Restaurant	Office	Others (hotel assumed)
Garbage discharge standard: kg/m^2/ day	0.8	0.2	0.04	0.06
Ratio of kitchen garbage	25%	55%	10%	14%
Total floor space m^2	613,136	153,284	5,234,612	424,589
Kitchen garbage amount: t/day	123	17	21	4
	164			

2. Power generation amount: about

2000 kWh/day ÷ 5 t/day × 164 t/day × 365/day/year = 23,944,000 kWh/year

→ 238,722 GJ/year (primary energy consumption original unit—9.97 MJ/kWh—is used for calculation)

3. Reduction effects: 238,722 GJ/year ÷ 15,962,282 GJ/year = about 1.50% (for Japanese original coefficients)

10.4 About the phased renewable energy plan

For the untapped energy plan described in section 10.2, it seems to be necessary to examine the biomass power generation at the stage of examining the facility installation location.

There seems to be merit if the photovoltaic power generation is installed not only at the beginning of the development but also in the mid and long term because technology innovation is expected. In addition, photovoltaic power generation does not require rearrangement of the large-scale infrastructure suitable for phased installation.

11. AEMS

(Area Energy Management System)

11. AEMS (Area Energy Management System)

Key points

- The overview of the area energy management system (AEMS) is introduced.
- The AEMS is to grasp the operation status on both sides of energy demand and supply in order to facilitate the implementation of more optimal low carbon operation.
- Visualizing the actual status of energy consumption (i.e., actual CO2 emissions) enables the sharing of problems and countermeasures among all stakeholders as well as the promotion of integrated efforts toward a low-carbon city.
- An appropriate type of network system for flexible AEMS is proposed.
- AEMS development is promoted in a mid-term perspective, while seeking the future development of a smart energy network.

11.1 Overview and examples of area energy management technology

1) Overview of area energy management

To realize a low-carbon city, it is important to make continued efforts in reducing CO2 on an urban area revel at the respective phases of designing, construction, and operating of the entire city, in addition to independent efforts by each building. Development of energy saving and low-carbon facilities alone in each building or in a regional energy system (and transportation system) is not sufficient to realize a low carbon lifecycle especially when such facilities are operated in a way to consume a large amount of energy in its operation phase.

Most of buildings already have installed the building energy management system (BEMS) which is successfully operating building equipments and facilitating energy saving in buildings.

Normally in the urban area development, the introduction of the BEMS is left to the discretion of the administration of each building. Even if more and more buildings introduce the BMS, the operation manners are still left to the discretion of each building administration, resulting in widely varying progress in CO2 saving. Thus, there is a limit with a stand-alone energy management of a building for further promoting energy and CO2 saving on wide area. To realize a “low-carbon city”, it is essential to install the Area Energy Management system (AEMS).

The AEMS is an approach on environment and energy (low-carbon) as well as a support system for implementing this approach, which derives from the idea of area management where local people, such as the residents, business operators, and landowners (land ownership holders) of an area, take initiatives to maintain and improve their regional environment and community values.

The AEMS limits its target range to an “area” and aims at achieving lower carbon emissions within the area by collecting and analyzing data, such as energy consumption data in each building. It is an integrated system to (1) investigate the actual status of CO2 emissions, (2) study CO2 saving solutions, (3) implement the solutions, and (4) analyze outcomes. Based on the BMS management data for each building, the AEMS implements energy and CO2 saving on an area-wide level.

In order to implement area energy management, it is important to establish the concept of lifecycle management of environment and energy. An architectural lifecycle should be considered so as to (1) set targets in its planning phase, (2) verify the possibility of achieving the set targets in designing and construction phases, and (3) check the status of target achievement on a regular basis in the operation phase.

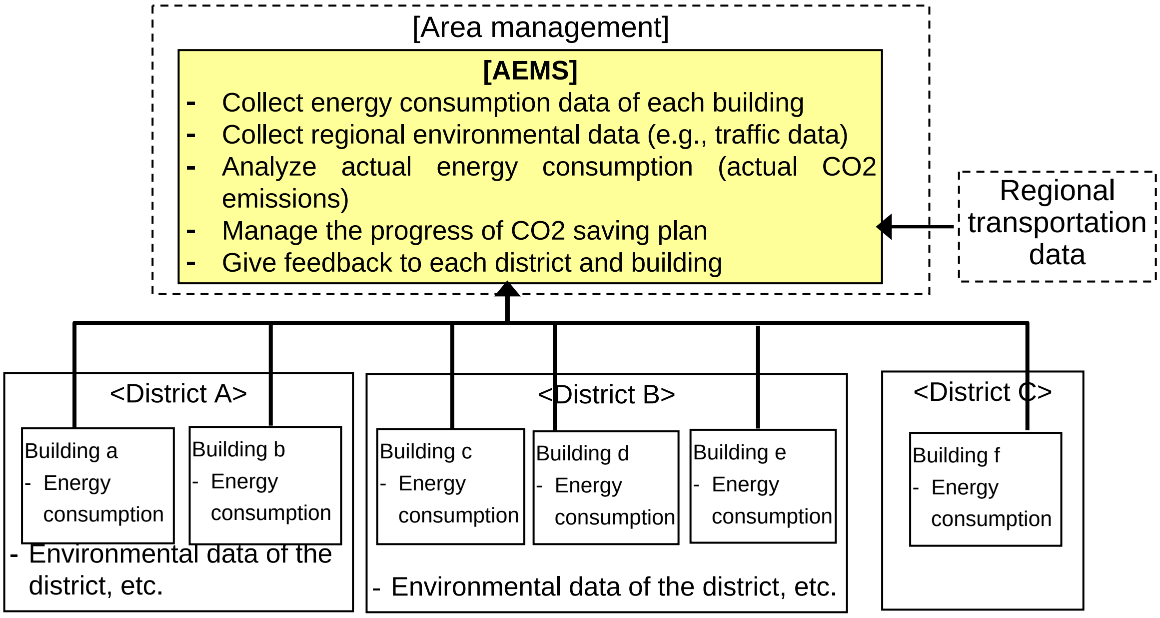


Figure11.1.1 Image of Area Management System

2) Overview of area management and relationship between AEMS

Area management is voluntary efforts by residents, business operators, and landowners (land ownership holders) to maintain and improve their regional environment and community values. Area management is characterized as follows:

a) Characteristic 1: From “constructing a town” to “nurturing a town”

In Tokyo, many redevelopment and construction projects have been successfully managed through a redevelopment associations organized by several business operators and landowners. Area management is to continuously maintain (and further improve) the values of a district during not only a construction phase but also an operation phase following the completion of building construction.

b) Characteristic 2: Regional development through voluntary participation of business operators, landowners, and residents

Conventionally, the mainstream of regional development has been government-driven also in developed countries. However, such a development has a limit for maintaining and increasing environmental values especially in a city. Especially in China, active participation of business operators enables the maintenance of city values. Involvement of business operators is critical also for making a continued and ambitious effort in attracting companies inside and outside of the country.

c) Characteristics 3: A framework allowing several business operators and landowners to work together for making a project move forward

Area management is targeting at an area where several business operators, landowners, and residents are working actively. In the development of their community, these people can be better informed of improvements in city values and low-carbon emissions if they work together under a unified framework rather than separately.

To realize area energy management, it is important from an equipment or system perspective to construct a network system for collecting various energy data, while it is important from a human resource perspective to construct and operate a framework for implementing energy management. Such a framework needs to be established and operated based on the above characteristics of area management.

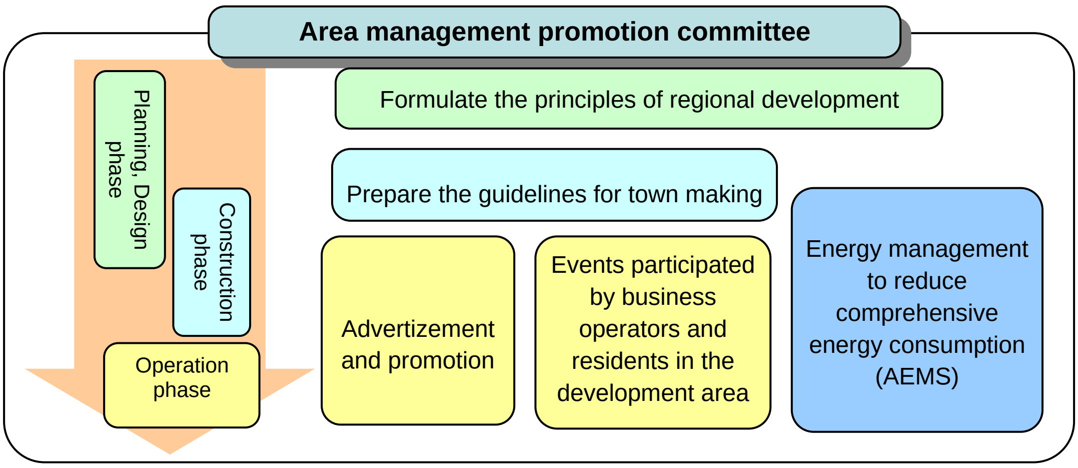
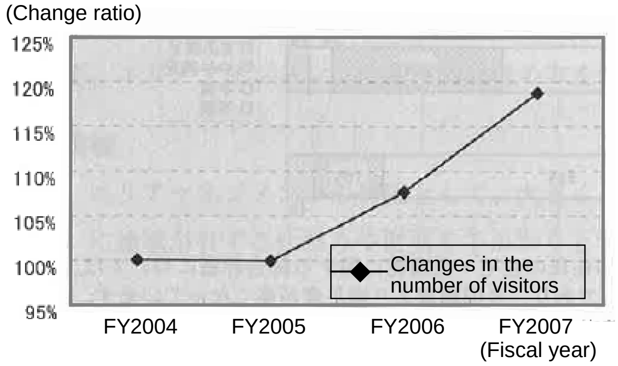


Figure11.1.2 Task of Area Management on each Development Phase

3) Outcome of area management

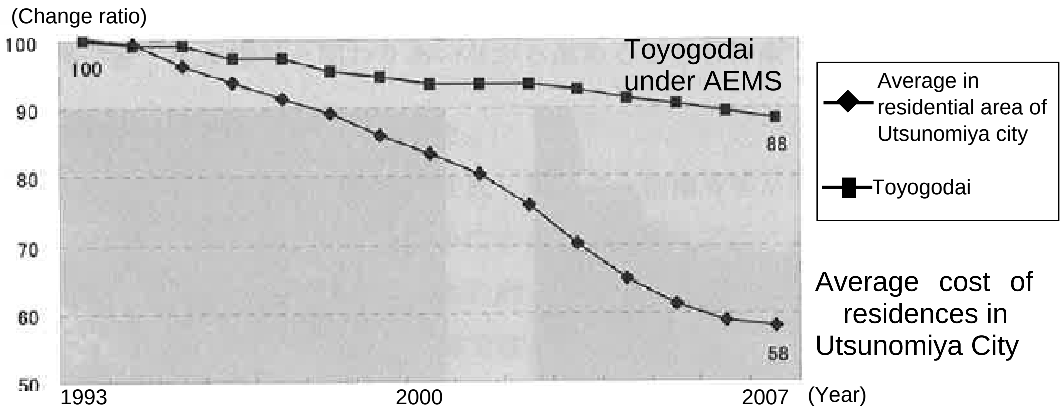
Some reports indicate that continued area management has contributed to an increase in the number of visitors and the maintenance of property values.



- In Otemachi-Marunouchi-Yurakucho area, NPO OMY Area Management Association was established in 2002 and has been enhancing software aspects of the area by organizing events and providing shuttle bus service.
- NPO OMY Area Management Association is also promoting the use of open spaces in the area. For example, an open space on the premises of Marunouchi building is used for various events.
- Marunouchi building opened in 2002. In 2007, after five years from the opening year, the number of visitors is still increasing.

OMY Area Management Association has been managing the area around Tokyo station, achieving growth in the number of visitors even after five years from the completion of the area development.

Figure11.1.3 Trend in the number of visitors to Tokyo Marunouchi Building (changes in the number of visitors compared to monthly average that is set at 100 percent: Data by Mitsubishi Estate)



“Toyogodai” in Utsunomiya, Tochigi has formed and maintained beautiful city landscape through greenery agreement and area planning. This effort made the area highly popular as a residential area. Land prices of the area have experienced a smaller drop compared to city average.

Figure11.1.4 Trend in the property price of a residential area with area management implemented (Toyogodai area) compared to the average property price of other residential areas in Utsunomiya (changes in the drop rate of property price compared to Toyogodai that is set at 100: Land price publication by Ministry of Land, Infrastructure, Transport and Tourism)

4) Purpose of introducing area energy management (AEMS) and expected benefits

The purpose of introducing AEMS as one of the management options of area management is as follows:

a) Understand the operation status on both sides of energy demand (e.g., building) and supply (e.g., district heating and cooling (DHC) on the premises of Center Business District (CBD)) in order to facilitate the implementation of more optimal low carbon operation.

b) Visualize the actual status of energy consumption (i.e., actual CO2 emissions) to facilitate the sharing of problems and countermeasures for realizing low-carbon operation among all stakeholders and to accelerate target achievement.

c) Continue PDCA cycle of understanding the actual status, study CO2 saving measures, implementing the saving measures, and analyzing outcomes in order to realize low-carbon emissions throughout lifecycle.

d) Introduce AEMS to realize CO2 saving operation, aiming at CO2 reduction by about 4 to 8 percent compared to business as usual (BAU).

11.2 Examples of area management and AEMS

1) Area management in Tokyo OMY area

The area management is targeting at the area surrounding Tokyo station covering Otemachi, Marunouchi, and Yurakucho areas (approx. 120 ha), implemented by NPO OMY Area Management Association (http://www.ligare.jp/).

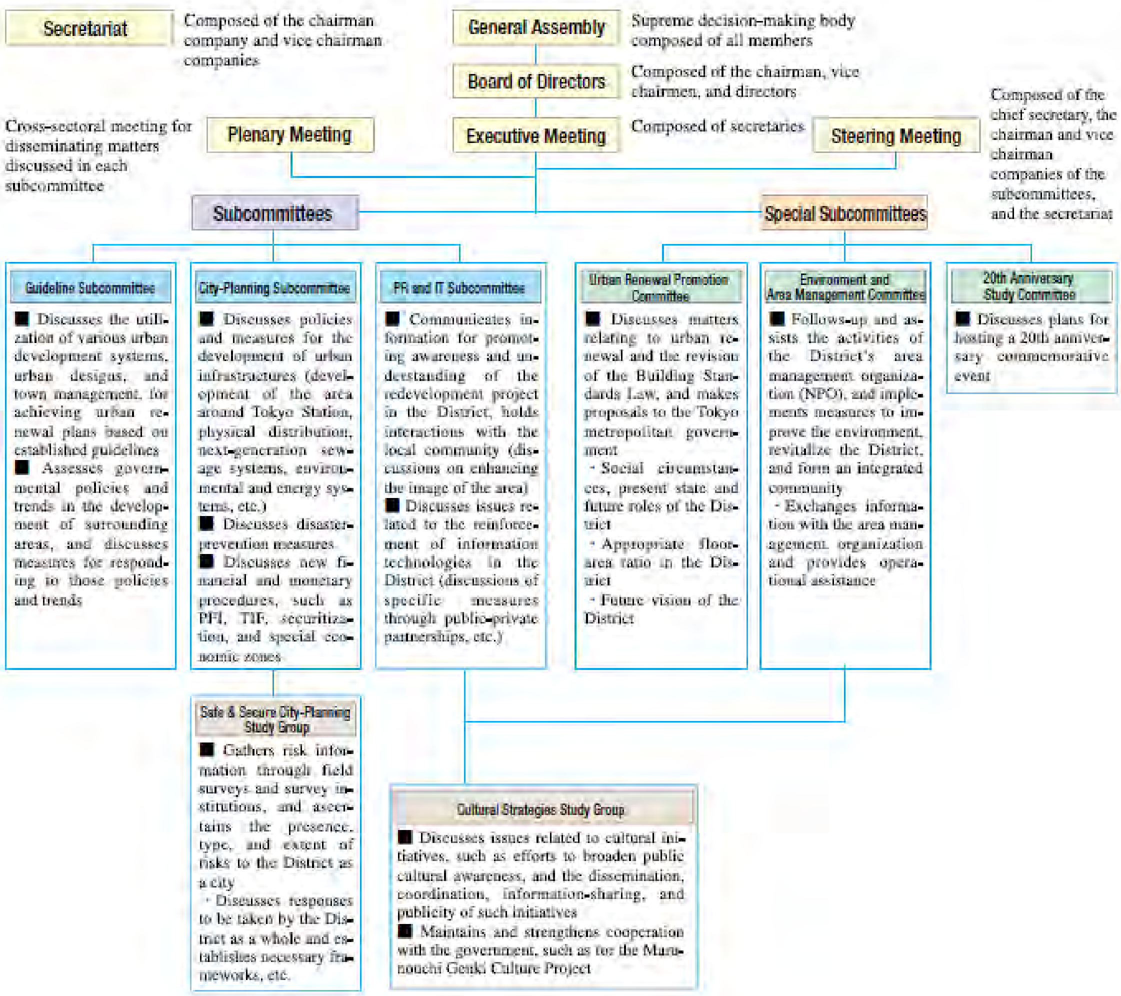


Figure11.2.1 Area management organization of OMY area and its management areas

Table11.2.1 Overview of the area management of OMY area

Location	Chiyoda, Tokyo
Area size	Approx. 120 ha (area subject to OMY Area City-planning Guidelines 2005)
Number of landowners	104 members
Number of business establishments	Approx. 4,000 establishments (as of 2001)
Number of working population	Approx. 214,000 (as of 2001)
Regulations	Otemachi, Marunouchi and Yurakucho Area Development Guidelines 2005
Management bodies (which covers the entire OMY area)	✧Otemachi Marunouchi Yurakucho District Redevelopment Project Council ✧The advisory Committee on Otemachi-Marunouchi-Yurakucho Area Development ✧NPO OMY Area Management Association
Management details	✧Council: Coordination and consultation among landowners ✧Advisory committee: Consultation between government and private bodies ✧NPO: Hosting events within the area and managing software aspects

In the district, as shown in the following diagram, many development projects (more than 20 projects) are in progress, where many business operators in the fields of business processing, finance, and commerce have gathered together, working as the member of area management. Likewise in Yujiapu Financial District, as development proceeds, a large number of business operators are expected to come to the district. Therefore, the OMY area management project should be a good reference for Yujiapu Financial District for establishing its area management system.

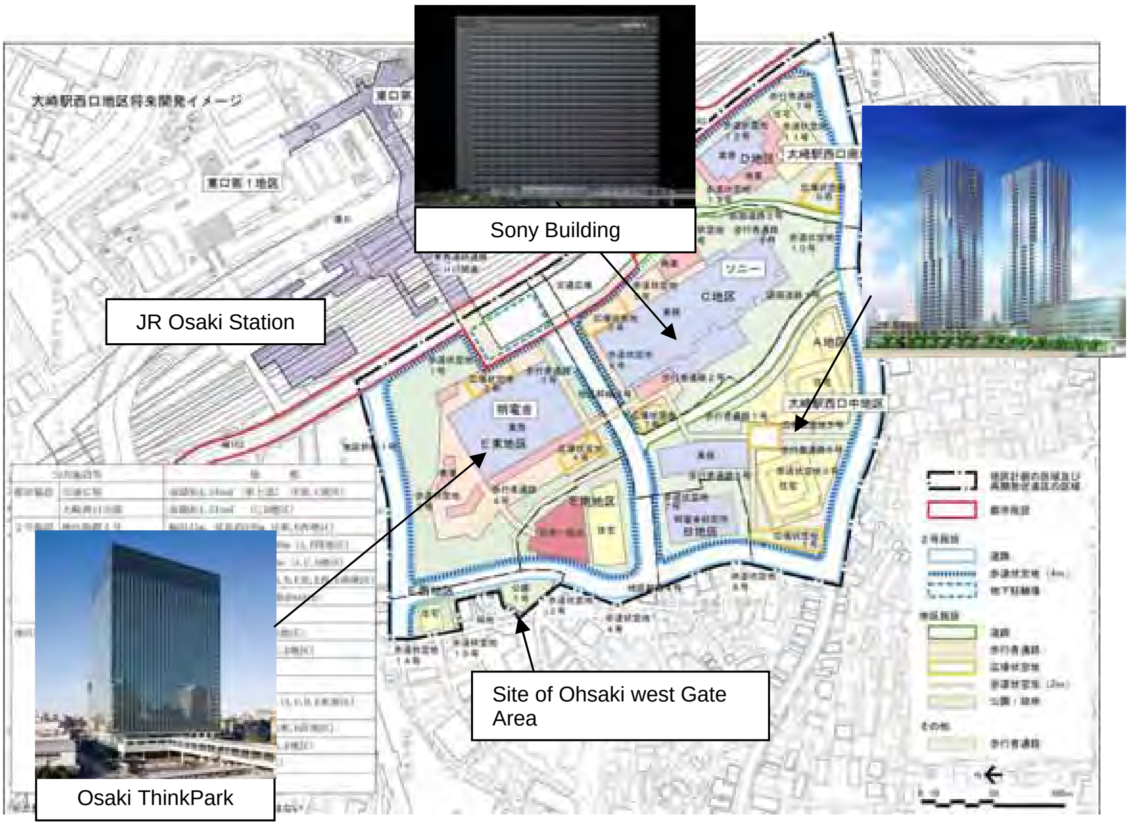
Figure11.2.2 Major development projects in OMY area (as of September 2010)

2) Area Management and AEMS in Ohsaki West Gate area of Tokyo

Area Management and AEMS at West Gate Area of Osaki station in Tokyo are shown below:

The association of "Ohsaki Area Management (OAM)" (http://ohsaki-area.or.jp/) is in charge. Figure11.2.4 illustrates the area management organization, where developers and landowners in West Gate area have gathered and joined the management body. Since the development area lies alongside Meguro River, forming "wind path" running parallel to the river is the key environmental consideration. In order to form the "wind path" for creating cool spots within the area, the West Gate area also has guidelines for thermal comfort designing (Figure11.2.5).

Its website provides information on environmental activities, such as CO2 saving and heat island mitigation (Figure11.2.6).



Fugure11.2.3 Area subject to the area management in Ohsaki West Gate Area

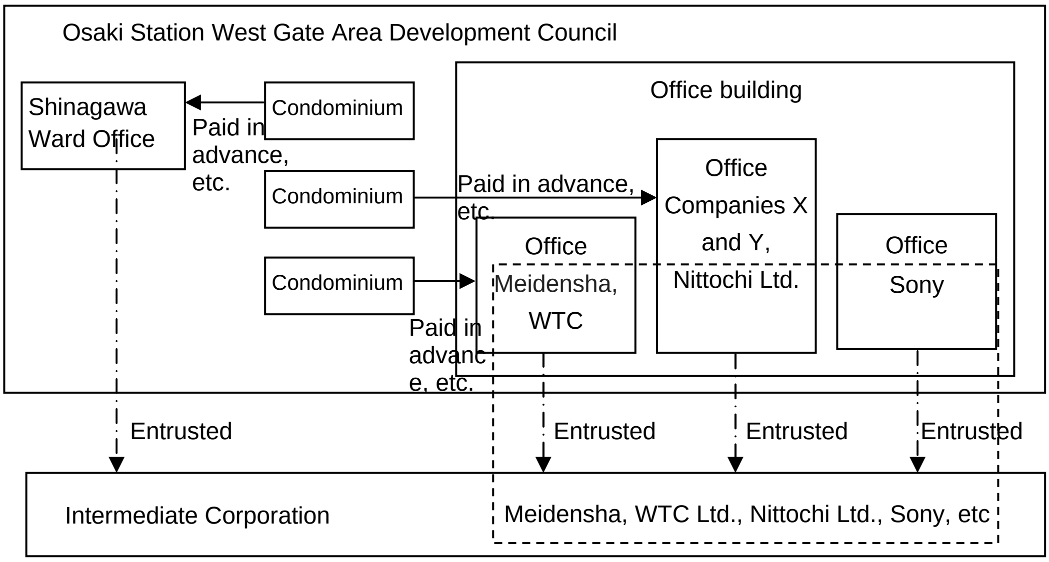


Figure11.2.4 Area management organization of Ohsaki West Gate Area

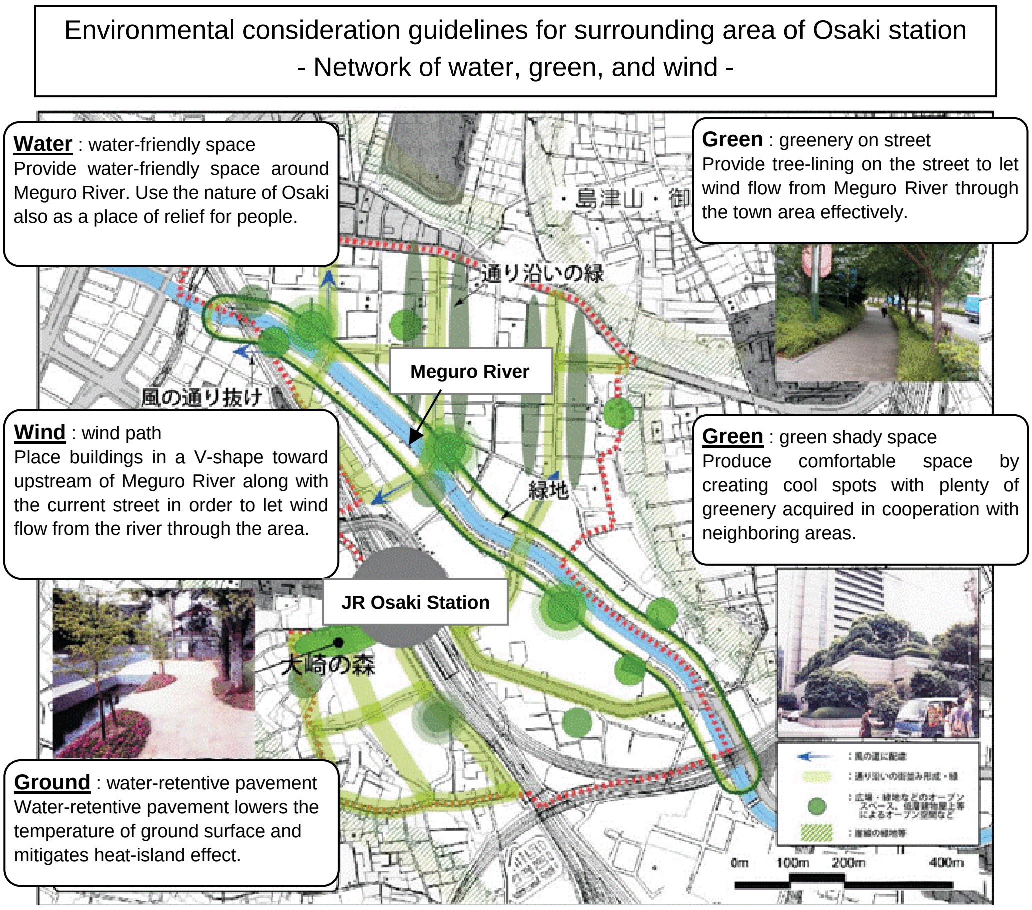


Figure11.2.5 Guidelines for building network of water, green, and wind

Figure11.2.6 Provision of information about environmental consideration and low-carbon operation by area management at Ohsaki West Gate Area (cited from OAM website)

3) AEMS of Harumi-island Triton Square

Harumi-island Triton Square has one of the most high-efficiency DHC in Japan and conducts energy management in order to realize efficient operation on supply side (i.e., DHC) and demand side (i.e., buildings).

Collecting and analyzing of data, such as the status of energy supply from DHC and energy consumption (including electricity, gas, and water) in buildings for each user or facility (Fugure11.2.8) has contributed to energy saving (CO2 saving) operation. Moreover, Harumi-island Triton Square publishes performance reports to disclose the actual status of low-carbon operation.

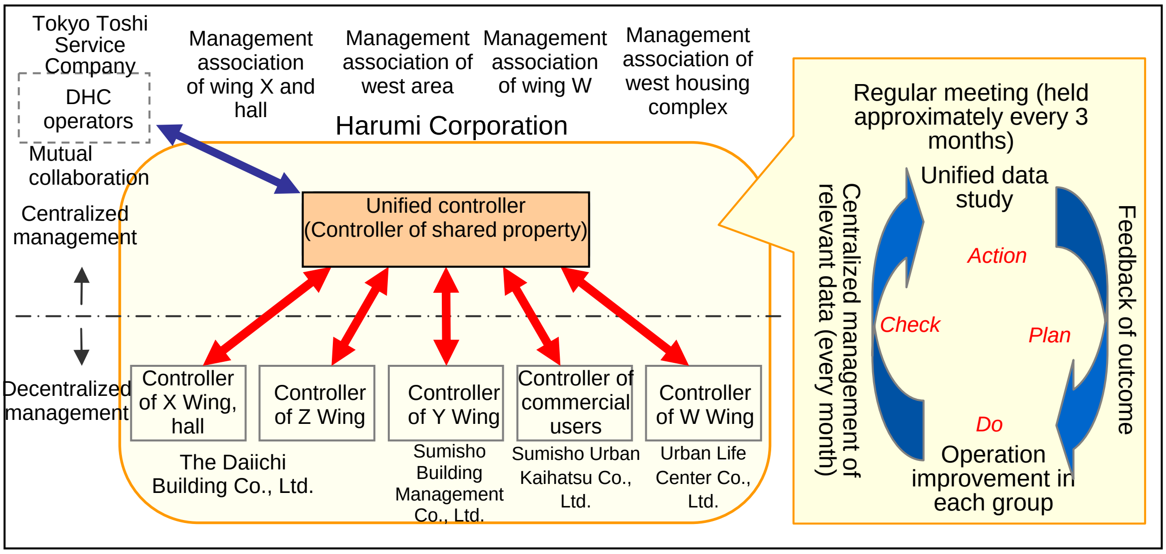


Figure11.2.7 Area energy management system of Harumi-island Square

Energy consumption on Energy type

		単位	管理エリア合計	オフィス	商業系	コンサートホール	全体共用部 グランドロビー	全体共用部 その他
延床面積		m²	463,200	383,300	27,100		52,800	
総エネルギー消費原単位		MJ/m²年	1,821	1,650	4,240		1,822	
エネルギー消費量		GJ	843,586	632,469	114,902	8,963	25,491	61,761
	CO_2排出量	kg-CO_2	29,579,772	22,175,124	4,033,872	315,949	894,189	2,160,638
内訳	電気エネルギー	GJ	715,243	537,525	94,231	6,523	21,372	55,591
	参考 二次エネルギー表示→	kWh	69,779,760	52,441,509	9,193,316	636,390	2,085,050	5,423,495
	CO_2排出量	kg-CO_2	24,911,374	18,721,619	3,282,014	227,191	744,363	1,936,188
	(内訳) 電灯(T:2次側比率換算)	GJ	418,656	334,645	54,530	3,531	12,384	13,566
	(内訳) 動力(T:2次側比率換算)	GJ	296,586	202,880	39,701	2,992	8,988	42,025
	熱エネルギー	GJ	128,344	94,944	20,670	2,440	4,119	6,171
	参考 二次エネルギー表示→	GJ	148,203	109,635	23,869	2,818	4,756	7,125
	CO_2排出量	kg-CO_2	4,668,398	3,453,506	751,858	88,758	149,827	224,450
	(内訳) 冷水	GJ	92,131	68,757	15,614	1,549	1,744	4,466
	(内訳) 温水	GJ	36,212	26,187	5,056	891	2,375	1,705
上水受水量		m^3	246,196	—	—	—	—	—
内訳	上水使用量=上水受水槽供給	m^3	209,843	108,157	86,279	1,944		13,463
	雑用水槽補給	m^3	33,717	26,619	5,373	234		1,490
	参考雑用水使用量	m^3	176,910	139,669	28,194	1,230		7,817
	外構用水槽補給	m^3	2,603	—	—	—	—	—
	消火水槽補給	m^3	33	—	—	—	—	—
廃棄物排出量		kg	2,611,313	1,664,219	899,267	2,728		45,100
内訳	可燃ゴミ系	kg	2,146,096	1,378,476	735,361	2,036		30,224
	(内訳) 可燃ゴミ	kg	464,178	333,075	106,048	1,530		23,524
	(内訳) 生ゴミ	kg	643,576	126,891	512,315	0		4,371
	(内訳) 新聞	kg	117,431	116,893	268	3		267
	(内訳) 雑誌	kg	190,338	183,637	5,902	191		609
	(内訳) OA紙	kg	143,137	143,104	28	0		5
	(内訳) ミックスペーパー	kg	362,636	362,028	551	54		3
	(内訳) 段ボール	kg	224,801	112,848	110,250	257		1,446
	不燃ゴミ系	kg	465,217	285,743	163,906	693		14,876
	(内訳) 不燃ゴミ	kg	240,592	151,021	79,507	440		9,624
	(内訳) ビン	kg	51,833	18,574	31,979	21		1,259
	(内訳) カン	kg	69,403	57,164	9,831	107		2,301
	(内訳) 発泡スチロール	kg	7,297	3,567	3,704	22		4
	(内訳) ペットボトル	kg	54,410	49,060	3,594	97		1,659
	(内訳) 乾電池	kg	402	331	35	6		29
	(内訳) 廃油	kg	41,281	6,025	35,256	0		0
その他廃棄物	汚泥	kg	103,530	0	0	0		103,530

Energy consumption on each building equipment

分類	環境負荷削減の取組み	消費(需要)量	削減(循環)量	削減(循環)率 個別比率	分類内比率	全体比率
地球環境保全のための取組み	温暖化防止(省エネルギー) 一次エネルギー表示→	843,586 GJ	254,734 GJ			23.2%
エネルギー種別内訳	電気エネルギー 一次エネルギー表示→ / 二次エネルギー表示→	715,243 GJ / 69,779,760 kWh	250,257 GJ / 24,415,351 kWh		25.9%	22.8%
内訳 (注)二次エネルギー表示	冷温水ポンプVWV 台数制御	879,508 kWh	4,347,070 kWh	83.2%	4.6%	4.1%
	冷温水ポンプVWV インバータ利用		1,770,577 kWh	66.8%	1.9%	1.7%
	冷温水ポンプVWV 差圧設定最小化		214,923 kWh	19.6%	0.2%	0.2%
	冷温水大温度差搬送		268,246 kWh	23.4%	0.3%	0.3%
	冷温水密閉配管		8,037,726 kWh	90.1%	8.5%	7.5%
	オフィス基準階空調機VAV	9,787,536 kWh	3,301,412 kWh	25.2%	3.5%	3.1%
	空調機最適起動制御	(排気ファンを含む, W棟を除く)	9,988 kWh	0.1%	0.0%	0.0%
	グランドロビー空調機インバータ利用	312,780 kWh	358,621 kWh	3.5%	0.4%	0.3%
	その他空調機インバータ利用		396,715 kWh	—	0.4%	0.4%
	オフィス事務室 Hf 照明 高輝度小型誘導灯利用	15,559,053 kWh	4,992,446 kWh	24.3%	5.3%	4.7%
	オフィス基準階共用部間引き照明		673,428 kWh	4.1%	0.7%	0.6%
	オフィス事務室窓際調光制御		44,199 kWh	0.3%	0.0%	0.0%
	参考(その他の電力消費)	43,240,883 kWh	—	—	—	—
	熱エネルギー 一次エネルギー表示→ / 二次エネルギー表示→	128,344 GJ / 148,203 GJ	4,477 GJ / 5,170 GJ		3.4%	0.4%
内訳 (注)二次エネルギー表示	オフィス基準階空調機外気冷房	109,635 GJ	2,506 GJ	2.2%	1.6%	0.2%
	オフィス基準階空調機設定値管理	(オフィス棟全体, W棟を除く)	335 GJ	0.3%	0.2%	0.0%
	グランドロビー空調機外気冷房	4,756 GJ	30 GJ	0.6%	0.0%	0.0%
	その他空調機外気冷房		36 GJ	—	0.0%	0.0%
	全熱交換器		2,263 GJ	—	1.5%	0.2%
	参考(その他の熱消費)	33,812 GJ	—	—	—	—
	特殊評価項目 力率改善	実績力率:99.9%		改善力率:4.4%		
資源循環のための取組み	節水・雨水利用等 合計	246,196 m3	138,539 m3			36.0%
用途内訳	雑用水用途	33,717 m3	137,804 m3		80.3%	35.8%
内訳	中水処理水再利用	—	91,417 m3	—	53.3%	23.8%
	冷却水ブロー水再利用	—	5,346 m3	—	3.1%	1.4%
	空調ドレン水再利用	—	38,971 m3	—	22.7%	10.1%
	雨水利用	—	2,070 m3	—	1.2%	0.5%
	参考(雑用水槽への上水補給水量)	33,717 m3	—	—	—	—
	外構用水用途	2,603 m3	735 m3		22.0%	0.2%
内訳	雨水利用	—	735 m3	—	22.0%	0.2%
	参考(外構用水槽への上水補給水量)	2,603 m3	—	—	—	—
	参考(上水受水槽給水量+消火水槽への上水補給水量)	209,876 m3	—	—		—
	廃棄物減量化・リサイクル等	2,611,313 kg	1,262,967 kg			48.4%
エリア内訳	オフィス棟	1,664,219 kg	1,053,231 kg		63.3%	—
	商業系・ホール・共用部	947,094 kg	209,736 kg		22.1%	—
ゴミ物種別内訳	可燃ゴミ系	2,146,096 kg	1,038,342 kg		48.4%	39.8%
内訳 リサイクル対象	新聞	117,431 kg	117,431 kg	—	5.5%	4.5%
	雑誌	190,338 kg	190,338 kg	—	8.9%	7.3%
	OA紙	143,137 kg	143,137 kg	—	6.7%	5.5%
	ミックスペーパー	362,636 kg	362,636 kg	—	16.9%	13.9%
	段ボール	224,801 kg	224,801 kg	—	10.5%	8.6%
参考(焼却処理)	生ゴミ	464,178 kg	—	—	—	—
	可燃ゴミ	643,576 kg	—	—	—	—
	不燃ゴミ系	465,217 kg	224,625 kg		48.3%	8.6%
内訳 リサイクル対象	ビン	51,833 kg	51,833 kg	—	11.1%	2.0%
	カン	69,403 kg	69,403 kg	—	14.9%	2.7%
	発泡スチロール	7,297 kg	7,297 kg	—	1.6%	0.3%
	ペットボトル	54,410 kg	54,410 kg	—	11.7%	2.1%
	乾電池	402 kg	402 kg	—	0.1%	0.0%
	廃油	41,281 kg	41,281 kg	—	8.9%	1.6%
参考(その他処理)	不燃ゴミ	240,592 kg	—	—	—	—

Figure11.2.8 Energy management report and energy management items

11.3 AEMS in Yujiapu Financial District (and area management)

1) Establishment of management system in Yujiapu Financial District

At the time of establishing a management system, a study is conducted on how to build a highly feasible operation system by sorting out the relationship among stakeholders and their roles as shown in the following diagram.

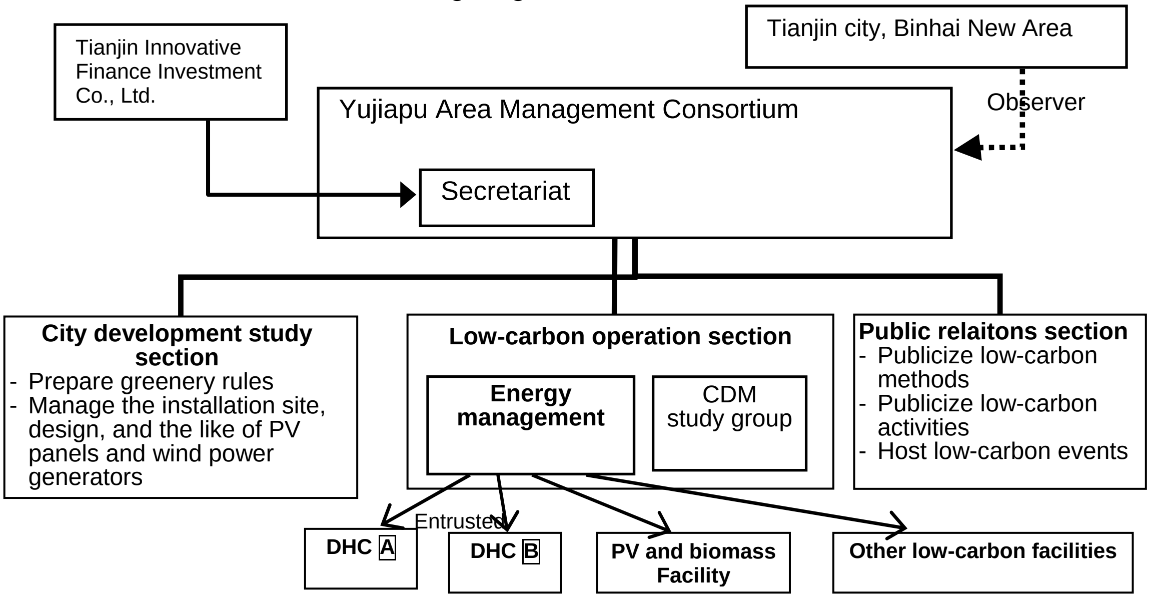


Figure11.3.1 Management system in Yujiapu Financial District and the relationship among sections

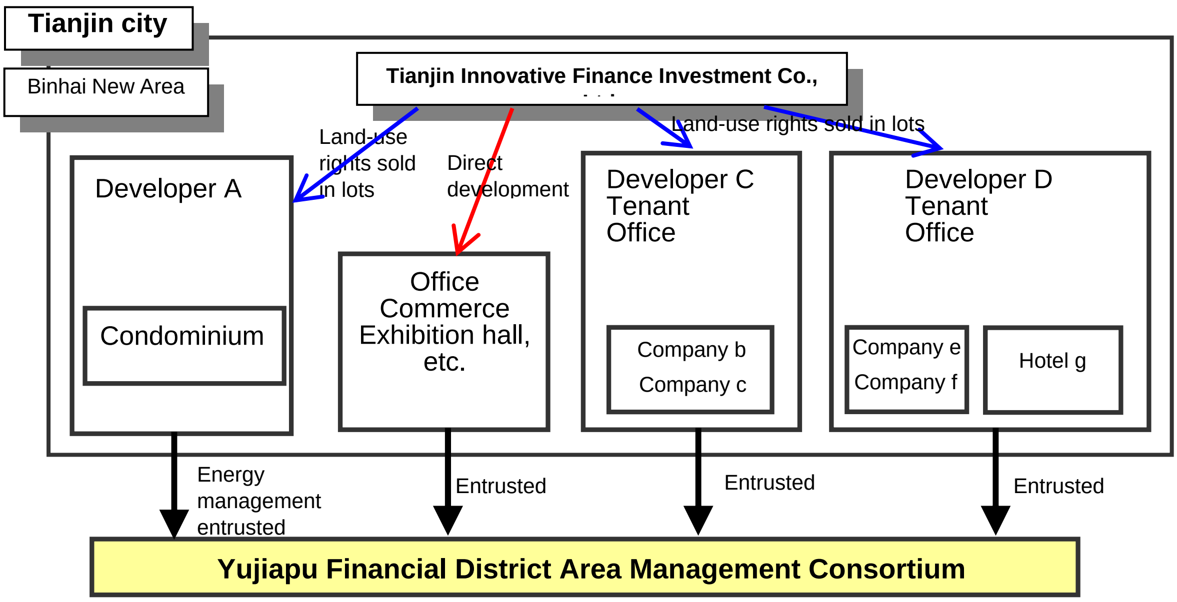


Figure11.3.2 Image of AEMS system development in Yujiapu Financial District

2) Study on area energy management system

In order to implement area energy management (AEMS) efficiently, it is necessary to conduct a study on a management system and information network in the development planning phase of the town while envisioning (1) specific types of energy to manage after the completion of construction (e.g., energy consumption in a building by energy types and by users), (2) visualization manners of various energy data, and (3) a management system (e.g. the aforementioned management consortium).

Also, to build a flexible information system appropriate to the progress status of town development, it is recommended to build a network of an appropriate size according to the development area and extend the network coverage later as the development area extends, rather than installing a network system that covers the entire Yujiapu financial district already in an early stage of the development, which enables a flexible and efficient investment in facilities.

[Items subject to management]

a) Demand side

- Collect data on energy consumption, including electricity, gas, and water for each building
- Understand the amount of waste at present (from each district or building)
- Collect data on energy consumption in a traffic system (*note)

*Note: To understand energy consumption data of a traffic system, further study is required on how to collect data because it depends on the configuration of a traffic system.

b) Supply side

- The operation status of direct heating and cooling (DHC) (the actual energy consumption for cold water and hot water, and electricity and gas in facilities)
- Power generating capacity of solar, biomass, and wind power generators, etc.

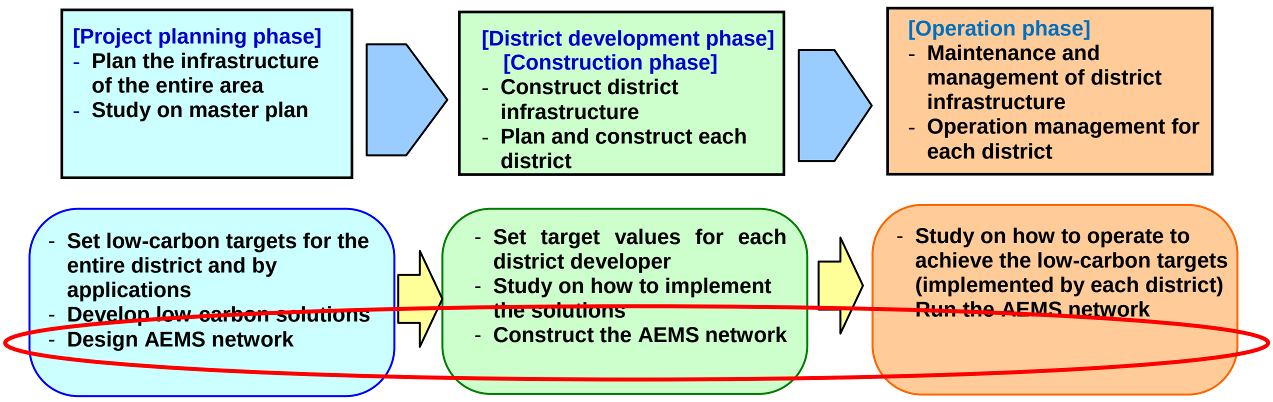
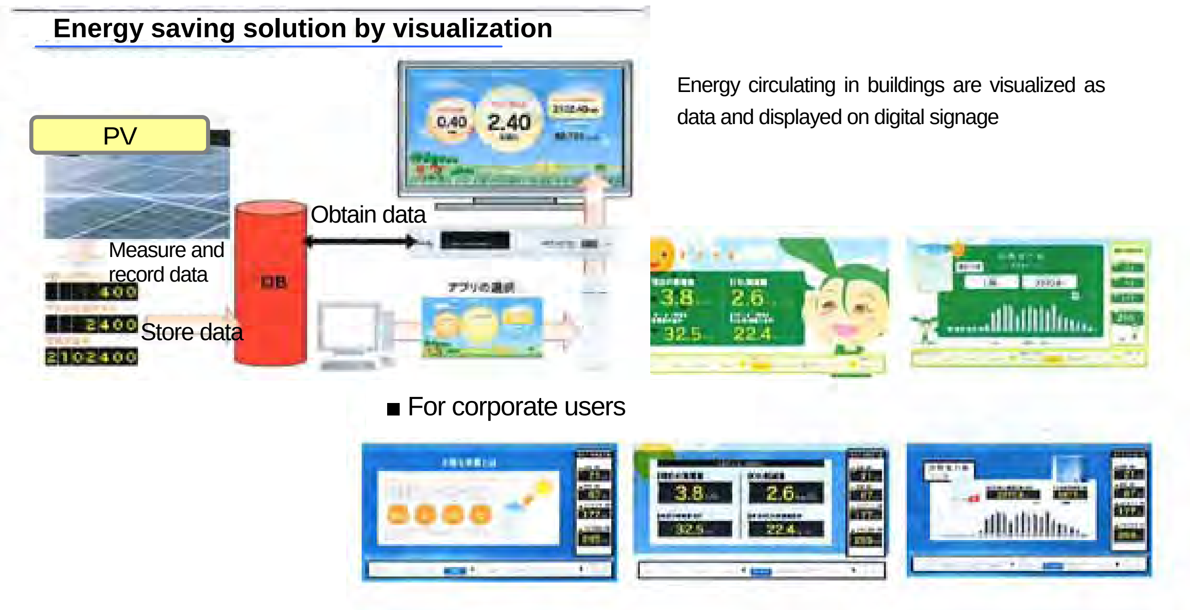


Figure11.3.3 Items to study at each stage from planning to operation and target setting in energy management



Fugure11.3.4 Image of visualization of the results of energy data analysis with AEMS

3) Study on network system configuring AEMS

The following diagram (Figure11.3.5) illustrates a network system configuring AEMS for Yujiapu district. Also, for the present development (up to 2020), Figure11.3.6 illustrates the relationship between AEMS, commercial power supply network (Tianjin Electricity Power Grid), DHC thermal supply network and others. Especially for PV and biomass power generation, the plants should be implemented as a grid-connected system with neighboring facilities. As for interconnection with commercial power supplies in this district, a study will be continued with a view to implementing the system while working closely with relevant authorities on regulatory reform and system review.

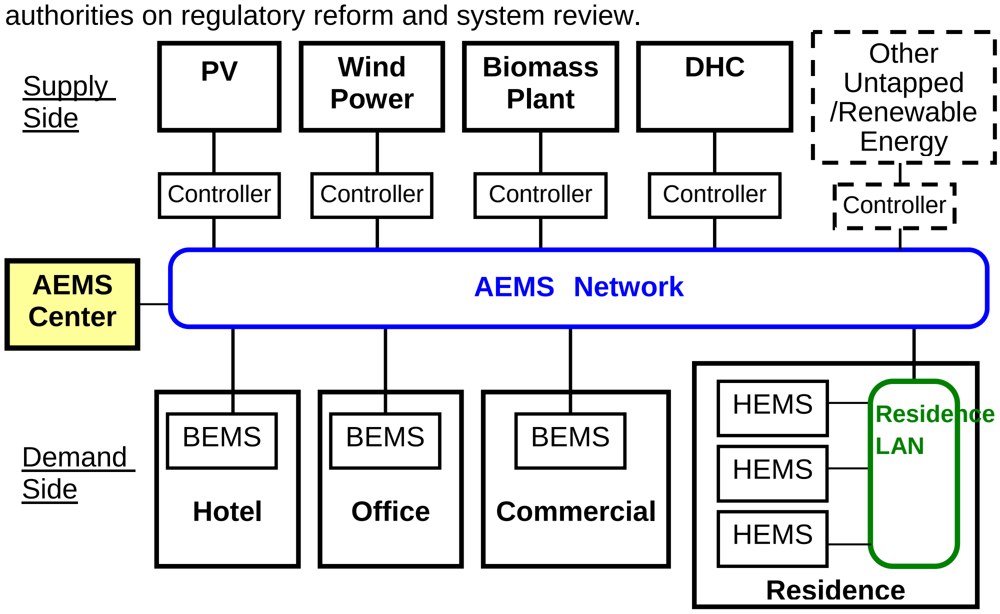


Figure11.3.5 Overview of AEMS network system configuration

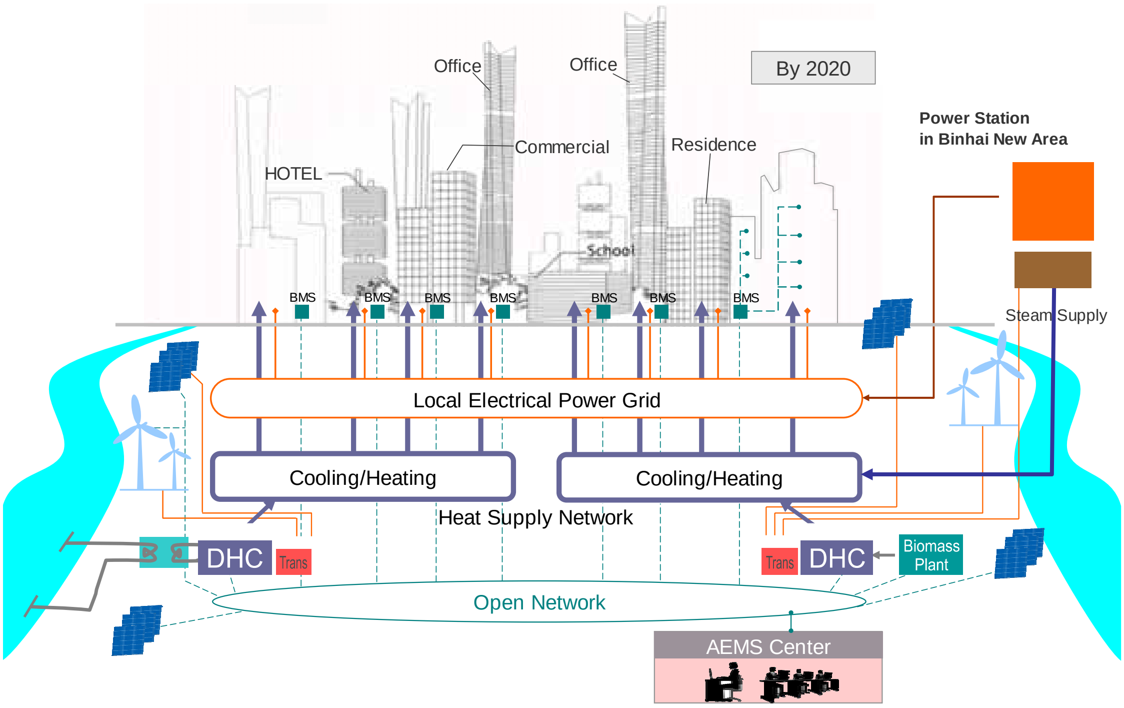


Figure11.3.6 Relationship between AEMS and other energy networks

Table11.3.2 shows the comparison between network infrastructures for configuring AEMS. If virtual private network (VPN) service is practically available, an open system can be realized on the Internet. Also as a reference, Figure11.3.7 shows the overview of a system developed jointly by China and Japan for open network operation in China.

Table11.3.1 Comparison between AEMS network infrastructures

	InterNet	Dedicated LAN
Reliability	Quality of service would be lowered because the communication quality is best-effort. B	The AEMS dedicated line provides high quality communication. A
Security	Use of virtual private network (VPN) services enables high security communication. A	The AEMS dedicated line provides highly secure communications, minimizing the risk of unauthorized access from outside the network. A
Network Extension	Easy to extend the network for additional bases, simply by concluding new agreement with a service provider A	Easy to extend the network within a planned area. However, additional bases outside the planned area requires equipment construction to extend the infrastructure B
System Structure	When network configuration is revised individually, detecting such a revision is difficult in some cases. C	System tuning is possible when the network configuration is revised. B
IP Address	Necessary to submit application and use global addresses. B	Possible to set arbitrarily A
Traffic Status	Difficult to estimate C	Possible to estimate to some extent according to connected device types and the number of devices B
Performance	Traffic may influence over the response rate. B	Performance can be guaranteed based on the above traffic estimate. A
Maintenance	Difficult to investigate in some cases when investigation is requested to a provider. B	Easy to investigate across the network when a failure occurs A
Total Costs	Implementation costs including initial and running costs are low because Internet service is used. A	Initial costs are higher because dedicated network cabling is required on the premises. C
Comprehensive Assessment	**A-** High security network can be configured at low costs if VPN service is available in the implementation area.	**B+** High quality and high security network can be configured; however, costs are higher compared to the Internet-based system.

[Suffix] A : Better than average level, B : Average level,

C : Holds more problems than average level iopeNet is the open technology framework jointly developed by China Architecture Design Institute and Panasonic

- Residential and non-residential systems are entirely connected using iopeNet/WS (protocol).

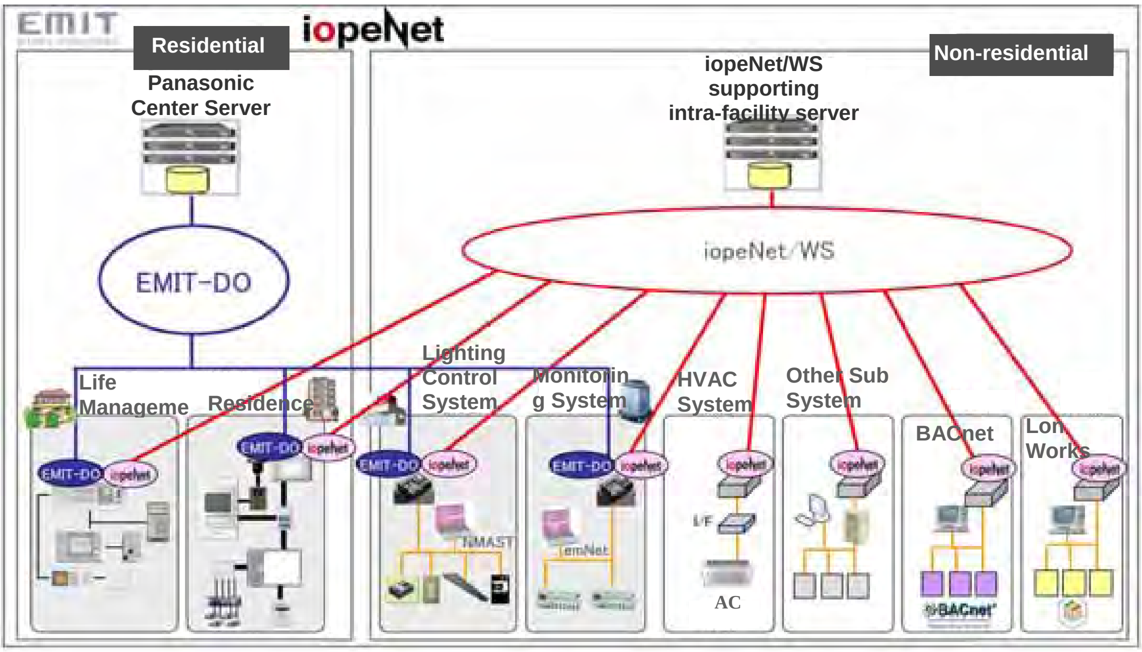


Figure11.3.7 Example of open network system with IopeNet

11.4 Developing into smart energy network

Constructing the above open network AEMS enhances the possibilities for developing linked operation with an energy network system in the future.

The smart energy network is a system that seeks to realize integrated operation of commercial electricity supply networks, heat supply networks (e.g., DHC), recyclable energy resources (e.g., photovoltaic power generation (PV) and biomass power generation), and untapped energy resources (e.g., waste heat from sewage treatment facilities and geothermal heat) through AEMS.

In the system, it is necessary to build a local network (i.e., a smart grid) between a commercial power supply network (Tianjin Electricity Power Grid) and the facilities of PV, biomass power generation, and wind power generation in the district. The AEMS network can be utilized to establish an operational system that directly controls over DHC and PV based on the actual operation status at the energy demand side (and supply side) across the district. Fugure11.3.9 shows an image of the smart energy network linked with various networks for information, electrical power, and heat supply in Yujiapu district.

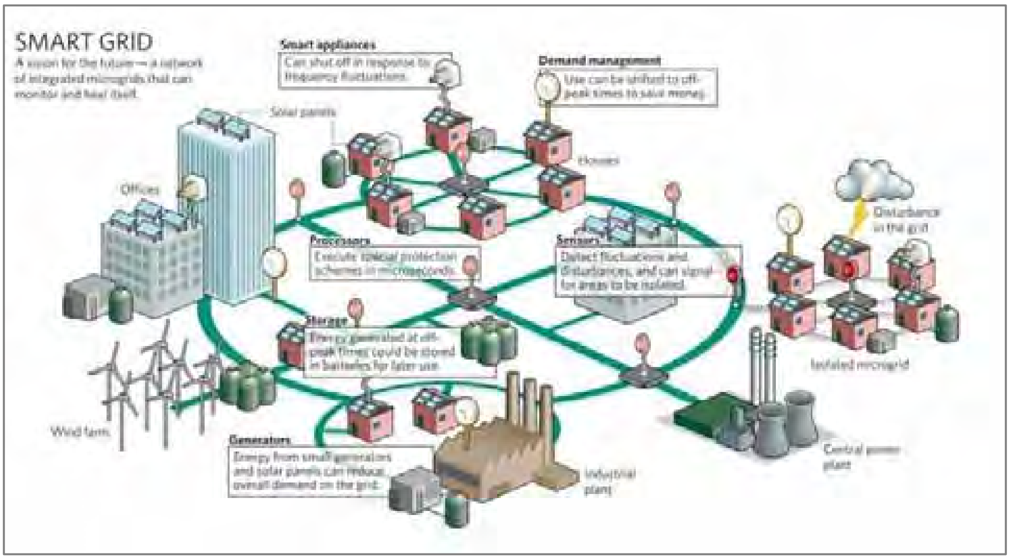


Figure11.4.1 Image of network (smart grid) for electrical power system

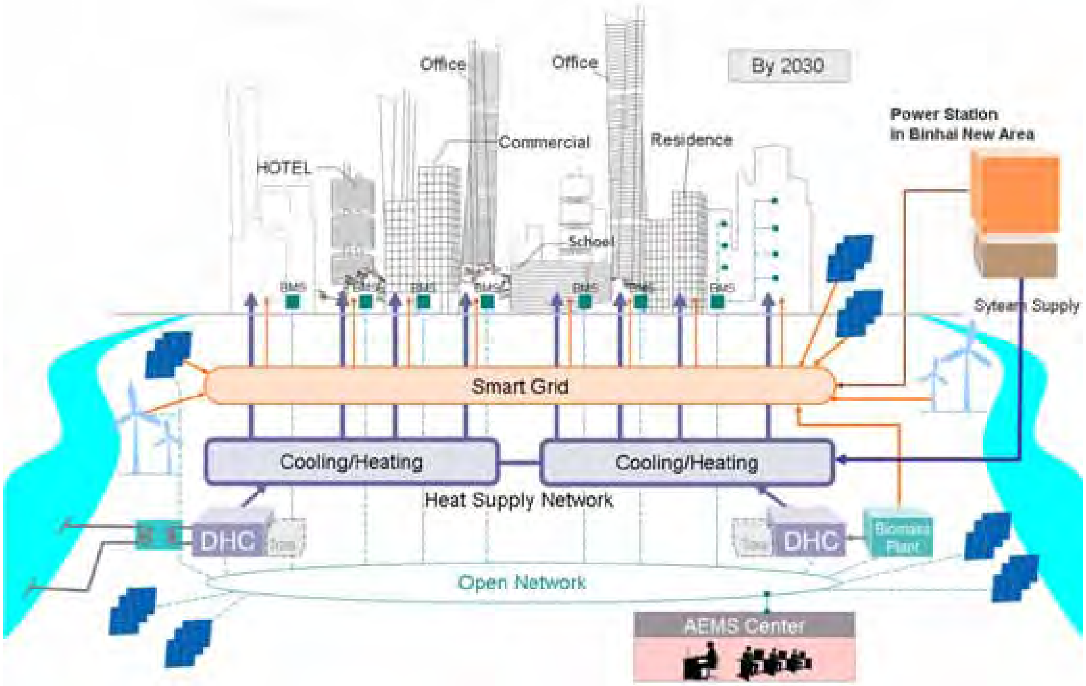


Figure11.4.2 Image of smart energy network development in Yujiapu district

12. Environmental Planning

12. Environmental planning

Key points

- This chapter introduces the outlines of the expected impacts of thermal environment improvement (heat island mitigation) measures, conducts quantitative estimate of the impacts using computer simulation, and demonstrates that temperature would become 1.5 °C lower than BAU if appropriate measures are taken.
- Approaches to waste and water resource circulation will be described as part of environmental resource management planning. In the section of waste recycling, estimate of waste quantity and methods of using waste as biomass energy resource are presented. In principle, all wastes will be actively utilized as resources.
- As for water resource circulation, adoption of regional water circulation system is proposed to allow multiplier effect and cost reduction in the entire district.
- More than 50% of gray water is to be recycled as gray water by 2020, while wastewater is aimed to be utilized by 2030.
- Since the pollution control is wide-area problem, in principle, environmental planning for Yujiapu district should observe standards set by national government and Tianjin city government. In addition, approaches to take advantage of the district's unique characteristics are also introduced.

12.1 Outline of environmental planning

In order to realize a low-carbon city, it is necessary to reduce CO2 emissions from individual buildings as well as from the entire city area. At the same time, it is also essential to establish a mechanism covering the entire city that facilitates the improvement of the thermal environment and resource circulation. Furthermore, construction and economic activities may cause the environmental degradation such as air pollution, water contamination, and chemical pollution. Therefore, it is critical that Yujiapu Financial District sets a basic framework for environmental planning.

This chapter introduces the outline of such environmental planning approach and case studies, and presents the methods for achieving the environmental targets. Table 12.1.1 shows the Indirect Indexes described in this guideline.

Table 12.1.1 Indirect Indexes for Environment, Resources and Pollution

Category	Items	Indirect indexes	By 2020	By 2030
Environment	1)Greenery, Biodiversity - Increase comfortableness, green scenery	Greenery coverage rate	Over 30%	Same as 2020 target
		Biodiversity rate	Select multiple kinds of plants considering Biodiversity	Same as 2020 target
	2) Heat Island - Improve the thermal environment	Decline of temperature	1.5 - 2.0 °C lower than BAU	
		Cool spot coverage rate	Over 40%	Over 60%
Resource circulation	3) Water resources - Encouraging the preservation of water resources	Gray water; Recycle rates	40%	80%
		Sewage water; Recycle rates	–	30%
		River water (Rain water); Recycle rates	15%	30%
	4) Reuse, Recycle of waste - Boosting the Waste Reduction and preservation of water resources	Waste, Kitchen waste; Recycle rates	40%	80%
		Waste Plastic; Recycle rates	40%	80%
		Paper; Recycle rates	40%	80%
		Recyclable Waste; Recycle rates	60%	90%
Pollution abatement	5) Pollution control - Boosting the improvement of Pollution	Air Pollution	Conform to National Standard	Aiming WHO standard
		Water	Conform to National Standard	Aiming WHO standard
		Soil	Conform to National Standard	Aiming WHO standard
		Chemicals	Conform to National Standard	Aiming RoHS Directive standard

12.2 Thermal environmental planning (microclimate planning)

1) Background and objective of thermal environmental planning

The urban temperature has been continuously rising due to global warming. The average temperature of Tokyo, for example, has risen by approximately 3.0°C as compared to that of 100 years ago. If the global average temperature is to rise by 1 to 4°C in the next 100 years as estimated by the IPCC, the temperature of large city areas is considered to rise more significantly than ever before. It is anticipated that his tendency would be significant in China that has a large number of overpopulated megacities with a population of over 10 million. It is reported in Japan that a substantial rise of the temperature in summer not only increases the energy consumption but also affects people through sleep disturbance and reduced productivity. In Tokyo's 23 wards, a rise of the summer temperature by 1°C increases the power consumption by approximately 0.3 to 0.5 million kW (the amount almost equivalent to power generated by a medium-scale thermal power station). In addition, a winter temperature rise in urban area contributes to reduced energy consumption for heating but may trigger public sanitary problems because, for instance, bacteria that do not normally survive during winter may breed due to higher temperature.

The improvement of urban thermal environment or urban heat island effect not only enhances the quality of the urban environment but also reduces the energy consumption in the wider region, thus it is recommended that appropriate measures to be taken at district levels.

2) Cases of thermal environment improvement (heat island mitigation measures) and their approaches

There are various methods for heat island mitigation. In Japan and other industrialized countries, "outdoor thermal environment" used to be only considered in a process of greening or landscaping. Therefore improvement of the outdoor thermal environment was considered as only the secondary effect of such greening and landscaping. However, recent urban development projects in large cities such as Tokyo, Osaka, and Nagoya consider the improvement of thermal environment in the project site and district as one of the key development objectives. For example, there is a case that reflected a study result that analyzed the thermal effects of not only the site itself but also the wider region by investigating the relationship between the site location, position of greenery and wind path.

Tokyo Midtown is an example showing the improvement of thermal radiation environment for the wider region by making the most of the site location and Osaki ThinkPark is an example of paying attention to the formation of cool spots and wind path. Iidabashi I-Garden Air takes integrated measures for improving the thermal environment by collaborating with multiple companies. Innovative Japanese cases that successfully improved the thermal environment in the course of urban development are shown below.

a) Tokyo Midtown

Tokyo Midtown created a large area of outdoor open space by densely locating the buildings and about 50% of the open space is covered by green. The greenery of Tokyo Midtown together with its adjacent parks provide extensive green space in Roppongi, which is one of the largest greeneries provided by development projects in Tokyo. Green roofs are adopted on low-rise building blocks. As a result, the average surface temperature of 10 hectare site of Tokyo Midtown is 3°C lower than that of the surrounding area in the daytime and 1°C lower in the evening. The average air temperature is also 1 to 2°C lower than the surrounding Roppongi area particularly in the evening because grass surfaces are cooled by nocturnal radiation. In this manner, Tokyo Midtown contributes to the improved thermal environment of the region.

Figure 12.2.1 Outdoor environment plan of Tokyo Midtown

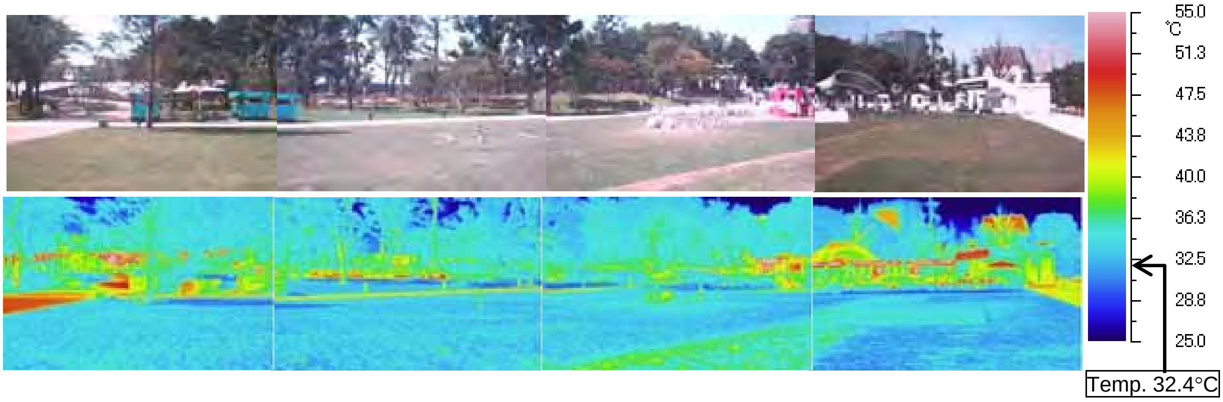


Figure 12.2.2 Thermal image of Tokyo Midtown site (View Point B; 13:38, August 9, 2007)

b) Osaki ThinkPark

Osaki ThinkPark formulated an environmental plan in accordance with the activity patterns of ThinkPark visitors and employees and also prepared a greening plan by taking the investment effects into account. Tall trees are densely planted along the open spaces facing the commercial facilities on the ground floor of the office tower toward the artificial mound on the southwest area of ThinkPark. This creates “Osaki Forest” and also forms area-scale “wind path” within the ThinkPark site.

The artificial mound provides a large-scale gently-sloping green hill that follows the shape of surrounding hilly topography. Most of the greening is planned on such an artificial surface, however planting and cultivation of large trees are difficult on such a ground. Therefore medium-sized trees such as maples are planted for greening the mound. These trees creating the wind path enclose the activity spaces within the site. In addition, improved thermal environment as well as cost saving are also achieved by adopting “vegetation mat” using weeds which makes the surface temperature cooler and easily collects cool air.

Photo of Osaki ThinkPark

Osaki ThinkPark implements environmental plan in accordance with the usage pattern of ThinkPark visitors and employees

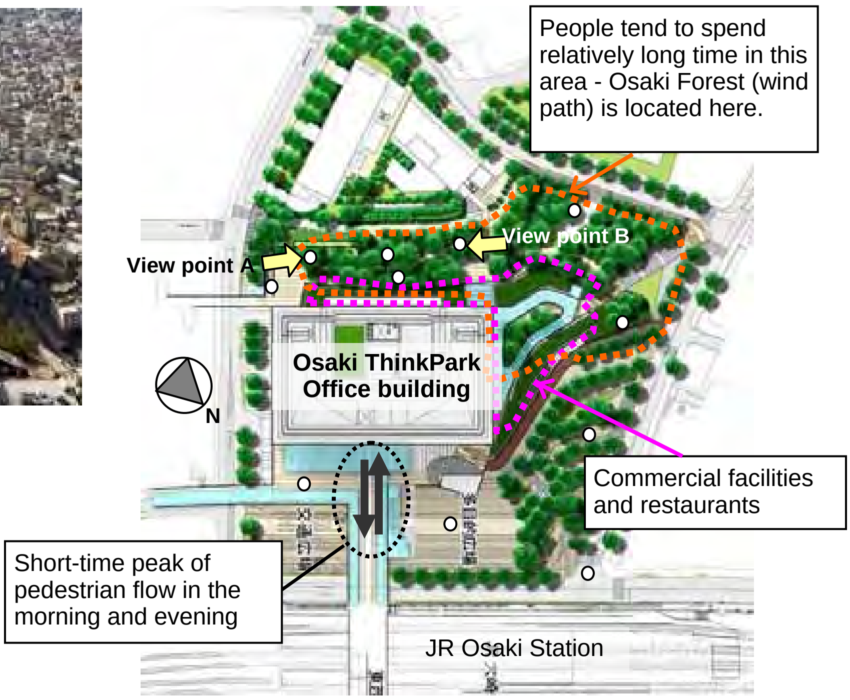
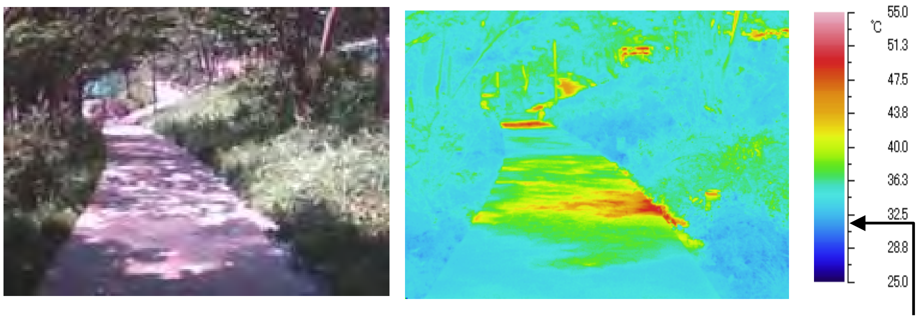
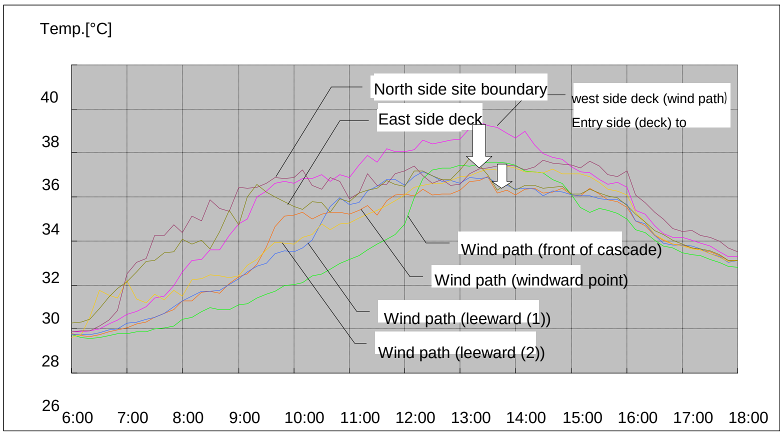


Figure 12.2.3 Environmental plan of Osaki ThinkPark



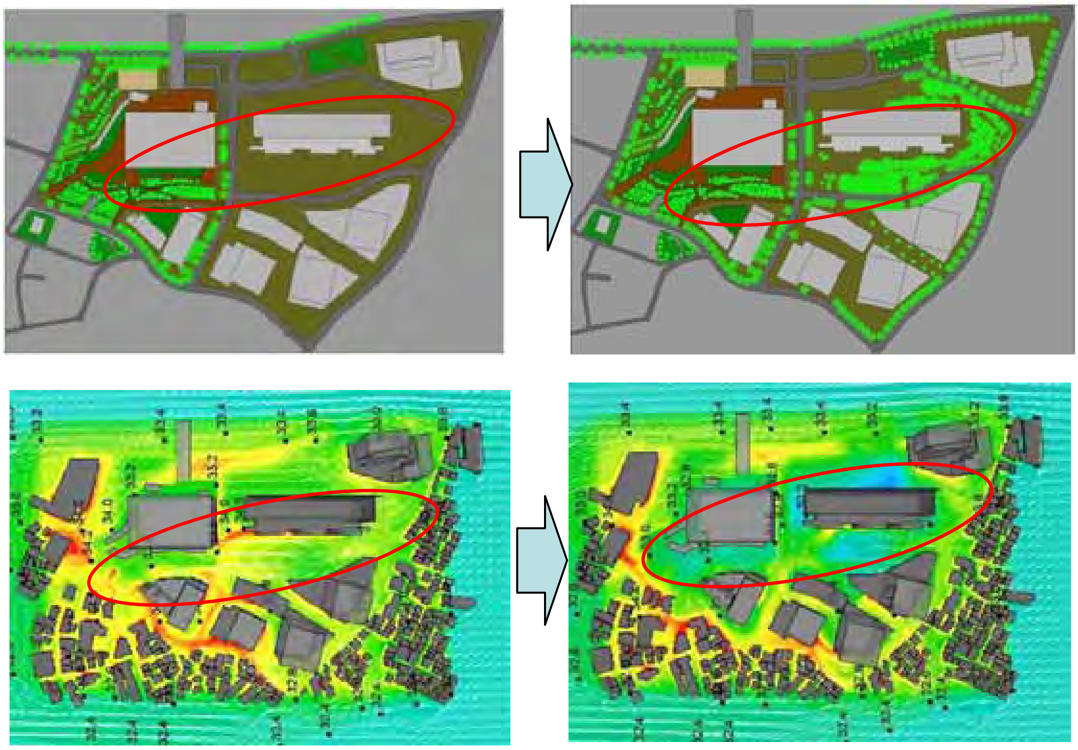
1) Thermal image of wind path (from View Point A, 12:00)

Wind Path average Temp.: 34.1°C



2) Temperature change within a day; August 2008

Figure 12.2.4 The effects of wind path for Improved thermal environment in summer in Osaki ThinkPark



(1) Measures taken by a single site

(2) Collaborative measures taken by multiple sites

Figure12.2.5 Simulation of temperature reduction effects by creating continuous "Wind Paths" extending multiple sites in Osaki west district

3) Thermal environment improvement plan in Yujiapu Financial District

For the improvement of thermal environment in Yujiapu Financial District, it is important to adopt a method that reflects the local weather conditions and the location of the district. The wind direction in the district during summer is not constant but it is possible to make use of the wind speed of 2 to 4 m/s. In addition, three sides of Yujiapu Financial District are facing to the wide river. Therefore, the thermal environment improvement plan should consider the following points:

a) Formation of "wind path" through the entire Yujiapu Financial District

As shown in the case of Osaki ThinkPark, an appropriate wind path design contributes to significant lowering of the air temperature of an area greatly. For the district enclosed by a river which water surface temperature in summer is lower than ground surface and generates cool air, the development project should make the most of its environmental and locational advantages. Since the wind direction is not constant, "wind path" should be planned in a way that wind from the river from any direction can flow into the district easily.

b) Planning of continuous greenery which retains lower temperature

The cool air from cool spots tends to lose coolness when it passes through places such as roads with high surface temperature. Therefore, it is very important to design uninterrupted “wind path” or “greenery corridor” as in Osaki ThinkPark through good outdoor open space planning and greening planning. According to the thermal environment simulation for Osaki ThinkPark, if continuous “wind path” is designed, the temperature cooling effect is larger than the case of discontinuous path. The similar effect is expected for Yujiapu Financial District therefore proper planning of greenery alignment is very important.

c) Creation of street spaces shaded by tall trees

Shady spaces created by tall trees are expected to have lower temperature than those created by shrubs or grass. When arranging tall trees along the streets, it is important to carefully plan the distance between the trees and buildings as well as the number of tree rows and the layout pattern. In addition, it is important to pay attention to the water retention ability of the ground surface when planning tall trees on the street.

d) Promotion of using pavement material that lowers the ground surface temperature

If thermal coating materials or water retention materials are used on the sidewalk and the roof of low-rise buildings, their surface temperature can be lowered by approximately 10°C as compared to the conventional materials for pavement or roofing.

e) Consideration of both landscape and thermal environment in waterscape or greening projects

When designing landscape for waterfront and green spaces, good quality outdoor space with high environmental value can be created by reflecting the result of study evaluating the thermal environment.

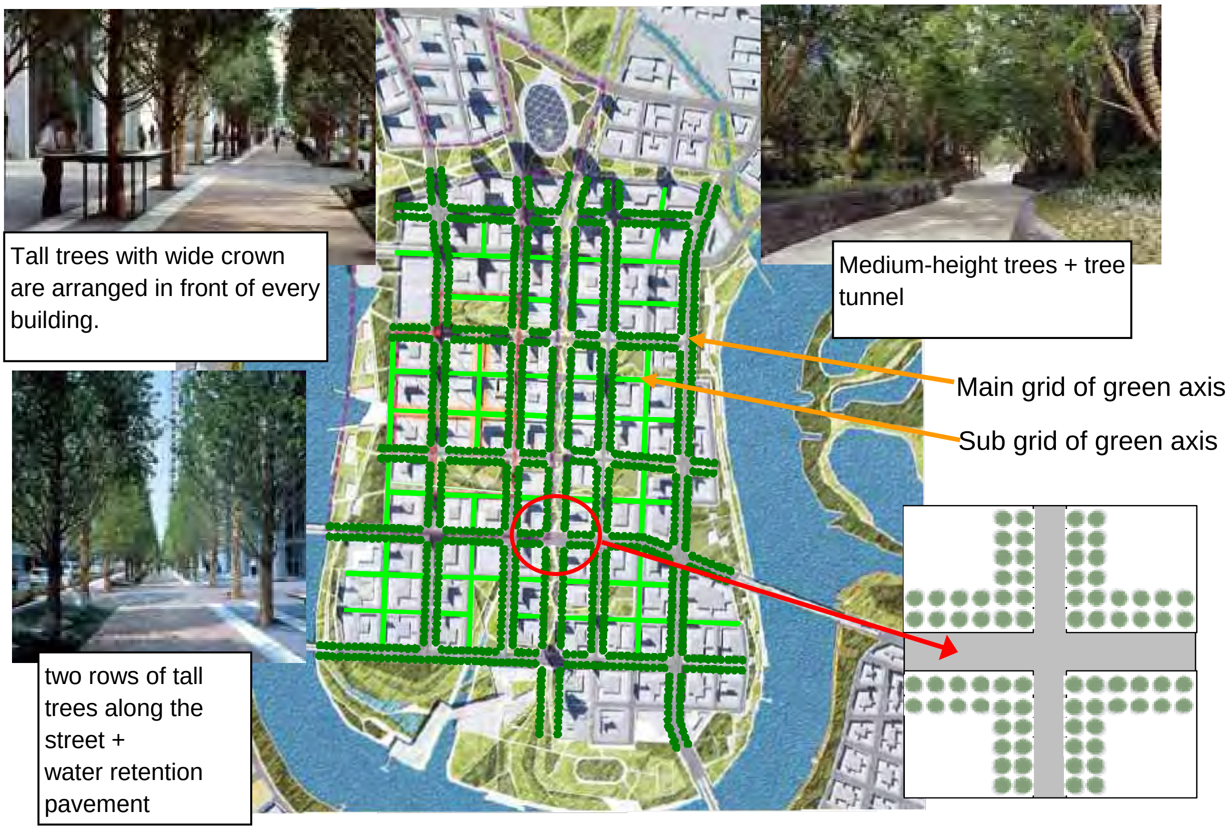


Figure12.2.6 Formation of continuous “wind path” by arranging tall trees along the streets in each district unit

4) Simulation of the thermal environment

a) Sample cases

Sample cases

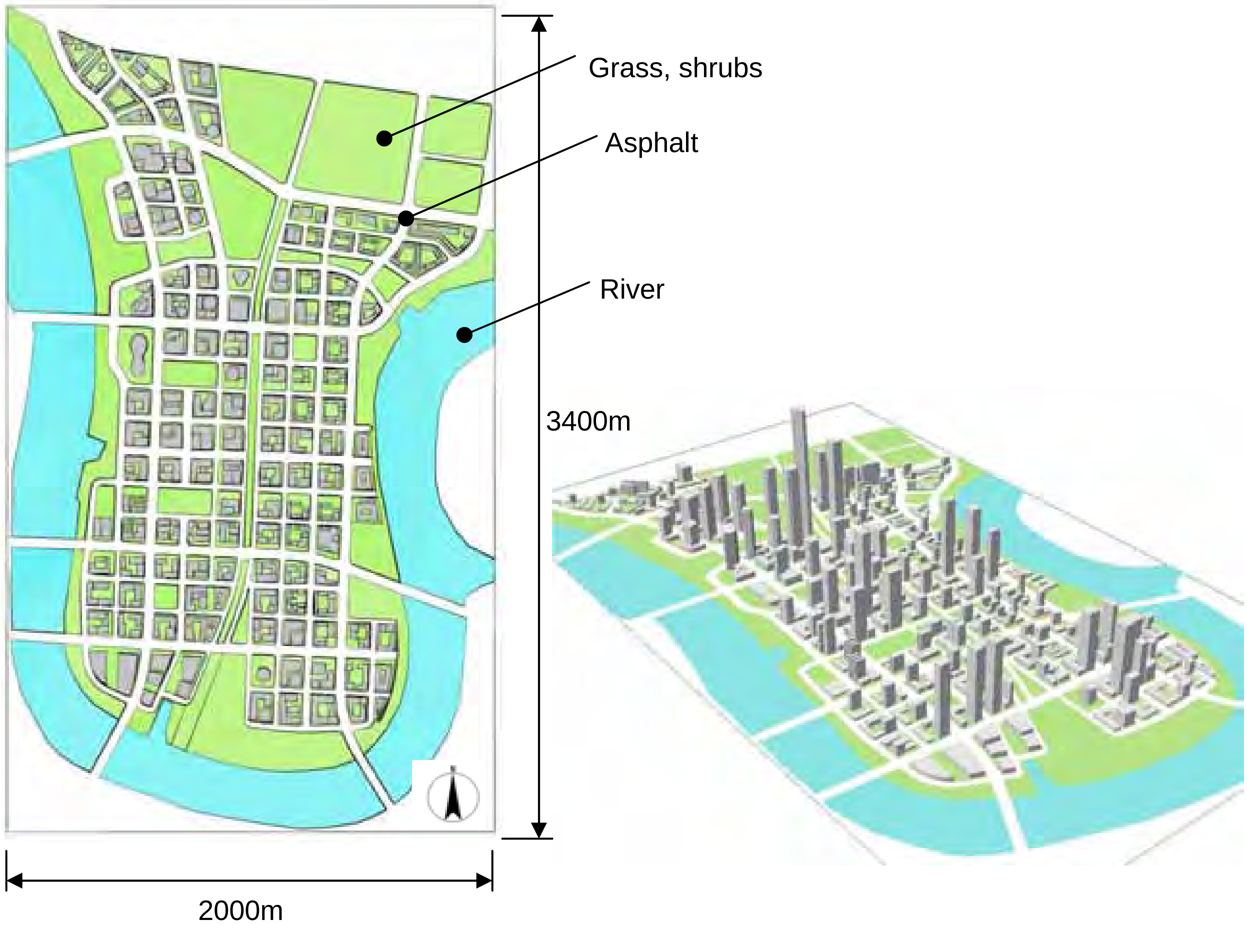
Cases	Wind direction	Greening		Artificial heat exhaust			Remark
		Grass, shrubs	Tall trees	A	B	C	
Case 1	South 2.0 m/s	○		○			BAU
Case 2			○	○			with wind path
Case 3			○		○		with building energy saving + river water
Case 4			○			○	with traffic measures

A: Traffic (cars), building, District heating and cooling (DHC)

B: Traffic (cars), building (energy saving), DHC + use of river water

C: Traffic (Bus Rapid Transit etc.), building (energy saving), DHC + use of river water

b) Analysis model (BAU)



Building specification

Building (1): H=20 or less	Reinforced concrete
Building (2): other than (1)	Multi-layered glass (FL6 + A6 + FL6)

c) Conditions for calculation

1. Weather data

Data from “Energy Plus (Tianjin)” is used.

For the weather condition data to use in surface temperature simulation, data of July is used because the monthly average temperature is the highest of the year. In particular, data of July 29th is used because the average temperature at 1:00 pm is the highest in July. The wind speed is assumed to be 1 m/s.

時	現地気圧 (hPa)	海面気圧 (hPa)	気温 (℃)	湿度 (%)	風向	風速 (m/s)	降水量 (mm)	日照時間 (時間)	全天日射量 (MJ/m2)	降雪 (cm)	積雪 (cm)
1時	--	--	27.1	93	--	1	--	0	0.00	--	--
2時	--	--	26.6	94	--	1	--	0	0.00	--	--
3時	--	--	26.3	95	--	1	--	0	0.00	--	--
4時	--	--	26	96	--	1	--	0	0.00	--	--
5時	--	--	25.8	96	--	1	--	0	0.00	--	--
6時	--	--	25.7	96	--	1	--	0	0.00	--	--
7時	--	--	26	95	--	1	--	0	0.36	--	--
8時	--	--	26.8	92	--	1	--	0	0.88	--	--
9時	--	--	28	88	--	1	--	0	1.47	--	--
10時	--	--	29.4	82	--	1	--	0	2.04	--	--
11時	--	--	30.8	76	--	1	--	0	2.55	--	--
12時	--	--	32.1	69	--	1	--	0.4	2.90	--	--
13時	--	--	33.2	63	--	1	--	0.7	3.06	--	--
14時	--	--	33.9	58	--	1	--	1	2.99	--	--
15時	--	--	34.2	56	--	1	--	1	2.71	--	--
16時	--	--	33.9	56	--	1	--	0.9	2.26	--	--
17時	--	--	33.3	59	--	1	--	0.7	1.70	--	--
18時	--	--	32.4	63	--	1	--	0.2	1.11	--	--
19時	--	--	31.6	68	--	1	--	0	0.56	--	--
20時	--	--	30.9	74	--	1	--	0	0.09	--	--
21時	--	--	30.5	80	--	1	--	0	0.00	--	--
22時	--	--	30.5	85	--	1	--	0	0.00	--	--
23時	--	--	30.3	89	--	1	--	0	0.00	--	--
24時	--	--	29.9	92	--	1	--	0	0.00	--	--

2. Area of greenery spaces

3. Heat exhaust from traffic

	(Unit)	BAU	After thermal environment improvement measures (assuming that the volume of car traffic is reduced to half)
Traffic volume at peak congestion	MJ/ peak hour, 1 hr/m^2	0.482	0.242
No. of running buses	MJ/ peak hour, 1 hr/ m^2	0.054	0.054
No. of trucks	MJ/ peak hour, 1 hr/ m^2	0.051	0.051
Total	MJ/ peak hour, 1 hr/ m^2	**0.586**	**0.346**

4. Artificial control of heat exhaust

It is assumed that turbo-type chillers would be used in the district before taking thermal improvement measures. It is also assumed that, after taking thermal improvement measures, river water would be utilized in addition to turbo-type chillers for controlling heat exhaust, and thus reduce peak load by 40% through energy saving in buildings and use of capacitors.

Construction Phase, DHC No.		Before (BAU) (kW)	After (kW)
PHASE-1	I	20,484	6,145
	II	30,523	9,157
	III	21,053	6,316
PHASE-2	I	17,952	5,386
	II	10,982	3,295
	III	13,041	3,912
	IV	9,742	2,923
PHASE-3	I	15,830	4,749
	II	6,509	1,953
PHASE-4	I	6,912	2,074
	II	6,120	1,836
	III	18,050	5,415

: Direction of river water flow

: DHC facilities that should utilize river water

: DHC facilities that should utilize untapped energy source other than river water

5. Other conditions for calculation

[Surface temperature simulation of the entire surface of the district]

Simulation software: Thermo Render ver.3 (A&A Ltd., Japan)

Analysis area: 2,000 m (X) × 3,400m (Y)

Mesh division: 4 m (limit value for Thermo Render mesh)

Room temperature setting: assumed to use air-conditioning to maintain 26 °C between 7:00 am and 24:00 pm; no air-conditioning for other time

Sunlight penetration ratio of trees: 40%

[Temperature and air flow simulation]

Simulation software: STREAM ver.8 (Cladle Ltd., Japan)

Analysis area: 2,500m (X) × 4,000m (Y) × 1,600m (Z)

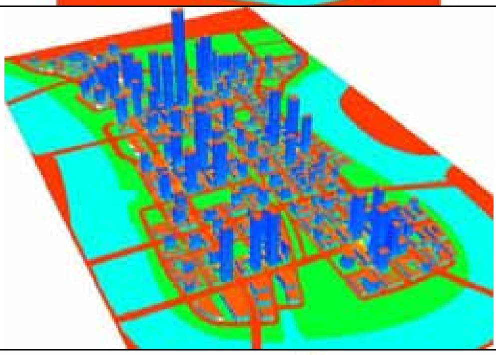
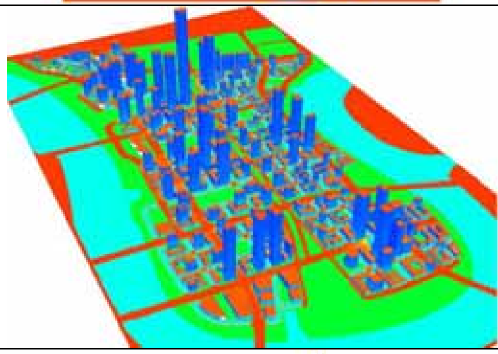
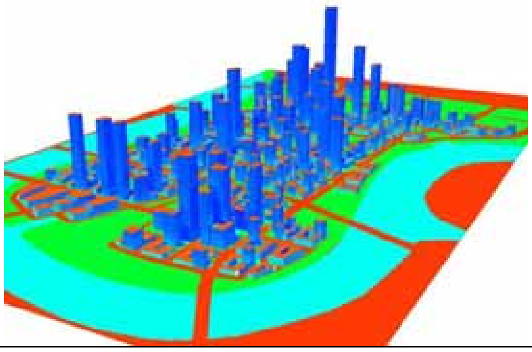
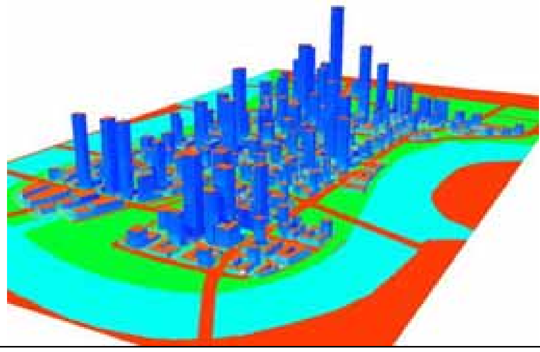
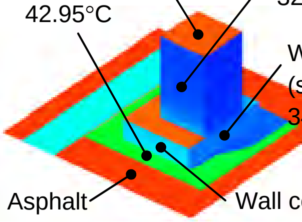
No. of meshes: 31,821,840 meshes (458 (X) × 772 (Y) × 90 (Z))

Tree settings: Resistance coefficient 0.8, leaf area density 1.17, ratio of green coverage:0.5, cooling and transpiration ability of tree crowns: -58W/m^2

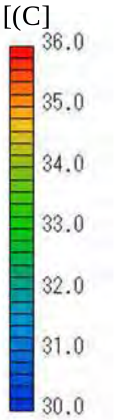
River settings: Heat loss by evaporation from water surface: -75.2W/m^2

Heat loss by heat transmission on water surface: -34.8 W/m^2

6. Simulation result: Surface temperature distribution (at 12:00 pm in August)

Case 1	Case 2/ Case 3/ Case 4
	
	
	
	

7. Simulation result: Air temperature distribution

<table>
<tr><th></th><th>Case 1</th><th>Case 4</th></tr>
<tr>
<td>Temp. distribution GL+1.5m

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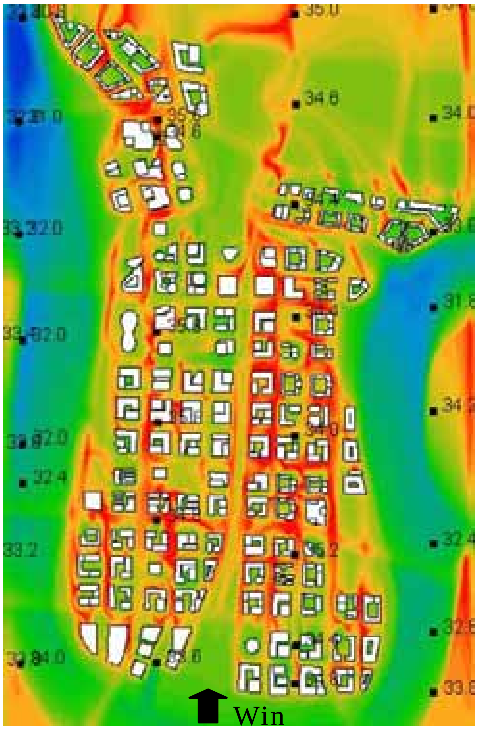
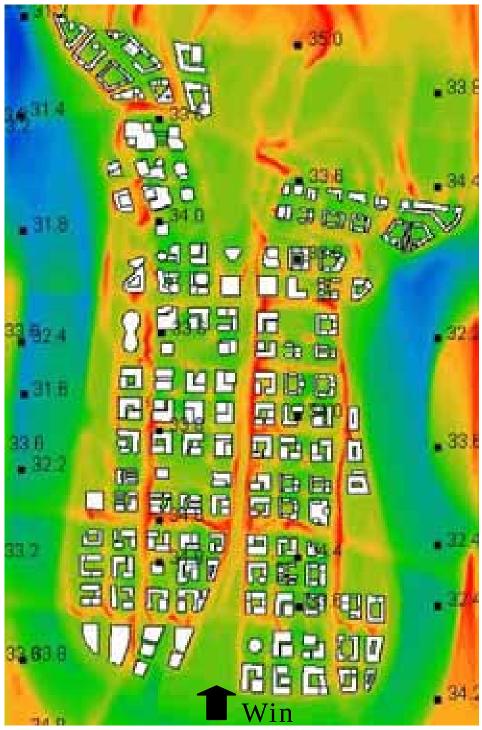
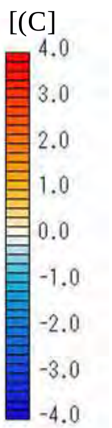
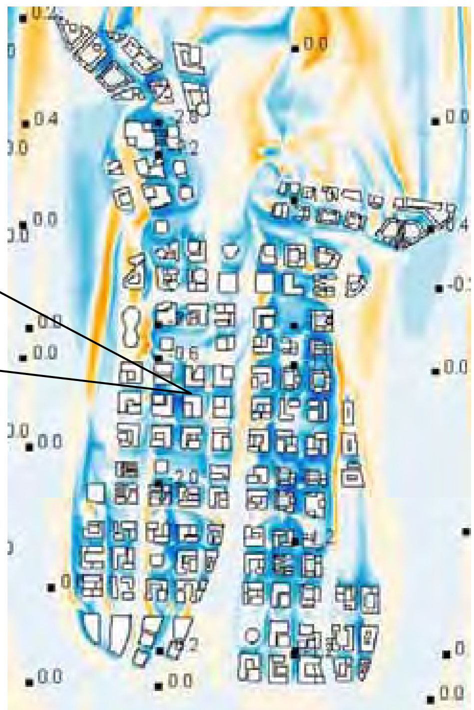
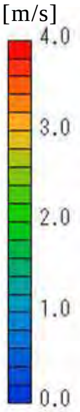
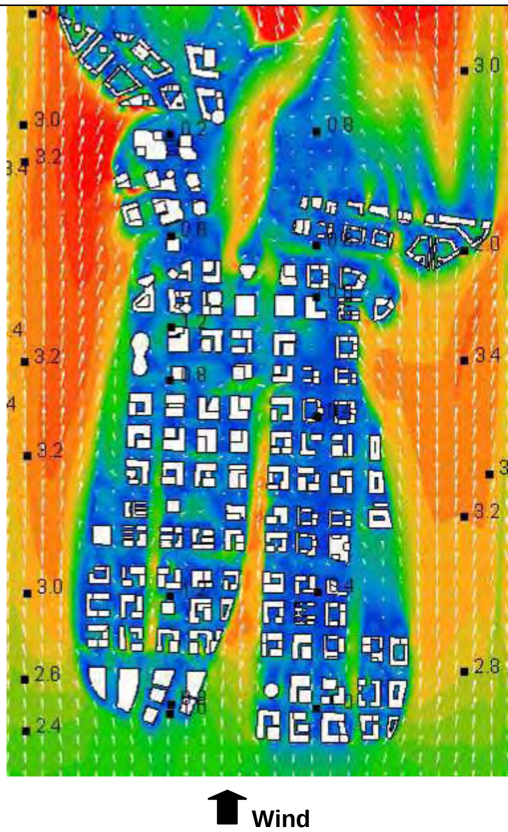
<td>
</td>
<td>
</td>
</tr>
<tr>
<td>Temp. difference distribution GL+1.5m

</td>
<td>Air temperature difference between case 4 and case 1 is calculated for every point in Yujiapu area district and its distribution is displayed.
As compared to BAU, the thermal environment improvement measure is confirmed to reduce the temperature by 1.0-1.5°C in approximately 70% or more area in the Yujiapu district,</td>
<td></td>
</tr>
</table>

8. Simulation result: Average wind speed distribution

<table>
<tr><th></th><th>Case 1</th><th>Case 2</th></tr>
<tr><td>Wind speed distribution GL + 1.5m

</td><td>
</td><td>
</td></tr>
</table>

If the thermal environment improvement measure is taken, the average wind speed is lowered by approximately 0.25 - 0.5 m/s as compared to BAU. It is analyzed that this is because the air flow is slightly weakened by the wide crowns of tall trees which are planted in rows along every roads. In addition, assessing from the temperature distribution pattern, formation of so-called “Cool Spot” can be expected because the thermal environment improvement measures expands the low temperature areas that retains cool air in the district more than BAU.

12.3 Resource circulation planning

1) Efficient use of waste

Yujiapu Financial District is a CBD with a daytime population of 500,000 and a nighttime population of 50,000, therefore a large amount of waste would be generated throughout the day. This section presents efficient ways of reusing wastes in the district, and estimate of waste quantity generated as well as ways of utilizing biomass energy as a reference.

a) Scenarios for efficient use of waste

Four scenarios for utilizing waste resource efficiently are described as follows:

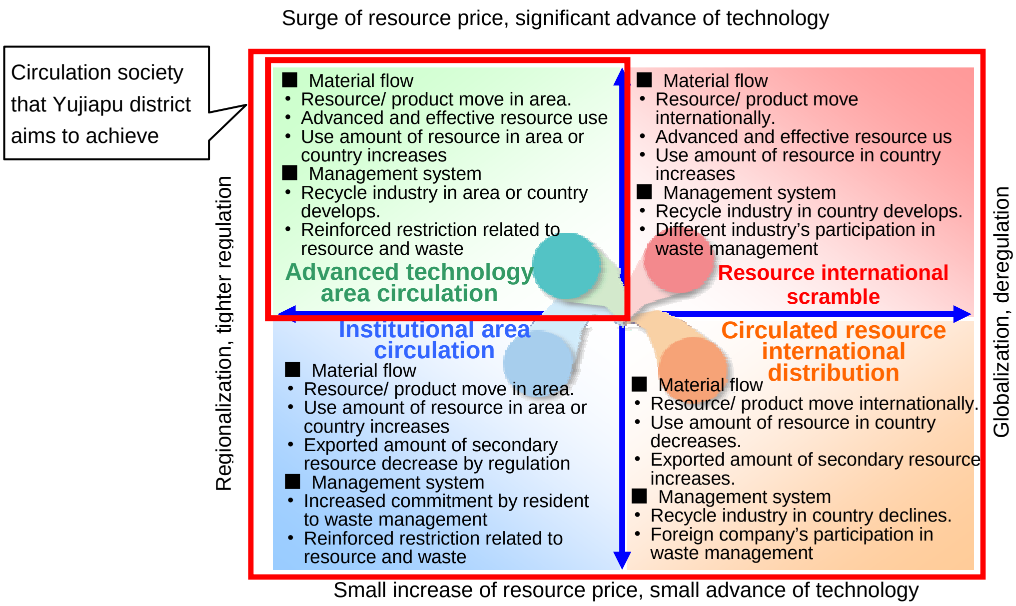
Scenario 1. “International distribution of recyclable resources”: This scenario assumes that globalization and deregulation further accelerate and the resource prices and recycling technology would not change significantly compared to current conditions. In this scenario, the secondary resources are exported overseas where the labor cost are cheaper than domestic costs for resource recovery because deregulation would allow free global transaction of wastes and the technology level would not advance greatly.

Scenario 2. “Global scramble for resources”: In addition to globalization and deregulation, this scenario assumes that a surge of resource prices and a significant advance of technology would occur. In this scenario, the recycling technology would advance because the prices of resources are very high. The resource recovery are conducted domestically because the profits from waste management activities are relatively high and thus private companies would operate waste management and recycling.

Scenario 3. “Regional resource circulation with advanced technology”: This scenario assumes that high-priced resources trigger global division of resource market into regional blocks and various regulations are tightened. Deindustrialization of domestic industries would be avoided, waste treatment and resource recovery would be conducted in a local region, and governments would have a major role in waste management.

Scenario 4. “Institutionalized regional resource circulation”: This scenario assumes that there would be no surge of resource price or significant advance in recycling technology. Regulations and institutions for waste management are adopted and thus waste management and resource recovery is conducted according to such regulations and institutions within the regional block or the country.

It is recommended that Yujiapu firstly establishes a satisfactory resource circulation system to follow the fourth scenario “institutionalized regional resource circulation”, and then shifts to follow the third scenario “regional resource circulation with advanced technology”.



Source: http://www.nies.go.jp/kanko/tokubetu/sr83/sr83.pdf

Figure 12.3.1 Scenarios for efficient use of waste resources

b) Types of waste

Wastes can be classified into several specific types. The table below is a sample of waste classification used by Tokyo Metropolitan Government. Wastes generated in Yujiapu Financial District could also be classified into specific types as shown in this table. Establishing a system to classify wastes into specific types is very important for introducing an integrated waste management system for the entire district in future.

Table 12.3.1 Types of domestic wastes

Class	Type	Detailed description
Household waste	1) Combustible waste	Kitchen waste (waste generated by cooking, leftovers), paper (tissue, newspaper, and magazine), wood waste (trimmed branches), and clothes etc.
	2) Incombustible waste	Glass (dishes and windows), ceramics (dishes and vase), metal (pan and flying pan), plastics (PET bottle) etc.
	3) Bulk wastes	Large-sized home electric appliances (excluding below), furniture (chest and sideboard), bicycle etc. Items too large for general waste collection.
	4) Electric home appliances (4 types)	Washing machine, air-conditioner, TV, and refrigerator
	5) PC	PC and peripheral equipment
	6) Car	Car
	7) Harmful wastes	Wastes including toxic substances such as battery, fluorescent lamp, and thermometer
Business waste	1) Combustible waste	Kitchen garbage, paper waste, and wood waste
	2)Bulk wastes	Large-sized sideboard and desk; wood waste which are too large for general waste collection
Human waste	1) Human waste	Human waste and toilet paper etc. in tank-type toilet
	2) Sludge in septic tank	Sludge accumulated in septic tank

Source: http://www.kankyo.metro.tokyo.jp/resource/general_waste/about.html

Table 12.3.2 Wastes generated by business activities

Class	Kind	Detailed description
Generated from general business activity	1) Cinders	Coal cinders, incinerator ash, remaining ash after furnace cleaning, and others
	2) Sludge	Mud-like sludge discharged by drainage processing or each production process, sludge after processing by active sludge method, building pit sludge (excluding human waste and the like), carbide sludge, bentonite sludge, car wash sludge etc.
	3) Waste oil	Mineral oil, animal/ plant oil, lubricant, isolation oil, cleaning oil, cutting oil, solvent tar pitch
	4) Waste acid	Photo fixing waste liquid, waste sulfuric acid, waste hydrochloric acid, all acid wastes such as organic acid
	5) Waste alkali	Photo development waste liquid, waste soda liquid, all alkali waste liquid such as metal soap liquid
	6) Waste plastics	All solid and liquid plastic macromolecule chemicals such as plastic waste, synthesis fiber waste, synthesis rubber waste (e.g. tire)
	7) Rubber waste	Natural rubber waste
	8) Metal waste	Polishing waste of iron and non-metal, cutting waste
	9) Glass waste and ceramics waste	Glass (plate glass etc.), firebrick, plaster board
	10) Slag	Casting waste sand, melting vessel waste, wrong coal, coal waste

	11) Concrete broken piece	Broken pieces of concrete and brick generated from new construction, remodeling, removal and other unnecessary waste
	12) Soot and rubbish	Unnecessary waste generated from a smoke generation facility and industrial waste burning facility defined in air pollution prevent law
Generated from specific business	13) Paper waste	Wastes from construction industry (generated by new construction, remodeling, or removal), pulp, paper, and paper processing, newspaper business (print and issue using newspaper roll), publication (print and issue), bookmaking etc.
	14) Wood waste	Wastes from construction industry (generated by new construction, remodeling, or removal), wood production (furniture production), pulp production, imported wood wholesales (wood piece, sawdust, and bark).
	15) Fiber waste	Wastes from construction industry (generated by new construction, remodeling, or removal), natural fiber waste such as cotton waste and wool waste from other than fiber product industry such as clothes
	16) Animal/ plant waste	Solid waste related to animal and plant used as materials in food, medical, and essence production; e.g. various dregs and parts of fish and animal
	17) Animal solid waste	Solid waste generated in abattoir of cow, pig, and chicken
	18) Animal waste	Wastes of cow, horse, sheep, chicken discharged from stock farming
	19) Animal dead body	Dead body of cow, horse, sheep, chicken discharged from stock farming

Source: http://www2.kankyo.metro.tokyo.jp/ippai/gaiyou.htm

c) Estimate of waste quantities

This section estimates the quantities of general waste that would be generated by household and business sectors in the Yujiapu Financial District.

1. Setting of basic waste generation unit

Based on the basic waste generation units of Japan (actual result value), basic waste generation units of Yujiapu Financial District are estimated as below.

Note: Since the data of the waste quantities in Tianjin was not available, the basic waste generation units of Japan was used to calculate the estimated quantity of waste. It is required to adjust the numbers according to the actual local situation when conducting feasibility studies.

Table 12.3.3 Basic waste generation unit for household wastes

Waste type	Basic waste generation unit (g/person day)
Combustible waste	500
Incombustible waste	50
Recyclable waste	50
Other waste	0.1
Bulk waste	10
Total	About 610

Table12.3.4 Basic waste generation unit for business waste (per employee)

	Total	Shop	Restaurant	Office	Factory	Transport center etc.	Others
Total no. of premises	461	243	43	95	55	12	13
Basic waste generation unit [g/ person/ day] (per employee)	838.3	1,139.4	1,784.0	492.6	811.9	249.7	305.1

Unit: g/person day

		Total	Shop	Restaurant	Office	Factory	Transport center etc.	Others
Combustible		581.1	765.5	1504.5	325.8	572.8	117.1	185.5
	Paper	264.0	347.8	247.4	241.5	259.2	68.3	127.5
	Kitchen waste	199.6	223.6	1185.8	49.3	121.0	24.4	45.0
	Fiber	17.1	32.3	8.3	11.9	5.2	1.2	5.2
	Plant	88.6	134.3	62.4	22.6	178.6	23.3	5.4
	Other combustible	11.8	27.5	0.5	0.5	8.8	0.0	2.4
Plastics		142.7	193.3	163.5	98.3	150.1	74.0	78.6
	Plastics	129.9	175.0	156.4	93.8	122.8	71.3	78.2
	Rubber, leather	12.7	18.3	7.1	4.5	27.3	2.7	0.4
Incombustible		114.5	180.6	116.0	68.5	89.0	58.7	41.1
	Glass (transparent)	12.8	18.8	18.9	9.0	6.0	6.7	9.6
	Glass (colored)	19.8	33.4	22.0	5.0	18.0	15.3	9.8
	Metal	65.3	102.2	61.7	40.0	57.1	29.7	17.6
	Others	16.7	26.1	13.3	14.4	7.9	7.1	4.2
Total		838.3	1,139.4	1,784.0	492.6	811.9	249.7	305.1

Source: http://www.tama-100.or.jp/pdf/jigyoukeigomikeiryou.pdf

2. Setting of the population distribution for each land use in Yujiapu district

In Yujiapu district, the population is assumed to be distributed among different types of land use as in below table.

Table 12.3.5 Estimate of number of employees and resident population by land use (10 thousand persons)

Site (ha)	Volume ratio × 100%	Total floor area (ha)	Office	Commercial	Hotel	Exhibition	Residential	Culture	Public	Recreation	Transport	Total
174.6	5.20	907.8	523.5	76.6	42.5	3.9	199.9	56.3	0.0	0.0	5.1	907.8
Employee density (assume) (m2/person)			12	50	60	12		50	12	12	50	
No. of employees (10 thousand)			43.62	1.53	0.71	0.32		1.13	0.00	0.00	0.10	47.42
Resident density (assume) (m2/person)							40					
No of residents (10 thousand)							5.00					5.00

3. Estimate of waste quantities

From 1.2 above, the quantities of general waste that would be generated by household and business sectors is estimated to be approximately 300 ton per day.

Table 12.3.6 Estimate of waste quantities

Class	Office	Commercial	Hotel	Exhibition	Residential	Culture	Public	Entertainment	Transport	Total
Quantities of waste generated (ton/ day)	215	27	13	4	30	13	0	0	0.3	302

Note: The "basic waste generation units for business wastes" in Table12.3.4 was used for calculation of waste quantities from land use classes other than residential use. Data for restaurant in Table 12.3.4 was used for the calculation for commercial use. Similarly, data for shop was used for hotel, exhibition and cultural use; while data for transport center was used for transportation use. For calculation of waste quantities from residential use, "basic waste generation unit for household wastes" in Table12.3.3 was used.

d) Strategy for efficient use of waste

As a strategy for using waste efficiently, infrastructure arrangement that supports resource circulation activities such as reuse, recycle, and use of energy generated from waste should be developed. Ultimately, reduction of the waste itself is the most important.

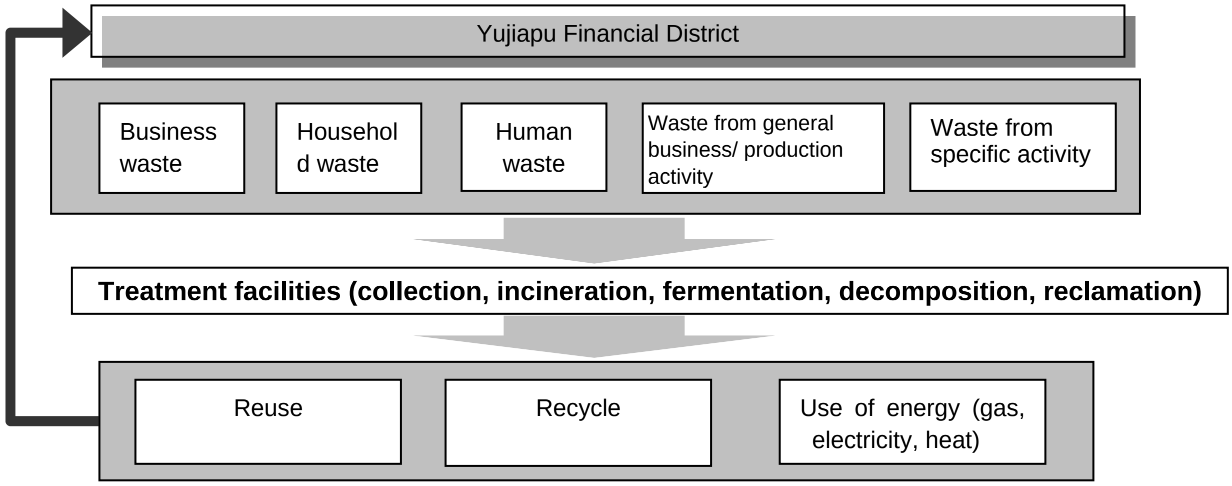


Figure 12.3.2 Efficient use of waste

2) Use of waste as biomass resource

a) Types of biomass resources

Biomass resources are classified as follows. This section describes methods of utilizing biomass resources colored in below table, including kitchen wastes and waste cooking oil.

Table 12.3.7 Types of biomass resource

Biomass resource	Non-used resource	Wood biomass	Forest biomass	Remaining wood
				Thinned wood
				Unused wood
			Others (e.g. trimmed wood)	
		Agriculture waste	Rice farming waste	Rice straw
				paddy
			Barley straw	
			Bagasse	
			Others	
	Wasted resource	Wood biomass	Sawing waste	
			Building waste	
		Paper production biomass	Old paper	
			Paper production sludge	
			Black liquid	
		Farm animal waste/ sludge	Farm animal waste	Cow
				Pig
				Chicken
				Others
			Sewage sludge	
			Septic tank sludge	
		Food biomass	Food processing waste	
			Food sales waste	Wholesales
				Retail
			Kitchen waste	Home
				Business
			Waste cooking oil	
		Others	Reclaimed land gas	
			Paper waste, fiber waste	
	Production resource	Wood biomass	Short-cycle culture wood	
		Grass biomass	Grass	
			Water grass	
			Sea grass	
		Others	Algae	
			Sugar, starch	
			Plant oil	Palm oil
				Rape oil

b) Estimate of usable quantity of waste as biomass resource

1. Usable quantities of kitchen wastes

The usable quantity of kitchen waste is estimated to be approximately 164 ton per day as shown below (for details, see Chapter 9):

Table 12.3.8 Usable quantity of kitchen waste

	Retails/shops	Restaurants	Offices	Others (e.g. hotel)
Standard quantities of waste generated; kg/m2 day	0.8	0.2	0.04	0.06
Ratio of kitchen waste	25%	55%	10%	14%
Total floor area; m2	613,136	153,284	5,234,612	424,589
Quantity of kitchen waste	123	17	21	4
ton/day	164			
ton/year	59,858			

2. Usable quantity of waste cooking oil

The usable quantity of waste cooking oil is calculated using the basic unit below:

- Waste cooking oil from household: 1.57 kg/ person/ year

  Nighttime population: 50,000 person × 1.57 kg/ person/year × 0.9

  = approximately 79 ton/ year → (216 kg/ day)

c) Methods of utilizing biomass

A comprehensive approach for utilizing biomass is required for all types of wastes including kitchen wastes and waste cooking oil.

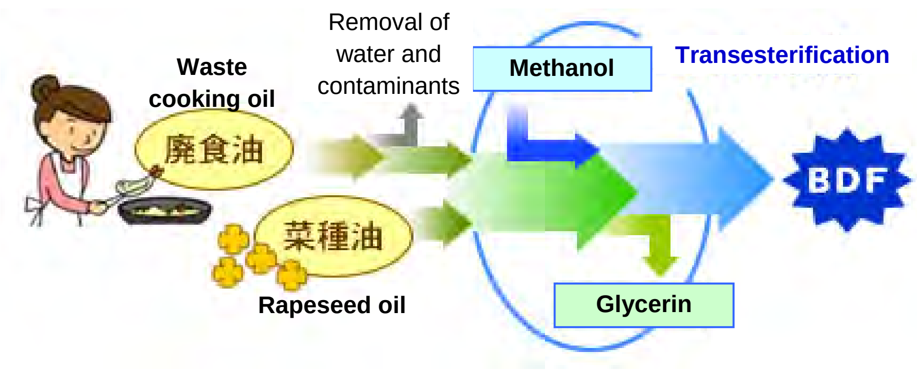
1. Method of utilizing kitchen waste as biomass energy resource

As a method for treating 164 ton per day of kitchen waste, power generation at a waste treatment facility is recommended. Setting of one such treatment facility in the district would be sufficient. The heat generated from the facility can be supplied as heating or used for power generation to supply electricity to the surrounding facilities (see Chapter 9).

2. Method of utilizing waste cooking oil as biomass energy resource

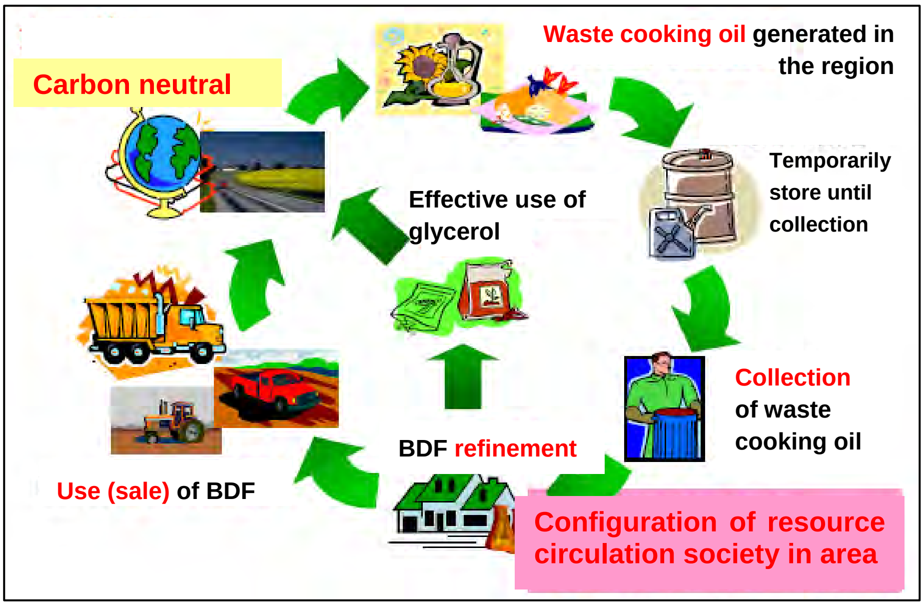
The waste cooking oil can be used as bio-diesel fuel (BDF). The BDF is expected to be used as an alternative liquid fuel replacing fuels using triglyceride as a main raw material (both light oil and heavy oil) for operating diesel engines. The BDF is carbon neutral, that is, even if CO_2 is generated when BDF is burnt, it does not increase the total amount of CO_2 in the atmosphere.

On a light oil equivalent basis, CO2 emission can be reduced by approximately 225 ton-C/ year.



Source: http://www.shizuokayuka.co.jp/bdf.html

Figure 12.3.3 BDF Production

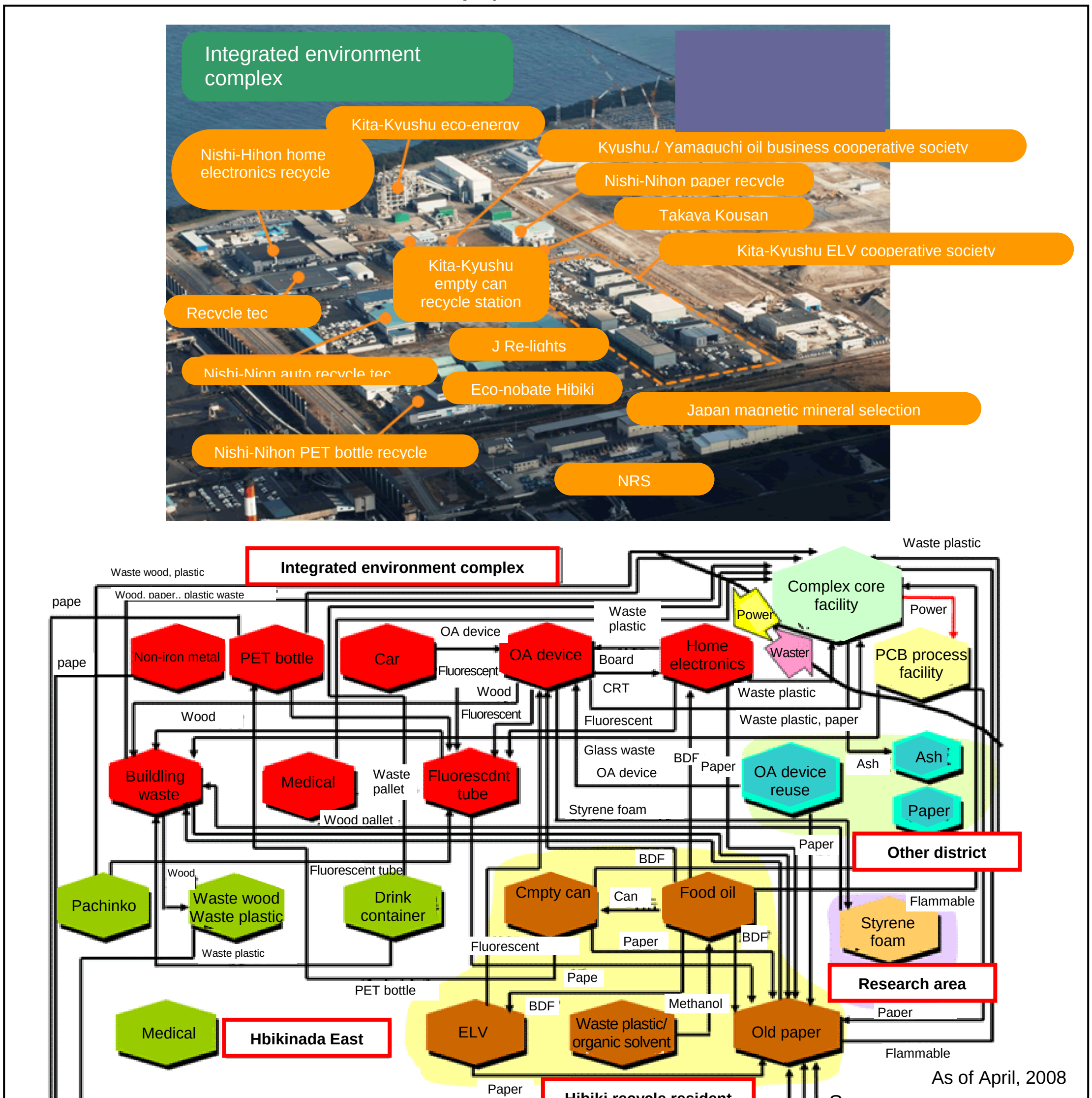


Source: http://www.pref.nagasaki.jp/kanhoken/study/happyoukai/h19/haiyu.pdf

Figure 12.3.4 Process flow of waste cooking oil, BDF production, and its usage

3. Other strategies for waste

The figure below is an example from Kitakyushu Eco-Town where waste treatment and its related facilities for achieving efficient waste circulation and zero-emission (see Chapter 4 for details) are concentrated in one location. Such intensive arrangement of waste related facilities is desirable in the future for Yujiapu Financial District.



As of April, 2008

Source: Kitakyushu Eco Town

Figure12.3.5 Outline of waste recycling system in Kitakyushu Eco-Town

Therefore, as a feasible goal of waste resource circulation, the following should be set as targets for 2020: 40% or higher recycle rate of waste plastics; 40% or higher recycle rate of kitchen waste; and 40% collection rate of paper waste. By 2030, the targets for all these three categories should be set as 80% or higher. Yujiapu Financial District will aim to be a zero-emission low-carbon society as much as possible.

3) Water reuse planning

a) Target water resource

This section assumes the use of “gray water (treated water)” which can be repeatedly used by treating the wastewater from the office and residential buildings. The gray water can be used in facilities or locations where water do not make direct contact with human bodies, for example, for toilet flush water or fountains in parks.

- Flushing water for toilet
- Water for plants and greenery
- Cleaning water of outdoor facilities
- Cooling water for machinery and equipment
- Water for various washing
- Water for recreation, etc.

b) Types of facilities and circulation system

1. Facility type

It is assumed that gray water will be widely used in principle in Yujiapu Financial District since the supply of gray water has already been planned for the district. Reuse of wastewater at each district by locating a water treatment facility in each district would reduce load to the sewers and also contribute to further efficient use of water resource.

2. Circulation system

Since the district already has a regional gray water supply plan, the supply of gray water takes regional water circulation system which collects wastewater from the entire district and then supplies the treated gray water to multiple buildings. The merit of this system is that the system operation cost is lower than other systems in which gray water are treated in circulation within each building or within each district (see below).

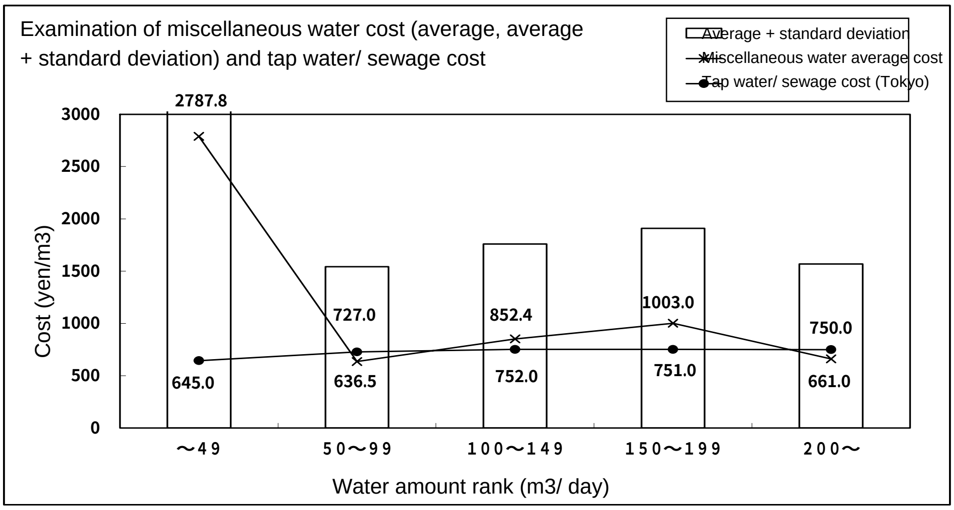


Figure 12.3.6 Comparison of water cost: water from gray water system and water from conventional clean/ sewage water system (Tokyo, Japan)

c) Expected impacts

The past experiences indicate that approximately 50% of wastewater can be reused as gray water. In addition, the following impacts are expected.

Table12.3.9 Use application and impact of using gray water

Use application	Impact
Flushing water for toilet	Saving tap water/ sewage cost
Cooling water for heat source equipment	Saving electricity cost
Spray and irrigation water for greenery	Saving tap water/ sewage cost; preventing heat island effect
Equipment/ car washing water	Saving tap water/ sewage cost
Water circulation within the district	Reducing load on public infrastructure
Water use in case of emergency and disaster	Emergency use is possible because a certain amount of gray water can be stored

Note: It is necessary to check the water quality at the end-user.

d) Setting of target values and gray water utilization strategy

The phased development target (Indirect indexes) for gray water use in Yujiapu district by 2030 and the use flow of reproduced water are set as shown below:

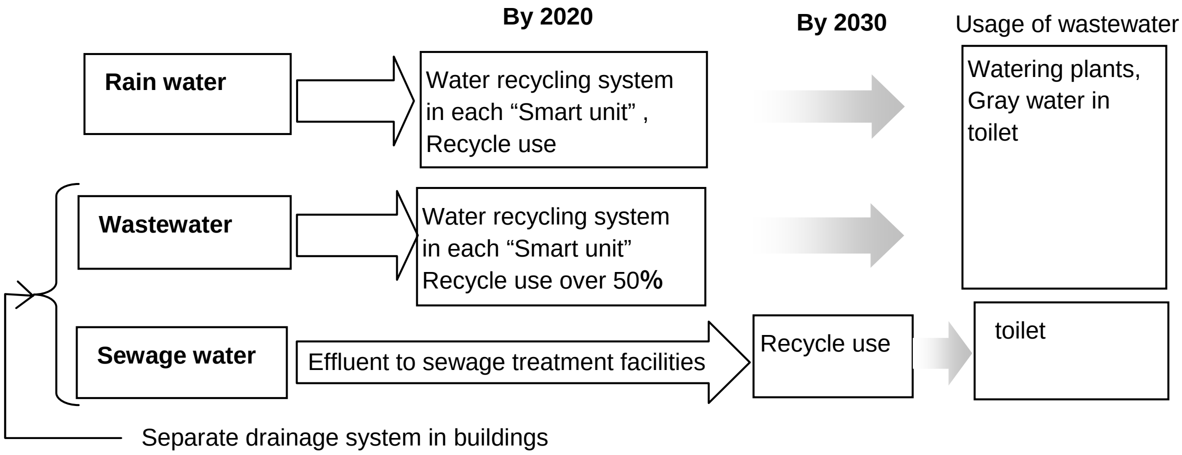


Figure12.3.7 Phased strategy for gray water utilization by 2030

12.4 Measures for pollution control

1) List of pollution control standards set by China National Government and Tianjin City Government

A legislative system on environment has been developed in China. A set of laws including environmental protection basic law, environmental protection special laws, environmental protection administrative regulations are instituted up to now. In addition, Chinese environmental management policy system follows the eight main principles below:

Table12.4.1 Eight environmental management policy principles in China

a)	‘‘Treble Simultaneity’’ (or ‘‘Three Synchronizations’’)
b)	Environmental impact assessments
c)	Compulsory levy on the excessive discharge of pollutants
d)	Heads of local governments and enterprises are held responsible for attaining certain environmental targets
e)	Quantitative assessment of comprehensive development of urban environment
f)	Pollutants discharge registration, license and permit system
g)	Centralized control and improvement of pollution sources
h)	Improvement of pollution sources with time limit

Table12.4.2 List of environment legislation in China (extracts)

Law system	Major Laws, regulations, articles	Approved/ revised date
Constitution	Article 26: The state protects and improves the environment in which people live and the ecological environment. It prevents and controls pollution and other public hazards. The state organizes and encourages afforestation and the protection of forests. Articles 9, 10, and 22	Revised in1979 Revised on Dec. 4, 1982
Environmental Protection basic law	Environmental Protection Law	Dec. 26, 1989
Environmental Protection special law	▪ Marine Environment Protection Law ▪ Law on Prevention and Control of Water Pollution ▪ Law on the Prevention and Control of Atmospheric Pollution ▪ Law on the Prevention and Control of Environmental Pollution by Solid Wastes ▪ Law on Prevention and Control of Pollution from Environmental Noise ▪ Forest law ▪ Grassland Law ▪ Fisheries Law ▪ Mineral Resources Law ▪ The Law of Land Administration ▪ Water Law ▪ Law on the Protection of Wildlife ▪ Soil and Water Conservation Law ▪ Coal Law	Aug. 23, 1982 May 11, 1984 May 15, 1996; revised Sep. 5, 1987 Aug. 29, 1995; revised Oct. 30, 1995 Oct. 29, 1996 Sep. 20, 1984 Jun. 18, 1985 Jan, 20, 1986 Mar, 19, 1986 Aug. 29, 1996; revised Jun, 25, 1986 Dec. 29, 1988 Jan, 21, 1988 Nov. 8, 1988 Jun, 29, 1991 Aug. 29, 1996
Environmental Protection administrative regulation	Regulations of the People's Republic of China on Nature Reserves Interim Regulations on the Prevention of Water Pollution in the Huai River Valley Decision of the State Council on Several Issues Concerning Environmental Protection (until July, 1997, 120 Dept. order)	Oct. 9, 1994 Aug. 8, 1995 Aug. 3, 1996
Environmental protection sectoral regulation	Provisions on the Administration of Report and Registration of Pollutants Discharge Notification by Country planning committee; financial Dept. for surcharge of pollution discharge table (until July, 1997, 120 Dept. order)	Aug. 14, 1992 Aug. 14, 1992

Source: http://www.acdfo-kyoto.jp/activity/gk0023.pdf

2) Approach for environmental protection and pollution prevention in Yujiapu district

Since environmental pollution such as air pollution and water contamination affects wide area, pollution prevention measures should cover not only Yujiapu district but also the entire Tianjin city. Discharge from Yujiapu district itself should be controlled. However manufacturing or production facilities would not be densely located in Yujiapu district since the area has been developed as a financial district. Therefore, the target performance indicators for air pollution, water pollution, and chemical use should be set as follows by paying careful attention to environmental laws at national level, Tianjin city, as well as environmental targets of Sino-Singapore Tianjin Eco City.

Table12.4.3 Guideline for setting environmental indicators on pollution prevention

- Air pollution: Observe the national "Law on the Prevention and Control of Atmospheric Pollution" and target to achieve lower air pollution level than national standard. (WHO standard will be used as reference indicator)
- Water pollution: Observe the national "Law on Prevention and Control of Water Pollution" and target to achieve lower water pollution level than national standard. (WHO standard will be used as reference indicator)
- Soil contamination: Observe the national standard. For construction waste soil, contamination level should be measured. (WHO standard will be used as reference indicator)
- Chemical use: Set a target to achieve lower chemical pollution level than national standard; in the long-term, higher target as European Union's RoHS Directive (restriction of the use of certain hazardous substances in electrical and electronic equipment) should be targeted

13. Transportation Planning

13. Transportation Planning

Key points

- In order to reduce the carbon footprint in transportation, the following concepts will be effective:
  - Control of traffic volume
  - Reduce greenhouse gas emissions by shifting the transportation modal share to public transportation
  - Shorten the travel distance required
  - Use of fuel efficient vehicles
- The following measures shall be effective based on past experience inside and outside of Japan as well as considering the geographical features of the *Yujiapu* district.
  - High density developing surrounding subway stations
  - Bus network development (Bus Rapid Transit (BRT) lines, loop bus services)
  - Encourage bicycle use (Parking spaces for bicycles, develop and establish a bike sharing program)
  - Road pricing scheme (Charge vehicles a fee for entering the district in order to reduce traffic volume)
  - Introduction of electric vehicles
- In this study, transportation demand is to be estimated through the use of the four step planning method. CO_2 emissions before implementation of the measures mentioned above would be estimated using the characteristics of the current transportation mode choice behavior in Tianjin city. This would be followed by an estimation of CO_2 emissions after the implementation of the measures as mentioned above in order to verify the effect the measures had in reducing CO_2 emissions.
- Given a 10% increase in the modal share of public transportation, CO_2 emissions could be expected to be reduced by 30% after the implementation of the measures mentioned above

13-1. Outline and Introduction of Methods and Technologies

1) Methods and Technologies for Reducing CO_2 Emissions in Transportation

CO_2 emissions emitted by cars accounts for a large portion of CO_2 emissions produced in transportation. This is partly because the amount of CO_2 emissions generated by a car carrying one person is large compared to public transportation such as subways and buses.

Basically, CO_2 emissions emitted by cars can be calculated by the multiplication of three parameters: traffic volume, distance traveled and emission intensity (Formula 1).

Accordingly, controlling traffic volume, modal shift to public transportation emitting less greenhouse gas, shortening of travel distance and the use of fuel efficient vehicles are effective in reducing CO_2 emissions in transportation.

CO_2 Emissions = Traffic Volume × Distance Traveled × Emission Intensity (Formula 1)

Formula 1 could be rewritten as follows:

CO_2 Emitted by Cars = Traffic volume (unit · km) × Fuel Consumption (l/km) × CO_2 Emission Coefficient by Fuel (kg-CO_2/l)

Based on the points above, measures to reduce CO_2 emissions in transportation are shown in Table 13.1.1.

Table 13.1.1 Methods and Technologies for Reducing CO_2 Emissions in Transportation

Category of CO_2 Reduction Effect	**Measures**	**Reasons for Implementation**
Modal shift to low carbon public transportation modes	Subway development	• Low-carbon public transportation with mass transit capabilities which are able to transfer workers and others from areas outside of the district into the district is needed
	Bus network development	• Low-carbon transportation is needed in areas not served by subways
	Encourage bicycle use	• Roads in the district are flat and the commuting distance is short. Therefore when living an urban lifestyle (working close to home), the convenience factor of the bicycle becomes quite high. • Short distance commuting or traveling could be covered by the use of bicycles as a substitute for public transportation modes such as subways and buses.
	High density development surrounding subway stations	• There are several subway stations which function as hubs of public transportation. High density development by concentrating land use in the areas surrounding subway stations would increase the convenience of public transportation, which holds the promise of shifting people away from cars.
Control of traffic volume	Road pricing scheme	• Control non-essential traffic volume by charging vehicles entering into the district. • Conduct development in each mode of transport simultaneously with the implementation of the system to attain to promote public transportation.
Improvement in vehicle fuel efficiency	Diffusion of Electric vehicles	• Seek to reduce CO_2 emissions from automobiles by introducing the use of electric vehicles as electric vehicles consume small amounts energy per passenger-km compared with conventional automobiles

2) Methods and Examples for Reducing CO_2 Emissions from Transportation

a) Reducing CO_2 emissions by Mode Shifting to Public Transportation

Within urban public transportation, there are different modes such as heavy rail, subways, light rail transit (LRT) and buses. The different modes could be further classified in terms of capacity. High capacity transit systems include heavy rail and subways while medium and low capacity transit systems include LRT and buses. CO_2 emissions per passenger-km of these public transportation modes are about one-sixth when compared to the emissions from cars. CO_2 emissions could be reduced by aiming to build a city (centered around public transportation) with more use of public transportation available.

Also, transporting large numbers of people via public transportation makes more efficient use of limited physical space in urban environments. Figure 13.1.3 compares the amount of physical space needed to transport 50,000 people by car and by subway. It can be seen that by automobile, a width of 175 meters in road infrastructure is necessary while by subway, only a width of 9 meters is necessary.

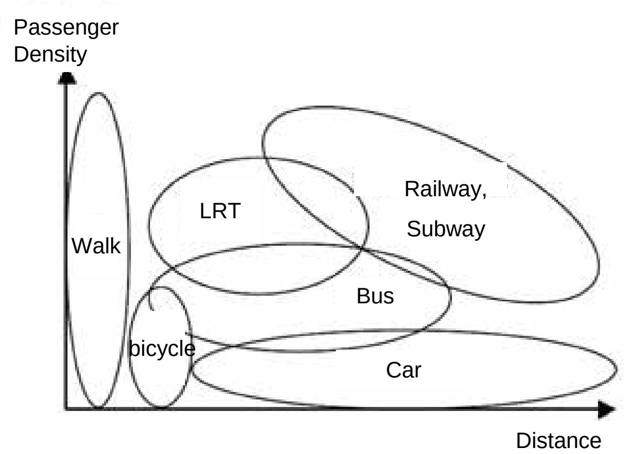
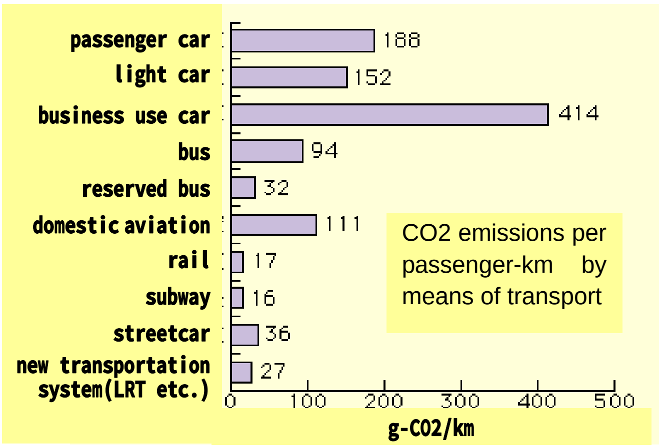


Fig. 13.1.1 Transportation Capacity in Terms of Public Transportation Modes



Reference: Materials from MLIT

Fig. 13.1.2 CO_2 Emissions per passenger-km In Terms of Transportation Mode

Fig. 13.1.3 Comparison of the Physical Urban Space Needed to Transport 50,000 People

b) Public Transportation Development Examples
i) Development of Urban Railway Systems

For public transportation in urban areas, the mode with the highest capacity for transporting people is the subway. Subways have a maximum transport capacity of 40,000 to 50,000 people per hour (per direction) during the rush hour. Therefore this has prompted the construction of subways in many of the world's major cities.

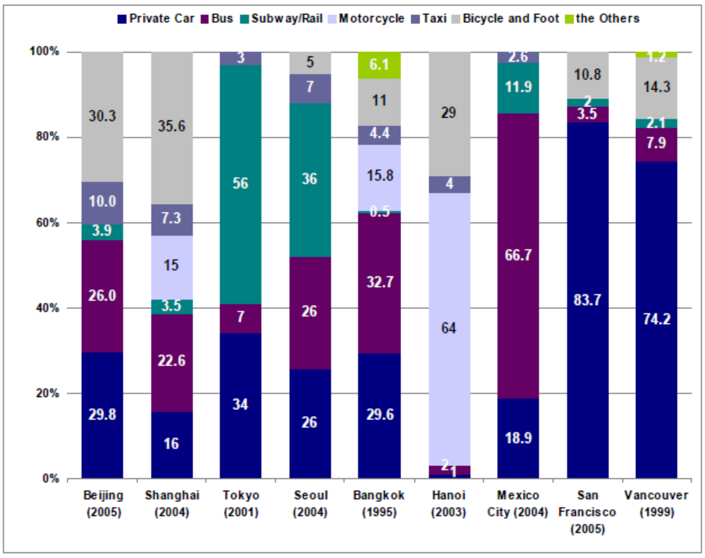
The following is an example of subway development in Tokyo. Development of extensive public transportation systems including subways resulted in a significant modal share of 56% for public transportation among all transport modes in Tokyo.

Table 13.1.2 Data about the Subway Network in Tokyo

Open	1927
Number of Lines	13 lines
Total Length	304.1km
Maximum Speed	80 km/h
Area of Tokyo (23 Wards)	621.98km^2
Population of Tokyo (23 Wards)	8.97 million

Reference: Wikipedia

Fig. 13.1.4 The Subway Network in Tokyo



Reference: Urban Transport Energy Use in the APEC Regions

Fig. 13.1.5 Modal Split for Cities in the Asia-Pacific Region

ii) Development of Bus Networks

Bus Rapid Transit (BRT)

Because the passenger carrying capacity and cost of building subways is large, a large number of cities and areas with medium sized transportation demand have implemented a bus rapid transit (BRT) system.

BRT systems have the ability to use existing road infrastructure, therefore the cost of building such systems in comparison with subways is rather low. Also because BRT systems can be built in a short amount of time, there are a large number of cities using BRT as a short term solution for medium sized transportation demand. For example, BRT systems have been introduced in Seoul, Korea and in Curitiba, Brazil.

In Curitiba, Brazil, four lanes are set aside for BRT and triple-articulated buses with a passenger capacity of 270 people are used. 95 buses are used in the system and about 320,000 passengers are transported each day.

Reference: EST (Environmentally Sustainable Transport) Portal Site

Fig. 13.1.6 BRT in Curitiba, Brazil

Fig. 13.1.7 Cities Which Have Introduced BRT Systems

Loop Bus Services

Development of loop bus services could be used for providing complementary transportation services in areas not directly served by subways.

In the case of Tokyo, the “Marunouchi Shuttle” operating in the Marunouchi area surrounding Tokyo station runs in a circular route (about 4.5 km) from 10 am to 8 pm at intervals of 12 to 15 minutes. The entire journey for the circular route takes 35 to 40 minutes. On the “Otemachi route” which mainly serves business users, two shuttle buses run every 10 to 12 minutes during the morning rush hour between 8 am to 10 am on weekdays. The shuttle buses make use of the uniquely shaped turbine “EV bus”.

Reference: Marunouchi Shuttle Website

Fig. 13.1.8 Loop Bus in the Area (Marunouchi) Surrounding Tokyo Station

iii) Encouraging the Usage of Bicycles

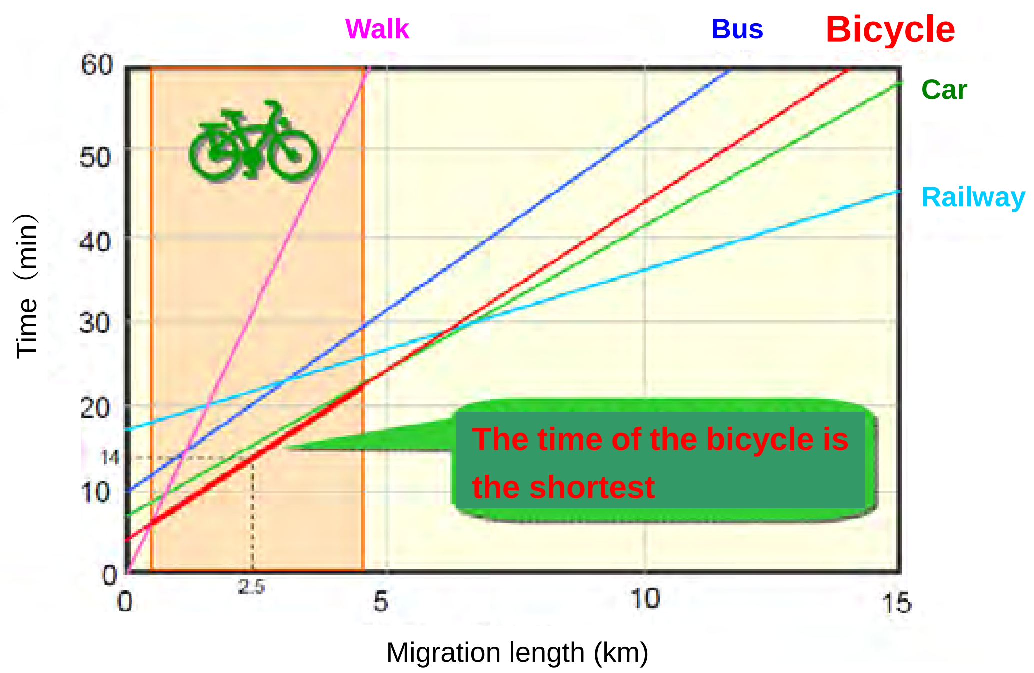
In APEC economies, bicycles have traditionally been used as a means of transportation. Recently, in Western countries, people have taken a second look at bicycles as a mode of transportation as bicycles have many advantages for short distance travel: flexibility, low cost and no CO_2 emissions.

In the case of Japanese cities, looking at the variation in travel time with regards to the distance traveled, the time needed to travel a distance of 2.5 km by bicycle is shorter than all other modes of transport. As a matter of fact, in Japan, bicycles are usually used to travel within a 3 km range in the city.

It is important to attempt to cut CO_2 emissions in a planned manner by reducing the utilization of cars. Therefore improving convenience to move around a city by making use of bicycles could cut down CO2 emissions.

To achieve this, the following is necessary: providing adequate physical space for safe bicycle travel, establishing the infrastructure necessary to enable the usage of bicycles anywhere in a city and reserving space for bicycle parking at subway stations and bus stops.

In China, the use of two-wheeled electric vehicles, “E-bike”, has been spreading but compared to such environmentally friendly motorized transport, the bicycle as a mode of transport is more on a human scale and has a closer relationship to pedestrians. Therefore it is the bicycle which should have a profound effect on creating an attractive low-carbon city block.



Reference: Materials from MLIT

Fig. 13.1.10 Comparison of the Running Speed between Bicycles and Other Modes of Transport

Bike Lanes/Paths

Allocation of physical space for bicycling in an attempt to separate cyclists from cars and pedestrians has been implemented in many cities including ones in the West.

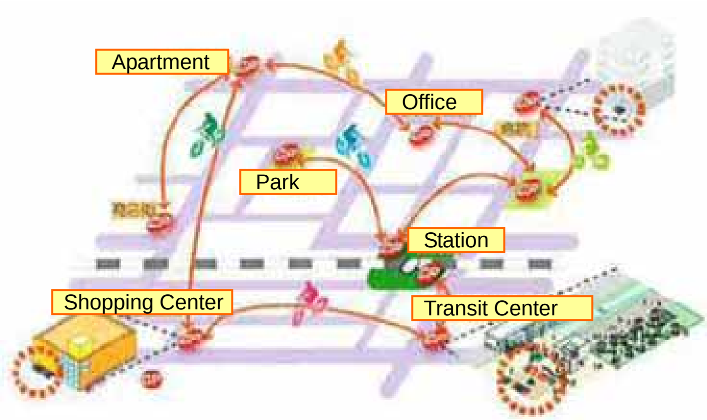
In the development of suitable plans for bike lanes/paths, safety, comfort and security of the cyclist in addition to the impact on road traffic all have to been taken into account for.

Reference: Materials from MLIT

Fig. 13.1.11 Examples of Bike Lanes/Paths [Munich (left), Paris (right)]

Bicycle Sharing System

The bicycle sharing system is where bicycle rental stations (bike docks) are established in major locations in cities to allow people to publicly rent bicycles for their usage. The system works by letting users rent bicycles from their nearest bike dock. Once the user reaches their destination, they can return the bicycle to the bike dock closest to them. Establishing bike docks near subway stations, bus stops as well as public and commercial facilities would enable people heading to their final destination in an urban area to easily get there via a combination of subway and other modes of transportation (public and non-motorized transportation). It is hoped that this could have an effect on reducing car usage.



Reference: Materials from Saitama city

Fig. 13.1.12 Bicycle Sharing System Concept

Table 13.1.3 Bicycle Sharing Systems Currently in Operation

country	number of cases
Spain	100
Italy	57
Germany	44
France	34
China	27
USA	16
Switzerland	10
UK	10
Brasil	5

Reference: Bus Rapid Transit Planning Guide

Experimental period: October 1st to November 30th, 2010
Operation hour: 8:00 to 20:00
Scale of project: Urban area (From Nagoya sta. to Sakae sta.)

Number of stations	30
Number of cycle ports	465
Number of bicycles	300

Reference: "MEICHARI" Website

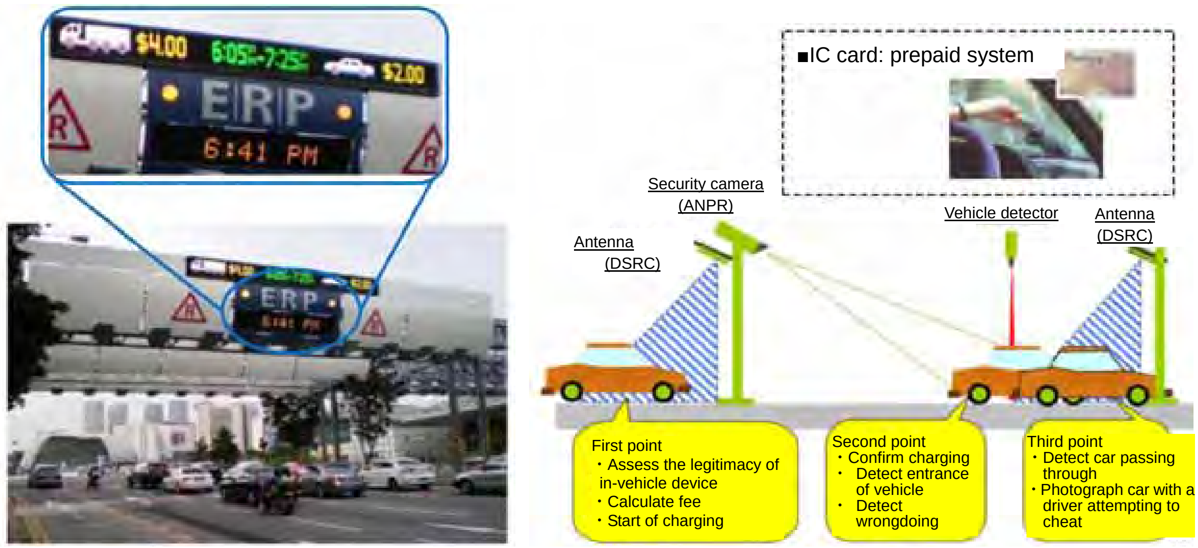
Fig. 13.1.13 Bicycle Sharing System Pilot Project in Nagoya, Japan

iv) Road Pricing Scheme

The road pricing scheme which is in operation in London, Singapore and Stockholm has achieved a certain effect in reducing traffic volume in inner urban areas as vehicles entering such areas are charged a certain fee.

In Singapore the road pricing scheme is used for the purpose of relieving traffic congestion in the central business district. The scheme, which has been in operation since 1975, manages traffic demand by charging vehicles a fee based on adaptive pricing.

When it was first implemented in 1975, a purchased ticket had to be attached to the windshield of a car for the purposes of manual inspection upon entry into the area under the road pricing scheme. By 1998, the manual inspection system had been upgraded into an automatic inspection system called Electronic Road Pricing (ERP) which uses wireless communications technology. Under the ERP system, a pre-paid smart card is inserted into an in-vehicle device. Once the vehicle passes through the ERP gantry, the toll is automatically and wirelessly withdrawn from the pre-paid smart card.



Reference: Materials from MLIT

Fig. 13.1.14 Road Pricing System in Singapore

v) Diffusion of Electric Vehicles

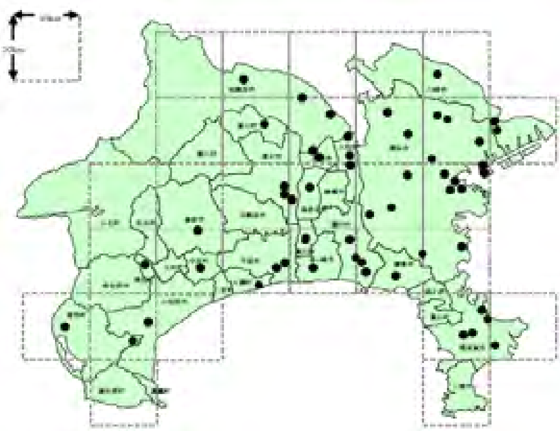
As electric vehicles are assumed to not directly emit CO_2 emissions because they do not use fossil fuels, globally, the adoption rate for commercial usage is growing steadily. However in Japan, real world experience shows that when you compare the CO_2 emissions from gasoline powered vehicles with electric vehicles, electric vehicles emit about 1/2 less CO_2 emissions per passenger-km than that of gasoline-powered vehicles.

In order for electric vehicles to contribute to the realization of a low-carbon society, the convenience factor associated with the usage of electric vehicles must be taken into account for. Therefore the development of infrastructure supporting the use of electric vehicles is an issue that still needs to be dealt with.

Currently, many local governments in Japan have already taken measures to speed up the adoption of electric vehicles. The measures taken by Kanagawa Prefecture are shown as follows.

Table 13.1.4 Measures to Speed Up the Adoption of Electric Vehicles by Kanagawa Prefecture, Japan

Measures	Details of Measures
Taking the initiative in promoting electric cars	All levels of government in Kanagawa Prefecture, members of the electric car promotion council and others decided to take the lead in promoting the adoption of electric cars. They realized that in order for the adoption of electric cars to spread quickly, cost reduction through volume efficiency at the early stage of sales is essential. Based on this concept, Kanagawa Prefecture has decided to set an example by progressively switching all of its official use vehicles to electric cars by 2014.
Electric car purchase subsidy	In addition to providing a subsidy equivalent to half of the subsidy provided by the central government for the purchase of an electric car, Kanagawa Prefecture decided to also offer a subsidy based on the upper limit of one-quarter of the price difference between a gasoline-powered car and an electric car. In 2009, 76 electric cars purchases were subsidized. Although the initial budget for 2010 allocated subsidies for the purchase of 350 electric cars, the prefectural government hastily allocated more funds for subsidizing 270 more electric cars due to rapidly growing orders for the Nissan Leaf electric car that was launched at the end of 2010.
Tax breaks	Additionally, in an effort to create demand for the next generation electric car from an early stage of its sale in the market, the prefectural government announced a plan in April 2008 to implement a 90% reduction in the automobile and automobile acquisition tax however by July 2009, the plan was greatly expanded so that electric cars received full exemption from the automobile and automobile acquisition tax.
Incentives for actual use	To maximize the benefit of electric cars not only at the time of purchase but also in usage, when driving on toll highways within the prefecture, 1/2 of the tolls charged would be returned to the electric car owner via a cashback subsidy scheme. Furthermore, when parking in paid parking lots under the control of the prefecture, electric car owners would receive a discount of 50% off.
Development of the electricity charging infrastructure	In order to relieve concerns regarding recharging drained electric car batteries and to boost the convenience of using electric cars, the prefecture aims for the goal of “installing 100 quick charge stations by 2014”. Currently 60 quick charge stations in total have been installed at public facilities in the prefecture, offices of Tokyo Electric Power Company, gas stations, parking lots and highway rest areas.
Investigating the development of the electric vehicle charging ecosystem	The pilot experiment of “Making Use of Environmentally Friendly Cars with Regards to Town Planning” has recently been started. In this pilot experiment, the purpose was the find problems and issues with regards to the installation and operation of electric vehicle charging ports. Also usability and safety issues were looked into. For this experiment, normal 200 volt charging ports were installed in apartments/condominiums as well as automatic mechanical multistory parking garages



Reference: Materials from Kanagawa Prefecture

Fig. 13.1.15 Location of Electric Vehicle Quick Charge Stations in Kanagawa Prefecture

13-2. CO2 Emissions Reduction Analysis

1) Hypothesis

The reduction in the emission of CO_2 should differ depending on the different measures that are to be implemented. The measures were shown in previously in Section 13-1 and in Table 3.1.1. The effect of the measures will be compared with the Business as Usual (BAU) case. They are as follows:

i) Business as Usual (BAU)
ii) High Density Development Surrounding Subway Stations
iii) Bus Rapid Transit (BRT)
iv) Loop Bus Services
v) Developing a Bicycle Friendly Environment
vi) Road Pricing Scheme
vii) Diffusion of Electric Vehicles

The assumptions for the analysis of each measure are shown in the following pages.

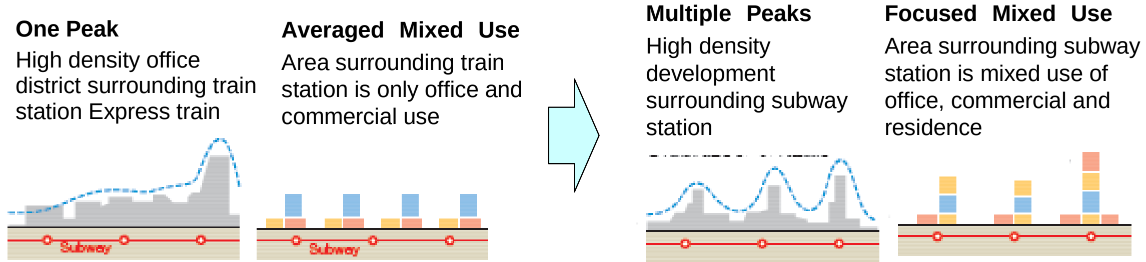
i) Business as Usual (BAU) Case

The Business as Usual (BAU) case assumes that the development in the transport infrastructure such as the road network and subway are completed and that the land use plan is based on the Tianjin city master plan for the *Yujiapu* district.

Therefore, high density development surrounding the subway stations in terms of land use is not assumed while the implementation of alternative transportation measures such as BRT, loop bus, and the bicycle sharing system are assumed. The subway and other public transportation systems are assumed to operate in an alignment in accordance to the routes planned by Tianjin city.

ii) High Density Development Surrounding Subway Stations

This measure refers to the concentration of residential, commercial and others in the vicinity surrounding the subway stations. (Refer to Figure 13.2.1). Compared with the BAU case, for this measure, the gross floor area by land use is concentrated around each of the five subway stations instead of just at one subway station in the BAU case.



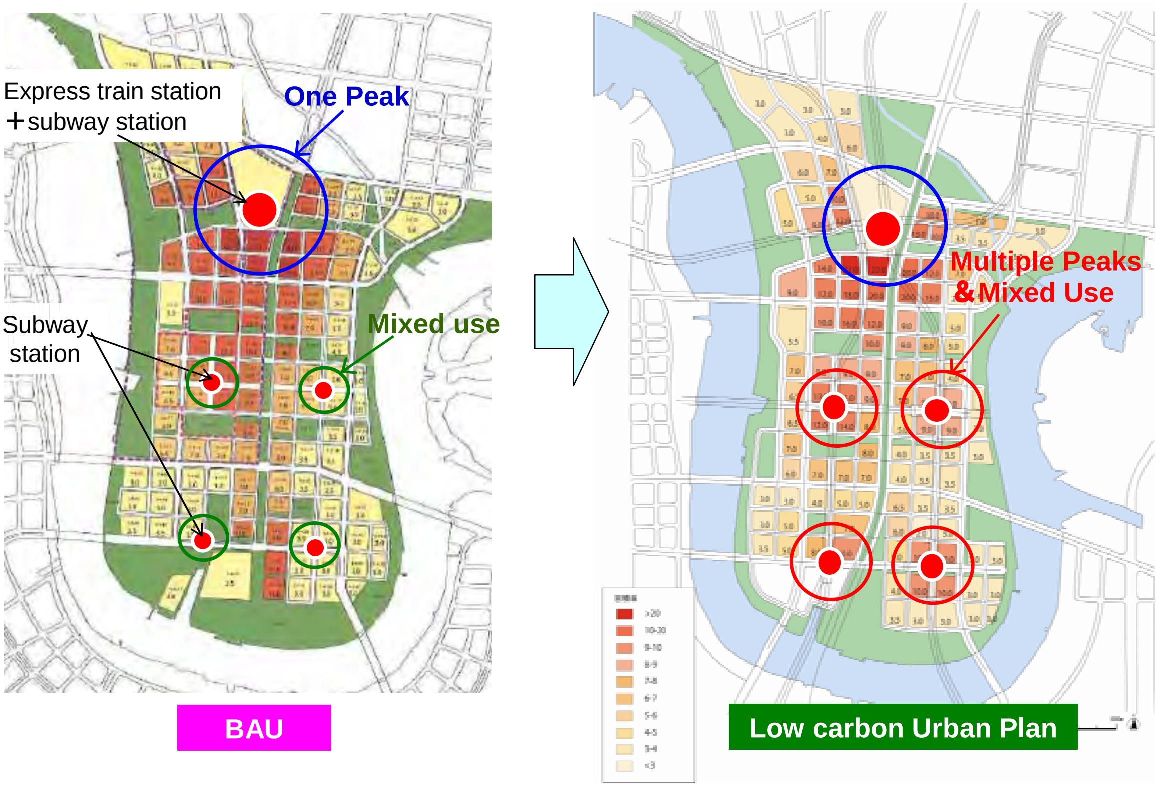


Fig. 13.2.1 High Density Development in the *Yujiapu* District

iii) Bus Rapid Transit (BRT)

Currently there is heavy traffic on the roads leading to the *Yujiapu* district from Tianjin city. Therefore it is assumed that the BRT lines being developed in the *Yujiapu* district will be extended to reach Tianjin city.

In the case of Beijing, BRT lines have already been extended by 15 km to 29 km. The station spacing for the BRT lines have been set at intervals of 1 km.

In the *Yujiapu*/Tianjin case, the station spacing is assumed to be set similar to that of Beijing but taking into account the local conditions such as the integration with stations on the existing railway network. The operating speed of the BRT lines is assumed to be same as that of subways.

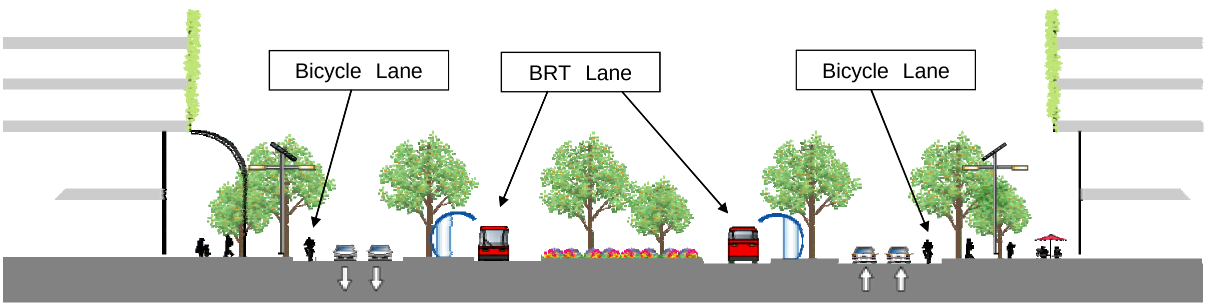


Fig. 13.2.2 Road Section with BRT in Operation (within the *Yujiapu* district)

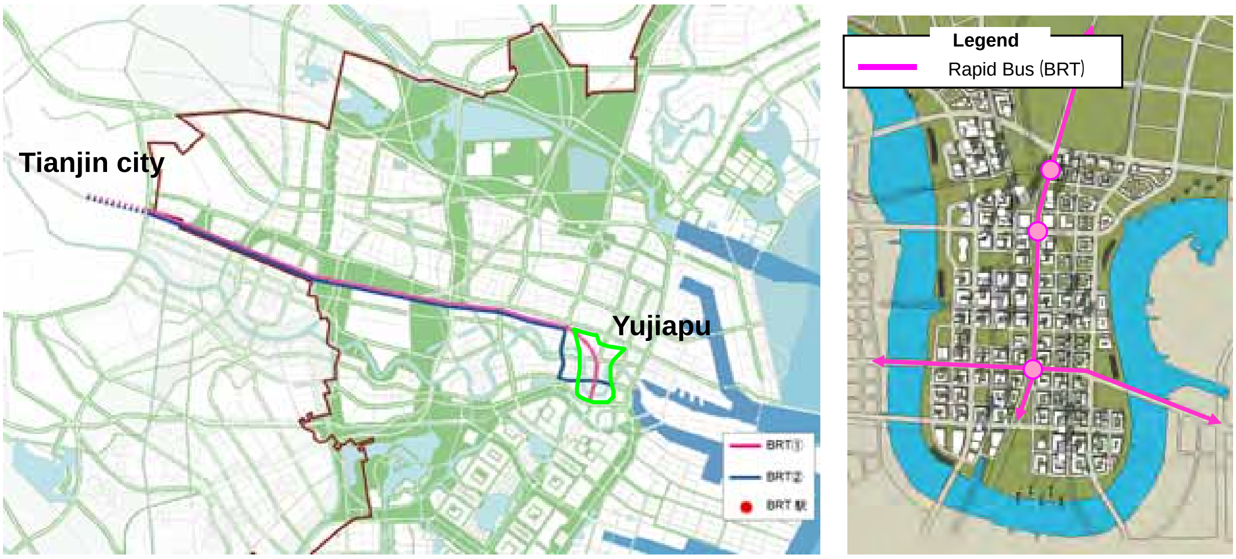


Fig. 13.2.3 BRT Routes and Stations in the Greater Tianjin Area

iv) Loop Bus Service

For the loop bus services with a small circular route, the bus stops are to be set at 200 metre intervals following the example of community buses in Japan (buses run in one direction in a clockwise manner).

For loop bus services with a large circular route, bus stops are to be set at intervals of about 300 metres and will be directly connected with subway stations (buses run in both directions). The operating speed of the loop bus will on average run at 15 km/h.

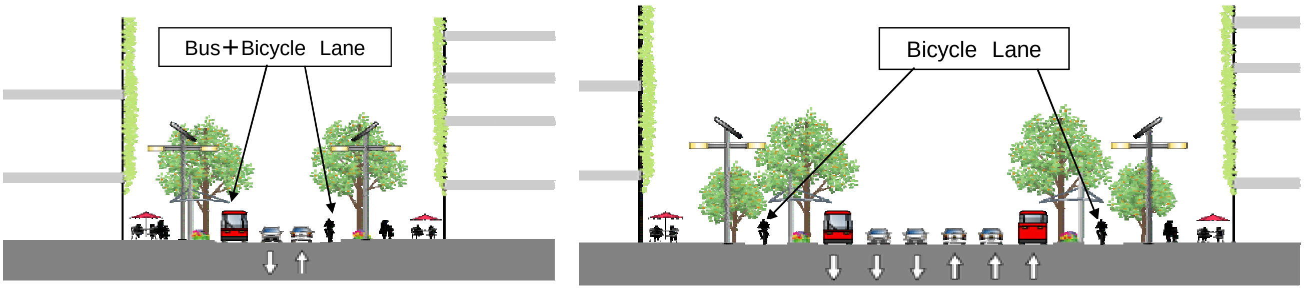


Fig. 13.2.4 Road Cross Section with the Loop Bus in Operation

Fig. 13.2.5 Loop Bus Service Routes and Stops

v) Developing a Bicycle Friendly Environment

Bike Lanes/Paths

Bicycle lanes give cyclists a dedicated right-of-way and would be set to run alongside the sidewalks as shown in Figure 13.2.6 below. Such bicycle lanes would be set on the major roads.

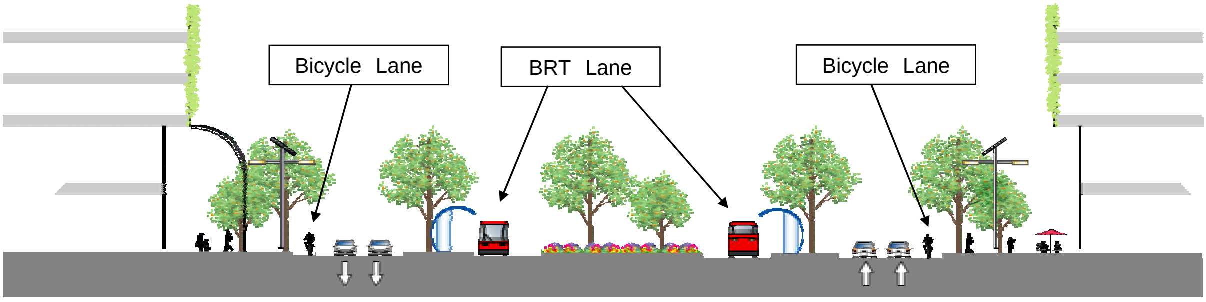


Fig. 13.2.6 Road Section with Bicycle Lanes

Bicycle Sharing System

The bike docks of the bicycle sharing system is to be set a major locations including subway stations at intervals of about 300 metres.

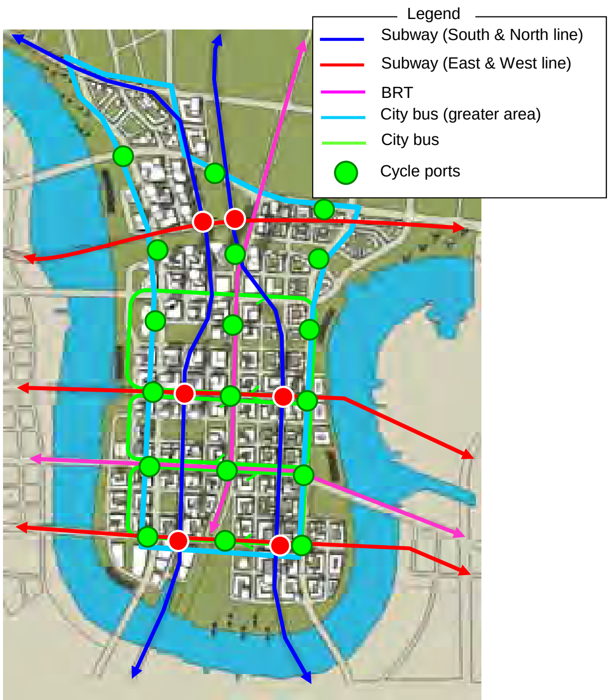


Fig. 13.2.7 Locations of the Bike Docks in the Bicycle Sharing System

Based on the above cited measure, the time required to move within the *Yujiapu* district between origin and destination would shorten as a result of combining walking and cycling within the same trip. The access (egress) time after the implementation of the measures could be measured as follows:

[Before the implementation of the bike sharing system]

Access Time: *x* minute(s)

[After the implementation of the bike sharing system]

Access Time: *x* minute(s) × (4.8 km/h /15 km/h) + 2 minutes (with the assumption of one minute for both picking up and returning the bicycle)

vi) Road Pricing Scheme

In Stockholm, after the road pricing scheme was introduced, the city experienced on average a 22% reduction in traffic volume. Based on the successful implementation in Stockholm, in the *Yujiapu* district, charging gates are to be installed on roads coming into the district. The congestion charge will be based on equivalent levels set in Stockholm, adjusting for income level differences.

The charge will be set at $0.20 USD (about 2 RMB) each time a vehicle crosses one of the charging gates.

Table 13.2. Road Pricing Scheme Charges

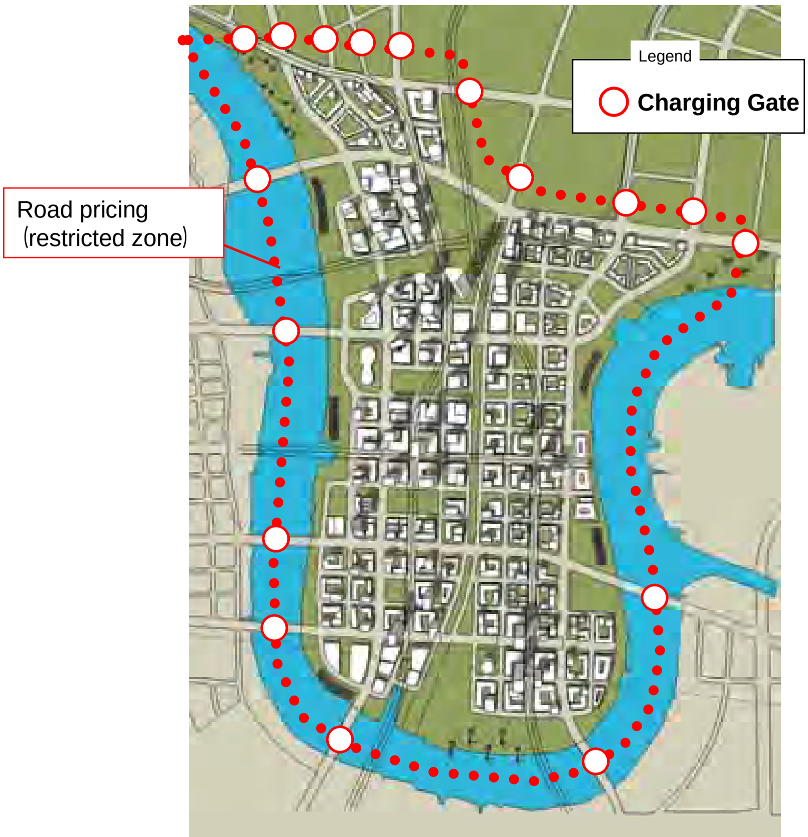
	National Income[1]	Amount of Charge Under the Road Pricing Scheme
Sweden	About $49,000 USD	About $1.50 to $3.00 USD
China	About $3,600 USD	About $0.10 to $0.20 USD

Reference: 1. Materials from Economic Affairs Bureau, Ministry of Foreign Affairs

<u>Example: The Stockholm Congestion Tax in Sweden</u>

In order to control the traffic volume entering central Stockholm during the rush hours, vehicles entering into the Stockholm central area **are charged in the form of tolls 10-20 SEK (1-2 EUR) depending on the time of day when crossing one of 18 control points**. Emergency services, buses, taxis, hybrid cars, vehicles operated by the physically challenged and foreign-registered vehicles are exempted from the charge.

During the trial period of the congestion tax in Stockholm, traffic volume was reduced by an average of 22% and drivers' improved their awareness of their cars' running speed. Improvements on transport infrastructure focused on public transportation and park and ride before the congestion tax trial also had a role in the reduction in traffic volume. The full scale implementation of the congestion tax started from August 1, 2007 and the system is in operation as to this day.



Reference: Environmentally Sustainable Transport Website

Fig. 13.2.9 Assumed Implementation of the Road Pricing Scheme in the *Yujiapu* District

vii) Electric Vehicles

Comparison of electric vehicles and gasoline-powered vehicles shows that an electric vehicle emits less than half of the CO_2 emissions generated by a gasoline-powered vehicle when travelling the same distance.

Regarding the adoption rate of electric vehicles, it has been expected that electric vehicles would account for about 10% of all vehicles on the road in Japan by 2030. However, unlike Japan in which motorization had already been widespread (the number of vehicles on the road has been decreasing since 2007) when the electric vehicle was introduced, in China the motorization of society has just begun when the electric vehicle started to become popular. Therefore China is expected to see a faster adoption of electric vehicles.

In light of the above, it is assumed that by 2020, in Japan, about 10% of the fleet of gasoline-powered vehicles will be replaced by a fleet of electric vehicles. For a 1 km drive on a gasoline-powered vehicle an equivalent electric vehicle would only produce half of the CO_2 discharged by the gasoline-powered vehicle

[Comparison of fuel efficiency between electric vehicles and gasoline-powered vehicles]

- Fuel efficiency of electric cars: about 10 km/kWh
  - ➢ Target value set by the joint development of electric cars by Tokyo Electric Power Company and other automobile manufacturers
- Fuel efficiency of gasoline-powered ultra-compact (light) cars: 18.8 km/l
  - ➢ Japan Mini Vehicle Association

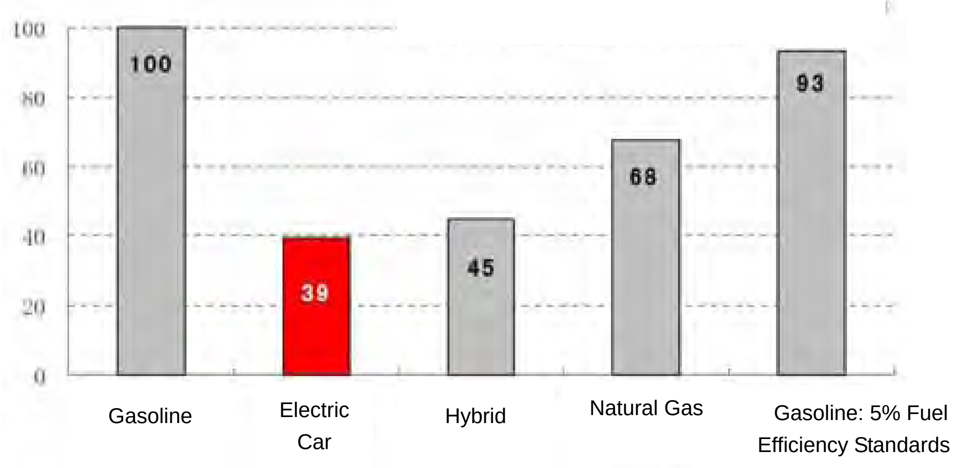


Fig. 13.2.10 Comparison of Fuel Efficiency among Different Types of Vehicles

Reference: Materials from Kanagawa Prefecture

table 13.2.2 Prospects Regarding the Diffusion of Electric Vehicles (EV) in Japan (Unit: 10 thousand)

	2020		2030		2050	
EV Light Car	34	140	45	380	44	550
EV Passenger Car	17	67	28	210	26	330
Total of EVs	51	207	73	590	70	880
Total of Cars	550	7249	510	6870	480	6320
Percentage of EVs in Overall Cars	9.3%	2.9%	14.3%	8.6%	14.6%	13.9%

Reference: Next-Generation Vehicle Strategy from MOE

viii) Verification of Subways' Passenger Carrying Capacity

Subway development that is assumed in the BAU case means that the development of subways cannot be considered a measure for reducing CO_2 emissions.

As the measures are aimed at increasing the number of users transferring to the subway system from other transportation modes, the capacity of the existing subway network needs to be verified whether or not it can handle this additional passenger volume.

The service level is set based on the subway line that carries the largest number of passengers in Tokyo, the Tokyo Metro Tozai Line.

- The number of trains in operation during peak time: about 30 trains per hour (Tokyo Metro Tozai Line starting from Otemachi station after 8 a.m.)
- The number of carriages: 10
- Passenger capacity (10 carriages): 1,520 people
- Congestion rate in the busiest section: 199%

- 1 line carries 1,520 people/carriage × 30 trains per hour = 45,600 people/hour
- If all planned 3 lines running in the east-west direction operates on the same level 45,600 people/hour × 3 = about 137,000 people/hour, will be transported.

The number of all railway trips during the peak time in the *Yujiapu* district is about 44,000 trips/hour. Considering the example from Tokyo, it can be concluded that the demand for subway does not exceed the subway's passenger carrying capacity.

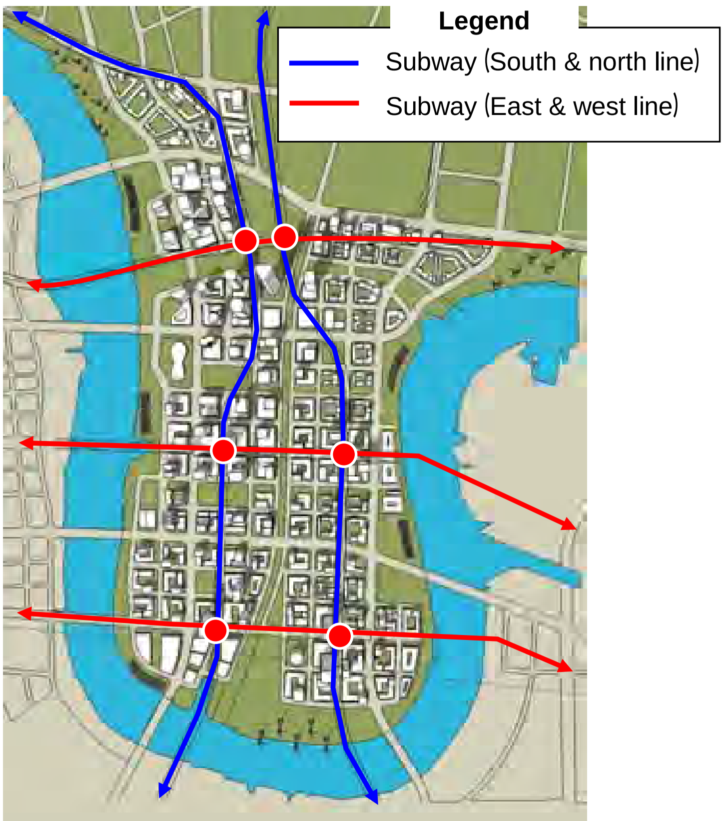


Fig 13.2.11 Planned Subway Lines

2) Simulation Implementation

a) Methodology

Estimation of CO_2 emissions reduction will be conducted by following the steps shown below.

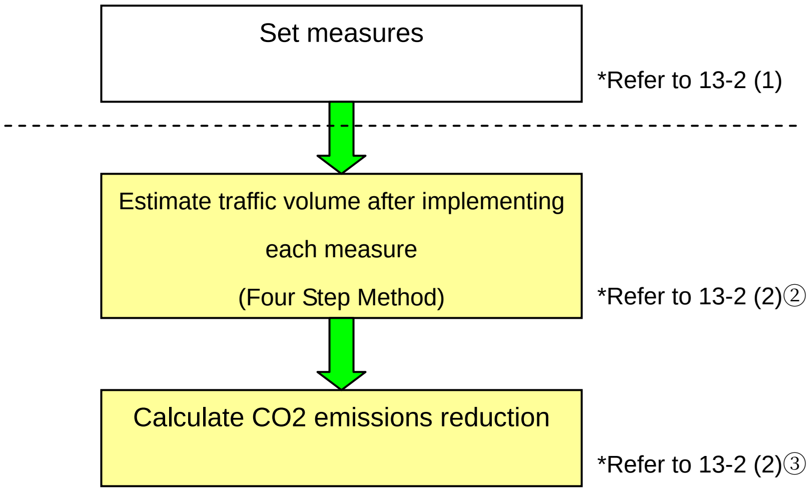


Fig. 13.2.12 Framework for the Estimation of CO_2 Emissions Reduction

b) Estimation of Traffic Volume by Using the Four Step Method

From the implementation of each measure, modal shift from cars to public transportation modes such as subways, buses, etc. are expected. Therefore for each transportation mode, the changes in demand should be estimated using the four step model.

Shift in transportation means from cars to railway, bus and others would be made by implementation of each measure, which should be followed by estimation of changes in demand for each transportation mode.

The first step is to estimate the trip generation within the district of *Yujiapu* and its surrounding areas such as Tianjin city, *Tanggu* district and TEDA. Tianjin city's night population data is to be utilized.

The second step is to estimate the trip distribution signifying the number of trips going from one district to another district.

The third step is to estimate, through disaggregate behavioral modeling, the mode choice. This step estimates the proportion for each transportation mode used based on the data from the trip distribution stage.

The fourth step is to estimate, through the shortest path search, the route assignment, signifying the route used for each transportation mode.

Based on the steps above, the traffic volume by road and by transportation mode can be analyzed.

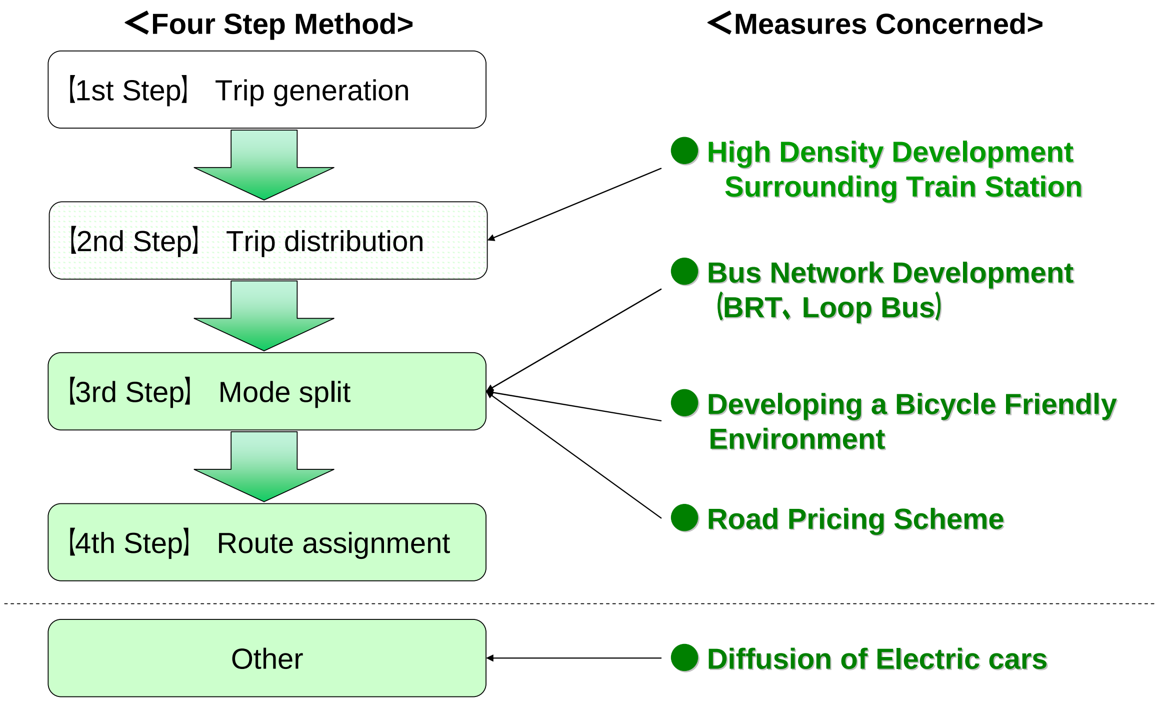


Fig. 13.2.13 Relationship Between the Four Step Method and the CO_2 Reduction Measures

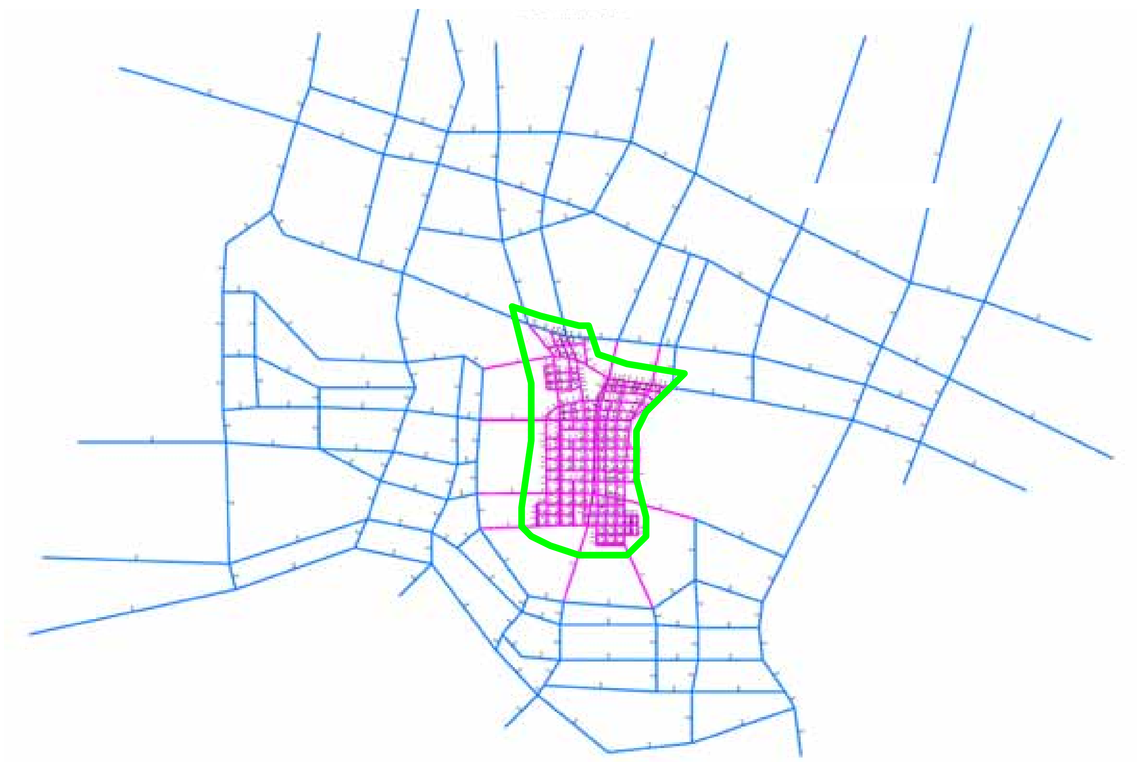


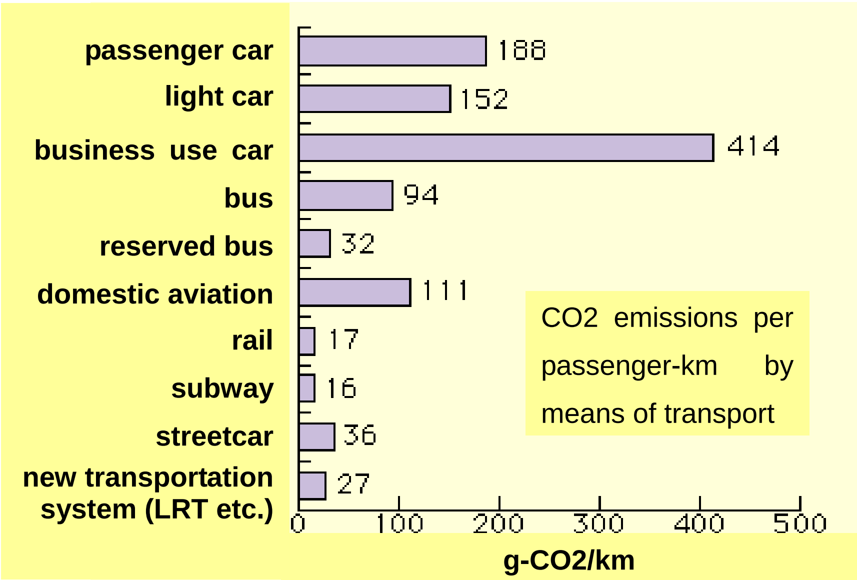
Fig. 13.2.14 Road Networks Used in the Simulation

c) **Calculation of CO_2 Emissions**

The amount of CO_2 released from each transportation mode is calculated by multiplying the traffic volume by CO_2 emission coefficient.

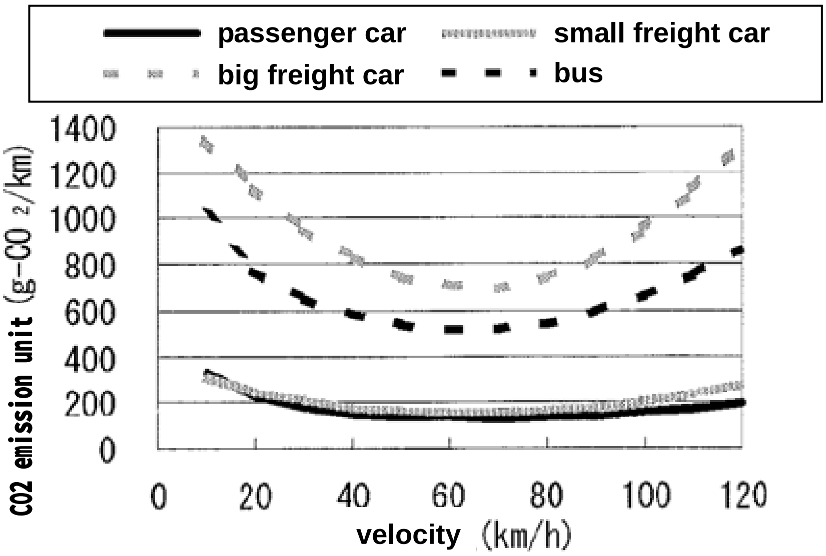
CO_2 released from each mode of transport = $\Sigma_{car,\ railway,\ bus}$ (traffic volume (vehicle · km) × CO_2 emission coefficient (kg-CO_2/vehicle · km))

In the particular case of the automobile, the National Institute for Land and Infrastructure Management at the Ministry of Land, Infrastructure, Transport and Tourism in Japan provides CO_2 emission factors by speed and simulation made it possible to assess traffic volume by speed. Therefore, the calculation of CO_2 emissions could be made in more precise terms.



Reference: MLIT

Fig. 13.2.15 CO_2 Emissions Coefficients by Transportation Mode (Year 2000)



Reference: National Institute for Land and Infrastructure Management, MLIT

Fig. 13.2.16 CO_2 Emissions Coefficients for the Automobile

3) Results from the CO_2 Emissions Reduction Calculations

a) Change in the Share of Transportation Modes

Implementation of each measure would bring down the mode share of the car while raising the mode share of public transportation. If all the measures are to be implemented, the share of car users would decrease to 44% while the share of public transportation users would rise to 56%.

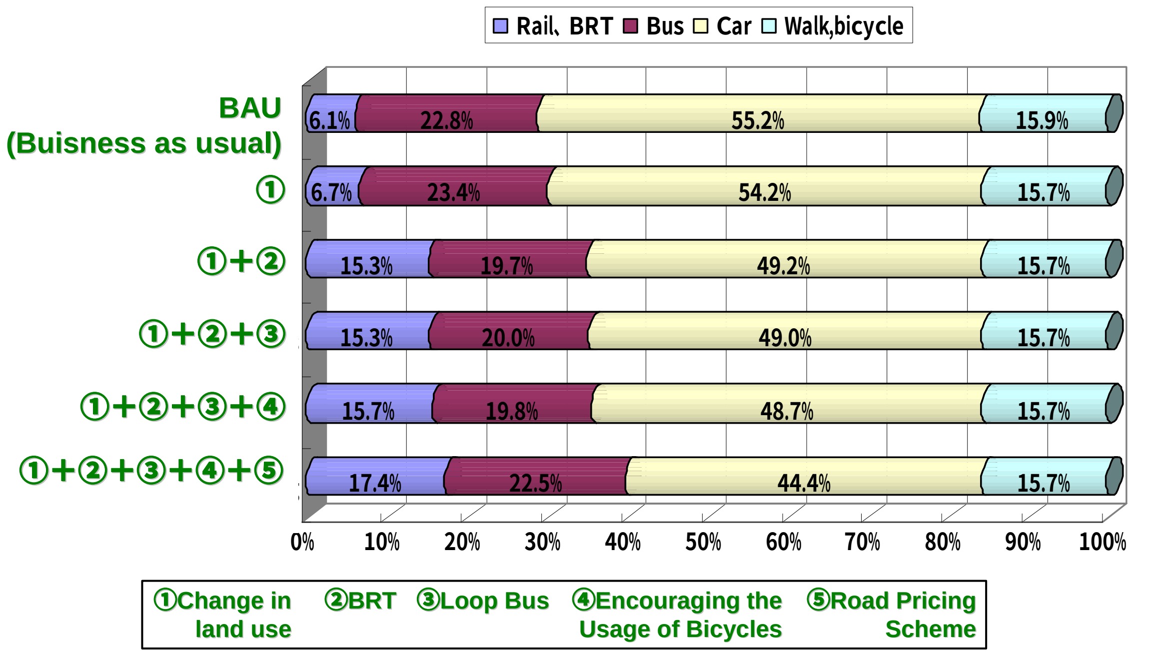


Fig. 13.2.17 Change in the Share of Transportation Modes after the Implementation of the Measures

b) Amount of Reduction in CO_2 Emissions

CO_2 emissions would be reduced by about 30% by implementing each measure.

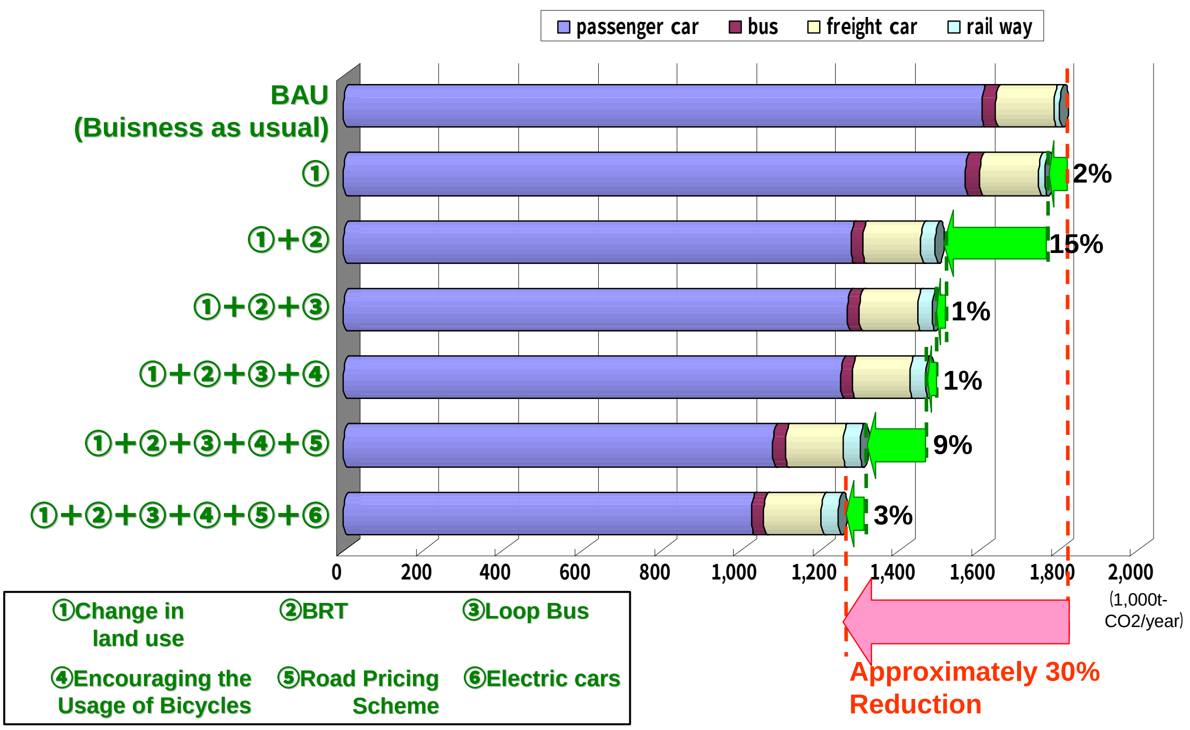


Fig. 13.2.18 Effect of the Measures on the Reduction of CO_2 Emissions

14. Examination of cost performance for low-carbon development in entire Yujiapu district (Quantitative analysis of CO_2 reduction and initial costs for low carbon measures)

14. Examination of cost performance for low-carbon development in entire Yujiapu district

14.1 Overall analysis of low carbon effects

1) Examination of commercial and residential sector

a) Calculation method for CO_2 emissions from commercial and residential sector

The following procedure is used to calculate the CO_2 emissions from commercial and residential sector and the low carbon effects in Yujiapu district. In addition, the following summarizes introduction of the DHC system, untapped energy, and renewable energy which are set as conditions for this trial calculation.

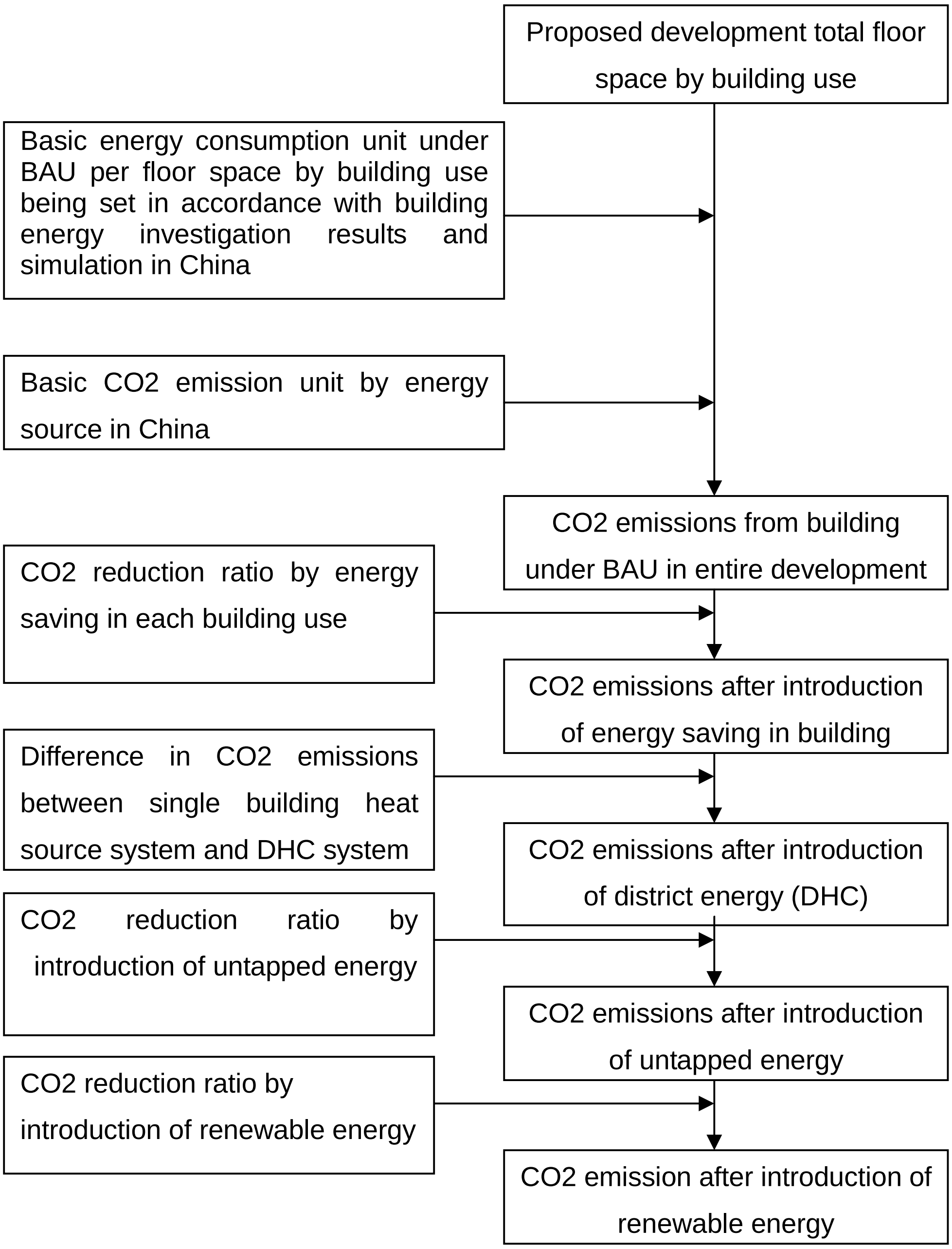
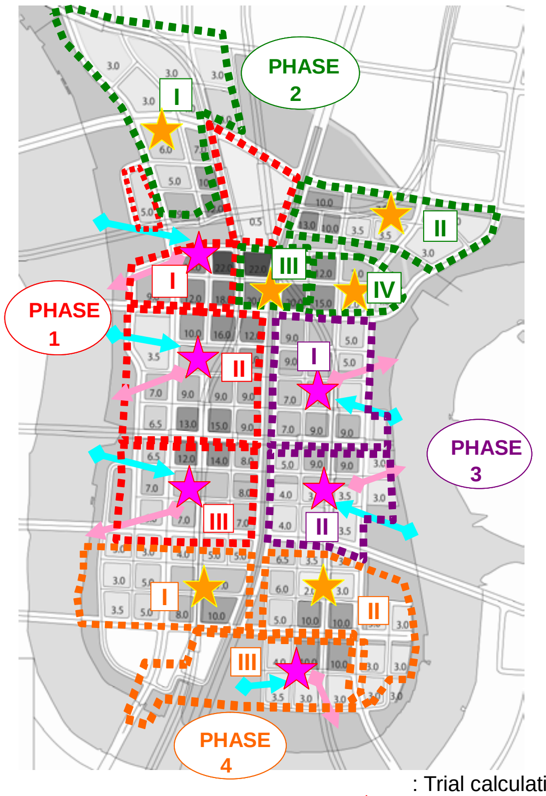


Figure 14.1.1 Flowchart of calculation method for CO_2 emissions from commercial and residential sector



: Flow of river water (untapped energy)

: Trial calculation assuming high efficient DHC system (ice storage system) + river water)

: Trial calculation assuming high efficient DHC system (Case in Chapter 8; 2 ice storage systems)

(1) DHC, Untapped Energy

Biomass power generation facility (use of kitchen garbage from entire district: about 164t/day)

+

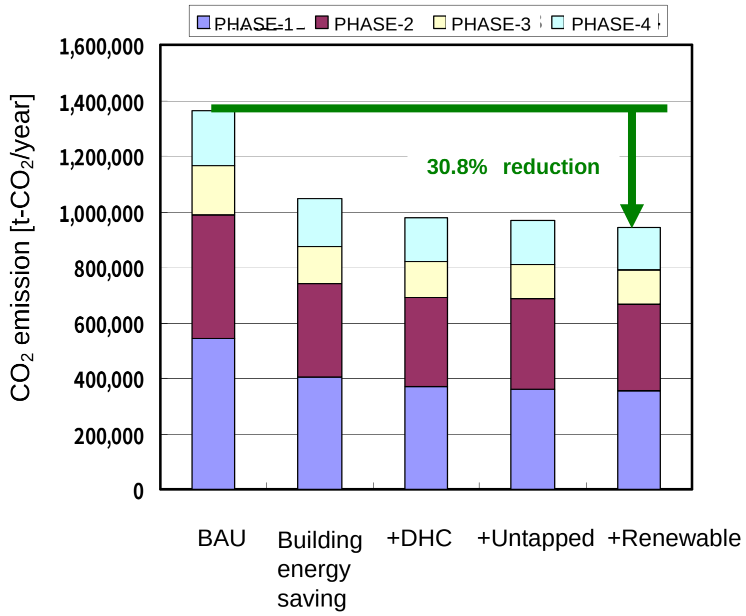
Large-scale solar panels (about 60,000m2)

(2) Renewable Energy

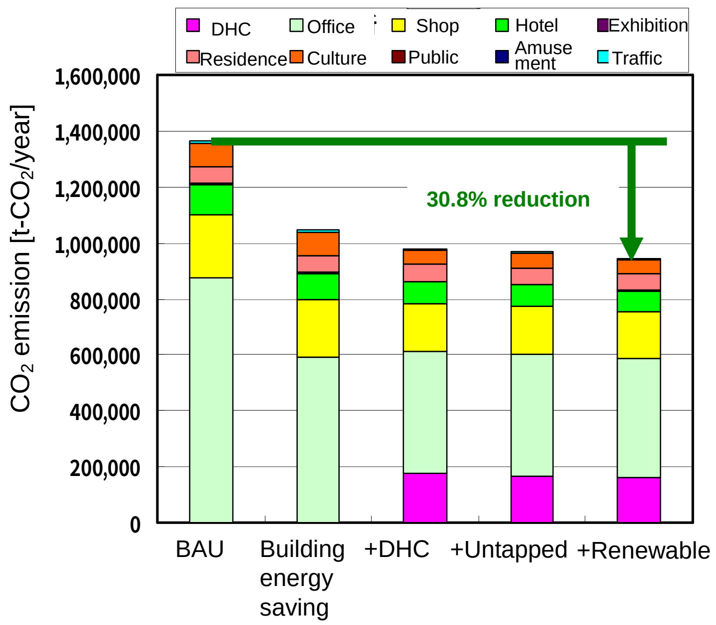
Figure 14.1.2 Conditions for trial calculation of CO2 emissions

b) Calculation results of CO2 emissions from commercial and residential sector

The following shows calculation results of the CO2 emissions from commercial and residential sector in this development district, and low carbon effects. CO2 emissions from buildings under BAU is about 13,7 million t-CO2/year. In addition, it is confirmed that about 30% or more of CO2 emissions can be reduced by saving energy building, use of untapped energy and renewable energy.



(1) Accumulation of trial calculation results by development area



(2) Accumulation of trial calculation results by building use

Figure 14.1.3 Calculation result of CO2 emission from commercial and residential sector

2) Examination of transportation sector

a) Calculation method for CO2 emissions from transportation sector

The following procedure is used to estimate the reduction of CO2 emissions.

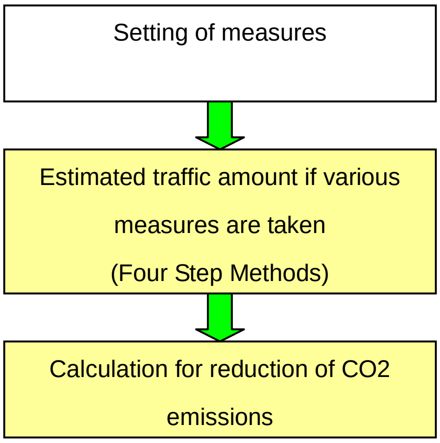


Figure 14.1.4 Flowchart of calculation for CO2 emissions from transportation sector

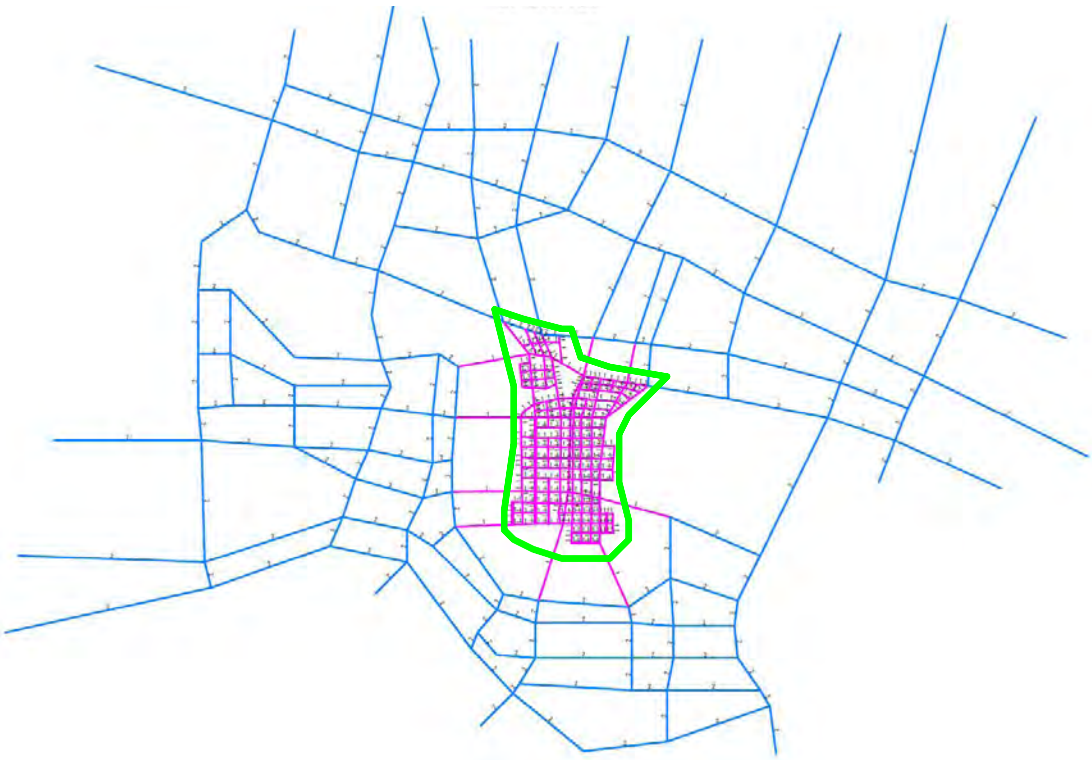


Figure 14.1.5 Calculation flow of CO2 emission from building energy

b) Calculation results of CO2 emissions from transportation sector

- Introduction of each measure causes the share of cars to decrease and share of the public transportation to increase. Implementation of all measures causes share of cars to be 44% and share of the public transpiration (other than cars) to be about 56%.

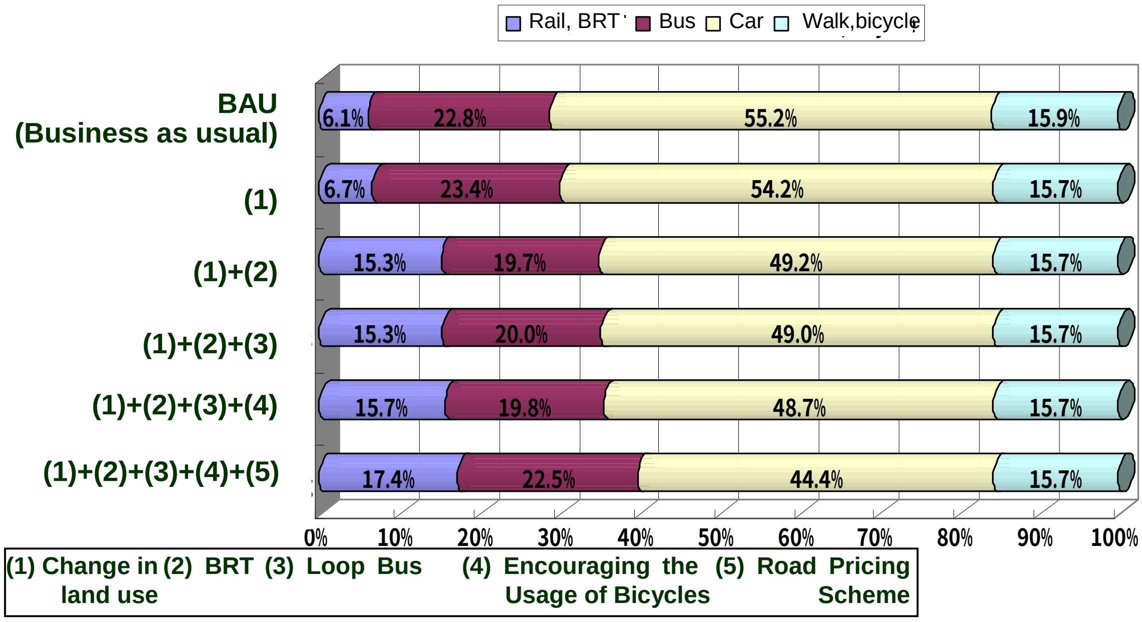


Figure 14.1.6 Calculation results of modal share by traffic measures

- Introduction of each measure causes CO2 emissions to be reduced by about 30%.
- CO2 emissions from public transpiration, in which its terminals are located in Yujiapu district, under BAU is about 1,8 million t-CO2.

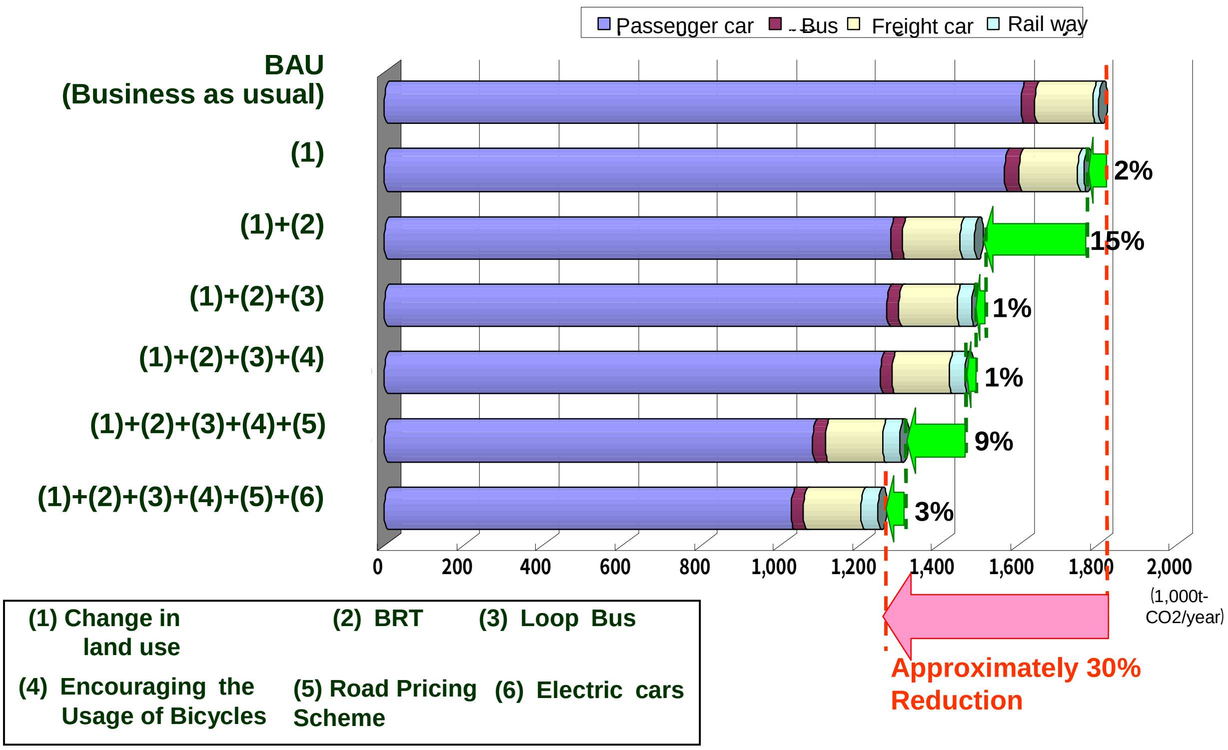


Figure 14.1.7 Calculation results of CO2 emission from transportation sector

3) Low carbon effects in Yujiapu district

[Achievement of about 50% reduction target by realization of low-carbon development]

- Mid-term target (by 2020): About 30% reduction (corresponding to about 50% per CO2/GDP reduction)
- Long-term target (by 2030): About 50% reduction

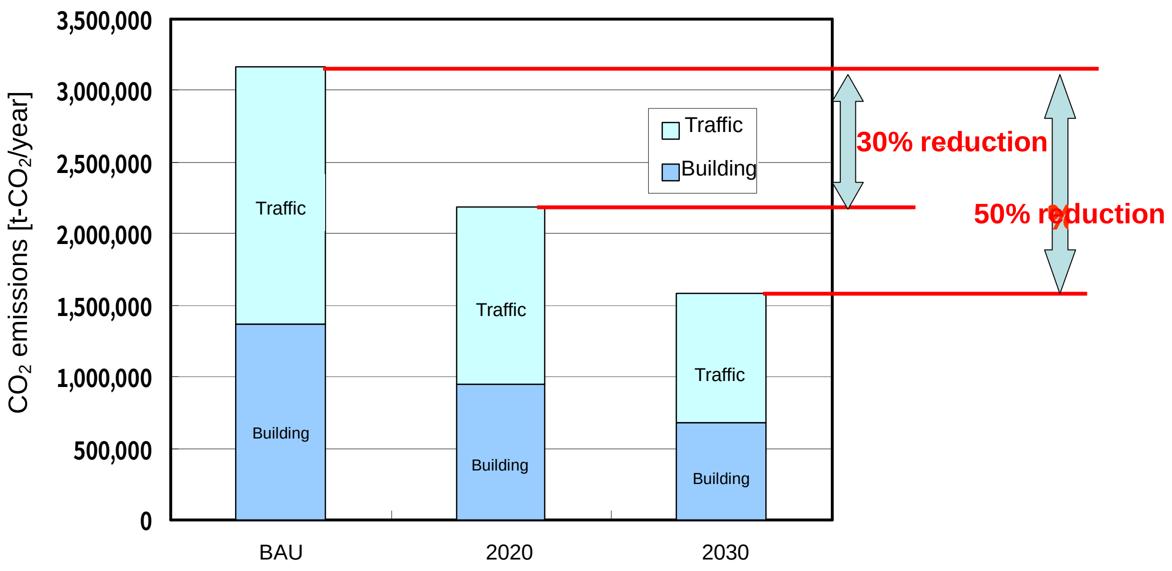


Figure 14.1.8 Calculation results of CO2 emissions in Yujiapu district

14.2 Examination of cost performance

1) Calculation of costs

a) Examination of commercial and residential sector

1. Investigation of building costs in China

Section 7.5 shows the effects of CO_2 reduction quantitatively achieved by each low carbon measures adopted by each building use. The result shows that, for offices, reduction by 30% or more per year of CO_2 emissions can be achieved by 2020 compared with that under BAU in 2009. In addition, the same result can be obtained for commercial facilities, hotels, and condominiums for which the other simulation is done.

On the other hand, if the building owner and the developer adopt certain low carbon measures to achieve the reduction target, it is necessary to present the increment of the initial cost. The increment of the building cost to reduce the annual CO_2 emissions by more than 30% in the office building is studied.

At first, we estimate the cost for the model office building under BAU and calculate the ratio of it to the building cost when adopting the low carbon measures. Since the building costs of office buildings in China vary greatly depending on the building scale, building use, and location, we investigate the building cost of the existing building with almost the same use and scale as the facility assumed to be built in the Yujiapu financial district. The costs change between 6000 RMB/m^2 to 11000 RMB/m^2, and this FS sets the cost to about 8000 RMB/m^2.

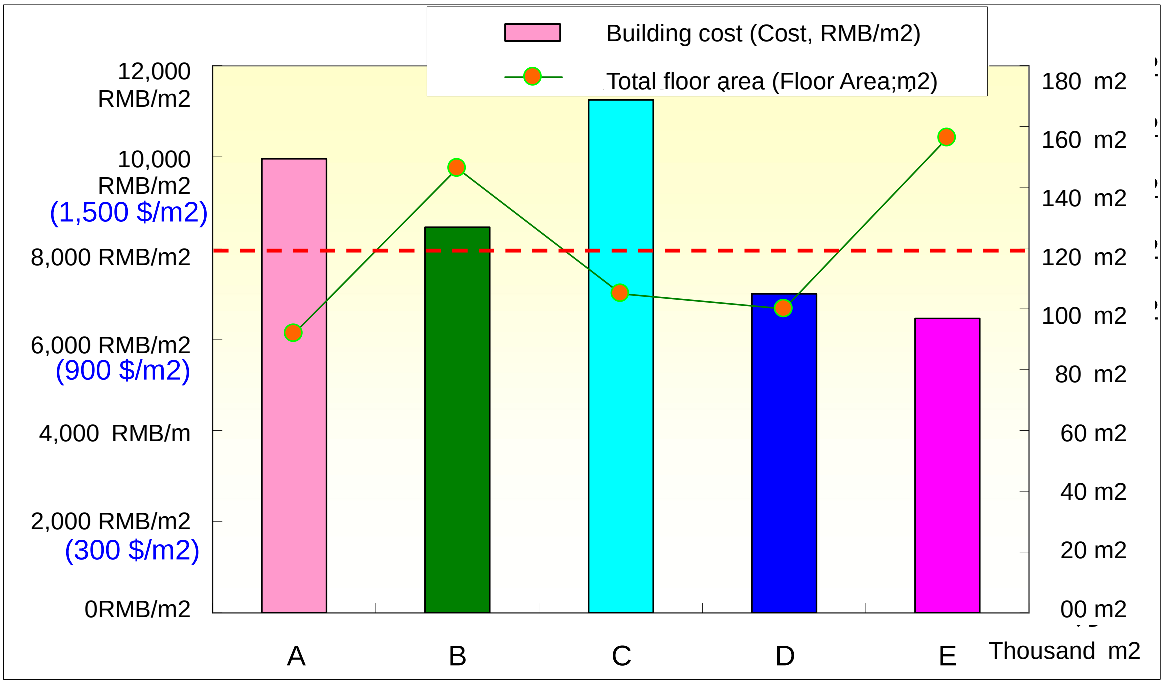


Figure 14.2.1 Example of building cost of office building in China

(Building designed by Nikken Sekkei, 2011)

2. Comparison of costs among DHC systems for district energy

Chapter 8: "Examination of district energy" calculates the primary energy consumption, the system efficiency (COP), and CO2 emissions simulated in Phase1•III district of this planned area, and compares DHC systems. This time, the cost for each system is compared. That is; we calculate the initial cost of the DHC heat source system and calculate the running cost by using the consumption of electricity, gas, and hot water obtained by the simulation, the energy cost in China, and the basic primary energy cost.

"Plans of heat source system for DHC"

CASE 1: discharged heat from power station: discharged heat/ steam + steam suction freezer (cool water)
CASE 2: Electricity base: discharged heat/ steam + electric turbo freezer + ice storage system
CASE 3: Electricity base: discharged heat/ steam + electric turbo freezer + water storage system
CASE 4: Gas base: discharged heat/ steam + gas cogeneration + steam suction freezer
CASE 5: Electricity and gas base: discharged heat/ steam + gas cogeneration + electric turbo freezer + gas suction freezer + water storage system

Table 14.2.1 Calculation result of secondary energy consumption for each case

	China			
	Electricity kWh/ year	Gas Nm3/ year	Hot water GJ/ year	Supply power kWh/ year
Case 1	9,120,006	2,948,440	233,672	0
Case 2	22,796,126	0	0	0
Case 3	21,117,317	0	0	0
Case 4	312,661	14,009,910	0	24,850,288
Case 5	5,506,964	11,575,171	0	25,878,713

Table 14.2.2 Energy cost and basic primary energy cost used to calculate running cost

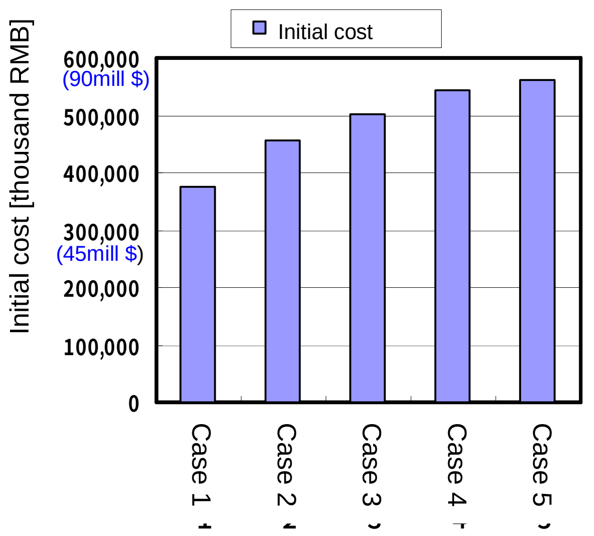
	Electricity kWh/ year	Hot water GJ/ year	Supply power kWh/ year
Japan	9 Yen/kWh	45 Yen /Nm3	0.4 Yen /MJ
China	0.75 RMB/kWh	2.2 RMB /Nm3	0.025 RMB /MJ

	Electricity	Gas
	kWh/ year	Nm3/ year
Japan	9.76	45
China	12	35.5

Table 14.2.3 Result of cost comparison by DHC system

	China		
	Initial cost	Running cost	Payback period
	1,000 RMB	1,000 RMB/year	Year
Case 1	377,083	19,300	Standard
Case 2	454,583	17,100	35.2
Case 3	500,833	15,900	36.4
Case 4	542,917	12,500	24.4
Case 5	562,917	10,200	20.4

In Case 4 and 5 with high efficient heat source system, the initial cost of the cogeneration system is high and the running cost is low. In addition, Case 1 (mainly uses discharged heat from power station) is used as a standard; the number of simple payback period for collection becomes the smallest for cogeneration + ice storage system in Case 5.



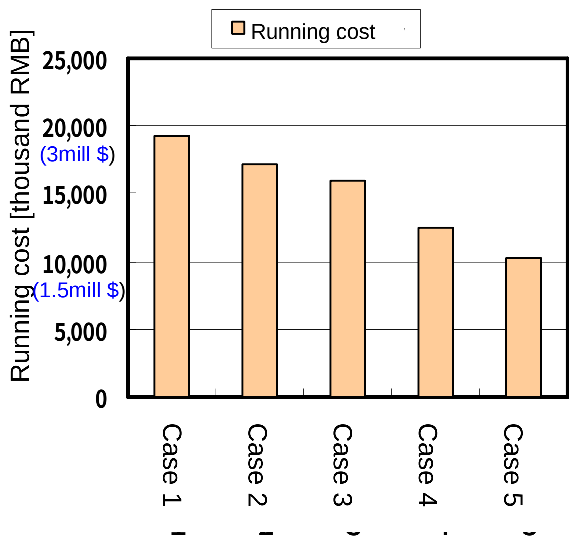


Figure 14.2.2 Trial calculation result of initial cost and running cost

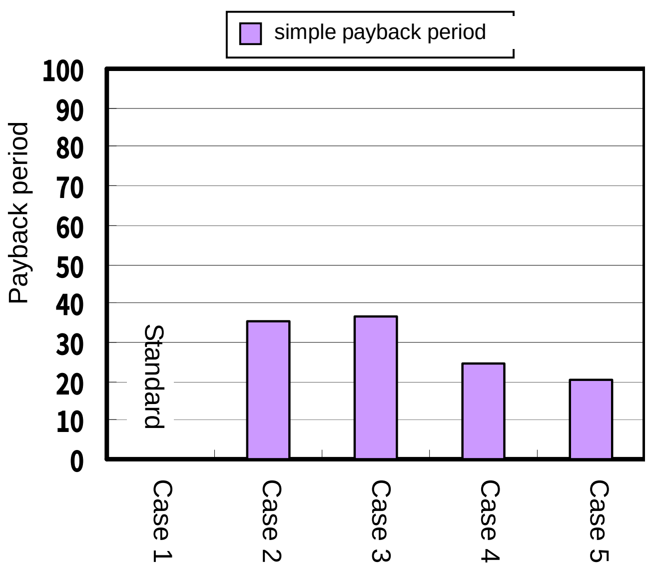


Figure 14.2.3 Simple payback period for each case by using Case 1 as standard

3. Cost performance in commercial and residential sector

In the commercial and residential sector, the annual cost is obtained by dividing the increment of the initial costs for the building energy saving, use of the district energy (DHC), untapped energy, and renewable energy by the life-span (years). Since the life of the building energy saving, DHC, and untapped energy is mainly based on the building materials and piping, it is assumed to be about 30 year. Since the life of the renewable energy is mainly based on such devices as the solar panel and biomass power generator, it is assumed to be about 15 years. In addition, the CO2 reduction cost required to reduce 1t of CO2 in a year is obtained by dividing the annual cost by the reduced amount of CO2 emissions for each item calculated in Section 14.1.

In the annual costs, the measures cost for building energy saving and DHC is high. Although CO2 reduction effect of them is high, that cost tends to be high too. In CO2 reduction costs, the cost of building energy saving measures is the lowest and the cost of DHC measures is the highest.

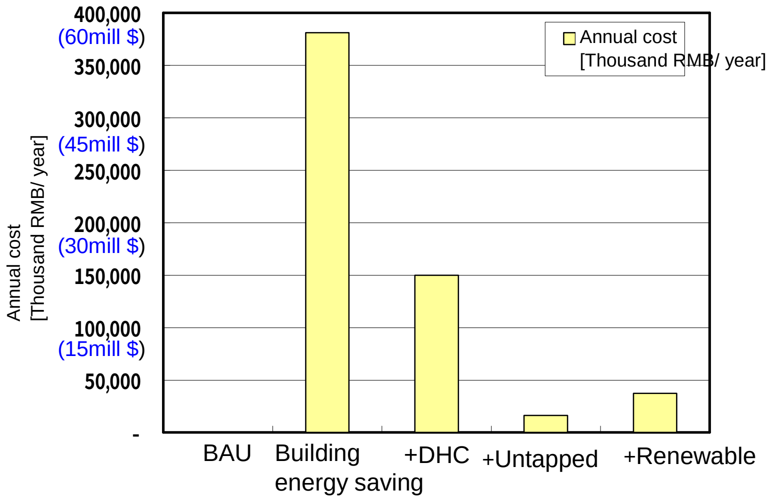


Figure 14.2.4 Annual cost for each measures

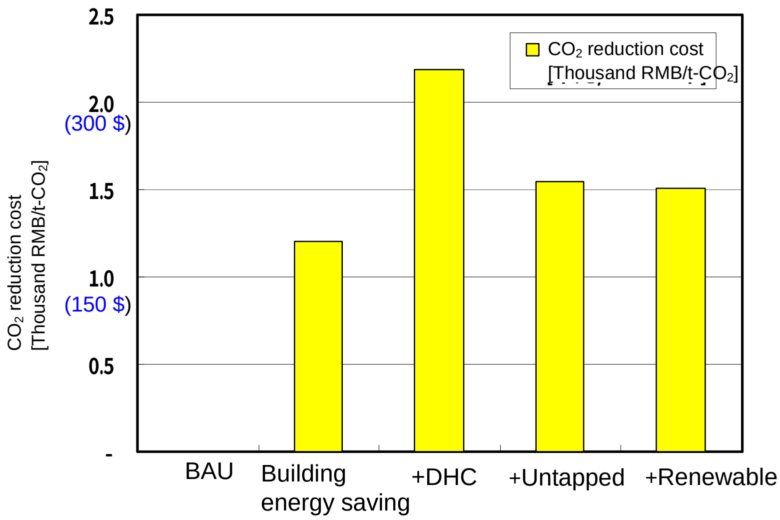


Figure 14.2.5 CO2 reduction cost for each measures

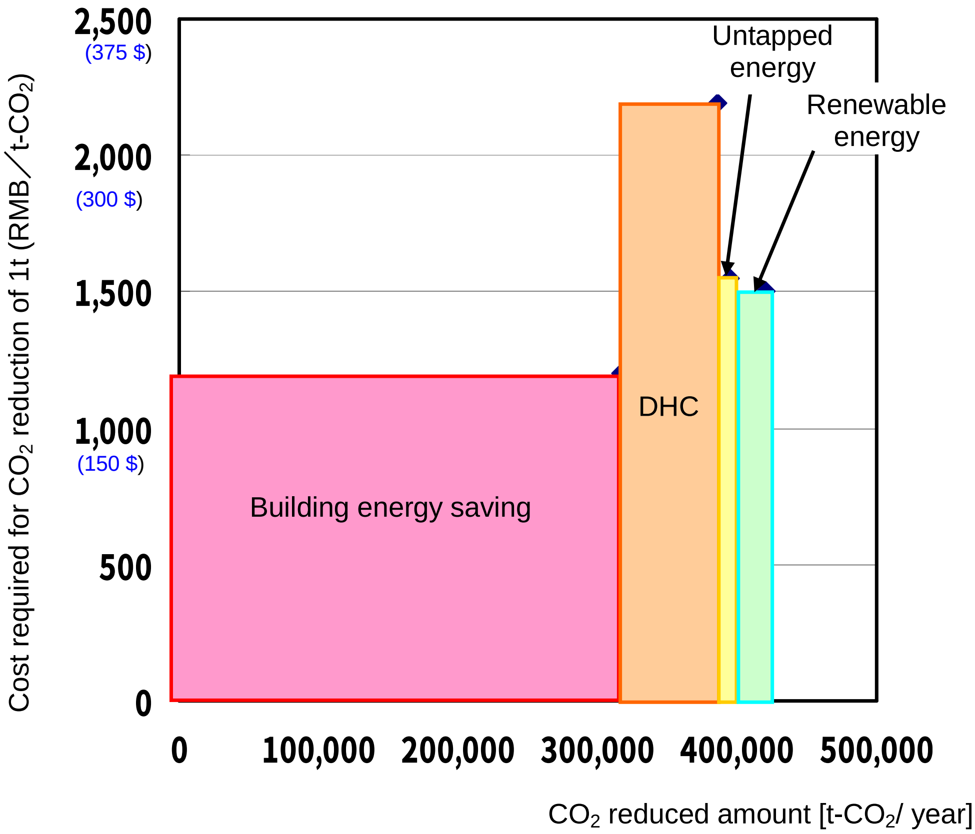


Figure 14.2.6 Cost of CO2 emission reduction per ton for each measure and reduced amount of O2 emissions

b) Examination of transportation sector

1) Technologies to be examined

For each measure to reduce CO_2 emissions in the transportation sector, the costs (estimated arrangement cost and operation cost) when implementing the measures to be assumed in the simulation are examined. (However, since high-density development around the station requires the comprehensive measures (i.e. not only measures for transportation), this cost calculation does not include it.)

[Cost-examination for below transportation modes]

i) BRT (Bus Rapid Transit)
ii) Loop Bus
iii) Bicycle-use environment arrangement (community cycle)
iv) Road pricing
v) Electric car

The following is the procedure to calculate the estimated construction cost.

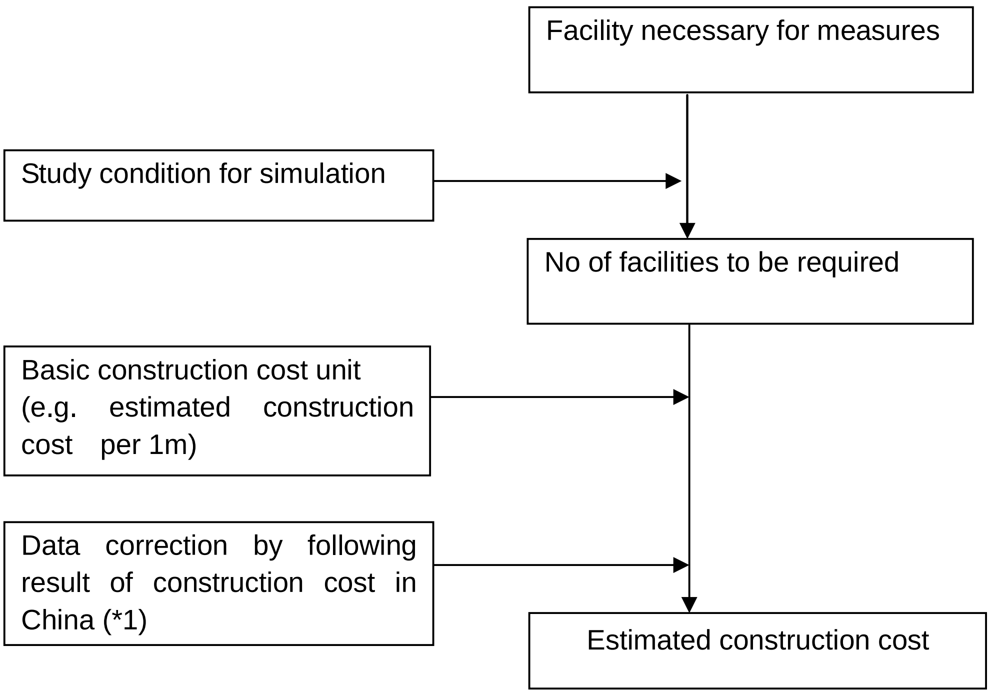


Figure 14.2.7 Calculation procedure of estimated arrangement cost

*1 The basic unit of the construction cost mainly uses the result in Japan. To match with the actual status of construction costs in China, correction (x0.5) is made considering the result of construction costs for the same businesses in Japan and China.

*2 $1 = ¥80, 1RMB = ¥12 are used for calculation.

i) BRT (Bus Rapid Transit)

■ Necessary facilities

- Infrastructures (dedicated lane arrangement, stops, footbridges, switchyard, etc.)
- Bus vehicles

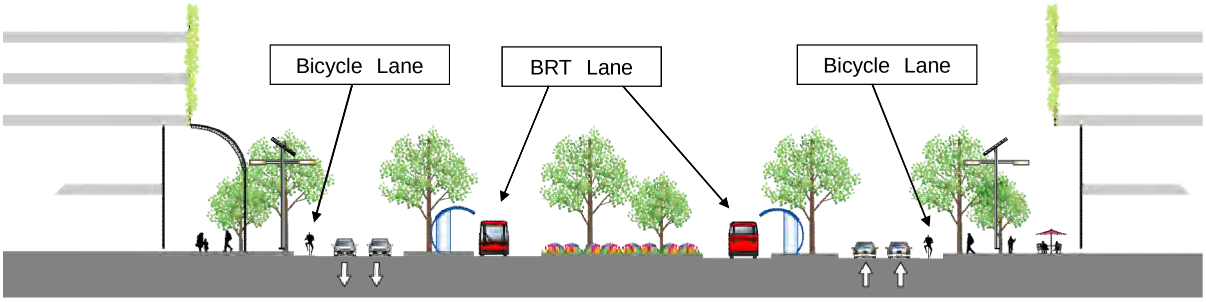


Figure 14.2.8 Image of road section at BRT traveling section (within Yujiapu district)

■ Examination condition for simulation

- Inflow amount of cars is large and routes are extended toward central Tianjin (BRT1: 43.6km, BRT2: 44.2km in figure below).
- The simulation result estimates that the number of BRT users in the peak time is about 22,000. Since the capacity of the 3-articulated bus is 270 persons and if about 150% of the congestion ratio in the peak time is assumed;

  22,000 person/ (270 persons ×150%) = about 55 buses

  That is; ensuring about 55 buses is assumed.

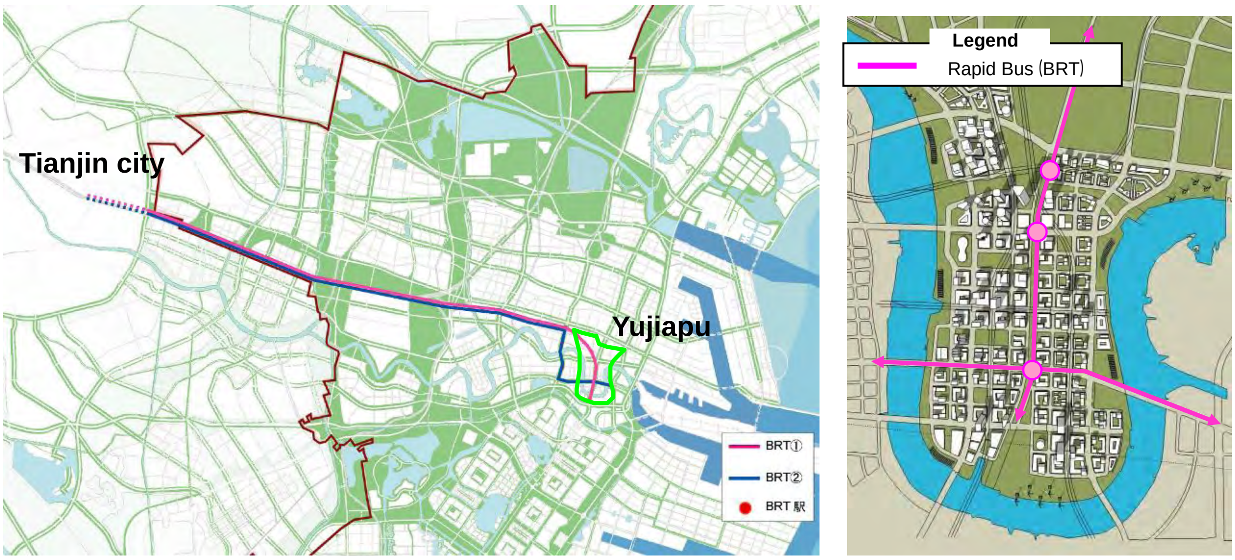


Figure 14.2.9 BRT assumed routes

Table 14.2.4 Example of BRT transportation capacity

Line	Type	Ridership(passengers/hour/direction)
Hong Kong Subway	Metro	80,000
São Paulo Line 1	Metro	60,000
Mexico City Line B	Metro	39,300
Santiago La Moneda	Metro	36,000
London Victoria Line	Metro	25,000
Buenos Aires Line D	Metro	20,000
Bogotá TransMilenio	BRT	45,000
São Paulo 9 de julho	BRT	34,910
Porto Alegre Assis Brasil	BRT	28,000
Belo Horizonte Cristiano Machado	BRT	21,100
Curitiba Eixo Sul	BRT	10,640
Manila MRT-3	Elevated rail	26,000
Bangkok SkyTrain	Elevated rail	22,000
Kuala Lumpur Monorail	Monorail	3,000
Tunis	LRT	13,400

■ Basic arrangement cost unit

- Initial cost

Arrangement cost per 1km• • • $5,3 million/ km

Table 14.2.5 BRT construction cost BRT per 1km (example of Bogota in Colombia)

Component	Cost per Kilometre (US$1million)
Trunk line bus ways	2.5
Stations	0.8
Terminals	0.4
Pedestrian overpasses	0.4
Depots	0.4
Control centre	0.1
Other	0.7
Total	5.3

Source: Bus Rapid Transit Planning Guide (2007)

- Vehicle cost

Articulated non-step bus• • • About $750 thousand (About ¥60 million)

Source: material from MLIT

Figure 14.2.10 Articulated bus

- Operation cost

Operation cost per passenger• • • $0.38/ person

Source: Bus Rapid Transit Planning Guide (2007)

ii) Route bus

■ Necessary facilities

- Bus stops
- Bus vehicles

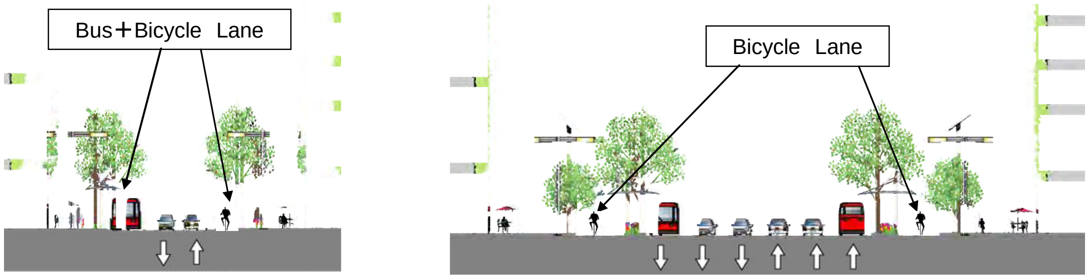


Figure 14.2.11 Image of road section at belt-line bus traveling section

■ Prerequisites for simulation

- The small circulation installs bus stops at the interval of about 200m referring to the example of the community bus in Japan (one-way clockwise traffic: total of 30 stops).
- The large circulation installs bus stops at the interval of about 300m because of connection to the subway stations (two-way traffic: total 16 stops x 2 = 32 stops).
- The service interval is assumed to be 5 minutes; therefore, necessary number of buses is assumed to be 4 for the large circulation and 6 for the small circulation (i.e. 2 buses for each circulation route)

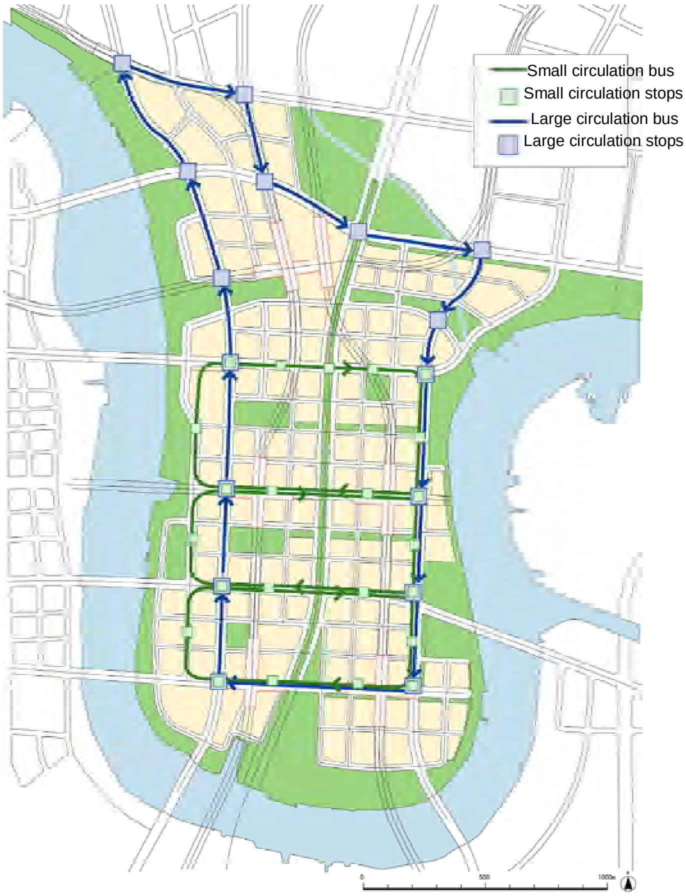


Figure 14.2.12 Routes and stops of belt-line buses

■ Basic construction cost unit

- Bus stop

  Bus stop with shelter• • • $12.5 thousand (about ¥1 million) * Calculation uses $1 = ¥80.

Source: Material from Asahikawa city

Figure 14.2.13 Bus shelter

- Bus vehicle

  Community bus (small bus) vehicle cost:• • • $250 thousand to $310 thousand (¥20 million to ¥25 million)

  Community bus (small bus) vehicle cost:• • • About $375 thousand (about ¥30 million)

  Source: Material from Saitama city, etc.

- Operation cost

  Operation cost per route:• • • $375 thousand/ route/ year ($30 million/ route/ year)

  Source: Material from Saitama city

iii) Bicycle-use environment arrangement (community cycle)

■ Necessary facilities

- Cycle port
- Bicycles

Source: Material from community cycle staff conference

Figure 14.2.14 Community cycle

■ Prerequisites for simulation

- Cycle port

The community cycle installs total of 18 cycle ports (i.e. main points such as subway stations) at the interval of about 300m. One port can accommodate about 10 bicycles (Ex. Velib in Paris installs 1,500 stations to accommodate about 20,000 bicycles).

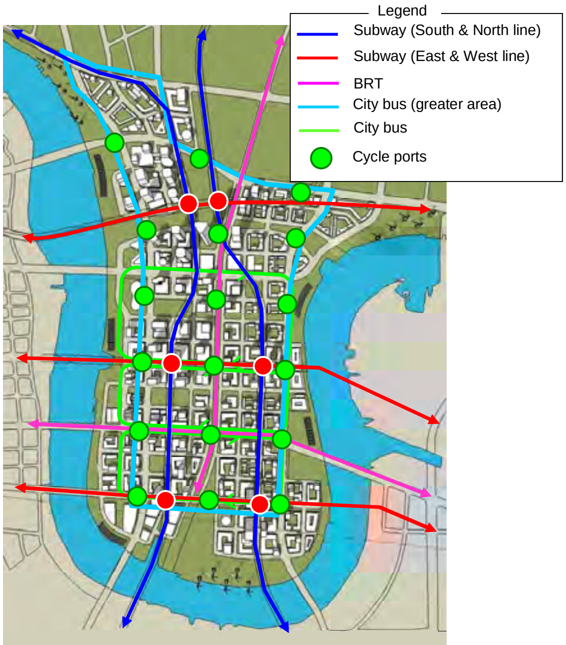


Figure 14.2.15 Installation image of community cycle

■ Basic construction cost unit

- Cycle port arrangement cost

Arrangement cost per port (including 10 bicycle installations):• • • About $55 thousand (about ¥ 4.4 million)

* Based on example examined for domestic installation

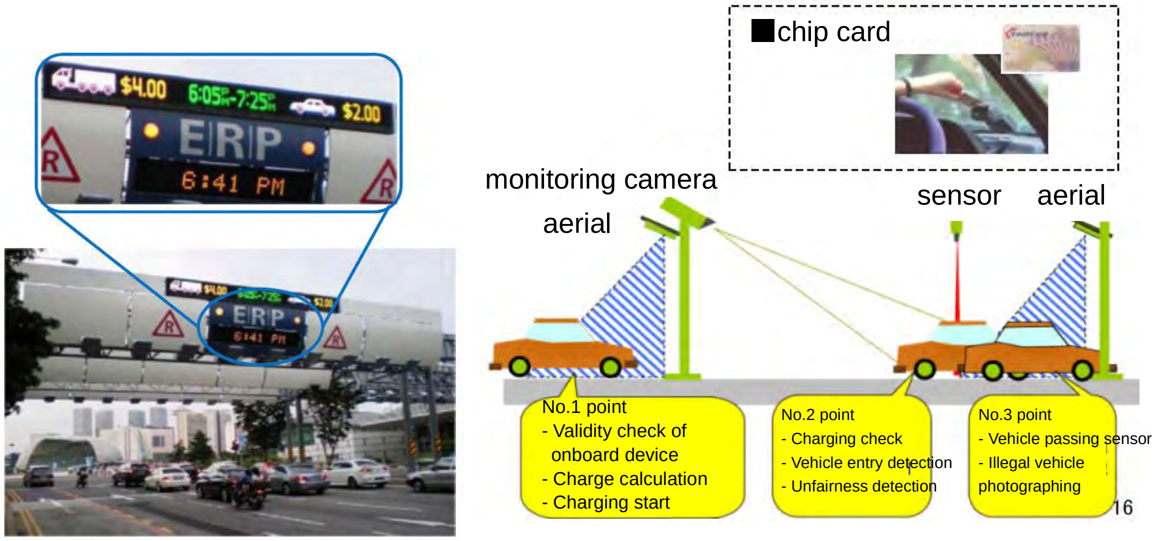
- Operation cost

Operation cost per port:• • • About $36 thousand (about 2.9 million/ year)

iv) Road pricing

■ Necessary facilities

- Cameras, communication devices above road, charge center facility cost



Source: Material from MLIT

Figure 14.2.16 Example of road pricing in Singapore

■ Prerequisites for simulation

Gates are installed at 17 points on the sections of the road entering the section to be examined.

Figure 14.2.17 Installation image of road pricing

■ Basic construction cost unit

- Construction cost per point on the entering route• • • About $1,375 thousand/ point (about ¥110 million/ point)
- Operation cost per point on the entering route• • • About $713 thousand/ location/ year (about ¥57 million/ point/ year)

Table 14.2.6 Introduction and operation costs of road pricing

		Loop 2/ Sumida river area	Yamate line/ Sumida river area	Loop 6/ Sumida river area	Loop 7/ Arakawa area
No. of entry routes/ points	Ordinary	59	93	247	322
	Highway	18	30	37	53
	Total	77	123	284	375
Introduction: ¥0.1 billion		50 to 120	120 to 200	260 to 330	370 to 440
:million $		62.5 to 150	150 to 250	325 to 412.5	462.5 to 550
Operation: ¥0.1 billion/ year		30 to 70	50 to 120	90 to 180	120 to 230
:million $		37.5 to 87.5	62.5 to 150	112.5 to 225	150 to 287.5

Source: created based on material from Tokyo Metropolitan Government

v) Electric car

■ Necessary facilities

Since the electric vehicle is the personal possession, the necessary facility should be the charging facility to charge it.

■ Prerequisites for simulation

The simulation assumes that the electric cars spread to 10% of the number of owned cars. Basically, nighttime charging at the home park is assumed; i.e. two charging facilities as the auxiliary position are to be installed in each street because of battery shutoff during going out.

Total of 280 rapid chargers are to be installed in 140 streets in the district.

■ Basic construction cost unit

Table 14.2.7 Basic construction cost unit of electric cars (charging facility)

Facilities	Price	Specification	Source
Rapid charger (50kW)	About $80 thousand (about ¥6.4million)	1 DC power supply 2 stands	Kyushu Electric Power HP
Installation cost	About $12.5 thousand (about ¥1million)	1 set (point)	CHADEMO council HP

2) Summary of estimated construction cost

In the arrangement costs, BRT cost is extremely high; i.e. about of 90% of the whole. In the operation costs, cost of BRT and road pricing is high and both occupies about 90% of the whole.

Table 14.2.8 Arrangement costs and operation costs for traffic field

	Construction cost (thousand RMB)	Operation cost (thousand RMB/ year)
BRT	1,689,478	38,019
Route bus	13,827	5,003
Community cycle	3,302	2,161
Road pricing	77,959	40,427
Electric car	80,540	
Total	1,865,106	85,610

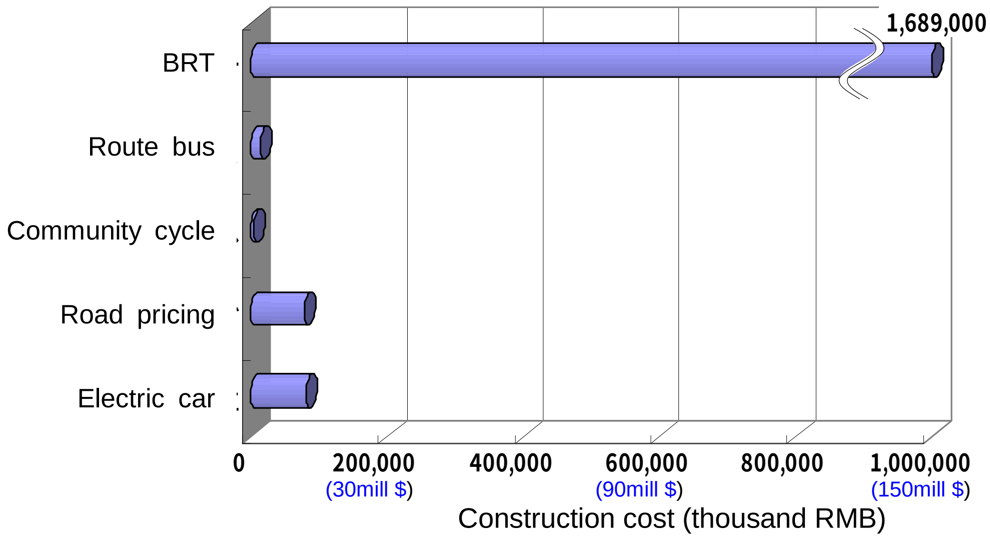


Figure 14.2.18 Construction cost for each measure

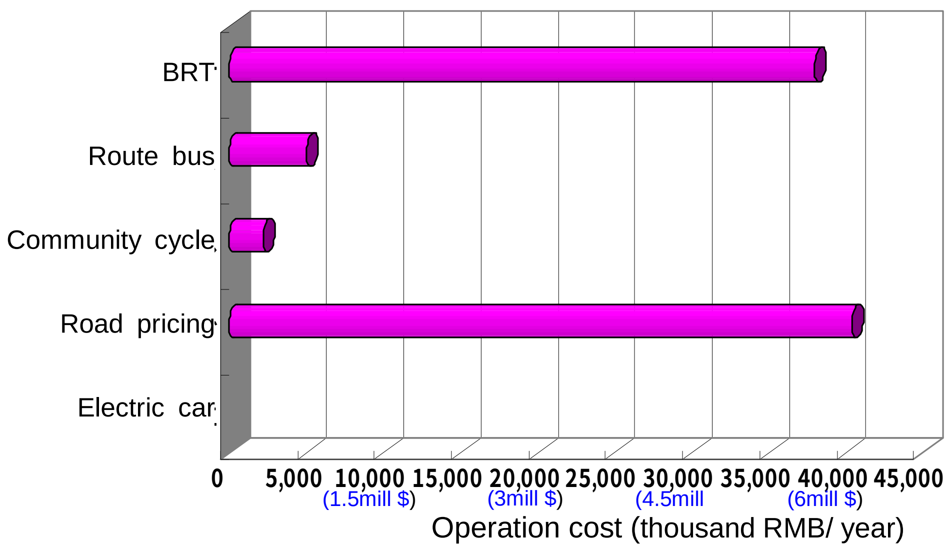


Figure 14.2.19 Annual operation cost for each measure

3) Examination of cost performance

For reduced amount of CO2 emission, the cost performance is verified. The annual construction cost is obtained by dividing the total amount of construction costs by the life (years) and the cost required to reduce CO2 emission per year is obtained by adding the annual construction cost and the annual operation cost.

Table 14.2.9 Annual construction cost considering the life

	Item	Construction cost (thousand RMB)	Life [*1] (year)	Annual construction cost (thousand RMB/ year)	
BRT	Vehicle	1,551,133	5	310,227	314,524
	Route	137,500	32	4,297	
Route bus	Vehicle	11,233	5	2,247	2,505
	Bus stop	2,583	10	258	
Community cycle	Bicycle parking device	3,302	10	330	330
Road pricing	Camera, on-road communication device, etc.	77,959	10	7,796	7,796
Electric car	Rapid charger	80,540	8	10,063	10,063

*1 Refer to the ministerial ordinance regarding the life (years) of the depreciated property (Article 15 from Ordinance of the Ministry of Finance, March 31, S40)

Based on the calculation result of the annual construction cost considering the life-span, the cost required to reduce 1t of CO2 emissions is calculated (Table 14.2.10).

Table 14.2.10 Cost required to reduce 1t of CO2 emission

	Total cost (thousand RMB/ year)	Annual construction cost (thousand RMB/ year)	Operation cost (thousand RMB/ year)	CO2 reduction (t-CO2/ year)	Cost required to reduce 1t of CO2 (thousand RMB/t-CO2)
BRT	352,543	314,524	38,019	275,057	1.28
Route bus	7,508	2,505	5,003	8,128	0.92
Community cycle	2,491	330	2,161	17,585	0.14
Road pricing	48,223	7,796	40,427	164,698	0.29
Electric car	10,063	10,063		54,077	0.19
Total	420,827	335,217	85,610	519,546	0.81

For the cost required to reduce 1t of CO2 emissions, that of “Community cycle” is the lowest; followed by “Electric car”, “Road pricing”, “Belt-line bus”, and “BRT”.

However, because of the viewpoint below, promotion of only low-cost measures cannot achieve the reduction target. In addition, each measure is required to ensure the smooth movement in the proposed district. Therefore, it is desirable to cope with them in parallel.

- The cost of the community cycle to reduce CO2 is low and installation is assumed throughout the proposed district. However, since there is no area allowing additional arrangement, additional CO2 reduction is not expected.

- Since the spread (purchase) of the electric car is individually selected, installation of the rapid charger is not always connected directly with increment of CO2 emission. However, there is large potential to reduce CO2 emissions by promotion of spreading electric cars.

- For road pricing, if the setting of the charging price is increased, reduction of CO2 emissions is expected without additional arrangement of the facility; i.e. the cost required to reduce 1t of CO2 is expected to be decreased more. However, it is difficult to increase the charging price freely because of consideration for car users.

- BRT is assumed to be installed between Tianjin and Yujiapu at which almost all of traffic is concentrated; i.e. large reduction of CO2 emission is expected. Because of measures expanding to outside Yujiapu district, it is necessary to examine it in cooperation with Tianjin from the viewpoint of the comprehensive traffic plan when executing it.

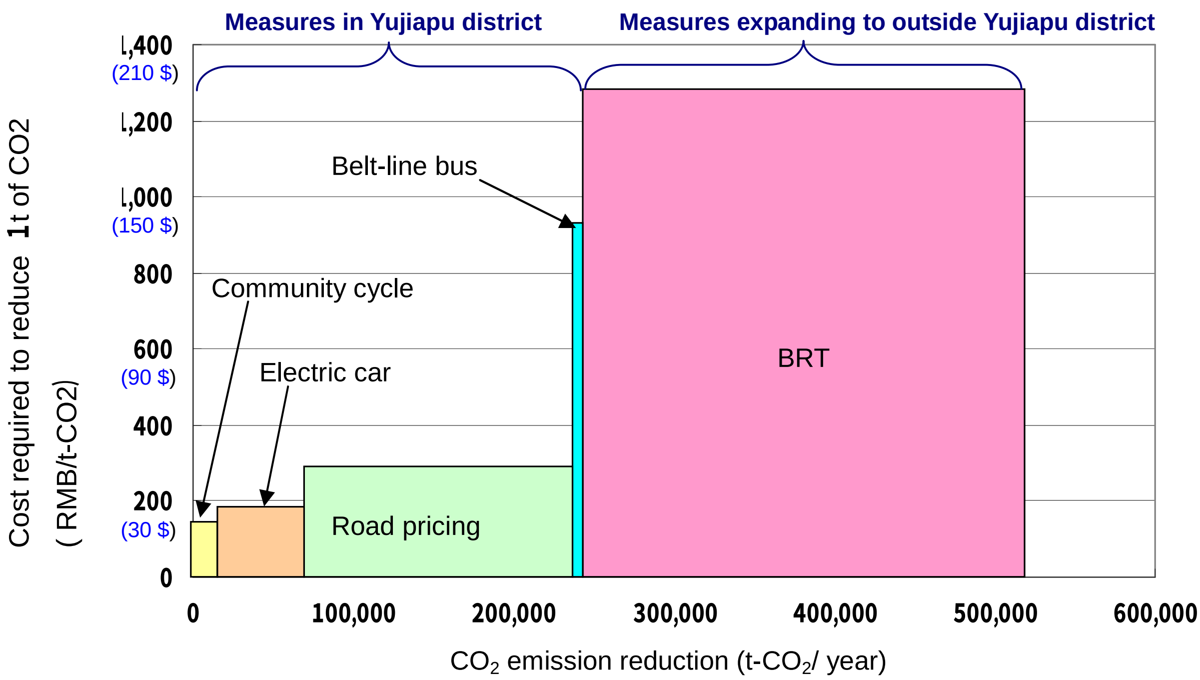


Figure 14.2.20 CO2 emission reduction cost per ton for each of measures and CO2 emission reduction amount

c) Comprehensive examination of commercial and residential sector and transportation sector

In comparison of costs required to reduce 1t of CO2 for all measures in commercial and residential sector and transportation sector, the transportation sector includes the measures with the low cost, but their reduction potential is limited. Therefore, for achieving the reduction target of CO2 emissions in Yujiapu district, it is necessary to cope with both commercial and residential sector and transportation sector.

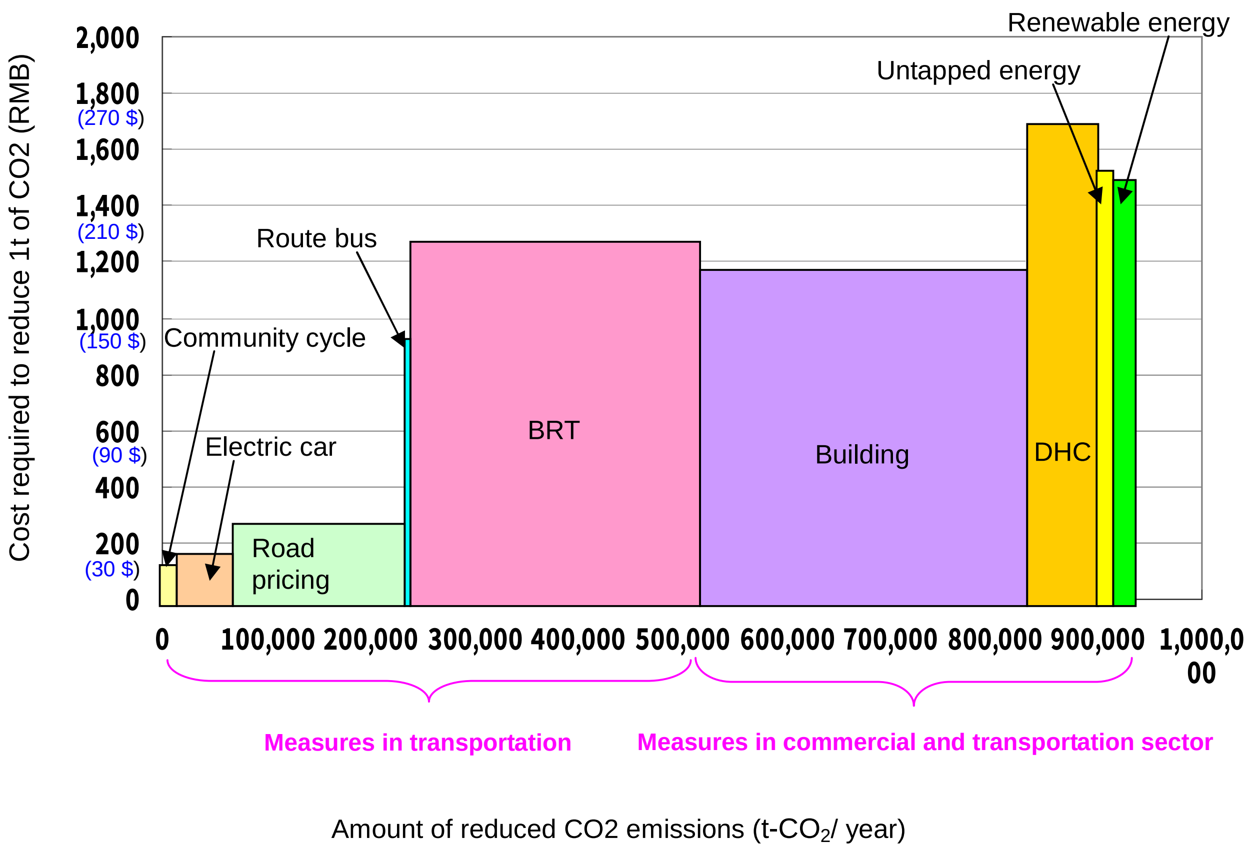
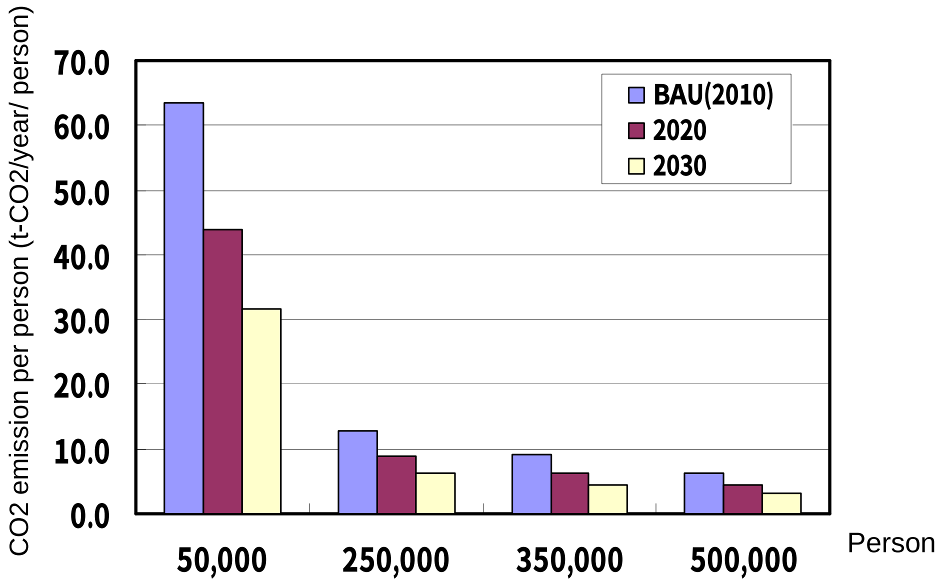


Figure 14.2.21 CO2 emission reduction cost per ton for each measure (including building energy, traffic) and amount of CO2 emission reduction

2) CO2 emissions in entire Yujiapu district and analysis of reduction effects

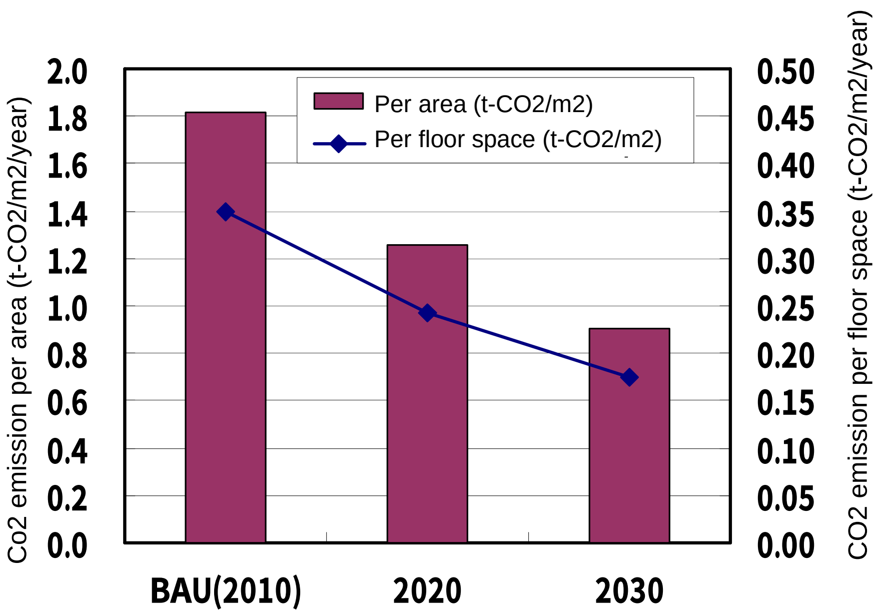
a) CO2 emissions per person

- It is estimated using cases where the nighttime population is 50,000 persons, daytime population is 250,000, 350,000, and 500,000 (max.).
- The case of 500,000 persons under BAU is about 6.3t-co2/year/person and it is estimated to be reduced to the half in 2030; i.e. 3.2t-co2/year/ person.



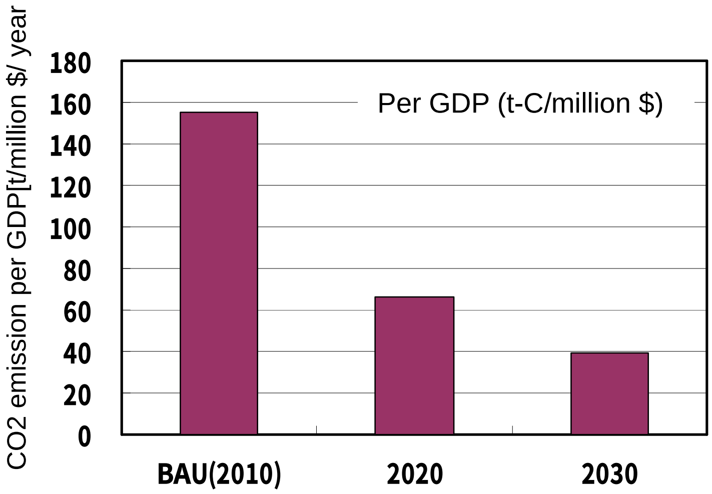
b) CO2 emission per unit area (t-CO2/m2)

- CO2 emissions per unit area is 1.92 t-co2/m^2 under BAU and it is estimated to be 0.91 t-co2/ m^2 in 2030.
- In addition, CO2 emission per unit floor space is 0.35 t-co2/ m^2 under BAU and it is estimated to be 0.18 t-co2/ m^2 in 2030.



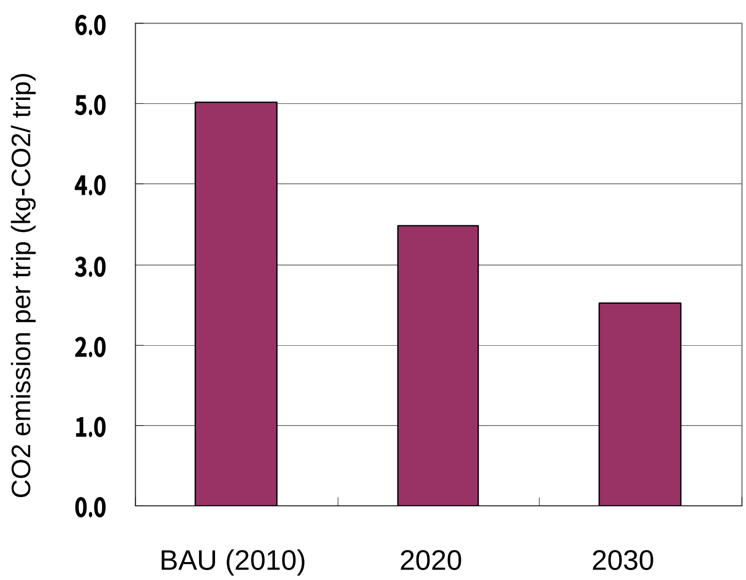
c) CO2 emission per GDP

- It is about 154t-c/million $ /year under BAU; i.e. it is almost the same as Nakashin Eco-city (150t-c/million$/ year)
- It is estimated to be reduced to about 40t-c/million$/ year by 2030.



d) CO2 emission per trip (kg-CO2/trip)

- CO2 emission per trip is 5.0 kg-co2/trip under BAU and it is estimated to be 2.5 kg-co2/trip in 2030.

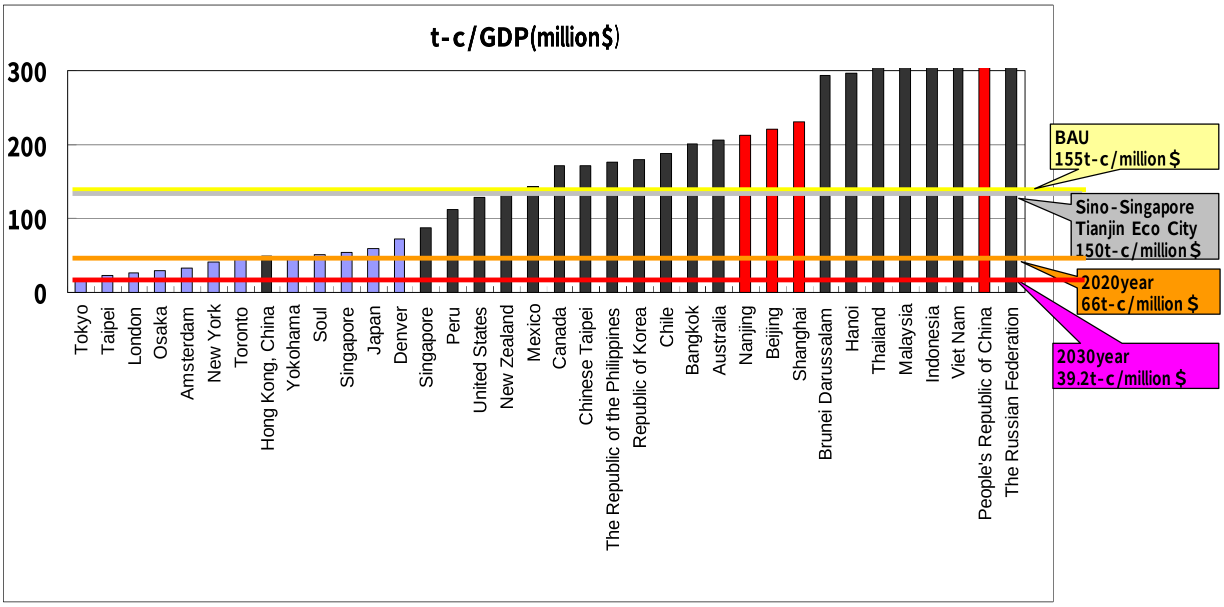


14.3 Comparison with other cities

The following compares Yujiapu district with other cities for t-c/GDP(million $) and t-co2/capita under BAU, 2020, 2030.

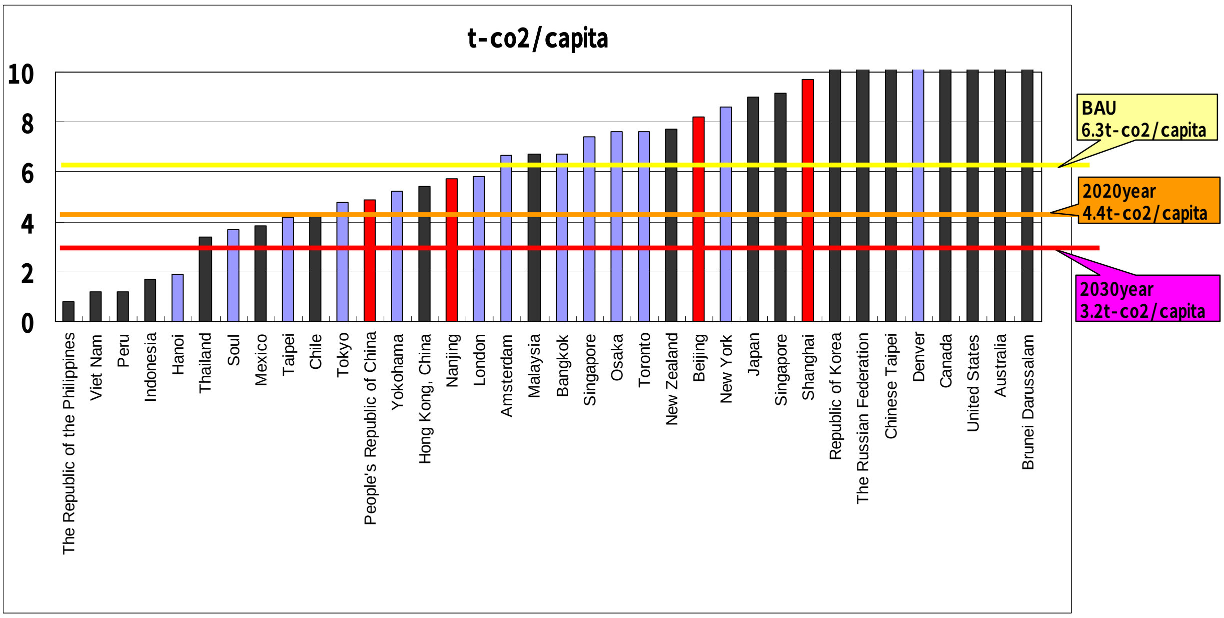
1) t-c/GDP (million $)

- It is estimated to be 155 t-c/million$ in BAU, 66 t-c/million $ in 2020, and 39 t-c/million $ in 2030.
- It is estimated to be 150 t-c/million $ for Nakashin Eco-city; i.e. the estimated values for Yujiapu district in 2020 and in 2030 are greatly lower than it.
- For main cities in China, it is 213 t-c/million$ for Nanjing, 220 t-c/million $ for Beijing, and 230 t-c/million$ for Shanghai.



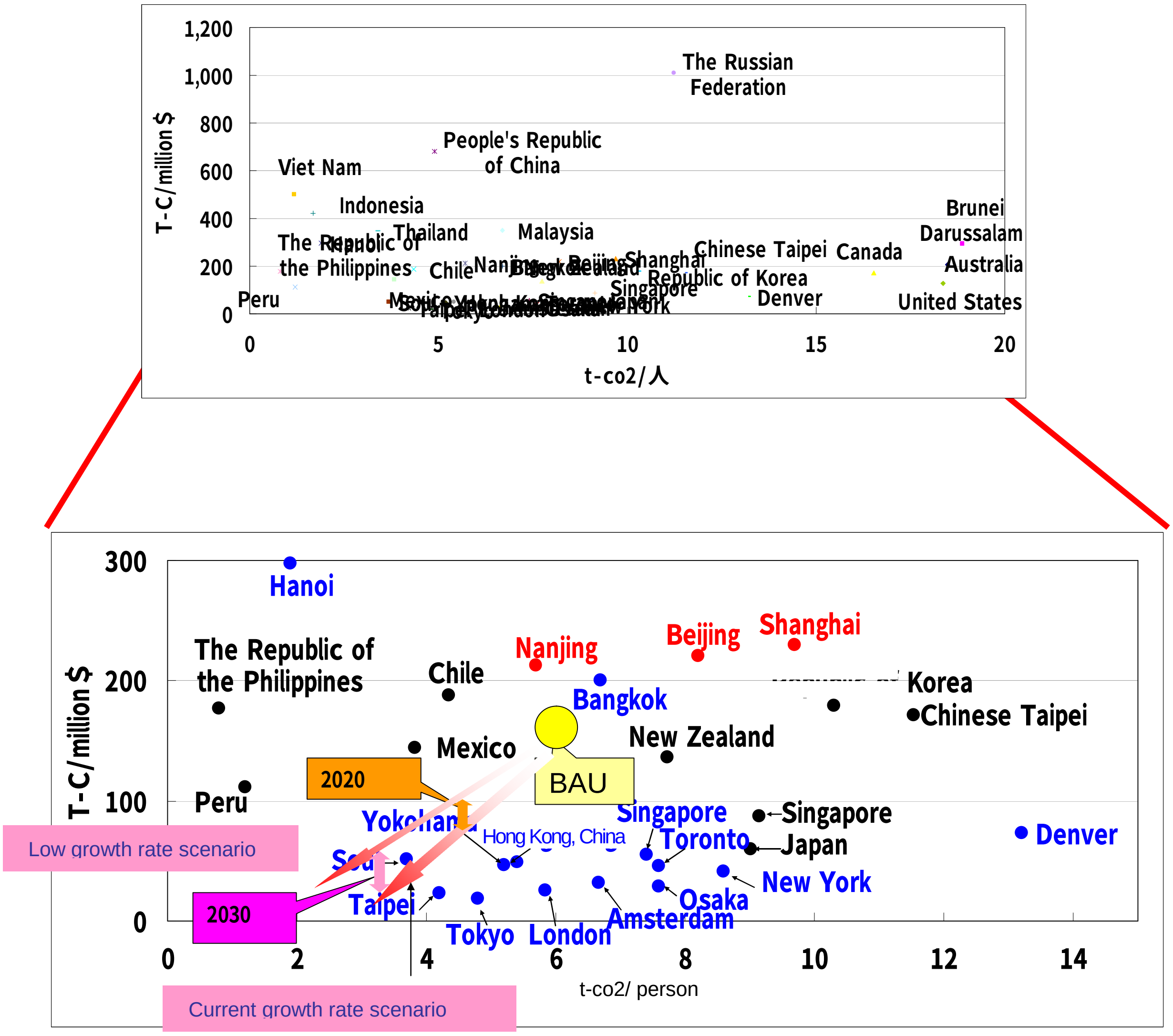
2) t-co2/capita

- It is estimated to be 6.3 t-co2/capita under BAU, 4.4 t-co2/capita in 2020, and 3.2 t-co2/capita in 2030.
- It is almost the same as that for London and Amsterdam under BAU, as that for Taipei and Tokyo in 2020, and as that for Seoul. For main cities in China, it is 5.7 t-co2/capita for Nanjing, 8.2t-co2/capita for Beijing, and 9.7t-co2/capita for Shanghai.



3) t-c/GDP(million$) & t-co2/capita

- For main cities, CO2 emission per GDP tends to be low. The value for Yujiapu CBD is estimated to be almost the same as that for Nanjing and Bangkok under BAU.
- The value is assumed to change between two arrow marks in the figire below in the future.

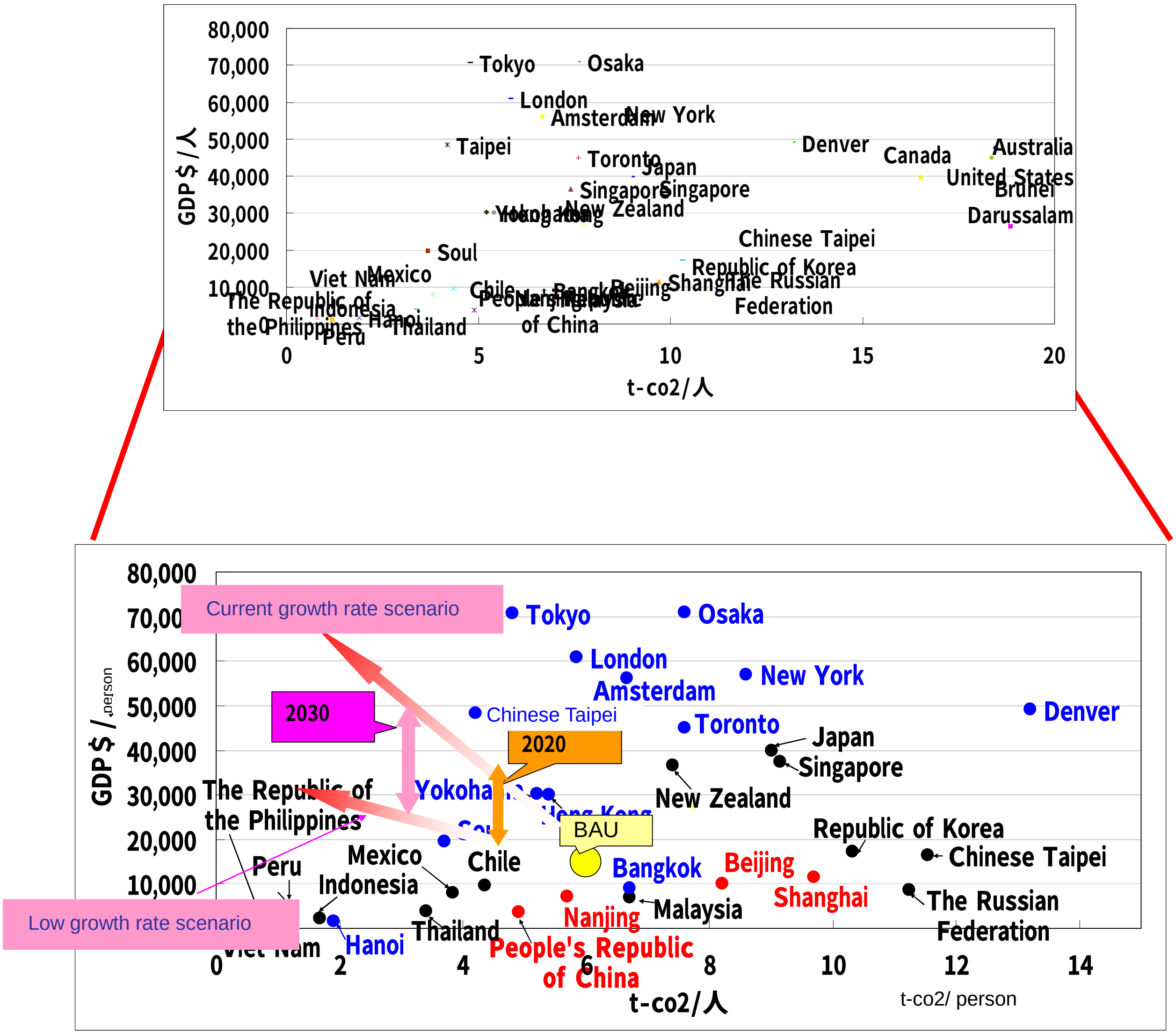


Source : national data：International Energy Agency (IEA)
City data：Asian Green City Index2011 Siemens、 European Green City Index2009 Siemens、 US and Canada Green City Index2011 Siemens

●national, ●city, ●city in People's of Republic of China

4) t-co2/capita & GDP($) /capita

- While the values for APEC economies are in proportional relation (i.e. strong positive correlation), values for Yujiapu CBD are in reverse relation (i.e. while CO2 emission per person decreases, GDP increases).
- The value is assumed to change between two arrow marks in the figire below in future.



Source : national data：International Energy Agency (IEA)
City data：Asian Green City Index2011 Siemens、 European Green City Index2009 Siemens、 US and Canada Green City Index2011 Siemens

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 • APEC#211-RE-01.8 • ISBN 978-981-07-0633-3