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Possibility of Cooperation for a Low Carbon Society: Comparison of the Fukuoka and Busan Metropolitan Cities

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This paper presents a review and compares current situations and policy issues related to reduction of greenhouse gases (GHGs) by several means and creation of a "low carbon society" in Fukuoka and Busan Metropolitan Cities. Analyses include viewpoints of urban and regional planning, environmental economics, waste management engineering, and environmental law. These cities are, geographically, the closest "sister cities" of any in Japan and Korea, located on respective sides of the strait, which suggests their mutual cooperation to execute effective international but nevertheless local policies.

1. Introduction

This paper presents a review of and compares the present situations and policy issues related to mitigation of global warming and related to establishing a so-called "low carbon society" in the Fukuoka and Busan Metropolitan Cities. The analyses incorporate viewpoints of multiple academic areas such as urban and regional planning, environmental economics, waste management engineering, and environmental law. Based on these observations, we investigate environmentally sound and effective cooperation, both administratively and privately, to produce a "super-wide economic zone" proposed by these cities.

To stop global warming and its resultant climate change, most developed countries assign top priority to reducing emissions of carbon dioxide and other greenhouse gases (GHGs) according to the Kyoto Protocol. Local governments have been expected to play more important roles than national governments in promoting such mitigation activities within their jurisdictions because it seems easier to enforce creative and locally adjusted policies therein.

However, only some awareness movements for residents can engender practical policies if local budgets allocated for saving energy and lowering carbon dioxide emission are so limited, especially in urban areas with many houses, offices, and cars and no large plants emitting large amounts of GHGs. Moreover, occasional changes in targets and instruments by a national government can affect the directions of local policies directly and negatively.

This paper presents an introduction to the cities we specifically examine. Fukuoka City, where all the authors live and work now, is the most populated area (1,458,063 people and 703,314 households as of May 2010) on Kyushu Island. The area offers varied landscapes with a short commute, seas and mountains, and urban and rural scenes. Fukuoka Airport, located near the center of the city (only five minutes by subway from Hakata Station), and the Port of Hakata offer convenient means to travel to neighboring countries, especially to Korea and China.

Among the large cities in these countries, the Busan Metropolitan City (BMC), the second largest city in Korea (3,574,340 people and 1,323,771 households as of December 2009), has been the nearest sister city of Fukuoka for 20 years (started as an administrative exchange). It is only 50 min away by air (waits for flights are much longer than the flights themselves) or about 3 hr by ferry (depending on weather conditions). Some familiarity is felt when one finds Chinese characters indicating the names of towns and stations in many places. The people speak to us in friendly and fluent Japanese if we walk on the street in Busan.

Such closeness of Fukuoka and Busan has led to a joint declaration of the formation of a "super-wide economic zone" (*Cho-Koiki Keizai-Ken* in Japanese) initiated by both cities in October 2008. Following the statement of mutual agreement signed in August 2009, cooperation projects of various types are planned for Fukuoka, Busan, and neighboring areas in Kyushu and southeastern Korea[1)].

These cross-border exchange commitments among different local cities represent unique features because they cooperate based on their own voluntary motivations, not for their respective national policies. In the agreement, the development of future industries including the construction of cooperative environment and energy sectors is emphasized as *the nine strategies*. Nevertheless, no single strategy or category is related to harmonization of environmental policies in both cities.

Global warming mitigation policies and measures should be harmonized internationally over wider areas. An emerging economic zone stretching across two nations promotes the exchange of more people, capital, and (intermediate and final) products, ultimately emitting more GHGs and waste on both sides. Proper waste management and resource recycling are also important policies in terms of reducing GHG emissions, especially in large cities such as Fukuoka and Busan.

With surveys and analyses from multiple academic areas, the first half of this paper introduces circumstances related to GHG emissions and policies to establish low-carbon areas in Fukuoka and Busan (Section 2), and proposes a microeconomic framework clarifying the quantitative effects of changes in monetary incentives and technology transfer (Section 3). Data for both cities show that the greatest amounts of GHGs (especially CO_2) have been emitted not from the industrial sector, but from the transportation and household sectors. Therefore, various local policies to change the economic behaviors of residents, international common policies between the two cities and neighboring areas, and cooperative technology transfers are effective.

The second half of this paper presents an examination of emissions, recycling, and treatment of municipal wastes in both cities and disposal systems contributing to lower carbon emissions (Section 4), along with an investigation of laws and regulations to establish low-emission societies (Section 5). As a remarkable case study in the waste management sector, we specifically examine benefits of a biomass utilization system conducted in Busan and its application to Fukuoka. Careful observation of existing laws and plans produced by national and local governments reveals both opportunity and instability in promoting effective measures to cope with global warming. The paper concludes with some remarks in Section 6.

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2. GHG Emissions near Fukuoka and Busan and Policies for Establishing Low Carbon

2.1 GHG emissions and policies for establishing low carbon in Fukuoka

2.1.1 GHG emissions in Fukuoka

Japan's GHG emissions have increased consistently from 1990, which is the base year of the Kyoto Protocol, although fluctuations exist. The amount of GHG emissions per person is also increasing; about 10 CO_2-tons of GHG are discharged per year per person in recent years.

The discharge amount of GHG from Fukuoka City presents a similar tendency; its rate of increase is higher than Japan's national rate. The GHG emissions per person per year in Fukuoka are about 5–6 CO_2-tons, which is about half the amount of the national figure for Japan.

That difference between Fukuoka and Japan is presumably attributable to the fact that the share of manufacturing in the industrial structure of Fukuoka is small. The main industries of Fukuoka are office work and sales. Their CO_2 emissions, based on almost equivalent energy consumption to that of the industrial sector, are lower than those of the consumer and transport sector, from which the amount of emissions have been increasing recently.

Figure 1 shows CO_2 emissions per person for major cities in Japan. This figure enables comparison of a sectoral breakdown of GHG emissions in Fukuoka City with those of other major cities in Japan.

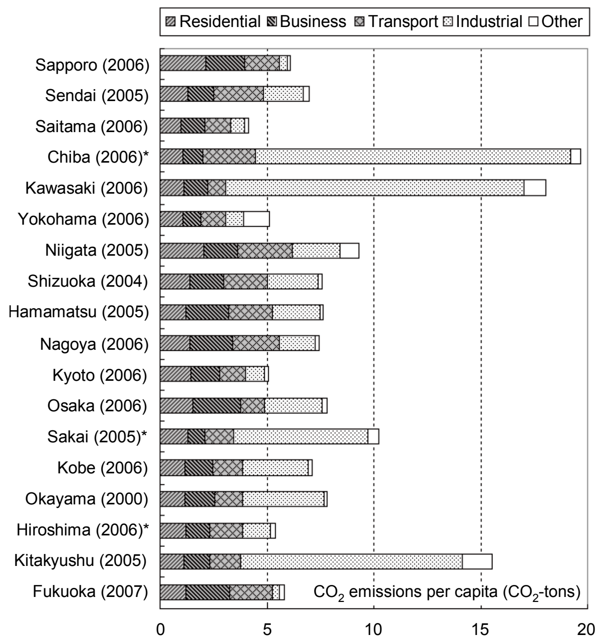

Fig. 1 CO_2 emissions from major cities in Japan.
Source: Tamura[2)] *Including other GHG than CO_2

First, the discharge amounts of industrial cities such as Chiba, Kawasaki, Sakai, and Kitakyushu are outstanding. Most emissions are from industrial sectors of these cities. Nevertheless, the emissions data of the consumer and transport sectors show no great differences, although the emissions tend to be small in cities near Tokyo. Furthermore, about one-third of emissions from the transport sector in Fukuoka issue from Fukuoka Airport, one of the largest airports in Japan.

The discussion above engenders the following findings. First, the per-capita amounts of CO_2 emissions in Fukuoka City are less than those of other cities because of the low share of manufacturing in its industrial structure. Secondly, for the consumer and transport sector, the patterns do not mutually differ. The characteristics of

Fukuoka's emissions highlight emissions from commerce and Fukuoka Airport.

Consequently, to reduce CO_2 emissions from Fukuoka City, a certain amount of reduction is needed in the consumer and transport sector.

2.1.2 Low carbon policies in Fukuoka

As described above, CO_2 emissions from the consumer and transport sectors constitute a large share of emissions from Fukuoka City. Despite this, emissions from these two sectors are increasing annually, even in other parts of Japan. Apparently, insufficiently effective measures have been taken to reduce the discharge of CO_2 from these sectors. Because public transport systems such as subways and buses are well developed in urban areas of Fukuoka, emissions from the transport sector are lower than in other major cities in Japan, except for emissions from aircraft. Furthermore, the Fukuoka City population is predicted to increase until about 2025, different from other cities in Japan. In consideration of such facts, the Fukuoka city government sets targets of basic units instead of the total amount, as described in Table 1.

Table 1 CO_2 emission reduction target of Fukuoka City

Target year	2010
Base year	2004
Residential Sector	8% reduction (per household)
Business Sector	14% reduction (per floor-area)
Transport (Automobile) Sector	8% reduction (per car)

Source: Fukuoka City[3)]

Main measures and policies to reduce CO_2 emissions in Fukuoka are fostering of environmental awareness of residents and environmental education of young people. Because most policies are expected to change residents' attitudes or behavior, except for funding programs for solar power generation systems and other energy-saving devices added to national or prefectural programs, they are less effective at reducing CO_2 emissions.

However, a few unique and characteristic measures have been adopted to reduce emissions in Fukuoka City: collective pickup and delivery (logistics) systems in urban areas, commuter tickets that combine bicycle parking and subways, and floor-area ratio bonuses for new buildings according to their environmental efficiency.

2.1.3 Some issues can be addressed in Fukuoka

First, it is necessary to reduce residential energy consumption, especially in Fukuoka, which is a nonmanufacturing city. That is difficult to accomplish because few effective measures entail low costs, but every municipality seeks this goal. Measures to solve this problem must be sought continuously.

Secondly, we must promote public transportation accessibility. It is important to create a "walkable city", in which everyone in the city, including foreign visitors, can move on foot and by public transportation. That can be expected to make Fukuoka more attractive and sustainable.

2.2 GHG emissions and policies for establishing low carbon in the Busan Metropolitan City (BMC)

2.2.1 Overview: GHG emissions of BMC

In fact, BMC boasts a population of approximately 3,500,000 (2009). It is a main harbor city in Korea, second only to Seoul. It has aimed to become a hub harbor of eastern Asia. Consequently, energy consumption and GHG emissions in the transportation sector are extremely high (Table 2).

However, its emission tendencies differ from Korea's overall. In Korea, energy consumption and GHG emissions are highest in the industrial sector, followed by those of the household and commerce sector, transportation sector, public services sector, and other sectors. In contrast, the transportation sector tops the list in BMC, followed by households and commerce sectors, the industrial sector, public sector, and other sectors. In particular, the transportation sector and household and commerce sector constitute 75% of energy consumption, making proactive measures for improving energy efficiency in these sectors an important issue.

In the transportation sector, most emissions are derived from the automobile (road) and shipping sectors. Emissions in the automobile sector have increased each year, although the shipping sector has reduced its emissions since 2000 (Fig. 2).

Table 2 Energy consumption and GHG emissions in BMC

sector / year	Energy Consumption (1000 toe)					GHG Emission (1000 tCO_2)				
	Industry	Transport	Household • Commerce	Others	Total	Industry	Transport	Household • Commerce	Others	Total
2000	1572	3291	2133	140	7136	3026	10045	5467	190	18728
2001	1634	3216	2177	121	7148	3053	10674	5335	192	19254
2002	1579	2923	2248	144	6894	3066	9999	5105	168	18338
2003	1543	2980	2298	153	6974	2853	10442	5118	217	18630
2004	1521	2846	2144	173	6683	2643	10780	4531	204	18158
2005	1537	2843	2216	186	6782	2526	11367	4559	218	18670

Source: Korea Energy Economics Institute (KEEI)[4)], Busan Metropolitan City[5)]

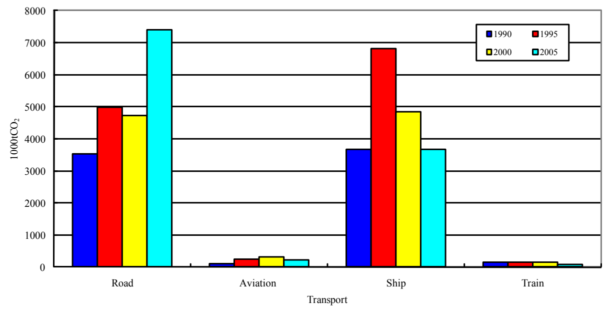

Fig. 2 GHG emissions from transport sector in BMC.
Source: Busan Metropolitan City

2.2.2 GHG abatement measures in BMC

In 2007, BMC began investigating the GHG emission amounts. It introduced a pilot business in emissions trading in January 2008. It continues to take steps to reduce GHG. The city also implemented a carbon point system in October 2008 and established the Measures against Climate Change Act in 2010.

Currently, BMC is working on a CDM project for a landfill gas business at the Saeng-gok Landfill Site. The city has acquired the state's approval, and has submitted the CDM project design documents (PDD) to the CDM Executive Board (EB). This project, as Busan's Unilateral CDM, is expected to generate economic effects and to reduce greenhouse gases.

The first project to be raised as a prospective CDM project for the future is the CDM related to waste matter. By changing the current incineration and landfill facilities with facilities for generating renewed energy, the amount of waste brought to landfills is expected to decrease from 559 tons to 131 tons per day, with CER credits for emissions trading. The second is solar power projects. In 2006, BMC generated 44 tons of solar power a year; it is considering implementation of a 3 MW solar power facility by 2011. The third is wind-power projects. The coastal region of BMC is optimal for large-scale wind power generation; FS research for a 1020 MW wind power facility is being planned[5].

The carbon point system was introduced with the purpose of reducing GHG emissions in the household and commerce sectors, which have been augmented recently. Each municipality conducts operation programs, with the Korea Environmental Ministry being the management and Korea Environment Corporation being the operation entity. Tentatively, BMC introduced a carbon point system in October 2008; which it wholly adopted in July 2009. In detail, the reduction amounts in electricity and water consumption at household and commercial facilities are calculated for the prior two years; then carbon points are awarded. Incentives (e.g. carbon cash-back) are provided according to the accumulated carbon points. Those include coupons and advantageous interest rates.

2.3 Possibility of establishing a low carbon society around Fukuoka and BMC in cooperation

In October 1989, BMC's international exchange and contribution to environmental issues began with the "Agreement Regarding Administrational Cooperation" settled with Japan's Fukuoka City for the solution of environmental issues. Since then, Korea and Japan have progressed with administrative cooperation on environmental issues and joint projects.

Regarding administrative cooperation, an environmental symposium was held in BMC in 1991 to promote cooperation in environmental technologies. In addition, in the meeting for administrative cooperation on environmental issues held in Fukuoka in 2004, administrative parties of both cities participated, and discussions related to the "Comprehensive Plan on Preserving the Atmosphere," "City Waste Matter," and "Harmony in the Natural Environment" were conducted.

Furthermore, for cooperation in environmental technologies, seven coastal cities of Japan and Korea (Busan, Chonnam, Kyungnam, Fukuoka, Saga Prefecture, Nagasaki Prefecture, etc.) came together in 1993 to conduct joint research related to acid rain. In 1999, Yamaguchi Prefecture also joined, and joint research on nitrogen fluid flow has been conducted by eight cities. During 2002–2003, the two countries collaborated on "Research on Air Pollution of Japan and Korea's Metropolis Atmospheres." This research was conducted to obtain objective assessments of air pollution of coastal regions in Korea and Japan; it is expected to be of use as a reference for establishing goals in the future[6].

It would also be possible to transfer technology to reduce GHG emissions. Jung states that if the technologies in the fields of agriculture, forestry and fishing are transferred from BMC to Fukuoka, and the technologies in the fields of ceramic, soil and stone in opposite direction, it can be estimated that CO_2 emissions will be reduced by about 1.04% (330 thousand tons) and that GDP will grow by about 0.07% (119 million dollars) within both cities[7].

Moreover, mutual introduction and operations are anticipated for policies adopted by the respective cities. For example, the *carbon point system* of the BMC could be transferred to Fukuoka City. In doing so, adopting the existing point system infrastructure such as the transport IC smart card "Hayaka-ken" is useful to reduce initial costs. Charging points to individual IC cards might engender promotion of greater usage of public transportation and further reduction of CO_2 emissions, rather than cash-back incentives.

3. Microeconomic Model and Effects of Incentive Policy

3.1 Microeconomic analysis in GHG abatement measures

Effects of environmental measures and cooperation of the Fukuoka and Busan Metropolitan Cities were explained in the preceding section, particularly addressing a carbon point system and environmental technology transfer related to GHG emission reduction. In this section, we analyze those effects using a theoretical economic model.

Related to the technical progress for the global environment problem, various studies have analyzed the impact of technology transfer based on a theoretical economic model[8,9,10]. In addition, CDM and the effectiveness of other environmental policies are also described in earlier works[11,12]. In this section, we present analyses of the effectiveness of such policies as the carbon point system and extended use of environmental technologies using a simple micro-model.

First, based on the example of the carbon point system of BMC, we analyze the effectiveness when we enforce a carbon point system in Fukuoka City. Furthermore, we consider introduction of a carbon point system and the related vouchers used in traffic IC cards that are used increasingly in Fukuoka City and determine whether it promotes a switch from automobiles to public transport and facilitates the control of automobile use. Next, we compare effects of a carbon point system with those of a subsidy provided from government authorities and each self-governing body to individuals to plan the promotion of measures to control global warming.

Furthermore, environmental technology cooperation between the Fukuoka and Busan Metropolitan Cities must be described. Regarding cooperation between areas for low carbon society realization, we analyze the effects in each area of the mutual transfer of comparatively advantageous technologies.

3.2 Comparison of subsidy and carbon point systems

3.2.1 Model

First, for analysis of the microeconomics of the consumer behavior, we examine the present expected effects of a voucher system (subsidy and carbon point system). Additionally, we presume that, to gain utility, the consumer uses three types of goods, namely, the goods corresponding to the environment (mainly used by individuals in private; for example, eco-cars, etc.), other goods corresponding to the environment (mainly for public use; for example, public transportation facility use, etc.), and other goods (non-eco cars, etc.).

A consumer receives an income m and decides its allocation to purchase the first good x_1 (goods corresponding to the environment), the second good x_2 (other goods corresponding to the environment), and the third good z (other goods). Prices of the three goods are represented by p_1, p_2, 1; we presume that the price of the third good is normalized to 1. Furthermore, the budget constraint is expressed as $p_1x_1 + p_2x_2 + z \leq m$.

Next, when a subsidy system is introduced, the budget constraint is as follows:

$$p_1(1-\sigma)x_1 + p_2x_2 + z \leq m, \tag{1}$$

where σ is a subsidy.

Furthermore, when a carbon point system is introduced, the constraint becomes as follows:

$$p_1x_1 + p_2x_2 + z \leq m, \tag{2}$$

$$p_2\hat{x}_2 \leq \tau p_1x_1. \tag{3}$$

Therein, τ signifies carbon points, and $\hat{x}_2$ stands for a good to be consumed with a carbon points. Eq. (3) shows the purchased amount for the carbon points, with $p_2\hat{x}_2$ signifying the expenditure of carbon points and τp_1x_1 denoting the points received by purchasing a good corresponding to the environment.

When we consider the subsidy case, the consumers' utility maximization problem is expressed as follows:

$$\max U(x_1, x_2, z) = x_1^{\alpha} x_2^{\beta} z^{\gamma}, \quad \alpha > 0,\ \beta > 0,\ \gamma > 0,$$

$$\text{subject to } p_1(1-\sigma)x_1 + p_2x_2 + z = m,$$

$$x_1 \geq 0,\ x_2 \geq 0,\ z \geq 0.$$

Using the Lagrangian and solving the problem by assuming λ as the Lagrange multiplier, the following conditions are obtained:

$$\lambda(1-\sigma)p_1 = \alpha x_1^{\alpha-1} x_2^{\beta} z^{\gamma}, \tag{4}$$

$$\lambda p_2 = \beta x_1^{\alpha} x_2^{\beta-1} z^{\gamma}, \tag{5}$$

$$\lambda = \gamma x_1^{\alpha} x_2^{\beta} z^{\gamma-1}, \tag{6}$$

$$m - p_1(1-\sigma)x_1 - p_2x_2 - z = 0. \tag{7}$$

From the first-order conditions of the utility maximization problem, the demand functions for the respective goods are:

$$x_1 = \frac{\alpha m}{(\alpha+\beta+\gamma)(1-\sigma)p_1}, \tag{8}$$

$$x_2 = \frac{\beta m}{(\alpha+\beta+\gamma)p_2}, \tag{9}$$

$$z = \frac{\gamma m}{(\alpha+\beta+\gamma)}. \tag{10}$$

Furthermore, when we consider the case of the carbon point system, the maximization problem becomes the following:

$$\max\ U(x_1, x_2 + \hat{x}_2, z) = x_1^{\alpha}(x_2 + \hat{x}_2)^{\beta} z^{\gamma},$$

$$\alpha > 0,\ \beta > 0,\ \gamma > 0,$$

$$\text{subject to } p_1x_1 + p_2x_2 + z = m,$$

$$\tau p_1x_1 = p_2\hat{x}_2,\ x_1 \geq 0,\ x_2 \geq 0,\ z \geq 0.$$

The first-order conditions follow:

$$\lambda p_1 = \frac{\tau p_1 \beta x_1^{\alpha}\left(x_2 + \frac{\tau p_1 x_1}{p_2}\right)^{\beta-1} z^{\gamma}}{p_2} + \alpha x_1^{\alpha-1}\left(x_2 + \frac{\tau p_1 x_1}{p_2}\right)^{\beta} z^{\gamma}, \tag{11}$$

$$\lambda p_2 = \beta x_1^{\alpha}\left(x_2 + \frac{\tau p_1 x_1}{p_2}\right)^{\beta-1} z^{\gamma}, \tag{12}$$

$$\lambda = \gamma x_1^{\alpha}\left(x_2 + \frac{\tau p_1 x_1}{p_2}\right)^{\beta} z^{\gamma-1}, \tag{13}$$

$$m - p_1x_1 - p_2x_2 - z = 0. \tag{14}$$

The demand functions for each good are the following:

$$x_1 = \frac{\alpha m}{(\alpha + \beta + \gamma)(1 - \tau)p_1}, \tag{15}$$

$$x_2 = \frac{(\beta - \alpha\tau - \beta\tau)m}{(\alpha + \beta + \gamma)(1 - \tau)p_2}, \tag{16}$$

$$\hat{x}_2 = \frac{\alpha\tau m}{(\alpha + \beta + \gamma)(1 - \tau)p_2}, \tag{17}$$

$$z = \frac{\gamma m}{(\alpha + \beta + \gamma)}. \tag{18}$$

Here, $x_2 + \hat{x}_2 = \frac{\beta m}{(\alpha + \beta + \gamma)p_2}$. This equation becomes the same as Eq. (9).

Finally, we consider the profit maximization problem of the firm which is a producer. Assuming a cost function $C_i(X_i)$, the profit is provided as follows:

$$\Pi_i = p_ix_i - C_i(x_i), \quad i = 1,2. \tag{19}$$

Therefore, the first order condition of the profit maximization is the following:

$$p_i = C_i'(x_i). \tag{20}$$

As presented in Eq. (20), $C_i'(x_i)$ is the inverse function of the supply. Additionally, we presume the cost function as $C_i'(x_i)>0$, $C_i''(x_i)>0$.

We consider the comparative statics in the inner solution. We use the result described above and consider the respective influences of a subsidy system and the carbon point system. From Eq. (8), the following result is provided using the implicit function theorem:

$$\frac{dx_1}{d\sigma} = \frac{\alpha m C_1'(x_1)}{(1 - \sigma)\left[(\alpha + \beta + \gamma)(1 - \sigma)C_1'(x_1)^2 + \alpha m C_1''(x_1)\right]} > 0. \tag{21}$$

Using Eq. (15), we have the following relations:

$$\frac{dx_1}{d\tau} = \frac{\alpha m C_1'(x_1)}{(1 - \tau)\left[(\alpha + \beta + \gamma)(1 - \tau)C_1'(x_1)^2 + \alpha m C_1''(x_1)\right]} > 0. \tag{22}$$

Therefore, Eqs.(21) and (22) show a positive effect of the goods for environment when using a subsidy and carbon point system. Subsidy σ does not affect x_2 or z ; τ does not affect $x_2 + \hat{x}_2$ or z.

Based on the results described above, σ and τ show a similar effect on x_1: no difference is found for the effects.

3.2.2 The case of a corner solution

We next examine a situation considering the case of a corner solution. We assume x_2 as the public transport use and consider the case in which the consumer uses no public transport or use no public transport expressly at its usual cost. We assess the problem of utility maximization, assuming $x_2 = 0$, given only a small demand for the second good.

$$\max U(x_1, \hat{x}_2, z) = x_1^{\alpha}\hat{x}_2^{\beta}z^{\gamma}, \quad \alpha > 0,\ \beta > 0,\ \gamma > 0,$$

subject to $p_1x_1 + z = m, \quad \tau p_1x_1 = p_2\hat{x}_2,$

$$x_1 \geq 0,\ z \geq 0.$$

Solving this problem, the first-order conditions are the following:

$$\lambda p_1 = \alpha x_1^{\alpha-1}\left(\frac{\tau p_1 x_1}{p_2}\right)^{\beta} z^{\gamma} + \beta x_1^{\alpha}\left(\frac{\tau p_1 x_1}{p_2}\right)^{\beta-1} z^{\gamma}\left(\frac{\tau p_1}{p_2}\right), \tag{23}$$

$$\lambda = \gamma x_1^{\alpha}\left(\frac{\tau p_1 x_1}{p_2}\right)^{\beta} z^{\gamma-1}, \tag{24}$$

$$m - p_1x_1 - z = 0. \tag{25}$$

The demand functions are as shown below:

$$x_1 = \frac{(\alpha + \beta)m}{(\alpha + \beta + \gamma)p_1}, \tag{26}$$

$$\hat{x}_2 = \frac{(\alpha + \beta)\tau m}{(\alpha + \beta + \gamma)p_2}, \tag{27}$$

$$z = \frac{\gamma m}{(\alpha + \beta + \gamma)}. \tag{28}$$

Here, from Eq. (27), we consider the effect of τ on $\hat{x}_2$.

$$\frac{d\hat{x}_2}{d\tau} = \frac{(\alpha + \beta)mC'(\hat{x}_2)}{(\alpha + \beta + \gamma)C'(\hat{x}_2)^2 + (\alpha + \beta)m\tau C''(\hat{x}_2)} > 0. \tag{29}$$

In the inner solution case, only the first type of goods x_1 increases. However, the demand for the second type of goods increases with τ at the corner solution as described above. Therefore, from Eq. (29), probably the effect encourages a switching to public transport use. The reason is that the purchase of goods corresponding to the environment helps save carbon points for traffic IC cards related to the introduction of a point system, which are thereafter used as public transport fees. Eventually, this measure reduces CO_2 emissions.

The result that energy consumption (CO_2 emission) decreases when technology increases is also implied in the corner solution. Therefore, the carbon point system shows an incentive to emission reduction as a policy.

The difference between the subsidy and carbon point system is that, with the latter, there is an increase in the demand of exchangeable goods. Similarly, in this system, there is an incentive for pollution abatement because of an increase in the second good. Consequently, the demand for the second type of good (such as train, subway) increases with the carbon point rate. If the government raises the tax rate to cover the expenditure for the carbon points, then the consumption of z decreases because the disposable income falls. Consequently, the CO_2

emission might decrease. However, an augmentation of the demand for the second type of goods necessitates a good maintenance of the infrastructure.

3.3 Effects of environmental technology cooperation

Next, we analyze the case involving transfer of environmental technology, where environmental technology cooperation is adopted in Fukuoka and Busan Metropolitan Cities.

Here, we assume the output of a certain sector as Y and set the production function as follows:

$$Y = AF(K,Z) = AK^{\varepsilon}Z^{\eta}, \tag{30}$$

$$0 < \varepsilon < 1,\ 0 < \eta < 1,\ \varepsilon + \eta \leq 1,$$

where A is the production technology in the sector. In F(K, Z), K is capital and Z is energy.

We assume a cost to affect production C and consider the following problem of cost minimization:

$$\min C = rK + bZ\,, \tag{31}$$

$$\text{subject to } Y = AK^{\varepsilon}Z^{\eta}.$$

We set the Lagrangian and presume that K* and Z* satisfy the first-order conditions in K and Z. Assuming that λ is the Lagrange multiplier, the first-order conditions will be the following:

$$r = \varepsilon\lambda AK^{\varepsilon-1}Z^{\eta}, \tag{32}$$

$$b = \eta\lambda AK^{\varepsilon}Z^{\eta-1}, \tag{33}$$

$$Y - AK^{\varepsilon}Z^{\eta} = 0, \tag{34}$$

where r and b are each a given factor price. From Eqs. (32), (33) and (34), K* and Z* are the following equations:

$$K^{*} = \frac{\varepsilon b\left(\frac{Y}{A}\right)^{\frac{1}{\varepsilon+\eta}}\left(\frac{\varepsilon b}{\eta r}\right)^{-\frac{\varepsilon}{\varepsilon+\eta}}}{\eta r}, \tag{35}$$

$$Z^{*} = \left(\frac{Y}{A}\right)^{\frac{1}{\varepsilon+\eta}}\left(\frac{\varepsilon b}{\eta r}\right)^{-\frac{\varepsilon}{\varepsilon+\eta}}. \tag{36}$$

Therefore, the following cost function is given:

$$C\left(\frac{Y}{A}\right) = rK^{*} + bZ^{*}. \tag{37}$$

From Eq. (37), we can introduce the properties of the cost function as:

$$C'\left(\frac{Y}{A}\right) = \frac{b\left(\frac{Y}{A}\right)^{\frac{1}{\varepsilon+\eta}-1}\left(\frac{\varepsilon b}{\eta r}\right)^{-\frac{\varepsilon}{\varepsilon+\eta}}}{\eta} > 0, \tag{38}$$

$$C''\left(\frac{Y}{A}\right) = \frac{b\left(\frac{Y}{A}\right)^{\frac{1}{\varepsilon+\eta}-2}\left(\frac{\varepsilon b}{\eta r}\right)^{-\frac{\varepsilon}{\varepsilon+\eta}}\left(\frac{1}{\varepsilon+\eta}-1\right)}{\eta} > 0. \tag{39}$$

Here, we consider the profit maximization problem:

$$\pi = PY - C\left(\frac{Y}{A}\right), \tag{40}$$

where P is the output price.
The supply function is given as shown below:

$$P = \frac{C'\left(\frac{Y}{A}\right)}{A}. \tag{41}$$

Using the implicit function theorem, we have the following:

$$\frac{\partial Y}{\partial A} = \frac{-C'\left(\frac{Y}{A}\right) + A^{2}C''\left(\frac{Y}{A}\right)Y}{C''\left(\frac{Y}{A}\right)}, \tag{42}$$

where $\frac{\partial Y}{\partial A}$ is positive if the numerator is positive and it is negative if the numerator is negative.

We assume the demand function as D(P), the reverse demand function becomes $D^{-1}(Y)$. From Eq. (41), we obtain the following equation:

$$D^{-1}(Y) = \frac{C'\left(\frac{Y}{A}\right)}{A}. \tag{43}$$

From the implicit function theorem in Eq. (43), we have the equation shown below:

$$\frac{\partial Y}{\partial A} = \frac{C'\left(\frac{Y}{A}\right) - A^{2}C''\left(\frac{Y}{A}\right)Y}{A^{2}\frac{dD^{-1}(Y)}{dY} - C''\left(\frac{Y}{A}\right)}. \tag{44}$$

Therefore, in Eq. (44) the relations in the parenthesis of the numerator determine the technical influence when $\frac{dD^{-1}(Y)}{dY} < 0$. When technology A rises, assuming the term in the parenthesis is positive, then the output Y rises.

In addition, assuming that the output is constant, using Eqs. (32), (33) and (34), the increased effect of technology on Z* is given as follows:

$$\frac{\partial Z^{*}}{\partial A} = -\frac{K^{\varepsilon}Z^{\eta}}{\frac{AK^{\varepsilon}Z^{\eta-1}(Kr + bZ)\eta}{bZ(1-\varepsilon) + Kr\eta}} < 0. \tag{45}$$

If the technology increases when the output is constant, then the energy consumption falls. Moreover, because of an emission reduction effect, Z* decreases if $\frac{\partial Y}{\partial A}$ is small.

We obtain the equation below if the output Y is not constant:

$$\frac{\partial Z^{*}}{\partial A} = -\frac{K^{\varepsilon}Z^{\eta} - \frac{\partial Y}{\partial A}}{\frac{AK^{\varepsilon}Z^{\eta-1}(Kr + bZ)\eta}{bZ(1-\varepsilon) + Kr\eta}}. \tag{46}$$

When the technology is low in a certain area, Z* falls through the increasing technology by technology transfer in certain sector.

When technology A is constant, we can examine the effect of Z* on Y using Eqs. (32), (33) and (34):

$$\frac{\partial Z^*}{\partial Y} = \frac{1}{\dfrac{AK^{\varepsilon}Z^{\eta-1}(Kr + bZ)\eta}{bZ(1-\varepsilon) + Kr\eta}} > 0. \qquad (47)$$

If the output Y increases, then Z* increases.

Up to the point, we have presented analysis of a transfer of manufacturing technologies. However, we can also assume that a transfer of CO_2 abatement technology has taken place that has lasted up until now.

Here, we assume the reverse demand function as:

$$P(Y,q) = h + \mu q - \theta Y, \quad h > 0, \quad \mu > 0, \quad \theta > 0, \qquad (48)$$

where q represents the CO_2 abatement in a sector; then h, μ and θ are the parameters. Consequently, $C^q(q,\varphi)$ is the abatement cost, which we define as:

$$C^q(q,\varphi) = \frac{q^2}{2\varphi}, \qquad (49)$$

where φ represents the abatement technologies.

The producer's problem of profit maximization can be considered as the following:

$$\max \ \pi = (h + \mu q - \theta Y)Y - C\left(\frac{Y}{A}\right) - \frac{q^2}{2\varphi}.$$

For solving this problem, when the firm chooses Y and q, the first-order conditions are as follows:

$$\frac{\partial \pi}{\partial Y} = h + \mu q - 2\theta Y - \frac{C'\left(\frac{Y}{A}\right)}{A} = 0, \qquad (50)$$

$$\frac{\partial \pi}{\partial q} = \mu Y - \frac{q}{\varphi} = 0. \qquad (51)$$

Here, because we examine the effect of φ on Y and q, we conduct a comparative statics analysis. From Eqs. (50) and (51), assuming that the production technology is constant, we introduce the following equations:

$$\frac{dY}{d\varphi} = \frac{A^2\mu q}{\varphi\left(2A^2\theta - A^2\mu^2\varphi + C''\left(\frac{Y}{A}\right)\right)}. \qquad (52)$$

$$\frac{dq}{d\varphi} = \frac{2A^2\theta q + qC''\left(\frac{Y}{A}\right)}{\varphi\left(2A^2\theta - A^2\mu^2\varphi + C''\left(\frac{Y}{A}\right)\right)}, \qquad (53)$$

When $2\theta > \mu^2\varphi$, then, $\frac{dY}{d\varphi} > 0$ and $\frac{dq}{d\varphi} > 0$. However, when $2\theta < \mu^2\varphi$, with $C''\left(\frac{Y}{A}\right) > A^2(\mu^2\varphi - 2\theta)$, then, Y and q increase with φ. If the abatement technology increases under a certain condition, then the output and abatement rise. Through environmental technology, a mutual transfer of emission reduction technology has merit to some extent for some sectors.

Finally, from Eqs. (50) and (51), we can draw Figures 3 and 4, and examine the effects on the output and CO_2 abatement (Eqs. (52) and (53)). In Figure 3, we take the marginal abatement cost (MAC) and μY in the vertical axis and the abatement in the horizontal axis.

We assume MAC_0 as the marginal abatement cost curve before the transfer of emission reduction technology and MAC_1 as the marginal abatement cost curve after the technology transfer. From Eq. (51), q is determined when MAC = μY. μY becomes a horizontal line. In the figure, μY_1 shows the additional revenue gained by increased q.

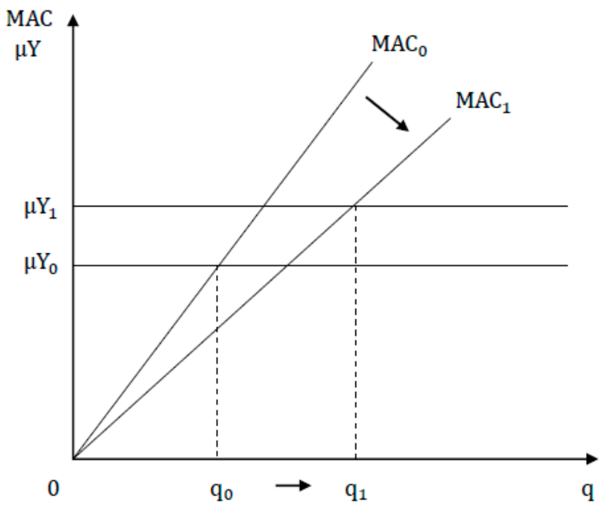

Fig. 3 Effect on the CO_2 abatement.

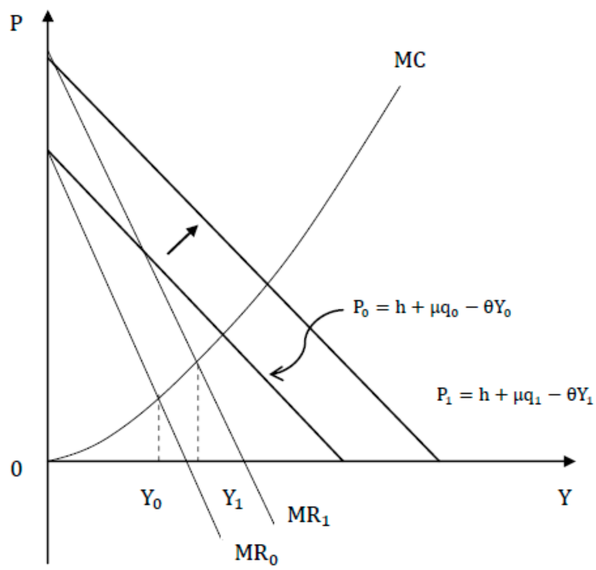

Fig. 4 Effects on the output.

The price increases from μY_0 to μY_1 and the abatement q increases from q_0 to q_1. If the emission reduction technology increases, then the marginal abatement cost decreases, and the abatement increases. For example, the abatement will increase because the marginal abatement cost decreases with the occurrence of technology transfer of the emission reduction technology.

In addition, the output price is shown on the vertical axis in Figure 4 and the output on the horizontal axis. We assume MC as the marginal cost curve and MR as the marginal revenue curve. When abatement increases, the demand curve $P = h + \mu q - \theta Y$ and the marginal revenue curve shift upwards, showing that the output rises with the occurrence of technology transfer of the abatement technology.

3.4 Summary of this section

We analyzed a carbon point system and the influence of technology transfer using an economic model as described above. Our results show the possibility of a switch in public transport use: CO_2 emission reduction can be encouraged by introducing carbon point systems into a traffic IC card using a method to charge carbon points. Furthermore, in both cities, CO_2 emission reduction effects increased by transfer of the technology, which was a comparative advantage for each. These analyses clarified, to some degree, that technology transfer can be an effective policy to achieve a low carbon society.

4. Waste Management Systems Contributing to Lower Carbon

4.1 Comparison of waste treatment systems in Fukuoka and Busan

Traditionally, waste treatment has been administered for public sanitation purposes. Today, because sanitary conditions have been greatly improved, the contribution of waste treatment as a public sanitation improvement measure is not evaluated so often[13)]. Evaluation of waste treatment systems in recent years has centered upon waste reduction, recycling rate improvement, and reduction of final disposal volume to realize a recycling-oriented society. Moreover, emphasis has been placed increasingly on achieving a good balance between achieving a recycling-oriented society and a low carbon society. Establishment of a waste treatment system that functions with low energy consumption and low CO_2 emissions is desired. This section presents a comparative analysis of general waste treatment systems' contribution to carbon emissions reduction in Fukuoka, Japan, and Busan, Korea.

4.1.1 Differences in MSW (municipal solid waste) treatment between Fukuoka and Busan

Tables 3 and 4 show the MSW treatment volumes in the two cities broken down by treatment process (recycling, incineration, landfill). As Table 3 shows, the rate of incineration in Fukuoka in 2008 was 82.9%,

Table 3 Breakdown of MSW treatment volume in Fukuoka

Year	Recycling		Incineration		Landfill		Total	
2001	85	(3.5)	1,876	(78.4)	432	(18.1)	2,392	(100.0)
2002	73	(3.0)	1,914	(78.7)	444	(18.3)	2,430	(100.0)
2003	78	(3.0)	2,032	(78.7)	471	(18.3)	2,581	(100.0)
2004	82	(3.2)	2,061	(81.4)	390	(15.4)	2,533	(100.0)
2005	76	(2.8)	2,040	(75.7)	578	(21.4)	2,694	(100.0)
2006	66	(2.6)	2,007	(79.8)	443	(17.6)	2,516	(100.0)
2007	58	(2.5)	1,912	(81.6)	372	(15.9)	2,343	(100.0)
2008	51	(2.3)	1,828	(82.9)	326	(14.8)	2,205	(100.0)

(Unit: tons/day. Figures in ( ) represent percentages)

Source: Environmental Bureau of Fukuoka City: Created from the Collection of Data on the Environment and MSW in Fukuoka 2009

Table 4 Breakdown of MSW treatment volume in Busan

Year	Recycling						Incineration		Direct landfill		Total	
	Glass bottles, can, paper, plastic, PETbottles, etc		Kitchen garbage		Subtotal							
2001	1,530	(37.7)	680	(16.8)	2,210	(54.5)	506	(12.5)	1,337	(33.0)	4,053	(100.0)
2002	1,531	(38.0)	663	(16.4)	2,194	(54.4)	473	(11.7)	1,364	(33.8)	4,031	(100.0)
2003	1,539	(38.7)	670	(16.8)	2,209	(55.5)	803	(20.2)	1,201	(30.2)	3,980	(100.0)
2004	1,546	(40.5)	700	(18.3)	2,246	(58.9)	706	(18.5)	863	(22.6)	3,815	(100.0)
2005	1,550	(42.1)	880	(23.9)	2,430	(66.0)	724	(19.7)	526	(14.3)	3,680	(100.0)
2006	1,551	(42.9)	789	(21.8)	2,340	(64.7)	719	(19.9)	560	(15.5)	3,619	(100.0)
2007	1,552	(43.6)	781	(21.9)	2,333	(65.5)	721	(20.2)	509	(14.3)	3,563	(100.0)
2008	1,484	(44.0)	817	(24.2)	2,301	(68.3)	733	(21.7)	337	(10.0)	3,371	(100.0)

(Unit: tons/day. Figures in ( ) represent percentages)

Source: Environment Bureau of Busan City: Created from Environment White Paper of Busan City 2005 and 2008 meaning that nearly all MSW was incinerated. The city's recycling rate was 2.3% and the landfill rate was 14.8% in 2008.

In BMC, the recycling rate increased from 54.5% in 2001 to 68.3% in 2008. The recycling rate of glass bottles, cans, paper, plastic, PET bottles, etc. was 44%; that of kitchen garbage was 24.2%. Conversely, the rate of direct landfill volume decreased from 33%–10% during the same period. The rate of incineration was 21.7% in 2008. The total volume treated decreased by approximately 17% from 4,053 tons/day in 2001 to 3,371 tons/day in 2008.

The tables show a major difference between Fukuoka and Busan: most waste treatment in Fukuoka is conducted through incineration, although a large part of waste treatment in Busan is accomplished through recycling.

4.1.2 CO_2 reduction measures in MSW treatment in Fukuoka and Busan

(1) CO2 reduction efforts in MSW treatment in Fukuoka

Waste treatment generally consists of three processes: collection and transportation, intermediate treatment, and final disposal. What is considered an effective measure for reducing CO_2 emissions in this system is reduction of waste generation itself because it reduces CO_2 reduction effects in all three processes. Fukuoka City started charging for garbage bags in 2005. The aim of the new system was to: 1) clarify the responsibility of people who generate waste, 2) allocate the burden fairly, and 3) create opportunities for proactive waste reduction and recycling behavior. As Table 3 shows, the MSW treatment volume in Fukuoka decreased during 2005–2008, indicating that charging for garbage bags had a certain effect on reducing waste generation.

Next, in intermediate treatment, one effective CO_2 reduction measures is waste power generation: generating power by recovering energy from garbage incineration. Waste power generation has advantages such as 1) adding no additional environmental load at the time of power generation, 2) constituting a stable source of electric power that can be obtained continuously, and 3) being a dispersed power system that is directly connected to the area demanding electric power—albeit a small-scale power generation system[14]. Fukuoka has four waste incineration plants: The Rinkai plant, Toubu plant, Seibu plant, and Nanbu plant, each of which generates electricity from waste incineration. The electricity obtained from waste power generation is used to operate the plants; surplus electricity is sold to the power company. In addition, part of the steam produced for use in power generation is used for indoor cooling/heating and heating water at the plants. The quantity of electricity generated every year at the waste incineration plants in Fukuoka is approximately 270 million kWh (electricity produced in 2007); the reduction of CO_2 emissions from waste power generation is estimated at around 100,000 tons. This amount is equivalent to the quantity of CO_2 discharged from around 40,000 general households in Fukuoka for a year[15].

Table 5 Waste power generation capabilities of waste incineration plants in Fukuoka

Incineration plant	Generation capability (kW)
Rinkai	25,000
Toubu	29,200
Seibu	10,000
Nanbu	5,000
Total	69,200

Source: Environmental Bureau of Fukuoka City website[15]

The last process of MSW treatment is final disposal. The final disposal sites in Fukuoka adopt a semi-aerobic landfill method (Fukuoka method). This landfill method was developed jointly by Fukuoka University and Fukuoka City in the early 1970s. In this method, leachate collection pipes are installed at the bottom of a landfill site to remove leachate from the landfill site system as quickly as possible and to prevent leachate from remaining within the landfilled waste layer. The system promotes aerobic decomposition of waste by sending air from the leachate collection pipes to the inside of the landfill site using natural ventilation[16]. Compared with the anaerobic landfill method, the Fukuoka method is a low carbon technology that enables reduction of methane gas emissions and reduction of energy consumption for management because of the shortened maintenance time.

(2) CO_2 reduction efforts in MSW treatment in Busan

Although Korea mainly pursued a landfill policy until around 1990, it laid out a policy for a changeover from landfill disposal to incineration because of the difficulty of constructing new landfill sites. The Korean Ministry of Environment had planned to build 13 incineration plants in Seoul and 47 incineration plants in Busan and other regional cities and new cities during 1992–2001. Incineration did not become widespread, however, many residents were opposed to the construction of incineration plants because of insufficient examination of waste properties, possible discharge of dioxins, environmental impact such as a relation with recycling policies, economic efficiency, and consistency with other policies[17]. One factor was that Korean garbage is unsuitable for incineration because 30–40% of Korean waste comprises kitchen garbage. It has been pointed out that preparing *kimchi* produces much waste. Furthermore, many leftovers are created because of different eating habits by preparing more food than is required. Such garbage is deemed unsuitable for incineration[18]. After the revision of the Waste Management Act in 1997, the use of raw garbage in landfill was to be banned following a moratorium of nine years. The revised act stipulated that only the residue of raw garbage after preprocessing such as incineration, composting, use as animal feed, and microbial cleavage can be buried. This marked a turning point for working on the recycling of raw garbage.

The MSW treatment policy of BMC is fundamentally administered based on the national policy. When considering this policy, the trend in Seoul is important. When a new technology or system introduced to Seoul proves successful, other municipalities such as Busan often begin to examine the introduction of the same technology or system. In contrast, if something proves to be unsuccessful in Seoul, then other municipalities do not consider adopting it.

What characterizes waste treatment in BMC is the recycling of raw garbage. Table 6 presents a breakdown of raw garbage treatment in 2005. In BMC, where 931 tons of raw garbage are treated daily, 817 tons (88%) are recycled through conversion of the garbage into animal feed (59.7%), composting (24.4%), or methane fermentation (10.4%). Separation of raw garbage in BMC was started in 2002. Raw garbage is placed in buckets for collection, usually using three-liter buckets for a free-standing house and a 120-liter bucket for an apartment unit. Garbage collection takes place three times per week. People must buy a plastic token (at a metered rate) for garbage collection. Although garbage was often not separated efficiently until around 2005, 80–90% of all garbage is now separated properly as a result of instructions such as not to collect garbage that was not properly separated.

Table 6 Breakdown of raw garbage treatment in Busan

	2005	
Animal Feed	556	(59.7)
Composting	227	(24.4)
Methane fermentation	97	(10.4)
Landfill	0	(0.0)
Incineration	51	(5.5)
Total	931	(100.0)

(Unit: tons/day. Figures in ( ) indicate percentages)
Source: Environmental Bureau of Busan City: Environment White Paper of Busan City 2005

Regarding MSW treatment in BMC, an especially effective measure for CO_2 reduction is methane fermentation of raw garbage. Actually, BMC has two methane fermentation facilities that use garbage as the raw material, one of which is the Busan Food Waste Recycling and Power Generation Plant. At this plant, anaerobic digestion treatment processing is applied to raw garbage, methane gas is collected, and power is generated. The digested sludge is composted. The digestive fluid is discharged into sewerage lines after primary treatment. The treatment amount as of September 2009 is 170 tons/day (treatment capacity is 200 tons/day), and the power generation from methane is 1400 kW, 30% of which is consumed within the plant. The remaining 70% is sold to the power company. At another raw garbage treatment plant (with treatment capacity of 120 tons/day) owned by the Busan Environmental Corporation, methane fermentation is conducted in cooperation with a sewage treatment plant. In this system, raw garbage and sewage sludge are mixed for methane fermentation. Then the digested fluid is treated at the sewage treatment plant.

To conclude, this explanation described how final disposal is conducted in BMC. Landfill at the Saeng-gok Landfill Site—the only final disposal site in BMC—started in 1996. At the site, landfill is permitted until 2041 under an agreement with local residents, but its capacity is sufficiently large to accept landfill until 2100. This site has two landfill zones: The first-term zone is almost finished; the second-term zone is under construction. The first-term zone adopts an anaerobic landfill method. Its surface is covered by a geomembrane cap. Methane gas generated inside the landfill is collected and used for power generation. However, because the burial of raw garbage has not been permitted in recent years, the amount of methane gas recovered has been decreasing. The second-term landfill zone, which is now under construction, uses a semi-aerobic landfill method like the Fukuoka method. At the Saeng-gok Landfill Site, where raw garbage has been buried with no treatment to collect methane gas, the system has been converted to one with raw garbage recycling; only the residue is disposed of using the semi-aerobic landfill method.

4.2 Benefits and applicability of food waste utilization systems in Fukuoka City

In Fukuoka City, as presented in Table 7, about 400 tons per day of food wastes are generated and incinerated as combustible waste of municipal solid waste (MSW)[19,20]. Food waste is a useful biomass of urban areas. It would be available as an energy source if it could be collected separately. Furthermore, food waste from business activities must be recycled according to the Act Concerning the Promotion of Utilization of Recyclable Food Waste (Food Recycling Law). Therefore, in designing a low carbon society, these biomass resources should be considered positively for their effective use.

In this section, we describe benefits and applicability of food waste utilization systems, such as the utilization model of BMC, in Fukuoka City.

Table 7 Amount of Food Waste Generation in Fukuoka City

Combustible household MSW	270,321	t/year
Combustible business activities MSW	252,573	t/year
Total combustible MSW	522,894	t/year
Composition ratio of misc. combustible MSW*	29.70%	
Misc. combustible MSW	155,300	t/year
≒	425	t/day

*It is highly possible that food waste is contained misc.combustible MSW.
Source: Fukuoka City[19,20]

4.2.1 Availability of urban biomass utilization systems

Characteristics of urban biomass utilization are presented in Table 8, which shows the utilization types as “urban” and “suburban” such as agricultural areas.

Table 8 Characteristics of biomass utilization

	Urban area	Suburban area
Main industry	commerce and industry	agriculture, forestry and fisheries
Biomass resources	food-processing waste, kitchen waste, bamboo felling, construction wood waste, sewage sludge, etc.	paddy straw, livestock excreta, thinned wood, lumber residue, sludge of Johkasoh, etc.
Infrastructure etc.	waste incineration plant, sewage-treatment plant, sewage system, utility gas supply system, etc.	agricultural land, forest land, pasture, orchard, etc.
Usage	feedstuff, fertilizer, compost, briquette fuel, generating electricity, etc.	biogas (methane-gas), biodiesel, bioplastic, generating electricity, etc.

Source: S. Matsuda[22)]

Existence of unused biomass resources

An urban environment produces various biomass resources such as construction waste, wastepaper, sewage sludge, and so on along with food waste. Most such resources are usually not available for effective use.

Reduction of initial costs

It is possible to reduce initial costs of introduction on biomass energy conversion facilities using urban infrastructure. For example, conventional incinerators and anaerobic digesters for sewage treatment are useful as energy plants and biogas reactors.

Existence of various usage patterns on biomass energy

The biomass utilization of urban types presents advantages in terms of energy efficiency compared with suburban types because urban areas have various patterns of energy use. It is considered that biomass energy use in BMC represents highly efficient utilization because the biogas (methane gas emitted from food waste) is used without conversion into heat or electricity, with low conversion efficiency. Wider usage of biomass energy is achievable if such usage were adopted. For example, gas is useful as fuel for natural gas vehicles, utility gases after calorie control, injection into gas mains, and so on. Especially, the number of cases in which it has been used as a utility gas has increased gradually since fiscal year 2009[21)].

4.2.2 Problems and merits of urban-type utilization in biomass conversion of food waste

Several issues must be resolved before introduction of biomass conversion (methane fermentation) of food waste, including adjustment of moisture contents (dilution) before introduction into a methane fermentation tank, and securing proper destinations for utilization of fermentation residue (digested sludge) and liquid (digested slurry).

One might use groundwater for water addition described above. When that water is unavailable, tap water will do, but it presents higher costs. Regarding the latter in the example presented above, they are usually returned to soil as compost or liquid fertilizer. Waste liquid treatment is unavoidable if such soil is unavailable. A sophisticated means of waste liquid treatment is necessary if wastewater from the treatment plant flows into a river. In turn, it incurs a high running cost. Therefore, groundwater is indispensable when waste liquid treatment must be introduced.

If sewage and food waste are processed in the same wastewater treatment plant, as is true in BMC, then most of the problems described above disappear. Municipal discharge is available to dilution water, and fermentation residue and digested slurry might be sent to a wastewater treatment plant in the Busan system. Although this type of system imposes an additional load on wastewater treatment plants, it might be mitigated by restricting the waste foods that are introduced to raw garbage to fruits and vegetables, which are readily degraded.

4.2.3 Does it work in Fukuoka City?

It might take some time for the food garbage collected from the whole area of Fukuoka City to be sent to an anaerobic digester. Problems related to the treatable volume of garbage might arise, along with problems related to engineering and technology. A gradual approach to such a system can be considered if such is the case. Wholesale markets and school catering businesses are convenient locations to start such operations because food wastes can be collected there efficiently for that approach.

A survey conducted in Kitakyushu City (a government-ordinance-designated city like Fukuoka City)[22)] revealed that 10 tons or more of raw garbage of fruits and vegetables (proper food waste for methane fermentation) can be collected daily from wholesale markets and neighboring food-processing factories. That much garbage generates about 600 m^3 of methane gas, assuming that one ton of raw garbage generates 100 m^3 of biogas (breakdown: 60% methane gas and 40% CO_2)[23)]. Furthermore, if used for natural gas automobiles, then this much methane gas derived from biogas can obviate about 840 tons of CO_2 emitted from combustion of fossil fuels.

Fukuoka City is running five sewage-treatment plants with 12 series of anaerobic digesters[24)]. Use of the raw garbage of fruit and vegetables from wholesale markets described in the preceding paragraph is advisable as an introductory approach to biogas generation systems from food waste in Fukuoka City, although it depends on the operational status of markets. Such a system might expand its extent of collection in addition to wholesale markets, to food waste from households if extension and awareness of systems were promoted, with progressive expansion to incorporate garbage from school catering businesses and MSW from business activities controlled by the Food Recycling Law of the central government.

5. Law and Regulation Establishing for Low Carbon Society

5.1 Positioning "low carbon society" in environmental law

No law or regulation in Japan defines a "low carbon society" explicitly. However, that language appears quite often in governmental policies and plans. It has remained a main theme of the state environmental strategy of Japan, especially after the conclusion of the Kyoto Protocol[25,26]. Today, it is embraced as one of the three state visions of a sustainable society toward a century of the environment, the other two being a sound material-cycle society, and a society in harmony with nature[26].

The Strategy for an Environmental Nation in the 21st Century – Japan's Strategy for a Sustainable Society (June 2007), for example, defines a "low carbon society" as one in which global emissions of GHGs (greenhouse gases) are balanced by the capability of nature to absorb them, by drastically reducing emissions derived through fossil fuel consumption. These measures must support our abundant lifestyles while maintaining atmospheric GHG concentrations at a level that does not exacerbate adverse climate change. In addition, to be specific, it proposes innovative change of our life styles and social systems to realize a "low carbon society" lifestyle that is in harmony with nature, appreciating forests, efficient commuting using public transportation, and compact urban development. Accordingly, fostering "low carbon society" targets as national goals not only reduces GHG emissions but also clarifies the task of enlarging our wide horizon by changing our economic system and social life.

However, the popular trend of implementation of measures is reflected in reduction of GHG emissions[27]. In the wake of the Kyoto Protocol, the Japanese central government formulated a Law Concerning the Promotion of the Measures to Cope with Global Warming (Law No. 117 of 1998) and the Kyoto Protocol Target Achievement Plan (April 2005). Furthermore, in the Action Plan for Building a Low Carbon Society (July 2008) issued at G8 Hokkaido Toyako Summit, it proposed policies of attainment of the world's largest solar power generation project, widespread use of new-generation vehicles, introduction of emissions trading, environmental taxes and carbon offsets, and other measures to reduce current GHG emissions by 60–80% by 2050. Moreover, the Bill of the Basic Act on Global Warming Countermeasures—which includes the short-term target of 25% reduction of GHGs emission compared to that of 1990 by 2020—was submitted to the Diet in 2010.

5.2 Strategies of advanced local governments making use of local ordinances

In contrast to the trends in national administration, local governments have adopted advanced measures. In 2005, in the wake of Kyoto Protocol, Kyoto City, enforced a local ordinance to fight global warming for the first time in Japan. That year, Kyoto prefecture became the first to enforce a similar ordinance[28]. As of May 2009, 25 prefectures have enforced local ordinances; 11 are independent ordinances. Some propose highly ambitious numerical targets for GHG emissions reduction[29]. Metropolitan Tokyo obligated itself to total GHG emission reduction and an emissions trading system (Ordinance of Metropolitan Tokyo for environmental conservation) starting April 2010, which enforced cap and trade for the first time in Japan. Cap and trade systems are being introduced into the EU and countries around the world [27,30].

In the field of environmental safeguards such as pollution control, advanced policies attempted by local governments have often been ahead of those that have been implemented by the central government[31]. Such is also the case in warming countermeasures. Incidentally, marked differences in attitudes prevail in relation to warming countermeasures. For example, the city of Fukuoka and Fukuoka prefecture, discussed in this report, have established no ordinance related to warming countermeasures.

5.3 Characteristics and problems of warming countermeasure as policies of local governments

Local governments must address problems occurring in residents' daily life, only one of which involves warming countermeasures. Governments allocate funds and labor to warming countermeasures as one aspect of environmental safeguards. Because the urgency of warming issues is not visible, the scale and scope of measures against warming are apt to be influenced strongly by every local circumstance.

Additionally, warming is a global issue; the borders of administrative divisions do not recognize carbon transfers. Accordingly, reduction of GHG emissions in the city of Fukuoka, for example, does not ease warming there. Consequently, local governments have many subjects of discussion: proper allocation of resources, effective measures and policies, estimation of cost-effectiveness, and evaluation of global problems in their local policies.

Global warming is a politically charged policy matter that has been used as a bargaining tool in diplomacy, as discussed at IPCC conferences, or as a political transaction material in negotiations between central and local governments[32]. As suggested above, global warming will continue to be a political and strategic matter of central governments. Therefore, measures taken by local governments might not yield great general impacts, except for those of huge cities such as Metropolitan Tokyo.

5.4 Summary of this section: possibility of cooperation between the Fukuoka City and BMC

Although warming countermeasures taken by local governments might not be strongly influential, measures by local governments promote structural reforms of regional economies and affect the daily lives of residents in terms of a transition to a low carbon society. In this respect, warming countermeasures are aimed at the remaining two visions of Japanese society. Biomass applications, contributions to warming countermeasures by reduction, reuse, and recycling (3 Rs), and conserving GHG sinks through fostering restoration of forests and nature are examples of effective measures that local governments can pursue, taking advantage of local characteristics. In terms of space management, Fukuoka City might share natural environment space and common policies with Busan, its next door neighbor. In fact, the distance between Fukuoka and Busan is about one-fourth of that between Fukuoka and Tokyo. Despite the international boundary separating these two neighboring local governments, the potential effectiveness of their cooperation is great.

Nevertheless, any scheme of cooperation between these two cities will confront obstacles. Although it ratified the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, Korea has set no GHG emission reduction targets. It has established the Presidential Council for Sustainable Development under the direct control of the President (PCSD) to manage global warming issues. In stark contrast, local governments show little direct concern about the issue. Creating a low carbon society related to the economic growth policy of nations and establishing cross-border cooperation between two cities of different nations might surmount important obstacles to appropriate policy.

6. Concluding Remarks

This paper presented an examination of the present situations and policy issues related to GHG emissions reduction and making efforts to establish a "low carbon society" in the Fukuoka and Busan Metropolitan Cities, from several academic perspectives such as urban and regional planning, environmental economics, waste management engineering, and environmental law.

Fukuoka and Busan are closely situated sister cities that have signed a mutual agreement related to formation of a wide economic zone that includes all of Kyushu and southeastern Korea. Comprehensive environmental policies affecting these areas, especially the common targets and measures of lowering GHG with more economic interchange, should be planned and enforced in the near future. Solid wastes and useful resources should be managed properly to minimize environmental burdens in every area, which also contributes to the mitigation of global warming.

Unfortunately, such intentional integration of environmental policies between low GHG emission and more resource circulation has not been promoted at the local city level because of a fundamental lack of ideas, insufficient budgets for the respective environmental administrations, and a strict vertical administrative division of these sections (*Tate-wari* in Japanese). Moreover, it seems difficult to coordinate integrated environmental policies at the international level despite close international friendship. The existing governance of domestic laws and regulations of each country cannot be disregarded, but they could be changed according to the higher demands of international cooperation.

Our challenge for the future, the unique intercity development among Fukuoka, Busan and other cities, will produce various benefits and costs. This model must attract researchers to undertake empirical studies of economics, business, transportation, tourist, urban planning, and environmental science. This paper is the first attempt to discuss the background and prospects of international but local movements through interdisciplinary research of members residing in those areas.

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