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An Evaluation of Carbon Dioxide Emissions Trading among Enterprises —The Tokyo Cap and Trade Program—

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Abstract**—**This study aims to propose three evaluation methods to evaluate the Tokyo Cap and Trade Program when emissions trading is performed virtually among enterprises, focusing on carbon dioxide (CO_2), which is the only emitted greenhouse gas that tends to increase. The first method clarifies the optimum reduction rate for the highest cost benefit, the second discusses emissions trading among enterprises through market trading, and the third verifies long-term emissions trading during the term of the plan (2010-2019), checking the validity of emissions trading partly using Geographic Information Systems (GIS). *The findings of this study can be summarized in the following three points.*

1. Since the total cost benefit is the greatest at a 44% reduction rate, it is possible to set it more highly than that of the Tokyo Cap and Trade Program to get more total cost benefit.
2. At a 44% reduction rate, among 320 enterprises, 8 purchasing enterprises and 245 sales enterprises gain profits from emissions trading, and 67 enterprises perform voluntary reduction without conducting emissions trading. Therefore, to further promote emissions trading, it is necessary to increase the sales volumes of emissions trading in addition to sales enterprises by increasing the number of purchasing enterprises.
3. Compared to short-term emissions trading, there are few enterprises which benefit in each year through the long-term emissions trading of the Tokyo Cap and Trade Program. Only 81 enterprises at the most can gain profits from emissions trading in FY 2019. Therefore, by setting the reduction rate more highly, it is necessary to increase the number of enterprises that participate in emissions trading and benefit from the restraint of CO_2 emissions.

Keywords**—**Emissions Trading, Tokyo Cap and Trade Program, Carbon Dioxide (CO_2), Global Warming, Geographic Information Systems (GIS)

I. Introduction

A. Background and Purpose of Study

GLOBAL warming has become a serious international issue and measures to reduce greenhouse gases have been implemented on a global scale according to the World Summit 1992 Framework Convention on Climate Change and the 1998 Kyoto Protocol. In this kind of international situation, there has been focus on Emissions Trading Programs which are systems that make it possible to implement a strategic reduction of greenhouse gases from both environmental and economic standpoints. Carbon dioxide (CO_2) Emissions Trading Programs commenced in the UK in 2002 and in the EU in 2005 and, in addition to the voluntary Chicago Climate Exchange which started in 2003 in the US, implementation at local and state levels is also being planned.

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Tokyo, which has a remarkably high consumption of energy in Japan, made it compulsory for large-scale enterprises to reduce total greenhouse gas emissions from FY 2010 in addition to implementing an Emissions Trading Program and methods that allow enterprises to efficiently trade emissions are being investigated. Therefore, this study aims to propose three evaluation methods to evaluate the Tokyo Cap and Trade Program when emissions trading is performed virtually among enterprises, focusing Carbon Dioxide (CO_2), which is the only emitted greenhouse gas that tends to increase. Onishi et al. (2010) [1] point out that 95% of Tokyo's greenhouse gas emissions is CO_2 originating from energy and that it is difficult to accurately grasp emission amounts for other gases.

B. Previous Studies and the Position of this Study

Previous studies in related fields can be divided into 4 categories: (1) those on the characteristics of emissions trading such as Kimura (2002) [2] and Otani (2005) [3], (2) those on the impacts and challenges of emissions trading such as Lee (1998) [4], Wakabayashi et al. (2005) [5] and Niizawa (2009) [6], (3) those on emissions rights and emissions trading system design such as Morotomi et al. (2006) [7], Saijo (2007) [8], Ogata et al. (2007) [9] and Morotomi et al. (2010) [10], and (4) those on evaluation of emissions rights and emissions trading programs such as Hanada et al. (2008) [11], Luo et al. (2007) [12], Luo (2009) [13] and Wakabayashi (2011) [14].

This study comes under the 4th category of studies that evaluate emissions rights and emissions trading programs. In this field, Hanada et al. (2008) [11], Luo et al. (2007) [12] and Luo (2009) [13] only go as far as evaluating emissions rights trading by region or city and do not evaluate specific emissions trading by enterprise. Further, Wakabayashi et al. (2011) [14] discusses a comparison of the Tokyo Cap and Trade Program with those in the US and Europe but does not evaluate emissions trading in a quantitative manner. Therefore, this study demonstrates the originality and usefulness in the evaluation of the Tokyo Cap and Trade Program with more detailed evaluation by enterprise than the above-mentioned previous studies as target units, proposing a quantitative evaluation method partly using Geographic Information Systems (GIS)[(1)].

II. Outline of Case for Evaluation and Evaluation Framework

A. Outline of Case for Evaluation

The Planning System for Measures against Global Warming was implemented for large-scale enterprises in Tokyo in FY 2002, and voluntary and well-planned measures have been sought from businesses. In 2008, due to the revision of the Ordinance on Environmental Preservation, mandatory total

greenhouse gas emissions reduction and an emissions trading program are implemented, and the Emissions Trading Program for large-scale enterprises commenced in FY 2010 in the same way as the above-mentioned previous program.

The Tokyo Cap and Trade Program is the first emissions trading program to be implemented in Japan, and it is the first urban emissions trading program in the world to target office buildings, etc. In order to reduce the FY 2000 level greenhouse gas emissions by 25% by FY 2020, it has been made mandatory for approximately 1,300 enterprises who are high energy consumers (enterprises that use volumes of fuel, heat and electricity with a crude oil equivalent of 1,500kl or more) to reduce greenhouse gases. As shown in Fig. 1, the plan period is from FY 2010 to FY 2019 and reduction goals are 6 or 8% reduction in the first period of the plan[(2)] and approximately 17% reduction in the second period of the plan (forecast) for CO_2 emissions that are standard for each enterprise (standard emissions).

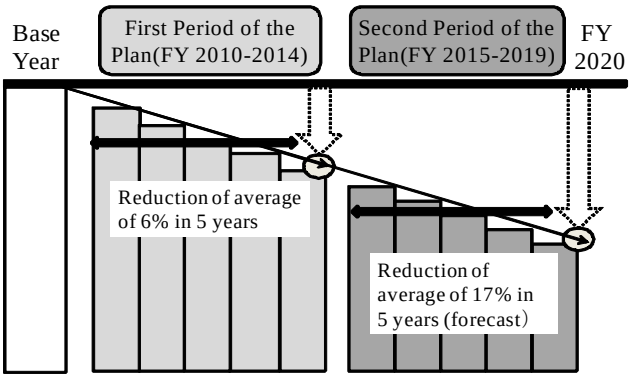

Fig. 1 Setting of Mandatory Reduction rates in the Tokyo Cap and Trade Program

Based on information from the Tokyo Metropolitan Government Environmental Bureau (2009) [15]

B. Evaluation Framework

This study proposes and assesses evaluation methods for (1) emissions trading that focuses on cost-benefit, (2) emissions trading through inter-enterprise market trading methods and (3) long-term emissions trading. (1) and (2) are eligible for evaluation as yearly short-term emissions trading. In the evaluation of (1), optimum reduction rates are demonstrated by deriving the maximum total benefits that enterprises can gain from emissions trading, and there is focus on mandatory reduction rates set by the Tokyo Cap and Trade Program. In the evaluation of (2), based on the results of the evaluation of (1), emissions trading is evaluated through inter-enterprise market trading methods that are mediated by the Climate Exchange in the above-mentioned program. In the evaluation of (3), based on the results of yearly short-term emissions trading in (1) and (2) and using GIS, long-term emissions trading in the planned period for the Tokyo Cap and Trade program is evaluated focusing on mandatory reduction rates. Specifically, reduction goals set by the program are investigated by deriving benefits obtained from emissions trading each year.

III. Evaluation Method

A. Emissions Trading focusing on Cost-Benefit

First of all, if the total number of enterprises participating in emissions trading is X, standard emissions that are the standard for each enterprise is $\bar{q}_i (i = 1,2 \cdots X)$, emissions that are the goals for standard emissions (emissions goals) is q_i^* and emissions that minimize reduction costs for all enterprises (optimum emissions) is q_i. Next, benefit π_i gained through emissions trading is calculated by assuming emissions price as P_x and the marginal abatement cost for each enterprise as MAC_i (MAC_i = 1/ basic carbon dioxide emissions unit in this study). In the case of $MAC_i > P_x$ the enterprise is a purchasing enterprise and in the case of $MAC_i < P_x$ the enterprise is a sales enterprise. Fig. 2 shows purchasing and sales enterprise's standard emissions $\bar{q}_i$, emissions goals q_i^* and optimum emissions q_i on the horizontal axis, and emissions prices P_x and marginal abatement costs MAC_i on the vertical axis.

Marginal abatement costs require diverse detailed data from each enterprise to make strictly accurate derivations and as it is very difficult to obtain this, the marginal abatement cost curve in Fig. 3 is consulted, then a marginal abatement costs curve is created with line segments of standard emissions and marginal abatement cost values, and a marginal abatement cost curve is derived for each enterprise. In addition, marginal abatement costs for all enterprises are put in order from high to low and given numbers from enterprise 1 to enterprise X. Marginal abatement costs for each enterprise MAC_i are put in order from the highest and emissions price estimates are calculated.

$$P_x = MAC_i \quad (x = i = 1,2,...,X)$$

In the calculation method for estimates, if the relationship between emissions price and emissions trading excess Per_x is demonstrated and for a certain P_x, if

$(\sum_{i=1}^{X} q_i - \sum_{i=1}^{X} q_i^*)$ increases, and approaches 0, it becomes

$$Per_x = \sum_{i=1}^{X} q_i - \sum_{i=1}^{X} q_i^* \cong 0$$

and in this way P_x is emissions price P.

Further, reduction goal rates are set at 1–50% and cost-benefit for each enterprise is calculated according to the flow chart in Fig. 4. The specific calculation method first calculates benefit π_i for the purchasing enterprise. In the process for purchasing enterprises to purchase emissions, the enterprise itself can reduce anything from standard emissions to optimum emissions and can purchase the remaining emissions

that are lacking from optimum emissions to emissions goals. If emissions trading (in the case of direct regulatory instruments) is not conducted, reduction costs become the area of the multiplication of marginal abatement cost MAC_i and $(\bar{q}_i - q_i^*)$, in other words, $MAC_i(\bar{q}_i - q_i^*)$. In the case of conducting emissions trading, reduction costs become the sum of the cost of emissions reduction $MAC_i(\bar{q}_i - q_i)$ and the cost of emissions purchasing $P_x(q_i - q_i^*)$. Benefit π_i is the cost difference between direct regulatory instruments and emissions trading, and can be expressed as

$$\pi_i(q_i) = MAC_i(\bar{q}_i - q_i^*) - \{MAC_i(\bar{q}_i - q_i) + P_x(q_i - q_i^*)\}$$
$$= MAC_i(q_i - q_i^*) - P_x(q_i - q_i^*)$$
$$= (q_i - q_i^*)(MAC_i - P_x)$$

Next the benefit π_i for sales enterprises is calculated. In the process for sales enterprises to sell emissions, the enterprise can reduce anything from standard emissions to optimum emissions by itself, and can sell the remaining emissions that are in excess from optimum emissions to emissions goals. In the case of direct regulatory instruments, reduction costs become the area of the multiplication of marginal abatement cost MAC_i and $(\bar{q}_i - q_i^*)$, in other words, $MAC_i(\bar{q}_i - q_i^*)$. In the case of emissions trading, reduction costs are calculated by subtracting profit from sales emissions $P_x(q_i - q_i^*)$ from costs incurred by reduction of excess emissions $MAC_i(\bar{q}_i - q_i)$. Benefit π_i is the difference in costs incurred from direct regulatory instruments and costs from conducting emissions trading, and can be expressed as

$$\pi_i(q_i) = MAC_i(\bar{q}_i - q_i^*) - \{MAC_i(\bar{q}_i - q_i) - P_x(q_i^* - q_i)\}$$
$$= (q_i^* - q_i)(P_x - MAC_i)$$

Therefore, total benefit for purchasing enterprises and sales enterprises is the sum of the apexes with the same shape, and can be expressed as

$$\sum_{i=1}^{X} \pi_i(q_i) = \sum_{i=1}^{X} (q_i^* - q_i)(P_x - MAC_i)$$

Further, we set conditions for purchasing enterprises to conduct trading only if they can obtain benefits by trading emissions. We also set conditions at sales enterprises with weighting conducted with reference to past emissions so that

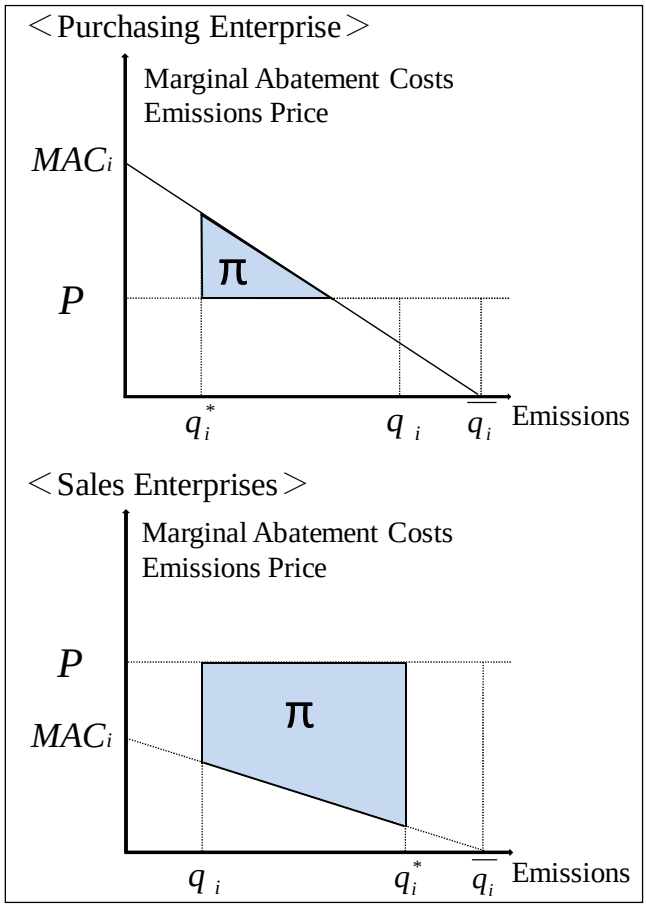

Fig. 2 Emissions Trading Benefits for Purchasing and Sales Enterprises

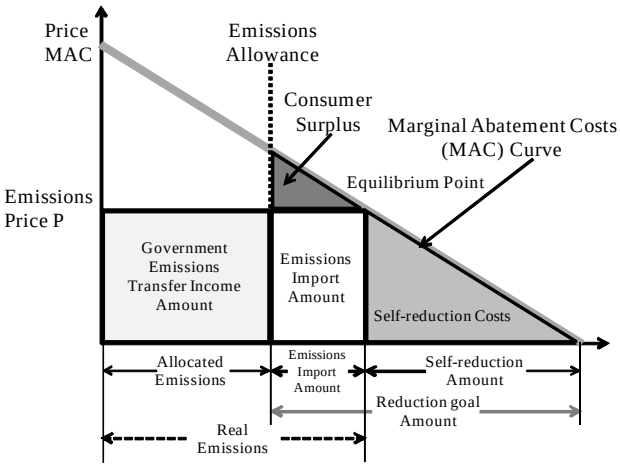

Fig. 3 Marginal abatement cost curve
Based on information from the Research Institute of Economy, Trade and Industry (2002) [16]

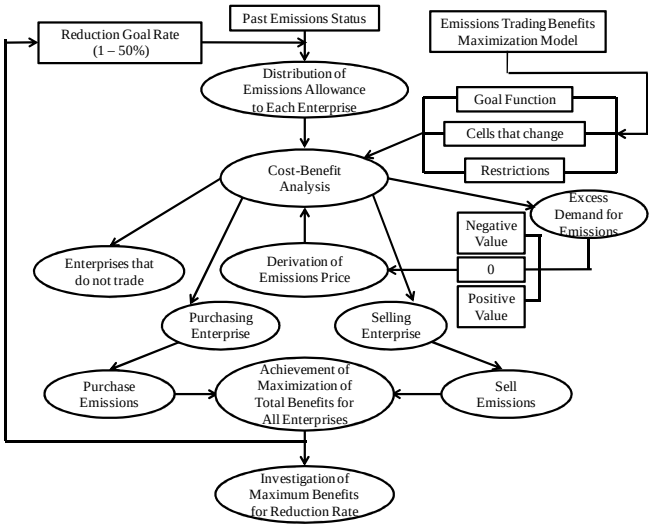

Fig. 4 Flow Chart of Calculation Methods for Cost-Benefit for Each Enterprise
Based on information from Luo (2009) [13]

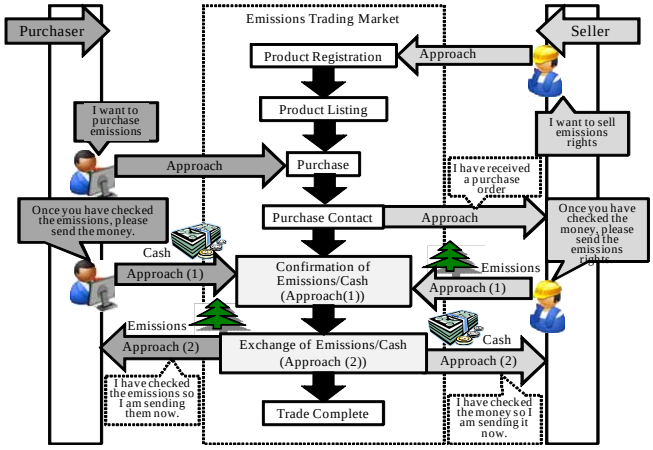

Fig. 5 Trading Flow in Climate Exchange
Based on information from the Ministry of the Environment (2009) [17] and the Japan Climate Exchange (2010) [18]

more emissions are sold by those enterprises with less standard emissions and more benefits can be obtained by them. Through these settings it is expected that incentives to reduce emissions, in particular in sales enterprises, will work.

B. Emissions Trading through Inter-enterprise Market Trading Methods

Under the Tokyo Cap and Trade Program, emissions trading among enterprises is conducted on the internet via a climate exchange as shown in Fig. 5 and an evaluation based on this flow is conducted. Market trading makes the purchase and sale of emissions possible through the payment of a fixed fee. As the configuration of transactions such as pricing, settlement and guarantee of performance is standardized, it is possible to keep prices down. In the evaluation of market trading methods, approach (1) is the result of checking emissions and cash with the climate exchange for purchasers and sellers of emissions, and approach (2) is the result of the delivery and receipt of emissions and cash from the climate exchange.

In addition, optimum reduction rates demonstrated by emissions trading evaluation results as proposed in III-A that focus on the cost-benefit are set as reduction rate goals, and evaluation of emissions trading among enterprises based on the above 4 inter-enterprise trading results is conducted.

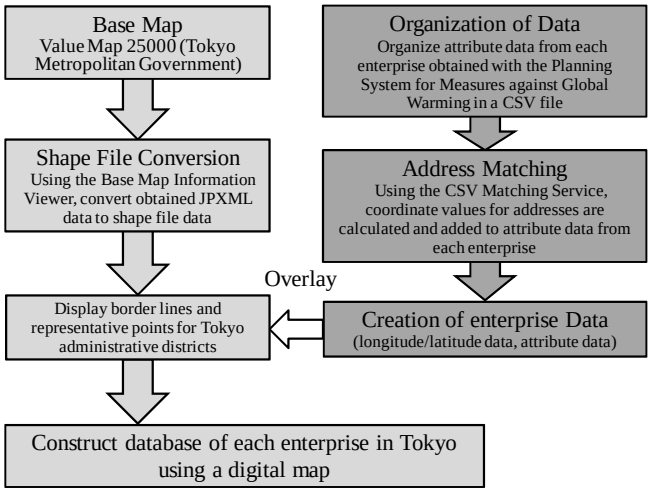

Fig. 6 Database Construction Flow Chart

C. Long-term Emissions Trading

Based on yearly short-term emissions trading evaluation results as proposed in III-A and B, evaluation of long-term emissions trading using GIS in the plan period between FY 2010 and FY 2019 is conducted focusing on the compulsory reduction rates of the Tokyo Cap and Trade Program as shown in Fig. 1. The first period of the plan, as it has a reduction goal of 6% in comparison to the base year (FY 2000) by FY 2014 for standard emissions, is set to have yearly averages – 1.2% reduction in FY 2010, 2.4% reduction in FY 2011 – giving reduction rates of 6% in FY 2014. The second period of the plan also, on top of setting yearly reduction rates in the same way, evaluates focusing on compulsory reduction rates between FY 2010 and FY 2019 based on yearly trading results.

D. Collection and Processing of Data Used

As information in the Tokyo Cap and Trade Program is not, at the present time, in the public domain, attribute data for each enterprise (address, type of business, standard emissions, CO_2 emissions, etc.) is obtained from FY 2005–2008 information in the previous Planning System for Measures against Global Warming[3]. Further, basic carbon dioxide units from each division of enterprises are obtained from the Embodied Energy and Emission Intensity Data for Japan using Input-Output Tables (3EID): FY 2005 table (β version)[4] published by the National Institute for Environmental Studies.

In (1) emissions trading focusing on cost-benefit and (2) emissions trading through inter-enterprise market trading methods, as the date of the standard emissions from each enterprise, we use the one derived from the average of emissions in the 3 years before the Planning System for Measures against Global Warming. In (3) long-term emissions trading evaluation, FY 2008 standard emissions data for each enterprise is

substituted and a database using GIS digital maps is constructed according to the flow chart in Fig. 6. Further, in addition to evaluation of emissions trading, a visualization of trading results among enterprises is shown on the maps.

IV. Evaluation of Emissions Trading focusing on Cost-Benefit

Table I organizes FY 2005–2008 yearly maximum total costs and benefits and reduction rates at maximum total benefits, when enterprises participating in the Tokyo Cap and Trade Program make virtual emissions trades using the calculation method described in III-A, and when emissions trading is not conducted (in the case of direct regulatory instruments). From this table, we can see that the optimum reduction rate at maximum total benefit is 44% over 3 years. Further, in a comparison of total benefit in the case of the Tokyo Emissions Trading Program compulsory reduction rate and that of 44%, as a difference of approximately 10 times each year is observed, it is clear that it is possible to obtain even greater total benefits by setting the reduction rate at a level higher than that of the above-mentioned program.

However, it is considered to be difficult for enterprises that have the same value for their own marginal abatement cost as for emissions price and purchasing enterprises that cannot obtain benefits from purchasing emissions to achieve reduction goals, and they conduct voluntary reductions rather than trading emissions. Further, it is evident that the second greatest total benefit is when reduction rates are 33% per year and that the difference with 44% is not so great. If we consider enterprises that reduce emissions only by voluntary reduction, it is necessary to set reduction rate goals low at, for example, 33% and to investigate how to obtain high total benefit as an easing measure.

V. Evaluation of Emissions Trading through Inter-enterprise Market Trading Methods

Based on the evaluation results of 320 enterprises in FY 2008 in the previous section, reduction rate goals are set at an optimum reduction rate of 44% which is the maximum total benefit obtained through emissions trading and inter-enterprise market trading methods are evaluated. Fig. 7 and 8 each show trading results based on the above settings for purchasing enterprise approaches (1) and (2) and sales enterprise approaches (1) and (2) shown in Fig. 5. From these figures, we can see that benefits are obtained by 253 out of a total of 320 enterprises through the trading of emissions.

Among the 8 purchasing enterprises shown in Fig. 7, only specified enterprises have both high purchase volume and amounts compared to other enterprises. This is because these enterprises have higher marginal abatement costs than others and they can obtain greater benefits by purchasing high volumes of emissions. Further, if we investigate in detail the location of sales enterprises as shown in Fig. 8, 165 of a total of 245 enterprises are located within the 23 special wards and 80 are in the Tama area so there are more within the 23 special wards. In addition, trading is high in the 23 special wards but a trend of low trading is observed in the Tama area.

This is because this study is set up so that the smaller standard emissions are, the more emissions sales enterprises can sell and as large-scale enterprises and enterprises that emit a high amount of CO_2 (container companies, etc.) are located in the Tama area, there is less emissions trading. Meanwhile, 67 enterprises either have the same values for marginal abatement costs and emissions prices or they cannot obtain benefits by conducting emissions trading even if they are a purchasing enterprise. Therefore they conduct voluntary reductions rather than emissions trading and it is considered to be difficult for them to achieve reduction goals.

In addition, in order to further advance emissions trading, it is necessary to increase the number of purchasing enterprises.

TABLE I
Maximum Total Costs And Benefits, Reduction Rate At Maximum Total Benefit Per Year (FY 2005–2008)

FY Year	2005	2006	2007	2008
Number of Participating Enterprises	264	292	309	320
Total Cost If No Emissions Trading (Direct Regulatory Instruments) (Million Yen/Year)	114,697.1	1,207,790.0	117,431.2	115,683.5
Total Cost of Emissions Trading (Million Yen/Year)	119,275.7	125,471.0	121,891.0	120,023.8
Total Cost of Emissions Trading (Million Yen/Year)	4,578.6	4,692.0	4,459.8	4,340.3
Reduction Rate at Maximum Total Benefit (%)	44	45	44	44

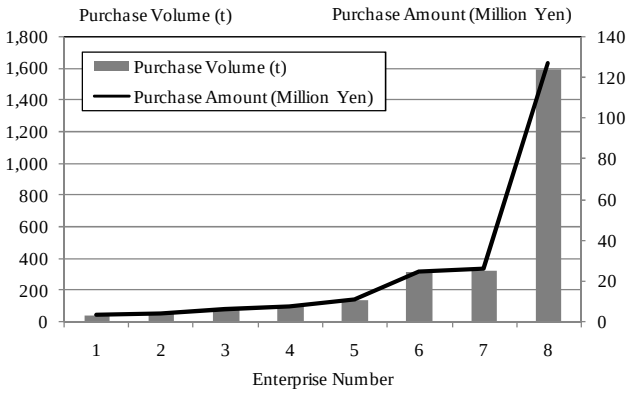

Fig. 7 Purchase Volume/Amount of Purchasing Enterprise (FY 2008)
Note: Enterprise numbers are allocated in order of emissions trading from lowest to highest

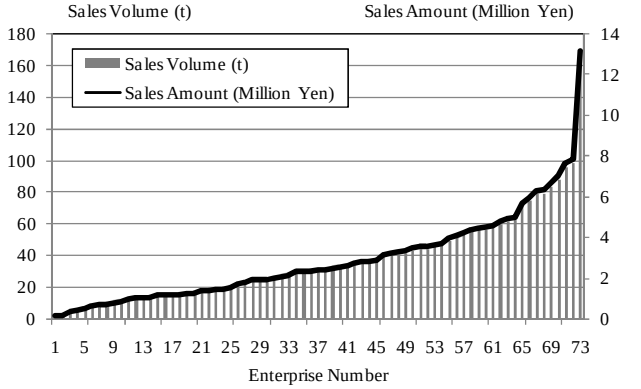

Fig. 8 Sales Volume/Amount of Sales Enterprise (FY 2008)
Note: Enterprise numbers are allocated in order of emissions trading from lowest to highest

Because if there are few purchasing enterprises, it is not possible to increase trading or the emissions that are available for sale from sales enterprises. Further, since this study has set up conditions so that benefits can be obtained by purchasing emissions if purchasing enterprises have higher marginal abatement costs than emissions prices, as this difference becomes greater, it is possible to increase emissions trading as well as purchasing enterprise's purchase volume. However, as sales enterprises aim to minimize marginal abatement costs in order to further increase benefits but emissions that can be purchased by purchasing enterprises do not decrease, it is possible that the dilemma in which incentives to minimize marginal abatement costs stop working may occur.

VI. Evaluation of Long-term Emissions Trading

A. Evaluation of Emissions Trading

This section evaluates the Tokyo Cap and Trade Program planned period from FY 2010 to FY 2019 long-term emissions trading using GIS for the 320 enterprises from FY 2008 based on the yearly short-term emissions trading evaluation results in Sections IV and V. Fig. 9 organizes the number of purchasing and sales enterprises and total emissions trading for each year. Between FY 2010 and FY 2012, as there are no purchasing enterprises that can obtain benefits even though they purchase emissions, trading will fall through and total trading is set to 0.

In FY 2013, 2 purchasing enterprises finally come forward and after that they increase as reduction rates increase. With this, the same trends in sales enterprises and total emissions trading are observed. Further, in FY 2016, the number of sales enterprises increases rapidly. The marginal abatement cost for each enterprise is calculated as 1/basic carbon dioxide emissions unit as stated in III-A and therefore reductions costs are 70,000 yen for many enterprises while emissions prices are 70,000 yen in FY 2015 and 80,000 yen in FY 2016, leading all of these enterprises to become sales enterprises at once in FY 2016. As a result, the above-mentioned sharp increase in the number of sales enterprises occurs. Fig. 10 shows the start year (FY 2013) and the end year (FY 2019) for approaches (1) and (2) for both purchasing and sales enterprises for long-term emissions trading. Fig. 11 and 12, which are examples of these trading results, are a map visualization of trading results (purchasing enterprise approach (1) and sales enterprise approach (2) as shown in Fig. 5) for FY 2019 which is the end year of the Tokyo Cap and Trade Program. From Fig. 10, we can see that purchasing enterprises are increasing year on year but even so, there are few in comparison to sales enterprises and, as well as there being a large difference between purchase volume in enterprises, only specified enterprises obtain great benefits. In this way enterprises, once they have become purchasing enterprises, have no reduction in the volume of emissions they can purchase, even if the number of purchasing enterprises increases year on year. This is because although reduction rates and total emissions trading are increasing each year, there is no more than a limited increase in the number of purchasing enterprises, and because new purchasing enterprises have smaller marginal abatement costs in comparison to purchasing enterprises up until that point. However, through the year on year increase in number of sales enterprises, the volume of emissions that each enterprise can sell reduces. This is because, in this study, settings are made so that the smaller the standard emissions are, the more emissions sales enterprises can sell therefore, when new sales enterprises make an appearance, emissions that can be sold by enterprises with larger standard emissions than these new sales enterprises decrease. For this reason, even if there is long-term trading, it is necessary to consider the dilemma caused by the situation in which sales enterprises aim to minimize marginal abatement costs, but, on the other hand, incentives to minimize marginal abatement costs for purchasing enterprises no longer work. On top of having lower emissions prices than marginal abatement costs, the lower reduction costs are, the greater the benefits of becoming a sales enterprise are; sales enterprises between FY 2013 and FY 2015 have extremely low marginal abatement costs in comparison to other enterprises. Further, in FY 2016, even though the number of sales enterprises increases dramatically, in order to sell emissions, it is necessary for sales enterprises to make their own reduction costs lower than other enterprises. For this reason, the Tokyo Cap and Trade Program does not consider the minimization of marginal abatement costs. However, by considering this aspect year on year, it is possible to expect the actual minimization of marginal abatement costs.

B. Comparison with Short-term Emissions Trading

As shown in Fig. 9, in long-term trading in the planned period of the Tokyo Cap and Trade Program, as well as a yearly increase in the number of purchasing enterprises, there is an increase in total trading volume in addition to the number of sales enterprises, but we can see that this increase is lower compared to that of the yearly short-term emissions trading among enterprises as described in Section V. Further, by setting a high reduction rate of 44% in short-term trading, it is possible for 253 out of 320 enterprises to obtain benefits, but in long-term trading the highest number of enterprises to obtain benefits in FY 2019 is 81. Consequently, taking the effectiveness of emissions trading in order to control CO_2 emissions into account, the Tokyo Cap and Trade program's reduction rate needs to be set even higher and it is necessary to make it possible for even more participating enterprises to obtain benefits in the future.

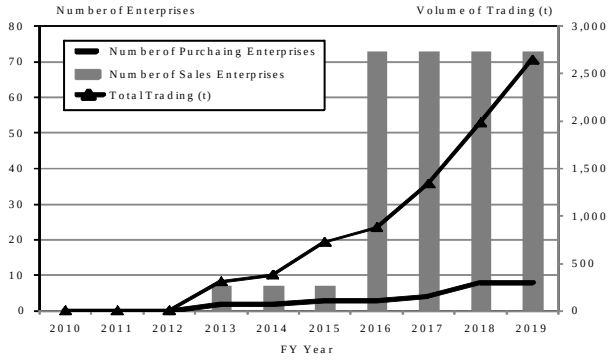

Fig. 9 Yearly Numbers of Purchasing/Sales Enterprises, Total Emissions Trading Volume (FY 2010–2019)

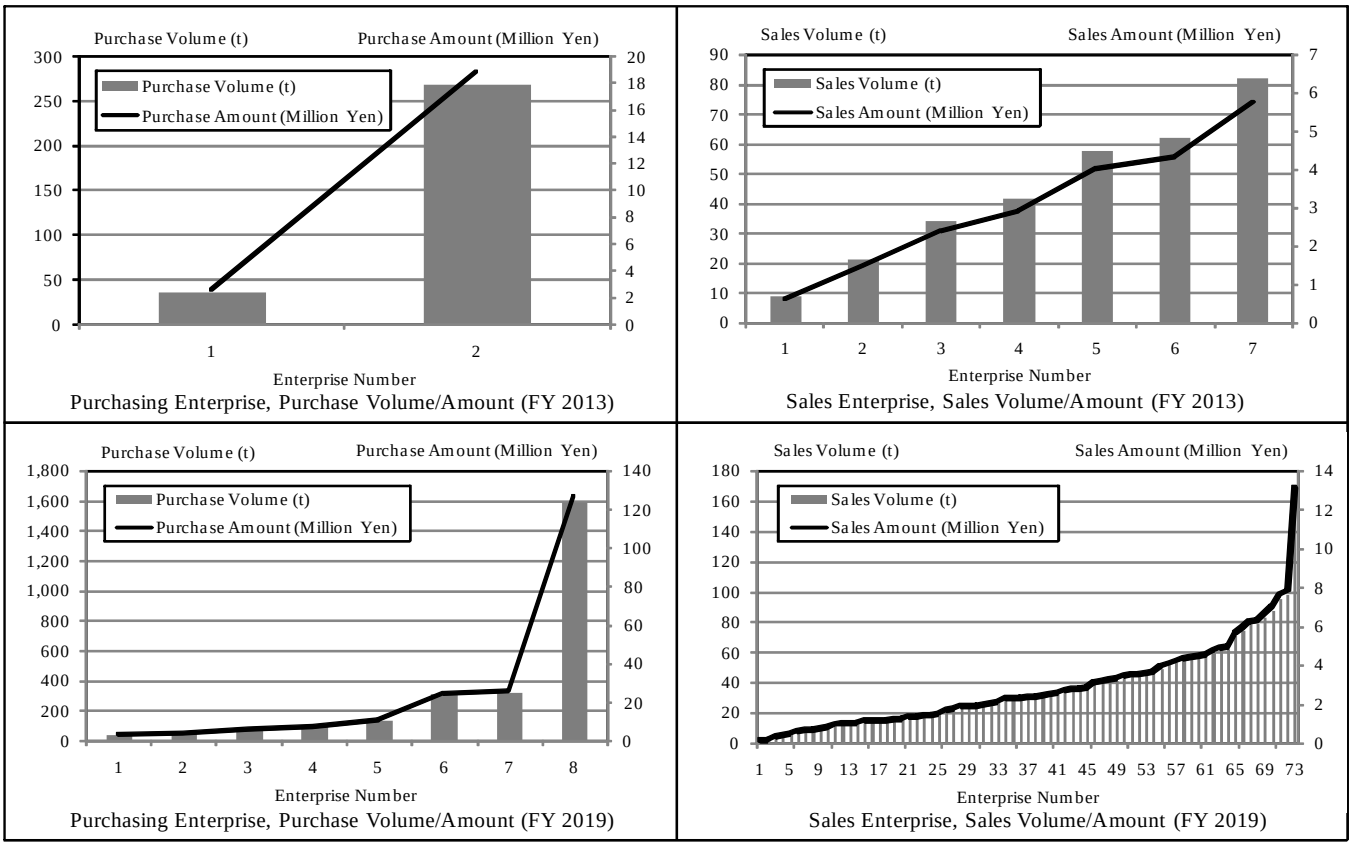

Fig. 10 Emissions Trading Results (FY 2013/FY2019)

Note: Enterprise numbers are allocated in order of emissions trading from lowest to highest

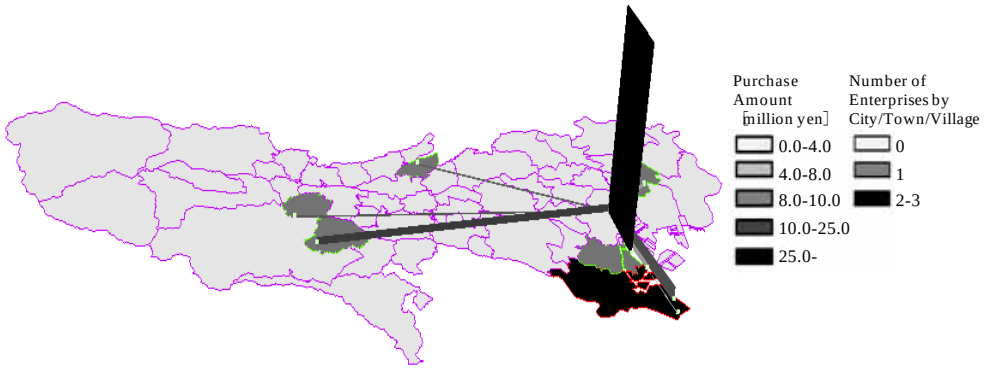

Fig. 11 Purchasing Enterprise Approach (1) (FY 2019)

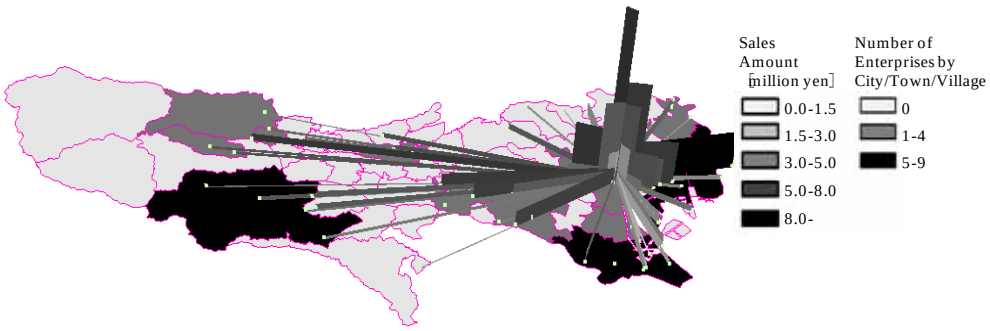

Fig. 12 Sales Enterprise Approach (2) (FY 2019)

VII. Conclusions and Future Research Challenges

The findings of this study can be summarized in the following three points.

1) In the evaluation of emissions trading that focus on cost-benefit, since the total cost benefit is the greatest at a 44% reduction rate, there is the possibility to set it more highly than that of the Tokyo Cap and trade Program to get more total cost benefit.
2) In the evaluation of emissions trading according to inter-enterprise market trading methods, among 320 enterprises, 8 purchase enterprises and 245 sales enterprises gain profits from emissions trading, and 67 enterprises perform voluntary reduction without conducting emissions trading. Therefore, by increasing the number of purchase enterprises, it is necessary to increase the sale volumes of emission trading in addition to sales enterprises to promote the emission trading.
3) From the evaluation of long-term emissions trading, it is evident that there are few enterprises which benefit in each year through the long-term emissions trading of the Tokyo Cap and Trade Program, comparing short-term emission trading. Only 81 enterprises can gain profits from emissions trading in the most FY 2019.Therefore, by setting the reduction rate more highly, it is necessary to increase the number of enterprises which participate in emissions trading and benefit from the restraint of CO_2 emissions.

Further, this study proposed three evaluation methods for emissions trading and, if it is possible to obtain data similar to this study, we can expect an improvement in evaluation accuracy through application to other regions in the spatial aspect and the updating of information in the temporal aspect. Future research challenges include obtaining as much detailed information as possible concerning the approximately 1,300 enterprises which participate in the Tokyo Cap and Trade Program such as marginal abatement costs, contents and scale of businesses to conduct more detailed evaluation.

Notes

(1) This study used ESRI, Inc. ArcGISVer.9.3.1.
(2) According to the Tokyo Metropolitan Government Environmental Bureau (2009), standard emissions are, as a general rule, the average of any 3 consecutive years from FY2002–2007 and it is possible for enterprises to select whichever 3 years they prefer. Compulsory reduction rates are 8% in subdivision I-1 (government administration office buildings, office buildings such as commercial facilities, accommodation facilities, education facilities, medical facilities and local air-conditioning facilities) and 6% in subdivision I-2 (office buildings with energy allocation supplied from a local air-conditioning facility comprising 20% or more of the total energy use for the enterprise) and enterprises such as factories that are not included in subdivisions I-1 and 2. In the previous Planning System for Measures against Global Warming, standard emissions are derived from the average emissions of the 3 years prior to the plan.
(3) Attribute data of each enterprise obtained from the Planning System for Measures against Global Warming: ＜ http://www6.kankyo.metro.tokyo.jp/tochou_2/Wroot/asp/W200. asp ＞ Accessed April 9, 2010
(4) Embodied Energy and Emission Intensity Data for Japan using Input-Output Tables (3EID):＜http://www.cger.nies.go.jp/ publications/report/d031/3eid.html＞ Accessed April 9, 2010

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