A scenario analysis of energy-economic in Ibaraki prefecture in 2030

*Eto Ryo *, Uchiyama Yohji *, and Okajima Keiichi**

* Department of Risk Engineering Faculty of Systems and Information Engineering
University of Tsukuba

Tel：+81-29-853-5134　Mail：r0820570@risk.tsukuba.ac.jp

Abstract

The analysis of CO_2 emissions in local government is required in Japan. This paper adopts multi-region input-output model for the analysis of CO_2 emissions in Ibaraki prefecture. Six energy-economic scenarios are developed to identify major impact factors of the emissions. Based on economic data and an input-output table in 2000, energy demand and CO_2 emissions per GDP are quantitatively analyzed for six different scenarios up to 2030 on both the prefecture and the rest of Japan by the model considering a sectoral and regional interdependency. Main results are obtained from this study as follows; in all scenarios, amount of CO_2 emissions increased in Ibaraki until 2030, the highest emission in a BAU scenario and the lowest one in a low domestic consumption scenario. On the other hand, CO_2 emissions per GDP decrease in all scenarios, the lowest emission in an energy-saving scenario. In terms of the ratio of CO_2 emission trade balance between the regions, the ratio of CO_2 emissions in the rest of Japan driven by Ibaraki increase relatively to CO_2 emissions in Ibaraki driven by the rest of Japan in all scenarios, the highest CO_2 emission in a low export scenario and the lowest one in a self sufficiency rate scenario and an energy-saving scenario. These results contribute to the policy implementations considering inter-sectoral and inter-regional relationship.

Keyword: multi-region input-output model, energy-economic scenarios analysis, Ibaraki prefecture, CO_2 emission

1. Introduction

The Kyoto Protocol was signed in 1997 in order to control the global warming and Japan committed to reduce greenhouse gases emissions (GHGs) by 6% under the level of 1990 during the first commitment period from 2008 to 2012. Nevertheless, the amount of GHG emissions in 2008 increases by 9% above the level of the base year even in the commitment period. In addition to the current situation, the G8 leaders in 2008 seek to consider and adopt in the UNFCCC negotiations, the goal of achieving at least 50% reduction of global emissions by 2050. Japan advocates in the international negotiation that the sectoral approach is the effective way to combat global warming. A new method should be developed to investigate future GHG emissions from industrial sectors which are mutually dependent among their activities.

Input-output model is one of the most suitable tools to investigate the direct and indirect CO_2 emissions among interdependent sectors on a macroeconomic scale as introduced in Leontief and Ford (1970). There have been numerical literatures applying input-output model focusing on energy demand and CO_2 emissions in national level represented by domestic input-output table (such as Lenzen, 1998, Tiwari, 2000, Sánchez-Chóliz and Duarte, 2004). For applications in Japan, Ishiro (2005) performed decomposition analysis in Japan from 1975 to 1995. Kondo and Moriguchi (1998) examined embodied CO_2 emissions with foreign trade in the case of Japan. Also, there have been some works analyzing future CO_2 emission in national level. (Fan *et al.*, 2007, Wei *et al.*, 2007, Limmeechokchai and Suksuntornsiri, 2007).

Within Japan, since the feature of industrial structure varies in each municipality, most local governments have set up their own environmental policies. Thus, the necessity to analyze environmental issues in long terms in association with the local characteristic is growing for implementation of appropriate policy in each municipality. Gomi *et al.* (2007) assessed the future CO_2 emissions in Shiga, one of the prefectures in Japan applying a backcasting method to develop four scenarios. They also discussed the role of the local government in the issue of the climate change and clarified the trends which should be reversed and enhanced hereafter. However, measuring CO_2 emissions generated from prefectural level entails to consider the amount of emissions not only within the region but the other regions trading with the region, which is ignored in the methodology of Gomi *et al.* (2007). It is meaningful to reflect the feature of the local circumstance, in which embodied CO_2 emissions as well as the movement of commodities and services are observed from one region to another. Multi-region input-output model (MRIO) enables us to analyze interrelated regions as discussed in Turner *et al.* (2007). Thus, many studies have examined CO_2 emissions applying MRIO reviewed in Wiedmann *et al*. (2007). Kawashima and Uchiyama (2004) developed four energy scenarios to analyze the effect of improving energy efficiency in each region in Philippine. Liang *et al*. (2007) examined regional future economic requirements and CO_2 emissions in China applying MRIO. Some studies analyzed CO_2 emissions in Japan with MRIO disaggregated into nine regions. The dataset has been published since 1960 and one of the old economic applications has been shown in Polenske (1970). For recent applications, Hasegawa (2004) examined CO_2 emissions dividing Japan with ten regions separating Tokyo capital of Japan from abovementioned MRIO, and estimated regional difference of both CO_2 emissions and economical effect. Similar environmental application is observed in Uchiyama (2003), Abe *et al.* (2001), and Abe *et al.* (2005). For the prefectural level, Ashiya (2007) summarized the condition of regional input-output table in Japan. It reported that some prefectures construct MRIO table recently and environmental analysis is scarce in comparison with other analysis such as employment effect in spite of the surge of the environmental interest.

The objective of this article is to analyze future CO_2 emissions in the prefectural level in Japan adopting a MRIO incorporating a government prediction which assess national economic development and CO_2 emissions up to 2030. To specify the probable factors, six energy-economic scenarios are developed with taking an Ibaraki prefecture as a case analysis. This study assumes the prefectural growth of economy and energy demand in proportion with the national level. CO_2 emissions and CO_2 emissions per GDP in 2030 are calculated from the input-output analysis based on monetary input-output table and energy balance table in 2000 in order to provide insight into the implementations of energy-environmental policy.

This paper is structured as follows. In Section 2, the input-output methodology employed in this study is described. In Section 3, the scenarios developed in this study are introduced with assumed data of economy and energy demand. In Section 4 the results are shown for each scenario. In section 5, policy implementation and future works are discussed.

2. The model

2.1 Single-region input-output model

Since a single-region input-output model involves one specific region, the model is suitable to analyze within the region. Given n goods and services, the balance of output for a single-region can be concisely described in equation (1)

$$AX + F + E + E_c - M - N = X \tag{1}$$

where X represents a total output vector with n dimensions; F an intra-regional final demand vector with n dimensions; E an export to the rest of the world vector with n dimensions; E_c an export to the rest of the countries vector with n dimensions; M an import from the rest of the world vector with n dimensions, N ; an import from the rest of the countries vector with n dimensions; A an input coefficients matrix with $n \times n$ dimensions which shows the technological coefficients of industries. The difference from a national input-output model is incorporating E_c and N (see Leontief, 1986a for the detail of a national input-output model). The elements of matrix coefficients A can be derived from equation (2)

$$a_{ij} = \frac{x_{ij}}{X_j} \tag{2}$$

x_{ij} represents the amount of the product of sector input i by sector j. Solving the equation (1) for X can be written in equation (3) with the unit matrix, I .

$$X = (I - A)^{-1}(F + E + Ec - M - N) \tag{3}$$

$(I - A)^{-1}$ is called the Leontief inverse matrix with $n \times n$ dimensions and it enables us to evaluate direct and indirect output with any given final demand exogenously.

2.2 Multi-region input-output model

The analysis of inter-region can be achieved with MRIO which involves more than 2 regions. The theory of MRIO is first identified by Isard (1951) and discussed the difficulty to obtain data for the table. To overcome the problem, Chenery (1953) and Moses (1955) developed the structure of trade coefficients which describes one trading pattern assumed among regions to combine over two regional tables in order to compensate for the limited data (see Leontief, 1986b, for the detail of the theory).

Given two regions, producing region r and consuming region s, trade coefficients can be calculated as equation (4)

$$t_i^{rs} = \frac{N_i^{rs}}{\sum_{j=1}^{n} a_{ij}^s X_j^s + F_i^s} \tag{4}$$

where N_i^{rs} represents an import from sector i of region r both for intermediate input and final demand of region s, $\sum_{j=1}^{n} a_{ij}^s X_j^s$ represents the total intermediate demand for sector i of region s and F_i^s represents the total amount of final demand for sector i of region s. Thus, the denominator represents the total demand of sector i of region s. Equation (1) can be rewritten in equation (5) with the trade coefficients

$$TAX + TF + E = X + M \tag{5}$$

where T represents the trade coefficients matrix with $n \times n$ dimensions where elements are calculated through equation (4). It enables us to account for production embodied in inter-regional trade.

Competitive import type input-output model is adopted in this study where imported and domestic goods and services are considered as unique commodities. In postulating that the amount of imports is in proportion with regional demand, M can be rewritten in equation (6)

$$M = \hat{M}(AX + F) \tag{6}$$

where $\hat{M}$ represents an import ratio matrix. By inserting equation (6) to equation (5), and solving for X, equation (7) can be derived.

$$X = (I - TA + \hat{M}A)^{-1}(TF - \hat{M}F + E) \tag{7}$$

Direct and indirect regional CO_2 emissions for industries can be calculated in equation (8), in terms of any given of final demand.

$$CO_{2ind} = C_{ind}X = C_{ind}(I - TA + \hat{M}A)^{-1}(TF - \hat{M}F + E) \tag{8}$$

where C_{ind} represents CO_2 emissions due to fossil-fuel combustion per unit of output vector with n dimensions.

Thus, multi-regional spillovers of CO_2 emissions are calculated through MRIO. Although emission embodiments of trade with the rest of the country are taken into account, those with the rest of the world are not, because emission restriction for national GHGs policies normally aims at reducing domestic greenhouse gas such as Kyoto Protocol.

Households also directly generate CO_2 emissions such as consuming electricity and using private cars (Proops, 1977), the emissions of households should be added and can be written in equation (9)

$$CO_{2hou} = C_{hou} \times Pc \tag{9}$$

where C_{hou} represents CO_2 emissions per unit of private consumption vector and Pc represents amount of private consumption vector. Ultimately, total regional emissions are written in equation (10).

$$CO_2 = CO_{2ind} + CO_{2hou} \tag{10}$$

CO_2 emissions per GDP are employed as an indicator of economic and environmental relationships in this study and calculated in equation (11) in this model framework

$$\frac{CO_2}{GDP} = \frac{CO_2}{\sum_{j=1}^{n} V_j} \tag{11}$$

where V_j represents a value added vector. A decrease of the ratio indicates an improvement of economic and environmental relationships.

2.3 Modeling CO_2 emissions in input-output model

The model adopted in this study calculates GHGs which are in proportion with production activities. On the basis of the characteristic of the model, measuring range of GHGs is only CO_2 emissions generated from the combustion of fossil fuel. Since non-CO_2 emissions depend on technology and combustion situation, the other GHGs and CO_2 emissions ascribed to combustion of lime stone used for manufacturing cements and to coke consumption of iron and steel are precluded. Also, the technology of CCS is ignored in the same context in this model. Since the CO_2 emissions generated from combustion of fossil fuel account for approximately 80% of GHG emissions of Japan, for the most part of GHG emissions of Japan is covered in this study.

3. Data and scenario

The objective region is set Ibaraki prefecture located north east from Tokyo in which appropriate MRIO with the rest of Japan (ROJ) is provided by Ibaraki Prefecture (IBARAKI Prefectural Government). The base year in this application is set in 2000 due to the latest input-output table for both the nation and Ibaraki and the target year is set in 2030. The industry is disaggregated with 10 sectors consisting of primary products, food products, chemical products, iron and steel, machinery, other manufacturing, construction, transportation, public services and other services taking the characteristic of Ibaraki into account in which industrial structure is composed mainly secondary industry relative to ROJ (see Table 2 for more details). The flowchart of this model is shown in Figure 1.

3.1 Data

3.1.1 Economical procedure and data

There are seven components for the term of final demand, *i.e.*, private consumption (PC), private investment (PI), government consumption (GC), government investment (GI), exports, imports and inventory investment. Excluding inventory investment, the annual growth rate of each final demand is obtained from the government prediction provided by the Agency for Natural Resources and Energy (a) and each of the growth rate is shown in Table 2. The sectoral share for each of the final demand is regressed with time under the assumption of the continuance of historical trends for 30 years adopting the Time Series Input-Output Table that the sectoral concept is unified with 155 sectors from 1970 to 2000 in Japan (see Kawashima, 2005 for the detail of the table). As a consequence, the sectoral shares of the machinery and the tertiary increase whereas those of the primary products and the other second industries decrease. Since the influence of inventory investment is negligible, for simplicity, the value of inventory investment is fixed from the base year. Sectoral output is estimated from the trend of the ratio of sectoral output to sectoral final demand. Similarly, sectoral value added is estimated from the ratio of sectoral value added to sectoral output. From the balance of the matrix, sectoral intermediate input and demand are obtained. To estimate the input coefficients, the RAS method is obtained with applying the input coefficients of the base year. In the assumption that the economic growth rate of Ibaraki equals with that of national level, the national growth rate is applied to Ibaraki input-output table for the base year. Sectoral trade coefficients between Ibaraki and ROJ are assumed constant, which implies the continuity of the same pattern of the regional flow. Since the relative supply prices are fairly stable between the regions, this assumption is sufficiently empirical. Ultimately, when parameters are estimated with an unreasonable size in some parts such as import ratio excessing 1 or negative demand, they are restricted to consistent with economical theory.

3.1.2 Energy data

Two sources are employed to convert the economic data into CO_2 emissions. The amount of sectoral energy consumption is available from energy balance table compiled by the Agency for Natural Resources and Energy (b). To convert energy consumption into CO_2 emissions, the CO_2 emission coefficients compiled by Ministry of Environment are applied (See Table 3 for the value). In this study, CO_2 emissions generated from power consumption are distributed each of the final consumers to identify responsibility of final electricity consumption. The CO_2 emission coefficients for electric power consumption are identified by CO_2 emissions generated by electricity generation divided by total amount of final electricity consumption. Up to 2030, CO_2 emissions per unit of output decrease 5% to reflect gradual decrease in past years.

3.2 Scenario description

Different scenarios are developed under different economic and energy factors; business as usual(BAU) scenario, low domestic consumption (A1) scenario, low export (A2) scenario, low carbon (C1) scenario, self sufficiency (C2) scenario and energy-saving (C3) scenario. Each scenario is developed in terms of a sensitive analysis from the BAU scenario and each factor is determined by anticipated changes over time. Thus, the BAU scenario is analyzed first, and added the each factor subsequently in the quantification process. The set of respective detailed scenario description is shown in Table 4.

3.2.1 Economic scenario

Two alternative economic developments, low domestic consumption and low export are developed as national level scenarios in order to evaluate how the demand change impacts on the local circumstance. The channel of economic development equals with the national level in these scenarios since Ibaraki is reported one of the average prefectures in terms of the population structural change. This implies sufficiently empirical to assume that the private demand change in Ibaraki follows the change of the nation. A scenario for self sufficiency rate is developed with respect to a local level scenario. The self sufficient rate in this study constitute reducing the ratio of the supplies of ROJ from the base year given rise to the demand in Ibaraki and increasing the ratio of the supplies of Ibaraki. As such, the value of trade coefficients is changed and it does not include the trade with the rest of the world. Since the self sufficiency rate for the primary products is one of the concerned issue and the service sectors are relatively dependent on ROJ in the base year, increasing 10% self sufficiency rates is applied for these sectors.

3.2.2 Energy scenario

Two alternative energy scenarios are developed for both sides of supply and demand. For the supply side, CO_2 coefficients for electric power is decreased 10% to reflect switching fuels to a low carbon intensity such as from coals to oil or from fossil fuels to renewable energy. Since CO_2 emissions per unit of output are not established in local government level, it is set that the change occurs in the national level. For the demand side, energy-saving is adopted and CO_2 emissions per unit of output are decreased 10% from the base year.

3.3 Treatment of households

For the BAU scenario and the energy-saving scenario, the change of CO_2 emissions of residential and private automobile sectors for 30 years is derived from Yanagisawa (2008) which analyzes CO_2 emissions up to 2030 in Japan. It is assumed that energy consumption and associated CO_2 emissions from household in Ibaraki changes the same as the national level as abovementioned. CO_2 emissions for households are adjusted in corresponding with the change of the private consumption for the scenario.

4. Results

4.1 Estimated CO_2 emissions per unit of output

Table 5 shows sectoral CO_2 emissions per unit of output under representative scenarios. In the BAU scenario, the CO_2 emissions per unit of output are set 5% decrease relative to the base year. This assumption provides that the decrease in each sector relative to the base year is determined in proportion with the value of CO_2 emissions per unit of output. In the C1 scenario, it is a little lower than the BAU scenario in some sectors where electricity consumption accounts for the large share of energy inputs since improving 10% CO_2 emission coefficients from the BAU scenario is set. On the other hand, in the C2 scenario, it is a little larger than in the BAU scenario in some sectors where intermediate input from the primary products and the services sectors is relatively large since the 10 % increase of self sufficiency rate is assumed in those sectors. In the C3 scenario, the presence of energy-saving where 10% decrease of CO_2 emissions per unit of output from the base year is assumed provides the lowest CO_2 emissions per unit of output among the scenarios.

4.2 CO_2 emissions in Ibaraki under each scenario

Figure 2 and Table 6 show the sectoral amount of CO_2 emissions and average annual growth rate in Ibaraki under each scenario. In the all scenarios, the amount of CO_2 emissions increases in contrast of the decrease of the CO_2 emissions per unit of output. The highest CO_2 emissions appear in the BAU scenario where the amount is 1.32 times as much as the base year and the average annual growth rate is almost 1% per year. The annual growth rate of CO_2 emissions in the C3 scenario rises more than 0.9 % per year. The assumption of the magnitude of energy-saving in the C3 scenario is insufficient to aim at reducing from the base year as a consequence while maintaining mild economic growth. The CO_2 emissions in both the A1 and A2 scenarios where economic development is restricted are lower than in the BAU scenario. The lowest CO_2 emissions considering only the industrial sectors appear in the A1 scenario. The primary factor is the decrease of exports in the chemical products, the iron and steel and the other manufacturing sectors where the CO_2 emissions per unit of output is relatively high. The lowest CO_2 emissions including households appear in the A2 scenario. This result is ascribed to the decrease of the household energy consumption. It implies that Japanese economy experiences the growth of both domestic consumption and exports, which entails the rise of CO_2 emissions in Ibaraki over 30 years. Furthermore, CO_2 emissions in the C2 scenario are smaller than in the BAU scenario. For this reason, the rise of CO_2 emissions driven by increasing 10% self sufficiency rate in both the primary products and the services sectors can be compensated by improving 10% CO_2 emission coefficients.

Figure 3 shows the sectoral share of CO_2 emissions under each scenario in Ibaraki. The sectors which increase the share in the BAU scenario are the chemical products, the machinery, the public services, and the other services sectors. The driver of this result is confirmed in comparing with the A1 and A2 scenarios where the way of economic development is different. In the A1 scenario where domestic consumption is sluggish, the share of secondary industries is larger than BAU and that of tertiary industries and residential is smaller. On the contrary, in the A2 scenario where exports are sluggish, the exact opposite tendency is observed. This tendency indicates that in principle, the increase of the chemical products and the machinery sectors is driven by increasing exports, and that of the public services and the other services sectors is driven by increasing domestic consumption. The sectors decreasing the share in all scenarios are the primary products, the food products, and the construction due to the fact that the outputs of the sectors decrease. In the C1, C2 and C3 scenarios, almost the same tendency from the BAU scenario is observed. For this reason, improving self sufficiency rate in both the primary products and the services sectors, CO_2 emission coefficients and energy-saving for the all sectors do not impact on the sectoral share of CO_2 emissions significantly, but the way of economic development does. However, if some environmental policies concentrating on some specific sectors are adopted, it is possible that improving CO_2 emission coefficient and energy saving affect the sectoral share of CO_2 emissions.

4.3 CO_2 emissions per GDP in Ibaraki under each scenario

Table 7 shows CO_2 emissions per GDP under each scenario to identify the relevance to economic development. In contrast to the total amount of CO_2 emissions, CO_2 emissions per GDP decrease in the all scenarios. It is ascribed to the industrial structural switch from the secondary industries to the tertiary industries in 30 years. Although the share of the second industry in the A1 scenario is higher than in the BAU scenario, the value is lower. It is due to the fact that CO_2 emissions generated from households are lower in the A1 scenario. The lowest value is observed in the C3 scenario due to the energy-saving. In the C1 and C2 scenarios, CO_2 emissions are lower than in the A1 and A2 scenarios. This indicates that energy policy which does not damage economical development is more desirable. Furthermore, in the C2 scenario, the value is lower than in the C1 scenario, which indicate that increasing self sufficiency rate both the primary products and the services sectors is superior to decouple economic development and CO_2 emissions. In the A2 scenario, the value is lower than the A1 scenario indicating that the desirable economic development to decouple CO_2 emissions is energy-saving and domestic demand led with increasing self sufficiency rate.

4.4 Embodied CO_2 emissions with the trade between Ibaraki and ROJ under each scenario

Figure 4 and 5 show the sectoral amount of CO_2 emissions in Ibaraki driven by ROJ and in ROJ driven by Ibaraki. Ibaraki is one of the 47 prefectures, therefore, Ibaraki and ROJ have a sizeable different magnitude of economy. For this reason, CO_2 emissions driven by Ibaraki are considerably larger than driven by ROJ. In the all scenarios, CO_2 emissions increase for both results reflecting a large increase of the machinery sector which accounts for a large sectoral share since the sector inherently generates indirect CO_2 emissions to the other sectors, particularly the iron and steel sector. The Figures show different results for the lowest scenario, in the A1 scenario in Figure 4 and in the C3 scenario in Figure 5. The downturn of the domestic consumption leads to reduce the amount of trade in the A1 scenario and the presence of energy-saving contributes to reduce the embodied CO_2 emissions in the C3 scenario. The different results occur due to the change of self sufficiency rate for the primary products and the services sectors since it leads to reduce the imports from ROJ. For the both cases, in the A2 scenario which produce no direct change of the CO_2 emissions from the BAU scenario, CO_2 emissions are lower than in the BAU scenario. The indirect intermediate input decreased as a result of the downturn of the exports to the rest of the world. For the service sectors, CO_2 emissions driven by Ibaraki are relatively larger than driven by ROJ and for the food products and the chemical products sectors, the exact opposite tendency is observed. It is due to the fact that the industrial structures for two regions are heterogeneous, implying that the share of secondary industry is relatively higher in Ibaraki.

To identify the relationship among the scenarios, the ratio of CO_2 emissions trade balance between Ibaraki and ROJ is calculated in equation (12) and the result is shown in Table 8.

$$\frac{CO_2 \text{ emissions driven by Ibaraki} - CO_2 \text{ emissions driven by ROJ}}{CO_2 \text{ emissions driven by Ibaraki}} \quad (12)$$

In the all scenarios, the values are negative since the magnitude of the economic of ROJ is considerably larger than Ibaraki as abovementioned. In the all scenarios, the ratio of CO_2 emissions driven by Ibaraki is relatively higher than the base year. This is due to the high growth rate of the output of the services, which Ibaraki imports from ROJ excessively. The aspect is observed comparing the BAU scenario with the other scenarios. In the A1 scenario, the result is higher than the BAU scenario whereas in the A2 scenario it is lower in accordance with the relative output between the secondary industry and the tertiary industry. In the C1 scenario, where it changes only CO_2 emission coefficients from the BAU scenario, thus the same results are obtained with the BAU scenario. Furthermore, in the C2 and the C3 scenarios, which share the exact same values, the value is lower than the BAU scenario, reflecting the increase of the self sufficiency rate of the sectors in Ibaraki. With regard to aiming at decreasing the ratio of regional balance, a higher increase of self sufficient rate of the sectors should be achieved.

5. Discussion and future works

In this study, CO_2 emissions in Ibaraki up to 2030 are estimated with six energy-economic scenarios applying MRIO to reveal inter-sectoral and inter-regional relationship. The results show that both CO_2 emissions in Ibaraki and in ROJ driven by Ibaraki increase in this assumption. Therefore, CO_2 emissions per unit of output and CO_2 coefficients are required pointedly to improve more than the energy-saving assumption in this study. The lowest CO_2 emissions in Ibaraki appear in the low domestic consumption scenario even in the framework for producer responsibility. However, considering the environmental and economic relationship, it is the second worst following BAU in the low domestic consumption scenario. On the other hand, although increasing self sufficiency rate leads to increase CO_2 emissions within the prefecture, CO_2 emissions per GDP are the second lowest. The CO_2 reduction target should be identified carefully whether the total amount of CO_2 emissions or CO_2 emissions per GDP. The local government should implement energy-environmental policy in correspond with environmental targets.

Considering the relationship with ROJ, the ratio of CO_2 emissions trade balance is definitely different for each scenario. Thus, it is essential to collaborate with other prefectures to clarify the emission responsibility. One remarkable result is that improving self sufficiency rate is desirable for Ibaraki prefecture to consider the relationship with ROJ. Since increasing self sufficiency rate for the primary products and the services sectors contributes to decrease the ratio of regional balance, considering interregional dependence with ROJ is essential. It is revealed that determining the balance of these points of views play a significant role for policy implementation in the local government.

There are three future works for this study. First, the limited data should be solved. CO_2 emissions per unit of output in Ibaraki are assumed in equivalent with the nation because of a shortage of the data for energy consumption in the municipal level. Since the feature of industrial structures for an inside of sectors varies in each prefecture, the data of CO_2 emissions per unit of output for local areas should uniquely be developed. Also, CO_2 emissions per unit of output are assumed 5% decrease for the BAU scenario and 10% decrease for the energy-saving scenario. The forecast of CO_2 emissions per unit of output should be developed in the future. Second, a model analyzing the local CO_2 emissions of households should uniquely be developed and incorporated with the model applied in this study. The local CO_2 emissions of household are referred from a precedent study in this study which analyzed the national level. It is required to combine with a simulation model which aims at analyzing local household in municipal level in Japan such as Ashina and Nakata (2008) and Shimoda *et al*. (2007) or an application of an input-output model such as Lenzen *et al*. (2004). Third, this analysis is still a rough estimate and should be considered as provisional. In practice, changing foreign demand should impact on domestic demand since income of domestic household is affected as well as energy-saving affects on economical cost. A more flexible computable general equilibrium model should be constructed in prefectural level to assess the environmental account in the future discussed by Gilmartin *et al*. (2008). The approach would lead to help a local energy-environment policy implementation.

References

Abe, H., Taniguchi, M. and Nakagawa, T. (2001) Regional Input-output Analysis for the Energy and Resource Consumption in Japanese Regions, 17th Pacific Conference of Regional Science Association International, Portland, USA.
Internet Site http://www.civil.okayama-u.ac.jp/~regional/abe/publish/2001PRSCO.pdf.

Abe, H., Shinke, T. and Nagare, T. (2005) Regional Economic Structure and Carbon Dioxide Emissions in Japanese Regions: An Application of Regional Input-Output Analysis, 19th Pacific Conference of Regional Science Association International, Tokyo, Japan.
Internet Site http://www.civil.okayama-u.ac.jp/~regional/abe/publish/2005PRSCO.pdf.

Agency for Natural Resources and Energy (a)
Internet Site http://www.enecho.meti.go.jp/info/committee/commit07.htm (in Japanese).

Agency for Natural Resources and Energy (b)
Internet Site http://www.enecho.meti.go.jp/info/statistics/jukyu/result-2.htm
(in Japanese).

Ashina, S. and Nakata, T. (2008) Energy-efficiency strategy for CO_2 emissions in a residential sector in Japan, Applied Energy, 85, pp.101-114.

Ashiya, T. (2007) The process of compiling and analysis of regional Input-Output Table, PAPAIOS, 15, 3, pp.22-32 (in Japanese).

Chenery, H.B. (1953) Regional Analysis, in H.B. Chenery, P.G Clark and V.C. Pnna(eds), The structure and Growth of the Italian Economy(US Mutual Security Agency, Rome).

Fan, Y., Liang, Q.M., Wei, Y.M. and Okada, N. (2007) A model for China' s energy requirements and CO_2 emissions analysis, Environmental Modelling & Software, 22, pp.378-393.

Gilmartin, M., Swales, J.K. and Tuner, K. (2008) A comparison of results from MRIO and interregional computable general equilibrium(CGE) analyses of the impacts of a

positive demand shock on the 'CO2 trade balance' between Scotland and the rest of the UK, The Intermediate Input-output Meeting, Seville, Spain.
Internet Site http://www.iioa.org/pdf/Intermediate-2008/Papers/6d4_Gilmartin.pdf.

Gomi, K., Shimada, K. and Matsuoka, Y. (2007) Scenario study for a regional low-carbon society, Sustain Sci, 2, 1, pp.121-131.

Hasegawa, R. (2004) A Study on the Regional Differences in Economic Effects and CO_2 Emissions, PAPAIOS, 12, 2, pp.29-38 (in Japanese).

IBARAKI Prefectural Government
http://www.pref.ibaraki.jp/tokei/betu/sangyo/sangyo.html.

Isard,W. (1951) Interregional and Regional Input-Output Analysis: A model of a Space Economy, Review of Economics and Statistics, 33, pp.318-28.

Ishiro, T. (2005) Structural Decomposition Analysis of CO_2 Emission in Japan by Using CO_2 Emission Inducement –Coefficient, the Decomposition of the Change in the Emission Volume, the Analysis of CO_2 Emission Skyline, PAPAIOS, 13, 1, pp.16-25 (in Japanese).

Kawashima, K. and Uchiyama, Y. (2004) An Analysis for Effects of Energy and Environmental Improvements Using the 1994 Philippines Inter-regional I/O Table, PAPAIOS, 12, 2, pp.39-49 (in Japanese).

Kawashima, K. (2005) A Quantitative Analysis of Energy Security Using TSIO Research Report for Agency for Natural Resources and Energy Directionality of Energy Security Measures in Asia-Pacific Region and Its Impacts on the Oil Industry in Japan, Institute of Energy Economics, pp.55-115 (in Japanese).

Kondo,Y. and Moriguchi, Y. (1998) CO_2 emissions in Japan influences of imports and exports, Applied Energy, 59, pp.163-174.

Lenzen, M. (1998) Primary energy and greenhouse gases embodied in Australian final consumption: an input-output analysis, Energy Policy, 26, pp.495-506.

Lenzen, M., Christopher, D. and Barney, F. (2004) Energy requirements of Sydney households, Ecological Economics, 49, pp.375-399.

Leontief, W. (1986a) Input-Output Analysis, Input-Output Economics: Second Edition, Oxford University Press, NY, pp.19-40.

Leontief, W. (1986b) Multiregional Input-Output Analysis, Input-Output Economics: Second Edition, Oxford University Press, NY, pp.129-161.

Leontief, W. and Ford, D. (1970) Environmental repercussions and the economic structure: an input-output approach, Review of Economics and Statistics, 52, pp.262-71.

Liang, Q.M., Fan, Y. and Wei, Y.M. (2007) Multi-regional input-output model for regional energy requirements and CO_2 emissions in China, Energy Policy, 35, pp.1685-1700.

Limmeechokchai, B. and Suksuntornsiri, P. (2007) Assessment of cleaner electricity generation technologies for net CO_2 mitigation in Thailand, Renewable and Sustainable Energy Reviews, 11, pp.315-330.

Ministry of Environment
Internet Site http://www.env.go.jp/earth/ondanka/santeiho/kento/h1209/09.pdf
(in Japanese).

Moses, L.N. (1955) The Stability of Interregional Trading Patterns and Input-Output Analysis, American Economic Review, 45, pp.803-32.

Polenske, K.R. (1970) An Empirical Test of Interregional Input-Output Models: Estimation of 1963 Japanese Production, American Economic Review, 60, 1, pp.76-82.

Proops, J.L.R. (1977) Input-output analysis and energy intensities: a comparison of methodologies, Applied Mathematical Modelling, 1, pp.181-186.

Sánchez-Chóliz, J. and Duarte, R. (2004) CO_2 emissions embodied in international trade: evidence for Spain, Energy Policy, 32, pp.1999-2005.

Shimoda, Y., Asahi, T., Taniguchi, A. and Mizuno, M. (2007) Evaluation of city-scale impact of residential energy conservation measures using the detailed end-use simulation model, Energy, 32, pp.1617-1633.

Tiwari, P. (2000) An analysis of sectoral energy intensity in India, Energy Policy, 28, pp.771-778.

Turner, K., Lenzen, M., Wiedmann, T. and Barrett, J. (2007) Examining the Global Environmental Impact of Regional Consumption Activities-Part1: A Technical Note on Combining Input-Output and Ecological Footprint Analysis, Ecological Economics, 61, pp.6-10.

Uchiyama, K. (2004) Regional Economies and CO_2 Emission in Japan, Economics Today, 24, 4 (in Japanese).

Wei, Y.M., Liang Q.M., Fan, Y., Okada, N. and Tsai, H.T. (2006) A scenario analysis of energy requirements and energy intensity China's rapidly developing society in the year 2020, Technological Forecasting & Social Change, 73, pp.405-421.

Wiedmann, T., Lenzen, M., Turner, K. and Barrett, J. (2007) Examining the Global Environmental Impact of Regional Consumption Activities-Part2: Review of input-output models for the assessment of environmental impacts embodied in trade, Ecological Economics, 61, pp.15-26.

Yanagisawa, A. (2008) Japan Long-Term Energy Outlook -A projection up to 2030 under Environmental Constraints and Changing Energy Markets-, Japan Society of Energy and Resources, 29, 6, pp.340-344 (in Japanese).

Table 1 Sectoral Breakdown

Sector	Corresponding Sector
Primary Products	Agriculture, Forestry, Fishery, Mining
Food Products	Food Products
Chemical Products	Chemical Products
Iron and Steel	Iron and Steel
Machinery	Metal Products, General Industrial Machines, Electric machines, Transit Machines
Other Manufacturing	Textiles, Pulps and Papers, Oil and Coal Products, Ceramic Products, Nonferrous Metal Products, Precision Machines, Other Manufacturing
Construction	Construction
Transportation	Transportation
Public Services	Power Generations, Gas and Heat Supply, Water Services and Waste Disposal, Civil Services, Education and Research, Medical and Social Security, Other Public Services
Other Services	Commerce and Financing and Insurance, Real Estate Communication and Broadcasting, Services for Business, Services for Consumers, Desk Work Products

Table 2 Annual Growth Rate of each Final Demand (%)

	2000-2005	2005-2010	2010-2020	2020-2030
Real GDP	1.1	2.0	1.5	1.1
Private Consumption	1.4	1.6	1.4	1.1
Private Investment	0.0	5.0	2.6	1.9
Public Consumption	2.8	1.4	1.2	1.1
Public Investment	-1.1	-2.7	-1.3	-0.7
Export	4.6	5.0	2.5	1.9
Import	3.7	4.4	3.7	2.4

Table 3 CO_2 Emissions Coefficients （tCO_2/TJ）

Original Coal	83.142	Bunker C	72.266
Import Coal	90.849	Lubrication	72
Coke	108	Petroleum Coak	93
Crude Oil	68.402	LPG	60.247
Gasoline	65.635	Other Petroleum Products	76
Naphtha	66.621	LNG	60.247
Jet Fuel	67	Natural Gas	52.739
Kerosene	67.199	City Gas	51.3
Light Oil	68.66	Electric Power	112.6316
Bunker A	71.192		

Table 4 Scenario Description

Scenario	Description
A1 (low domestic consumption)	The growth rate of private consumption is lower 1% than BAU scenario for every year in the national level.
A2 (low export)	The growth rate of exports is lower 1% than BAU scenario for every year in the national level.
C1 (low carbon)	Improving 10% CO_2 emission coefficients for electric power in the national level.
C2 (C1 + high self sufficiency rate)	The trade coefficients for primary products and both services are higher 10% than scenario C1 in Ibaraki.
C3 (C2 +energy-saving)	Energy-saving is accelerated faster than scenario C2 in the national level.

Table 5 Sectoral CO_2 Emissions per unit of Output (10^3t/10^9 Yen)

	2000	BAU	C1	C2
Primary Products	1.83	1.62	1.61	1.61
Food Products	0.99	0.77	0.75	0.76
Chemical Products	7.17	6.32	6.22	6.22
Iron and Steel	12.80	11.47	11.27	11.28
Machinery	0.98	0.84	0.80	0.82
Other Manufacturing	2.94	2.53	2.45	2.46
Construction	1.01	0.82	0.81	0.83
Transportation	5.78	5.34	5.31	5.32
Public Services	1.46	1.28	1.21	1.22
Other Services	1.47	1.34	1.32	1.32

Table 6 Annual Growth Rate for CO_2 Emissions in Ibaraki (%)

BAU	A1	A2	C1	C2	C3
0.962	0.511	0.690	0.864	0.919	0.652

Table 7 CO_2 Emissions per GDP (10^3t/10^9 Yen)

2000	BAU	A1	A2	C1	C2	C3
1.914	1.678	1.665	1.632	1.631	1.620	1.500

Table 8 Ratio of CO_2 Emissions Trade Balance between Ibaraki and ROJ

2000	BAU	A1	A2	C1	C2	C3
-13.8	-14.8	-14.6	-15.2	-14.8	-14.1	-14.1

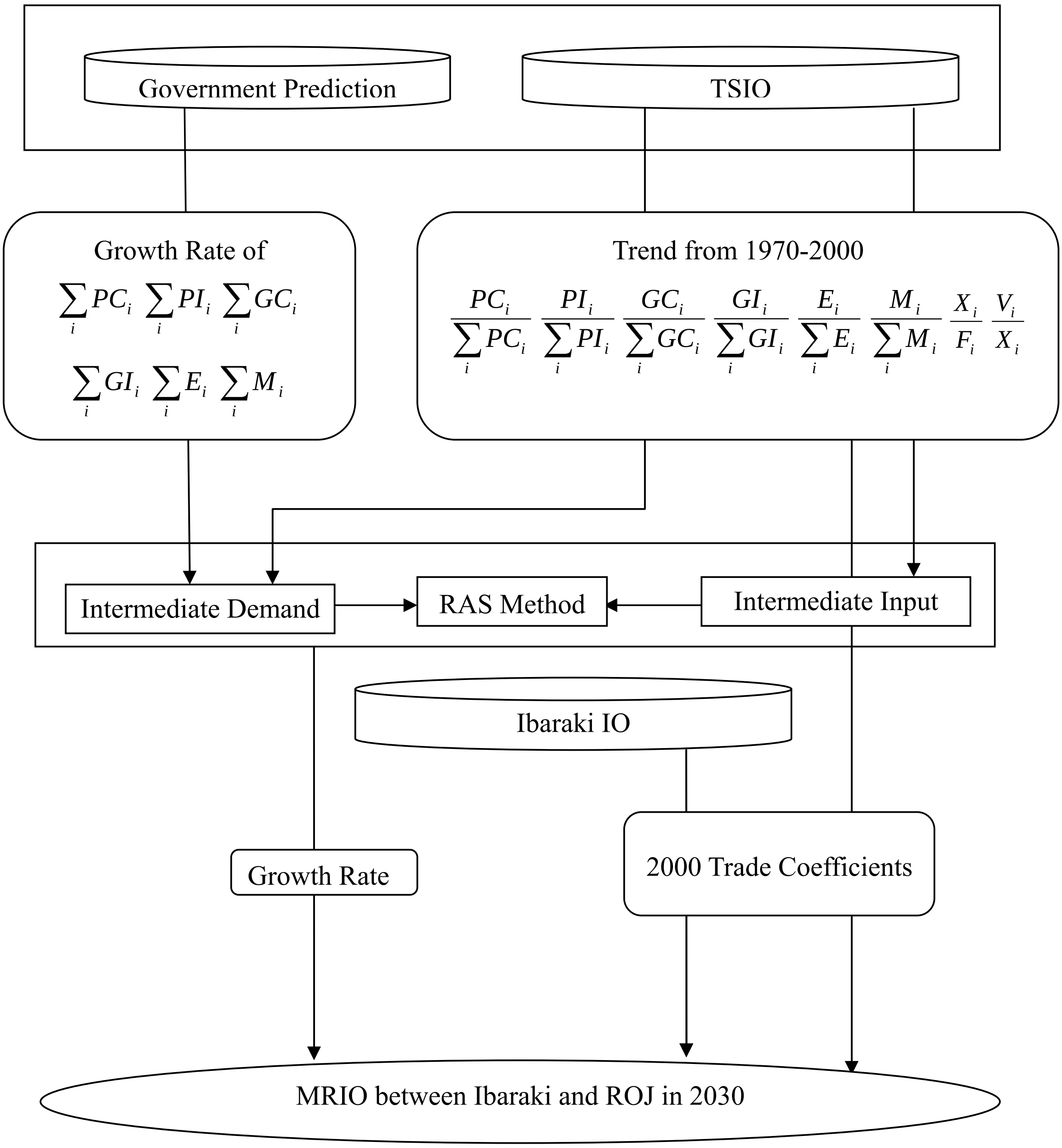

Figure 1 Flowchart of Input Output Model

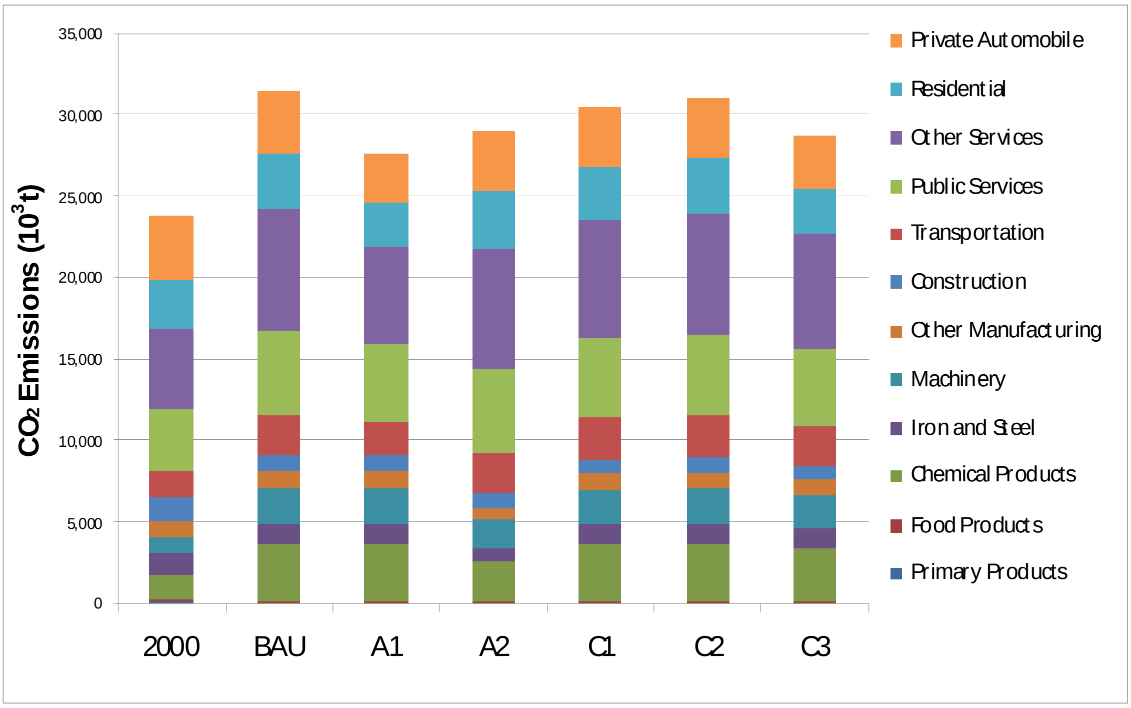

Figure 2 Sectoral amount of CO_2 Emissions in Ibaraki

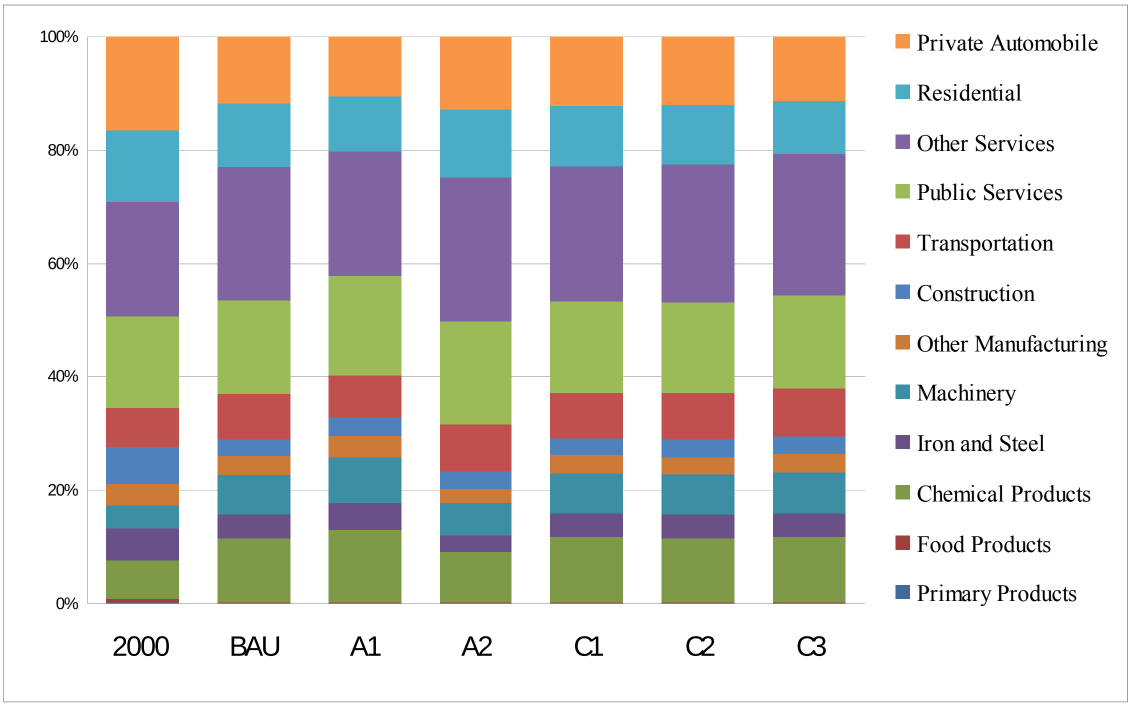

Figure 3 Sectoral Share of CO_2 Emissions in Ibaraki

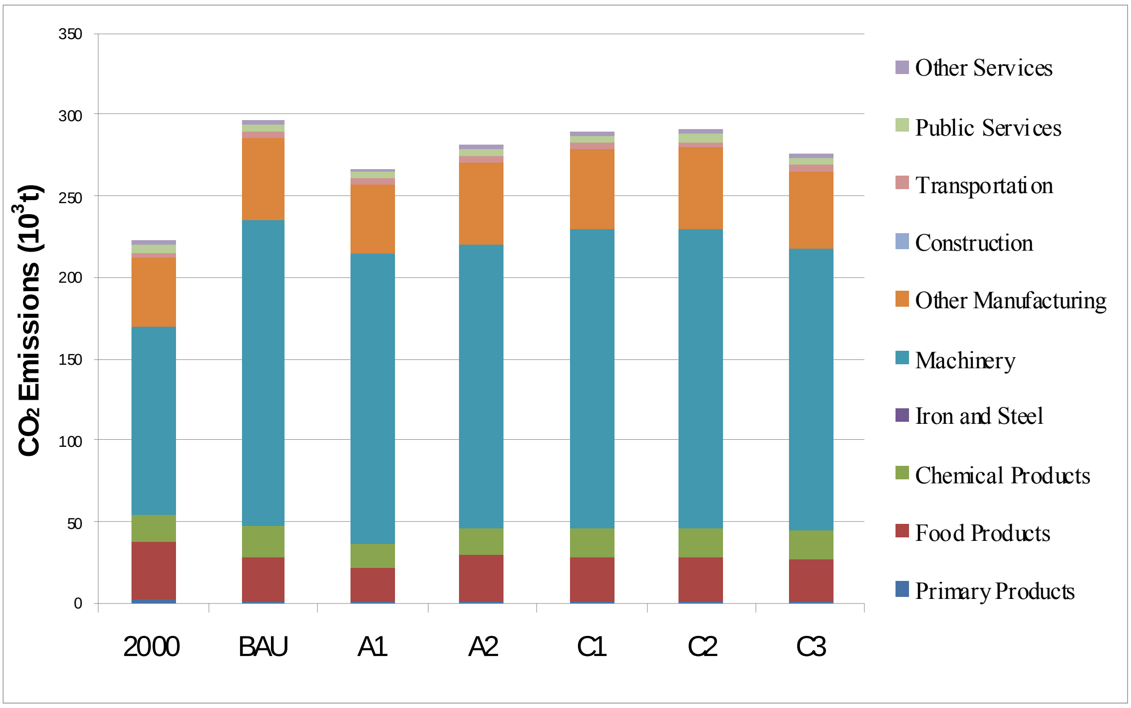

Figure 4 Sectoral amount of CO_2 Emissions in Ibaraki Driven by ROJ

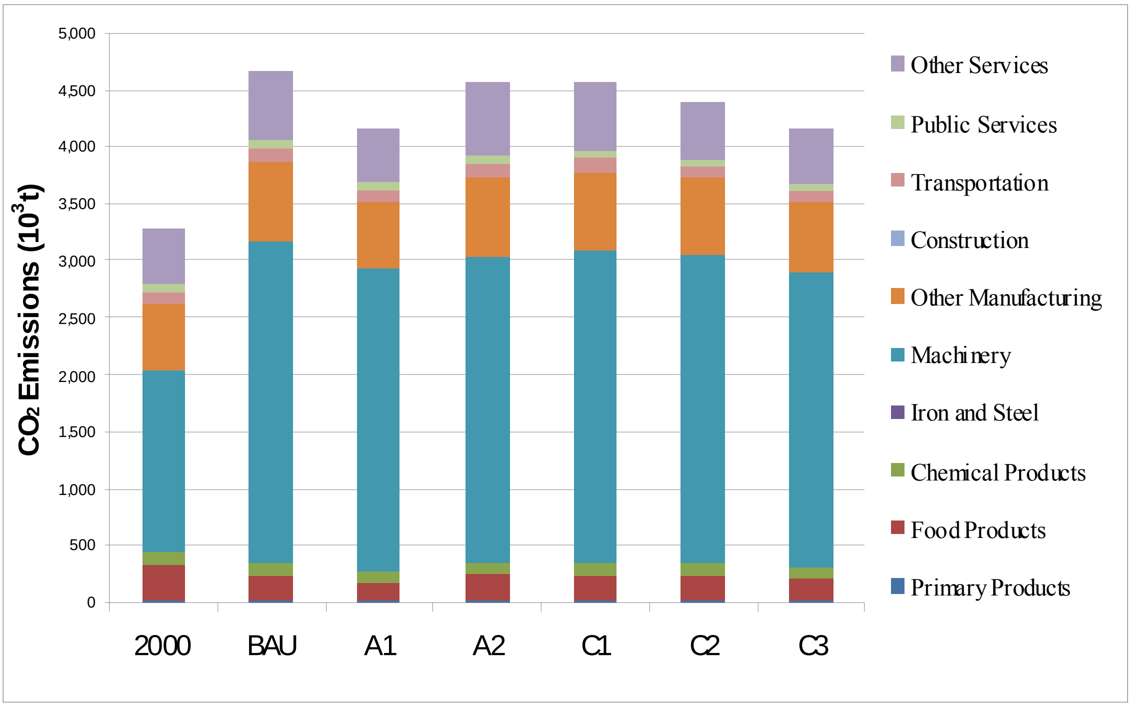

Figure 5 Sectoral amount of CO_2 Emissions in ROJ Driven by Ibaraki