An Easily Traceable Scenario for 80% CO_2 Emission Reduction in Japan for Local Energy Strategy Development

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Abstract
To develop a scenario sure and easily traceable even for ordinary citizens toward the national challenge target of 80% CO_2 reduction by 2050, we first developed a model to calculate the total CO_2 emission corresponding to the final consumption and second developed an appropriate technology based scenario consisting of the following consumer oriented sub-scenarios: (1) energy saving through electrification of all transportation, (2) promotion of wood utilization for housing and household energy saving; (3) introduction of renewable energies; and (4) efficient energy utilization of wastes. Applying the scenario to Kyoto that has the similar strategies to our proposed scenarios, we found that about 80% CO_2 emission reduction is possible just within the appropriate technology limit with the effect of population reduction and with the potential emission reduction from construction of private and public infrastructures, and that shifting our final consumption mode into low CO_2 emission mode has a significant impact.

Keywords: CO_2 emission reduction, appropriate technologies, local energy strategy, the final consumption

1. Background and Objectives

CO_2 concentration has risen by 100ppm since pre-industrial times and is now approaching 380ppm. The IPCC concluded in the 4th report that the rapid rise of CO_2 concentration is the results of human activities [1]. Considering the IPCC' s simulation results of climate change, G8 leading industrial countries finally admitted the necessity to reduce CO_2 emission by 80% or more by 2050 in July 2009 in order to limit the rise of the average atmospheric temperature to within 2ºC.

However, there are very few scenario building studies toward a 60-80% CO_2 emission reduction in Japan. A study conducted by National Institute for Environmental Studies (NIES) applied a general equilibrium model with consideration for a variety of low-carbon technologies of the present time under the constraint of CO_2 emission reduction and a certain level of economic growth [2][3]. This is a consensus building model at the policy making level to see how much CO_2 emission reduction potential we would have with the current possible measures and technologies. Such a model has been also applied to develop the local level scenarios for massive CO_2 emission reduction. However, models based on general equilibrium formula have limitations of several folds: 1) they tend to require heavy computation load, 2) for ordinary people it is difficult to examine the details of assumptions for computation, 3) thus it is not appropriate to examine a variety of scenarios freely, particularly in the regional application, and 4) also, it is not appropriate, because of its complexity, to simply convince people for a consensus with clear visibility.

The recent reform of Act on Promotion of Global Warming Countermeasures (June 2008) requires local governments in Japan to build local energy strategy for CO_2 emission reduction based on specific natural and social conditions of each territory. In this work, we see the significance to develop a simple method, traceable even for laymen, to quantify the impact of specific technology and socio-economic scenarios both at the national and the local level.

Japan's CO_2 emission in 2005 is 1,287 million ton which is consisted of the Industry sector (35% of the total CO_2 emission), the Transportation sector (20%), the Commercial (18%) and Residential (14%) sectors, the Energy industry sector (6%), the Industrial processes sector (4%) and the waste sector (2%) in the direct & indirect emissions data [4]. Apart from industrial sector, Transportation, Commercial and Residential sectors are main CO_2 emission sources. Since the latter three sectors are strongly related to our daily life, shifting our consumption behaviour to low CO_2 emissions basis should lead the significant nock-on effect to other sectors, particularly industry and transportation sectors of high direct CO_2 emission. Thus, it is of interest to examine how much CO_2 emissions are actually related to the final consumptions, and to design massive emission reduction scenarios through the change in the final consumptions.

The current direct and indirect emission data of Japan, however, only allocates CO_2 emissions from power generation and steam generation in each final demand sector, and does not consider the CO_2 emissions from other materials or goods consumptions. There is a study on estimation of CO_2 emissions at the final demand in Japan including low materials and parts for production as well as power generation and steam generation [5]. This study shows an interesting overview that about 47% of CO_2 emissions are derived from private consumption expenditures in Japan. However, this work is based on the analysis of the Input-Output tables which is provided by every 5 years at the prefectural level and rarely at the city and town level. With this data, it is limited to examine the impacts of change in the individual consumption behavior resulted from a variety of CO_2 emission reduction scenarios.

In this study, we propose a model to calculate the final consumption related CO_2 emissions by combining the CO_2 emission data based on Japanese Input-Output tables and a data set of household consumption expenditures. We then discuss the technology scenarios that could be appropriate to achieve massive CO_2 emission reduction from the demand side, and examine the effect by simple, easy and traceable calculation.

2. Model and Data

2-1. The Boundary of Household Consumption

In Japan's direct and indirect CO_2 emissions data [4], CO_2 emissions at residential sector only considers CO_2 emissions from power generation and steam generation in each final demand sector in addition to direct fuel use at households. In this study, we further extend the boundary of CO_2 emission burden to fuel production for household fuel use, agriculture for food, and other production for consumption goods as seen in Figure 1. CO_2 emissions from wastes and waste water resulted from household consumptions are also considered, but CO_2 emissions from imports and oversea consumptions are not included.

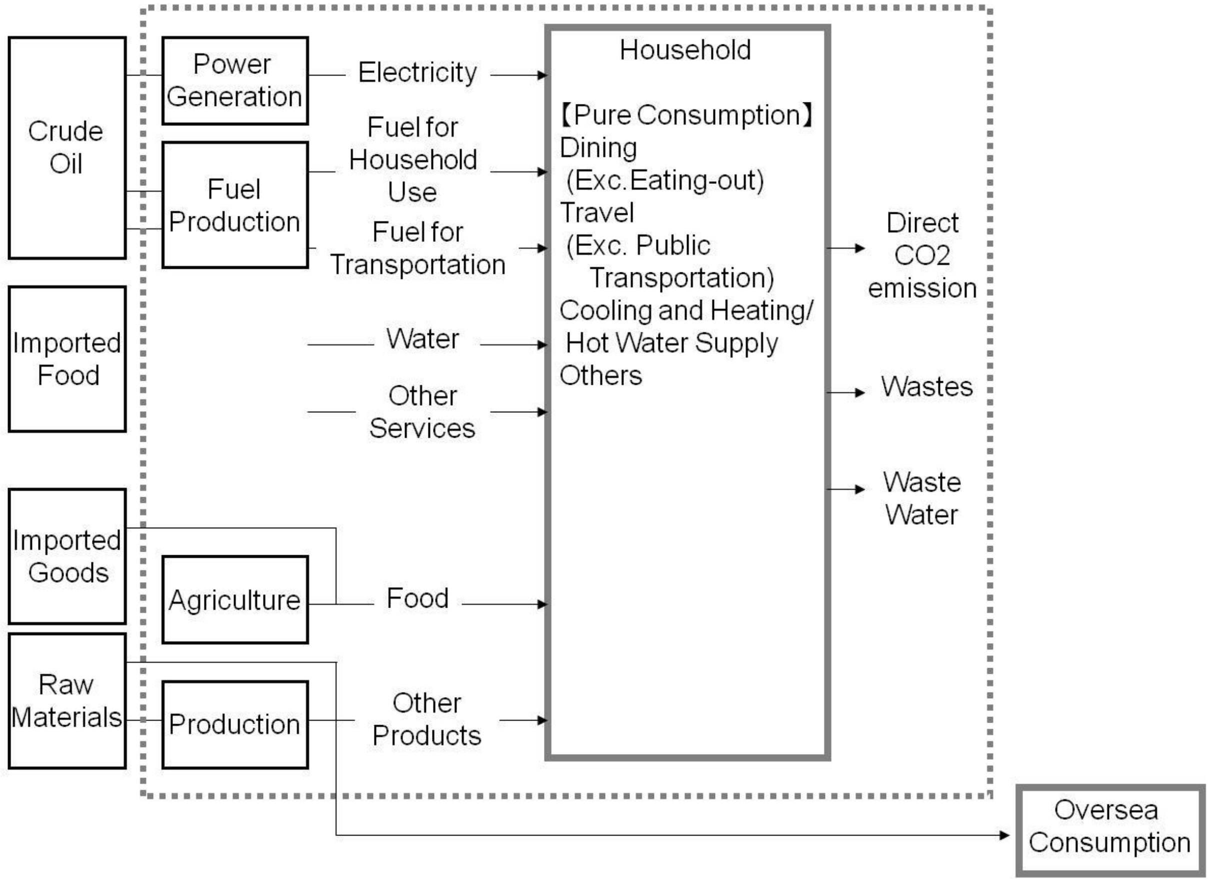

Fig. 1. Boundary of CO_2 emission in this study

2-2 Data

2-2-1. Data for estimation

In order to estimate lifecycle CO_2 (LC-CO_2) related to household consumptions as defined in 2-1, we employ Household Expenditure Survey (HES) and Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables (3EID).

(1) HES [6]

The HES is a survey to learn the actual state of household incomes and expenditures in terms of money and quantity. This survey is conducted every month for about 981 consumption items for 8000 households in 168 villages, towns and cities all over Japan by Statistics Bureau, Ministry of Internal Affairs and Communications. The result of survey is announced monthly and yearly by cities, regions, the types of households (i.e. total household, household of more than two, single person household).

(2) 3EID [7]

3EID contains embodied environmental burden intensity data which is calculated using Japanese Input-Output tables. Japanese Input-Output tables consist of about 400 commodity sectors, which are display economic relationships among these sectors by matrix description based on annual transactions among sectors. 3EID shows direct and indirect energy consumption or CO_2 emission (i.e. environmental burden) from the unit production activity (equivalent to one million yen). In this study, we employ the CO_2 emission intensity data estimated by the consumer price excluding imports.

2-2-2. Estimation of CO_2 emissions from household consumptions

In order to estimate CO_2 emissions from household consumptions within the boundary defined in this study (see Figure 1), we correspond the items of Household Expenditure Survey to 3EID sectors in group of Food (i.e. Cereals, Fish and shellfish, Meat, Dairy products and eggs, Vegetables and seaweeds, Fruits, Oils, fats and seasonings, Cakes and candies, Cooked food, Beverages, Alcoholic drinks, Meals outside the home, Charges of board), Housing, Fuel and lights (i.e. Electricity, Gas, manufactured and piped, Liquefied propane, Kerosene, Other fuel and light), Water charges (i.e. Water and sewerage charges), Furniture and household utensils, Clothing and footwear, Medical care, Transportation and communication, Education, Culture and recreation, and Other consumption expenditure. Then we estimated annual CO_2 emission per household (kg-CO_2/year) of each expenditure group by the following equation.

$$CE_j = \Sigma E_i \cdot ce_i + CW_j \qquad (1)$$

where $CW_j = QD_j \cdot 365(\text{days}) \cdot n \cdot q \cdot cp$

CE_j annual CO_2 emission of j type of household (kg-CO_2/ year)
CW_j annual CO_2 emission of j type of household from waste disposal (kg-CO_2/ year)
E_i annual amount of i expenditure group (yen/year)
ce_i basic unit of CO_2 emission of i expenditure group (kg-CO_2/yen)
QD_j daily quantity of waste disposal per person of j type household (=1,131g/day)
n average number of persons per household
q mixing ratio of plastic in the disposals (=10%)
cp basic unit of CO_2 emission of plastic disposal per person (=2.69kg-CO_2/kg) [8]

Table 1 shows the estimation results of national average of annual expenditure and CO_2 emission per household divided into the item groups related to direct energy consumption and those related to indirect energy consumption. While the expenditure in the group of direct energy consumption is about 600 thousands yen/year (i.e. about 6,500 US dollars when 1$=90yen) which is 18.4% of the total household expenditure, the CO_2 emission accounts for 60.5% of the total CO_2 emission from household consumptions. On the other hand, the CO_2 emission in the group of indirect energy consumption accounts for 39.5% although 81.6% of the total household expenditure is from this group. Thus, the results show that CO_2 emission from household consumptions is mainly derived from the direct energy and fuel consumption, particularly use of electricity, gas and gasoline rather than goods consumption.

Multiplying 11,716kg of the national average of CO_2 emission per household by 49 million households in 2005 (see Table 2), we figured that the total CO_2 emission from household consumptions is about 575 billion t-CO_2. This accounts for 44.7% of the total CO_2 emission in 2005, and indicates the importance of CO_2 emission reduction corresponding to the final consumptions as well as the rest of CO_2 emission originated from the construction of private and public infrastructure towards the national level of 80% CO_2 emission reduction.

Table 1. National average of annual expenditure and CO_2 emission per household

Direct energy consumption	Expenditure [yen/year]	Ratio* [%]	CO_2 emission [kg-CO2/year]	Ratio** [%]
Fuel and light	169,577	5.3	5,524	47.1
(Electricity)	(94,691)	(3.0)	(2,496)	(21.3)
(Gas, manufactured and piped)	(32,774)	(1.0)	(1,864)	(15.9)
(Liquefied propane)	(25,345)	(0.8)	(633)	(5.4)
(Kerosene)	(16,470)	(0.5)	(530)	(4.5)
(Other fuel and light)	(297)	(0.0)	(1)	(0.0)
Transportation and communication	418,412	13.1	1,564	13.3
(Gasoline)	(56,261)	(1.8)	(1,004)	(8.6)
Total	587,989	18.4	7,088	60.5
Total per household	3,198,092	100.0	11,716	100.0

Indirect energy consumption	Expenditure [yen/year]	Ratio* (%)	CO_2 emission [kg-CO2/year]	Ratio** (%)
Food	799,816	25.0	1,485	12.7
Housing	245,590	7.7	65	0.6
Water and sewerage charges	49,915	1.6	56	0.5
Furniture and household utensils	105,543	3.3	196	1.7
Clothing and footwear	148,858	4.7	270	2.3
Medical care	133,993	4.2	220	1.9
Education	108,966	3.4	91	0.8
Culture and recreation	354,994	11.1	628	5.4
Other consumption expenditure	662,428	20.7	1,387	11.8
Disposals	–	–	230	2.0
Total	2,610,103	81.6	4,628	39.5
Total per household	3,198,092	100.0	11,716	100.0

Note: * The ratio of total expenditures per household in 2005.
** The ratio of total CO_2 emission per household in 2005.
*** CO_2 emission from the direct combustion of disposal is added to 3EID data.

Table 2. The total CO_2 emission from household expenditure

Source of CO_2 emission	CO_2 emission [million t-CO_2]	Ratio [%]
Household expenditure	574,822	44.7
Others	712,513	55.3
Total emission in 2005	1,287,335	100.0

3. Discussion

Seeing the indirect CO_2 emissions through household consumptions, about 50% of CO_2 emission in Japan is related to the final demand for consumptions. Since the proportion is high, shifting our consumption behavior to low CO_2 emission basis is a key to achieve massive CO_2 reduction. But what kinds of technology are applicable?

3-1. Technologies for Achieving Massive CO_2 Reduction

In this study, we propose an “appropriate technology” concept. “Appropriate technologies” are normally described as simple technologies suitable for developing countries, or less developed rural areas in developed countries. This study is not particularly concerned with ‘simple’ technologies, but with technologies that contribute not only to CO_2 emission reduction but also to regional sustainability by utilizing local resources at most. Here we discuss the following simple consumer oriented technology scenarios and the possible effects of CO_2 emission reductions: (1) all electric transportation, (2) woody housing and household energy saving; (3) renewable energies; and (4) efficient energy utilization of wastes.

(1) All electric transportation

As seen in Table 1, about 65% of CO_2 emission in the group of Transportation and communication is from combustion of gasoline. Electric transportation, particularly electric vehicles enable to reduce the CO_2 emission from transportation drastically. Besides, the modal shift from vehicles and trucks to rails and other electric transports is similarly significant. In this study, we assume that the household does not consume any gasoline for transportation in 2050 due to all electric transportation systems.

(2)Woody housing and household energy saving

About 67% of land in Japan is forest. Forestry used to be an important industry in hilly and mountainous areas, and 85.7% of wood was self-sufficient in 1960. As demand of wood increased under the rapid economic growth and timber trade liberalization, Japan started highly relying on imported wood, declined to about 20% self-sufficiency now. Revitalization of domestic forest industry is a crucial issue in Japan, as well as restoring devastated forest in the last several decades and ensuring forest carbon uptake. Dissemination of woody houses utilizing domestic wood does not only increase carbon stocks but also underpin the recovery of Japanese forest industry. Hino-city in Tokyo formulated the guideline of woody eco-house that enables to reduce CO_2 emission 50% [9]. In addition to house itself, the guideline indicates that 80% of CO_2 emission reduction can be achieved with a combination of energy saving home appliances (+15%) and utilization of renewable energy (+15%).

(3)Renewable energies

The current proportion of renewable energy in total energy supply of Japan is about 3% excluding hydro power, and including hydro, accounts for about 6% [10]. Meanwhile, there are several studies on the potential of renewable energy in Japan, but the estimated potential varies widely from study to study [11]. One of the highest possibilities of renewable energy introduction by 2050 in Japan is estimated to be 558 billion kWh of electric power and 1,303 PJ of heat [12]. According to the estimation, 59% of system power supply and 79% of dispersed power supply, and 100 % of household heat supply can be provided by renewable resources. With the maximum utilization of renewable energy at household, 15% of CO_2 reduction can be achieved as expected of scenario (2). In addition, we assume that CO_2 emissions from goods consumption could be reduced at least by half as the result of renewable energy utilization in the process of production and processing.

(4)Efficient energy utilization of wastes
Japan has been highly reliant on incineration for waste disposal. Power generation from wastes have gradually introduced, but the average power generation efficiency for incineration plants remains considerably low. Efficient energy utilization of wastes could reduce about 15 million tons in CO_2 emissions as alternatives to fossil energy resources [13]. With the combination of efficient energy utilization of wastes and the effort to the decrement of disposal, we assume that the CO_2 emission from disposal becomes nearly zero by 2050.

3-2. The Scenario Application to Kyoto-city
Kyoto-city is one of designated cities as Eco-Model Cities for a Low Carbon Society by Japanese government. 13 Eco-Model Cities are selected on the basis of potential for taking up the challenge of pioneering approaches with high CO_2 emission reduction targets. CO_2 emission in Kyoto in 2005 is 8.2 million ton, and similar to the national trend, CO_2 emission has recently increased particularly in the commercial and residential sector although other sectors have reduced their emission. Kyoto-city, as an Eco-Model City, sets a target of 40% CO_2 emission reduction by 2030 and 60% reduction by 2050. The following strategic actions are planned: (a) creation of a pedestrian friendly city; (b) formation of low carbon landscape through recognition of woody culture; (c) lifestyle change and technology innovation; (d) the maximum utilization of renewable energy and wastes. The main purpose of the action (a) is the shift to low CO_2 emission transportation, and corresponding to our scenario (1). The action (b) and (c) are the similar approach to our scenario (2). The scenario (3) and (4) are corresponding to the action (d).

Table 3 shows CO_2 emissions of each emission group per household in Kyoto when the related scenarios are applied. We assume that 80% of CO_2 emission is achieved in group of ‘fuel and light’ by energy saving and the maximum utilization of renewable energy and wastes as assumed in the scenario (2). We also apply the assumption of zero gasoline consumption in 2050 as the result of the shift to the low-carbon transportation and communication system. As to disposals, the reduction of wastes and energy recovery from wastes, we assume that the nearly zero CO_2 emission is achieved in 2050. Other consumption goods including food, we assume that about the half of CO_2 emission is reduced by the maximum renewable energy utilization and the shift to low-carbon system in the process of production and distribution process.

As the whole of CO_2 emission per household in Kyoto, 7,320 kg (=10,984－3,664) reduction is estimated from the emissions in 2005. Based on the result, the CO_2 emission of the total household in Kyoto is calculated by multiplying the CO_2 emission per person by population in Table 4. Even without the consideration of population reduction, the estimated CO_2 emission reduction is 4.4 million ton, which is a 67% reduction of the emissions in 2005. With the consideration of population reduction to 2050 (i.e. from 1.47 million in 2005 to 0.8 million in 2050), the further 1 million t-CO_2 is reduced, and with forest carbon uptake (i.e. about 1 million t-CO_2 absorption from forest), the ratio of CO_2 emission reduction increases further, reaching 83% of emissions in 2005. Thus, applying the simple methods of scenario applications, the results indicate the possibility of over 80% CO_2 emission reduction by shifting the final consumption into the low CO_2 emission basis. Anticipating the high potential of CO_2 emission reduction in private and public infrastructures through the development of low carbon construction methods as well as the recent trend of the strict cut of wasteful constructions, it is well within the capacity to achieve about an 80% CO_2 emission reduction in the total by 2050.

Table 3. CO_2 emissions under the scenarios per household in Kyoto

Emission groups	CO_2 emission in 2005 [kg-CO_2/year]	CO_2 emission under the scenario [kg-CO_2/year]	Reduction ratio [%]	Related Scenario*
Fuel and light	6,043	1209	80	(2)&(3)
Transportation and communication	836	461	50	-
(Gasoline)	(375)	(0)	(100)	(1)
Disposals	116	0	100	(4)
Food	1,558	779	50	(1)&(3)
Others	2,431	1,216	50	(1)&(3)
Total CO_2 emission per household	10,984	3,664	33.4	-

Note: *) The number is corresponding to the scenario numbers discussed in 3-1.

Table 4. CO_2 emission of the total household in Kyoto

	CO2 emission per person [kg-CO2/year] <a>	Population <b>	Total CO2 emission [t-CO_2/year] <a>*<b>	Reduction ratio to 2005 [%]
(a) In 2005	4,465	1.47million	6.6 million	-
(b) Under Scenarios (no population change)	1,489*	1.47million	2.2million	67
(c) Under Scenarios (with population change)	1,489*	0.8million**	1.2 million	82
(d) With forest carbon uptake	1,489*	0.8million**	1.1million**	83

Note: *) Total CO_2 emission per person divided by average number of persons per household of 2.46 [6].
**) Kyoto city estimated the population in 2050 based on National Population Census [14].
***) Carbon uptake in 2050 is estimated as 145,600t-CO_2 by Kyoto-city [15].

4. Conclusions

To develop a scenario sure and easily traceable even for ordinary citizens toward the national challenge target of 80% CO_2 reduction by 2050, in this study, we first developed a model to calculate the total CO_2 emission corresponding to the final consumption, and second developed an appropriate technology based scenario consisting of the following consumer oriented sub-scenarios: (1) energy saving through electrification of all transportation, (2) promotion of wood utilization for housing and household energy saving; (3) introduction of renewable energies; and (4) efficient energy utilization of wastes. Applying the scenario to Kyoto that has the similar strategies to our proposed scenarios, we found that about 80% of the total CO2 emissions from household expenditures is possible just within the appropriate technology limit with the effect of population reduction and with the potential emission reduction from construction of private and public infrastructures, and that shifting our final consumption mode into low CO_2 emission mode has a significant impact.

The consumption behaviour varies according to such as household composition, economic conditions and climate. Although we have discussed the possibility of CO_2 emission reduction mainly under the technology based scenarios in this study, it is also of interest to see impacts of change in future household composition and population migration in the future. The further studies are needed particularly on the impact of socio-economic change.

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