参考資料３－２

Sustainable development under ambitious medium term target of reducing greenhouse gases

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Abstract. Japanese prime minister, Yukio Hatoyama declared the commitment that Japan would decrease 25% of greenhouse gases compared with 1990 emissions. This commitment was highly evaluated worldwide. However, some experts criticize that it is impossible to maintain sustainable development under such severe target. This article aims at investigating whether we could realize sustainable development under such ambitious target of reducing greenhouse gas emissions. For this purpose, we first evaluated possible technology options and system innovation along with economic options. Technology options include efficiency improvement, renewable energy technologies and nuclear power technologies. Economic options include carbon tax, emissions trading scheme and feed-in-tariff for renewable energies.

Once the promising technologies and policy options were listed up, we integrated these options in a computable general equilibrium model for Japan, which we developed, so as to evaluate the impact to national economy. As results, we identified the condition, how we could realize sustainable development under the 25% target of reducing greenhouse gas emissions. Finally, we investigated the applicability of the same concept to other countries or regions.

Keywords: post-Kyoto frameworks, medium-term numerical targets, computable general equilibrium model, technology options, sustainable development, impact to national economy

1. Introduction

Since the fourth assessment report of IPCC was published in 2007, worldwide concern on global warming has been escalating unprecedentedly. (Bernstein, L. et.al. 2007). Response strategies to climate change were raised as the most important issue also in the Heiligendamm summit in June, 2007. Since the first commitment period already started, they are making the sincere effort to comply with the numerical target in Annex-one countries ratifying Kyoto Protocol.

On the other hand, international negotiation has also started from COP13 in 2007 on the framework to mitigate climate change after 2013, what we call post-Kyoto framework. (Matsuhashi, R. et. al., 2009) Even in COP15 in Copenhagen, the post-Kyoto framework has not been determined yet.

2. Negotiation on post-Kyoto frameworks

Although they could not reach concrete consensus on the post-Kyoto frameworks, 73 countries submitted their own reduction targets of greenhouse gases to the secretarial office of Framework Convention on Climate Change, according to Copenhagen accord. Table 1 shows the submitted results of major countries or regions.

As one of these numerical targets, Japanese prime minister, Yukio Hatoyama declared the commitment that Japan would decrease 25% of greenhouse gases compared with 1990 emissions. This commitment was highly evaluated worldwide. However, some experts criticize that it is impossible to maintain sustainable development under such severe target.

Table 1. Numerical targets of greenhouse gas reductions in 2020.

	Reference year	Target	Numerical target	Regarding 1995	Regarding 2005
Japan	1990	GHG emissions	−25%	−25%	−30%
EU	1990	GHG emissions	−20%〜−30%	−20%〜−30%	−13%〜−24%
U.S.	2005	GHG emissions	−17%	−3%	−17%
China	2005	GHG/GDP	−40%〜−45%	−	4〜8%／year
India	2005	GHG/GDP	−20%〜−25%	−	3〜8%／year

Therefore Japanese government established a committee in the cabinet office to evaluate impacts of the medium-term target to national economy. This committee organizes a task force, which consists of experts for evaluating economy, environment and technology. After a few months' intensive work by the task force, they submitted the result of evaluation as shown in table 2.(Cabinet office for Japanese government, 2009) Variables in table 2 show differences from a reference case, in which they realize 4% reduction from 1990 level. They all use their CGE model to evaluate economic impacts of 25% reduction from 1990 level. They evaluate 25% reduction from 1990 level in the all case studies, in which domestic reduction varies as shown in each column title. Namely, they assume to compensate the rest by emission credits to meet the 25% reduction. In this respect, we also note that proposed frameworks such as SCM, sectoral crediting mechanism, NAMA, nationally appropriate mitigation action, REDD, reduced emissions from deforestation and forest degradation, and MRV, measurable, reportable and verifiable, as well as above numerical targets.

Table 2 implies larger loss of GDP in higher domestic reduction cases. At the same time, we need to be aware of the fact that electricity price and light and fuel expenses drastically increase in higher domestic reduction cases. In particular, electricity price and light and fuel expenses escalate as twice as reference case. Such escalation of energy prices lead to serious economic impacts.

As shown in table 2, experts evaluated impacts of the above reduction target to national economy.

Table 2. Evaluation of economic impact of Japan's numerical targets

	10% reduction domestically	15% reduction domestically	20% reduction domestically	25% reduction domestically
Loss of real GDP(%)				
CGE of Nikkei Center	−0.8	−1.3	−2.1	−3.1
CGE of NIES	−0.9	−1.4	−2.9	−3.2
CGE of Keio University	−1.3	−2.2	−3.6	−5.6
Increase in electricity price(%)				
CGE of Nikkei Center	20.4	44.2	77	117
CGE of NIES	12.8	19.6	43.6	113.6
CGE of Keio University	37.1	56.2	76.9	97.3
Increase in light and fuel expenses(%)				
CGE of Nikkei Center	12.9	27	46.1	69
CGE of NIES	5.5	9.1	22.3	93.2
CGE of Keio University	26.7	40.6	55.9	71.7
Marginal cost (Yen／t-CO_2)				
CGE of Nikkei Center	10620	21940	39078	63180
CGE of NIES	8678	10252	23869	52438
CGE of Keio University	30303	46764	66093	87667

Nikkei Center: Japan Center for Economic Research, NIES: National Institute for Environmental Studies

3. Evaluation of economic impacts using a computable general equilibrium model

We developed a CGE model, a computable general equilibrium model for Japan, based on Ichioka's analysis. (Ichioka, O., 1991) We used this CGE model in order to evaluate impacts to national economy. In this CGE model, households determine present consumption, in which nineteen kinds of goods are classified as shown in figure 1, and savings to maximize their utility. On the other hand, households themselves are classified into eighteen brackets according to their annual income. This classification is significant in this analysis to evaluate economic impacts in each income bracket. Since products for efficiency improvement and renewable energy are more expensive than ordinary products, households in higher income brackets can afford the products than those in lower income brackets. Consequently, impacts to households are different depending on annual income. We should be very careful about economic impacts to lower income households.

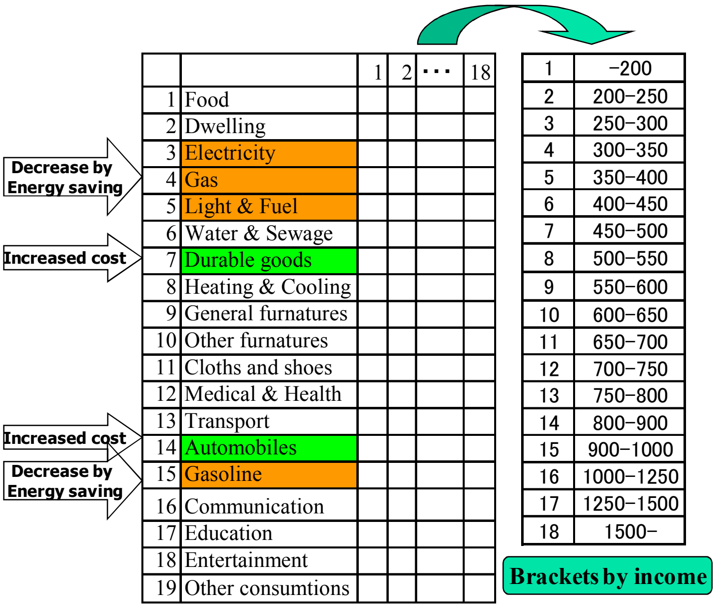

Figure 1. Consumption and production sectors of our CGE models.

Firms determine factors of production, labor and capital inputs to minimize their costs for producing goods. At the same time, intermediate demand is determined based on Leontief production function, in which thirty nine kinds of goods are classified in input-output table shown in figure 2.

1	Agriculture, forestry and fishery	20	General machinery
2	Limestone	21	Electric machinery
3	Coal	22	Automobile
4	Oil	23	Transport machinery
5	Natural gas	24	Precision machinery
6	Other minerals	25	Other manufacturing
7	Food	26	Construction
8	Textile	27	Electricity
9	Wood products	28	Gas
10	Pulp & paper	29	Heat
11	Printing	30	Water & Sewage
12	Chemistry	31	Waste disposal
13	Petroleum products	32	Commerce
14	Coal products	33	Finance & Innsurance
15	Ceramic products	34	Real estate
16	Cement	35	Transport
17	Iron & steel	36	Broadcasting
18	Non-ferrous metals	37	Service
19	Metal products	38	Governmental service
		39	service

Figure 2. Industrial sectors in input-output table.

In the case of deploying energy saving and renewable products for households, production values increase in electric machinery, precision machinery, automobiles and so on in industrial sectors. On the other hand, households consume less electricity and gasoline due to efficiency improvement, so that production values in industrial sectors of electricity and of petroleum products decreases. And then complicated repercussion effects occur in industrial sectors from the above change in final demand of households.

Governments impose various kinds of taxes, including carbon tax, to meet their final demand and public investment. Finally we compute equilibrium points, in which supply and demand for all goods and factors of production are equal, as shown in figure 3.

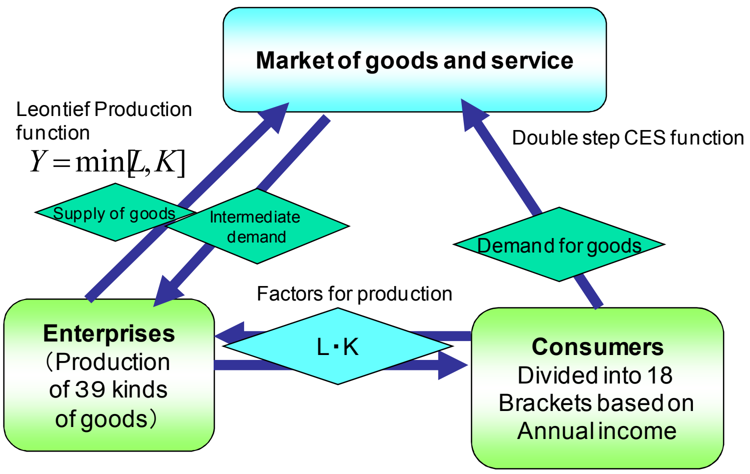

Figure 3. Conceptual figure of general equilibrium

4. Mitigation options to realize 25% reduction and impacts to national economy

Using the CGE model described in the last chapter, we actually evaluate economic impacts of the 25% reduction target. First, we computed a reference case, in which national economy expands without complying with the above reduction target. Growth of real GDP is assumed to be 1.3% from 2005 and 2020. This growth rate is same as the evaluation by the task force in table 2.

Then we realized the 25% reduction target by adopting the options below.

(1) Eight new nuclear power plants are assumed to begin operation until 2020. This assumption is coincident with the plan of maximum efforts case depicted by Japanese government.
(2) Present average rate of operation in nuclear plants are low around 70% mainly due to earthquake. We assume average rate of operation to be increased as 90%.
(3) Deployment of photovoltaics is promoted based on the Japanese system of feed in tariff, in which surplus of electricity generated by photovoltaics must be purchased by electric power companies.
(4) Deployment of highly insulated houses is also promoted. Average rate of adopting highly insulated houses is assumed to amount to 80%.
(5) Deployment of eco-cars such as hybrid and plug-in hybrid vehicles is also promoted. Average rate of adopting eco-cars is assumed to amount to 80%.
(6) Efficiency improvement is promoted in home electric appliances and automobiles, according to the top runner institution by Japanese government.
(7) Fuel switching from petroleum products to gas is promoted in industrial sectors.
(8) Modal shift is promoted from trucking to rail and to marine transport in transport sectors.
(9) We also assume to impose carbon tax.

By these options, we domestically realize 15% reduction from 1990 level. With emission reduction credits, the 25% reduction target was realized from 1990 level.

We first define Case 1, in which the reduction target is satisfied without efficiency improvement and lowering price in electric appliances, automobile and photovoltaics for households. Figure 4 is the result of Case 1, showing changes from the reference case. Namely, it depicts changes of utility based on the concept of equivalent variation, in which utility changes are expressed in terms of price in goods before change.

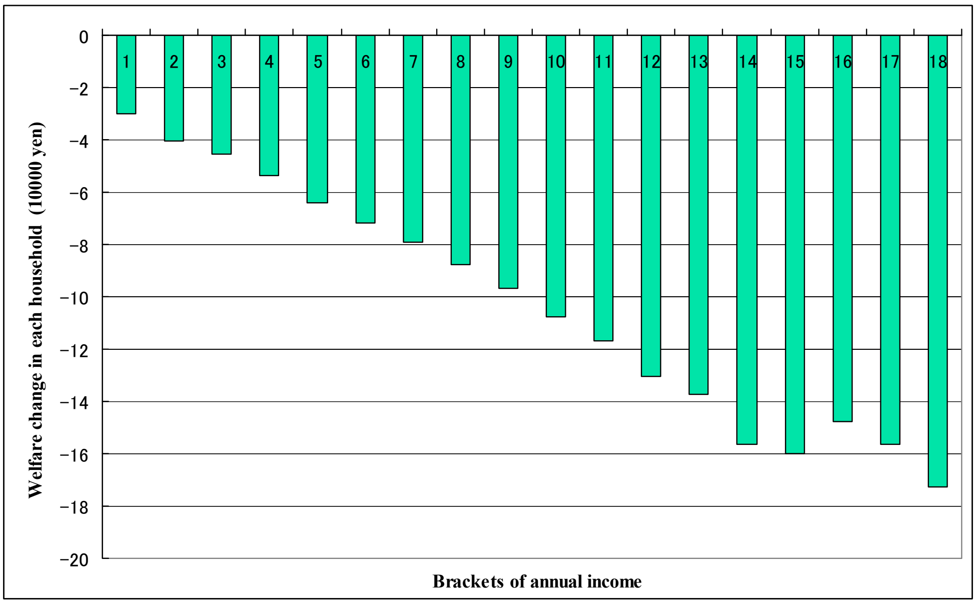

Figure 4. Changes of utility expressed based on equivalent variation in Case 1.

Figure 4 implies that utility values decreased in all income brackets by realizing the 25% reduction of greenhouse gases, unless efficiency improvement and lowering price in home electric appliances, automobile and photovoltaics. Then we aggregate total changes of utility in equivalent variation by multiplying number of households in each income brackets. We define this value as aggregate welfare change, AWC.

Next we adopt efficiency improvement by deploying eco-cars such as hybrid and plug-in hybrid cars in Case2. Figure 5 shows the computed results in Case2. Utility values increase especially in higher income brackets by deploying eco-cars. Aggregate welfare change amounts to 829 Billion yen.

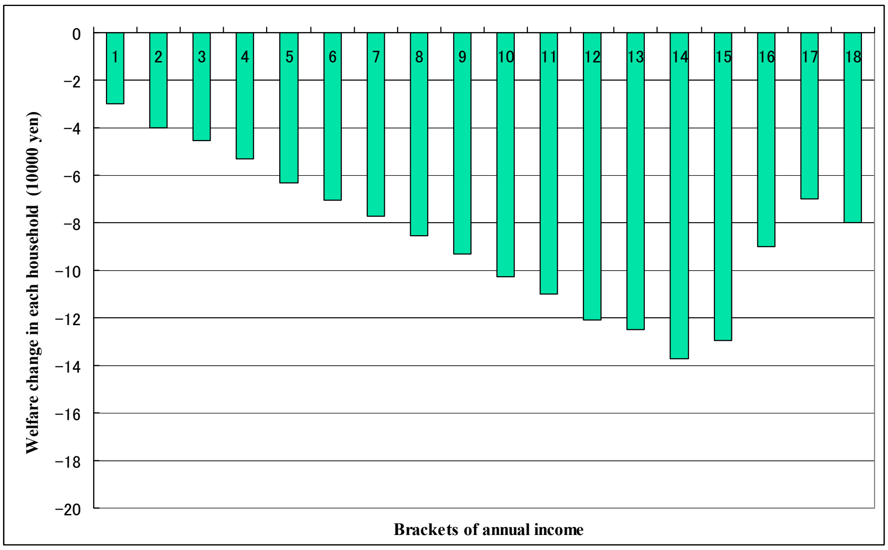

Figure 5. Changes of utility expressed based on equivalent variation in Case 2.

Next we adopt efficiency improvement in home electric appliances in Case3. Figure 6 shows the computed results in Case3. Welfare values increase in all income brackets by efficiency improvement in home electric appliances. Aggregate welfare change amounts to 8.04 trillion yen. Adoption of efficiency improvement in household electric appliances is such dramatic that governments should promote the policy for the improvement.

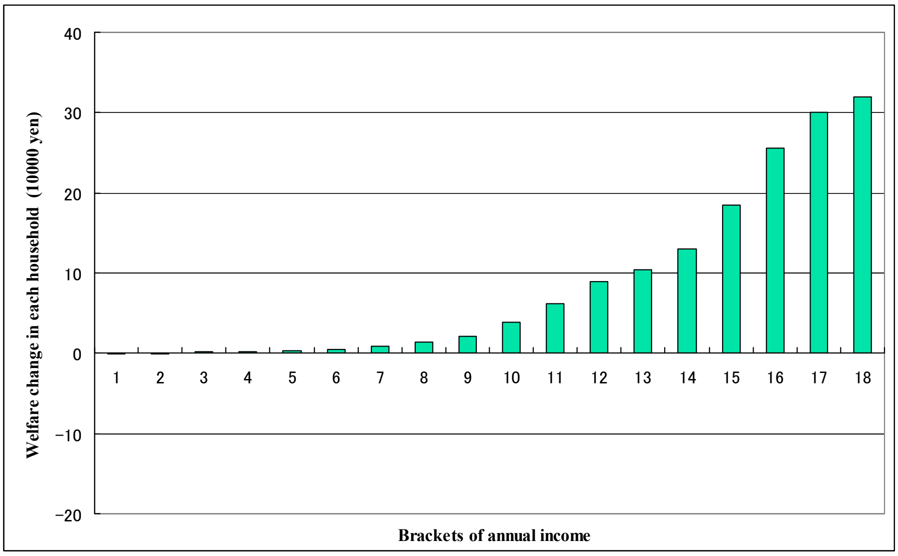

Figure 6. Changes of utility expressed based on equivalent variation in Case 3.

Next we investigate an effect of technology innovation in photovoltaics. According to Yamada (Yamada, 2010), cost of photovoltaics could be decreased by technology innovation as in table 3.

Table 3. Examples of costs in photovoltaics and batteries.

YEAR	2010	2020	2030
Photovolataics (yen/W)	200	100	50
Efficiency (%)	17	20	35
Setting up (yen/W)	200	100	50
Cost (yen/kWh)	40	20	10
Li-ion batteries (yen/Wh)	10	5	2 (Novel)
Lifetime 5years 20h (yen/kWh)	40	20	4 (10years)
5h (yen/kWh)	10	5	1
Total (5h, yen/kWh)	50	25	11

Then we computed the new equilibrium point, assuming the cost in table 3. We define this case as Case 4, in which the result is shown in figure 7. Utility values increase especially in higher income brackets by innovation in photovoltaics. Aggregate welfare change amounts to 625 Billion yen.

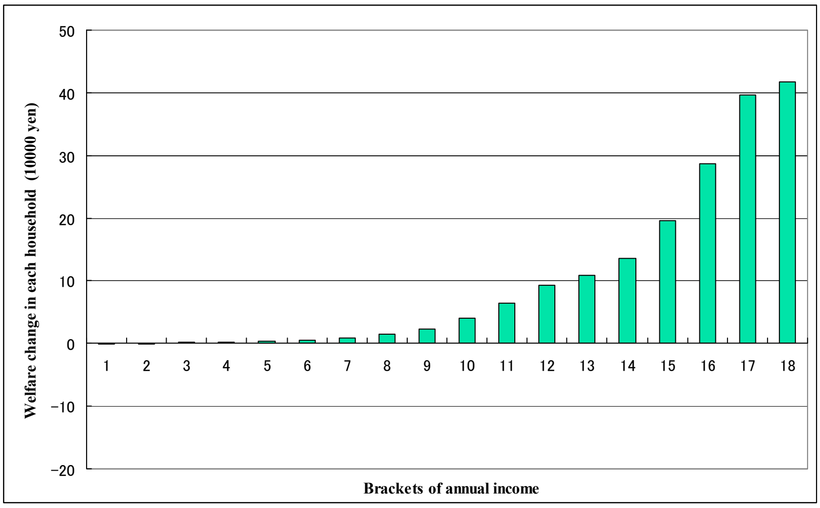

Figure 7. Changes of utility expressed based on equivalent variation in Case 4.

We consider the reason, why the utility values increase. Table 4 shows examples of products on renewable energy and energy saving by Komiyama. (Komiyama, H. 2009) According to Komiyama's presentation, most of energy saving and renewable technologies contribute to reduction of lifecycle energy costs.

Table 4. Economic performances of products on renewable energy and energy saving.

		Payback years	CO_2 reduction (10^6 ton)
renewable energy	Photovoltaics	15	75
energy saving	insulation of window	10	64
	Airconditioning	5	27
	high efficiency water heating	10	25
	Hybrid vehicles	5	50

The reason is as follows, why the utility values increase in adopting photovoltaics. First adoption of photovoltaics contributes to reduction of lifecycle energy costs as shown in table 4. It implies that annual savings in electricity cost is larger than annual payment on purchasing photovoltaic systems. Consequently, surplus in disposable income increases in households adopting photovoltaic systems. Then they can afford other kinds of goods to increase their utility values. This logic is also true of other energy saving products in table 4.

Lastly, economic impacts of the reduction target to industrial sectors are depicted in figure 8. Figure 8 shows the computed result in Case 4. As described in chapter 3, impacts to national economy vary industry by industry. Because of accelerated deployment of energy saving and renewable products, production values in electric machinery, precision machinery, automobiles and so on. On the other hand, households consume less electricity and gasoline due to efficiency improvement, so that production values in industrial sectors of electricity and of petroleum products decreases.

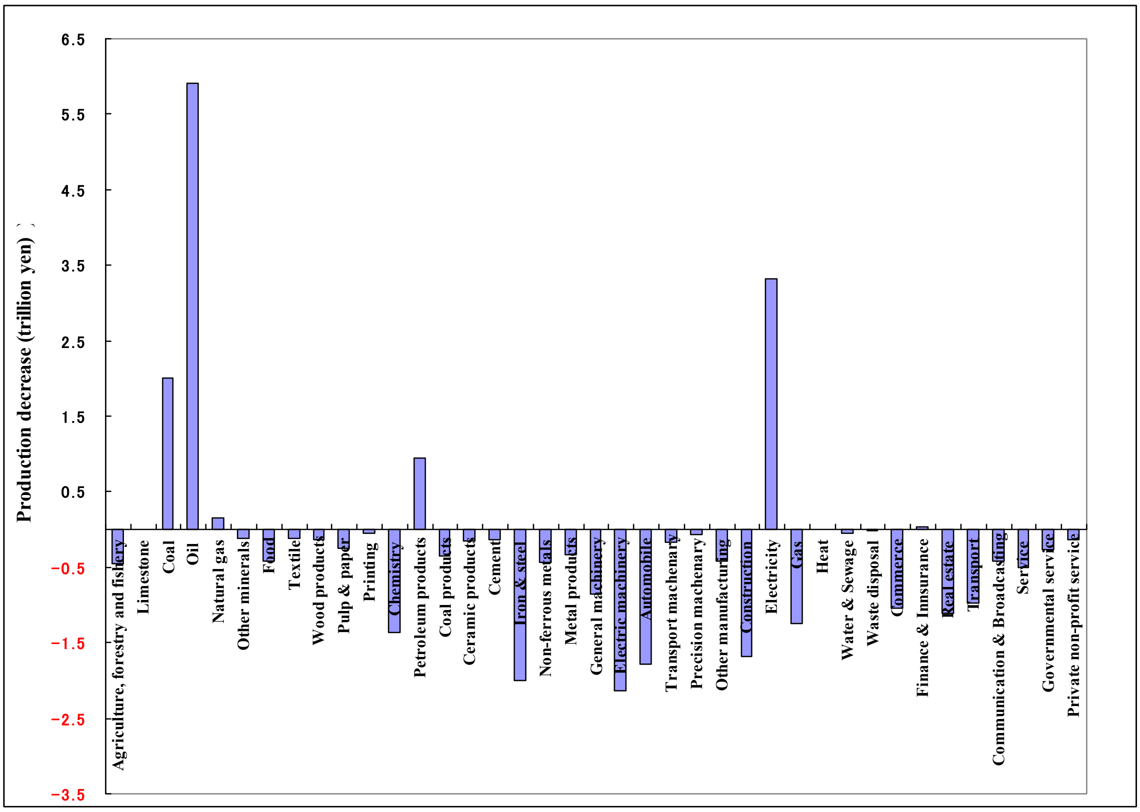

Figure 8. Impacts of the reduction target to industrial sectors in Case 4.

5. Conclusion

In this article, we investigated whether we could realize sustainable development under the 25% target of reducing greenhouse gas emissions. For this purpose, we developed a computable general equilibrium model for Japan, by which we evaluated possible technology options and system innovation along with economic options. Technology options include efficiency improvement, renewable energy technologies and nuclear power technologies. Economic options include carbon tax, emissions trading scheme and feed-in-tariff for renewable energies.
Then we estimated economic impacts to national economy including households and industries. As results, we showed the condition, how we could increase utility values of households even under the 25% reduction target. Computed results showed that efficiency improvement and renewable technologies have remarkable effect on increasing welfare values in society. Thus we should promote accelerated deployment of these technologies as well as R&D on them. If we succeed in accelerated deployment of energy saving and renewable technologies, we could realize low-carbon society with higher welfare values.

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