B-14.3.1 Analysis and Evaluation of Countermeasures in Transportation Area (Final Report)

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Total Budget for FY1991-1993 16,046,000 Yen (FY1993; 4,200,000 Yen)

Abstract

Climate change caused by greenhouse effect is a serious threat to the sustainable development of mankind. Energy system need to change significantly to mitigate climate change. In transport sector, alternative fuel vehicles are expected to be introduced from environmental viewpoint. This study aims at investigating costs and effectiveness of alternative fuel vehicles so as to reduce CO2 emissions. We have developed a model representing total energy system, in which the cost-effective technologies are introduced into the market under restrictions on CO2 emissions. Model analyses have clarified cost-effective future vehicles and effective economic incentive to introduce these vehicles into the market. Energy consumption in the transport sector is also influenced by life styles, traffic condition and so on. These problems are also investigated in this study.

Key Words Linear Programming, Static Analysis, Dynamic Analysis, Alternative Fuel Vehicles, Life Styles.

1. Introduction

There have been growing public concerns on environmental problems in recent years. In particular, climate change caused by greenhouse effect is a serious threat to the sustainable development of mankind. Since the CO2 produced by burning fossil fuels is a dominant source of anthropogenic greenhouse gases, energy system need to change significantly to cope with the problem. In transport sector, alternative fuel vehicles are expected to be introduced, since they have several advantages from environmental point of view. However, some problems awaiting solution still lie before us especially on their practical use and cost. In this study, we have investigated costs effectiveness of alternative fuel vehicles so as to reduce CO2 emissions. And we have developed a model representing total energy system, in which the cost-effective technologies are introduced into the market.

On the other hand, energy consumption in the transport sector is also influenced by life styles, traffic condition and soon. These problems are also investigated.

2. Research Method

At first we have developed linear programming models representing whole energy systems including power generation, industry, residence and transport sector. We have analyzed both static and dynamic performances of the models.

(1) In static analyses, we investigated the costs and effectiveness of alternative fuel vehicles in the total energy system. The model allocates resources and technologies to minimize a sum of capital costs and fuel costs of the whole energy system. Then we examined costs and effectiveness of technologies including future vehicles under restrictions on CO2 emissions.

(2) In dynamic analyses, optimizations are repeated every 10 years from 1990 to 2030. Assuming stabilization of CO_2 emissions in 2030 at 1990 level, the analyses clarified the effective economic incentives so as to introduce cost-effective technologies into the market.

(3) We assume fuels used in transport sector as shown in table 1 and 2.

Table1. Fuels used in passenger cars.

	ordinary	small	light
Gasoline	○	○	○
Diesel	○	○	
CNG	○	○	○
Electricity	○	○	○
Methanol	○	○	○
LPG	○	○	○
Hybrid			

Table2. Fuels used in trucks.

	Long distance ordinary	Short distance ordinary	Small type	Light type	Bus
Gasoline	○	○	○	○	○
Diesel	○	○	○		○
CNG	○	○	○	○	○
Electricity			○	○	
Methanol	○	○	○	○	○
LPG	○	○	○	○	○
Hybrid	○	○	○		○

(4) Sectors of demand

We assumed the value for final demand based on data of 1990 in following demand sectors.

○Aviation sector : Jet fuel.

○Petrochemical sector : Naphtha.

○Navigation sector : Heavy oil.

○Industrial heat : Coal, natural gas, heavy oil, diesel, LPG, crude oil, electricity and hydrogen.

○Residential heat sector : Natural gas, light oil and LPG.

○Steel production sector (Smelting) : Coke and Hydrogen.

3. Results

(1) Static analysis

Concerning energy demand projection, we have adopted two cases, lower and higher demand, assuming 2030 in a future. The optimization results are shown in table 3 for these two cases. As restrictions on CO_2 emissions become severer, the model adopts fuel switching in electric power and industry sector. Then in the case of higher demand, alternative fuels such as CNG and electricity are introduced in the transport sector.

However, in the case of lower demand, fuel switching are not adopted in the transport sector.

Table3. Optimization results of static models for energy systems in 2030.

Sectors	Shares of fuels (The case of lower demand)	Shares of fuels (The case of higher demand)
Transport (passenger cars)	Conventional fuel 100%	Electricity 52%, Conventional fuel 48%
Transport (truck)	Conventional fuel 100%	Conventional fuel 38%, electricity 33% and CNG 29%
Power generation	Nuclear fuel 51%, heavy oil 21%, pulverized coal 14%, hydropower 9% and others 5%	LNG combined cycle 51%, nuclear fuel 39%, hydropower 7% and heavy oil 3%
Industrial heat	LNG 85% and coal 15%	LNG 100%
Residential heat	LNG 100%	LNG 100%

(2) Dynamic analysis

Utilizing the results of static analyses, we specified the cost-effective technologies including alternative fuel vehicles. In dynamic analyses, we examine effective policies for introducing the cost-effective technologies to suppress CO2 emissions. Since this study focuses on introduction of future vehicles, we utilize the result of the case of higher demand, in which the model adopts fuel switching in the transport sector.

We have developed following three scenarios and investigated the performances. Carbon tax is adopted as economic incentive to reduce CO2 emissions. In one scenario, subsidy is also taken into consideration for introducing new technologies to offset the revenue by carbon tax.

Scenario1 : Carbon tax is adopted so as to suppress CO2 emission below the restriction. The tax revenue is not assumed to be offset by the subsidy. Carbon tax level is determined in the model to be minimum necessary value so as to suppress CO2 emission within the restriction.

Scenario2 : Carbon tax is adopted so as to suppress CO2 emission below the restriction. The tax revenue is not assumed to be offset by the subsidy. Carbon tax is assumed to increase gradually, so that we can avoid economic disturbances caused by sudden changes of carbon tax level. Carbon tax is determined to be minimum necessary value in the last time period of the model.

Scenario3 : Carbon tax is adopted so as to suppress CO2 emission below the restriction. The tax revenue is assumed to be offset by the subsidy only in the beginning. The promising alternative fuel vehicles and infrastructures such as fuel stands are subsidized until the costs of these vehicles are reduced by mass-production effect. After that, only the carbon tax is utilized for these vehicles to penetrate into the market.

Results of Scenario 1 are shown in Fig.1. This figure indicates steep increase in carbon tax rates in the last period. The level of carbon tax in the last period is prohibitively high. Therefore Scenario 1 is not desirable from economic viewpoint.

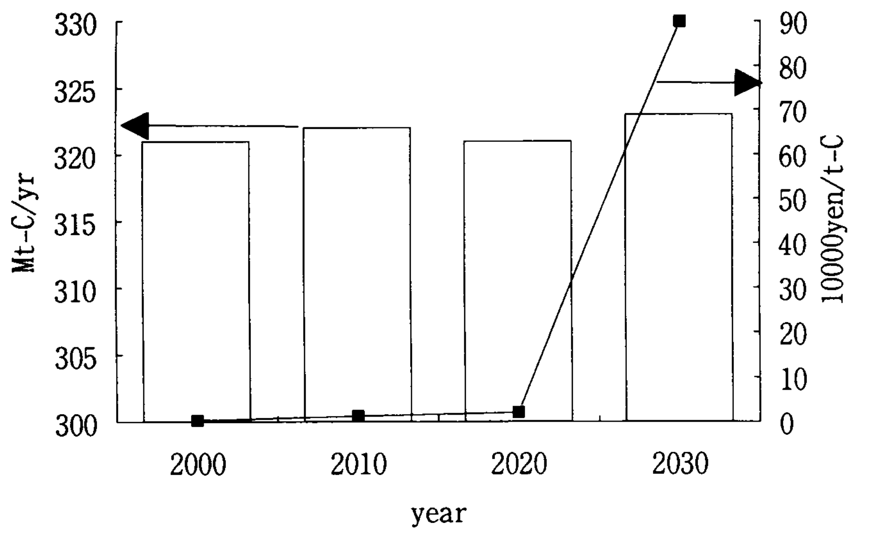

Fig.1. Carbon tax rates and CO2 emissions. (Scenario1)

Results of Scenario 2 are shown in Fig.2. This figure indicates gradual increase in carbon tax rates toward the last period. In this sense, damage to economic activity by the tax is much less in Scenario2 than in Scenario1. But the level of carbon tax in the last period is still too high. Therefore Scenario 2 would not be permitted from economic viewpoint.

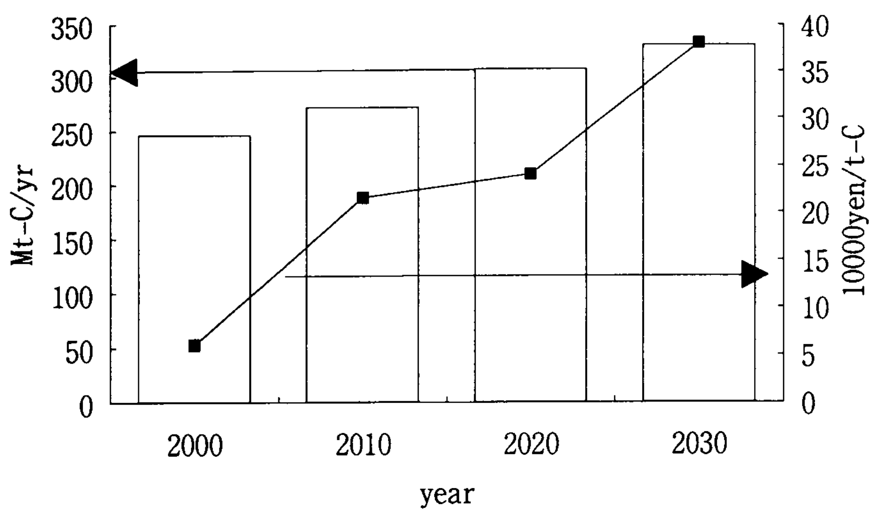

Fig.2. Carbon tax rates and CO2 emissions. (Scenario2)

Results of Scenario 3 are shown in Fig.3. This figure indicates gradual increase in carbon tax rates toward the last period. Furthermore the level of carbon tax is much lower than in Scenario 1 and 2. In this sense, damage to economic activity by the tax is much less in Scenario 3 than in the above two scenarios. Therefore Scenario 3 is the most desirable one from economic viewpoint.

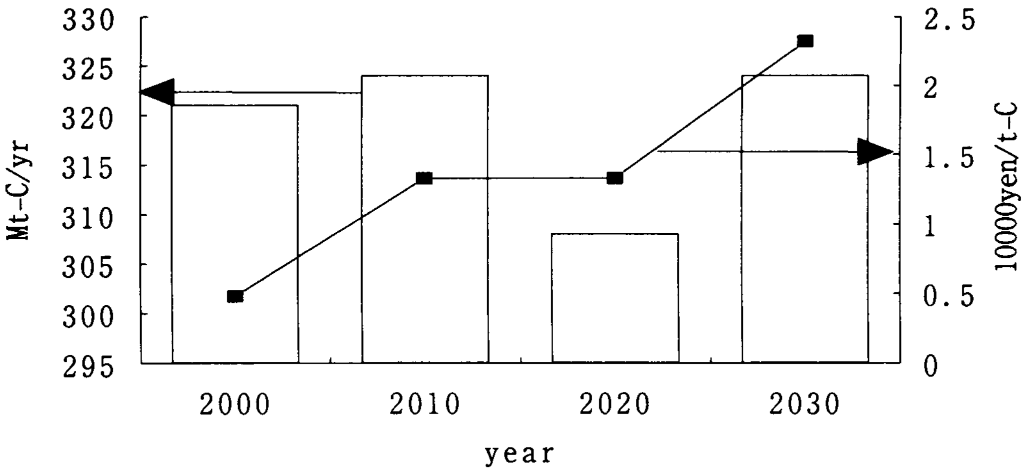

Fig.3. Carbon tax rates and CO2 emissions. (Scenario3)

4. Conclusions

(1) We have investigated the costs and effectiveness of alternative fuel vehicles in the total energy system. Both static and dynamic performances of the system have been analyzed utilizing linear programming models.

Static analyses indicates following things.

① Fuel switching in the transport sector are much more expensive than in power generation or in industry sector.

② In the case of lower energy demand, we can stabilize Japan's CO2 emissions only by fuel switching in electric power and industry sector. In the case of higher energy demand, we need to introduce alternative fuel vehicles.

Dynamic analyses indicates a following thing.

③ It is an economic burden to introduce the alternative fuel vehicles only by carbon tax. If we utilize carbon tax to subsidize the vehicles and infrastructures such as fuel stands, we can introduce the vehicles and reduce CO2 emissions without prohibitively high economic burden.

(2) Energy consumption in the transport sector is also influenced by life styles, traffic conditions and so on. In particular, people tend to drive larger cars, which is lowering average fuel economy. We have also investigated these effects by regression analyses.

Publication

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