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Analysis of the vehicle mix in the passenger-car sector in Japan for CO_2 emissions reduction by a MARKAL model

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Abstract

Carbon dioxide (CO_2) emissions from the passenger-car sector in Japan are increasing rapidly and should be reduced cost-effectively in order to stabilize energy-related CO_2 emissions in Japan. The purpose of the present paper is to clarify the most cost-effective mix of vehicles for reducing CO_2 emissions and to estimate the subsidy that is necessary to achieve this vehicle mix. For this analysis, the energy system of Japan from 1988 to 2032 is modeled using a MARKAL model. The most cost-effective mix of vehicles is estimated by minimizing the total energy system cost under the constraint of an 8% energy-related CO_2 emissions reduction nationally by 2030 from the CO_2 emissions of 1990. Based on the results of the analysis, hybrid vehicles are the only type of clean-energy vehicle, and their share of the passenger car sector in 2030 will be 62%. By assuming the subsidization of hybrid vehicles, the same vehicle mix can be achieved without constraining CO_2 emissions. The peak of the total subsidy estimated to be necessary is 1.225 billion US$/year in 2020, but the annual revenue of the assumed 31 US$/t-C carbon tax from the passenger car sector is sufficient to finance the estimated subsidy. This suggests that we should support the dissemination of hybrid vehicles through subsidization based on carbon tax.

Keywords: Carbon-dioxide emissions reduction; Passenger car; Energy system model; MARKAL; Subsidy; Hybrid vehicles

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Nomenclature

CNG	compressed-natural gas
CO_2	carbon dioxide
FCV	fuel-cell vehicle
MARKAL	market allocation
ICE	internal combustion engine
LHV	lower heating value
LNG	liquefied natural gas
LPG	liquefied petroleum gas
RDF	refuse derived fuel

1. Introduction

To mitigate global warming, the reduction of carbon dioxide (CO_2) emissions is necessary. In the Kyoto Protocol [1], Japan has promised to reduce the total emissions of greenhouse gases, as measured by global-warming potential, by 6% in 2010, compared with the total emissions for 1990. To achieve the Kyoto Protocol, the target of CO_2 emissions in 2010 from the transportation sector is set to an increase of 17% compared with 1990. However, the CO_2 emissions from the transportation sector increased by 23% in 2001 compared with 1990, although the total amount of CO_2 emissions in Japan increased by 5% in 2001, compared with 1990.

Under such circumstances, the Japanese government set an introduction target of new energy technologies [2] in the long-term energy supply and demand outlook of Japan [3]. For example, the introduction target of clean-energy vehicles [4] is 3.48 million in 2010. To achieve such targets, it is preferable to analyze the condition under which these technologies are introduced. In other words, it is preferable to quantify the cost competitiveness and CO_2-emissions reduction effect of each energy technology and to evaluate the means of support for the introduction of such technologies, such as subsidies and the carbon tax, quantitatively. In particular, in the passenger-car sector, it is important to clarify the possibility of achieving the CO_2-emissions target and the necessary vehicle mix to do so. Moreover, it is also important to clarify the amount of subsidy required in order to realize this vehicle mix.

In this field, Fukui et al. [5] estimated vehicle mixes according to various consumer preferences by a detailed consumer automobile selection model and quantified the CO_2-emissions reduction-effect. Kinugasa and Nakata [6] analyzed the impact of fuel-cell vehicles on energy systems in the transportation sector in Japan and the amount of CO_2 emissions while considering both the economy and energy efficiency by using an energy and economic model. However, they did not clarify the possibility of achieving the CO_2-emissions target or the necessary vehicle mix to achieve the target. Kitajima and Shimazaki [7] applied a MARKAL [8–10] model to the transportation sector in Japan and estimated the vehicle mix when subsidies were given and the necessary vehicle mix to achieve the CO_2 emissions target, respectively. However, they did not clarify the amount of subsidy required in order to realize the necessary vehicle mix to achieve the CO_2-emissions target.