Energy Policy 81 (2015) 215–225

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Diffusion of low emission vehicles and their impact on CO_2 emission reduction in Japan

Ken Oshiro [a,*], Toshihiko Masui [b]

[a] Tokyo Institute of Technology, Ookayama2-12-1, Meguro-ku, Tokyo 152-8552, Japan
[b] National Institute for Environmental Studies, Onogawa16-2, Tsukuba, Ibaraki 305-8506, Japan

HIGHLIGHTS

- Impact of low emission vehicles is assessed using AIM/Enduse model in Japan.
- The model is revised to reflect demand side management using low emission vehicle.
- The share of low emission vehicles increases by 60% or 90% of total demand in 2050.
- Share of intermittent renewable energy increases due to demand side management.
- CO_2 emissions from transport sector in 2050 decreases by 81% compared to 1990.

ARTICLE INFO

Article history:
Received 16 May 2014
Received in revised form
7 August 2014
Accepted 9 September 2014
Available online 26 September 2014

Keywords:
Climate change mitigation
Demand side management
Low emission vehicle

ABSTRACT

In order to achieve the long-term CO_2 emission reduction target in Japan, diffusion of low emission vehicles can contribute by integration of intermittent renewable energy by demand side management using low emission vehicles, such as smart charging battery electric vehicle (BEV), in addition to improvement of energy efficiency and carbon intensity. In this study, impact of the low emission vehicles is assessed using AIM/Enduse model with 10 regions in Japan. The model is revised to integrate power generation sector and to separate the transportation demand into small, medium and large size vehicles in order to reflect the availability of BEV and fuel-cell electric vehicle (FCEV) in each vehicle size. In the Reference case, hybrid vehicle accounts for more than a half of transport demand in 2050. However, by introducing the carbon tax to achieve the 2 degree target, the share of both BEV and FCEV in 2050 reaches around 90% and 60% in passenger and freight transport, respectively. In addition, electricity demand pattern is transformed by demand side management in 2050 while integrating more intermittent renewable energy into electricity system. As a result, the CO_2 emissions from transport sector in 2050 decreases by approximately 81% compared to the 1990 level.

1. Introduction

After the Fukushima Daiichi nuclear plant accident in 2011, Japan's mid- to long-term energy policy was sought to be revised from the previous plan published in 2010 in which the nuclear power accounted for approximately a half of electricity supply in 2030. Though the revised Strategic Energy Plan in Japan has been published in April 2014 (METI, 2014), availability of nuclear power is mentioned just qualitatively, and is quantitatively still uncertain in the future. However, large scale deployment of energy efficient technologies and low carbon energy from renewables or fossil energy with carbon capture and storage (CCS) would become more important regardless of availability of nuclear power in order to achieve the long-term GHG emission reduction target in Japan, which is to reduce the GHG emission by 80% by 2050 compared to the 1990 level.

In 2012, the CO_2 emissions from transport sector, including direct and indirect emission, was approximately 19% of the total CO_2 emission in Japan, but it accounted for less than the emissions from industrial or commercial sector which were approximately 35% and 23%, respectively (GIO, 2014). The CO_2 emission from transport sector has been already declining in Japan since 2002, while the emissions from residential and commercial sector have been increasing in this period.

However, importance of diffusion of low carbon technologies in transport sector can be emphasized when considering their impact on electricity system through demand-side management of electricity using battery electric vehicle (BEV) and fuel-cell electric

* Corresponding author. Tel.: +81 3 5734 3319.
E-mail address: oshiro.k.ab@m.titech.ac.jp (K. Oshiro).

http://dx.doi.org/10.1016/j.enpol.2014.09.010
0301-4215/

vehicle (FCEV), in addition to emission reduction by low emission vehicle. As mentioned in IEA (2012), BEV can act as a demand side management resource for electricity system through smart charging from grid to vehicle, and it would be helpful for large scale deployment of intermittent renewable energy, such as solar PV and wind power. FCEV may also be helpful when electrolysis technologies act as demand side management resources and using hydrogen fuel generated from intermittent renewable energy is economically competitive.

Previously, Fujino et al. (2008) have focused on achieving the long-term emission reduction target in Japan by 2050 and have shown a requirement of energy demand reduction in demand-side and appropriate choice of low carbon energy sources in supply-side. According to Ashina et al. (2012) who have estimated a feasibility of Japan's long-term mitigation target using AIM/Backcasting Model (an inter-temporal dynamic model), 80% emission reduction in Japan by 2050 is feasible and early action would be needed in transport sector. In Matsuo et al. (2014), the long-term hydrogen introduction scenario with CO_2-free imported hydrogen in Japan has been estimated and some scenarios with large scale diffusion of FCEV were reported. While these studies have shown the implication of substantial emission reduction opportunity in transport sector with large scale diffusion of low emission vehicle, the effects of demand-side management for electricity system by smart charging of BEV and conversion of intermittent renewable energy into hydrogen are not taken into account. In order to consider these effects the existing model needs to be revised not only in transport sector but also in energy transformation sector.

In addition, several studies have examined interactions between deployment of electric vehicle and electricity systems. The WILMAR (wind power integration in liberalized electricity markets) model has been used to examine impacts of BEVs on electricity systems (Kiviluoma and Meibom, 2011). However, their contribution toward achieving long-term emission reduction target is uncertain, because this model has focused only on power sector. Though EnergyPLAN model has treated both power sector and other energy sectors, competitiveness of BEV between other low-carbon options is not considered, because the number of BEVs is given exogenously (Lund and Kempton, 2008).

In this paper, the existing AIM/Enduse model (Kainuma et al., 2003) is revised in order to assess the impact of low emission vehicles on CO_2 emission reduction in Japan and disaggregated into 10 regions. The scenario of 80% emission reduction target is assessed while considering the effect on flexible electricity system by diffusion of low emission vehicles, including BEV, FCEV, high efficient gasoline or diesel vehicle, hybrid vehicle, plug-in hybrid vehicle (PHEV), and compressed natural gas (CNG) vehicle.

2. Methodology

2.1. Modelling framework

AIM/Enduse model is a dynamic recursive, technology selection model for the mid- to long-term mitigation policy assessment developed by National Institute for Environmental Studies and Kyoto University. While this study focuses mainly on transport sector, the model needs to cover not only transport but all sectors including power generation, as mentioned in the previous section, in order to analyse the impact on the whole electricity system in Japan. Therefore, the model covers both end-use sectors (transport, industrial, residential and commercial) and energy supply sector. In addition, non-energy sectors (e.g. agriculture, industrial process, waste) are also included in order to assess feasibility of achieving Japan's long-term GHG emission reduction target. GHG emissions include CO_2, CH_4, N_2O, hydrofluorocarbon (HFC), perfluorocarbon (PFC) and SF_6, and emissions are converted into CO_2-equivalents based on GWP from Greenhouse Gas Inventory Office of Japan (2014), but emissions and removals in agriculture, forestry and other land use (AFOLU) sector are excluded. Fig. 1 depicts the estimation process of the model used in this study in end-use, power generation and non-energy sectors. Technology selection in power generation sector is implemented subject to electricity demand derived from end-use sectors, and carbon intensity of

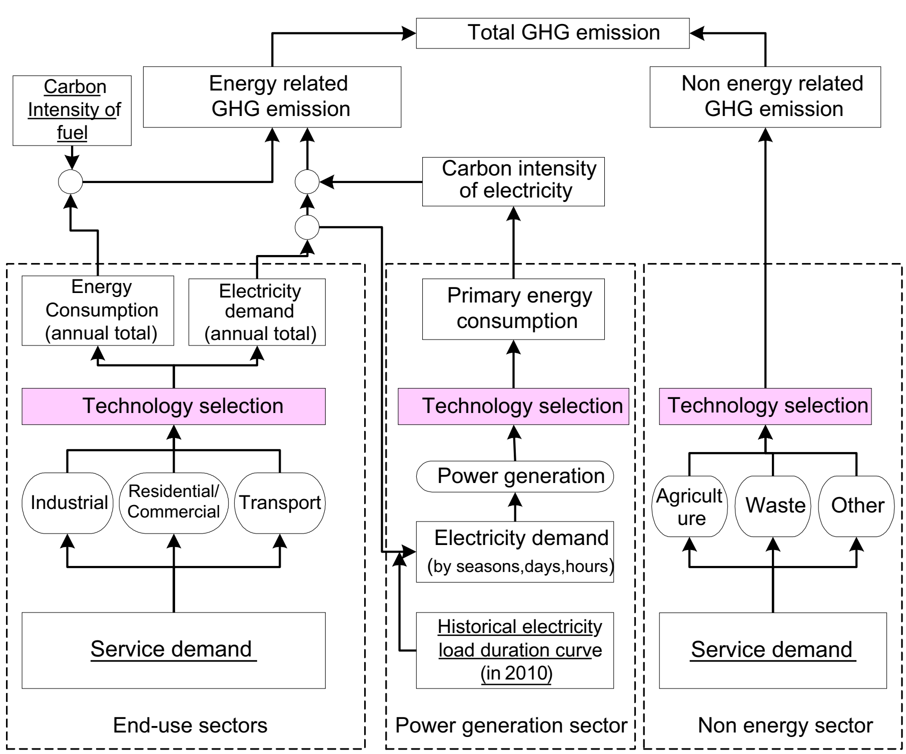

Fig. 1. Estimation process of the model.