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Greenhouse gas mitigation policies in Taiwan's road transportation sectors

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ABSTRACT

The main concept of this paper is derived from the Government of Taiwan's Greenhouse Gas Reduction and Management Act (GGRMA), which mandates that greenhouse gas emissions in 2050 should be reduced to half of the rate of greenhouse gas emissions in 2005. To reach this carbon emission goal by 2050, this paper examines three potential policy options (each accompanied with four illustrative scenarios). The results show that: (1) it is impossible to reach the goals of the GGRMA solely through the use of carbon allowance allocations and the use of alternative fuels if the use of vehicles is allowed to grow. (2) By keeping the increase in the use of vehicles to zero, by encouraging a use of PHEVs, and by implementing a carbon allowance allocation, it will be possible to reach the government's 2050 carbon emissions goals. (3) If the use of vehicles can actually be reduced, it will be possible to achieve carbon emissions which are lower than the 2050 targets by 1.30–5.18%. The use of alternative fuels proves to be a reliable way to decrease carbon emission. Carbon emissions could also be lowered by encouraging the use of public transportation.

1. Introduction

The fifth climate change assessment report published by the Intergovernmental Panel on Climate Change (IPCC, 2013) noted that the Earth's temperature rose by 0.89 degrees between 1901 and 2012. It also pointed out that the increase in the global average temperature since the beginning of the 20th century is highly related to the concentration of greenhouse gases in the atmosphere. According to a report from the International Energy Agency (IEA, 2014), carbon dioxide accounts for about 90% of greenhouse gases. In addition, the IEA (2017a, 2017b) pointed out that carbon dioxide emissions have significantly increased over the last century, increasing 2 ppm/year in the last ten years, reaching 403 ppm in 2016.

With the development of the global economy, the demand for transportation has continued to increase. This has caused the amount of carbon dioxide emitted by the transportation industry to increase annually. The IEA, (2017a, 2017b) reported that the main sources of emissions in 2015 were electric power generation accounting for 42%; the transport sector accounting for 24%; industry accounting for 19%; housing accounting for 6%; and other lesser categories accounting for 9%. The IEA (2017a, 2017b) also noted that road transportation accounted for 75% of the carbon dioxide emissions in the transport sector. The transport sector increased its level of emissions by 68% between 1990 and 2015.

The aforementioned statistics report carbon dioxide emissions globally. A report from IEA Key World Energy Statistics (2016) pointed out that in 2014 Taiwan produced 249.66 million tons of carbon dioxide emissions, which ranked it 21st in the world. In terms of the average annual carbon dioxide emissions per person, Taiwan had 10.68 t / person, ranking it 19th in the world. The per capita carbon emissions for other neighboring Asian countries include Japan, which had 9.35 t / person and mainland China, which had 6.66 t / person. Taiwan's per capita carbon emissions are much higher than those of other countries.

According to a report published by US research institutions (www.climatecentral.org), if the current trend in global warming continues, the temperature will increase by 4 °C in the not so distant future, and the rise in sea level will affect more than 600 million people. If we narrow the scope, and the temperature is only increased by 2 °C in the future, the sea level will rise 4.7 m. In the case of Taiwan, this will lead to the submersion of many places on the island, including the Kuantu Bridge, the Miramar straight, Jiantan MRT station, Songshan Airport, Taichung Wu, and 85 buildings in Kaohsiung, as well as many other sites.

In 2017, the Energy Bureau of the Ministry of Economic Affairs of Taiwan released carbon dioxide emissions statistics for fuel combustion,

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which indicated an increase of 1.32% between 2000 and 2016 (the report excluded electricity consumption). Among all sectors, the transport sector ranked third largest in emissions. The road transport sector was the largest and accounted for 88.06% of the total transportation sector, with an increase of 92 million tons of carbon emissions between 2015 and 2016. The road transportation sector produced 1964.64 million metric tons in emissions in 1990. This has subsequently grown by 1.87 times. This shows that the transport sector is a major cause of the increase in carbon dioxide emissions in Taiwan.

Based on data from the Ministry of Transportation and Communications (2015), in 2014 the proportion of passenger cars (including small passenger cars and buses) accounted for 30.53% of all motor vehicles in Taiwan; trucks (including small trucks and trucks) accounted for 4.93%; special vehicles accounted for 0.29%, and motorcycles accounted for 64.25%. Though the proportion of trucks is not high, it is the second largest source of carbon dioxide emissions.

Qiu et al. (2017) studied how to reduce air passenger transport pollution. Their research indicated that a carbon allowance allocation could mitigate emissions, and in addition, that it would reduce carbon intensity. They also suggested that airline operations should be a focus of emission reduction. Aziz et al. (2015) and Aziz et al. (2017) examined personal mobility carbon allowance (PMCA) schemes to determine whether they would help mitigate carbon emissions. They found that PMCA schemes can achieve the emissions reduction goals for the transportation sector, because under such schemes, drivers will reduce their energy consumption. Chang and Lai (2013) studied carbon allowance allocations in the transportation industry and found that the allocation of carbon allowances and the development of intermodal modes of transportation could mitigate CO_2 emissions.

In view of the fact that the EU Emissions Trading System (ETS) had not yet taken the transport sector itself into consideration, Heinrichs et al. (2014) did an independent study of the energy sector and the transport sector, establishing a power system model (the PERSEUS-EU road transport model) and a road transport model (COMMIT, the transport sector of carbon dioxide emissions). Taking Germany as the main object of discussion, they analyzed changes in carbon emissions from 2010 to 2030. Their projections were based on different price levels, the share of renewable energy generation and the electric vehicle occupancy rate. The results showed that, on the whole, the expansion of the EU ETS to include road transportation could reduce carbon emissions, but the effect of such emission reductions was insignificant because of the small increase in the quota price that would be incurred.

Shukla et al. (2014) studied sustainable low carbon transport in India. Their framework was used to simulate two scenarios: (1) Business As Usual (BAU) and (2) Sustainable Low Carbon Transport (SLCT), which explores multiple scenarios for changing India's transport system by 2050. The results show that, in the case of SLCT, transport energy demand is estimated to be 169 MtE in 2050, which is significantly lower than the BAU scenario (299 MtE). In the SLCT program, carbon-tax and battery costs are reduced, and improvements in technologies such as hybrid cars are used, making it more cost-effective than traditional vehicle internal combustion engine (ICE) technology. In addition, in the case of SLCT, between 2010 and 2050 the transport sector was projected to experience a cumulative reduction in emissions of around 2155 million tons of carbon dioxide. The study also pointed out that there's not a single technology that alone will significantly reduce the greenhouse gas emissions from transportation. Thus a combination of strategies will be necessary to achieve the goal of building a low-carbon transportation system.

Pongthanaisawan and Sorapipatana (2013) calculated the energy consumption and GHG emissions of the transport sector (including road, rail, air, and maritime transport) in Thailand from 1989 to 2007. They used an econometric model to forecast the future to 2030 in three scenarios: (1) business-as-usual (BAU), (2) the use of alternative energy sources, (3) energy efficiency, reduced energy consumption, and reduced GHG emissions. The results show energy consumption and greenhouse gas emissions in the transport sector to be equivalent to 70.78 million tons and 208.5 million tons of carbon dioxide respectively. In the fuel-switching option scenario (bioethanol and biodiesel instead of conventional fossil fuels), by 2030 energy consumption in the transport sector and greenhouse emissions can be reduced by 1283 kt and 3751 kt of carbon dioxide equivalent respectively. In the energy efficiency vehicles promotion option scenario, the energy use of the transport sector and greenhouse gas emissions can be reduced by the equivalent of 1001 kt and 3182 kt of carbon dioxide respectively.

Stanley et al. (2011) studied greenhouse gas emissions from road transport in Australia with the following targets: (1) GHG emissions reduced by 20% in 2020 as compared with 2000 and (2) GHG emissions reduced by 80% in 2050 as compared with 2000. It uses six key methods to achieve these targets: (1) a reduction in the amount of travel between cities; (2) an increase in the proportion of urban trips by foot and bicycle, (3) an increase in the proportion of urban motorized trips making use of public transport, (4) a reduction in the load rate of urban vehicles, (5) a reduction in the use of road freight fuel, and (6) an improvement in vehicle efficiency. The findings of the study suggest nine key measures that could be taken to achieve these results: (1) charging road tolls, including congestion fees, (2) investment in public transport equipment and services, (3) investment in facilities for pedestrian and bicycle usage, (4) more suitable pedestrian routes for those walking in urban residential areas, (5) improvements in fuel efficiency, (6) investment in rail freight and multi-transport thubs, (7) improvement in freight efficiency, (8) redistribution of road usage privileges, giving priority to low-emission modes of transport and (9) encouraging vehicle sharing and low-carbon transport model behavioral reform programs. The study projects that these policies would not only reduce greenhouse gases, but would also improve road congestion, reduce air pollution, traffic noise, and accident costs and would also improve community livability.

Ong et al. (2011) used the COPERT 4 model to examine potential emission reduction policies for Malaysian road transportation and to review Malaysia's road traffic emissions. The results showed the promotion of the use of public transport or natural gas vehicles (NGV) and vehicle renewal to be effective, feasible emission reduction behavior. They found that if 10% of passenger cars transferred to public transport, this would reduce fuel consumption and drop CO_2 emissions by about 6%, which would in turn also reduce CO, NOx, and HC emissions, by 5.9%, 5.3%, and 5.3% respectively. If 10% of passenger cars were replaced by natural gas vehicles, CO, NOx, and HC emissions would be reduced by 5%, 5.7%, and 5.3% respectively. In addition, the study also found that renewing 10% of used vehicles would reduce emissions of CO, NOx, and HC by 11.5%, 11%, and 10.6% respectively. In addition, such a renewal could save 1.3% of fuel consumption and reduce 3.5% of CO_2 emissions.

Ou et al. (2010) analyzed the future emission trends of direct energy demand (ED) and greenhouse gas (GHG) emissions in China's road transport sector and used alternative vehicle / fuel approaches to assess potential reductions in GHG emissions. The results projected a 4.6-fold rise in road transport carbon emissions from 2007 to 2050 should no energy conservation policy be enacted. The study also projected that the conversion of energy use in vehicles from conventional fuel into alternative fuel, for instance into hybrid electric vehicles or electric vehicles, could reduce energy consumption by 6.62% and 21.58%, respectively. Ristovski et al. (2005) studied five kinds of unleaded petrol and six kinds of liquefied petroleum gas products (LPG) and compared emissions of passenger cars under speeds of 40, 60, 80, and 100 km per hour. The results showed that liquefied petroleum gas is a cleaner fuel. The use of liquefied petroleum gas vehicles as compared to the use of unleaded petrol vehicles was shown to reduce particulate emissions by 30%. Carbon dioxide emissions were reduced by 10–18%. In addition, they also found that, at higher speeds, the amount of emissions reduction was more apparent.

Abrell (2010) analyzed the usage of market-based emission controls