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A low-carbon transport infrastructure in Taiwan based on the implementation of energy-saving measures

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ABSTRACT

Transport is the lifeblood of a nation's economy. Because fossil fuels are being gradually depleted and global warming phenomena are becoming more and more serious, the aim of this article is to study a low-carbon transport infrastructure based on existing energy efficiency indices and green transport policy formulated by Taiwanese Department of Transportation. First, via data collection and analysis, we observed that small passenger cars and large trucks are the largest energy users in the transport sector due to their high energy intensities and large transport volumes. Therefore, the energy-conserving potentials of these vehicles are the focus of this study. According to "Top-Down" methodology, the most effective and economical energy-saving strategies for Taiwan's transport sector are the significant adoption of rail transport and electrification mode. With a maximum energy-saving scenario, including the adoption of Best Available Technologies (BAT) and the comprehensive expansion of public transport infrastructure, the energy savings potential in the land transport sector of Taiwan is 2931 million liters of oil equivalent (MLOEs). This savings is equivalent to a greenhouse gas emissions reduction of approximately 5.91 Mt CO_{2e} with a scale of 16.73% or crediting 2.40% reduction in national greenhouse gas (GHG) emissions. Finally, we suggest that the green transport infrastructure of Taiwan should primarily include railway, mass rapid transit (MRT), and hybrid electric vehicles (HEVs).

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Abbreviations: BAT, Best Available Technologies; MLOE, million liters of oil equivalent; MRT, mass rapid transit; HEV, hybrid electric vehicle; KLOE, kilo liters of oil equivalent; IEA, International Energy Agency; BOE, Bureau of Energy; MOEA, Ministry of Economic Affairs; ITS, intelligent transportation system; GHG, greenhouse gas; LED, light-emitting diode; HSR, high speed rail; MOTCIOT, Institute of Transportation, Ministry of Transportation and Communications; LOE/p-km, liters of oil equivalent per person-kilometer; LOE/t-km, liters of oil equivalent per tonne-kilometer; EV, electric vehicle; DGBAS, Directorate-General of Budget, Accounting and Statistics; BRT, bus rapid transit

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1. Foreword

Transportation is an indispensable tool and condition in our modern daily lives [1–3] and can enhance a nation's economic activity [4–6]. As Taiwan's economic growth and population mobility continue to increase, the transportation demand increases daily, resulting in increasing energy use in the transport sector [7–10] and increasing GHG emissions and air pollution, seriously damaging the environment [11–13]. For example, in 1990, 2000 and 2010, the annual energy used by the transport sector was 7958, 14,316 and 15,546 KLOEs [14], equivalent to an average annual growth rate of 3.3%, which is the second highest growth rate of all of the final energy use sectors, after the industrial sector. The fuel use rate clearly shows that there is substantial growth in the energy demand within the transport sector. However, this growth also means that this sector did not fully implement policies and measures for energy conservation.

In 2010, the energy used in Taiwan's transport sector was approximately 15,546.3 KLOEs, of which land transport alone used 12,643.9 KLOEs, a share of 81% of the total energy used [14]. The majority of the energy sources used by land transport are fossil fuels, resulting in amazing carbon dioxide emissions from the current land transport [15,16].

According to the statistics of International Energy Agency [17], Bureau of Energy, and Ministry of Economic Affairs [18], the transport sector is the primary source of energy use and greenhouse gas emissions both worldwide and in Taiwan. To reduce the greenhouse gas emissions and significantly save energy, the energy efficiency issues in the transport sector need to be discussed and analyzed in depth.

This study investigates Taiwan's transport sector as the main object, which contains a variety of major means of transportation, for example, cars, motorcycles, buses, trucks, MRTs, railway, high-speed rail and other transport modes. According to the transport reports issued by Taiwan's Ministry of Transportation and Communications as well as the Energy Statistical Yearbook published by BOEMOEA, this study estimates the transport volume, load capacity, and energy use in the all kinds of land transportation of Taiwan.

Transportation is the lifeblood for sustaining a nation's economy [4–6]. In recent years, since of the gradual depletion of fossil fuels and the emerging seriousness of global warming [19,20], this article aims to study the development blueprint for Taiwan's future green transportation infrastructure based on the optimization of energy-saving and carbon-reducing measures. In other words, this study assessed the energy-saving potential of Taiwan's land transportation through the application of scenario analysis. Wherein, the pursuit goal is based on the national energy's policy released by Executive Yuan in 2009; namely, "Sustainable Energy Policy Guideline", which declared "The CO_2 emissions in 2025 should be reduced to that in 2000." The energy-saving mechanisms adopted in this study focus on the BAT of land transport vehicles and the comprehensive expansion of public transportation infrastructure.

2. Literature reviews

In 2007, Lu et al. [21] adopted the Divisia index approach to explore the impacts of five factors on the total carbon dioxide emissions from highway vehicles in Germany, Japan, South Korea and Taiwan during 1990–2002. These five factors were emission coefficient, vehicle fuel intensity, vehicle ownership, population intensity and economic growth. The decoupling effects among economic growth, transport energy demand and CO_2 emission were analyzed to better understand the fuel performance and CO_2 mitigation strategies for each country. From the results, Lu et al. [21] suggested that the rapid growths of economy and vehicle ownership were the most important factors for the increased CO_2 emissions, whereas population intensity contributed significantly to emission decrease. Energy conservation performance and CO_2 mitigation in each country are strongly correlated with environmental pressure and economic driving force, except for Germany in 1993 and Taiwan during 1992–1996. To decouple the economic growth and environmental pressure, proponents of sustainable transport policy in Taiwan should focus on improving the operation and energy use of its highway transportation system by implementing an intelligent transportation system (ITS) with demand management, constructing an integrated feeder system, and encouraging the use of green transport modes.

In 2009, a gray forecasting model, GM (1, 1) was adopted by Lu et al. [22] to capture the development trends of the number of motor vehicles, vehicular energy consumption and CO_2 emissions in Taiwan during 2007–2025. Results showed that the vehicle fleet, energy demand and CO_2 emitted by the road transportation system continued to rise at the annual growth rates of 3.64%, 3.25% and 3.23% over the 18 years from 2007 to 2025. The simulation of different economic development scenarios revealed that the lower and upper bound values of allowable vehicles in 2025 are 30.2 and 36.3 million vehicles, respectively, with the traffic fuel consumption lies between 25.8 million kiloliters to 31.0 million kiloliters. The corresponding emission of CO_2 will be between 61.1 and 73.4 million metric tonnes in the low- and high-scenario profiles.

In Taiwan, the Government regards zero-emission scooter as a sustainable transport form like walking, cycling and public transport, which plays a vital role to support sustainable urban mobility. Therefore, the development of zero-emission scooter is an important strategy in constructing the sustainable transport network of Taiwan. It is also a Government's top priority about the policies of emission-reduction and energy-conservation in the transportation sector. Recently, Taiwan launched a new subsidy program for purchasing zero-emission scooters, which aimed to shift the petroleum powered scooters to the electric scooters. In 2010, Hwang [23] provided an update review of the promotional programs in developing zero-emission scooters in Taiwan. It introduces the status of the establishment and progress of policy, standards, subsidies to users and manufacturers, practice infrastructure, and technology development. Moreover, the contribution of replacing petrol scooters by zero-emission scooters such as battery-powered electric scooters and fuel cell scooters to reduction in GHG emissions and improvement in energy efficiency was evaluated.

In 2012, Trappey et al. [24] used a system dynamics approach designed to construct a model for evaluating the green transportation policy on Penghu Island. Simulations are conducted to model green transportation system behavior and related policy effects in a smaller, controlled environment before creating policies for Taiwan Island that will impact the lives of over 23 million people [25–27]. As demonstrated in the scenario analyses, no green transportation policy can achieve the 50% carbon reduction goal in 2015 for the Penghu Low Carbon Island. Therefore, the Taiwanese government has planned additional actions and measures beyond green transportation. For instance, there are plans to expand and promote a variety of renewable energy sources, substitute light-emitting diode (LED) street lamps for traditional ones, and subsidize the purchase of energy-saving appliances.

3. Energy use structure of the transport sector in Taiwan

As shown in Table 1, Taiwan's total energy use in the transport sector was 15,546.3 MOLEs in 2010 [14], accounting 12.92% for the