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The energy-saving measurements of on-land transportation in Taiwan

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ABSTRACT: Transportation is one of the major livelihoods and work forces for sustaining a nation's economy. In recent years, the gradual depletion of fossil fuels and the emerging threat of global warming are affecting human societies and ecosysetms. In this article the optimization of energy-saving and carbon-reducing measures of on-land transportation in Taiwan are addressed and discussed.

I. INTRODUCTION

In Taiwan, there had been a constant controversy over both the government and the legislature. The media focus on the Legislative Yuan is the forward-looking plan of the Executive Yuan. It is worth noting that, in the huge total budget of 880 billion NTD (New Taiwan Dollars), the rail infrastructure accounts for about 400 billion NTD or more (Chinatimes, 2017). We can see how important the rail infrastructure construction in Taiwan is. Basically, the governmental administrative initiatives are strongly agreed by the author because the rail transportion system powered by electricity is essentially a green tool that opens the door for mitigating the traffic congestion in Taiwan. Due to the elevated and under-ground constructions, the rail vehicle is free from traffic light restrictions with ultra-high speed and enjoys unimpeded access to metropolitan areas with dense population and buildings. It completely solves the problem of public traffic congestion which has long been criticized by the public. More importantly, the rail transportation will not emit exhaust gas at all. In currently increasingly polluted air environment, the proactive construction of rail transport is another major injection of clean air into the polluted metropolitan. In addition, taking the Taipei metropolitan area as an example, the motor vehicle density in Taipei is 6463 vehicle/km2 that is about ten times of the national average—595 vehicle/km2 (MOTC, 2017). Therefore, in the metropolitan areas where vehicles are not easily accessible and parked, Mass Rapid Transit (MRT)—a rail mass transit—is a self-motivated transportation option that at least eliminates annoying traffic and parking problems.

II. THE ON-LAND TRANSPORTAION IN TAIWAN

The main purpose of on-land transport is to carry people. According to statistics, the total energy consumption of all passenger cars in Taiwan accounts for 70% of the total energy consumption of on-land transport and 50% of the total energy consumed in transport sector. In other words, passenger cars use about 1/10 crude oil

resources in this country (Lu, 2015; Lu, 2016). Basically, small passenger cars should be the main target of implementing energy-saving measures in the transport sector. According to the analysis, the rail transport unit passenger carrying energy consumption is only 13% of ICE (Internal Combustion Engine) passenger cars. If the majority of passenger light buses were shifted to the rail transport, there could save a lot of energy consumption, so Taiwan with fully imported energy resources can ensure the policy of national energy security. Therefore, even in the long distance between urban and rural areas, the rail transport is also an indispensable green energy-saving transport. Transport is the lifeblood of maintaining the overall national economic development. In recent years, due to the gradual lack of fossil fuels, the worsening climate change and the fact that air pollution has drawn much attention from all parties, it is not only a key issue in Taiwan, but is also a crucial factor for the sustainable global development. In Taiwan, in terms of transportation capacity and energy intensity, the passenger cars are the largest ones for the all land vehicles.

Therefore, the passenger cars have the greatest potential for energy saving. Meanwhile, the implementation of energy-saving strategies, including the application of BAT (Best Available Technologies) and the augment of green and cleaner public transportation infrastructure can result in the fulfillment of national green house gas (GHG) abatement targets. Transportation is an indispensable system and a mandatory condition in modern daily life and economic activity. As Taiwan's economic growth and population mobilize, transport demand increases day by day, increasing the transport sector's energy consumption, which leads to the increases of GHG emissions and the amount of pollution seriously. In Taiwan’s transport sector, the on-road transport accounts for the largest portion of energy consumption. In other words, Taiwan's on-land transport consumes about 81% of all fuel used in the transport sector, while the majority of energy sources consumed by on-land transport belongs to fossil fuels, compared to the rail transport based on electricity (Lu, 2015; Lu, 2016). We found that air pollutants emissions from current on-road transport are of great concern. To reduce air pollutants emissions and save energy, the transport sector is a very important block that is needed to be discussed and analyzed in depth.

The rapid growths of economy and vehicle ownership are the most important factors for the increase of CO2 emissions and air pollution, whereas population intensity contributed significantly to emissions increase, such as in the metropolitan area. Energy conservation performance and CO2 mitigation in each country are strongly correlated with environmental pressure and economic driving force. To decouple the economic growth and environmental pressure, proponents of sustainable transport policy 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 Taiwan, the government considers the zero-emission scooters to be a sustainable form of transport like walking, cycling and public transport, which play a vital role to support sustainable urban mobility. Therefore, the development of zero-emission scooters is an important strategy in constructing the sustainable transport network of Taiwan.

It is also the government's priorities about the policy of emission-reduction and energy-conservation in the transportation sector. Recently, Taiwan launched a new program for subsidy of purchasing zero-emission scooters, which aimed to shift the petroleum powered scooters to the electric scooters. Moreover, the contribution of replacing petrol scooters by zero-emission scooters such as battery-powered electric scooters and fuel cell scooters to reduction in greenhouse gas (GHG) emission and improvement in energy efficiency is evaluated (Hwang, 2010). 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 LED street lamps for traditional ones, and subsidize the purchase of energy-saving appliances. In Taiwan, more populated, developed industrial, and commercial cities/counties consume more transportation energy. However, in the viewpoint of energy consumption per capita, the cities with high population density have lower value of specific energy consumption, due to the popularity of public transportation (MOTCSD, 2012). Pursuant to transport objects, the "on-land transport" can be divided into two categories: "passenger" and "freight"; in Taiwan, the total energy consumption of the former is about twice the latter. The cars consume 70% energy in the passenger transport, accounting for 50% by taking the transport sector as a whole. In other words, the cars consume one tenth oil of Taiwan.

Therefore, we regard the cars as the major energy-saving objects in the transport sector. Basically, the rail transport consumes only 13~19% energy of traditional car and 50% energy of electric vehicle. Apparently, in the passenger vehicles, the rail transport is more energy efficient than electric car, and of course much more energy efficient than traditional car. Moreover, in terms of the transport sector to meet the goals of energy conservation and carbon reduction, it will be much more economical and feasible by increasing the number of runs of the rail transports, instead of purchasing gigantic amount of electric vehicles additionally, because there are already many kinds of rail transports in Taiwan, like, the high-speed rail, the Taiwan Railway and MRT. However, motorcycle is not the case because in terms of energy intensity the MRT is almost as energy efficient as electric motorcycle with close values of 0.01 LOE/p-km and 0.0124LOE/p-km, respectively. The MRT and electric motorcycle are as twice energy-efficient as traditional motorcycle as the specific energy consumption of which is 0.0241LOE/p-km. In addition, due to personal convenience, motorcycle is very popular in Taiwan. Impressively, every Taiwanese owns 0.64 unit of motorcycle averagely (MOTC, 2010; DGBAS, 2010). Therefore, motorcycles have 33% transport volume but consume 21% energy in the manned vehicle sector. Motorcycles do contribute significant energy conservation to Taiwan's transport infrastructure. Thus, basically in terms of passenger vehicles, the main energy-saving measures for the cars should concentrate on shifting the transport volume to MRT or adopting the BAT (e.g., HEV), while those for traditional motorcycles is mainly on the electrification mode. As for freight/cargo carriers, the main energy consumers are heavy trucks, the transport volume of which accounts for 83%. However, in the unit of liters of oil equivalent per ton per kilometer (LOE/t-km), the energy intensity of heavy truck is twice that of rail transport (e.g., Taiwan Railway). On the other hand, the energy intensity of small truck is remarkably high, about four times that of large truck and seven times that of Taiwan Railway. Obviously, the railway transport has significant energy-saving effectiveness.

However, railway has very low transport share (1.4%) in Taiwan's freight sector. Therefore, the proposed energy-saving practice for fright transport is to shift the majority of large truck transport to railway transport. In addition, in terms of light trucks, the fossil-fueled engines should be converted to electric motors, because the energy consumed by the former can be lowered by 20%.

III. METHODOLGY: BAT IMPLEMENTED IN PROJECTED SCENARIOS

In the energy-saving scenario for passenger transport, the strategies of the expansion of public transportation and the implementation of BAT (Table 1) are adopted. Although the passenger transport is increased by 16% in 2025, it is still possible to reduce the energy use from the original 7,661 KLOEs down 5,676 KLOEs, whereas the energy savings and energy-saving rate are as high as 1,984 KLOEs and 25.9%.

Table 1 Energy performance parameters of passenger vehicles.

	Energy intensity (LOE/p-km)	GHG emissions (kg CO_2/p-km)	Note
Car	0.054	0.122	
EV	0.027	0.061	0.15 kW*hr/p-km, Nissan Leaf
HEV	0.018	0.041	25 km/l, with 2 passengers
Motorcycle	0.0241	0.055	
Electric motorcycle	0.0124	0.028	31.4 W*hr/p-km
Bus	0.024	0.054	
Electric bus	0.016	0.036	0.8 kW*hr/p-km
Taiwan railway	0.011	0.025	60% loaded
Taiwan railway	0.007	0.016	80% loaded
MRT-Taipei	0.011	0.025	87.5% loaded
MRT-Kaohsiung	0.027	0.061	50% loaded
MRT	0.012	0.027	80% loaded
HSR	0.015	0.034	48.97% loaded
HSR	0.0075	0.017	80% loaded

Data sources: Lu, 2015; Lu, 2016.

HSR−high speed rail, MRT−metropolitan rapid transit, HEV−hybrid electric vehicle, EV−electric vehicle.

On the aspect of freight transport, when shifting the transport volume of heavy truck to Taiwan Railway with

appropriate proportion and converting the light truck from the mode of fossil-fueled to hybrid, the total energy saving would be 947MLOE or 30% down from original 3,194MOLE to inferred 2,247MOLE. Wherein, the energy saving of the largest energy consumer in freight transport sector is the heavy truck, namely, up to 1,891MLOE or 70%—. But overall, the effect of the performance is limited because at the same time the energy consumed by Taiwan Railway increases 1,006MLOE remarkably. However, as mentioned above, in energy saving measure of rail mode, the only one thing needed to do for the Taiwan Railway is to increase the runs. From the economical point of view, it is still very cost-effective.

IV. RESULTS AND DISCUSSION

If taking 2010 as the base year, according to the 2025 energy scenario analysis of land transportation in this study, the two kinds of transportation systems (passenger and freight) could totally save energy 2,931KLOEs with reduction rate of 27%, accounting for the national total energy consumption by 2.43%. In addition, under the thermoelectric conversion efficiency of 36% and an energy conversion formula: 10,470 kiloliters of oil equivalent equal to one kWh, the above energy savings are equivalent to the electricity of 101,300 kWh, with the electricity emission factor 0.535kg-CO2e/kWh in 2010, a total reduction of greenhouse gas emissions is estimated to be 5.91 Mt CO2e, accounting for 2.40 percent of total carbon emissions in this country, and fully achieving the 2025 national carbon reduction target in transport sector (5.2 million metric tons of carbon dioxide). The detailed data of national energy consumption, carbon emissions, and electricity emission coefficient are referred from Bureau of Energy, Ministry of Economic Affairs, Taiwan (MOEABOE 2012a, 2012b, 2012c).

V. CONCLUSIONS AND SUGGESTIONS

Finally, from the data analyses and results discussion aforementioned, we suggest the following strategies for the on-land transport sector of Taiwan to meet the goals of energy conservation and carbon reduction. First of all, the extensive rail mode, including the increase of number of runs and the enhancement of transport volume, is the most effective energy-saving measure, particularly for the cars and the heavy trucks that should be replaced by rail transport in a large scale. Secondly, as the popularity of motorcycles in Taiwan, where the population is very dense, instead of being replaced by rail transport completely, we suggest that the adoption of electric motorcycle would be a feasible and economical measure, due to the consideration of the reason of personal convenience and preferences. In the energy-saving assessment of freight transport, if the majority of freight is turnover to TRA, the cargo would be increased from 0.87 billion ton-kilometers in 2010 to 42 billion ton-km in 2025, which is equivalent to an cargo increase to TRA in nearly 50 times compared with today's. Such a large increase in freight volume, the loadable capability of TRA is very problematic. On the other hand, in the energy-saving measures with respect to passenger's transport, the number of passenger will be significantly increased as well, due to the increase of run in frequency, resulting in the shortening of the time interval of each shift. Under the situation of increasing the volumes for both passenger and cargo for TRA, a further detailed assessment and analysis are necessary.

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