Estimating Electrical Energy Consumed by Electric Vehicles Penetration to realize a Carbon-free Jeju Island

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Abstract

The Jeju Special Self-Government Provincial Government made and has been working on the 'Carbon Free Island Jeju by 2030' Plan. Currently, it has been working on a plan of gradually penetrating (introducing) EVs to Jeju province to realize a carbon-free Jeju Island.
In this paper, we made a model equation estimating the electrical energy consumed by EVs in a definite region, and then the number of EVs to be introduced every year according to the 'penetrating EVs plan' was estimated. Finally, the electrical energy consumed yearly for the next 10 years by the EVs was calculated.

Key words :
EV(electric vehicle), Electrical Energy, Fuel Economy, Penetration of EVs

Introduction

Electric cars are divided into three types; electric vehicles (EV), hybrid electric vehicles (HEV) and plug-in hybrid electric vehicles (PHEV). They use electricity either as their primary fuel or to improve the fuel economy of conventional combustion cars. The HEV and the PHEV are operated selectively by an internal combustion engine or by a motor with a battery system according to necessary power on driving while the EV is operated solely by a motor and battery system. The difference between the HEV and the PHEV is that the battery of the PHEV is chargeable from the external electric power grid while the battery of the HEV is not chargeable. Even though the HEV has a drive system based on the motor, it can be classified into a petroleum car (such as petrol car, diesel car, gas car, LP gas car) because its fuel is supplied externally by petroleum. In terms of a point in being rechargeable from the external electric power grid, the EV and the PHEV are called plug-in electric vehicle (PEV)[1].

The EV, regarding a battery, has a few weaknesses such as price, weight, volume of the battery, time to charge battery, and the travel distance without recharging battery, but has a few important strengths that it has high fuel efficiency and does not cause pollution while driving and the electrical energy, being its fuel, can be generated by renewable energy sources such as wind turbines and solar cells. Due to these reasons the EV has a high potential of development as a transport mean in the future [2-3].

The Jeju Special Self-Governing Provincial Government in South Korea has been working on the Jeju Electric Vehicle Model City Project in order to realize the 'Carbon Free Island Jeju by 2030' Plan. According to this project, 10% of the vehicles being used in Jeju will be replaced by the year 2017 as the first step and 30% of them will be replaced by the year 2020 as the second step.

In this paper, the amount of electric energy consumed by EVs during the next 10 years is calculated on the bases of fuel economy of cars, driving distance during a day, and the estimated number of EVs. We compared the value with the amount of total electrical energy consumed in all parts on Jeju Island. There are big differences in the daily driving distances of cars according to types used; such as business cars, official vehicles and non-business personal cars. So, we are going to divide the car usage into 3 types, the official cars, the non-business personal cars and the business cars in order to improve accuracy in estimating the electrical energy consumed by electric vehicles. Because the commercialization of electric vehicles such as trucks and buses is delayed relatively, our study is limited to the case of replacing petroleum cars with electric vehicles in the field of small passenger cars.

MODEL AND FACTORS ESTIMATING ELCTRICAL ENERGY CONSUMED BY EVS

A. The Equation Calculating Electric Energy Consumed by the EVs

The yearly total electrical energy consumed by EVs can be calculated by the equation;

$$E = \sum_i \frac{N_i L_i}{\alpha_i} \times 365 \quad \text{(kWh)} \qquad (1)$$

where:
α_i: fuel economy (km/kWh)
N_i: number of electric vehicles
L_i : daily driving distance (km)

Subscript is introduced to distinguish the car usage types of EVs such as official usage, non-business personal usage and business usage.

B. The Certified Fuel Economy of Evs

In Korea and U.S.A the fuel economy of vehicles is divided into City Fuel Economy, Highway Fuel Economy and Combined Fuel Economy which is a weighted average of City Fuel Economy and Highway Fuel Economy into 55% vs. 45% respectively.

In Korea, like Table 1, fuel economy of EVs are evaluated and registered on Transportation Energy of Energy Management Corp's internet website [4].

〈Table 1〉 FORMALLY EXPRESSED FUEL ECONOMIES OF EVS IN SOUTH KOREA(IN THE SEP. 2016)

Model	Combined Fuel Economy [km/kWh]	1 time charging distance [km]	Curb weight [kg]	Release year
LEAF	5.2	132.0	1,520	2014
Soul	5.0	148.0	1,508	2014
Spark EV	6.0	128.0	1,240	2014
BMW i3	5.9	132.0	1,300	2014
SM3 Z.E.	4.4	135.0	1,580	2013
Ray	5.0	91.0	1,185	2012
Change	4.3	50.0	8,400	2012

C. The relation of EV Fuel Economy and Electrical Energy Consumed by EVs

Shown in Table 1, the fuel economy of EVs is in the range of 4.3~6.0(km/kWh) [4]. In case of PHEV its fuel economy is in this range while they move by motors. With the development of technologies on EVs, the fuel economy of new EVs will be improved while the fuel economy of the used

EVs will decrease due to aging. In this study, we assumed the EV fuel economy being in the range of 4.3~6.0(km/kWh) over the next 10 years.

Electrical energy consumed by EVs is at the minimum when EV fuel economy is at the maximum; while electric energy consumed by the EVs is at the maximum when EV fuel economy is at the minimum.

D. Daily Driving Distance of EVs

In this study, the daily driving distance of EVs was chosen as the same one for petroleum cars, and we used the daily driving distances of official usage cars, non-business personal usage cars and business usage cars presented by the study, 'The analysis on the car driving distance during a day in 2013' conducted by the Korean Transportation Safety Authority [5]. Table 2 is showing the figure.

〈TABLE 2〉 THE AVERAGE DAILY DRIVING DISTANCE OF THE PASSENGERS CARS IN THE JEJU SPECIAL SELF-GOVERNMENT PROVINCE

Usage purpose	Daily driving distance (km)
Official usage	36.5
Non-business personal usage	32.4
Non-business personal usage Business usage	101.7

ESTIMATION OF ELECTRICAL ENERGY CONSUMED BY EVS

A. Estimation of the Number of EVs Penetrated yearly

To estimate the number of EVs penetrated from 2016 to 2025, firstly, the number of vehicles using petroleum as fuel was estimated from 2016 to 2025 by the simple regression analysis based on the statistics values of the cars registered on Jeju Island from 2006 to 2012 [5],[6]. And then the number of EVs to be penetrated is calculated by multiplying the penetrating rate of EVs according to the EV penetrating plan of Jeju Special Self-governing Provincial Government by the estimated number of petroleum vehicles. Table 3 is showing the result.

〈TABLE 3〉THE ESTIMATION NUMBER OF EVS TO BE PENETRATED IN THE JEJU SPECIAL SELF-GOVERNMENT PROVINCE

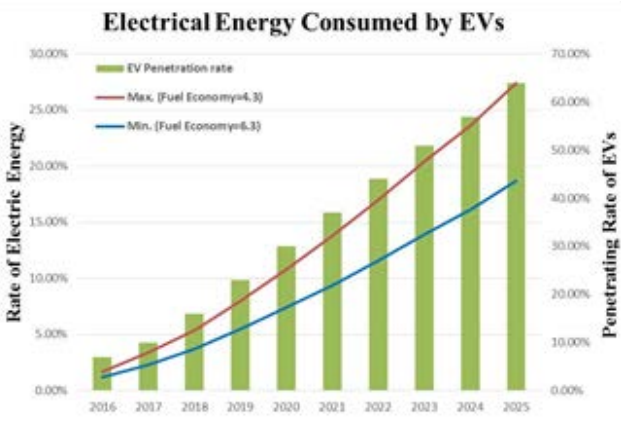
Year	No. of cars estimated			Goal of EV penetration	No. of EVs estimated		
	Official	Private	Business		Official	Private	Business
2016	698	223,832	38,083	5.0%	138	11,192	1,904
2017	735	234,294	40,971	10.0%	175	23,429	4,097
2018	773	244,756	43,859	16.0%	213	39,161	7,017
2019	810	255,218	46,747	23.0%	250	58,700	10,752
2020	848	265,680	49,636	30.0%	288	79,704	14,891
2021	885	276,142	52,524	37.0%	325	102,172	19,434
2022	922	286,604	55,412	44.0%	362	126,106	24,381
2023	960	297,065	58,300	51.0%	400	151,503	29,733
2024	997	307,528	61,188	57.0%	437	175,290	34,877
2025	1,034	317,989	64,077	64.0%	474	203,512	41,009

B. Estimation of Electrical Energy Consumed by EVs

According to the equation (1), the electrical energy consumed yearly by EVs was calculated. The maximum and minimum value of the electrical energy consumed by EVs were calculated to choose the fuel economy at the minimum 4.3(km/kWh) and at the maximum 6.0(km/kWh) respectively. The results are shown on table 4. In table 4, the estimated value of the total electric energy is based on "The Sixth Power Supply and Demand Basic Plan in South Korea"[7].

〈TABLE 4〉 THE ESTIMATION OF THE ELECTRICAL ENERGY CONSUMED DURING 1 YEAR BY THE EVS IN THE JEJU SPECIAL SELF-GOVERNED PROVINCE

Year	Total electrical energy consumed in Jeju [GWh]	EV Penetration rate	Electrical energy consumed by EVs[GWh]		Electrical energy rate consumed by EVs[%]	
			Max. (Fuel Economy =4.3)	Max. (Fuel Economy =4.3)	Max. (Fuel Economy =4.3)	Min. (Fuel Economy =6.0)
2016	4,161	7.0%	47.6	34.1	1.1%	0.8%
2017	4,234	10.0%	100.3	71.9	2.3%	1.7%
2018	4,314	16.0%	168.9	121.0	3.9%	2.8%
2019	4,385	23.0%	255.0	182.7	3.9%	4.1%
2020	4,435	30.0%	348.6	249.8	7.8%	5.6%
2021	4,424	37.0%	499.7	322.3	11.2%	7.2%
2022	4,399	44.0%	558.4	400.1	12.6%	9.0%
2023	4,361	51.0%	674.5	483.4	15.4%	11.0%
2024	4,347	57.0%	674.5	562.2	18.0%	12.9%
2025	4,405	64.0%	915.1	655.8	20.7%	14.8%



〈Fig.1〉 Electrical Energy Consumed by EVsIV.

DISCUSSION

It is most important to increase the accuracy in estimating electric energy consumed by EVs. In the equation (1) calculating the energy, the accuracy of the calculation depends on 3 factors: fuel economy of cars, EV numbers and daily driving distance. EV numbers depends on the penetrating (market share) goal of the province government. We focused on fuel economy and daily driving distance in order to increase the accuracy of estimation. We used the fuel economy formally expressed in U.S.A. and Korea. The maximum of electric energy consumed by EVs is fixed at the minimum of fuel economy of EVs and the minimum of electric energy consumed by EVs is fixed at maximum of fuel economy of EVs. Also, daily driving distance is differs greatly in business cars, nonbusiness personal cars and official cars. We used the respective statistic values on daily driving distance for the 3 car usage types.

In the case of charging EVs at an end-place of the demand side of the electric energy supply system, sufficient consideration is needed on the ability to safely receive electric energy, because the charging power of EV usually exceeds the facility capacity of a house.

If we could obtain more statistic data on the movement of EVs in the future, we may increase the accuracy in estimating electric energy consumed by EVs.

CONCLUSIONS

From 2011 to 2015, the fuel economy of EVs registered on Korea Official Site is in the range of 4.3~6.0(km/kWh). With the development of technology, there are factors that EV fuel economy has improved and, after purchasing an EV, some factors decrease the fuel economy of EVs, such as aging.

The calculation results show that the rate of the electric energy used by EVs will become at maximum, 2.3% of total electric energy consumed in Jeju for the year 2017, when the penetration rate of EVs for passenger cars becomes 10%. In addition, the rate of the electric energy consumed by the EVs will become at maximum, 7.8% of the total electric energy for the 2020 year when the penetration rate of EVs for passenger cars becomes 30%.

Our study on the basis of "The Sixth Power Supply and Demand Basic Plan in South Korea" shows in a macroscopic point of view that the electric power supply system of Jeju Island can sufficiently afford the electric vehicles increased according to the penetration plan of Jeju Special Self-Governing Province.

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