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Analysis on Greenhouse Gas Emissions Potential by Deploying the Green Cars in Korean Road Transport Sector

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Abstract**—**South Korea, as the 7th largest greenhouse gas emitting country in 2011, announced that the national reduction target of greenhouse gas emissions was 30% based on BAU (Business As Usual) by 2020. And the reduction rate of the transport sector is 34.3% which is the highest figure among all sectors. This paper attempts to analyze the environmental effect on deploying the green cars in Korean road transport sector. In order to calculate the greenhouse gas emissions, the LEAP model is applied in this study.

Keywords**—**Green car, greenhouse gas, LEAP model, road transport sector.

I. Introduction

CLIMATE change has a negative effect on human life in a variety of fields because greenhouse gas (GHG) emissions are increasing rapidly after the Industrial Revolution. That is why the number of localized heavy rain, typhoon, and heat wave in the Earth is recently on the increase. South Korea, meanwhile, is not free from responsibility for climate change problem. Greenhouse gas emissions are dramatically increasing due to fossil energy-guzzling industry in Korea. The increase rate of total greenhouse gas emissions is 113% from 1990 to 2007, and the figure is very high level among the members of OECD [1]. Furthermore, the economic power of Korea is ranked approximately 10th around the world. So Korea has been forced to make a greater effort of reducing greenhouse gas emissions in order to be suitable for global positioning.

Under these conditions, the Korean government announced that the national reduction target of greenhouse gas emissions would be set at G8 summit in 2008. And the goal was determined at Korean Cabinet meeting in 2009. The national midterm target of reducing greenhouse gas emissions is 30% compared with BAU (Business As Usual) by 2020 [2]. In spite of the voluntary goal, the 30% reduction is the most challenging target. And then Korean government announced the national reduction target was divided by sector, for example, industry, transport, commercial, residential, and transformation, etc. in 2011. Recently, the action plan was determined for meeting the sectoral reduction target in 2014, which means national GHG emissions reduction roadmap.

According to the National GHG emissions reduction roadmap, the transport sector has the highest reduction rate of greenhouse gas emissions for meeting the national reduction target by 2020. The figure is 34.3% [3].

This study attempts to calculate the environmental effect on deployment of green cars for Korean road transport sector. The rate of greenhouse gas reduction in road transport sector is the highest among whole sectors in Korea. In order to reduce greenhouse gas emissions, the deployment of green cars would be one of the best options in road transport sector. The green cars classified into 4 types which are clean diesel vehicle, a hybrid vehicle (including Plug-in hybrid vehicle), electric vehicle, and hydrogen fuel cell vehicle.

In order to estimate the environmental effect of deploying green cars in road transport sector, this study attempts to apply LEAP (Long-range Energy Alternatives Planning system) model which is a useful accounting or simulation model in energy system analysis tools [4], [5].

II. Methodology and Modeling

A. LEAP Model

In order to analyze energy system including energy supply and demand, a variety of analytic models are used. There are two groups. One is a top-down analytic model, and the other is a bottom-up analytic model. Since a top-down analytic model is based on macroeconomic theory, the key information is demographic data, GDP, the number of households, ratio of value added, and industry structure and so on. The representative models of top-down approach are CGE, Input-Output model. On the other hand, the bottom-up analytic model is based on technology deployment or energy intensity in the energy system. So the key information in the bottom-up analytic model is a technical specification, the penetration rate of technology, energy intensity, and life span of technology and so on. The representative models of bottom-up approach are LEAP, MARKAL, and TIMES [5].

This study attempts to use the LEAP model which was developed by the Stockholm Environment Institute in 1980 [4]. The LEAP model is one of the bottom-up analytic models and a representative accounting model in energy system analysis. The LEAP model is one of the useful tools for calculating greenhouse gas emissions by consuming energy of each

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technology evaluated [6]. And the model includes a technological and environmental database (TED), and could be used to calculate energy consumption and greenhouse gas emissions by scenario [7].

The calculation flow of LEAP model is shown in Fig. 1. First of all, the demographic and macroeconomic data are considered as key assumptions in the model. And the LEAP model could carry out demand analysis, statistical differences, transformation analysis, stock changes, resource analysis and non-energy sector emission analysis in order. Furthermore, the model could be considered environmental loadings and cost-benefit analysis as well [4].

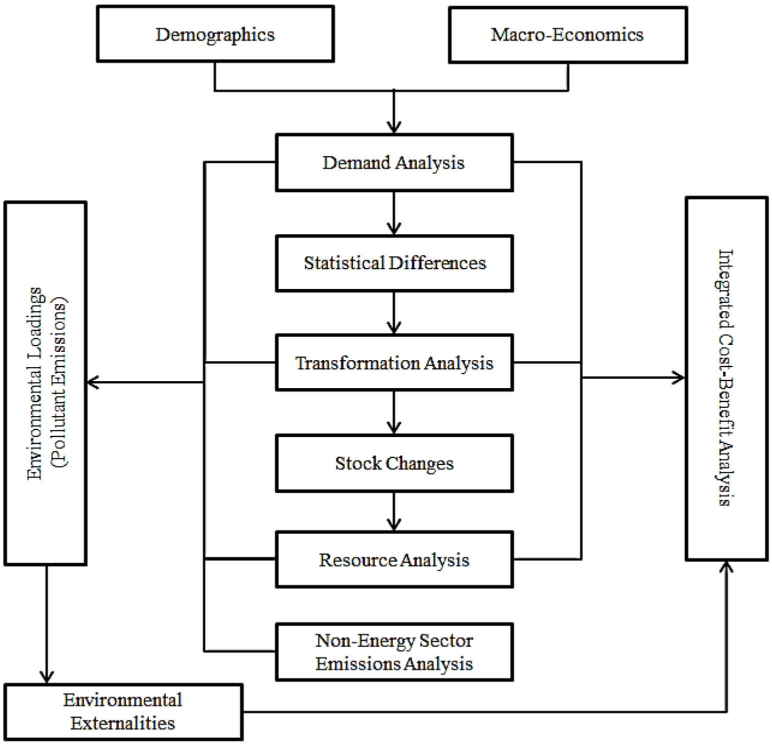


Fig. 1 Calculation Flows of LEAP Model [2]

B. Scenario Design

The precondition of baseline scenario is that all conditions related to existing energy system would be kept the same based on BAU (Business As Usual) in the future. So baseline scenario is used as a reference for comparing with alternative scenarios.

According to the National development strategy of green car industry [8], Korean government would push forward deployment of green cars aggressively. When it comes to the production of green cars, the target of domestic production of green cars is 1,900 thousand vehicles by 2020, and the target of overseas export is 1,300 thousand vehicles by 2020. In terms of deployment of green cars, the target of penetration rate is 43% by 2020. According to, meanwhile, Roadmap for achieving National GHG emissions reduction targets, 200 thousand electric vehicles, and 5 hundred hydrogen fuel cell vehicles would be supplied in existing transport system by 2020.

This study attempts to consider baseline and three alternative scenarios in order to calculate GHG emissions reduction potential of green cars. CDVHEV scenario places emphasis on clean diesel vehicle (CDV) and hybrid electric vehicle (HEV) among green cars.

EV/FCV scenario keeps the accent upon electric vehicle (EV) and hydrogen fuel cell vehicle (FCV).

Lastly, C-EVFCV scenario lays emphasis upon electric vehicle (EV) and hydrogen fuel cell vehicle (FCV) as well. Additionally, the scenario is a more challenging than EV/FCV scenario based on the opinions of experts in road transport sector.

TABLE I
THE RATIO IN CDVHEV SCENARIO (UNIT: %)

	2011	2020	2030	2050
EV	0	5	25	17
HEV	1	10	6	30
FCV	0	1	5	3
CDV	99	84	64	50
Total	100	100	100	100

TABLE II
THE RATIO IN EVFCV SCENARIO (UNIT: %)

	2011	2020	2030	2050
EV	0	6	29	40
HEV	1	9	3	5
FCV	0	3	8	20
CDV	99	82	60	35
Total	100	100	100	100

TABLE III
THE RATIO IN C-EVFCV SCENARIO (UNIT: %)

	2011	2020	2030	2050
EV	0	20	30	50
HEV	1	10	15	10
FCV	0	15	20	30
CDV	99	55	35	10
Total	100	100	100	100

The ratio of CDVHEV and EVFCV scenario is based on previous research which was conducted by the Korea Transport Institute [9].

III. RESULTS

When it comes to environmental effects, the result of baseline scenario is shown in Fig. 2. The total amount of greenhouse gas emissions is 85,512 thousand $MtCO_2e$ in 2011, 99,289.9 thousand $MtCO_2e$ in 2020, and 105,108.8 thousand $MtCO_2e$ respectively. The sectoral ratio of road transport is that the ratio of a taxi is 5.3%, a passenger car is 48%, the bus is 13.2%, and the truck was 33.6% in 2011. The ratio of a taxi is 6.1%, a passenger car is 54.2%, the bus is 9.7%, and the truck is 30% in 2020. In 2050, the ratio of a taxi is 6.3%, a passenger car is 56.4%, the bus is 8.6%, and the truck is 28.7%.

The result of CDVHEV scenario is shown in Fig. 3. The total amount of greenhouse gas emissions is 98,927 thousand $MtCO_2e$ in 2020, 99,048.7 thousand $MtCO_2e$ in 2050. The sectoral ratio of road transport is that the ratio of taxi is 5.9%, a passenger car is 54.5%, the bus is 9.3%, and the truck is 30.3% in 2020. The ratio of taxi is 6.3%, a passenger car is 55.9%, the bus is 8.2%, and the truck is 29.6% in 2050 respectively.

The result of EVFCV scenario is shown in Fig. 4. The total amount of greenhouse gas emissions is 98,485.4 thousand $MtCO_2e$ in 2020, 89,138.2 thousand $MtCO_2e$ in 2050. The sectoral ratio of road transport is that the ratio of taxi is 6.1%, a passenger car is 54.5%, the bus is 9.3%, and the truck is 30.1% in 2020. The ratio of taxi is 9.7%, a passenger car is 59.4%, the bus is 6.8%, and the truck is 24.1% in 2050.

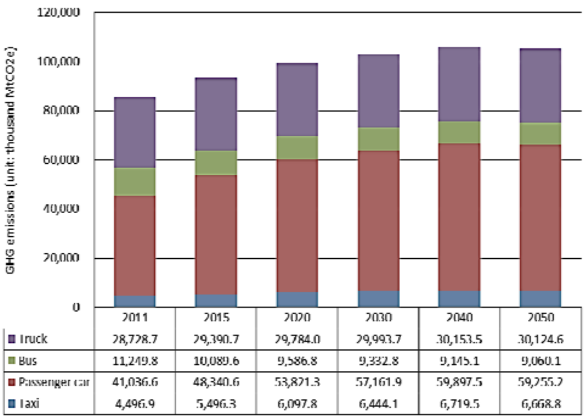


Fig. 2 Result of Baseline Scenario

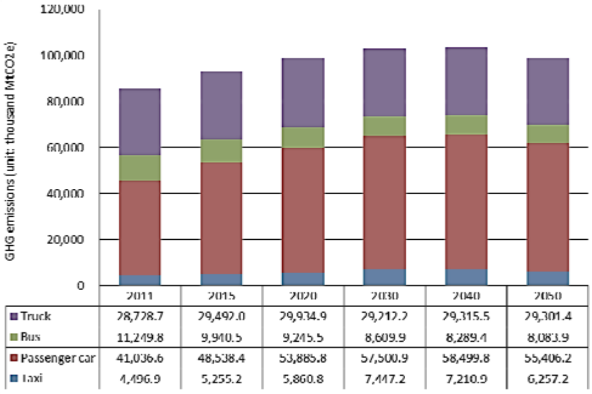


Fig. 3 Result of CDVHEV Scenario

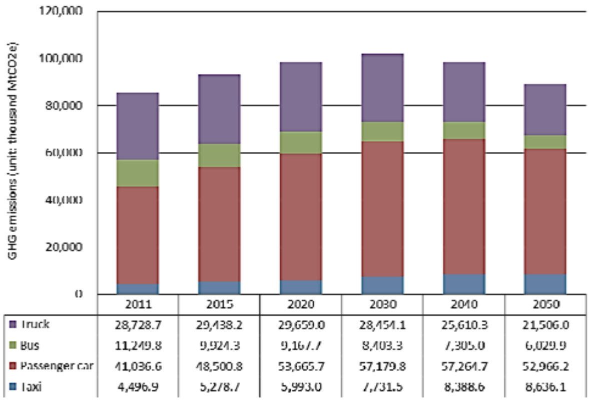


Fig. 4 Result of EVFCV Scenario

The result of C-EVFCV scenario is shown in Fig. 5. The total amount of greenhouse gas emissions is 94,398.4 thousand $MtCO_2e$ in 2020, 68,633.7 thousand $MtCO_2e$ in 2050. The sectoral ratio of road transport is that the ratio of a taxi is 6.9%, a passenger car is 54.9%, the bus is 9.1%, and the truck is 29.1% in 2020. The ratio of a taxi is 12.2%, a passenger car is 65.7%, the bus is 5%, and the truck is 17.1% in 2050 respectively.

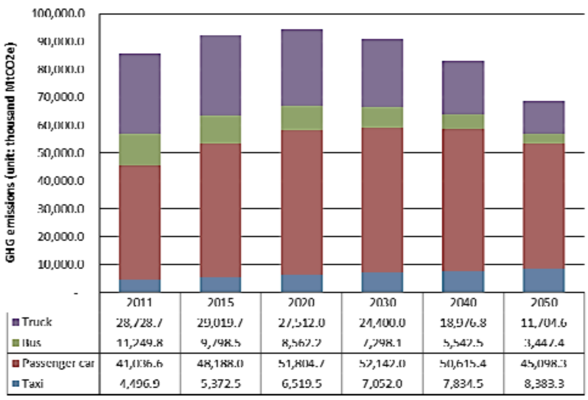
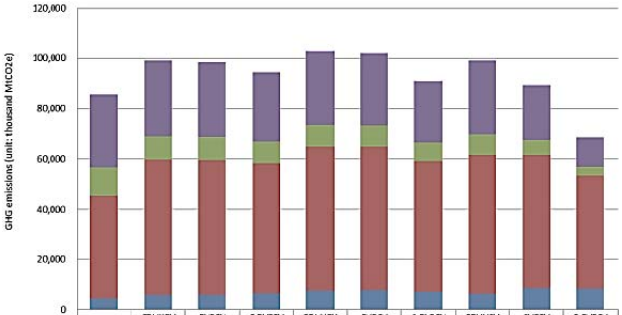


Fig. 5 Result of C-EVFCV Scenario

The sectoral comparison with the result of each scenario is shown in Fig. 6.



	2011	2020 CDVHEV	2020 EVFCV	2020 C-EVFCV	2030 CDVHEV	2030 EVFCV	2030 C-EVFCV	2050 CDVHEV	2050 EVFCV	2050 C-EVFCV
Truck	28,728.7	23,934.9	29,659.0	27,512.0	29,212.2	28,454.1	24,400.0	29,301.4	21,506.0	11,704.6
Bus	11,249.8	9,245.5	9,167.7	8,562.2	8,609.9	8,403.3	7,298.1	8,083.9	6,029.9	3,447.4
Passenger car	41,036.6	53,885.8	53,665.7	51,804.7	57,500.9	57,179.8	52,142.0	55,406.2	52,966.2	45,098.3
Taxi	4,496.9	5,860.8	5,993.0	6,519.5	7,447.2	7,731.5	7,052.0	6,257.2	8,636.1	8,383.3

Fig. 6 Comparison of result of each scenario

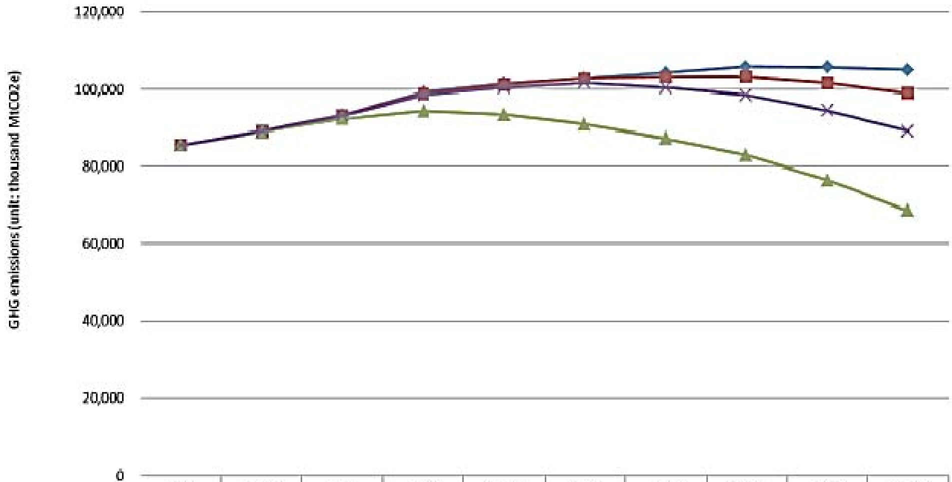
IV. Discussion and Conclusion

This paper tries to analyze the environmental effect on deploying green cars in Korean road transport sector. And the LEAP model is used for calculating the greenhouse gas emissions in baseline and alternative scenarios which are composed of four types; baseline, CDVHEV, EVFCV, and C-EVFCV scenarios.

According to the result of CDVHEV scenario compared with baseline scenario, the reduction ratio of greenhouse gas emissions is just 0.4% in 2020, and 5.8% in 2050 respectively.

The reduction effect of greenhouse gas emissions is low than expected figure. That is because the clean diesel vehicle applies Euro 6 standard which imposes a restriction on nitrogen oxide (NOx) among exhaust gas of vehicle. So, carbon dioxide emissions could not be decreased. And the hybrid electric vehicle is based on internal combustion engine with an electric motor. Therefore, the option could not contribute to a fundamental solution in order to reduce greenhouse gas emissions in road transport sector.

The reduction ratio of greenhouse gas emissions is 0.8% in 2020 and 15.2% in 2050 under the EVFCV scenario. The reduction effect of greenhouse gas emissions is low than expected figure as well. This paper considered existing electricity generation technology such as coal, LNG, and nuclear power plant. By-product hydrogen and nature gas reforming technology were considered as hydrogen production technology. A huge amount of electricity and hydrogen would be needed by deploying more electric vehicle and hydrogen fuel cell vehicle in the future. At this time, the process of electricity generation and hydrogen production should not be emitted greenhouse gas by using renewable energy or CCS technology and so on.



	2011	2013	2015	2020	2025	2030	2035	2040	2045	2050
Baseline	85,512.0	89,192.1	93,317.3	99,289.9	101,512.9	102,932.4	104,399.6	105,915.6	105,881.6	105,108.8
CDV & HEV	85,512.0	89,157.3	93,226.1	98,927.0	101,219.5	102,770.2	103,171.1	103,315.6	101,656.0	99,048.7
Challenging EV & FCV	85,512.0	88,954.3	92,378.7	94,398.4	93,414.0	90,892.1	87,347.7	82,969.2	76,463.6	68,633.7
EV & FCV	85,512.0	89,136.9	93,142.1	98,485.4	100,523.6	101,768.7	100,487.6	98,568.5	94,496.6	89,138.2

Fig. 7 Aggregated Result by Each Scenario

Lastly, the reduction ratio of greenhouse gas emissions is 4.9 % in 2020 and 34.7% in 2050 under the C-EVFCV scenario whose environmental effect is the best among all scenarios. That is because C-EVFCV scenario has the highest penetration rate of electric vehicle and hydrogen fuel cell vehicle among green cars. Even though the process for electricity and hydrogen needed in C-EVFCV scenario emits greenhouse gas, the effects of decreasing existing internal combustion engine and clean diesel vehicle is largely positively influenced on road transport sector.

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