Integrated Assessment of Economic and Environmental Impacts of Expanding Supply of Electric Vehicles over Transportation and Electricity Industries

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Abstract

The expansion and dissemination of electric vehicles (EVs) is expected to reduce CO2 emissions in the transportation industry by replacing other vehicles that emit greenhouse gases (GHGs). On the other hand, as the demand for electric power used by the EVs increases, the expansion of EV supply causes an adverse effect on GHG reduction in the electric power industry. In order to adequately evaluate the amount GHG reduction due to EVs, it is thus required an integrated assessment that considers the positive and the negative effect together in the transportation and the electricity industry, respectively.

We in this work have modeled the technical details of the two industries as optimization problems (referred to bottom-up models), respectively, and linked them with a common general equilibrium economy (referred to a top-down model). And we then apply it to evaluating the effect of expanding supply of EVs in South Korean GHG reduction efforts until 2030.

Model

Integrated top-down and bottom-up model

- The model used in this paper is a hybrid model where a top-down and a bottom-up model are linked.
- The model is developed to evaluate policies to reduce GHG emissions in South-Korea.

Top-down model

- Our top-down module (TDM) is primarily based on computational general equilibrium (CGE) models.
- TDM is modified to accept supply decisions from the two industries.
- TDM investigates macroscopic effects of expanding EVs over 56 Korean industries as a whole.
- TDM arranges fuel (i.e. energy inputs needed to produce industry services) and factor (i.e., labor and investment) prices as well as consumer prices of the services (i.e. transportation and electricity) from the two industries in national economic growth perspectives and provides those prices as well as the respective demand to the bottom-up modules .

Bottom-up model

- Bottom-up modules (BTMs) are coupled with TDM.
- BTMs analyze micro-behaviors of transportation and electricity industries, respectively.
- Transportation BTM (TBTM) describes the response of each sector in the transportation industry to the demand and the prices provided by TDM and finalizes a transportation supply plan.
- Electricity BTM (EBTM) consists of bulks of technical constraints that reveal current and future characteristics of power generation plants and determines the final electricity supply derived by each generation technology that also counts for the electricity demand and the various prices provided by TDM.

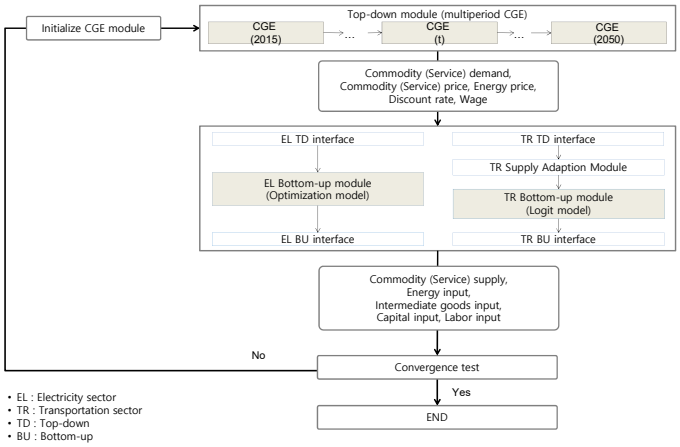

Fig. 1 : Integrated top-down and bottom-up (Electricity-Trasnportation) model

Scenarios

Reference scenario

- The stock of electric vehicles reaches **1 million** by 2030.
- In ESDP (Electricity Supply and Demand Plan, which is a key government plan relevant to future GHG emission estimation in South Korea), the penetration of EVs is expected to be 1 million in 2030.

EV2M scenario

- The stock of electric vehicles reaches **2 million** by 2030.
- No renewable energy policy.

EV2M + RE3020 scenario

- The stock of electric vehicles reaches 2 million by 2030.
- In 2030, 20% of the power supply is from renewable resources.

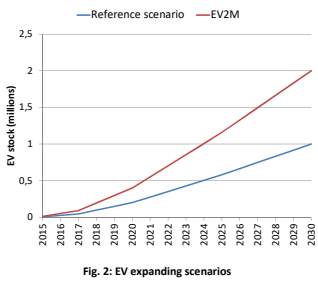

Fig. 2: EV expanding scenarios

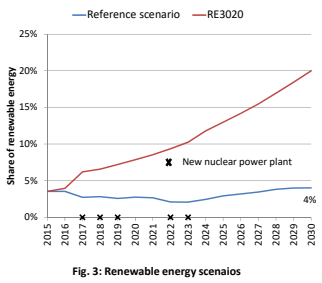

Fig. 3: Renewable energy scenaios

Simulation results

Impacts on energy demand

- The EV growth projected in the scenarios result in an increase of electricity demand.
- In 2030, Korea's electricity consumption by EVs reaches 3689 GWh in the Reference scenario and 5536 GWh in EV2M (regardless of generation mix in the power sector).
- As the number of electric vehicles increases by 1 million in EV2M, the share of power in fuel-use in the transportation sector increases from 4.22% to 6.44%.

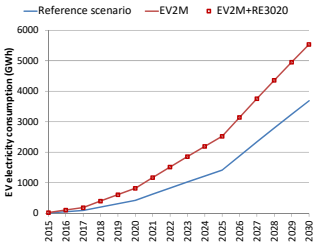

Fig. 4 : Electricity demand from EV

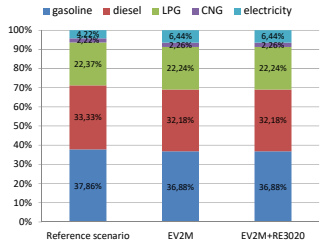

Fig. 5 : Energy consumption from EV
Notes : The fuel consumption is calculated by converting it all into TOE units and calculating the ratio.

Impacts on CO2 emissions and GDP

- The future CO2 emission by the EV stock is determined by the combination of EV stock evolution and GHG intensity of power generation.
- Increasing EVs certainly reduces the energy demand by other types of vehicles and consequently the diesel and gasoline combustion, but increases the electricity demand, which has different environmental impacts on transportation and electricity industries, respectively.
- In 2030, CO2 emissions in the transportation sector are 26.99 Mton/yr in the reference scenario and 25.78 Mton/yr in the EV2M and EV2M+RE3020 scenarios. In the EV2M scenario, CO2 emissions are reduced by 4.5% compared to the Reference scenario.
- On the other hand, CO2 emissions in the electric power sector in 2030 are 222.84Mton/yr in the reference scenario, 229.60Mton/yr and 201.56Mton/yr in the EV2M and the EV2M+RE3020 scenario, respectively.
- The reference scenario and the EV2M scenario result in the similar generation mix. In both of these scenarios, over 73% of the electricity supply are generated from fossil fueled power plants. In the EV2M scenario, CO2 emissions from the electric power industry increase due to the demand for additional electric power from the expansion of electric vehicles. In the EV2M + RE3020 scenario, which enforces renewable energy expansion policies, about 58% of electricity demand is met by fossil fuels. Despite the increase in electricity demand due to electric vehicles, the CO2 emissions of the power industry are reduced by 9.5% compared to the Reference scenario.
- The total CO2 emissions from the industry as a whole are 957.17, 961.75 and 929.14 Mton/yr, respectively.
- In the EV2M scenario, where the proportion of fossil fuels in power supply is large, CO2 emissions from the industry as a whole are projected to increase by 0.5% compared to the Reference scenario.
- In the EV2M + RE3020 scenario, the total emission is reduced by 2.9% compared to the Reference scenario, despite the increase in electric power demand due to the expansion of electric vehicles while achieving CO2 reduction effect as the electric power industry structure changes.

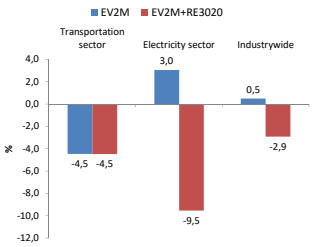

Fig. 6: CO2 reductions in the tested scenarios compared to EV1M (in 2030)

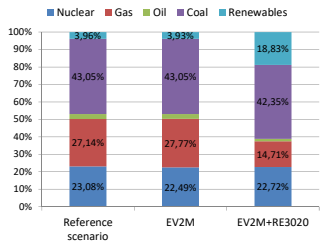

Fig. 7: Power generation

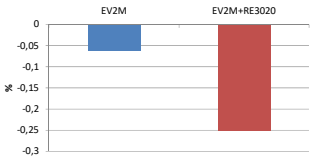

Fig. 8: GDP increases compared to referecne scenario (in 2030)

- GDP would decrease by 0.06% in 2030 owing to EV supply increasing to 2 millions.
- In the EV2M+RE3020 scenario, GDP reduction would be 0.25% by 2030.
- In the both scenarios, a negative on GDP pathway is observed.

Conclusions

- The EV growth projected in the scenarios result in an increase of electricity demand.
- Although CO2 emissions from the transportation sector have decreased, the increase in the power sector might rather increase CO2 emissions throughout the industry.
- With a new renewable energy policy (RE3020), the increase in CO2 emissions in the power sector can be under control, and the increase in CO2 emissions throughout the industry can be reduced to 2.9%.
- When supplying electric vehicles, it is shown that the decarbonisation of electricity supply is important to reduce CO2 emissions.
- The lower emission of local air pollutants is one of the main drivers of interest in electric vehicle, therefore, we will develop an advanced version of the model to analyze the effects of local air pollutants reduction.

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