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Comprehensive analysis of GHG emission mitigation potentials from technology policy options in South Korea's transportation sector using a bottom-up energy system model

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ABSTRACT

The South Korean government released a greenhouse gas (GHG) emission mitigation target for 2030 under the 2015 Paris Agreement and developed a detailed implementation plan in 2016 to achieve the target. In this study, we analyzed the GHG emission reduction potential of South Korea's transportation sector under the implementation plan. We first identified six technology policy options already adopted or being considered for adoption by the Korean government in the near future. Next, we quantitatively analyzed the GHG emission mitigation potential of each option, as well as the combination of all the options, via the best-known and most widely used bottom-up energy system model. In addition, we estimated the marginal mitigation costs of the options and their combination. We found that more than 30% of GHG emissions can be reduced compared to the business-as-usual scenario by adopting technology options, and that most reductions can be achieved by the road transportation subsector. We also showed that a comprehensive analysis is required to estimate the total potential of the entire transportation sector, because some duplication effects exist between the options. Lastly, based on the comprehensive analysis results, we provide four implications of the plan for climate change and transportation policy makers.

1. Introduction

Climate change related issues, including global warming and extreme weather events, are considered by many as one of the biggest challenges facing the world today. On December 12, 2015, nearly 200 countries at the United Nations Framework Convention on Climate Change (UNFCCC) agreed to adopt the Paris Agreement, a legally binding framework for an internationally coordinated effort to prevent climate change beyond 2020. In the Paris agreement, the UNFCCC established a global warming target of well below 2 °C of pre-industrial averages and defined a universal framework to enhance the global response to meet that target (UNFCCC, 2015). The Paris Agreement emphasizes processes rather than establishing mitigation targets and requires that each country prepares, communicates, and maintains successive nationally determined contributions (NDCs). NDCs are voluntary commitments from participating countries to pursue actions, policies, and regulations necessary to accomplish targets to mitigate greenhouse gas (GHG) emissions and to adapt to a changing climate.

Prior to the Paris Agreement, about 150 countries submitted "intended" NDCs (INDCs), which became the first NDCs under the

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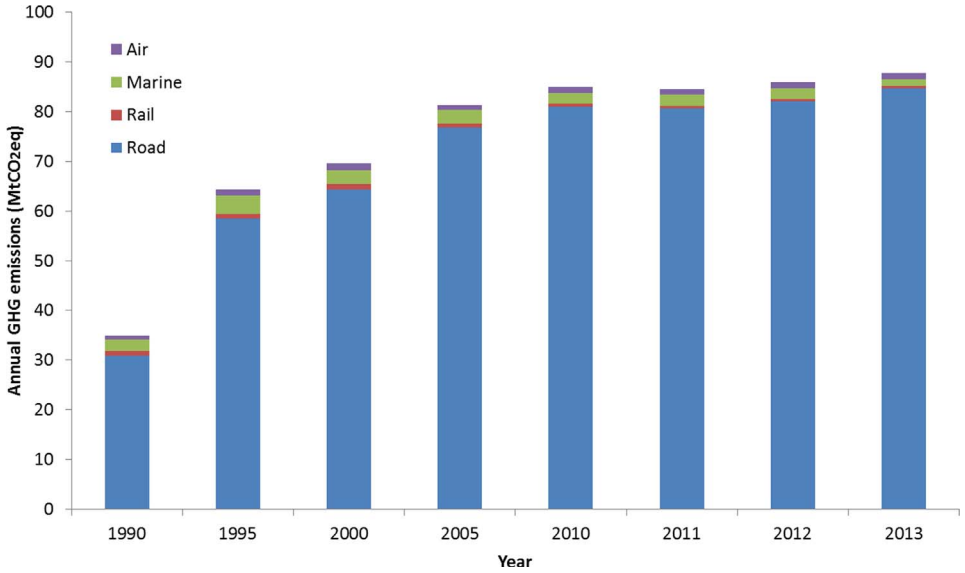

Fig. 1. Historical data of annual GHG emissions from South Korea's transportation sector.

Paris Agreement. In June 2015, the South Korean government also released an INDC, in which the government pledged to reduce GHG emissions to 37% below the business-as-usual (BAU) level of 850.6 Mt CO_2eq. by 2030 across all economic sectors (ROK Government, 2015a). The target includes an actual mitigation of 25.7% and an additional decrease through international market mechanisms equivalent to 11.3%. After the announcement, many domestic experts suggested that this target could only be achieved by taking very aggressive actions. South Korea is among the world's top 10 carbon emitters. As of 2013, the nation's total annual GHG emission was approximately 694.5 Mt CO_2eq (GIR, 2015). Considering the country's international responsibility and leadership in responding to climate change, the government has decided to commit to meeting its target by 2030.

After the Paris Agreement, the South Korean government developed a road map for achieving the target on time. To establish the plan, the government first segmented the sources of GHG emissions into eight sectors, including electricity, industry, commercial and residential, transportation, and agriculture. The government then analyzed GHG emission mitigation levels, potentials, and strategies considering the existing national policies and socioeconomic and technical changes in each sector. In December 2016, after combining the analysis results for all sectors based on the bottom-up approach, the government published a basic national plan for POST-2020 (ROK Government, 2016).

This study discusses how GHG emission mitigation potentials in South Korea's transportation sector for the plan were analyzed. As of 2013, the transportation sector was the fourth largest GHG emitter and accounted for about 12.7% of the nation's total annual GHG emissions (88.3 Mt CO_2eq). The average annual growth rate (compound annual growth rate, CAGR) of GHG emissions from this sector was 4.1% from 1990 to 2013, and the share from the road transportation sub-sector in GHG emissions has been 95% for the last 24 years (GIR, 2015) (Fig. 1).

For this study, we had three objectives: (1) to identify technology policy options that can be incorporated into the government's implementation plan for the transportation sector; (2) to quantitatively analyze the GHG emission mitigation potential of each option as well as the combinations of these options; and (3) to provide the implications of the plan to climate change and transportation policy makers. In order to analyze the GHG mitigation potential, we used the bottom-up energy system model, TIMES (The Integrated MARKAL-EFOM System), which is the most widely used and best-known optimization-based model and was created by the International Energy Agency's Energy Technology Systems Analysis Program (IEA-ETSAP) (Loulou et al., 2016). Even though there are other energy system models and methodologies to analyze GHG emission mitigation potential, we chose the TIMES model for future coordination with the results of the INDC, which were analyzed using the same model and released in 2015. In addition, the marginal mitigation costs of options were estimated and compared.

The remainder of this work is organized as follows: Section 2 reviews previous literature on GHG emission mitigation potential analysis for the transportation sector. Section 3 describes the model construction and the development of a baseline scenario. Section 4 introduces the details of these technology policy options we identified and the implementation of the options in the model. Section 5 provides the analysis results for each option and for the entire sector. Lastly, Section 6 presents our conclusions.

2. Literature review

Research on GHG emission mitigation potential for the transportation sector started in the mid-2000s when the Kyoto Protocol entered into force. Many studies used commercial bottom-up energy system models for this research. Ichinohe and Endo (2006) identified the most-effective mix of vehicles in the passenger car sector in Japan for reducing CO_2 emissions by using the MARKAL (MARKet ALlocation) model, a predecessor of the TIMES model that was also created by the IEA-ETSAP. Yeh et al. (2008) determined