UTF Project Number: MITR24-11A

Project Title: Time Dependent Environmental Impact of Transportation

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  Federal: New England University Transportation Center at MIT
  Cost Share: Massachusetts Institute of Technology

Total Project Cost:
  Federal: $30,000.00
  Cost Share: $30,000.00

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Brief description of project:

Energy technologies emitting differing proportions of methane (CH₄) and carbon dioxide (CO₂) vary in their relative climate impacts over time, due to the distinct atmospheric lifetimes and radiative efficiencies of the two gases. Standard technology comparisons using the global warming potential (GWP) with a fixed time horizon do not account for the timing of emissions in relation to climate policy goals. In this project we developed an alternative approach for policy makers, engineers, and private investors to use in evaluating the time-dependent greenhouse gas emissions impacts of energy technologies, and in optimizing energy technology portfolios.

We use a dynamic portfolio choice approach that selects a technology portfolio to maximize energy consumption while meeting a policy target. This leads naturally to an analytical expression for technology impact that changes over time and can be used to derive an emission equivalency metric, the ICI. The optimal results from the model are compared to choices relying on the standard GWP-based method for a set of transportation technologies. The benefit of this method is numerically quantified for three transportation technology pairs: compressed
natural gas (CNG) and gasoline, electric vehicle (EV) and algae biodiesel (algae), switchgrass E85 (switchgrass) and renewable natural gas (RNG), with the first in each pair being relatively CH\(_4\)-heavy compared to the second. Data on emissions intensities of the greenhouse gases (GHGs) CO\(_2\), CH\(_4\), and N\(_2\)O are obtained using the GREET model. The radiative forcing impact of each GHG over time is calculated using the values of radiative efficiency and decay lifetimes given in the IPCC AR5 report. The global radiative forcing target used is 3 W/m\(^2\), which is consistent with an equilibrium temperature change of 2°C above pre-industrial levels.

Solving the optimization model we find that the optimal technology portfolio calls for the use of the more CH\(_4\)-heavy technology in earlier years, switching to the CH\(_4\)-light technology as the intended RF stabilization year approaches. This switching portfolio facilitates greater energy consumption than the exclusive use of either technology alone. The early use of the CH\(_4\)-heavy technology is optimal only if the horizon exceeds 22 years for CNG and gasoline pair, 14 years for algae and EV pair, and 19 years for the RNG and switchgrass pair. Given a stabilization horizon from the present to mid-century, a switching portfolio can allow a gain in energy consumption of up to 15% (50%) over the corresponding CH\(_4\)-light (CH\(_4\)-heavy) technology. In contrast, using a standard GWP based method leads to the choice of a single technology over the entire horizon, which for the most commonly used 100-year GWP results in either a significant overshoot of the RF target or, if constrained by the target, allows significantly lower energy consumption. The use of a 35-year GWP does not lead to a target overshoot but allows lower energy consumption.

Describe implementation of research outcome:
[place any photos here]
The results of this project have been published in a peer-reviewed academic journal: Environmental Research Letters, and presented at an international conference (ISIE 2015).

Publication:

Conference Presentations:


Describe the impacts/benefits of implementation [actual, not anticipated]:

Web links: