The Effect of Clean Electricity on CO_2 Emissions from Plug-in Electric Vehicles

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Overview

The net change in U.S. CO_2 emissions from plug-in vehicle (PEV) deployment will depend on how the U.S. electric grid mix evolves over time. This paper fills a gap in the literature by employing an energy system model to quantify the incremental impact of PEV deployment on national U.S. CO_2 emissions through mid-century under different clean electricity scenarios. We investigate the effect of several plausible clean electricity scenarios on the electricity generation mix, electricity prices, and system-wide CO_2 emissions throughout mid-century under high PEV deployment levels. In addition to a base case, we consider a federal renewable portfolio standard (RPS), a clean energy standard (CES), the proposed EPA power sector rules, and low cost wind/solar technologies. The Integrated MARKAL-EFOM System (TIMES) and the National U.S. Technology Database (NUSTD) are used to conduct this analysis. PEV deployment produces the largest CO_2 reductions in the EPA Rules and Clean Energy Standard scenarios. The model results demonstrate that the incremental CO_2 emissions benefit associated with PEV deployment largely depends on marginal emissions rates associated with the power plants used to meet the PEV charging requirements and to a lesser extent changes across the broader energy system. In scenarios where electric sector emissions are not constrained, the model utilizes electricity at the margin with high CO_2 intensity for vehicle charging, particularly towards mid-century as natural gas prices increase relative to coal. While the maximum reduction in national CO_2 emissions from a fully electric light duty vehicle (LDV) sector powered by CO_2-free electricity is 20%, we find under the studied scenarios that the emissions change ranges from a 0.6% increase to 6% decrease.

Methods

The model used for this analysis consists of two components: The Integrated MARKAL-EFOM System (TIMES) (Loulou et al., 2005), which serves as a generic energy optimization framework and operates on the National U.S. TIMES Dataset (NUSTD), a TIMES-compatible dataset constructed for this analysis. TIMES is a widely used bottom-up, technology rich energy system model, which represents an energy system as a set of networked technologies linked together via flows of energy commodities (Loulou et al., 2005). TIMES employs linear programming techniques to identify the optimal installed technology capacity and utilization in order to meet a set of end-use demands over time, subject to a number of built-in constraints that ensure proper operation of the energy system as well as user-defined constraints such as emissions limits and growth rate limits on specific technologies. We developed a TIMES-compatible input dataset called NUSTD, which contains fuel price trajectories, technology cost and performance estimates, and end-use demands to represent the U.S. as a single region over the next four decades. NUSTD was carefully documented in Babaee (2015).

Results

Figure 1 presents national U.S. CO_2 emissions under all 5 modeled scenarios with and without PEV availability and splits the changes in 2050 national CO_2 emissions into two components: (1) the CO_2 emissions change between the Base and each scenario without PEVs, and (2) the incremental change in CO_2 emissions within each scenario due to PEV deployment. PEV deployment in the Base and RPS scenarios actually produce a slight increase (less than 1%) in 2050 CO_2 emissions. Because the EPA Rules scenario effectively provides a cap on CO_2 emissions, the increased electricity demand from PEV charging does not lead to higher CO_2 emissions, but rather an additional 6% drop by 2050. The incremental emissions benefit under the Low Cost Wind/Solar scenario is a more modest 3% in 2050, as a higher share of existing coal is retained in later time periods in order to meet the increased demand from vehicle charging. Finally, PEV deployment under the CES scenario also results in an additional 5% decrease in 2050 CO_2 emissions, similar to the EPA Rules scenario. As PEV charging demand ramps up, the share of clean electricity under the CES must be preserved, so the absolute amount of renewables rises and CO_2 intensity remains relatively constant. For comparison to these modeled scenarios, a carbon-free electricity used to charge a 100% electric LDV fleet would produce a 20% reduction in national CO_2 emissions. In the alternative electricity scenarios tested here, the largest reductions in national CO_2 emissions due to PEV deployment are on the order of 5-6%.

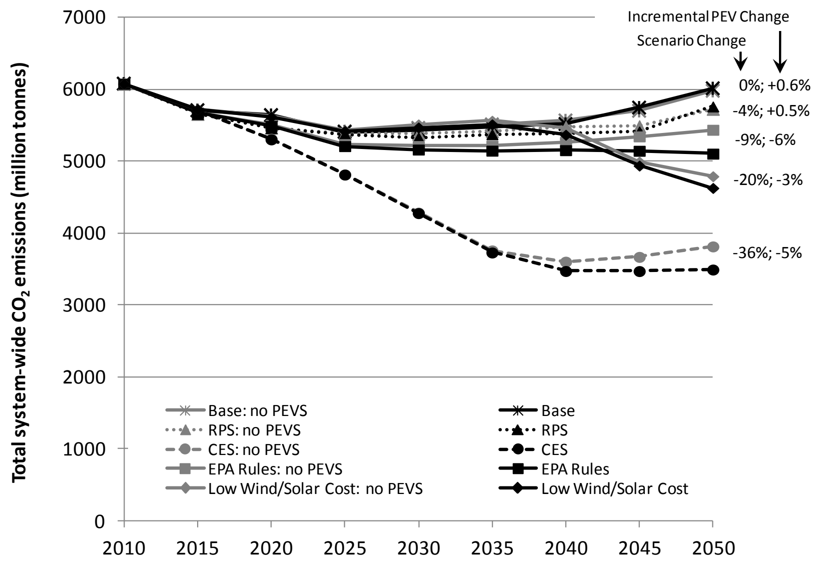

Figure 1. CO_2 emissions pathways for all five scenarios with and without the availability of PEVs, which are represented by black and gray lines, respectively. The percentages labeled 'Scenario Change' represent the 2050 emissions change between the Base and each scenario without the availability of PEVs, and the percentages labeled 'Incremental PEV Change' represent the incremental change in 2050 emissions within each scenario due to PEV deployment.

Conclusions

We have employed an energy system model to quantify the incremental change in CO_2 emissions associated with PEV deployment under several plausible clean electric sector scenarios. We focus attention on scenarios that are favorable to PEV deployment, including high oil prices, low battery cost, and use of a relatively low 10% hurdle rate for alternative vehicle purchases, which collectively result in a 34% share of PEVs within the LDV market in 2050. As shown in Figure 1, the alternative electric sector scenarios without PEVs result in national CO_2 emissions reductions ranging from 4-36% in 2050. Allowing PEV deployment changes emissions by an additional +0.5% to -6% in 2050. Thus the direct effect of electric sector policies in reducing CO_2 emissions is much larger than the effect produced by PEV deployment. Overall, policymakers must be attentive to electric sector developments when considering policy related to PEV deployment, as the marginal changes to electricity supply to accommodate vehicle charging can produce a range of effects on net CO_2 emissions.

References

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