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Electric-Sector Fuel Switching Under Carbon Constraints

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Overview

Petroleum-based liquid fuels are the source of nearly 40% of the total primary energy consumed in the United States and are used overwhelmingly for transportation and heating purposes [1]. Concerns about greenhouse gas (GHG) emissions from liquid fuel combustion, energy security, and price volatility are all cited as reasons to reduce U.S. petroleum consumption [2]. Because electricity can be generated from domestic, renewable and low-carbon fuel sources, researchers and policymakers are increasingly exploring options to replace liquid fuels with electricity. Motivated by the significant potential for fuel switching, this paper examines the impact of increased electricity demand for plug-in electric vehicle charging on the costs of electricity generation and carbon allowance prices given a CO_2 emissions pricing scheme that imposes a cap-and-trade structure on the electricity sector but does not directly regulate emissions from other sectors.

Methods

We use a linear optimization, generation expansion/dispatch model to evaluate the price impact in the year 2020 for varying levels of transportation sector fuel switching, carbon-cap restrictiveness, and power plant capital costs. In addition to estimating marginal generating costs, which are a good approximation for wholesale electricity prices in functionally competitive electricity markets, key model outputs include the resulting generating portfolio, the overall generating fuel mix, and the net change in emissions resulting from fuel switching. Since the electric energy fuel mix varies considerably from region to region, we ran the model for two distinct US Regional Transmission Organizations (RTOs): ISO-New England, where natural gas plants are the largest single source of electricity; and PJM Interconnection, where coal-fired power plants currently produce the largest share of electric energy.

Results

We find that a shift from coal toward natural gas and wind generation is sufficient to achieve a 50% reduction in electricity-sector CO_2 emissions while supporting vehicle charging for 25% of the vehicle fleet. The price impacts of these shifts are sensitive to demand side price responsiveness and the capital costs of new wind construction.

Conclusions

Our results illustrate the potential to substantially reduce CO_2 emissions from the electricity sector by increasing the use of natural gas for power generation. This results holds even in the face of increasing demand for electricity via electrified transportation or other causes. Our analysis also suggests, consistent with [3], that a non-trivial amount of electric-sector decarbonisation can effectively be provided by the demand side of the market. Finally, our results support previous research indicating that fuel switching can reduce GHG emissions from the transportation sector. Regional differences in potential wind resources also impact the number of options available for substantial regional CO_2 emissions reductions.

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