POLICY, TECHNOLOGY, AND ECONOMIC UNCERTAINTY: WHICH MATTERS THE MOST FOR GLOBAL ENERGY SYSTEM MODELING?

David Daniels, U.S. Energy Information Administration, David.Daniels@eia.gov

Overview

Global, national, and sub-national models of various designs are often employed to evaluate energy policies. While the scope of laws and regulations is typically restricted to national or sub-national scales, effects may be global, such as on greenhouse gas emissions. This disconnect leads to a conundrum for the modeler: whether to model at the scale of the policy or at the scale of the impact. Modeling at the national or sub-national level often allows for models with great detail in technology, region, sector, commodity, and demographics. While these models may capture the local impacts of a policy, they often lack sufficient linkages with the rest of the world to reflect global effects accurately. Global models sacrifice detail to maintain methodological consistency or computational tractability across a closed system, and policies are typically represented in a stylized and simplified manner.

This paper presents some preliminary results of research investigating the utility of linking a detailed model of the U.S. energy system with a less-detailed global model, both of which contain representations of the macroeconomy. The utility of the combined system of models is illustrated by example, using it to model the impact of one specific regulation, the U.S. Clean Power Plan (CPP), on energy-related carbon dioxide (CO2) emissions in the U.S. and globally. To address the title question, the robustness of these emissions impacts are examined under alternate model scenarios that represent different assumptions about technology or economic growth.

Three results emerge. First, while this particular policy has previously been shown to cause significant fuel switching in the U.S., its impact on global annual energy-related CO2 emissions by 2050 is relatively small. This illustrates the difference in scope between a national policy and a global effect. Second, as U.S. CO2 emissions decrease as a result of this regulation, rest-of-world (ROW) emissions generally increase, though to a much lesser extent, partially offsetting the change in U.S. emissions. This is interpreted as evidence of global trade linkages impacting commodity prices. Third, the impact on emissions from the CPP depends on the model assumptions. Across the range of scenarios explored in this study, the global energy-related CO2 emissions reduced by the CPP varies from 200 to 400 million tons per year in 2030, and the impacts after 2030 follow different trajectories. This emphasizes the importance of conducting robustness checks when evaluating the impact of a policy.

Methods

The U.S. Energy Information Administration (EIA) maintains two long-term (to 2050) energy system projection models, the National Energy Modeling System (NEMS), which it uses for the Annual Energy Outlook (AEO), and the World Energy Projection System (WEPS), which produces global results for the International Energy Outlook (IEO). Both models are modular, partial equilibrium models with macroeconomic feedback to capture the interaction of energy prices and activity in energy sectors with the rest of the economy. The macroeconomic modules in both NEMS and WEPS are based on commercially-available econometric models: NEMS' is based on the IHS/Markit models and WEPS' is provided by Oxford Economics. Trade between the U.S. and the rest of the world is largely represented via import and export curves in NEMS, while WEPS represents trade linkages between its 16 regions explicitly. NEMS has significant regional detail as well as sufficient technology detail to represent many of the features of the CPP, but WEPS lacks such detail. EIA's models are available to and operated by other organizations as well.

The results presented in this paper represent ongoing research into methods and techniques and do not constitute official EIA data. NEMS runs are based on the version of that model that was used to prepare results for AEO2017, but WEPS runs are based on the version that was available in May 2017 and therefore do not reflect IEO2017 published results. Nevertheless, the results illustrate the effects one might expect by linking NEMS and WEPS.

For this analysis, we seed the initial WEPS starting point for the U.S. region with results from NEMS. The macro module of WEPS uses these results to find a consistent solution across all 16 WEPS regions, including the U.S., after which they are again overwritten with NEMS results. The other WEPS modules respond to these results and find global solutions of their own. This process of successively overwriting U.S. values with NEMS results continues throughout the WEPS iteration process until global convergence is achieved across all modules.

We compare U.S. and global energy-related carbon dioxide emissions between pairs of cases representing the U.S. with and without the CPP in a reference case and two types of side cases. We examine side cases that represent high and low assumptions about the size and cost of extraction of U.S. shale oil and gas resources, and we explore side cases that represent high and low economic growth assumptions for the world. The economic growth assumptions are designed to achieve GDP growth rates different from reference by 0.2%/year in OECD countries and 0.5%/year in non-OECD countries, and they are implemented primarily by adjusting factor productivity assumptions in the macroeconomic modules of NEMS and WEPS.

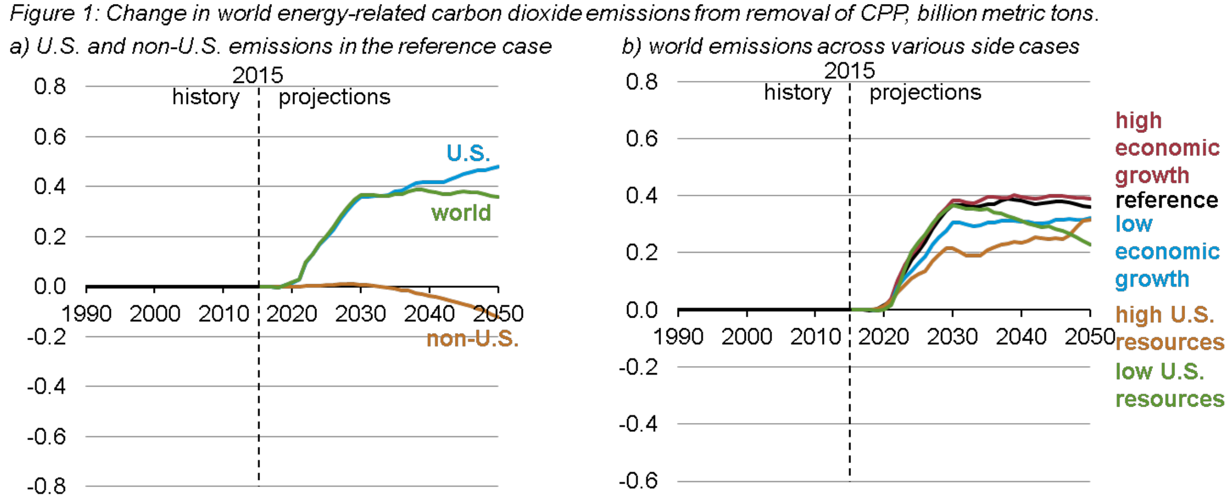
Results

Previously-published results from the AEO2017 have shown the impact of the CPP on the U.S. energy system. While liquid fuels and electricity demand are largely unchanged, the power generation mix changes after 2022 when the CPP begins to take effect. The principle impact of the CPP is to replace a significant share of coal-fired generation with natural gas and renewables generation.

Figure 1a shows the corresponding impact of removing the CPP on U.S. and world energy-related CO2 emissions. Without the CPP, U.S. emissions are almost 500MT/yr higher by 2050, but there is a compensating impact from the rest of the world (ROW) that brings the net CO2 emissions increase down to under 400MT/yr. Thus, the presence or absence of the CPP represents roughly a 1% change in world emissions of about 42 GT/yr by 2050 in WEPS.

Figure 1b shows the net world emissions increase from the removal of the CPP across several side cases. The high and low global economic growth cases show similar absolute sensitivities to the CPP as in the reference case, but these represent a greater (low macro) or lesser (high macro) percentage of the world's emissions in 2050. Conversely, the high and low U.S. resource cases show significantly different trajectories of emissions impacts, but by 2050 the impact is similar across these two cases. Overall, the impact of the CPP ranges from 200MT/yr to 400 MT/yr in 2050 across these cases.

Figure 1: Change in world energy-related carbon dioxide emissions from removal of CPP, billion metric tons.



Conclusion

Using the example of the CPP, we have shown that the impacts of national policies on global emissions depends both on the interactions of those policies with the energy system outside the country and on the scenario assumptions used in the simulation. This demonstrates the importance of incorporating uncertainty into the analysis of policy outcomes. Since both technological and economic growth patterns are rarely as predicted in the long run, robustness of modeled policy outcomes across multiple side-case scenarios should be evaluated.