What happens today, tomorrow, and the future matters: the effects of foresight in modeling the impacts of energy policy

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Overview

Energy models are frequently employed to explore or project the potential impacts of policy on the evolution of the energy sector, including changes in the supply and demand of various fuels, as well as their costs, prices, and emissions. These models are typically structured in one of two ways: 1) as a sequential myopic model in which a solution for a given model-year is determined with limited to no consideration of future year conditions (e.g., technology costs, fuel prices, policy or regulatory changes), or 2) as an intertemporally optimized model in which solutions for all model-years are made simultaneously with perfect knowledge (or foresight) of future year conditions. These approaches represent the two extremes when it comes to capturing real-world decision-making. One approach assumes zero information about future conditions, and the other assumes perfect information. Although there is much to learn from both formulations, the reality lies somewhere in between, and the ability to execute only a single formulation within a modeling framework may lead to bias in simulated outcomes and, by extension, to study conclusions. To date, no comparison of the effects of these representations has been possible under a single modeling framework.

In this study, we employ the redeveloped version of the Regional Energy Deployment System, ReEDS 2.0, a capacity expansion model of the US-Canada-Mexico power system, to demonstrate how the solve structure can, in some cases, substantially impact projected outcomes. We leverage the flexible solve structure of ReEDS 2.0 which allows the model to be initialized as a myopic sequential model (stepping through time with no knowledge of future conditions), a intertemporally optimized model, or a model with “sliding window foresight,” under which the solution for a given year has perfect information for a set number of years in the future. We simulate a suite of scenarios under which policy, fuel, and technology cost inputs vary through time and explore how projected outcomes change under the various solve structures—sequential, sliding-window, and myopic.

Results indicate that the sequential approach can match closely with the intertemporally optimized approach if there are no abrupt changes in future conditions throughout the modeling horizon. However, conditions that change rapidly—be they policies, regulations, or prices—can drive a substantial wedge between outcomes under the alternative solve methods.

Methods

Using ReEDS 2.0 we simulate a suite of scenarios that vary policy stringency, fuel prices, and technology cost and performance projections over time. We solve these scenarios in both sequential and intertemporally optimized modes to quantify how the solution approach impacts projected outcomes.

ReEDS 2.0 is a mathematical programming model of the US-Mexico-Canada power sector. Given a set of input assumptions, it simulates the evolution and operation of generation, transmission, and end-use demand technologies. ReEDS 2.0 employs a modular structure to maximize user flexibility. Currently, the model consists of three separate but interrelated modules: a supply module, which solves a linear program for the cost-minimizing levels of power sector investment and operation; a demand module, which solves a separate linear program for the utility-maximizing levels of end-use device investment and operation; and a variable renewable resource (VRR) module, which calculates key parameters for assessing the value of VRR generators. The modules are executed iteratively until a supply-demand equilibrium for electricity is achieved.

Results

Results consist of the electricity capacity, generation, and prices for various regions of the United States across a wide range of scenarios that vary technology cost, policy, and fuel cost assumptions. We present these results for the sequential, sliding-window, and intertemporally optimized representations of foresight to elucidate the implications of the extent of the social planner’s knowledge in solving long-term capacity expansion models.
Conclusions
The flexible solve structure of ReEDS 2.0 presents a unique opportunity to explore under a single modeling framework how different levels of foresight impact projected outcomes. We show that under conditions in which policies, technology costs, or fuel prices change rapidly over time, differences in solve structure can have considerable impacts on the projected evolution of the power sector and, therefore, on the estimated cost-effectiveness of alternative policies, or the impacts of technology cost reductions on future technology deployment. As a result, it is crucial that energy modeling results used to inform policy, market, or other industry decisions should only be viewed in the context of the associated model optimization structure.