AN ADVANCED, OPEN-SOURCE MODEL FOR PREDICTING THE EFFECTS OF POWER-SECTOR POLICIES, INVESTMENTS, RETIREMENTS, AND PRICES

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(1) Overview

Proper assessment of electricity policies, potential new generation units, and potential expansions of the power transmission system requires prediction of their system-wide and long-term effects. The SuperOPF Planning Tool is an integrated new economic, engineering, and environmental model for the electric power system developed with support from the US Department of Energy and from industry. We plan to make it freely available and open source in the future. This model uses new methods, described below, to predict the short- and long-term effects of policies, investments, input prices, and behaviors on key variables such as power prices, the total cost of power, the use of each fuel type, emissions, estimated health effects by county, and the profitability of generation units. We describe the model and a set of sample findings selected for the the IAEE 2013 European conference. We report on our application of the model to the eastern 75% of the US and Canada. With different input data, the model can be applied to any region of the world. In addition, the modeling methods and the generalizable policy lessons from its use can also be used globally.

(2) Methods

To forecast short-term effects of a policy or investment, the model predicts the operation of the power system in the presence of the policy or investment by optimizing the output of each generation unit, just as a system operator does. To forecast long-term effects, the model uses an expanded version of that optimization problem that predicts the construction and retirement of generators along with the operation of the power system. The model can incorporate a detailed and realistic model of the power grid, with thousands of nodes, thousands of generation units, and tens of thousands of operating constraints. This realism is important because the flows in a power grid do not just follow the shortest or most under-utilized route from where power is generated to where it is consumed, but instead flow along all connected lines, including ones that may already be congested, in accordance with laws of physics known as Kirchoff's Laws. Our model also couples an electrical network model with an air pollution transport model, such that the health effects of a generation unit's emissions depend on its location. This allows for estimation of the health effects associated with policies and investments. In addition, electricity consumption in our model responds to the price of electricity, in the short and long terms.

The software that implements the model can be applied to a representation of any power grid. Our grid representation includes detailed information about the power grid and utility-scale generation units in the eastern 75% of US and Canada, assembled from thirteen sources.

(3) Results

We present representative uses chosen for the 2013 IAEE European conference. First, we consider the effects, over the next 20 years, of several policy options: a cap-and-trade program on carbon dioxide emissions from the entire modeled region, a cap-and-trade program that produces emission leakage because it applies to only part of the region, tax credits for wind and solar power, the retirement of all nuclear power plants, and three different schemes for pricing sulfur dioxide and nitrogen oxide emissions. For each policy, we report the predicted direct cost, carbon dioxide emissions, annual mortality from fine airborne particulate matter, average electricity prices, and plant investment and retirement over twenty years.

Second, we predict the effects of high versus moderate natural gas prices over the next 20 years. Their largest effects would on the future prevalence of non-emitting versus new gas versus old gas units and, in the event of a CO2 cap-and-trade program or emission fee, on the price of electricity.

CHARACTERISTICS AND NAMES OF SIX OF THE MODELED CASES	High gas prices ($2.50 in 2012, $7 in 2022, $14 in 2032)	Low gas prices ($2.50 in 2012, $4.77 in 2022, $5.86 in 2032)
No green policies	"Base HG"	"Base LG"
(CO2 cap and trade) + (Wind and solar tax credits)	"C&T HG"	"C&T LG"
(New coal plant ban) + (Wind and solar tax credits)	"EPA HG"	"EPA LG"

Table 1: Characteristics and Names of Six of the Modeled Cases

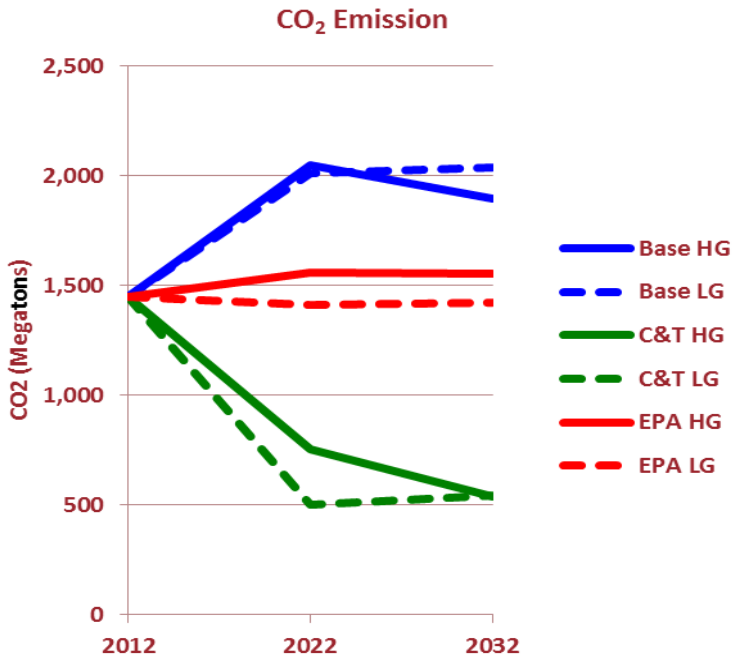

Fig. 1: Annual Carbon Dioxide Emission Quantities Under Six of the Modeled Cases

(4) Conclusions

The SuperOPF Planning Tool can predict the short- and long-term effects of policies, new infrastructure, and prices. These effects include the capital costs, fuel costs, health effects, carbon dioxide emissions, wholesale electricity prices, and generator retirement and construction. The improvements of the model over conventional modelling include the use of a detailed underlying power grid, price-responsive consumption, the inclusion of health effects of emissions, the prediction of future construction and retirement of generation units, and planned future free availability of the model.