Does a Detailed Model of the Electricity Grid Matter?
Estimating the Impacts of the Regional Greenhouse Gas Initiative

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The impacts of an electricity policy, a new generator, a generator's retirement, or an expansion of the transmission system depend in part on the electric power grid. The constraints and flow patterns in a grid strongly influence the extent to which, for example, generation units favored by a policy change can substitute for others, or the extent to which a proposed generator will be used, or the extent to which a proposed transmission line will reduce the total cost of electricity supply. 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; instead they are distributed over all transmission lines in accordance with laws of physics known as Kirchoff's Voltage Law. Grid operators choose which generation units will operate in such a way as to avoid overloading any of the lines. With support from the US Department of Energy and industry, we have developed a model that simulates the operation of the power system for policy analysis and system planning. It incorporates the generators, locational demand functions, transmission lines, flow equations based on Kirchoff's Voltage Law, and the grid operator's decision-making. The model uses dozens of hour types to represent each year. It realistically represents the joint temporal and spatial distribution of demand, wind, and sun by using hourly, location-specific demand multipliers and wind and solar availability factors from a year of recent historical data compiled and calculated by the authors. To predict long-run impacts, the model simulates the economic decisions of generation unit owners regarding the construction and retirement of generators, enabling prediction of long-run consequences of policies, investments, and retirements. Finally, it predicts emissions, pollution transport, and pollution health effects. The generator dataset we have created, and use, is one of the two most detailed in existence for the US. The model, including the datasets, will be available to other researchers and will become open-source.

We use this modeling capability to explore the effect of transmission model simplification on simulation results. Specifically, we simulate the proposed, more-stringent Regional Greenhouse Gas Initiative in nine northeastern US states. We use three transmission system models that simplify the actual 62,000-node Eastern US-Canadian system to varying degrees. Our 5,000-node model matches the behavior of the 62,000-node model very closely. We use it as the basis for evaluating two more highly simplified models: a 300-node model and a model with just one node, i.e. no transmission constraints. Projections are made for the short run and for ten and twenty years into the future. We find that 1) carbon emissions in and out of the RGGI region are very sensitive to the model of the grid used, which implies that a detailed model is necessary to know how to set the RGGI cap, and 2) as outcomes are projected further into the future, it becomes more important to represent the electric system in detail, because the more accurate spatial pattern of wholesale prices (in Fig. B vs. Fig. A) is required to predict where new generation is likely to be built and existing units retired. These location-specific investment and retirement decisions in turn significantly influence the net effect of the RGGI policy. The less-detailed models suggest that the regional emission price aspect of RGGI will have little aggregate impact on carbon dioxide emissions, because of leakage. But when the detail of the transmission grid is included, the emission price is shown to yield a long-run net reduction in carbon dioxide emissions.

Figure A: 300-node model wholesale price map

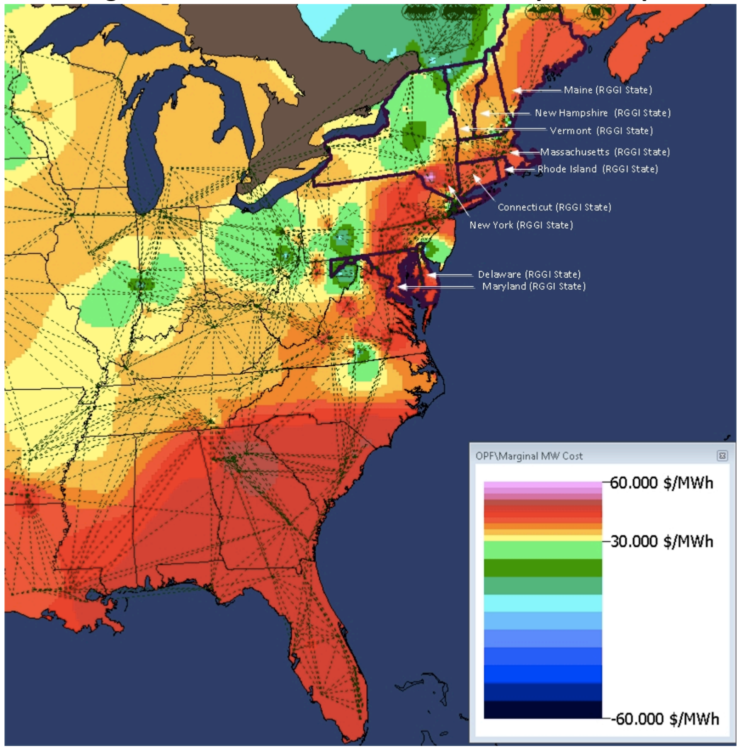

Figure B: 5000-node model wholesale price map