Rachel Gelman *is a consultant at Ecocion. Previously, she worked as a research analyst at the National Renewable Energy Laboratory and as an investment banking analyst at Bank of America Merrill Lynch. She holds a B.A. in Statistics and Economics from Rice University and an M.S. in Mineral & Energy Economics from the Colorado School of Mines.*

Jeffrey Logan *has two decades of experience in energy policy analysis and clean energy project management. His current work at the National Renewable Energy Laboratory in Golden, Colorado, focuses on analysis of U.S. energy policy options, the interaction of natural gas and renewable energy technologies, and greenhouse gas mitigation. Previously, his work focused primarily on Chinese energy challenges. He recently led a multi-client study on how natural gas is transforming the U.S. electric power sector. He served as Special Advisor to the IPCC on the Special Report on Renewable Energy in 2010 and 2011.*

Dana Max *is a summer intern at the National Renewable Energy Laboratory. She holds a B.A. in Economics/Mathematics from Emory University.*

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Carbon Mitigation from Fuel-Switching in the U.S. Power Sector: State, Regional and National Potentials

A bottom-up analysis of 2012 data suggests that re-dispatching the fleet of coal generating units to natural gas combined-cycle generation holds the technical potential to mitigate over 500 million metric tons of carbon dioxide, or about 25 percent of the sector's total emissions in 2012. As expected, mitigation potential generally increases with spatial aggregation and combined-cycle utilization level.

Rachel Gelman, Jeffrey Logan and Dana Max

I. Introduction

The U.S. power sector had approximately 255,000 megawatts (MW) of natural gas combined-cycle (NGCC) generating capacity in 2012. The national, generation-weighted average capacity factor for the fleet of NGCC generators was 48 percent in 2012, even after four years of moderate shifting from coal to NGCC generation.

On average, these NGCC generators produce a unit of electricity with approximately 60 percent fewer carbon dioxide emissions than a typical coal unit, although this considers only direct, or burner-tip, emissions and not the full fuel lifecycle (JISEA, 2012; Brandt et al., 2014). MIT (2011) found that roughly one-third of

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U.S. coal generation could be displaced by operating NGCC units at higher capacity factors, while Lafrancois (2012) found a technical potential to reduce power sector emissions by a maximum of 1,024 million metric tons of carbon dioxide from a 2007 baseline. JISEA (2012) estimated that U.S. burner-tip emissions in the U.S. power sector declined by 13 percent between 2008 and 2012 from a combination of coal to natural gas fuel switching, expanded use of renewable generation, and energy efficiency.

This study considers the maximum carbon mitigation potential of operating the NGCC fleet at capacity factors ranging from 70 percent to 90 percent, and evaluates the potential over different power sector groupings. It does not consider many of the real world barriers—including insufficient electricity transmission and natural gas pipeline capacity, lack of natural gas storage capacity, or cost impacts—that might limit the economic or practical potential (Kaplan, 2010).

II. Methods

We consider re-dispatch[1] from coal to NGCC, and determine the maximum carbon mitigation potential at different boundaries using 2012 data. Boundaries include state, independent system operator (ISO)/planning region, interconnection, and national. Data for the existing fleet of generators in 2012 was obtained from EIA forms 923 and 860,[2] and includes unit-level generation, capacity, heat rate, capacity factor, and other characteristics for over 11,000 generating units in the U.S. power sector. We exclude some generating units from the analysis (those less than 25 MW in size and those that are industrial and commercial combined heat and power, or CHP, units). The remaining units are referred to as ''qualifying units.''

We consider re-dispatch from coal to NGCC, and determine the maximum carbon mitigation potential at different boundaries using 2012 data.

The mitigation potential is determined by applying the following steps:

1. Aggregate all qualifying coal and NGCC generator data for a given boundary classification and calculate weighted average capacity factors, heat rates, fuel consumption, and other information.
2. Calculate the highest potential output from the existing fleet of qualifying NGCC generators in a given boundary by assuming a maximum fleet-wide capacity factor, or utilization rate. Values examined range from targets of 70 percent to 90 percent.
3. For all qualifying units, compare this potential output to the actual coal generation within the boundary. If there is sufficient NGCC generation potential to replace all coal, we assume the entire switch occurs. If there is more coal generation than potential NGCC generation, then coal generation will not be able to ramp down to zero. If there is more potential NGCC generation than coal generation, then coal generation will be ramped down to zero, but the NGCC units may not achieve their target capacity factors. Excess NGCC generation is not allowed to be used to offset coal generation outside the boundary.
4. Calculate how much carbon dioxide will be reduced within that boundary based on the level of coal-to-gas fuel switching that occurs. We use generation-weighted average heat rates at the boundary level for coal and NGCC plants to estimate net carbon dioxide savings.

The steps noted above provide a maximum upper bound potential for fuel switching and carbon mitigation in a given boundary.

III. Results

Maximum mitigation potentials for different boundaries and NGCC target utilization levels are summarized in **Figure 1**. At the low end, assuming fuel switching is confined to be within state boundaries,

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