Redesigning the Regulated Power Plant: Cost-Effective Emissions Control through Innovation in Policies, Processes, and Materials

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Coal fired power plants (CFPPs) are the largest industrial emitters of air toxics, aqueous contaminants, and greenhouse gasses in the US. Though market conditions and regulatory pressure have reduced the fraction of electricity generation by CFPPs to 33% in 2015, some regions are still highly dependent on coal. Most atmospheric CO_2 stabilization scenarios assume that the US will cut >80% of electricity sector CO_2 emissions by 2050, but transitioning away from high-carbon intensity CFPP generation will be a 20-35 year process.

To encourage this transition process, the US Environmental Protection Agency (EPA) has proposed or promulgated a number of rules that systematically reduce the emissions from CFPPs in order to reduce human health damages and limit the profitability of old CFPP facilities. Some combination of SO_2, NO_x, mercury, ozone, CO_2, and wastewater effluent pollution control regulations are likely to affect every CFPP over the next decade. Cost-effectively reducing the human health and environmental externalities of electricity generation will require integrated decision models that aid researchers, engineering practitioners, and policy makers in moving away from boundedly rational or short-term fixes toward holistic sustainability solutions.

For instance, compliance with recent regulations limiting carbon and aqueous emissions at coal-fired power plants (CFPPs) in the United States will require installation of new carbon capture and wastewater treatment systems. These air and water separations systems require energy, either in the form of heat or electricity, and may significantly reduce the generation efficiency and revenue of CFPPs. A systematic reevaluation of the use of all thermal and electricity sources at CFPPs will aid power plant designers in maximizing the efficiency and cost-effectiveness of emissions control retrofits and long-term geologic sequestration.

We will share recent work to evaluate plant trade-offs between dispatching steam, electricity, or waste heat to carbon capture processes, to wastewater treatment processes, or to electricity generation. We perform this trade-off analysis for the National Energy Technology Laboratory's 550 MW pulverized coal combustion power plant model. We first build mass- and energy-balance models of the turbines in the model plant. We then vary the allocation of steam among three "sinks": the turbine for electricity generation, the solvent regeneration for carbon capture, and the wastewater treatment unit to maximize revenue. We find that the revenue maximizing balance of electricity or steam allocation to emissions control processes is a function of the efficiency of conversion, the efficiency of the process, and the value of the emission control (e.g. the price on carbon). As a result, the optimal allocation of energy sources is likely to vary significantly between individual plants.

Another example of the need for integrated decision models concerns the design and operation of CO_2 sequestration sites. Geologic sequestration is being widely explored for

long-term storage of the carbon captured during fossil fuel generation, but many of the formations are saturated with saline brines. Large-scale sequestration is likely to require displacement of a significant fraction of the brine, in turn requiring energy intensive brine management. We report on recent work estimating this energy penalty to power plants, and its effect on the effective price of coal and gas fired power generation.