Effluent Characterization and Pollution Control Tradeoffs at Coal Power Plants: A 3-Phase Approach

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Problem

Over the past few years, much attention has been paid to potential cost-effective strategies to mitigate climate change effects by de-carbonizing United States coal electricity generation. Such transition to future sustainable energy systems will require large changes in the electricity fleet, which will have consequences in terms of air and water emissions, as well as overall costs of generating electricity.

Given its reliance on fossil fuels, U.S. electricity generation is associated with substantial criteria and hazardous air pollution emissions – which lead to substantial health and environmental damages. Some of these damages can be avoided with air pollution control technologies, such as scrubbers and selective catalytic reduction, which will remove SO_2 and NO_x emissions, respectively. Carbon capture technologies may also be added in the near future. In addition to greenhouse gas and air pollutant emissions, water withdrawal, water consumption, and contaminated water discharge may be associated with important environmental impacts.

However, no work that we are aware of has consistently assessed the trade-offs associated with the social and private costs of air emissions, penalties in electricity generation, and water use and water quality impacts for U.S. coal plants in a systematic, comparative way. In particular, effluent discharges of many pollutants are the least described, *especially* the impact of air pollution control technologies on effluent levels. We focus on this aspect.

Research goal

Provide decision makers, from regulators to power plant operators, with a decision space in which they can make informed policy and operational choices across air pollution controls, electricity generation, cost, and water impacts.

Phase 1: Pollutant Characterization

In Phase 1, we are characterizing the relative fates of various pollutants and toxic elements within U.S. coal power plants, accounting for differences in pollution control technologies at each plant. The basic approach and initial data sources are described in Figures 1 and 2, respectively. With these data, we will be able to produce the first systematic assessment of energy production, associated air emissions, and water use and contamination for US power plants, using a common set of metrics and units from all plants.

Phase 1 Methods

Figure 1: Diagram of Bottom-up and Top-down Pollutant Comparison in Phase 1

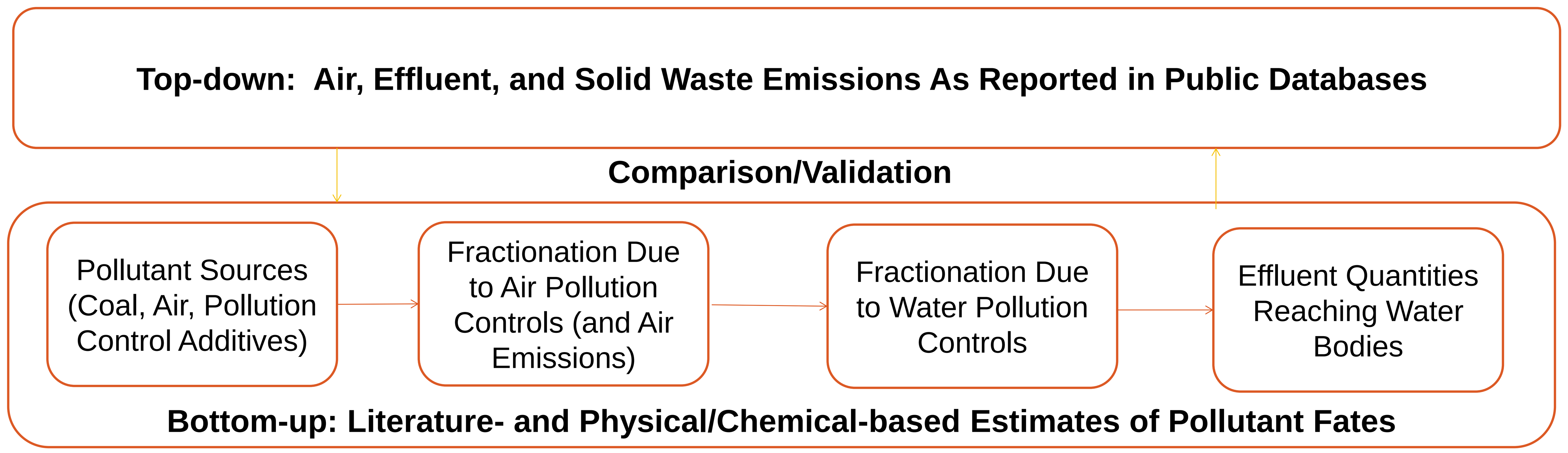

Figure 2: Schematic of a Common Coal Power Plant, Highlighting Air, Liquid and Solid Pollution Pathways and Pollution Control Strategies. Initial Data Sources for Bottom-up and Top-down Comparison are Listed.

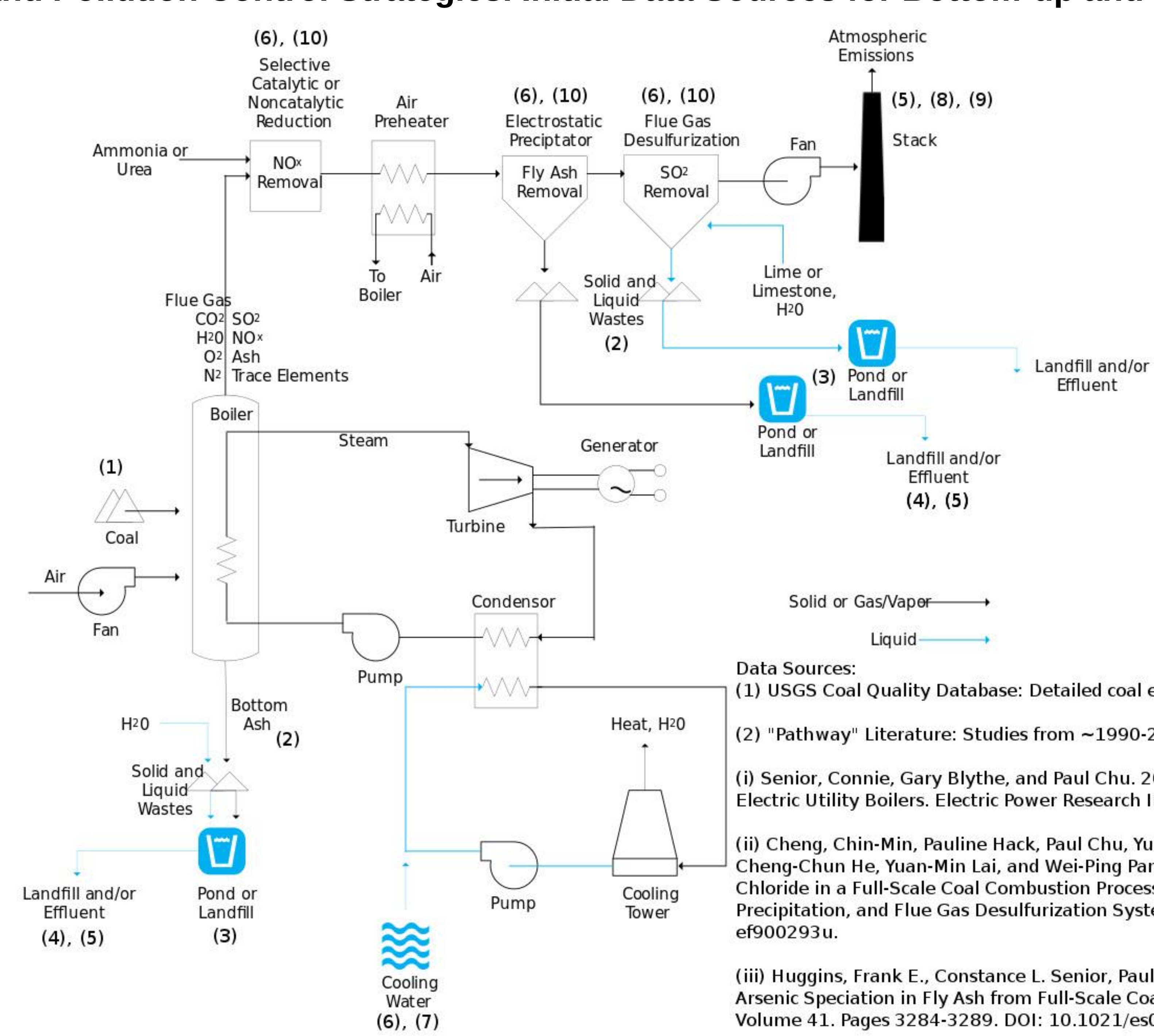

Image Source: Authors, adapted from Rubin, Edward S, and Cliff I Davidson. 2000. Introduction to Engineering and the Environment. McGraw-Hill: New York.

Data Sources:

(1) USGS Coal Quality Database: Detailed coal element analysis from 6500+ U.S. coal samples

(2) "Pathway" Literature: Studies from ~1990-2011 of the fates of various elements in coal power plants

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(iv) Otero-rey, Jose R., Jose M. Lopez-Vilarino, Jorge Moreda-Pineiro, Elia Alonso-Rodriguez, Soledad Munitategui-Lorenzo, Purificacion Lopez-Mahia, and Dario Prada-Rodriguez. 2003. As, Hg and Se Flue Gas Sampling in a Coal-Fired Power Plant and Their Fate during Coal Combustion. Environmental Science and Technology. Volume 37. Pages 5262-5267. DOI: 10.1021/es020949g.

(v) Rubin, Edward S. 1999. Toxic Releases from Power Plants. Environmental Science and Technology. Volume 33. Pages 3062-3067. DOI: 10.1021/es990018d.

(3) EPA Effluent TDD, Year: 2010: Survey data on fossil power plant effluent treatment systems

(4) EPA DMR, Years: 2007-2011: Effluent discharge reports for coal power plants, for various elements

(5) EPA TRI, Years: 2007-2012: Element and chemical releases into various media (air, water, etc.) for plants

(6) EIA Forms 860/923, Years: 2008-2012: Water use and pollution control efficiencies for coal power plants
ed
(7) UCS "Thirsty Power Plant" Report: Attempts to estimate better plant water use data than EIA forms

(8) EPA eGRID, Years: 2007, 2009, 2010: Select coal power plant air emissions

(9) EPA NEI, Years: 2008, 2011: Detailed estimated chemical emissions for all power plants

(10) Power Plant Engineering by Black & Veatch. 2003. Lawrence F. Drbal, ed. Chapman & Hall: Boston.

Phases 2 and 3 Methods

Phase 2: Economic Impacts

Phase 1 will inform the next step in the research, which aims to understand the consequences that the adoption of various air control, carbon capture, and water conservation technologies have across different metrics. The metrics considered will be penalties in electricity generation and associated economic loss, changes in air and water emissions and associated health, environmental and climate change monetized impacts.

Phase 3: Optimization Model

Much as been said about carbon mitigation supply curves: such curves, like the ones produced by McKinsey & Company (2009) and others, display the amount of carbon that can be saved by deploying different climate mitigation interventions, and their associated cost effectiveness in dollars per ton of CO_2 avoided. However, so far very few studies focus on trade-offs between CO_2 avoided and other metrics (Azevedo et al, 2013). Using water efficiency data collected, in Phase 3 we will develop an optimization model that selects regionally appropriate mixes of cost-effective electricity generation and pollution control technologies to reduce water use and contamination. To do so, we will use outputs from Carnegie Mellon University's Integrated Environmental Control Model (IECM). IECM assesses pollution, electricity generation and costs for fossil fuel plants. Our research may also provide new data to improve IECM's ability to model effluent generation based on varying power plant configurations.

In this last stage, we will account for policy constraints such as current and expected air pollution regulations, including carbon pollution limits; anticipated power plant effluent discharge limits and their relationship to available pollution control technologies; and expected climate change impacts on water availability.

References

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