CO2 CAPTURE

GCEP

Global Climate & Energy Project
STANFORD UNIVERSITY

Systems Analysis of Advanced Power Plant Carbon Capture Technologies

Investigator

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Objective

This project will develop a powerful systems-analysis modeling tool that relates the design and performance characteristics of power plants to the process and materials parameters of carbon capture and storage (CCS) technologies. In addition to specific case studies, the project will provide the model as a user-friendly tool available to anyone for analysis of any CCS technology or scenario.

Background

Significant research effort is focused on developing new technologies for carbon dioxide (CO_2) capture at power plants. Analyses are also underway to evaluate the prospects of various technology options. However, evaluating a CO_2-capture technology—particularly its impact on overall plant emissions, performance and cost—requires knowledge about the design and operation of both the capture unit and the power plant to which the unit is attached. Factors such as the base power plant efficiency, plant fuel properties, pollution-control equipment design and capacity are important considerations when quantifying the impacts of a CO_2-capture technology.

Consequently, any systems model intended to guide research priorities and identify potential "breakthrough" technologies must include not only the CCS system, but also a reasonable set of power-generation options where CCS might be employed. A robust analysis should include combustion and gasification-based systems with a range of fuel types and pollution-control technologies. Without this level of detail, the assessment of any particular carbon-capture technology is likely to be incomplete at best or incorrect at worst.

Approach

This project will employ and substantially expand the Integrated Environmental Control Model (IECM) framework (Figure 1) developed by Carnegie Mellon University in prior research supported by the U.S. Department of Energy (DOE). IECM has unique features that make it especially suitable: (1) complete performance and cost models for a broad array of power-plant configurations that can employ CCS, and (2) a library of representative U.S. coal types and typical natural gas compositions. This extensive characterization of system components provides the ability to comprehensively model and evaluate different applications of CO_2-capture processes.

In this project, the research team also will develop life cycle analysis (LCA) capability for CO_2-capture materials and integrate this option into the IECM. This system-level model will then be

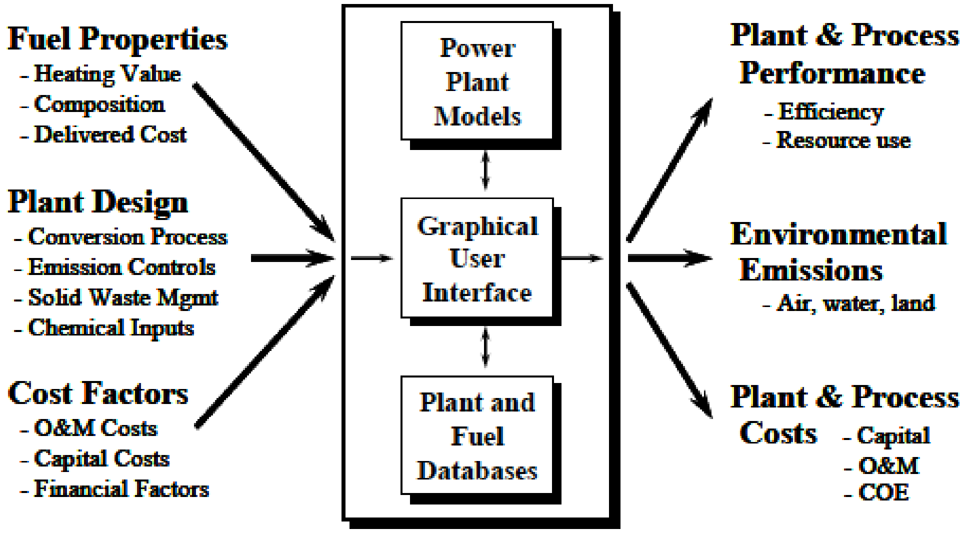

Figure 1. Schematic of the IECM software package showing major inputs and outputs

employed to quantify key performance metrics, and to conduct case studies and comparative analyses of emergent capture-technology options. The new technologies modeled in this work will be systematically compared to other competing options in the system-level framework.

Toward this end, the researchers will extend the IECM framework to include advanced-capture materials currently being investigated in other GCEP projects, including ionic liquids, metal-organic frameworks and biomimetic sorbents. The team will collaborate with other GCEP investigators to develop preliminary designs using several of these materials for power-plant capture processes.

For each process, the researchers will develop a thermodynamic-performance model, a technology-level cost model and a preliminary techno-economic assessment. Next, each capture technology will be embedded in the plant-level model to assess the uncertainty and variability of key process parameters for the CO_2-capture process.

At this stage of integration, the research team will be able to: (1) assess the impact of the CO_2-capture process on overall plant performance and cost, and (2) identify key technology, cost and materials issues that must be addressed for an advanced capture technology to become viable at scale. Both deterministic and probabilistic analyses will be used for these assessments, since probabilistic analysis offers a more complete and robust method of quantifying the interactions among many uncertain variables.

Finally, the research team will apply the newly expanded IECM to case studies that compare the performance, cost, resource requirements and environmental impacts of different carbon-capture technologies used by electricity-generating plants. These case studies will provide a deeper understanding of the advantages and disadvantages of alternative technologies under different conditions, as well as the key parameters involved. Again, both deterministic and probabilistic analyses will be performed for a range of power-plant systems to assess the likelihood of various outcomes, identify technology bottlenecks and establish targets for the development of capture materials and processes.