PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Carbon Sequestration

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An Integrated Modeling Framework for Carbon Capture and Storage Technologies

Background

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) is developing safe, lower-cost methods of carbon dioxide (CO_2) capture and storage (CCS) as a potential option for climate change mitigation. In addition to technology development, there is a need for modeling and assessment tools to evaluate and compare the cost and effectiveness of CCS methods. Analytical tools also are needed to help identify and prioritize the most promising research and development efforts. This project was initiated in July 2000 to develop and demonstrate such capabilities.

Integrated Environmental Control Model Framework

Carnegie Mellon University (CMU) has developed the Integrated Environmental Control Model (IECM) to provide electric utility companies, equipment suppliers, government agencies, researchers, and policy analysts with an easy-to-use tool for estimating the performance, emissions, and cost of alternative fossil fuel power plant configurations and emission control technology scenarios. In the current project, the IECM is being extended to incorporate current and advanced systems for CCS as model options in addition to control technology options for criteria air pollutants and air toxics such as sulfur dioxide (SO_2), nitrogen oxides (NOx), particulates, and mercury. Figure 1 shows a schematic of the model inputs, outputs, and internal structure.

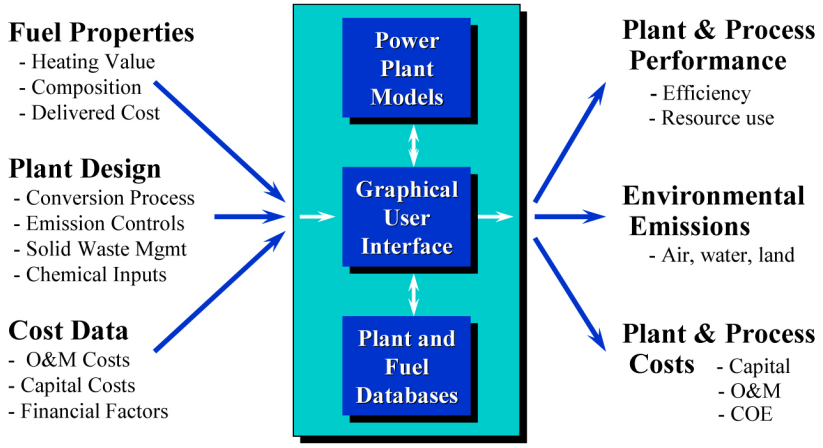

Figure 1. Structure of the IECM modeling environment. A graphical user interface allows the model to be easily used to configure a plant design of interest, set values for key parameters, and get results in tabular or graphical form.

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IECM Software
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The power system options incorporated in the IECM include a pulverized coal-fired (PC) power plant, a natural gas-fired combined cycle (NGCC) power plant, and a coal-based integrated gasification combined cycle (IGCC) plant. Input parameters for all three systems can be adjusted to represent either current technology or advanced, high-performance designs. The IECM thus can be used to simulate advanced gasification-based as well as advanced combustion-based designs for power systems with near-zero emissions. In all cases, the probabilistic capability of the IECM allows uncertainties in performance and cost results to be quantified, enabling more rigorous assessments of technological risks and benefits.

Options for CO_2 Capture, Transport, and Storage

The IECM incorporates a variety of CCS options for both pre-combustion and post-combustion CO_2 capture, as well as oxyfuel combustion for PC plants. To simulate a complete CCS system, the costs of CO_2 transport and storage also are included in the modeling framework. Figure 2 shows a schematic of the overall system.

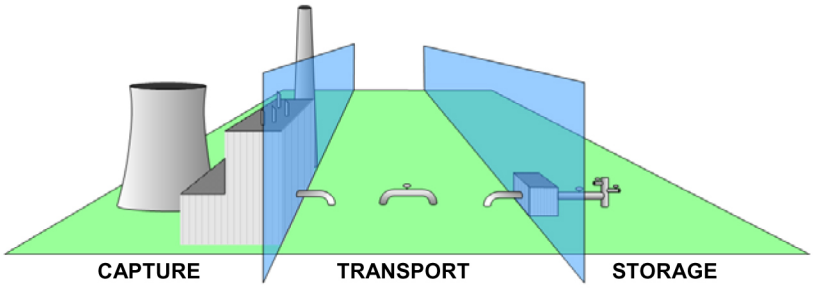

Figure 2. The IECM framework includes component modules and options for CO_2 capture, transport, and storage. CO_2 compression is included as part of the capture system.

CO_2 capture process options incorporated in the IECM include an amine-based chemical absorption system for post-combustion capture on PC and NGCC plants and a sorbent-based physical absorption system for pre-combustion capture at IGCC plants. The oxyfuel plant option produces a concentrated CO_2 stream using oxygen rather than air for combustion in a PC plant, with recycle of the CO_2-rich flue gas. Additional options under development include advanced power system components and CO_2 capture technologies promising lower costs.

The IECM also includes a CO_2 pipeline transport model plus several options for CO_2 storage, including geological sequestration in deep saline formations, in depleted oil reservoirs using enhanced oil recovery (EOR), or in unmineable coal seams with enhanced coal bed methane recovery (ECBM). An option for ocean sequestration also is available. For all plant designs, interactions between the CCS system and other environmental control technologies is accounted for in simulations of overall plant performance, emissions, and cost. Figure 3 illustrates several of the input and output screens available in the IECM.

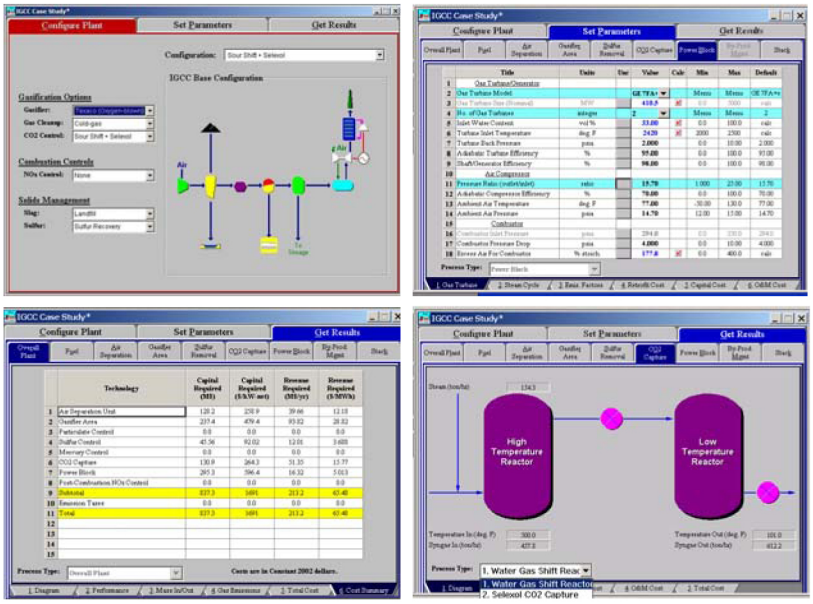

Figure 3. Sample screens from the IECM graphical user interface for a case study of an IGCC plant with CCS. Tabs at the top and bottom of each screen allow a user to configure the plant, set values of key design parameters, then get results for the overall plant or a specific component, such as the water gas shift reactor illustrated in the lower right

Benefits

The IECM—

- Determines the economic cost and cost of CO_2 avoided for alternative plant designs.
- Identifies the most cost-effective CCS options for a particular application.
- Simulates and optimizes the environmental design of new or existing power plants.
- Quantifies plant resource requirements and multimedia environmental emissions.
- Characterizes impacts of key interactions between plant components.
- Has fast run-time on a desktop or laptop computer, which provides reliable results without costly setup time or waiting.
- Quantifies the benefits of R&D, and identifies options with the highest potential payoffs.

- Is fully supported, documented, and updated periodically.

- Is available free online at www.iecm-online.com.

Accomplishments

- Developed and demonstrated a flexible modeling framework for the preliminary design of power plants employing CO_2 capture and storage.

- Provided a tool that can be freely and widely used to simulate and analyze alternative power systems and emission control options.

- Accounted for avoided carbon emissions, as well as multi-pollutant impacts for criteria air pollutants, air toxics and solid wastes.

- Estimated the costs of plant components and the overall system and its dependence on key design, operating, and financial parameters.

- Accounted for uncertainties in model input parameters and their influence on results.

- Made available free online at www.iecm-online.com

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