

Retrofitting of Coal-Fired Power Plants for CO₂ Emissions Reductions²

from
An MIT Energy Initiative Symposium

S U M M A R Y F O R P O L I C Y M A K E R S

On March 23, 2009, the MIT Energy Initiative (MITEI) sponsored a symposium on *Retrofitting Coal-fired Power Plants for CO₂ Emissions Reductions* to investigate different pathways for CO₂ emissions reductions using current technology, identify promising RD&D for cost reduction, and discuss policy and institutional barriers to CO₂ emissions reductions in the United States. The deliberations were informed by three commissioned white papers and from additional contributions submitted by workshop participants. These documents are available at www.mit.edu/mitei.

We summarize for policy makers the key points from the lively discussions among the diverse group of participants. **We stress that the observations here are those of the authors and are not offered as a consensus view of the participants.**

• There is today no credible pathway towards stringent GHG stabilization targets without CO₂ emissions reduction from existing coal power plants, and the United States and China are the largest emitters.

The United States and China account for about 40% of global anthropogenic CO₂ emissions and for over half of global coal use. Both countries have immense reserves of relatively low cost coal. In the United States, almost half of all electricity is supplied by coal power plants that average 35 years of age and produce about a third of U.S. CO₂ emissions. China has brought on line in the last five years a coal electricity production capacity about equal to the total US installed capacity. Coal will continue to be used for power generation from existing plants in both countries, so mitigation of CO₂ emissions from these plants is a high priority for research, development, demonstration, and deployment (RDD&D).

Workshop discussions focused mainly on options and actions for the United States. However, the dominant contribution of China in coal-based emissions highlighted the importance of developing more economical CO₂ emissions mitigation technologies. *There is a “China Test” about whether CO₂ emissions mitigation can be accomplished at a sufficiently small incremental cost that China and other emerging economies can afford to implement it.* Passing this test is a critical RD&D goal for the next decade.

- **There are multiple pathways to reduce CO₂ emissions from existing coal plants.**

For existing coal plants, post-combustion capture followed by long-term, large-scale, sequestration is the most direct pathway to avoiding nearly all CO₂ emissions. The workshop discussion focused in large part on this path, addressing which plants are amenable to capture retrofits.

Efficiency retrofits of existing coal plants can result in modest reductions of CO₂ emissions per unit of electricity produced. This is especially attractive for older, less-efficient plants. There is a range of approaches from boiler to control system improvements. A rough estimate is that 4–5% emission reduction could be realized relative to business as usual if efficiency improvements were introduced at less efficient coal plants. This action has the highest benefit/cost ratio for CO₂ mitigation.

Bio-mass co-firing is another retrofit option for net CO₂ emissions reduction, if the feedstock is available. Indeed, if biomass use is combined with CCS there are negative net CO₂ emissions.

Major rebuilds of existing coal plants are another option. There is a range of possibilities for such rebuilds, starting from capturing substantial value from use of an existing site and its infrastructure, and perhaps from its existing permits as well. Rebuilds are likely to be expensive, but will include large efficiency gains, for example, rebuilding an old subcritical unit to a high MIT Energy Initiative Symposium | March 23, 2009 5

efficiency supercritical (SCPC) or ultra-supercritical (USCPC) unit, with or without CCS. More extensive rebuilds include conversion to oxygen-driven combustion or to an IGCC plant with CCS. Additional options discussed in the background papers include co-generation and, for gasification plants, poly-generation of fuels and electricity.

Finally, repowering (biomass, natural gas) at coal plant sites is an option when CO₂ emissions charges are high and retrofit and rebuild are not attractive. Use of some elements of existing infrastructure (e.g., grid connections) can reduce project costs.

- **The US government must move expeditiously to large-scale, properly instrumented, sustained demonstration of CO₂ sequestration, with the goal of providing a stable regulatory framework for commercial operation.**

Obviously, without sequestration, CO₂ capture has no purpose. A substantial sequestration demonstration program should include several sites with storage of one to several megatons per

year scale. EOR projects provide some useful information about geological storage, if properly instrumented and monitored, but neither the EOR regulatory framework nor the potential for EOR is adequate for CO₂ mitigation from coal fired generating units at a scale that will be material for climate change risk mitigation. The primary focus of the government program for the long-term sequestration at scale should be deep saline aquifers. Since a major source of CO₂ emissions is the existing coal fleet, *the DOE CCS demonstration program should include projects at existing plants*. The Clean Coal Power Initiative (CCPI) is placing increased emphasis on retrofits, but it has neither sufficient funds nor project management resources to support the large-scale projects called for here, certainly not in sufficient numbers.

A robust R&D program should include exploration of *advanced sequestration technology options*. Examples are enhanced biological sequestration and beneficial uses of CO₂ in materials.

• Relatively large (300MWe or greater), high efficiency coal plants with installed FGD and SCR capability are the best candidates for CCS retrofit.

Such plants make up less than half of the existing fleet. With current and evolutionary amine-based capture technology, *estimates of the capture cost were generally in the \$50-70/ton of CO₂ range for the Nth-plant*. This estimate of the cost of CO₂ emissions abatement is significantly higher than is generally recognized in the United States, but is not dramatically higher than the costs experienced in Europe (at current exchange rates).

China has a significant number of recently built supercritical plants because of its aggressive deployment of coal power plants in this decade. Consequently there may be many opportunities for retrofit of Chinese coal plants when CO₂ emissions are priced, assuming that the incremental cost for CCS for air-driven combustion units is reduced substantially through RD&D.

By contrast, retrofit is not attractive for old, lower efficiency, smaller, subcritical units. Rebuilding or repowering are options depending on significant CO₂ prices being in place.

Extensive modifications require both retrofit and rebuild. An important option is oxy-combustion modification to the existing coal fleet to replace an air fired combustion system with an oxygen fired combustion system. This modification requires both significant retrofit and rebuild, so there many challenges. For example, infiltration into existing air fired older boilers may be acceptable for current operation, but the retrofit oxy-combustion system is likely to require plugging the leaks, which is an expensive undertaking. MIT Energy Initiative Symposium | March 23, 2009 6

• “Real world” retrofit decisions will be taken only after evaluation of numerous site-specific factors. Some of the key screening factors include:

- Proximity to geologic sequestration or EOR site and/or CO₂ pipeline

- Available space: space constraints may make carbon capture retrofit impossible, or limit the amount of capture that is possible
- Access to increased water supply
- Existence of FGD and SCR capability
- Practicalities of heat and power integration
- Implication of a retrofit for dispatch in the regional system.

It is unclear at the moment how restrictive these criteria will be for the existing fleet. EPRI is carrying out five site-specific case studies to help inform the discussion. It is quite possible that these site-specific screens will substantially limit that part of the existing coal fleet in the US for which retrofit or rebuild is attractive or result in partial capture solutions tailored to the current plant configuration.

• CO2 capture cost reduction is important.

CO2 capture costs are large because both the capture and release step is expensive and because the capture process conditions influence other steps in the conversion process. Accordingly, CO2 capture technology deserves significant R&D support as part of a balanced retrofit program.

• A robust US post-combustion capture/oxy-combustion/ultra-supercritical plant R&D effort requires about \$1B/year for the next decade.

A balanced R&D effort includes advanced simulation and analysis, exploratory research, proof of concept, pilot plants, leading to large scale demonstrations. Such an R&D program should be pursued with urgency. There are many important directions for research of intermediate term and “over-the-horizon” technologies. Near term R&D opportunities that are being pursued include a chilled ammonia capture project and exploration of new amine chemical solvents for binding CO2. Longer-term opportunities included ionic liquids, membrane separations, and perhaps use of algae or other biomaterials to capture and convert the CO2.

Exploratory research could lead to a major breakthrough relevant to the “China test”. It should be noted that some of the advanced capture approaches are appropriate only for oxygen driven systems. Oxygen separation cost reduction would be a critical enabler for both oxy-combustion retrofit and for various rebuild options, including gasification. Advanced materials research is important for ultra-supercritical plants.

In addition there are R&D opportunities directed principally at new builds based on advanced gasification or novel approaches such as chemical looping.

• The Federal government should dramatically expand the scale and scope for utility-scale commercial viability demonstration of advanced coal conversion plants with CO2 capture.

The program should specifically include demonstration of retrofit and rebuild options for existing coal power plants. New government management approaches with greater flexibility and new government funding approaches with greater certainty are a prerequisite for an effective program.

Symposium participants discussed the range of desirable demonstration projects for retrofit of pulverized coal combustion including oxy-combustion, re-powering, and poly-generation. The estimated cost range for these projects to be borne by industry and government was \$12-15B over the next decade, in addition to the research budget. MIT Energy Initiative Symposium | March 23, 2009 7

Given the urgency of establishing CO₂ emissions reduction options for the existing coal fleet, and the likelihood that there will not be a strong CO₂ emissions price signal for several more years, a Federal utility-scale cost- and risk-shared demonstration program needs a clear near term focus on commercial viability within the electricity market structure reasonably anticipated over the next 10-15 years, rather than technology-forcing requirements. The financial assistance agreements with the private sector should be based on commercial terms and conditions rather than government procurement restrictions. Multiple demonstrations will be needed in parallel, requiring substantial outlays, experienced management, and careful evaluation.

Such a strategy can be begun under the current DOE Clean Coal Power Initiative (CCPI) demonstration program, if it is expanded and has enhanced flexibility for speeding up the government process and for private sector project management and financial accounting.

However, new legislation should be considered in parallel with the CCPI program solicitation and implementation. An expanded commercial viability utility-scale demonstration program should be established through a quasi-government corporation. The authorities of the new corporation should be designed with a broader mandate than that of the CCPI program, encompassing the full range of low-carbon electricity technologies and fuels and financed from a multi-billion dollar annual small electricity line charge (as has been under consideration in the Congress).

Time is of the essence.

The retrofit, rebuild, or re-powering of the existing coal fleet, in the US and in China, to reduce CO₂ emissions dramatically is a necessary step towards achieving GHG stabilization targets. Practical options that will justify the vast investments needed over the next decades require validation from demonstration, development and research. Failure to do so will both drive up CO₂ prices (and the cost of electricity) and leave us with a continuing dearth of appropriate technology options.

John M. Deutch, Institute Professor

Ernest J. Moniz , Cecil and Ida Green Professor of Physics

MIT and Engineering Systems

Director, MIT Energy Initiative

Symposium co-chair