CO2 CAPTURE AND STORAGE FOR RETROFIT APPLICATIONS

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Bringing solutions to address carbon capture and storage (CCS) has put the focus on research and development of the capture process technology. However, deploying CCS across the existing coal fleet will also still require risk management, guarantees, and practical solutions for customers to achieve acceptable operations, maintenance and reliability. This seemingly obvious statement drives home the point of this paper, which is that retrofitting new emission controls into the existing coal fleet is often a difficult, complicated process requiring unique, innovative solutions. CCS is no exception, and in fact brings added constraints not dealt with in the past – one size will not fit all, and perhaps each and every project will require it's own size.

Carbon controls may take different forms (i.e., tax vs. cap and trade), but we presume legislation will fundamentally drive a utility to make the most economic choices and will not significantly affect the selection of technology or retrofit approach in the long term. When the cost of emitting carbon reaches a price threshold, perhaps in the range of \$40 to \$60/ton of CO2 avoided, CCS solutions will enter the market, starting with the easiest retrofit sites. Some similarities can be drawn to how the cap and trade market for sulfur dioxide and nitrogen oxide emission allowances drove SO2 scrubber and SCR retrofits. However, new dimensions enter with CCS retrofits, in particular siting for geologic storage and significant auxiliary power demands, making the evaluation and decision process more challenging.

Screening Retrofit Candidates

As the price of emitting CO2 begins to rise, utilities will progress through economic alternatives such as operating on coal as usual and just paying the tax or penalty or buying credits, to perhaps reducing coal capacity factors to reduce emissions costs, to shutting down the oldest coal units, and eventually to CCS retrofits where continued investment in coal is justified. To sort out the best CCS opportunities, several screens will be needed to down-select to the most economic solution.

<u>Geologic Storage</u> – The first screen of plants will be based upon suitability of geologic storage. Figures 1 and 2 depict where major U.S. point sources of CO2 emissions from power plants exist and potential storage capacity. CO2 pipeline networks are being contemplated which could greatly expand the list of plants available to permanently store CO2, but would likely be in the later phases of retrofit activity and tied to new build plants.

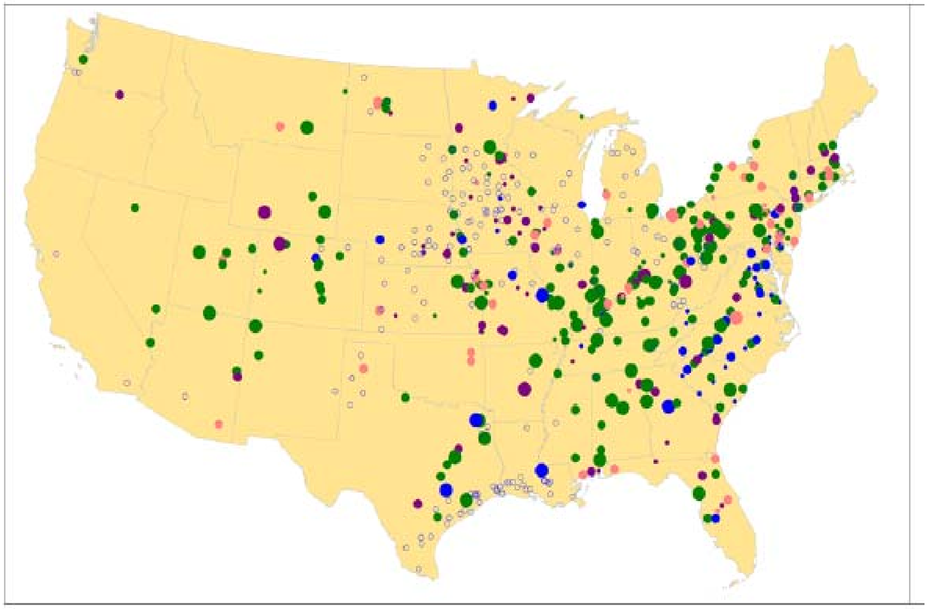


Figure 1. U.S. Sources of Power Plant CO2 Emissions
(Source: DOE NETL – Office of Fossil Energy)

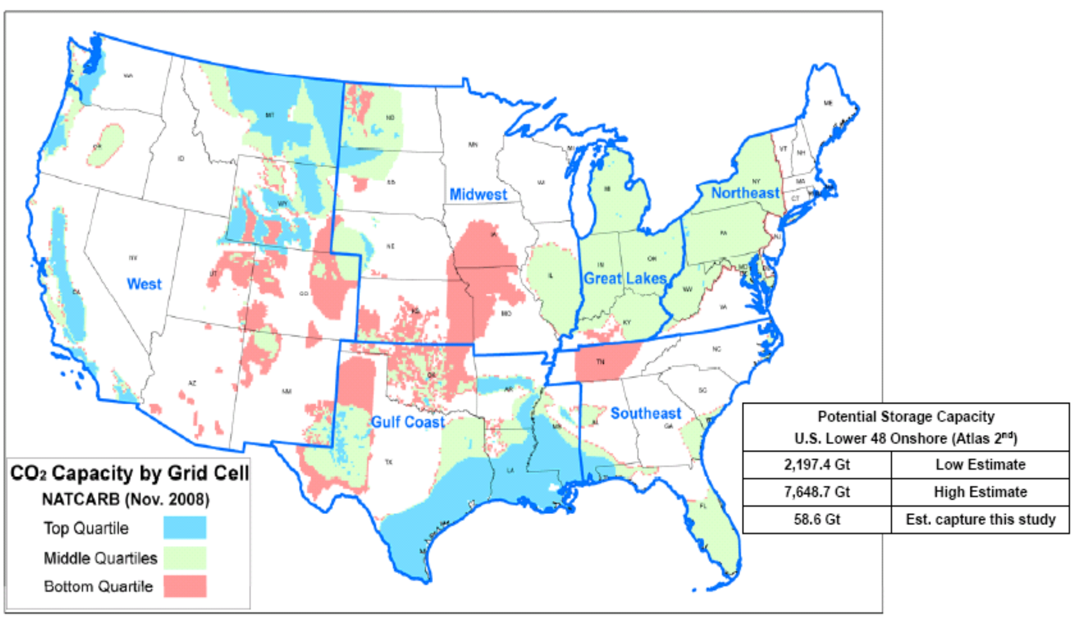


Figure 2. U.S. Potential CO2 Storage Capacity
(Source: DOE NETL – Office of Fossil Energy)

Unit Age and Efficiency – The age and efficiency of units will be a significant factor in determining further investment in coal at a given site. Consider the map in Figure 3 as having four quadrants. The old and less efficient plants will not be retrofit and are strong candidates to get shut down, reducing the carbon footprint. To continue operations, most of these would need to add SO2 and NOx reduction equipment in addition to CCS, and some already run at reduced capacity factors. The old and efficient will be evaluated, as fully depreciated coal power assets have tremendous residual value, not just financially but in local support and acceptance as well. New and less efficient plants are likely small and grid strategic and must operate. New and efficient plants become likely targets for CCS retrofits.

These first two screens will set the upper limit on the gross quantity of potential CO2 emissions reductions at CCS entry prices. While we have not calculated this limit, the question is whether this practical reduction potential is within the reduction targets being contemplated for the 2020 and 2050 time frames. Figure 4 shows the age of units versus total capacity, which would indicate the path to reaching significant reductions is from large units (above 400MW) 20 to 35 years old, about half of the total installed capacity.

Plant Specifics – The next screen moves down to the specifics of an individual plant. Many constraints fall into this category, but the most significant is available space. Current CCS systems require a large footprint, and many units have already exhausted available space to add modern emission controls.

From a capital investment view, how much new equipment must be added? All carbon capture systems require high levels of performance for emissions control, such as FGD (flue gas desulphurization) and SCR systems. If this equipment has not been installed or was not planned, the high cost of also retrofitting new air quality controls will affect the investment decision for the plant. Both of these systems are sensitive to scale, as small units are unfavorable, and are also sensitive to available space and plant configuration flexibility.

There is a large difference in CCS plant design for “purpose built” as opposed to retrofit. A new, purpose built plant allows multivariable optimization through management of the entire design process in a holistic fashion. With a CCS retrofit, compromises in cost and/or performance may be needed to enable implementation within an existing plant structure. With much of the plant constrained, some redesign is possible to a limited degree, causing design compromises to fall disproportionately to the new equipment. Sub-optimal heat and power integration are critical considerations, as CCS systems add a large auxiliary energy demand which could render the post-retrofit efficiency too low to justify investment.

Finally, some components in an existing power plant have a finite life, where other components will “last indefinitely” if they have been properly maintained. Thus, the operating history will have a large impact on the investment required to support increasing the asset value of the plant.

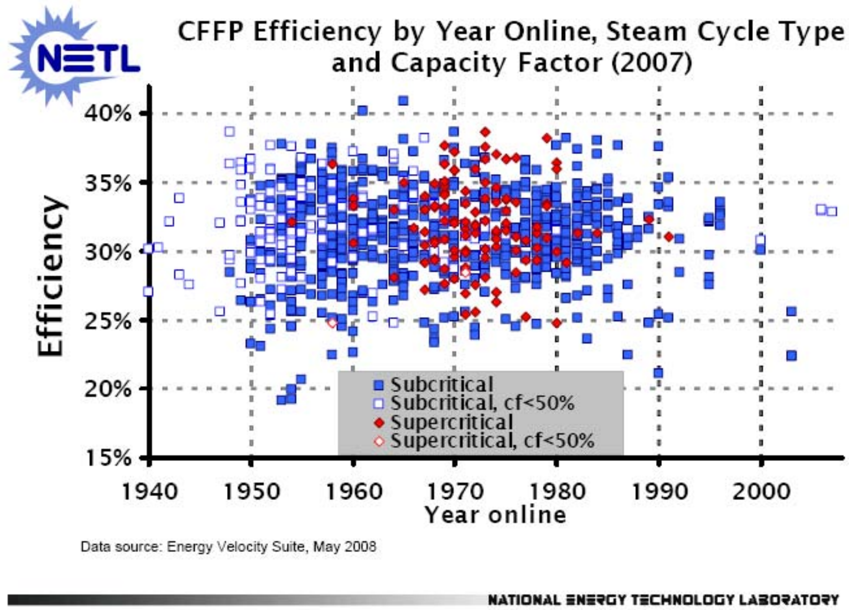
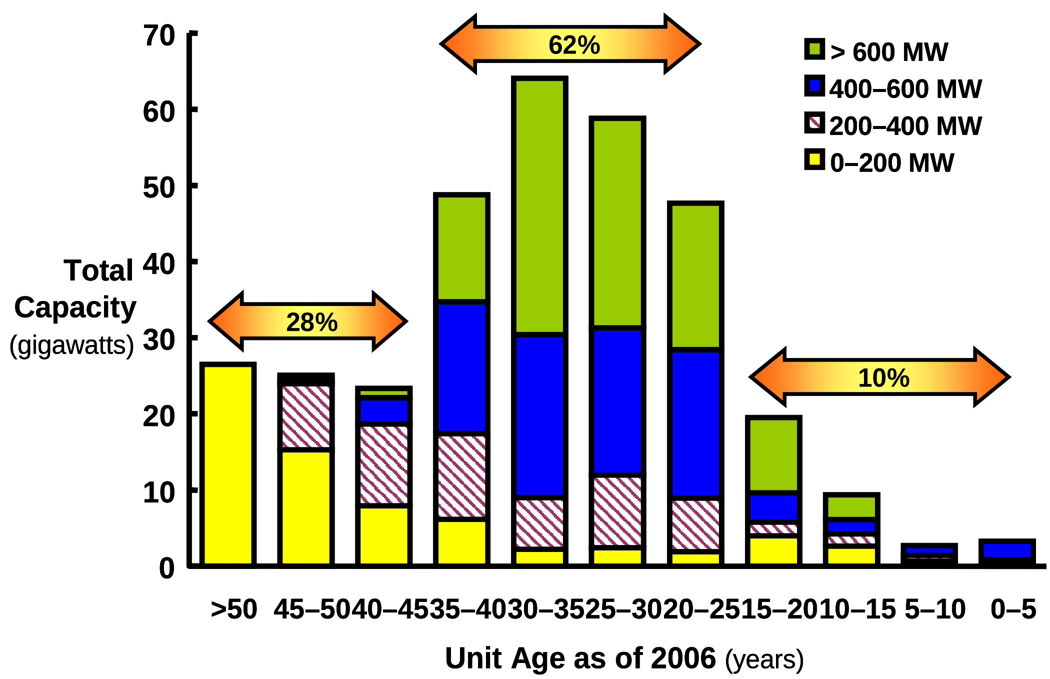


Figure 3. U.S. Power Plants – Age Versus Efficiency
(Source: DOE NETL-2008/1329)



Source: Cambridge Energy Research Associates.
Existing plant ages.

Figure 4. U.S. Power Plants – Age Versus Capacity (Source: CERA)

Solving the Equation

With the most promising candidates screened through the criteria described above, a utility with a number of assets across different technologies and fuels will need to consider economic models that encompass all financial factors across their system. In addition to assessing the "least impact" capital cost of reducing their carbon footprint, a utility must forecast the impact to their dispatch curve to understand future asset utilization. The dispatch model will not only have to incorporate variable operating costs, but also satisfy carbon emission reduction targets. The effect of CCS on future coal and natural gas prices and unit efficiency may significantly change the cost of electricity and thus dispatch order. The loss of net power output from adding CCS also brings in the question of whether to replace the lost output with new capacity (gas, coal, or renewable), buy it at market cost, or pursue demand side management to alleviate any gaps.

CCS retrofit projects will be quite complex and most assuredly require significant engineering efforts that produce unique solutions. There is not likely some "standard" for retrofit that will lead to savings with standardization or with multiplicity in deployment. These are really unique solutions that are sensitive to the plant configuration, local conditions such as climate and resource availability, available design margins, fuel quality (as compared to design) and remaining life of the equipment.

Plant Level Opportunities – CO2 scrubbing and oxy-combustion are the two primary capture technologies being considered. With CO2 scrubbing, current technologies will require a substantial amount of thermal energy to drive the solvent regeneration process. The popular low capital cost source of energy targeted is steam extraction from the existing steam turbine. This method has its operational and efficiency drawbacks, and there appears opportunity for other more creative sources of energy input. With oxy-combustion, the primary energy need is added electrical power to drive compressors, which is less intrusive to the plant operation.

It is possible that some units have extra capacity potential due to conservative design. This could allow some up-rating of equipment to help offset the capacity degradation with increased energy usage for capture and compression processes. Units could also be modified using modern designs to potentially supply more energy. That is, additional boiler heating surface could be added in conjunction with additional firing equipment to generate more energy output. More fuel throughput could be problematic but may be offset by efficiency improvements, supported by supplemental biomass fuels, or by adding natural gas fired equipment.

Repowering could also be an option to explore, especially for units tending to be smaller and older. Repowering, as contrasted to retrofitting, retains certain plant items such as site infrastructure, steel, electrical grid interconnection, fuel and ash systems, and even the steam turbine power block. Modernized new equipment for fuel energy conversion and emission control would be added. For example, B&W has looked at novel ideas of replacing old PC equipment with new Cyclone firing systems that would allow an increase in capacity utilizing the existing footprint of the plant. These are likely exceptional situations, but the high value of existing coal plant sites will motivate a hard look at their reuse before just "plowing them under".

CO_2 scrubbing technology offers an additional opportunity to evaluate – partial versus full scrubbing. Oxycombustion inherently is a full process conversion. Economic studies show the cost per ton of CO_2 removed climbs with partial scrubbing, all else being equal, which would preference high CO_2 removal rate retrofits. However, the practical use of a site (turbine extraction, load profile, space available, increased energy input), along with the amount of total CO_2 reductions required, may favor partial retrofits across more sites over time for some utilities.

Over the Horizon

The projected costs of current CCS technology and the economic impact of large scale CCS deployment are expensive and well documented. Much R&D continues to pursue lower cost carbon capture processes. In oxycombustion, B&W in conjunction with Air Liquide have made significant improvements in process design, increasing plant efficiency for new units to a range of 33% to 34% with today's state-of-the-art steam cycles. For retrofits, some of these improvements will not be exploitable, but oxycombustion still appears economically competitive with today's regenerable solvent CO_2 scrubbing solutions, especially for larger units.

With CO_2 scrubbing, embryonic new processes being developed hold promise for significant reductions in thermal energy requirements. Even with breakthroughs in new solvents and sorbents at the lab scale, whether they lead to significant cost reductions will depend on how robust and how affordable they are.

As an example, the DOE/NETL study "Carbon Dioxide Capture from Existing Coal-Fired Power Plants (DOE/NETL-401/110907) considers a CCS retrofit of an existing 435MW PC unit. For 90% CO_2 removal, the incremental levelized cost of electricity (LCOE) impact was an added 69 $/MWhr, based on a solvent regeneration energy of 1550 Btu/lb CO_2 (considered state-of-the-art for MEA solvent). Reducing this energy to 1200 Btu/lb lowered the LCOE impact to 63 $/MWhr, a 9% reduction. There are lab scale experiments underway with regeneration energy targets of less than 300 Btu/lb, which could potentially reduce the LCOE impact to 50 $/MWhr, a 28% reduction (assuming similar overall capital and absorbing agent costs).

As the added energy level for regeneration goes down, there may be a threshold of reduced impact to the plant that enables a step change in ease of retrofit and thus cost of CO_2 capture.