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NETL's Updated Performance and Cost Estimates for Power Generation Facilities Equipped with Carbon Capture

In October 2022, NETL released its updated study on the performance and cost of fossil-fuelled commercial power generation systems, which was the subject of a USEA webinar given by Marc Turner on Thursday, 2 February 2023. Apart from minor updates to its models, NETL's report, entitled Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity, includes several important new elements compared to the 2019 revision:

- New cases for H-class natural gas combined cycles (NGCCs), with and without CO_2 capture
- More recent cost and performance data for the Shell CANSOLV post-combustion capture system
- A revision of its 90% capture cases for pulverised coal (PC) and NGCC plants
    - Noting that, for pulverised coal, results address both sub-critical and supercritical PC.
- Extended capture rate cases to 95% for PC and NGCC plants
    - With technoeconomic analyses of even higher capture rates (97% NGCC and 99% PC) included in the report's appendices.

The primary aim of NETL's baseline studies is to generate an independent assessment of the cost and performance of select, state-of-the-art, fossil-fuelled power-generation systems with and without CO_2 capture. Using a systematic, transparent, technical and economic approach, it not only provides reference data for R&D guidance, but also offers a very useful perspective for regulators and policy makers. Conversely, users must also recognise the limitations of the analysis. For example, real projects will have a variety of location-specific factors that affect costs and will require more extensive analysis and study to reduce uncertainty. Moreover, the deployment of plant that includes technologies, such as CO_2 capture, that are not yet fully mature may incur higher costs.

Performance and cost assumptions for the solvent-based post-combustion capture systems used have been reworked based on 2021 data. While the update now incorporates 95% capture cases, NETL felt the relatively limited experience with the design and operation of capture systems that can achieve very high removal rates (97% NGCC, 99% PC) requires further study – hence placing the results relating to the very high capture rates in the appendices.

Assumptions made for the modelling were consistent with the 2019 revision, covering plant location, local ambient conditions, air and water regulations, capacity factors, fuel composition and fuel costs, and CO_2 transport and storage costs. The CO_2 transport and storage costs applied throughout were \$10/t CO_2.

For the NGCC cases, the efficiency penalty is less for the PC cases as natural gas is less carbon intensive than coal and the NGCC non-capture plant is more efficient. These effects are offset slightly by the lower concentration of CO_2 in the NGCC flue gas (4% versus 13% for PC).

As would be expected, with and without CO_2 capture, the NGCC cases have the highest net efficiency of all the technologies considered. On increasing the capture rate from 90% to 95%, the net power generated and net plant efficiency both fractionally decreased.

For NGCC plants with capture and PC plants with capture, raising the capture rate from 90% to 95% revealed only very modest increases in the costs incurred, i.e., in the total overnight cost, the cost of CO_2 captured and the cost of CO_2 avoided. The addition of CO_2 capture technology significantly impacts the total overnight costs for the NGCC cases and the PC cases. On a $/kW basis, adding capture to NGCC demonstrates the largest increase at between 100 and 104% for H-frame cases. Adding capture to supercritical PC raises the total overnight cost by between 64 and 66%. Importantly, the cost of capture and the cost of CO_2 avoided both show marked reductions compared with values reported in NETL's 2019 update.

Significantly, if future legislation assigns a cost to carbon emissions, all the technologies examined in the report will become more expensive. The technologies without carbon capture will be impacted to a larger extent than those with carbon capture, and coal-based technologies will be impacted more than natural gas-based technologies.

Increasing capture from 90% to 95% resulted in a small increase in water consumption. However:

- NGCC has the lowest raw water consumption of all cases, i.e., with and without-capture. This is expected given the higher steam turbine output in the PC cases, which results in higher condenser duties, higher cooling water flows, and, ultimately, higher cooling water makeup.
- CO_2 capture imposes a significant water demand on all technologies. Post-combustion capture technology has a significant cooling water demand that results in increased raw water consumption because of increased cooling tower blowdown and cooling tower evaporative losses.

While commercial-scale demonstration of solvent-based post-combustion CO_2 capture systems at PC power generation facilities has shown the ability to capture 90% of the CO_2 in the flue gas stream, confidence gained from industry and equipment/solvent vendors indicate that capture rates of 95% are eminently feasible for both coal-and natural gas-fuelled electricity generating units.

It is now broadly acknowledged that solvent-based, post-combustion capture technologies can achieve CO_2 removal rates beyond 95% on low-purity streams representative of fossil-fuelled combustion. However, NETL points out that the relatively limited experience with design and operation of capture systems that can routinely, reliably, and economically achieve CO_2 removal rates of, say, 97% (NGCC) and 99% (PC) does require further study.

For a much deeper appreciation of the latest update to NETL's cost and performance analysis, readers need to access the report directly. At 863 pages, it is packed full of quantitative insights on the range of technologies addressed.

Finally, and notably, in recent years, IEAGHG has undertaken cost studies[1] on NGCC and PC plants, without and with capture – where IEAGHG has also covered high capture rate cases for NGCC and supercritical PC. Importantly, results from IEAGHG's analysis are broadly consistent with those published in NETL's report. With the updates included in this, its most recent report, NETL's costs are generally found to be slightly lower.

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[1] IEAGHG, "Towards zero emissions CCS from power stations using higher capture rates or biomass", 2019/02, March 2019 and IEAGHG, "Update techno-economic benchmarks for fossil fuel-fired power plants with CO_2 capture", 2020/07, July 2020.