# Flexibility and Efficiency of Steam Turbine Extraction vs Gas Fired Generation as Steam Source for Post Combustion $CO_2$ Capture on Coal Fired Power Plant

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Abstract

Coal is used to generate 40% of global electricity. CO2 emissions from coal fired power plants must be reduced to meet global climate change mitigation targets. Renewables provide intermittent power generation. As preferential usage of renewable resources increases, the demand for flexible mode operation of non-renewable generation processes in order to backup these intermittent energy sources will become more prevalent. Post combustion $CO_2$ capture is the only proven full scale option currently available for reducing emissions from existing coal fired power plants. The post combustion capture process requires significant thermal energy (or steam) to regenerate the solvent used for $CO_2$ capture. Numerous studies have evaluated sources of this thermal energy; such as the existing steam turbine, or the integration of gas fired sources.

This study proposes that a gas fired generation source that has been integrated with the capture system of coal fired power plant will not be as flexible or will operate with sub-optimum performance relative to standalone gas fired generation. The study also proposes that a coal plant can be modified to provide the steam for regeneration at a lower cost in net output than the gas fired case. Comparisons of the output and flexibility of two configurations: 1) a coal plant with post-combustion capture and a stand-alone natural gas combined cycle plant (NGCC) considering only the combined output but no integration of the two plants and 2) a coal plant with post combustion capture that is fully integrated with the natural gas plant providing the steam in a

combined heat and power (CHP) arrangement, will be done. Neither configuration includes capture from the emissions of the gas turbine. Optimal configuration is very project specific. This study aims to identify the relative advantages and limitations of these two configurations.

Thermoflow software, including GT-Pro, GT-Master, and ThermoFlex, is used for modelling of the NGCC and CHP configurations. The coal fired power plant is modelled using GateCycle using heat balances and performance data for an existing 550 MW coal fired power plant. Heat integration will consider the heat recovered from the flue gas cooling as well as heat available from CO2 compression inter-cooling and after-cooling. The performance of the capture system will assume energy demands for an advanced post-combustion capture solvent and process.

The NGCC arrangement considers a modern state of the art gas turbine with heat recovery steam generator (HRSG) and the condensing steam turbine. The CHP arrangement is similar to the standalone NGCC configuration though the low pressure (LP) steam turbine and condenser is eliminated and the steam from the IP turbine exhaust is used for solvent regeneration.

The coal plant is based on an actual 550 MW plant firing a lignite fuel. Changes to this existing plant are limited to:

1) Steam path upgrades for optimized steam conditions at the intermediate to low pressure (IP-LP) crossover to facilitate solvent regeneration, and

2) Additions to the feedwater heating configuration to allow for heat integration through condensate preheating.

Steam path upgrades include replacement or modification to expansion stages without major changes to the turbine external casing or steam piping. The upgrade will provide recovery of degradation in the existing steam turbine and allow performance improvements resulting from advances in steam turbine technology. This level of modification is thought to offer the best balance of cost and performance. Performance is expected to be close to that obtained in the Boundary Dam Unit 3 ICCS Project, which had a custom designed turbine, but at a fraction of the cost. The steam turbine includes other novel but low-cost adaptations to facilitate capture at reduced loads.

The evaluation process will consider the following parameters:

- $CO_2$ emissions
- Quantity and reliability of $CO_2$ production for sale
- Fuel cost and other variable costs for a number of operating modes
- Dispachable range of operation
- Response or ramp rate in electrical output
- Capital cost

A few of the relative advantages and disadvantages for the two configurations are as follows:

- Standalone coal plant with standalone NGCC
  - The NGCC plant has full flexibility in load and can be shut down when market conditions dictate.
  - Steam will be available to the capture plant at all times when the coal plant is operating and producing CO2.
- Coal plant with capture steam from CHP arrangement
  - The combined cycle plant will not be available or may have to operate in a simple cycle mode when the capture plant is not operating.
  - A significant amount of duct firing will be required if maximum CO2 capture is to be maintained while the gas turbine is dispatched to lower loads. This is a less efficient use of natural gas than firing within the gas turbine.
  - The HRSG cost is reduced and the need for an LP turbine and condenser with cooling are eliminated from the combined heat and power arrangement. This could account for as much as 20% of the capital costs for the combined cycle plant.
  - The elimination of the LP turbine and condenser in the CHP arrangement results in a higher feedwater temperature to the HRSG and an increase in stack temperature.

The combined CO2 emissions and fuel costs for the standalone configuration are respectively 3% to 6% lower and 2% to 9% lower than in the CHP configuration due to elimination of need for part load duct firing and improved heat recovery in HRSG. The standalone configuration has a higher capital cost but a 3% higher net output.