Brownfield IGCCs as an Option in the National Energy Modeling System (NEMS)

DOE/NETL-2008/1311

February 2007

Disclaimer

Summary

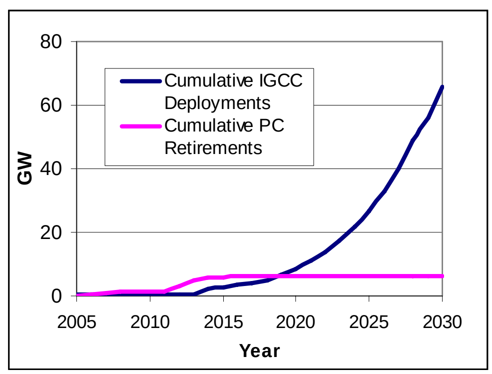
The purpose of this analysis is to present information on the capital cost and schedule impacts of a brownfield Integrated Gasification Combined Cycle (IGCC) deployment (that is, re-powering an existing pulverized coal plant) relative to a greenfield project. Inclusion of the brownfield IGCC option in the National Energy Modeling System (NEMS) will enable a more accurate characterization of the market opportunity for IGCCs.

Introduction

Several U.S. utility companies are considering the option of retiring old coal-fired power plants and installing new IGCC facilities at the site[1, 2]. Whether or not the existing steam turbine is utilized or scrapped is a case-by-case decision, but a fair amount of infrastructure and ancillary equipment (e.g., coal handling, power conversion, cooling towers, rail and power lines) can be utilized. Estimates of the net savings in capital cost for a "brownfield IGCC" versus a greenfield project range between 100 and 250 \$/kW[1,2]. Developers also expect the tasks of securing permits and gaining public acceptance to be easier and quicker at an existing power plant location.

The Department of Energy's Energy Information Administration (EIA) forecasts the deployment of IGCCs, nuclear, wind and other advanced power generation technologies in the U.S. through 2030. The EIA forecasts are developed using NEMS. Currently, NEMS only models greenfield IGCC deployments. Figure 1 shows IGCC deployments and pulverized coal (PC) retirements in the Annual Energy Outlook (AEO) reference case through 2030. Many analysts feel that both the retirements and new coal deployments should be higher, especially through 2020.

Figure 1 - PC retirements and IGCC deployments through 2030 in the AEO 2007 reference case[3]



A utility company that re-powers an existing PC power plant is essentially "walking away" from a unit that operates. Repowering would be strategic decision, based on the expected future prices of coal and CO_2 emissions. It may also be motivated by a need for a selective catalytic reduction (SCR) unit or an SO_2 scrubber at an existing site.

There are approximately 300 GW of coal-fired power plants currently operating in the United States. Of that, 123 GW are both above 200 MW of capacity and do not have an SCR or SO_2 scrubber installed within the past ten years[4]. We estimate this as the market opportunity for IGCC repowering.

Assumptions

The Existing Steam Turbine A key decision in a re-powering project is whether or not to utilize the existing steam turbine. The advantages to using the turbine are in the replacement cost and also the fact that it is already permitted. The disadvantage is a suboptimal match among IGCC components and/or the need for custom designs. The experience at Wabash tends to indicate that salvaging the existing steam turbine will not be worthwhile in many cases. In this analysis we assume that the existing steam turbine is not salvaged. As such we estimate that the heat rate, fixed O&M, variable O&M, and availability are the same as for a greenfield IGCC.

Generation Hiatus The host utility company will lose generating capacity during a re-powering project, between the time when the old unit is shut down and the new unit starts up. The work can be scheduled to limit the hiatus to roughly 6-8 weeks[5]. We assume 8 weeks and that the utility company will need to buy make up power during that period. We add the cost of purchased power to the capital cost of the project.

Lag Time Lag time is the delay between the investment decision and when the plant is operating. The possibility exists that a re-powering project will require less time to implement than a greenfield project, due to ease of permitting and public acceptance. The two currently operating IGCC plants show otherwise, though. The Wabash River plant was retrofitted between July of 1993 and November of 1995 (28 months), while the Polk Power Station was constructed on a greenfield site between November of 1994 and September of 1996 (22 months)[6]. Increased construction time for a retrofit over a greenfield plant is likely due to constraints associated with working around existing equipment, especially if generation is to continue up to the point of connecting the new generators to the existing transmission equipment. We assume that the constraints associated with re-powering counterbalance the ease of permitting and gaining public acceptance, and that the lag time for a brownfield IGCC is the same as for a greenfield project.

Decommissioning Cost Part of the cost of a brownfield project is decommissioning the non-utilized components from the existing power plant. One could argue that the utility company would have to decommission a retired plant even if it was not retrofit, so those costs should not be charged to the repowering project. We assume that the decommissioning of the existing plant under the no-re-powering case is far out in time so that the net present value of the decommissioning cost is essentially zero. Thus the re-powering project is charged the full decommissioning cost.

Methodology

The technology characterization parameters within NEMS for a greenfield IGCC deployment are shown in Table 1. With the existing steam turbine un-salvaged, we assume that all metrics, except the capital cost, are the same as for a greenfield plant.

Table 1. IGCC Cost and Performance Metrics in NEMS	
NEMS technology characterization metric	**Value in AEO 2007 for 2008 deployments**
Capital cost ($/kW)	1394
Heat rate (Btu/kWh)	8309
Fixed O&M ($/kW/yr)	36.38
Variable O&M (mills/kWh)	2.75
Capacity Factor (%)	85
Lag Time, Decision to Online (yrs)	5

Equation {1} presents a methodology for calculating the capital costs for a repower IGCC, relative to the greenfield cost. The overall cost is the summation of several opposing factors. On the one hand, the capital cost is reduced relative to a greenfield commensurate with the replacement value of the items from the old plant that can be utilized. On the other hand, the utility will suffer the cost of decommissioning the un-utilized equipment and also the cost of purchased power to make up for the capacity hiatus during the transition. Each of the factors in {1} is discussed below and an estimate for Cap_{RP} is presented.

$$Cap_{RP} = Cap_{GF} - Salvage + Decom + PurcPow \qquad \{1\}$$

Where:

Cap_{BP}	capital cost of an IGCC built by re=powering an existing PC power plant ($/kW)
Cap_{GF}	capital cost of an IGCC deployed at a green field site ($/kW)
Salvage	the value of items from the existing plant that can be reused in the new plant ($kW)
Decom	the cost of decommissioning the unusable components of the existing plant
PurcPow	the cost of purchased power to make for the discontinuity of capacity

Cap_{GF} We assume the cost contained in the AEO 2007, 1,394 $/kW

Salvage Table 2 below shows itemized cost estimates (excluding process and project contingencies) from two power plant systems analyses. For each category we made assumptions as to whether equipment from the existing plant could be utilized. We assumed the brownfield IGCC would require no investment in land, coal handling, coal prep, and cooling water. We assumed that salvageable equipment would reduce by half the cost of feed water equipment, power conversion, and buildings. In sum, these items reduce the cost of the IGCC by 16% compared to a greenfield deployment. Based on Cap_{GF} above, this equates to a 223 $/kW cost reduction.

Table 2. Itemized Cost for Greenfield IGCC					
		Case 1 of NETL Report[7]		Case 3B of DOE/EPRI Report[8]	
Item/Description	**Percent Cost Reduction for New Plant**	**Total Plant Cost (2006 $/kW)**	**Cost Avoided for Brownfield (2006 $/kW)**	**Total Plant Cost (1999 $/kW)**	**Cost Avoided for Brownfield (1999 $/kW)**
Coal Handling	100%	38.4	38.4	34.1	34.1
Coal Prep and Feed Systems	100%	67.4	67.4	41.7	41.7
Feed water & Misc. BOB	50%	44.0	22.0	30.8	15.4
Gasifier and Accessories	No	497.4	0	325.4	0
Gas Cleanup and Piping	No	127.0	0	66.2	0
Combustion Turbine/Accessories	No	209.2	0	154.5	0
HRSG, Ducting, Stack	No	76.5	0	51.6	0
Steam Turbine Generator	No	94.7	0	59.0	0
Cooling Water System	100%	47.0	47.0	32.4	32.4
Ash/Spent Sorbent Handling	No	55.7	0	20.3	0
Accessory Electric Plant	50%	66.3	33.2	57.6	28.8
Instrumentation and Control	No	21.3	0	24.1	0
Improvements to site	No	20.1	0	20.7	0
Buildings and Structures	50%	21.2	10.6	21.2	10
Land Cost	100%	0.7	0.7	1.6	1.6
Preproduction Costs	No	42.3	0	29.9	0
Inventory Capital	No	12.5	0	10.1	
Total	**-**	**1,441.7**	**219.3**	**981.2 1187.3 ($ 2006)**	**164.0 198.45 ($ 2006)**
Percentage of plant cost that can be recovered from re-powering	**-**	**15.2%**	**-**	**16.7%**	**-**

Decom The cost associated with decommissioning a coal-fired power plant is dependent upon many variables. The cost of dismantling and removing components of the plant will depend upon the station design and site conditions. A credit is applied to the dismantling and removal cost to account for scrapping and salvaging (in addition to salvaging for reuse in the retrofit plant). A scrap credit is an allowance for the monetary value of plant metal materials (i.e. carbon steel, stainless steel, and copper) that can be recovered from components that have no useful value in their current form. A salvage credit is also taken for the monetary value of equipment that has retained some useful operating life. Equipment that can, typically, be resold includes draft fans, auxiliary boilers, and circulating water pumps[9]. With these factors taken into consideration, practitioners estimate the cost of decommissioning to be between $40/kW and $60/kW[10]. We use the upper range, $60/kW was assumed.

PurcPow Equation {2} presents an estimate for the cost of purchased power based on the capacity and capacity factor of the existing plant.

$$PurcPow = Duration * Cap_{old} * CF * K_1 * (Power\_cost – (HR_{old}*Coal*K_2) – Var\_O\&M) / Cap_{new} \quad \{2\}$$

Where:

PurcPow – the cost in $/kW the utility suffers to purchase power during the re-powering project
Duration – duration of the generation hiatus (weeks)
Cap_{old} – the capacity of the existing power plant (MW)

Cap_{new} – the capacity of the repowered facility (kW)
CF – capacity factor of the existing power plant (%)
HR_{old} – the heat rate of the existing power plant (Btu/kWh)
Coal – the cost of coal ($/mmBtu)
Var_O&M – the variable operating costs (non-fuel) of the existing power plant ($/MWh)
Power cost - the price the utility company will pay for purchased power ($/MWh)
K_1 – unit conversion, 168 hrs/wk
K_2 – unit convesion, 0.001 (mmBtu * kW) / (Btu * MW)

To develop an estimate we assume a case where an existing 300 MW coal-fired power plant with a heat rate of 11,500 Btu/kWh, variable O&M of 2.75 $/MWh, capacity factor of 70% is being replaced with a 500 MW IGCC. Coal cost is assumed to be 1.69 $/mmbtu[11]. The cost of purchased power is estimated to be $40/MWh[12]. The cost of purchased power is calculated from {2} as follows.

PurcPow = 8 wk * 300 MW * 0.7 * 168 h/wk * (40 – (11,500 * 1.69 * 0.001) – 2.75)$/MWh / 500,000 kW

= 10.0 $/kW

From {1} the estimated capital cost for a repower IGCC equals:

Cap_{RP} = 1,394 $/kW - 223 $/kW + 60 $/kW + 10 $/kW = 1,241 $/kW

Results

We estimate 153 $/kW capital cost reduction for a repower IGCC compared to a green field facility. This compared to NRG estimates of 100-150 $/kW savings and a GE estimate of 150-250 $/kW savings.

Recommendation

NETL proposes that a brownfield IGCC be added to NEMS as a retrofit option for PC power plants, with a cap on deployments set at 123 GW. The technology characterization of the retrofitted power plant would be the same as for a greenfield IGCC, except the capital cost would be 153 $/MW less. NETL's goal is to have a brownfield IGCC option incorporated into the NEMS PC retrofit module and tested by July 2007 for inclusion in the Annual Energy Outlook 2008.

To get a sense of whether such a change would be worthwhile, the AEO 2007 NEMS model was run with the IGCC cost reduced by 153 $/MW. The result was a 2.6 mills/kWh reduction in cost of electricity for IGCC plants online in 2010, as well as a doubling of the amount of deployments through 2030 (from 65 GW to 129 GW)[13]. This NEMS run is not fully representative of the retrofit option, because it does not incorporate the retirement of PC power plants. Still, it indicates that the magnitude of capital cost reductions for brownfield IGCCs represented in this analysis would produce a significant change in the model results.

Additional analysis tasks to better characterize the opportunity

- Develop more robust estimates for the reduction in time lag for a re-power IGCC compared to a green field.
- Develop more rigorous estimates of decommissioning costs.
- Conduct a more rigorous screening analysis to estimate the percent of existing coal-fired power plants that would be amenable to an IGCC re-powering.

References

1. *Integrated Gasification Combined Cycle Panel Discussion*, Robert Rigdon, GE Energy, Presentation Given at PowerGen International, December 8, 2005.
2. *Repowering Existing PC Plants with IGCC*, Morton Sissener, Jim Falsetti, NRG/Process Energy Solutions, Presentation Given at 2006 Gasification Technologies Conference.
3. *Annual Energy Outlook 2007*, Energy Information Administration, 2007.
4. NETL Coal Plant Database – Data found by filtering "Generator Nameplate Rating," "NO_x Control Process," and "FGD Unit Status" fields.
5. Telephone conversations with Gary Stiegel (US Department of Energy – National Energy Technology Laboratory) and Phil Amick (ConocoPhillips).
6. *IGCC Engineering and Permitting Issues Summaries*, Energy Center of Wisconsin, Clean Coal Study Group, April 2006.
7. *2006 Cost and Performance Comparison of Fossil Energy Power Plants*, NETL, May 2006.
8. *Evaluation of Innovative Fossil Fuel Power Plants with CO_2 Removal Interim Report*, DOE/EPRI, December 2000.
9. *D&D Cost Estimating for Fossil Plant Retirement*, TLG Services, www.tlgservices.com, 2007.
10. *Fossil Plant Decommissioning: Tracking Deferred Costs in a Competitive Market*, John S. Ferguson, Public Utility Reports, June 15, 1995 (Note: Costs from this source were converted from 1995 dollars to 2006 dollars using a multiplier of 1.323 based on the Consumer Price Index).
11. *Electric Power Monthly*, Energy Information Adminstration, January 12, 2007.
12. *Steam Generator Degradation and Its Impact on Continued Operation of Pressurized Water Reactors in the United States*, Kenneth Chuck Wade, Energy Information Administration/Electric Power Monthly, August 1995.
13. NEMS runs performed by Jay Ratafia-Brown and available at www.netl.doe.gov/energy-analyses/benefit/html
14. *Wabash River Coal Gasification Repowering Project: A DOE Assessment*, US Department of Energy – National Energy Technology Laboratory, January 2002.
15. *IGCC Development in Delaware – Coal Without Compromise*, NRG, Presentation Given at Meeting of Scientific & Technical Advisory Committee of the Center for the Inland Bays, September 15, 2006.
16. *Integrated Environmental Control Model*, Version 5.02, Carnegie Mellon University, 2005.