ASSESSING THE ECONOMIC POTENTIAL OF IGCC WITH LIQUID SPARING

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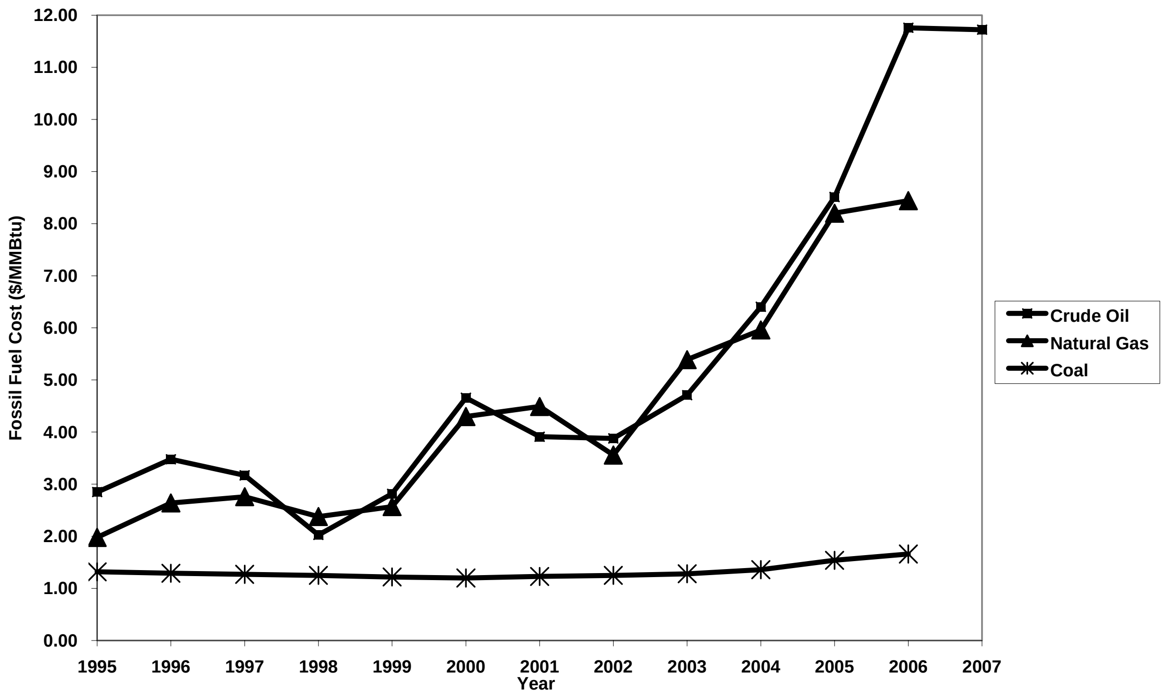
ABSTRACT

This paper examines the potential for revenue enhancement for an Integrated Gasification Combined Cycle (IGCC) power plant using a spare gasifier train as an operating unit to assure electrical output and to convert any surplus syngas, after power generation needs have been met, to marketable liquid fuels ("liquid sparing"). The liquid fuels production technology considered is the well-established Fischer-Tropsch (F-T) technology. The F-T technology is used to convert natural gas and syngas to liquid fuels and is available for license from Sasol, Rentech, Exxon, Shell, and others. This option is made more attractive by the potential to run several of the commercially available gasifiers at feed rates above rated levels. The ability to do this without life reduction has been demonstrated on operating units. Other options such as storing syngas to fire co-located peaking generation units might also be attractive should liquid prices drop. The goal is to keep the capital equipment as productive as possible while assuring high system availability for power generation. This paper also considers a number of ownership perspectives, each with different financing structures, financing costs, desired rate of return, and/or taxes obligations. The ownership perspectives considered include independent power producer (IPP), non-recourse financing; corporate owned, balance sheet financing; regulated investor-owned utility (IOU); and municipal-owned utility (MOU).

INTRODUCTION

Following the boom in installations of natural gas fired combined cycle (NGCC) power plants during most of the 1990s, the U.S. experienced a significant slowdown in the construction of new base load power generation facilities as the market digested the impact of higher natural gas prices, a general overcapacity in most regions, and financial weakness in the sector. High prices for natural gas have forced many NGCC plant owners into default on their debt service obligations.(1) From December 2002 to January 2004, 15 merchant

NGCC plants with a total capacity of more than 14 GW defaulted on their loans. In early 2004, Power Magazine reported that NGCC plants with a total capacity of about 33 GW or about 33% of the U.S. NGCC capacity could be classified as financially stressed.(2) High and volatile natural gas prices, particularly relative to coal (see Figure 1), have led to economically unacceptable dispatch rates for many NGCC plants which has resulted in a series of financial failures and asset foreclosures. Now, as demand finally catches up with this oversupply, developers are again considering investing in new power producing facilities. A new generation of coal plants – due to enormous domestic supplies and low, stable prices – is being seriously considered. Whether these investments are in traditional pulverized coal or next generation advanced technologies could have enormous implications for the nation's environmental and security futures.



All prices are annual average delivered prices to U.S. generating facilities except for crude oil which is the U.S. annual average well head price. Source: Table 9.10, Monthly Energy Review, June 2006, EIA and Annual Average U.S. Wellhead Prices, USDOE.

Figure 1. Delivered Fuel Prices.

There are several potential competitors in the advanced coal electricity generation marketplace. A focus on gasification technology is justified for several reasons:

- Gasification technology allows for the production of power, chemicals, and liquid fuels. The ability to draw more on domestic energy reserves is a positive security benefit. The potential to utilize coal to offset petroleum consumption in the transportation sector is extremely important, given the emerging national security concerns surrounding U.S. reliance on foreign sources for the majority of its oil supplies.

- Gasification provides the most technologically robust and cost-effective process for capturing and collecting most of the input fuel's carbon before release into the atmosphere. As the world develops strategies to address the risks presented by global climate change, demonstrating this technology will certainly position the U.S. economy to better handle potential mandatory CO_2 regulations that may be imposed in the future.
- Gasification has matured as a result of significant government investment in the U.S., Europe, and Japan as well as more than 60 years of experience with coal gasification to make syngas (CO plus hydrogen) for the synthesis of liquid fuels, valuable organic chemicals, and fertilizers via well understood and reliable process designs (about 11,200 MWt of coal syngas is accounted for by synfuels production in South Africa, 5,200 MWt by plants that make ammonia and other chemicals in China, and 1,900 MWt by the Dakota Gasification Company's Great Plains Synfuels Plant in the U.S. that makes synthetic natural gas and other byproducts and four fully integrated, utility scale coal gasification combine cycle plants in the U.S. and Europe).

Uncertainties regarding gasifier technology's ability to be available for an adequate portion of the operating schedule have resulted in cost premiums for investors. For the IGCC, the most relevant enhancement is to build a spare gasifier train which can eliminate the largest source of planned outages for refractory refurbishment and drive the overall plant availability into the 90+% range. An IGCC system consisting of three (2 plus 1 spare) gasifier trains and the necessary syngas to liquid fuel production facility can achieve 85 to 90% targeted availability for power generation and 85% availability for liquid fuel production assuming two year refractory life and 5% plant forced outage. Recent reports support this claim. Eastman Gasification Service Company, operating a ChevronTexaco (now GE) gasifier system for chemical production, has reported syngas availability of greater than 96% for 2001-2004, using a spare gasifier.(3) In a recent site visit to the Eastman facility, operators reported syngas availability of 96–98% and a single gasifier train availability of 92%.(4) The Buggenum plant has also reported availability of about 90%, the highest reported availability for a single train gasifier.(5) Shell has announced that it will guarantee 90% availability for the Shell gasifier.

F-T TECHNOLOGY

The major challenge in producing liquid fuel from coal is to increase the hydrogen to carbon ratio on a molecular basis (H/C). As a point of reference, the H/C ratio for gasoline and diesel is about 2, the ratio for typical crude oil is 1.3-1.9, and for typical bituminous coal, 0.8. F-T technology relies on first gasifying the coal to produce a syngas. The H/C ratio is then adjusted, as needed, using the water-gas-shift reaction ($CO + H_2O \rightarrow H_2 + CO_2$) and by removing the CO_2. The CO and H_2 molecules are then catalytically combined to produce synthetic fuel containing primarily diesel or gasoline.

The F-T process operates in two temperature regimes, high and low. The high temperature ($570^{o}F$ - $625^{o}F$) processes convert CO and H_2 to a liquid fuel consisting predominantly of gasoline and light olefins (ethylene, propylene, pentene, etc.). The liquid fuel is further processed to separate gasoline and olefins. Olefins are sold into the polymer industry sector or are converted to diesel fuel. The low-temperature (390°F - 445°F) F-T processes convert CO and H_2 to a liquid fuel which can easily be converted to a predominantly high quality diesel.

Both, the low- and high-temperature processes are exothermic and heat must be removed from the reactor vessel to maintain the desired reactor temperature. Sasol, Shell, BP, Rentech, Sasol Chevron, and others supply proprietary F-T technology; most use a slurry-phase reactor with a cobalt- or iron-based catalyst. Shell and BP use a fixed reactor. Sasol relies on iron-based catalysts and now offers slurry phase reactors instead of the original circulating and fixed bed reactors, respectively for high and low temperature processes. Typical Sasol's high-temperature reactors are 26-36 feet in diameter and about 125 feet high, capable of producing up to 20,000 barrel per day per reactor. The low temperature reactors are typically about 16.5 feet in diameter and 72 feet high and are capable of producing about 2,500 barrel per day of F-T liquids.

DESIGN, COSTS, AND ECONOMIC ASSUMPTIONS

The energy and material balances as well as IGCC plant design and EPC costs are extrapolated from a study conducted by the National Energy Technology Laboratory (NETL).(6) The design basis for this study is summarized in Table 1.

Table 1. Design Basis

Plant Type	PC Plant	IGCC	IGCC with Spare
Design Capacity, MWe	550	577	627
Auxiliary Power, MWe	55	66	75
Net Capacity, MWe	495	511	552
Liquid Fuel Production, bpd	0	0	3,766
Sulfur Production, tpd	0	118	199
Coal Consumption, tpd	5,467	4,793	7,189
Average Plant Efficiency, %	34	40	42
Number of Boilers/Gasifiers	1	2	3

The NETL study was used as the basis for estimating plant installed costs and electricity, liquid fuel, and sulfur production as well as coal consumption for the power only and power plus liquid fuel IGCC scenarios evaluated in this study. The primary differences between the two studies are:

- NETL power-only IGCC scenarios were optimized using natural gas as back-up fuel, while this study assumes a spare gasifier is available to meet combustion turbine demand for gas.
- NETL power and liquid fuel IGCC scenarios were optimized by maximizing liquid fuel production, while this study assumes only syngas that is not utilized by the combustion turbine to meet IGCC plant availability for power generation is converted to liquid fuel.
- This study does not attempt to optimize plant configuration or economics. Its goal is to establish the relative economic impact of IGCC plant configuration by maximizing

plant availability for power generation using a spare gasifier and converting any excess syngas to liquid fuels assuming different financing structures.

After establishing estimated EPC costs, in-house cost data, confidential sources, and published data were used to develop the total plant capital and O&M costs(7)(8)(9). Interest during construction (IDC) was estimated assuming a four year construction period with funds dispersed in four equal amounts. Table 2 summarizes EPC and soft costs, interest during construction, and total capital costs.The operation and maintenance costs are presented in Table 3. The total variable operation and maintenance (O&M) cost - fuel cost plus variable O&M cost - is an important consideration for dispatching a plant. This cost for the IGCC system is less than the cost for the PC system, primarily due to the IGCC system's higher efficiency. Delivered prices for Illinois No. 6 coal is assumed to be $25 per ton, while coal liquid and sulfur prices are assumed to be $38 per barrel (bbl) and $40 per ton. The assumed coal liquid price of $38 per barrel is some what conservative considering current crude oil market spot prices of about $55 per barrel or higher.

Table 2. Capital Costs

Plant Type	**PC Plant**		**IGCC**		**IGCC with Spare**	
Financing Structure	**IPP**	**Leveraged, GenCo, IOU, and MOU**	**IPP**	**Leveraged, GenCo, IOU, and MOU**	**IPP**	**Leveraged, GenCo, IOU, and MOU**
EPC Cost, $/kW	1,258	1,258	1,673	1,673	1,977	1,977
Soft Costs, $/kW	278	88	348	119	409	141
Interest During Construction, $/kW	162	129	208	170	245	201
Total Capital Costs, $/kW	1,698	1,475	2,229	1,962	2,631	2,319

Table 3. Operating Costs

Plant Type	**PC**	**IGCC**	**IGCC With Spare**
Power/Liquid Production Availability, %	88 / Zero	88 / Zero	88 / 85
Fixed O&M Costs, $/MWh	7.36	10.87	13.20
Variable (excluding coal) O&M Costs, $/MWh	1.57	1.2	1.15
Liquid Fuel/Sulfur Credit, $/MWh	0	(0.38)	(11.02)
Net Variable O&M Cost, $/MWh	1.57	0.82	(9.87)
Coal Cost, $/MWh	11.50	9.77	13.41
Total Variable O&M Cost, $/MWh	**13.07**	**10.59**	**3.54**

Finally, simplified spreadsheet financial models were used to estimate tariff and/or internal rates of return on equity (IRR) from various ownership perspectives. Tariff is the price that a power generator must charge for electricity in order to recover all of its operating costs and meet its financial obligations to local and federal governments, lenders, and equity share holders. The IRR is the interest rate corresponding to a net present value of annual net cash flows over the life of the plant that equals the equity investment amount.

Table 4 lists economic assumptions for different financing structures.

Table 4. Economic Assumptions.

Financing Structure	IPP	Leveraged	GenCo	IOU	MOU
Interest on Debt, %	8	6	6	6	5
Term, Year	15	15	15	30	30
Debt Service Reserve	6 months	None	None	None	None
Interest on Debt Service Reserve, %	5	None	None	None	None
Debt, % total capital	70	80	35	47	100
Equity, % total capital	30	20	65	53	0
Plant Life, year	20	20	20	30	30
Depreciation, Year/ Method	20/ Straight Line	20/ Straight Line	20/ Straight Line	6/ Accelerated	6/ Accelerated
Income Tax	38%	38%	38%	38%	None
Inflation	None	None	None	None	None
IRR (Equity), %	12	12	12	None	None
Annual Return on Stock					
Preferred Stock	None	None	None	5.50%	None
Common Stock	None	None	None	9.00%	None

RESULTS

Figure 2 shows calculated tariff values (in real term) over the life of plants for different project ownerships or financing structures. The tariff profile over the life of a project varies depending on the financing structure and applicable tax laws. Different approaches (i.e., declining, increasing, and constant) are usually used to smooth the step changes in tariff while maintaining the desired IRR. However, it is difficult to compare an array of tariffs through 20 – 30 years of plant life for different plant types using different financing structures. In this section, levelized tariff (amortized present value of the sum of the tariff over the life of the project) is used to simplify the presentation of the results. The first year tariff is assumed to be the minimum tariff needed to recover all operating costs and meet all financial obligations for that year, but not less than the minimum tariff for PC plants.

Figure 3 compares the estimated levelized tariff over the life of the plant for PC and IGCC plants with and without a spare gasifier for different financing structures assuming $38 per barrel and $50 per barrel for F-T liquids. It indicates that the most favorable financing structure for financing IGCC plants, particularly IGCC plants with a spare gasifier is MOU, while the least favorable is GenCo. It could also be argued that customers of MOUs benefit most directly from improved environmental attributes of IGCC plants (i.e., improved air quality and lower health costs, etc.) and therefore municipalities are in a better position to justify financing and implementing IGCC projects.

Figure 4 shows that at F-T liquid prices of greater than $55 per barrel, an IGCC plant with three (2 plus 1 spare) gasifier trains, 88% availability for power generation, and 85% availability for liquid production could be competitive with a PC plant.

Table 5 shows the gap between IGCC and PC systems' tariff. The tariff for IGCC without liquid sparing is 8 - 17% higher than the PC's tariff and for IGCC with liquid sparing it is

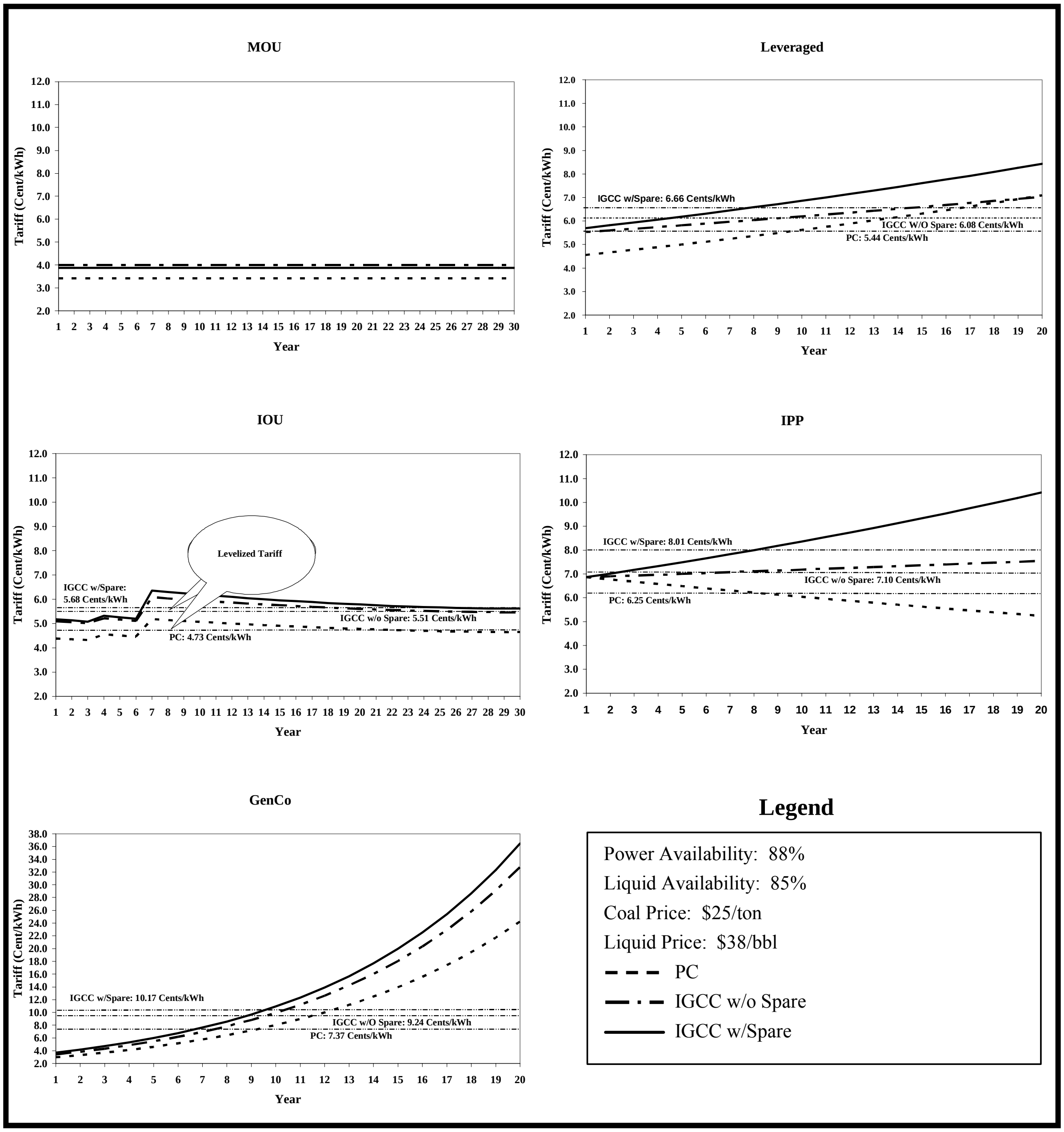


Figure 2. Tariff Comparison for Different Project Ownership Structures.

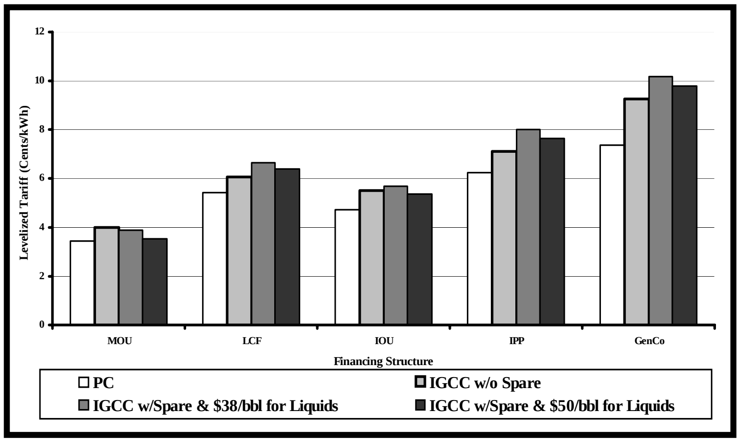


Figure 3. Levelized Tariff Comparison

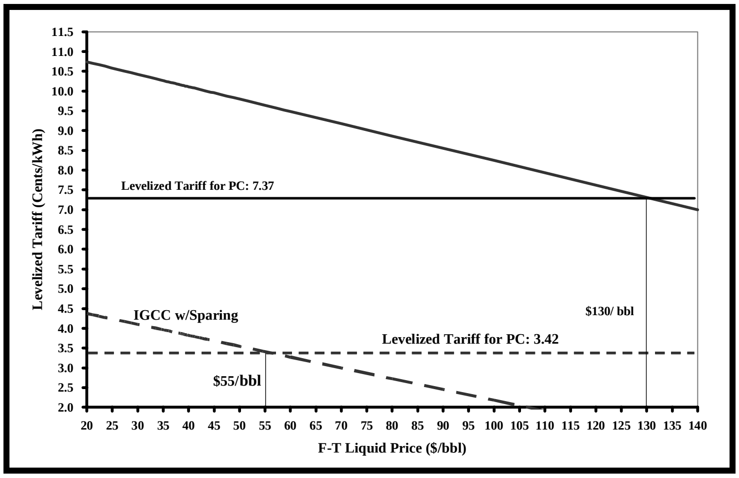


Figure 4. Impact if Liquid Fuel Prices on Electricity Tariff for IGCC with Liquid Sparing

Table 5. Average Tariff Between IGCC and PC Systems

Financing Structure	**IGCC ($/MWh)**	**IGCC With Liquid Sparing ($/MWh)**	
		$38/bbl	**$50/bbl**
MOU	5.8	**4.6**	**1.3**
Leveraged Corporate Financing	4.4	8.6	6.2
IOU	7.8	9.5	6.2
IPP	5.2	11.7	9.1
GenCo	5.9	13.8	11.2

3 - 20% higher depending on the liquid fuel prices. Table 5 also indicates that under the current cost and economic assumptions, the MOU financing structure favors the addition of liquid sparing due to its lower financing costs and tax exempt status. Principal and interest payments, return on equity and taxes account for about 72% of the IGCC's tariff for GenCo financing and for about 45% of the tariff for MOU financing cases. This suggests that reducing capital costs (and thus, principal and interest payment) and reducing taxes may have the greatest impact on enhancing market acceptance of IGCC systems.

Figure 5 shows the approximate reduction in IGCC systems costs that would make them competitive with PC systems under different financing schemes. This figure also shows the impact of increased liquid fuel prices on relative capital cost reductions and tariff of IGCC systems with liquid sparing. Figure 5 shows that:

- Approximately a 5% reduction in the capital costs of IGCC with spare gasifier would make this system competitive with PC under MOU financing structure, while capital cost reductions of about 15% and greater would be needed for other financing structures.

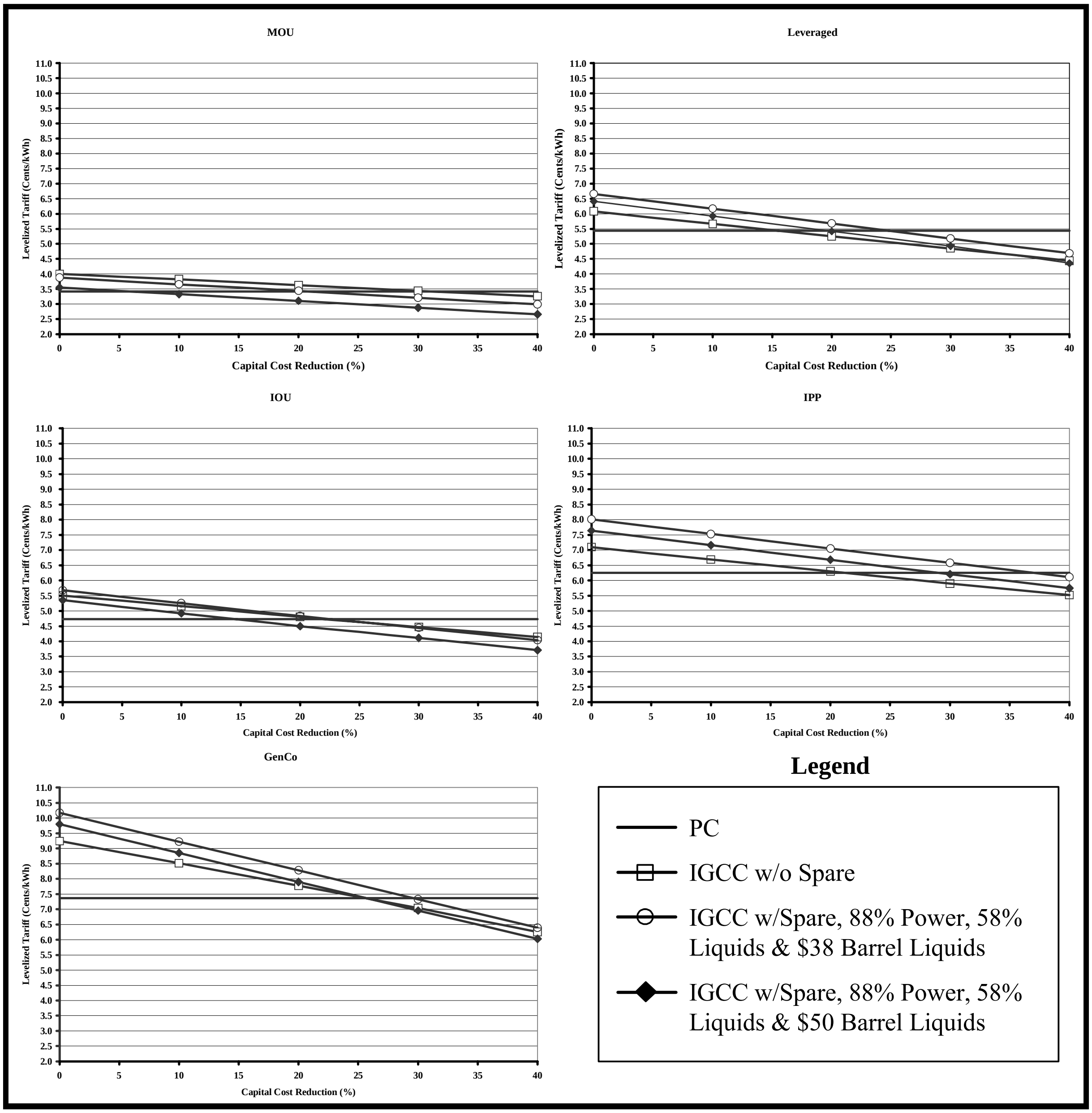


Figure 5. Impact of Capital Cost Reductions on Tariff

- IGCC with liquid sparing is more competitive than IGCC systems without liquid sparing at liquid prices of $38 per barrel and higher for MOU and IOU plants.

Figure 6 shows the sensitivity of the levelized tariff to coal prices. Tariff generally decreases with lower coal prices; the rate of decrease is however greater for IGCC with liquid sparing than IGCC without liquid sparing. In other words, lower coal prices favor IGCC with liquid sparing. Figure 6 clearly indicates that at a liquid fuel price of $50 per barrel and coal prices of less than $15 per ton, IGCC with liquid sparing is more favorable than IGCC without liquid sparing and can compete with PC systems, even at current higher IGCC capital costs, when MOU financing is considered.

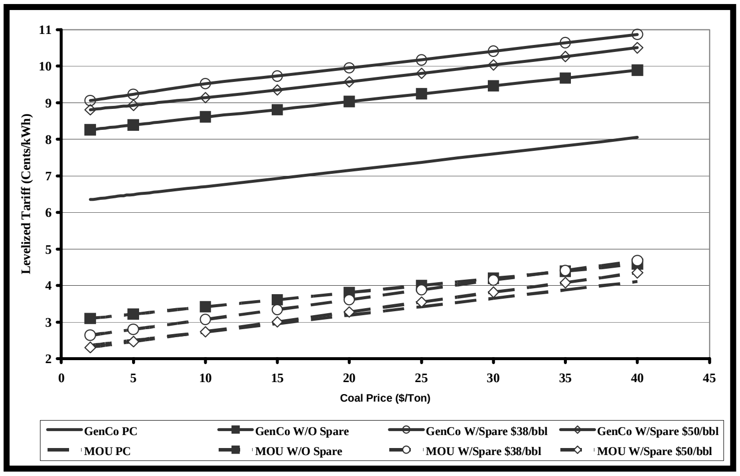


Figure 6. Levelized Tariff vs. Coal Prices

An uncertainty analysis which takes into account the estimated capital costs, interest rates, coal feed rate, and prices of coal and liquids indicates that at a coal liquid price range of $40 to $80 per barrel, IGCC with sparing has a higher probability of achieving the desired rate of return or tariff than IGCC without sparing independent of their financing structure. IGCC with sparing also has a greater probability of meeting targeted tariffs than PC systems at those liquid coal prices when MOU financing is considered.

CONCLUSION

At coal liquid prices of greater than $55 per barrel IGCC liquid sparing could be competitive with PC depending on the project financial structure. MOU and IOU financing structures favor IGCC with liquid sparing at liquid prices of greater than $38 per barrel.

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