# Integrated Gasification Combined Cycle

# Compared to the Desert Rock Energy Project

May 3, 2005

# I. INTRODUCTION

Recent discussions in the public domain suggest that technology advances for Integrated Gasification Combined Cycle (IGCC) have resulted in substantially better emissions and comparable costs such that it can be prudently installed in lieu of conventional coal burning technology.

Sithe decided to evaluate the use of the IGCC technology to determine whether or not it offers substantial environmental, technical, financial and operational advantages over the Supercritical Pulverized Coal (SCPC) boiler technology, the technology of choice for the Desert Rock Energy Project.

This document was developed by Sithe Global LLC for internal use purposes.

# II. Summary

The following is a summary of the key findings of this study:

- On average, and when compared to currently operating IGCC plants, the Desert Rock Energy Project will generate lower NOx, $SO_2$, PM, and VOC emission.
- An IGCC plant would have a higher capital, annual operational and maintenance costs compared to a SCPC plant. This is based on estimates developed by the Electric Power Research Institute (EPRI) and American Electric Power (AEP)
- At an elevation of 5,415 ft, an IGCC plant would generate significantly lower power output and significantly higher auxiliary load compared to a SCPC plant. This is due to the syngas turbine derating, caused by the high elevation of the Desert Rock plant site, and the additional power needed to operate the gasifier.
- Existing IGCC plants burn alternative fuels 10-25 percent of the time to compensate for availability issues caused by the gasifier. This operating scenario results in significant increase in fuel costs, and reliance on natural gas or distillate fuels.
- IGCC plants have lower availability than SCPC plants, especially in the early years of operation and they are more prevalent to incidents of forced outage as operations of the plants mature.
- An IGCC plant's gas turbine would have significant capacity reductions on hot summer days when generation has the greatest demand and highest value in the Southwest.

- The technology risk of building an IGCC plan would make the plant less desirable to utility investors and power purchasers. The increased risk would also increase financing costs, as lenders will want more equity and higher maintenance and debt coverage reserves. If lenders required equity level to increase from the expected 30 percent level to 40 percent, the resulting increase in capital cost would be $400 million over 25 years.

The following table summarizes the potential incremental increase in costs of an IGCC plant at the Desert Rock site over 25 years.

**Desert Rock SCPC vs. IGCC**
**Summary of Cost Increases**

| | **Annual** | **NPV** |
|---|---|---|
| Capital Cost Increases | $48,037,913 | $288,000,000 |
| O&M Costs | $14,221,800 | $74,288,292 |
| Impact of Using NG Fuel for 10% of Hours | $10,400,568 | $114,945,466 |
| Impact of 10% Reduction in Availability | $44,347,500 | $402,544,032 |
| Impact of 25.5 % Reduction in Net Generation | $90,468,900 | $821,189,826 |
| Total Annual Cost Increase | $207,476,681 | $1,700,967,616 |
| Cost Increase $/MWh | $17.54 | |
| Percentage Increase | 35.09% | 79.97% |

## III. COMPARISONS

Comparisons of publicly available information were evaluated with the following conclusions that will support the selection of Supercritical Pulverized Coal technology:

### A. Emissions Comparisons

IGCC plant's greatest claimed advantage is in its emissions profile compared to traditional PC designs.

Robynn Andracsek of Burns & McDonell had completed an independent evaluation of air emission from an IGCC plant compared to other conventional coal burning technologies, and has published his work in the 2003 CoalGen conference under a paper titled, "Comparison of IGCC Air Emissions Versus a Conventional Coal Plant". In this paper, NOx, $SO_2$, PM, and VOC emissions from various operating IGCC plants were compared to modern conventional coal fired units that have been recently permitted.

The following table summarizes Andracsek's findings with regard to IGCC and recent conventional coal projects and compares these emission profiles to those expected emission rates proposed for the Desert Rock Energy Project using Supercritical Pulverized Coal technology.

| Pollutant | Recent PC Projects | IGCC Projects | Proposed Desert Rock |
|---|---|---|---|
| **NOx (lb/mmBtu)** | 0.08 (Sand Sage)<br>0.08 (Hawthorn)<br>0.15 (Two Elk Power)<br>0.17 (Wygen)<br>0.12 Average | 0.07 (Kentucky Pioneer)<br>0.08 (Tampa Electric)<br>0.15 (Wabash)<br>0.176 (Global Energy – Lima)<br>0.119 Average | 0.06 |
| **SO2 (lb/mmBtu)** | 0.12 (Sand Sage)<br>0.12 (Hawthorn)<br>0.15 (Two Elk Power)<br>0.17 (Wygen)<br>0.14 Average | 0.03 (Kentucky Pioneer)<br>0.17 (Tampa Electric)<br>0.1 (Wabash)<br>0.038 (Global Energy – Lima)<br>0.0845 Average | 0.06 |
| **PM (lb/mmBtu)** | 0.018 (Sand Sage)<br>0.018 (Hawthorn)<br>0.018 (Two Elk Power)<br>0.018 Average | 0.011 (Kentucky Pioneer)<br>0.013 (Tampa Electric)<br>0.005 (Wabash)<br>0.018 (Global Energy – Lima)<br>0.012 Average | 0.01 |
| **VOC (lb/mmBtu)** | 0.004 to 0.015<br>0.009 Average | 0.002 to 0.015<br>0.006 Average | 0.003 |
| **CO (lb/mmBtu)** | 0.14 to 0.16<br>0.15 Average | 0.03 to 0.25<br>0.1 Average | 0.1 |

As evidenced in this table, IGCC is found to offer much lower emission rates compared to the most recently built pulverized coal technology projects. This result supports the well publicized notion that IGCC offers an environmental performance advantage over conventional coal burning technologies.

However, when the IGCC emission profiles are compared to the Desert Rock proposed limits, this performance advantage gap is completely eliminated. In fact, Desert Rock is likely to produce 50% less NOx emissions, 29% less $SO_2$ emissions, 16% less PM emissions, and 50% less VOC emissions when compared to average performance of an IGCC plant.

### B. Capital and O&M Costs

Capital and Operations and Maintenance (O&M) Costs are evaluated on the following table for 1,500 MW (2004 Dollars):

| **IGCC vs. Desert Rock Cost Comparison** | **Desert Rock** | **EPRI** | **AEP Filing** |
|---|---|---|---|
| **Capital Costs** | | **ICCC w/ Spare** | **w/ Ohio PUC** |
| Cost $/kW | 1,418 | 1,610 | 1,722 |
| Cost $ | $2,127,000,000 | $2,415,000,000 | $2,583,000,000 |
| Increase Capital Costs | | $288,000,000 | $456,000,000 |
| | | | |
| **Fixed O&M** | | | |
| Fixed O&M (EPRI) $/kW-yr | 41.1 | 56.1 | 56.1 |
| Fixed O&M Annual $ | $61,650,000 | $84,150,000 | $84,150,000 |
| | | | |
| **Variable O&M** | | | |
| Variable O&M $/MWH | 1.6 | 0.9 | 0.9 |
| Variable O&M @ 90% AF | $18,921,600 | $10,643,400 | $10,643,400 |
| | | | |
| **Combined Costs** | | | |
| Annual Fixed and Variable O&M | $80,571,600 | $94,793,400 | $94,793,400 |
| Annual O&M Increase for IGCC | | $14,221,800 | $14,221,800 |
| Increase O&M NPV 25 Years | | $74,288,292 | $74,288,292 |
| | | | |
| **Total Capital Cost & O&M Costs** | Base | $362,288,292 | $530,288,292 |

AEP filed the above cost estimates March 18, 2005 with the Ohio PUC for a 600 MW IGCC plant to be built in Meigs County, Ohio. EPRI's values have been publicly presented at several conferences and were included in the AEP Ohio PUC filing. The total cost for each plant was escalated to 1,500 MW for comparison to Desert Rock. Other government agency publications validate these estimates.

From the results, it can be said that in both IGCC cases that the Total Capital Costs and O&M Costs combined create a significant financial argument to conclude that Supercritical Technology is a more economical installation. Further, this conclusion is supported by the effect of availability factor (AF).

### C. Availability Factor

IGCC plants do not have a history of availability that compares with SCPC plants. The best SCPC plants operate with availability of well over 90 percent. IGCC plants have a history of gasifier leaks, fouling, and slagging of the air separation units (ASU). Installation of multiple trains of gasification, with the associated increased capital cost, have relieved, but not totally resolved this issue. The secondary trains were often added two to five years after constructions was complete in an effort to improve plants' performance when no other solution proved effective. IGCC plants have also relied upon use of alternate fuels (natural gas or distillate fuel) to maintain availability and capacity factors when the gasifier trains fail. Units have historically operated up to 25% on these alternate fuels to achieve plant availability of near 90%. As an example, the Polk Power Station's best new IGCC unit, commissioned in 1996 and operated by Tampa Electric, had an annual capacity factor for gasification of 67.5% and alternate fuel of 22.5% in 2003.

Some of the best IGCC plants have reported >85% plant AF in a quarter year for single train gasifier, but <85% for a full year; and >90% plant AF per year for two train gasifiers, but with no less than 13% use of alternate fuels of distillate or natural gas.

Further in this report are the actual causes of reduced availability from forced and planned outages at the world's four operating IGCC power plants as discussed at the Gasification Technology Council Conference (April 2005). (Of note, gasifiers require that units must take at least a month long outage every two years or less for new refractories to be installed. These refractories are a significant contributor to planned and forced outages.)

The financial effects of a conservative 10% use of natural gas to meet a 90% AF would result in a NPC cost over 25 years of $114.9 million dollars as summarized below:

**Impact of Using Natural Gas Fuel for 10% of Hours**

| | |
|---|---|
| Coal Cost $/mmBtu | 1.3 |
| NG Cost $/mmBtu | 5.5 |
| Difference $/mmBtu Delta of Coal and Nat. Gas $/ | 4.2 |
| Difference $/MWh | 3.61 |
| Annual Gas Cost | $4,746,168 |
| Annual Gas Transport Cost (1/3 total need) | $5,654,400 |
| Annual Total | $10,400,568 |
| NPV Fuel Price Increase 25 Years | $114,945,466 |

Even with the use of natural gas to improve IGCC availability, there is still a significant risk that an IGCC plant would have a lower availability than a SCPC plant, especially in the early years of operation, as even the best existing IGCC plants have taken several years to reach their current level of availability. Ideally, IGCC plants are generally engineered and quoted to achieve an 80% availability factor compared to Desert Rock's 90% minimum availability factor. The following table estimates the impact on capital cost by a 10% difference in availability factor and may be used two-fold, to show the existing disparity, or future losses should the IGCC plant be placed into forced outage for 37 days (10% of a year) such as for refractory replacement:

**Impact of 10% Reduction in Availability**

| | |
|---|---|
| Estimated Capital Costs at 90% AF / MWh | $30.00 |
| Estimated Capital Costs at 80% AF / MWh | $33.75 |
| Annual Cost Difference | $44,347,500 |
| NPV Availability 25 Years | $402,544,032 |

Other significant events that affect AF are flame instability, which is the pulsation or sputtering of the combustion flame. This results in a harmonic in the combustion turbine caused by syngas moisture content that ultimately results in erosion and fractures in the GT blades and buckets. Consequently, GE has requested a turn-down in GT temperature settings, i.e. a derating of the IGCC turbines. Efforts are being made to resolve this issue, but in the meantime, rotors are being wiped and extended outages taken for the repairs.

To reduce the slagging of the gasifier train and moisture content of the syngas, all of the existing IGCC plants have shifted from coal to 100% petcoke supply and recommend nitrogen dilution to control NOx instead of steam, thus, no longer relying on their intended initial fuel supplier and plant configurations. This shift in fuel strategy further makes the IGCC plants an ideal candidate for industrial and refinery settings where waste and fuel streams can be synergized, rather than a mine mouth plant such as Desert Rock.

## D. Net Generation

The net output (generation available for sale) of an IGCC unit is significantly impacted by the elevation of the Desert Rock site and also by the increase in the auxiliary load of an IGCC unit. The net output of a 1,500 MW SCPC plant at the of Desert Rock site is expected to be 1,366 MW, while the 1,500 MW IGCC unit at the Desert Rock site would have a net output of 1,017 MW. Conversely, an IGCC unit with a net output of 1,366

MW would need to generate 1,727 MW gross at 5,415 feet above sea level the Desert Rock site.

The results in the 8.4 percent reduction in capacity and energy sales from the IGCC plant which has the following impact on capital costs.

| **Impact of 25.5 % Reduction in Net Generation** | |
|---|---|
| Estimated Capital Costs at 1386 Net MWh | $30.00 |
| Estimated Capital Costs at 1,017 Net / MWh | $37.80 |
| Annual Cost Difference | $90,468,900 |
| NPV Net Generation 25 Years | $821,189,826 |

## 1. Desert Rock Site Affects on Gas Turbines Net Output

Gas turbines are subject to correction factors in power output based on relative humidity, barometric pressure (elevation changes), and temperature. Reduction in barometric pressure reduces air density resulting in decreased mass flow of air and power output from the gas turbine. The elevation at Desert Rock is approximately 5,415 ft. and average annual relative humidity is 40%, and average temperature is 51.5°F. International Standards Organization (ISO) conditions for gas turbine ratings are 59°F, 60% RH and sea level (14.7 psia).

5,415 ft (12.0 psia Barometric Pressure) causes a correction power output of 0.825 (GE supplied value); therefore, gross power from an advanced IGCC plant at 1500 MW at sea level would become 1237.5 MW at Desert Rock’s elevation.

40% relative humidity correction factor is 1.0012 times the power output. The affect of humidity in this case is negligible with an increase in gross power of 1.8 MW.

Lower annual average temperature less than ISO of 59°F will create an increase in power by passing cooler denser air through the gas turbine. The increase in power is effectively 2% or 30 MW.

Gross power adjustment due to gas turbine correction factors is significant for IGCC plants at the elevation and ambient conditions of Desert Rock:

$1{,}500 \text{ MW} + 30 \text{ MW}_{\text{temp}} + 1.8 \text{ MW}_{\text{humid}} - 262.5 \text{ MW}_{\text{elevation}} = 1{,}269.3 \text{ MW}_{\text{IGCC gross output}}$

### 2. Auxiliary Electrical Load and Affect on Net Generation

Although an IGCC plant's output would be reduced from 1,500 MW due to the correction factors above, the plant's efforts to produce 1,269.3 MW still required the auxiliary power demands to be the same as for 1,500 MW of generation.

IGCC plants consume approximately 21% of their gross power for internal use as can be seen in advanced IGCC technologies listed in DOE and EIA reports. A 316 MW gross plant is expected to produce 250 MW of net power in the year 2010. This is considered an efficiency improvement over existing IGCC plants' auxiliary load.

Therefore, to generate 1,500 MW, it can be assumed that 21% auxiliary load is 315 MW, or net generation would be 1,185 MW. (*If 20% adjustment is made for economy of scale for five plants having shared services, then auxiliary load is reduced 63 MW to 252 MW, or net generation of 1,248 MW net due to auxiliary load only, essentially the output of another complete IGCC plant.)*

1,269.3 MW $_{\text{ISO corrected gross output IGCC}}$ – 252 MW $_{\text{aux load (EOS)}}$ = 1,017.3 MW $_{\text{net IGCC output}}$

Whereas, auxiliary load for Desert Rock is 8.9% or 134 MW for 1,500 MW gross production, totaling 1,366 MW net.

1,500MW $_{\text{gross output DR}}$ – 134 $_{\text{aux load}}$ = 1,366 MW $_{\text{net Desert Rock}}$

Conversely, as before, for an IGCC plant to achieve the same net output as an SCPC plant at the same site conditions, it would have to generate 2,008 MW of gross output compared the Desert Rock Energy Projects 1,500 MW gross.

1,017.3 MW $_{\text{IGCC net}}$ / 1,500 MW = 68%
2,008 MW $_{\text{IGCC gross}}$ – 68% = 1,365.4 MW $_{\text{IGCC net}}$

## E. Plant Heat Rates

The EPRI report shows an expected average heat rate for an IGCC plant of 8,630 Btu/kWh (HHV) which is very similar to the expected heat rate of Desert Rock of 8,650 Btu/kWh (HHV). However, EPRI concludes that as the heat content of coal decreases, both the heat rate and the capital costs of an IGCC plant increases at a greater rate than for a SPCP plant. EPRI estimates the actual heat rate for an IGCC plant using 8,910 Btu/lb coal (the heating value of Navajo Mine coal) could be approximately 10% higher than a SCPC plant. This would result in a further 10% increase in fuel costs and a 10% increase in fuel consumption (see attachments).

In addition, the IGCC heat rate at ISO conditions does not take into account site and ambient effects. If the IGCC plant site conditions require 2,008 MW of gross generation to achieve the same net output as a 1,500 MW SCPC plant, then with Navajo coal heat content of 8,910 Btu/lb, the total coal consumed at the site conditions may be calculated for a 90% capacity factor and the same net output. The below calculations show that coal use would increase by 33.6% and emissions would increase by a similar amount:

**IGCC at site conditions:**

8,630 Btu/kWh / 8,910 Btu/lb x 8,760 hr/y x 2,008 x$10^3$ kW / 2,000 lb/ton x 0.9 =

7.67 Million tons of coal

**SCPC at site conditions:**

8,650 Btu/kWh / 8,910 Btu/lb x 8,760 hr/y x 1500 x$10^3$ kW / 2,000 lb/ton x 0.9 =

5.74 Million tons of coal

The results of this calculation show that an IGCC plant at the Desert Rock site would consume 1.93 million more tons of coal per year than an SCPC plant for the same 90% capacity factor and net output.

### F. Technology Risks of IGCC

As discussed many of the existing fleet of IGCC plants have had significant problems, including cost over runs and availability issues. Some of the existing IGCC plants have been shut down or converted to natural gas only including Sierra Pacific's Pinion Pine plant in Reno. This risk will make a plant less attractive to Southwest utilities who will be equity participants or power purchasers of the project. The increased risk of IGCC will also increase financing costs, as lenders expect higher contingency reserves, higher maintenance reserves, and higher levels of equity. Increased equity levels would have a significant impact on the project costs. A chance in equity levels from 30 to 40 percent would increase the average cost of capital approximately 10 percent which would increase the project cost $44 million per year or $400 million net present value over 25 years.

### G. Byproducts

Byproducts handling at a non-industrial site may cause problems with slag disposal, molten sulfur storage and transport, and waste syngas flaring similar to a petrochemical facility. Ultimately, an IGCC plant looks more like a refinery than a power plant. Without beneficial reuse at or near the same location, transport of byproducts can become a cost instead of a financial benefit with additional environmental impact and risk.

### H. Plant Site Requirements

On average a 500 MW IGCC plant general arrangement consumes 125 acres or 375 acres for 1,500 MW, compared to Desert Rock's 1,500 MW 120 acre footprint.

### I. Heller Tower vs. Gas Turbine Deratings at Summer Peak Temperature

Selection of the Heller Natural Draft Cooling Tower for Desert Rock is based on the need for conservation of water demand and auxiliary load. The Heller system however, has an efficiency derating at high ambient temperatures similar to the gas turbine. The derating is caused by high condensate return temperature to the condenser causing a backpressure increase on the steam turbine exhaust buckets up to 7.5 "Hg without operator influence at 114°F ambient temperature.

This derating was designed to be minimized through humidification (water spray) of the lower quarter of the tower radiator cells when ambient temperature is >80°F and engineering design of a high backpressure steam turbine. Both modifications are proven to be effective at existing plants. The humidification still makes the plant competitively operational with only 20% of the water demand of a conventionally cooled plant; and steam turbines designed for a back pressures of 8.5 "Hg are readily available and in operations with a further margin to destruction or degradation of exit blades.

Without humidification of the tower, generation losses are 50 MW for the 1,500 MW plant, which is 3% degradation, compared to a 20% (300 MW) degradation effect on a 1,500 MW IGCC plant. The IGCC losses only account for the losses in the gas turbines air intake density and not the losses of the combined cycle steam turbines which would be similar to the losses due to backpressure on Desert Rock's steam turbine.

**Desert Rock IGCC at 114°F**

$1{,}017.3\text{ MW}_{\text{net IGCC output}} - 300\text{ MW}_{114°\text{F turbine losses}} = 717.3\text{ MW}_{\text{net ICC at }114°\text{F}}$

**Desert Rock Supercritical Coal at 114°F**

1,366 MW $_{\text{net Desert Rock}}$ – 50 MW $_{\text{backpressure losses}}$ = 1,316 MW $_{\text{net SCPC at 114°F}}$

With this final conclusion, it would be obvious that Supercritical Pulverized coal is ideal for the Desert Rock mine-mouth site with consideration of the customer peak demand loads in the Desert Southwest occurring in the summer season up to 114°F. In this scenario, Desert Rock SCPC capacity is 180% or more than IGCC capabilities.

Conversely, an IGCC plant at the Desert Rock site would have to generate 2,522 MW $_{\text{gross}}$ at 114°F to achieve the same output as a 1,500 MW $_{\text{gross}}$ SCPC plant with Heller cooling for the same output of 1,316 MW $_{\text{net}}$.

## IV. Summary Table of Desert Rock Compared to Existing IGCC Plants

| **Plant Parameter** | **Nuon Buggenum, Netherlands** | **Wabash River, Indiana** | **Polk Power Station Tampa, Florida** | **ELCOGAS Puertollano Spain** | **Desert Rock Burnham, New Mexico** |
|---|---|---|---|---|---|
| Start-up Date | Jan 1994 | Oct 1995 | Sept 1996 | Dec 1997 | 2010 |
| MW Net | 253 | 262 | 250 | 300 | 1366 |
| GT Output | 155 | 192 | 192 | 200 | |
| Fuel | 30% Biomass 4-6% Sewage Sludge, Wood Waste | Petcoke 100% Distillate, Natural Gas | 55% Petcoke 45% Coal Distillate | 50% Petcoke 50% Coal | Bituminous Coal, Distillate |
| Gasifier Technology | Shell (Kruppe Uhde) | E Gas (Conoco Phillips) | Texaco (GE Energy) | Prenflo (with Shell) | N/A |
| Turbine Technology | Siemens V94.2 | GE 7FA | GE 7FA | Siemens V94.3 | Varioplant |
| Gasifier AF | 81.8% (2004) | 54% (2002) 59% (2003) 22% (2004) | 82% (2004) | 69.2% (2004) | |
| Alt Fuel AF | | | 13% (2004) | 17% (2004) | |
| Plant AF | 89.9% (2004) | | 95% (2004) | 65.8% (2004) | |
| Outage Factor | 16.8% (2004) | | | 34.2% (2004) | |

## V. Issues Affecting Existing IGCC Plant Availability

Reported at the Gasification Technology Council Conference in October, 2004 and April, 2005.

### A. Polk Power Station, Tampa Electric

- 2 GT Generator rewinds
- GT rotor replacement
- New syngas saturator added to achieve 15 ppmv NOx
- Slag accumulation
- Heat stable salts (HSS) corrosion of the MDEA unit; black and gray water systems from fines
- Carbon Conversion lower than expected exacerbated by petcoke use
- Convective syngas cooler and upstream path fouling
- Distillate back-up fuel reliability, coking in lines and nozzles
- Transferring to 100% petcoke operation
- Sootblowers installed

### B. Wabash River, Indiana

- Unit is repowering after ten years of operation
- 100% petcoke operations after completion of DOE program demonstrations
- 15 ConocoPhillips personnel on site for Technical and Management support
- Changes being made to all support and process systems to resist corrosion
- Removed from service for commercial reasons
- Mechanical cleaning of fire tubes required
- Wet scrubber added to reduce chlorides
- Waste treatment systems added
- Ion Exchange added to remove heat stable salts from MDEA circulation
- GT compressor failures
- Distillate system unreliable
- HRSG failures (leaks) and natural gas leaks

### C. Nuon - Buggenum Netherlands

- Syngas cooler pipe leaks
- Sour gas tube sheet leaks
- Piping corrosion in slag bath

- Nitrogen quality trips, steam conversion for NOx control
- Burner tip vibrations in GT
- Sewage sludge fouls syngas cooler
- Emission limits are difficult to meet and limit operations

### D. ELCOGAS – Puertollano, Spain

- 3 month overhaul of GT for tile repairs and annular ring replacement
- Troubleshooting fuel switchover from syngas to natural gas
- Fouling of catalyst and pre-heater tubes which capture COS at a given exhaust temperature
- Fuel mixing and grinding failures
- Slag Removal
- Corrosion of cold areas of process

## VI. IGCC Lessons Learned

- Single train IGCC has not achieved >85% AF
- Multi-train IGCC has achieved > 90% AF
- Operation on petcoke is ideal over coal due to coal's higher ash and mineral content that fouls the syngas coolers
- GT reliability has as great an effect on reliability and availability as the gasifier train.
- Fuel instability in fuel switching causes vibration in the GT and results in burner and rotor damage.
- Corrosion control in the process stream needs to have detailed engineering to prevent extended outages.
- IGCC trains need a one month outage for refractory replacement every two years, resulting in a need for a spare gasifier to achieve >90% availability for all IGCC technologies.
- GE recommends derating the gas turbines with a lower firing temperature due to flue gas moisture content and the affect on long term service agreements and blade erosion. Nitrogen dilution for NOx control is preferred over steam injection for the same reasons.

## VII. Conclusions

Any one category of the comparison topics Capital Costs, Availability, Operating Costs, Technology Risks, Emissions, GT Correction Curves, Siting, Schedule, Existing Plants' Issues or Auxiliary Load is enough to cause a close review of IGCC technology which has strong public proponents for a "Green" power plant. Combined, these items weigh heavily in support of a supercritical pulverized coal plant at the Desert Rock site.

The opinion that some IGCC plants need to be built to meet the demands for cleanest emissions and that the technology will continue to improve is shared by Sithe Global, but for current application at the Desert Rock location and when the proposed emission rates of a SCPB technology are considered, an IGCC offers no environmental, technical, operational, or financial advantages.. Another location, particularly lower elevations with a supply of petcoke in an industrial complex would be more appealing.

Last, investment necessary to support the development of an IGCC plant is two to four times the amount necessary for a SCPC plant, and difficult to gather and place at risk for new technology, even for a large utility company such as AEP which they discussed in their filings with the state of Ohio PUC. Schedule extensions and average three year shake-downs with higher capital costs, combined with the other comparisons clearly point to a supercritical pulverized coal Desert Rock Energy Project.

## VIII. References

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4. *Coal-Based Integrated Coal Gasification Combined Cycle: Market Penetration Recommendations and Strategies*; (Booz, Allen, Hamilton); Produced for the Department of Energy (DOE)/ National Energy Technology Laboratory (NETL) and the Gasification Technologies Council (GTC), September 2004
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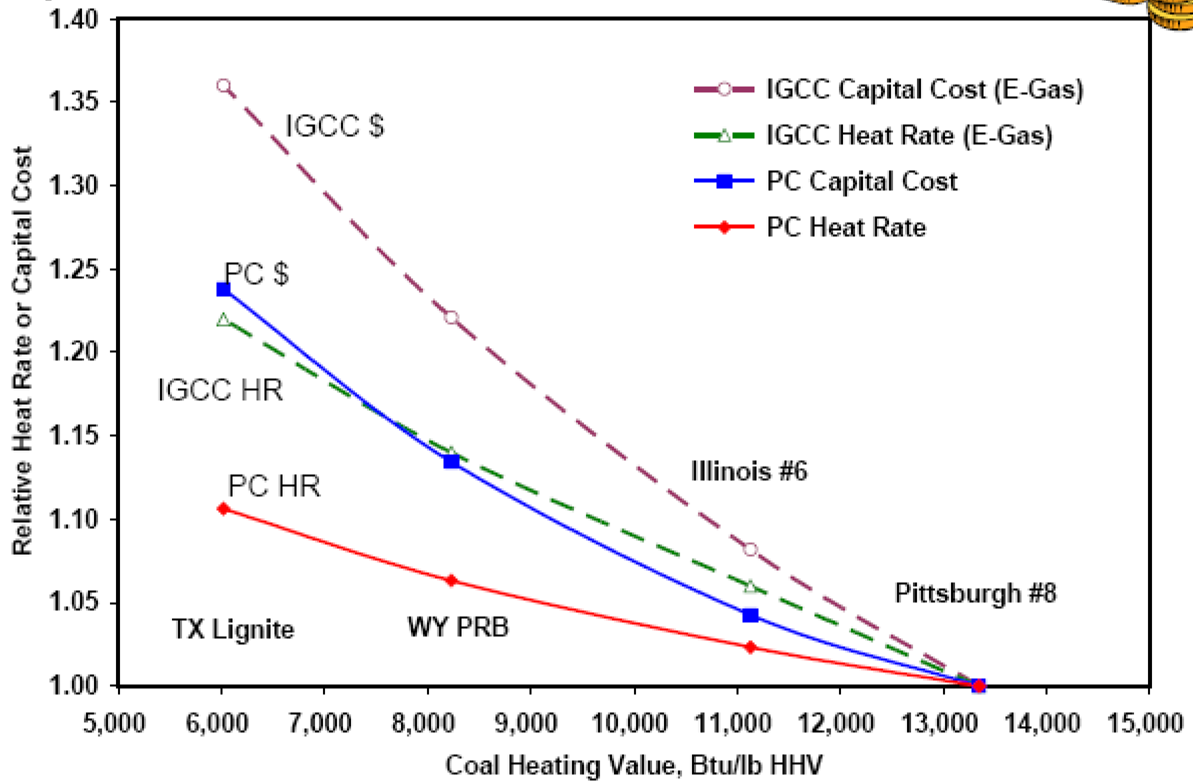
9. *IGCC for Medium Sized Power Plants at Coal Mines*, (David W. Wakefield and Robert G. Jackson – Econo-Power International Corporation); Presentation for CoalGen August 6, 2003, Columbus, Ohio
10. *Tampa Electric IGCC Program, Project Performance Summary Clean Coal Technology Demonstration Program*, Report to the Department of Energy by Tampa Electric Company June 2004

# IX. Attachments

| Technology | PC Subcritical | PC Supercritical | IGCC (E-Gas) W/ Spare | IGCC (E-Gas) No Spare | NGCC High CF | NGCC Low CF |
|---|---|---|---|---|---|---|
| Total Plant Cost, $/kW | 1,230 | 1,290 | 1,350 | 1,250 | 440 | 440 |
| Total Capital Requirement, $/kW | 1,430 | 1,490 | 1,610 | 1,490 | 475 | 475 |
| Fixed O&M, $/kW-yr | 40.5 | 41.1 | 56.1 | 52.0 | 5.1 | 5.1 |
| Variable O&M, $/MWh | 1.7 | 1.6 | 0.9 | 0.9 | 2.1 | 2.1 |
| Avg. Heat Rate, Btu/kWh (HHV) | 9,310 | 8,690 | 8,630 | 8,630 | 7,200 | 7,200 |
| Capacity Factor, % | 80 | 80 | 80 | 80 | 80 | 40 |
| Levelized Fuel Cost, $/Mbtu (2003$) | 1.50 | 1.50 | 1.50 | 1.50 | 5.00 | 5.00 |
| Capital, $/MWh (Levelized) | 25.0 | 26.1 | 28.1 | 26.0 | 8.4 | 16.9 |
| O&M, $/MWh (Levelized) | 7.5 | 7.5 | 8.9 | 8.3 | 2.9 | 3.6 |
| Fuel, $/MWh (Levelized) | 14.0 | 13.0 | 12.9 | 12.9 | 36.0 | 36.0 |
| **Levelized Total COE, $/MWh** | **46.5** | **46.6** | **49.9** | **47.2** | **47.3** | **56.5** |

**Source: Electric Power Research Institute**

# Effect of Coal Quality on PC and IGCC Plant Heat Rates and Capital Cost



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## Cost and Performance for 500 MW Power Plants

*Pittsburgh #8 Bituminous Coal –for National Coal Council Report*

| | PC Subcritical | PC Supercritical | IGCC (E-Gas) Spare/No Spare | NGCC |
|---|---|---|---|---|
| Total Plant Cost, $/kW | 1,230 | 1,290 | 1,350/1,250 | 440 |
| Total Capital Requirement, $/kW | 1,430 | 1,490 | 1,610/1,490 | 475 |
| Fixed O&M, $/kW-yr | 40.5 | 41.1 | 56.1/52.0 | 5.1 |
| Variable O&M, $/MWh | 1.7 | 1.6 | 0.9 | 2.1 |
| Ave. Heat Rate, Btu/kWh (HHV) | 9,300 | 8,690 | 8,630 | 7,200 |
| Capacity Factor, % | 80 | 80 | 80 | 80/40 |
| Levelized Fuel Cost, $/MBtu | 1.50 | 1.50 | 1.50 | 5.00 |
| Levelized COE, $/MWh (2003$) | 46.5 | 46.6 | 49.9/47.2 | 47.3/56.5 |



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## Impact of Capacity Factor on Levelized COE