APPENDIX B:

INTEGRATED COAL GASIFICATION COMBINED CYCLE (IGCC) TECHNOLOGY STATUS

TECHNOLOGY OVERVIEW

Gasification technology has been well established over many years for chemical and refinery processes. While there are reportedly over 100 gasification plants world wide, these are predominately small scale, utilizing heavy oil as the gasification media. The basic physics and science of gasification is well established for these applications. In addition there are a number of firms with experience in design, material selection, fabrication and construction of these refinery/chemical-grade gasification units. There is also significant operating experience, which has served to improve designs and material applications as well as improving availability and reducing operating costs for these refinery gasification processes.

IGCC, utilizing solid coal fuels appears to be a promising new technology, which offers the hope of providing environmental improvements for coal fired power generation. However, the development of IGCC, combining gasification technology with combined cycle technology, is a significant step from the well-established refinery gasification process. One of the most significant issues facing IGCC is the scaling gasification technology to be able to reliably produce and handle large volumes of syngas that are required to reach the necessary economies of scale for an economical IGCC installation. The use of solid fuel instead of heavy oil introduces new requirements for temperature designs and waste product treatment. Material applications are different under a solid fueled IGCC to accommodate temperature and by-product issues as well as to account for the ash content of coal and its impacts on tube wastage. Syngas quality must be compatible with the fuel requirements for new high temperature combustion turbines. The combustion designs of the combustion turbines need to be

redesigned to accommodate the lower quality syngas. Due to the many differences, there are a limited number of firms with the necessary experience or capability to design, fabricate or construct an IGCC unit. There is little operating experience to provide documentation of expected operating costs or unit reliability.

There are only 4 demonstration IGCC units worldwide designed specifically for power generation based on the use of coal as the primary fuel. The location, size and in-service dates are shown below:

1. Wabash River, Indiana (262 MW, October 1995). During the first three quarters of 2003, the gasification unit was online 61.3%, with 15.5 % not required. Syngas availability was 74%.
2. Tampa Electric, Florida (250 MW, September 1996). This unit currently burns a mixture of 55% petroleum coke and 45% coal. Gasifier on-stream time has averaged 75% in 2001-2003.
3. NUON, Buggenum, The Netherlands (253 MW, January 1994). Due to CO2 emission restrictions, this plant now runs on natural gas. Coal gasification is no longer utilized, however, attempts are underway to test the gasifier with biomass fuel.
4. ELCOGAS, Puertollano, Spain (300 MW, December 1997). From August 2003 to July 2004, the gasifier on-steam time averaged 69.2%. Operating hours in IGCC mode peaked at 5,408 hours in 2002 (62%).

All four are demonstration projects designed to test a specific component of the technology and none of the projects are considered to be demonstrations of commercially viable projects. All four use different design technologies. All four included significant cost sharing through governmental and/or developmental grants. In addition to these 4 units, Pinon Pine is a demonstration plant under the DOE CCT demonstration program located at Sierra Pacific's Tracy station near Reno, Nevada.

Coal derived fuel gas was never delivered to the combined cycle unit during the demonstration period. The longest gasifier run was conducted in early 2001 for approximately 25 hours. The unit is now operated in combined cycle mode on natural gas.

Interest in IGCC technology is growing rapidly as demonstrated by recent announcements within the industry. In August 2003, Conoco Phillips (COP) purchased the gasification technology from E-Gas and announced an agreement with Fluor to provide development support, conceptual design, detailed engineering and turnkey construction of solid fuel IGCC facilities. In June 2004, GE Energy acquired Chevron Texaco's gasification technology business and soon after signed a letter of intent with Bechtel to "study the feasibility of constructing a commercial, integrated gasification combined cycle (IGCC) generating station".

These are promising developments for the future of IGCC technology due to the available resources these multi-national corporations can devote to the development of IGCC technology. However, the fact remains that the viable cost competitive commercialization of IGCC technology is still very early in the developmental stage. The US DOE has provided funding for the development of this technology through its Clean Coal Power Initiative (CCPI) in early 2002. The CCPI solicited demonstration projects, which potentially could qualify for DOE co-funding of up to 50% of project cost. In the 2002 solicitation, one IGCC project was selected, the WMPI in Pennsylvania. This project utilizes the Shell gasification technology to gasify coal and anthracite waste to produce power, steam and diesel liquids. A second solicitation was issued in 2004 and received 7 IGCC proposed projects. Selection of qualifying projects is expected by the end of 2004.

The 4 existing IGCC plants discussed above can be considered the "Alpha version" of IGCC technology. The issues/problems listed below are examples of typical items

encountered with the first rollout, or "Alpha version", of a new technology. The next cycle of IGCC units to be built would be considered the "Beta version" of the technology, or the second attempt at commercialization. It is expected that the problems listed below would be corrected in the Beta version of the technology. However, the design changes incorporated to alleviate these problems can often result in new problems. In addition, the Beta versions will be attempts to scale-up the size of the units for economies of scale. Design changes for the scale-up can also introduce new operating issues, material issues, expansion and support issues as well as other problems.

Examples of Developmental Issues at Wabash River

- 1997, main steam piping support systems were modified to allow for needed expansion during start-ups. Tube leaks continued to be a problem after this modification
- 1997, HRSG was planned for replacement due to Foster Wheeler designed support issues.
- 1997, feed water heating problems limited steam turbine output by 9 MW.
- 1999, a 14-week unscheduled outage occurred due to failure of the air compressor rotor
- 1999, a water spray system was added to the air intake to eliminate capacity limitations due to temperature
- 1999, unit set continuous operating record of over 1,300 hours, 128 consecutive days of gasification operation
- 2000, Air Separation Unit (ASU) and power block showed high downtimes, HRSG tube failures caused 19 days of unscheduled outage.
- 2002, unplanned outage rate of 6.5%, planned outage rate of 6%. Syngas unit availability was 78.7% with a forced outage rate of 11%. 4th quarter slag-tap pluggage caused a 10-day forced outage.
- 2003, unplanned outage rate of 13%, planned outage rate of 10.3%
- Syngas Cooler (SGC) requires two outages per year due to fouling.

- Refractory change out required every 2-3 years. Refractory patching required on each outage (planned and unplanned), especially in the slag-tap area.
- Wabash has a spare gasifier, so the outage impact of refractory problems is minimized.

Generic Issues With Existing IGCC Technology

Listed below are various equipment components and their associated operational and developmental issues. Design changes for the Beta version IGCC units will no doubt address these issues; however, the success of design changes cannot be verified until the Beta units accumulate adequate operating experience.

Air Separation Units (ASU)

ASU's are utilized in many industries and numerous applications. Historically, ASU's have experienced high availabilities around 98%, however, the ASU's developed for the Wabash and Tampa IGCC's have experienced unusual problems and outages.

Coal Feeding

Wet coal slurry feed pumps are very reliable at Wabash; however, Tampa made design decisions to eliminate some of the features of the Wabash pumps and has encountered forced outages due to these pumps. Dry coal feed systems used at NUON and ELCOGAS require more maintenance than the wet slurry systems for continuous operation.

Fuel Injector Tip Life

Initial fuel injector life for the wet slurry was initially 60 to 90 days. Modifications have improved performance to over 4,000 hours of operation between replacements. New operating procedures allow tip replacement in as little as 18 hours.

Refractory Life

Refractory life for both Wabash and Tampa is typically 2-3 years, however patching repairs are performed during each outage. Partial replacements require a 12-15 day outage, while full replacement requires 30-35 days.

According to EPRI reports, for future commercial IGCC plants in the 500-600 MW range, spare gasifiers will be required for the Texaco and the E-Gas designs to achieve availabilities in the 90% range. E-Gas presented a paper in 2002 indicating a single gasifier is expected to provide 80% availability in the next generation of IGCC units. However, neither of these projections has been documented in practice.

Circulating Slag Water

Circulating water from the slag quench chamber contains sharp fine solids so erosion is a constant problem. Future designs need to incorporate long radius bends where possible to minimize erosion problems. Acid or Alkali are often required to be added to the quench water to keep pH in a range to avoid corrosion and prevent precipitation.

Slag Tap Blockage

This problem has occurred occasionally at all 4 units. Generally 8-10 days of outage are required to remove the blockage.

Syngas Cooler Fouling and Corrosion

Fouling of this component has lead to forced outages on all 4 existing units. For the NUON and ELCOGAS units, this has not been a significant cause of plant outages.

Salable By-Products

One of the advantages claimed for IGCC is its potential to produce by-products such as slag, elemental sulfur or sulfuric acid, which can be sold as useful commercial materials.

This also holds true for SCPC units also can produce by-products such as fly ash for use in concrete and gypsum for the manufacturer of wallboard.

IGCC EMISSION COMPARISONS

One of the reported benefits of IGCC technology that has been characterized in numerous press releases is that IGCC offers significant environmental benefits over the traditional pulverized coal technology. Most often the emissions of an IGCC plant are compared to existing coal fueled power plants. When the comparison is made between IGCC and a new state-of-the art SCPC the results can be quite different. As shown in Table B1, which compares the emissions data for both technologies, the two technologies are reasonably close in all emissions categories. With the newer high efficiency supercritical designs offered today, the pulverized coal projected heat rates have moved much closer to the projected IGCC heat rates which are lower than the traditional natural gas fired combined cycle heat rates due to the addition of the gasifier and emissions controls. In the area of NOx removal, SCPC is projected to achieve lower levels than IGCC technology.

Table B1

Emission Comparison - IGCC vs. SCPC Iatan 2				
	SO_2 Removal	**NOx Emission Rate**	**Mercury Removal w/o carbon injection**	**CO2 Emissions**
Iatan 2 SCPC	95 – 98%	0.07 - 0.08 lb/MMBtu	≥70%	1,866 lbs/MWh
IGCC (without SCR)	99%	≤0.07 lb/MMBtu	>90%	1,716 lbs/MWh
Iatan 2 Heat Rate	9100 Btu/kWh			
IGCC Heat Rate	8370 Btu/kWh			

Source: IGCC emissions data was sourced from EPRI Technical Assessment Guide

Iatan 2 data is based on expected permit levels from Burns and McDonnell Iatan Unit 2 Project Definition Report

NOx Emission Issues

While projected IGCC units may be able to achieve NOx emissions as low as 5 ppm there are significant issues to achieving further reductions in NOx emissions . A paper presented by General Electric at the 5th European Gasification Conference in April 2002, noted the following; "However, if NOx emissions below 5 ppm are required with current IGCC combustion technology, it is possible to configure the plant with an exhaust SCR (Selective Catalytic Reduction system) if the amount of SO2 in the syngas is limited to below 16 ppm (or about 2 ppm in the exhaust). However, this approach, though technically feasible, adds significant capital costs, maintenance, and plant complexity and is, thus, not recommended".

IGCC COST COMPARISONS

The table below indicates the price comparison for IGCC and Supercritical Pulverized Coal (SCPC) units. The IGCC costs are from EPRI's Technical Assessment Guide, Power Generation and Storage Technology Options, Report # 1004973, December 2003. The SCPC costs are from Burns & McDonnell's Iatan Unit 2 Project Definition Report. The two columns under IGCC and SCPC represent the low and high range of costs or operating performance in 2004 $.

COST ASSUMPTIONS FOR IGCC & SCPC				
Cost Item	IGCC		SCPC	
Installed Cost ($/kW)	$ 1,501	$ 1,736	$ 1,212	$ 1,313
Fixed O&M ($/kW-Yr)	$ 46.13	$ 50.84	$ 15.40	$ 17.00
Variable O&M ($/MWh)	$ 2.05	$ 2.26	$ 1.89	$ 2.04
Heat Rate (Btu/kWh)	8,621	9,733	9,000	9,100

In an article entitled GETTING TO 'CLEAN COAL' published in the February 23, 2004 issue of Chemical and Engineering News, it was noted that the cost of an IGCC is

expected to be 20 - 40% higher than a SCPC. This article's expectations regarding the cost differential between an IGCC and a SCPC reinforce the data shown in the table above.

Updated cost data and other IGCC issues are shown in the Supplemental IGCC Attachment at the end of this report.

KCP&L FINDINGS AND RECOMMENDATIONS

Although IGCC appears to be a promising new technology, there are still numerous developmental, operational and design/construction cost issues that need to be resolved before large-scale IGCC electric generation facilities utilizing coal as the primary feedstock can become commercial viable. There are significant operating cost, capital cost, and reliability risks associated with adopting this technology over more proven SCPC technology.

As part of KCP&L's Resource Plan's screening process IGCC was thoroughly studied and evaluated. After many months of data acquisition and evaluation IGCC was rejected due to the immaturity of the technology. KCP&L's concerns with premature implementation of IGCC technology are consistent with the concerns expressed by other utilities and regulatory agencies concerning this technology (see Supplemental IGCC Review located at the end of this appendix). KCP&L believes that since no utility scale IGCC plant has been fully developed into a mature, cost competitive and reliable technology, the addition to KCP&L's generating fleet of an IGCC plant instead of a SCPC by the end of this decade is not in the best interest of its customers.

KCP&L recommends the installation of SCPC technology as proposed in the Comprehensive Plan. This alternative will provide KCP&L customers greater protection

from exposure to the technology risks associated with IGCC. KCP&L will continue to follow the development of IGCC technology and assess its application for future decisions on generating additions.

SUPPLEMENTAL IGCC REVIEW:
PUBLIC SERVICE COMMISSION OF WISCONSIN, Re: W.E. PROPOSED IGCC PLANT

In testimony before the Public Service Commission of Wisconsin, Docket No. 05-CE-130, Allan Mihm, Director of Engineering for W.E. Power provided the cost estimates shown below:

"The cost in 2003 $'s for both SCPC (Super Critical Pulverized Coal) generating facilities is approximately $1.7 billion or $1,400/kW. The 2003 cost of the single IGCC facility is about $920 million or $1,740/kW." These costs were developed as part of an IGCC Technology Evaluation Study performed by Fluor Corporation.

Mr. Mihm also added the following comments:

"To date, only a few commercial scale coal-based IGCC power plants have been constructed and none at the size contemplated in our application. The engineers and contractors who constructed these (existing) plants were not required to take any significant risk for performance guarantees for the gasification section of the facility, nor the facility as a whole. The EPC industry is not likely to provide total plant guarantees for IGCC plants in today's market. As more experience constructing and operating IGCC plants is acquired, it is believed that the EPC industry may be willing to provide performance guarantees similar to those for conventional power plants....In today's market, it was a general consensus (among several EPC vendors) that a cost adder of at least 10% would be needed to cover the risk associated with cost, schedule and performance guarantees."

Mr. Douglas H. Cortez, Vice President, Project Development and Finance, at Fluor Corporation also testified in front of the PSCW. His response to the question, "How would you answer the arguments of those who support the position that all 3 proposed coal-based units be IGCC," is shown below:

"Although the technology has the potential to deliver these benefits (principally lower air emissions), the technology has yet to be proven as reliable as the SCPC technology on the same commercial scale. In addition, the cost of electricity from the IGCC technology available today is expected to be higher based on currently available equipment...Although W.E. could choose to construct three IGCC units at this time to meet electricity demands, it would place the utility consumers in Wisconsin at a level of risk that may be difficult to measure or control at this time."

The Citizens' Utility Board (CUB, of Wisconsin) filed a brief in Docket 05-CE-130 addressing the substantive issues of W.E.'s proposed construction plans. Key portions of that filing are shown below.

"The commission should reject the proposal for approval of an IGCC unit to be ready for operation by 2011." Technology issues sited as reasons for rejecting the proposed IGCC unit are shown below:

- "There is inadequate information to justify cost, reliability and design and operation of the proposed IGCC unit; and,
- The record does not indicate that an IGCC unit is appropriately added in 2011 (or in fact any year in the study period is an IGCC unit found to be a cost-effective resource option)."

In its final ruling regarding the proposed W.E. IGCC unit, the PSCW determined, "The IGCC unit is not cost-effective at this time."

SUPPLEMENTAL IGCC NEWS:

IGCC PRESS RELEASES

GE Energy, Bechtel Announce Alliance for Cleaner Coal Projects; Companies to Offer Standard, Optimized Package for IGCC Power Projects

ATLANTA & SAN FRANCISCO--(BUSINESS WIRE)--Oct. 4, 2004--GE Energy and Bechtel Corporation today announced their intent to establish an alliance to develop a standard commercial offering for optimized integrated combined-cycle gasification (IGCC) projects in North America.

IGCC systems convert coal and other hydrocarbons into synthetic gas, which after cleanup is used as the primary fuel for a gas turbine in a combined-cycle system. IGCC systems offer significant environmental benefits compared to traditional pulverized coal power plants.

The alliance will integrate the development, marketing, commercialization and implementation of GE's IGCC process with Bechtel's engineering, procurement and construction (EPC) expertise.

Bechtel is one of the world's leading EPC contractors, with significant experience in the design and construction of gasification plants.
GE Energy is a leading supplier of gas turbines for IGCC applications, having provided gas turbines for more than 60 percent of the world's operating IGCC plants. The company also recently purchased the Chevron Texaco gasification technology business, whose technology has been applied to many of the world's IGCC power plants.

GE Energy has worked with Bechtel on a number of IGCC projects, including the 100-megawatt Cool Water plant in California, a demonstration project completed in 1984, and the Tampa Electric Company's 250-megawatt Polk Power Station in Florida, which began operation in 1996.

Edward Lowe, general manager of gasification and product line management for GE Energy, said: "We look forward to our alliance with Bechtel, which will enable both companies to integrate their complementary strengths and resources. The IGCC

alliance will benefit our clients through commercialization and execution of IGCC projects, based on a standard GE IGCC product."

Lowe added, "The alliance will initially focus on establishing successful IGCC ventures for the power generation market in the U.S., establish a leadership position in the production of cleaner power from coal and petroleum coke, and bring value to a wide range of customers."

Scott Ogilvie, President of Bechtel Power Corporation, said: "We are very excited to be aligning Bechtel's and GE's expertise and resources to further advance gasification technology, and to provide competitive gasification solutions to the industry. This alliance can significantly improve prospects for developing cleaner coal projects and will enhance the competitiveness of IGCC in the areas of price, performance, schedule, availability and emissions."