IGCC Working Group

Jim Bridger IGCC Study

March 27, 2008

Overview

- Summary of Work Performed
- Deliverables
- Design Basis
- Summary of Proposals
- Technical Summary
- Summary of Results – (Blinded)
- Questions or Comments

Summary of Work Performed

- In July 2006, the Wyoming Infrastructure Authority (WIA) issued an RFP seeking a partnership to develop a Wyoming based IGCC facility to pursue federal co-funding under Section 413 of the US Energy Policy Act of 2005. Required key attributes:
  - Elevation above 4,000’
  - Coal heating value not to exceed 9,000 Btus per lb
  - 200 MW or larger
  - Sited in Wyoming
  - Carbon capture capable
  - Demonstrated project capabilities
- PacifiCorp worked with Siemens Power Systems and Kiewitt to prepare a proposal based on Siemens gasifiers and power generation equipment. Balance of plant effort prepared by Sargent & Lundy
- PacifiCorp submitted its proposal to WIA in October 2006
- PacifiCorp short listed in February, 2007

Summary of Work Performed

- WIA and PacifiCorp executed an MOU in April 2007 in which PacifiCorp agreed to perform detailed IGCC feasibility studies with one or more gasification technology providers.
- PacifiCorp agreed to spend up to $2 million to perform feasibility studies.
- PacifiCorp engaged Sargent & Lundy (S&L) in May 2007 to provide owner's engineer support
- WIA engaged RW Beck for technical support

Summary of Work Performed

- PacifiCorp issued an RFP to six IGCC technology companies in mid-July, 2007; responses by 8/2/07.
- Following companies/technologies made proposals:
  - Black & Veatch (Shell)
  - General Electric @ no cost
  - Siemens
  - WorleyParsons (ConocoPhillips "E-Gas")
- Mitsubishi (air blown gasifier) and Southern Company/Kellogg-Brown-Root (transport gasifier) declined

Summary of Work Performed

- Proposals were independently evaluated by PacifiCorp, RW Beck and S&L. The proposals / technologies were rank-ordered as follows:
  1. Shell
  2. ConocoPhillips “E-Gas”
  3. General Electric
  4. Siemens
- Engineering services contracts and confidentiality agreements were entered into with all four companies representing the various gasification technologies.

Confidentiality Agreements

- Confidentiality agreements were entered into with all four companies representing the various gasification technologies.
- These confidentiality agreements prevent PacifiCorp from making the study results available to outside parties.
- The summary content of this presentation has been reviewed and approved by Black & Veatch, ConocoPhillips, and Siemens.
- We can forward any requests for additional information to the technology providers.

Feasibility Study Deliverables

- Performance on syngas derived from design coal & natural gas at Jim Bridger & an alternate site:
  - Capacity (gross and net)
  - Heat Rate (gross and net)
- Capital (~+/-25%) and O&M cost estimates
- Water balances
- Summary level heat and material balances
- Criteria pollutant emissions (NOx, SO_2, PM_{10})
- CO_2 emissions
- Availability analysis
- Plot plan & general arrangement drawings

Feasibility Study Deliverables (cont'd)

- Interface requirements (water, coal, waste..)
- Cost estimate for CO_2 capture & performance impact of capture
- Project schedules
- System descriptions
- FEED scope and cost
- Commercial arrangement for project execution
- Documentation and support for federal funding application

Jim Bridger Plant – IGCC Site

Jim Bridger Site & Design Basis

- Jim Bridger is a coal-fired plant with 4 - 530 MW pulverized coal units
- Mine mouth plant
- Access rights to additional water from Green River
- Dedicated operations and maintenance staff
- Elevation: 6,620 feet
- Proposed new interconnection point for major interstate transmission system upgrades

Design Basis

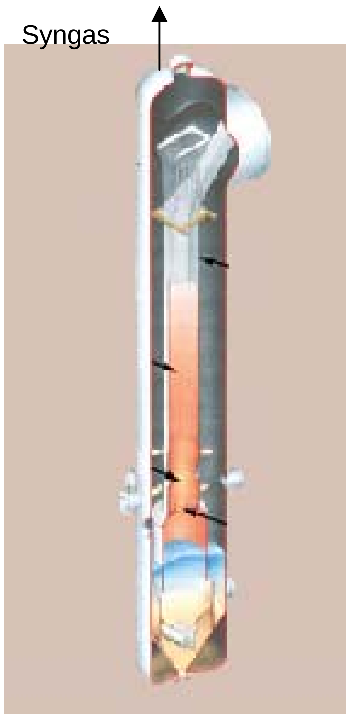
- Design coal: Powder River Basin, 8,800 Btus/lb
- Performance coal: Jim Bridger, 9,540 Btus/lb (one technology provider limited its study effort to a proxy PRB 8,800 coal only)
- Nominal Duct Firing (natural gas only)
- CO_2 capture levels design targets:
  - Better than California standard of 1,100 lbs CO_2/MWh (net)
  - Single stage shift – technology supplier identified ”sweet spot”
  - CO_2 delivered at 2500 psig (dry, H_2S less than 20 ppm)
- Average site ambient temperature: 41.6 degrees Fahrenheit
- Natural gas backup @ transmission pressure
- 500 kV delivery
- Alternate site (4,650’ using PRB-8,800 Btu/lb coal)

Many different kinds of gasifiers….

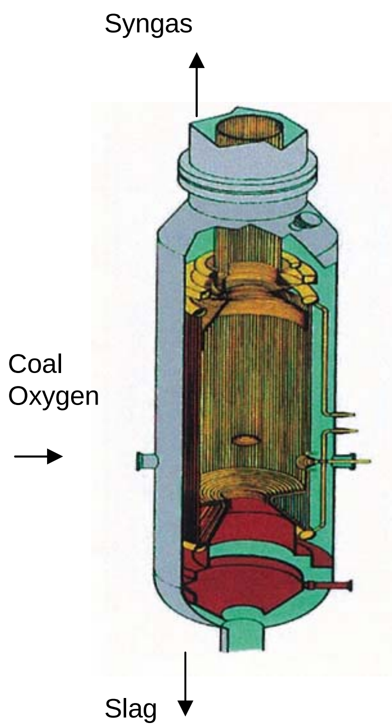
← Air-blown → ← Oxygen-blown →

← Dry-feed → ← Slurry-feed →

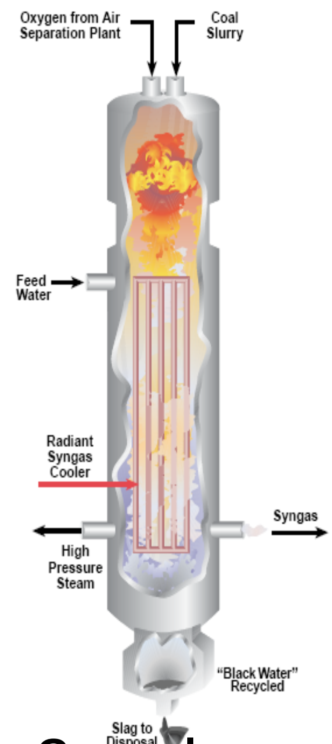
← Membrane Waterwall → ← Refractory →



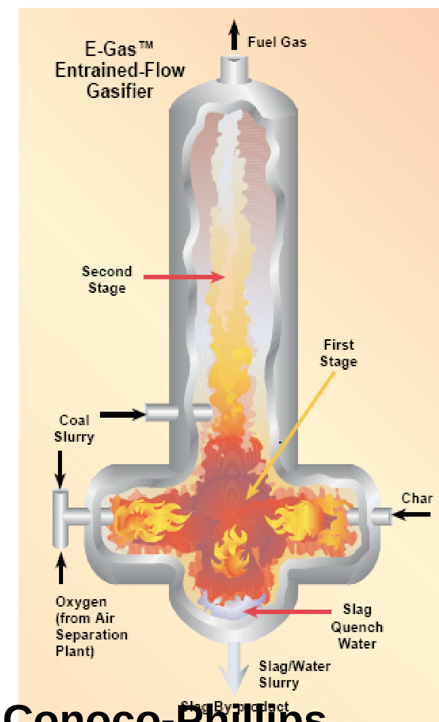
Mitsubishi



Shell

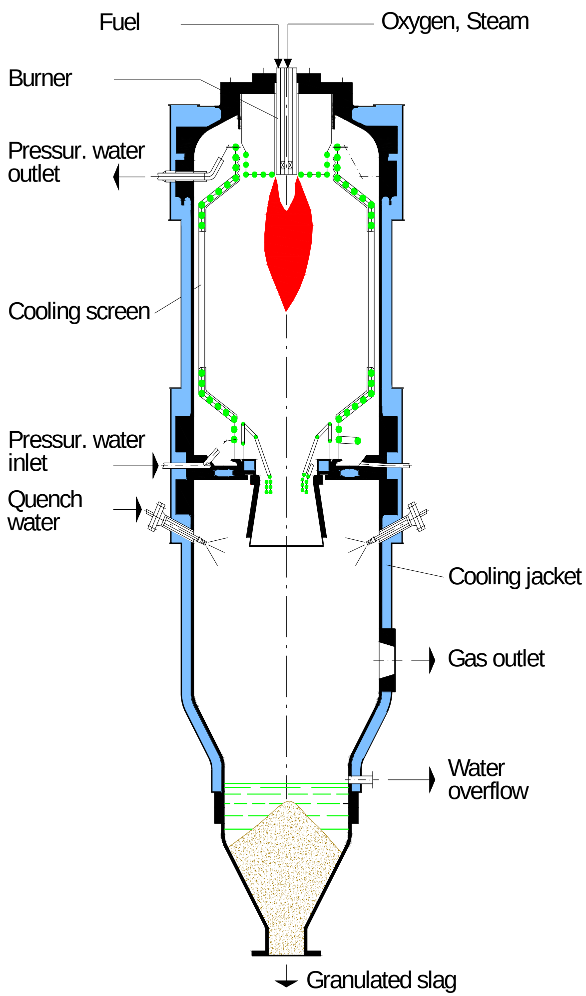


General Electric



Conoco-Phillips

Siemens Gasifier



General Electric

- Dry feed (with Stamet pump), entrained flow, oxygen blown, single stage, refractory lined, slagging gasifier
- Two (2) “Texaco” gasifiers feeding a 2x1 combined cycle utilizing GE 7FB gas turbines
- No constructor identified
- No PRB coal experience – Stamet pump is GE’s low rank coal solution; needs to be demonstrated at scale. Scale injection technology also needs to be verified.
- Commercial IGCC experience (one operating IGCC plant in U.S.- TECO Polk); multiple GE gasifiers operating in world
- Provided summary level cost and performance information
- No results are presented due to difference in Jim Bridger design basis and General Electric’s.

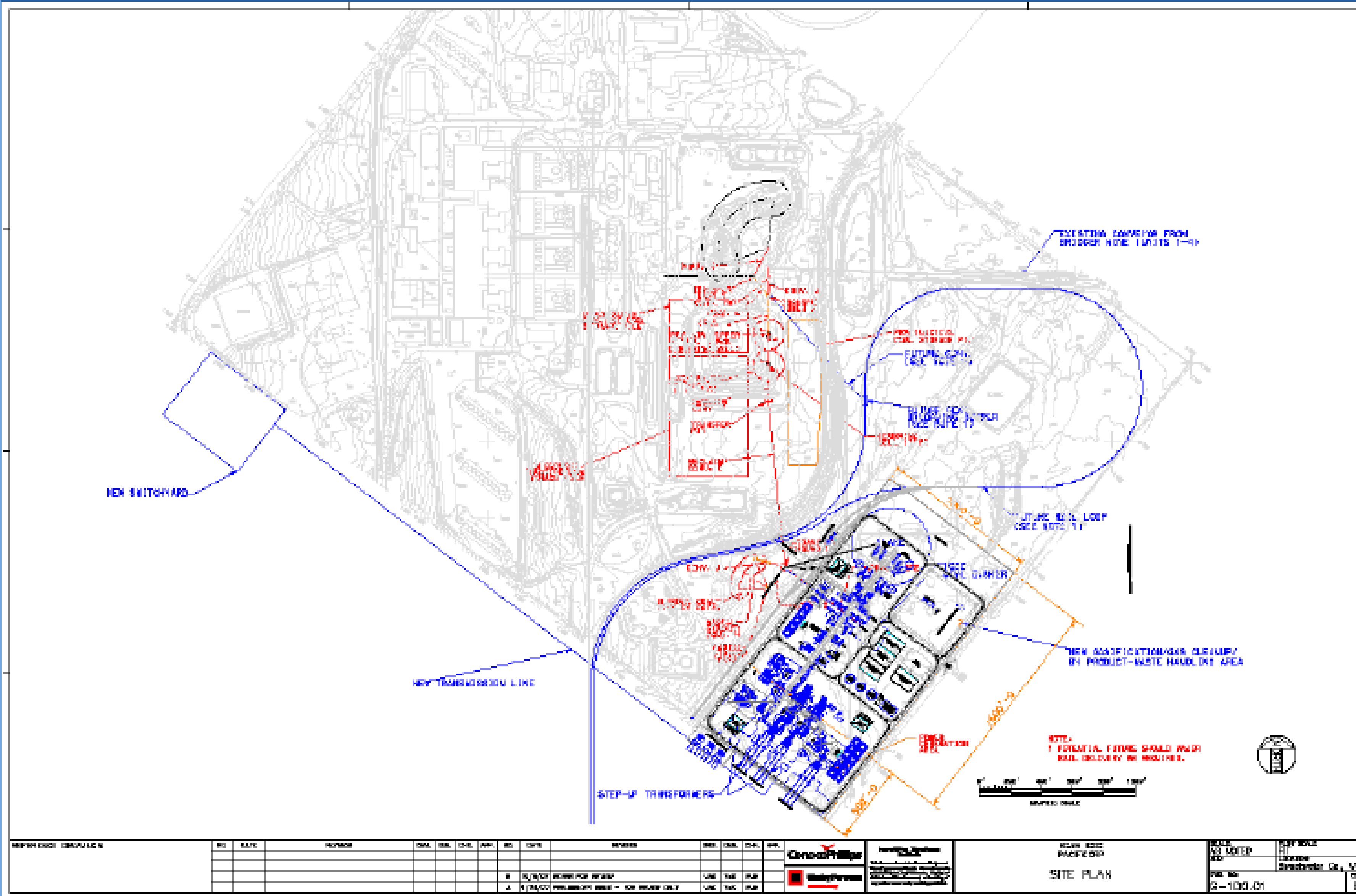
Siemens

- Dry feed, entrained flow, oxygen blown, membrane wall, single stage, quench, slagging gasifier
- Three gasifiers feeding 2x1combined cycle using Siemens SGT5000F gas turbines, Selexol acid gas removal system, SCR system
- Sour shift, single stage (single vessel) for CO_2 removal
- Proposed gasifier (500 MWthermal) – no experience at this size
- Constructor supported proposal (Kiewitt)
- CO_2 capture and IGCC experience minimal
- Low rank coal gasification experience (but not with PRB)
- Potential for a low cost gasifier
- Perceived to have greater promise of funding for gasifier development
- Technology has limited heat recovery from syngas cooling resulting in a lower steam turbine generator output than other technologies.

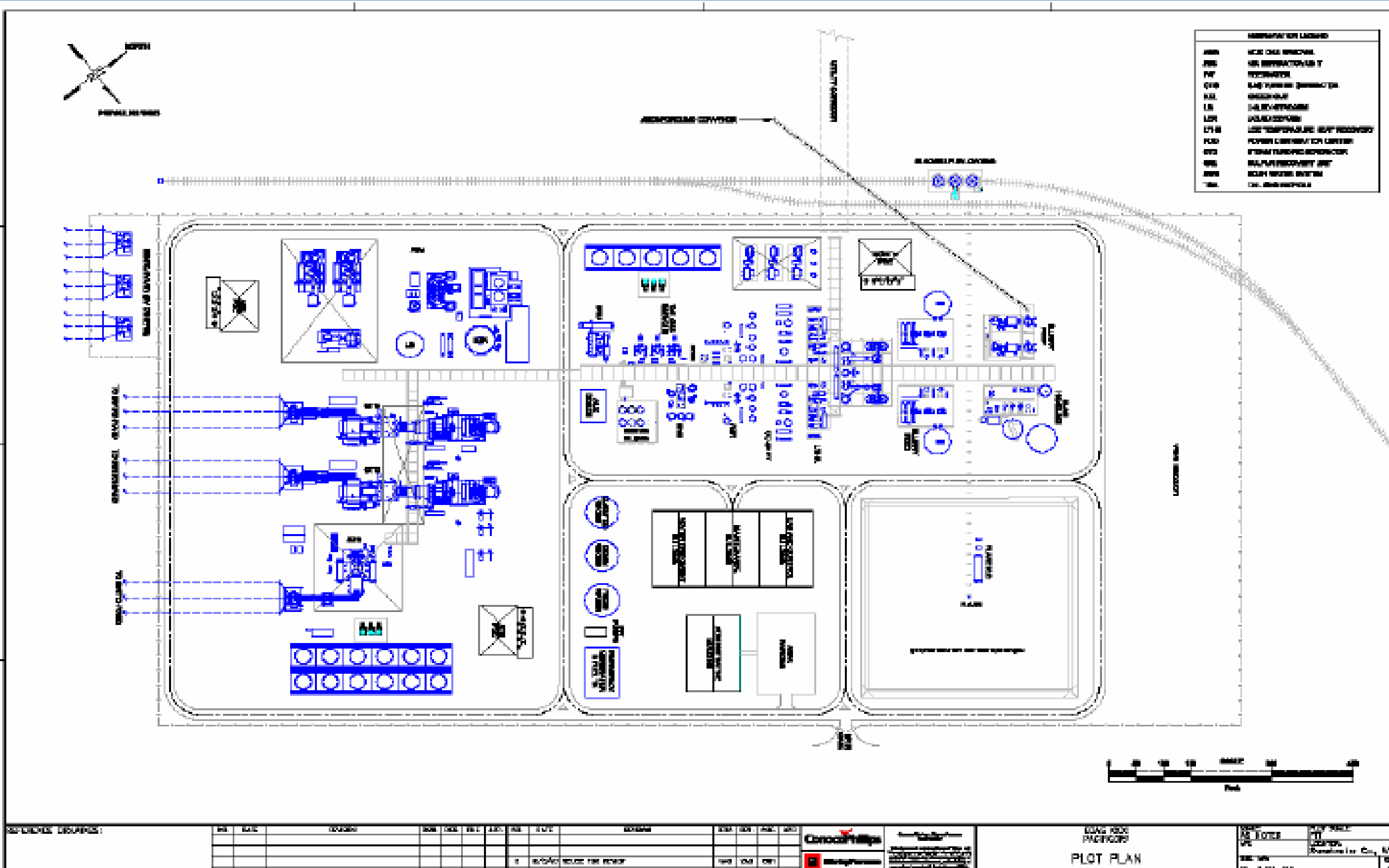
WorleyParsons ("E-Gas") Proposal

- Slurry feed, entrained flow, oxygen blown, refractory-lined, two-stage, slagging gasifier
- Two (2) "E-Gas" gasifiers feeding a 2x1 combined cycle utilizing Siemens SGT5000F gas turbines, Selexol acid gas removal system with SCR system
- Sour shift, single stage for CO_2 removal
- No constructor affiliation proposed (Zachry and TIC suggested)
- Qualified engineer for both process & CO_2 capture
- Low rank coal experience (significant commercial use)
- IGCC experience (one commercially operating at Wabash)
- EPCM contracting methodology proposed
- Highly integrated plant design utilizing compressed air from the combustion turbine to feed the Air Separation Unit. High degree of steam optimization.

WorleyParsons (“E-Gas”) Plot Plan



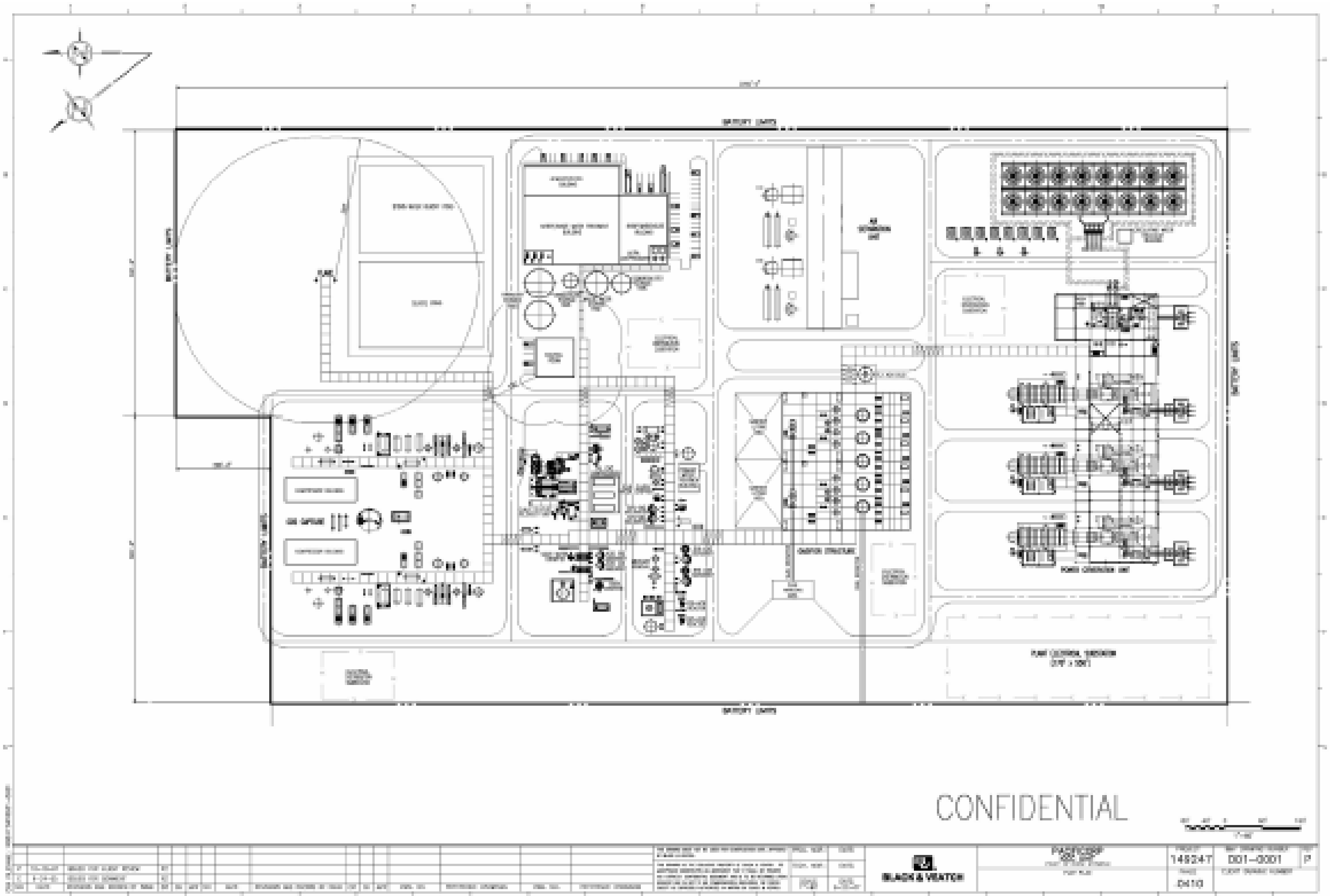
WorleyParsons (“E-Gas”) Plot Plan



Shell

- Dry feed, entrained flow, oxygen blown, membrane wall, multi-injector, slagging gasifier
- Two (2) gasifiers feeding a 3x1 combined cycle configuration using GE 7FB gas turbines, Genosorb acid gas removal system, SCR system.
- Sweet shift for CO_2 removal
- No constructor as part of the proposal, but potential candidates identified with strong relationships
- Qualified engineer with broad gasifier & process experience
- IGCC experience (2 full scale commercial facilities in Europe) and multiple gasifier experience in the world
- Potential for funding for advanced gasifier development is perceived to be low but overall gasification technology risk is low.
- Although Shell technology is considered "most efficient" in the industry, not the case with CCS.

Black & Veatch (Shell) Plot Plan



Gasifier Comparisons (S&L)

Shell Rank: 1	ConocoPhillips Rank: 2	Siemens Rank: 3
The design has now been replicated in a variety of applications in China. This design is updated from the design demonstrated at Buggenum and is the most commercially tested of the 3 systems. The B&V design uses dry pulverizers to grind the coal; a review is needed to evaluate if the system can be operated safely on PRB coal. The Shell gasifier produces little H_2 requiring more shift conversion.	The design has been operating in an IGCC environment at Wabash and before that at LGTI for many years. Annual refractory maintenance is still an issue. Advanced refractory designs developed for DOE may improve maintenance requirements. The 2-stage gasifier design provides both high-efficiency energy conversion from coal, and the slurry feed yields high H_2 generation in the gasifier reducing the requirement for shift-conversion catalyst. The slurry feed system is simpler to operate and maintain than the dry-feed systems proposed.	The design has had excellent operational history at Schwarze Pumpe. The design shows promise but has not been replicated yet for new commercial facilities. There are several gasifiers currently in design. The Siemens design uses dry pulverizers to grind the coal; a review is needed to evaluate if the system can be operated safely on PRB coal. The Siemens gasifier produces little H_2 requiring more shift-conversion.

Gas Clean-Up Systems Comparisons (S&L)

ConocoPhillips Rank: 1	Shell Rank: 2	Siemens Rank: 3
The CoP design uses hot gas filters to clean the raw gas of particulate. This allows for maximizing the recovery of waste heat and production of steam. They have demonstrated excellent performance of this design at Wabash.	Shell uses recycled cooled syngas to quench the temperature of the raw gas leaving the gasifier to protect the waste heat recovery exchanger. This has proven effective at Buggenum, but is costly.	Siemens uses venturi scrubbing to clean the gas prior to waste heat recovery. This is a reliable and effective technology, but results in a lower process efficiency.

Performance Summary (Design Coal)

	A	B	C
Net Capacity on syngas, MW	**483**	**529**	**409**
Net Heat Rate on syngas, Btus/kWh	**11,350**	**11,765**	**12,361**
Annual Availability on syngas	**84.4%**	**79.3%**	**84.6%**
CO_2 Stack Emissions, lbs/MWh on syngas	**477**	**837**	**659**
Percent CO_2 Removal	**79%**	**66%**	**75%**

Performance shown is the expected long term value at average temperature.

Performance does not include duct firing capability.

Cost Summary ($/MWh, 2012 Levelized)

	A	B	C
Total Cost of Energy (Fuel, Capital, and O&M)	**$113.0**	**$133.7**	**$132.6**
Environmental Emissions Costs (CO_2 and criteria pollutants)	$2.85	$4.4	$3.5
Cost of Energy Plus Environmental Cost	**$115.6**	**$138.1**	**$136.1**
Market Value of Duct Firing Capability	($10.1)	($7.1)	($7.0)
Market Value of CO_2 ($0.50/thousand cubic feet, 2007$)	($9.1)	($7.7)	(9.1)
Cost of Energy net of Environmental Costs, Duct Firing Benefit & CO_2 Sales	**$96.4**	**$123.3**	**$120.0**

$133 million investment tax credit would lower IGCC cost of energy

by ~ $3-3.50 MWh

Supercritical Pulverized Coal Cost of Energy (no CO2 capture) = $65/MWh

Alternate Site Performance Summary

	A Design Coal	B Design Coal	C Design Coal
Capacity, MW, New & Clean, 4,650’	512	588	469
Heat Rate, Btus/kWh, New & Clean, 4,650’	11,171	11,514	11,724?
Capacity, MW, New & Clean, Bridger	498	545	422
Heat Rate, Btus/kWh, New & Clean, Bridger	11,151	11,518	12,148

Impact of Varying CO_2 Capture Levels

	A Design Coal	B Design Coal	C Design Coal
Capacity, MW, New & Clean	498	545	422
Heat Rate, Btus/kWh, New & Clean	11,151	11,518	12,148
Capacity, MW, New & Clean, Max Removal	490 (90% removal)	522 (90% removal)	408 (~83% removal)
Heat Rate, Btus/kWh, New & Clean, Max Removal	12,565	12,565	12,759
Capacity, MW, New & Clean, Capture Off	557	589	466
Heat Rate, Btus/kWh, New & Clean, Capture Off	9,251	10,643	10,985
EPCM Capital Cost Attributable to CO_2 Capture	17%	12.5%	13-15%

Availability during Initial Years of Operation

	A	B	C
First Year Expected Availability	**70%**	**63%**	**55%**
Second Year Expected Availability	**80+%**	**72+%**	**76%**

Water Consumption

	790 MW Supercritical Pulverized Coal	A	B	C
Water Consumption, GPM	**5,530**	**4,500**	**4,642**	**5,344**
Water Consumption, Gallons/MWh	**421**	**542**	**511**	**759**

Average annual consumption rates at average temperature with no duct firing

Pulverized Coal is Jim Bridger Unit 5 with no CO_2 capture

Summary of Conclusions

- Performance differences between Bridger coal and 8,800 Btu-PRB coal are relatively minor.
- Contracting methodology has a significant impact on cost of plant; still major capital cost uncertainty; market reluctant to provide "full-wrap" lump sum turn key pricing.
- Federal EPACT income tax credit provides minimal benefit

Summary of Conclusions (Cont'd)

- Long term marketing of CO_2 for enhanced oil recovery necessary to overcome cost and performance premium
- Some improvement in overall performance and cost of energy at lower elevation (depending on technology); needs to be balanced against transmission, coal and water availability
- Front End Engineering Design (FEED) studies are $20+ million.