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Direct Testimony and Schedules
Frank Miao

State of Minnesota
Before the Office of Administrative Hearings
For the Minnesota Public Utilities Commission

*In the Matter of a Petition by Excelsior Energy Inc. for Approval of a Power
Purchase Agreement Under Minn. Stat. § 216B.1694, Determination of Least
Cost Technology, and Establishment of a Clean Energy Technology Minimum
Under Minn. Stat. § 216B.1693*

OAH Docket No. 12-2500-17260-2
PUC Docket No. E6472/M-05-1993

IGCC Technology

September 5, 2006

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1 I. INTRODUCTION AND QUALIFICATIONS

2
3 Q. PLEASE STATE YOUR NAME .

4 A. My name is Frank Miao.

5
6 Q. BY WHOM ARE YOU EMPLOYED AND WHAT IS YOUR POSITION?

7 A. I am the Supervising Process Engineer for WorleyParsons Group.

8
9 Q. FOR WHOM ARE YOU TESTIFYING?

10 A. I am testifying on behalf of Northern States Power Company doing business
11 as Xcel Energy ("Xcel Energy" or the "Company").

12
13 Q. PLEASE SUMMARIZE YOUR QUALIFICATIONS AND EXPERIENCE.

14 A. I have 21 years of experience in chemical process and power generation
15 engineering. I hold a 1991 PhD from Illinois Institute of Technology with a
16 concentration in power generation, waste treatment, and emission control. I
17 also received a 1985 BA degree in Chemical Engineering from Beijing
18 University of Chemical Technology. From 1990 to 1995 I worked for the Gas
19 Technology Institute as a Process Engineer. From 1995 through 1996, I
20 worked for Siemens Westinghouse Power Company as a Senior Engineer.
21 From 1996 to 1997, I was employed by ABB Power Generation in Windsor,
22 Connecticut as a Technical Fellow/Senior Consulting Engineer. In 1997,
23 ABB Power generation was acquired by Alstom, SPA. From 1997 to 2004, I
24 served as a Proposal Manager/Senior Consulting Engineer, Alstom Power
25 (ABB Power Generation) in Windsor, Connecticut.

26
27 Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY IN THIS PROCEEDING?

1 A. The purpose of my testimony is to provide: (1) a discussion of the evolution
2 of Integrated Gasification Combined Cycle ("IGCC") technology; and (2) a
3 discussion of MEP-I LLC's ("Mesaba 1 LLC") proposed IGCC plant,
4 including how it compares to current IGCC plants.
5

6 II. BACKGROUND OF IGCC 7

8 Q. WHAT IS IGCC?

9 A. IGCC is a process used to produce electricity by integrating gasification
10 technology with a combustion turbine based combined cycle operation. In this
11 process, low value fuels such as coal and/or petroleum coke are converted
12 into a mixture of hydrogen (H_2), carbon monoxide (CO), carbon dioxide
13 (CO_2) called "synthesis gas" or simply "syngas." The syngas is then burned in
14 the combustion turbine(s) to generate electricity in a combined cycle mode.
15

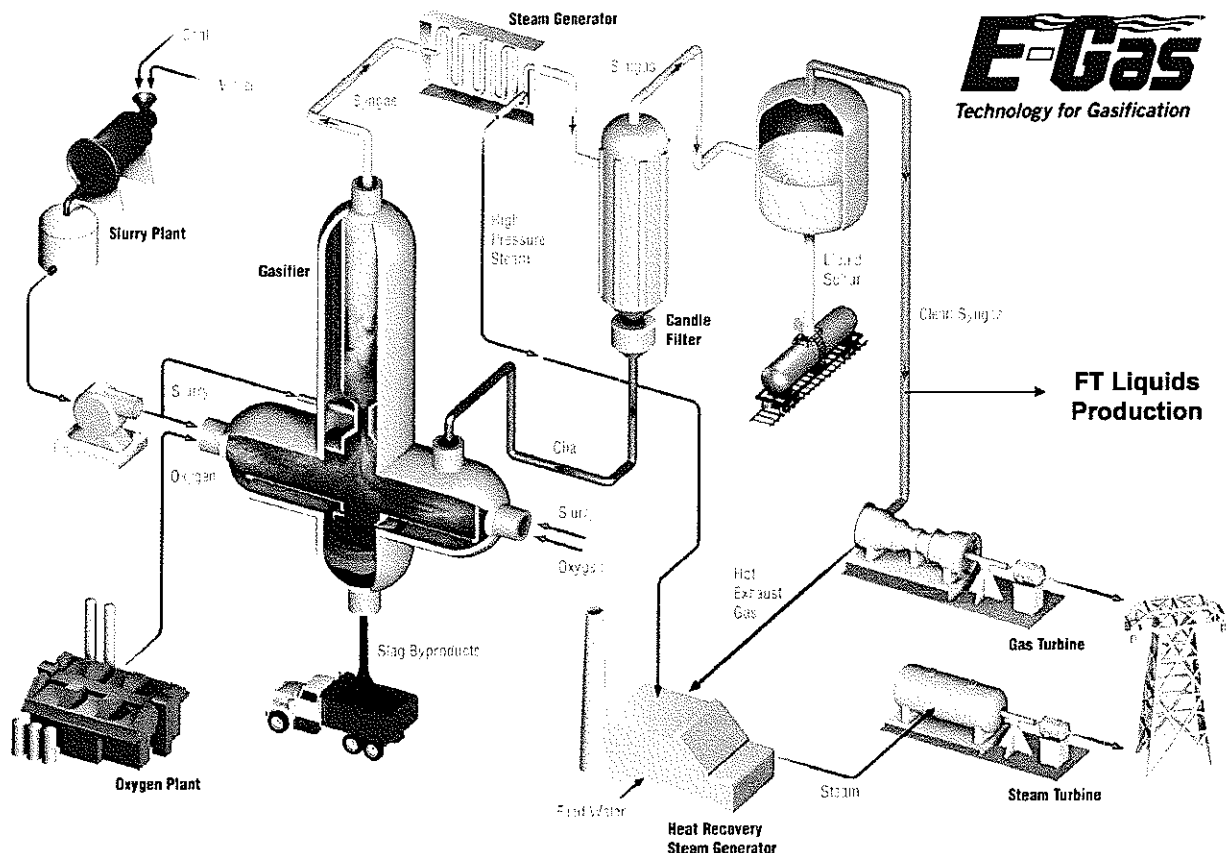
16 Q. HOW DOES IGCC TECHNOLOGY WORK?

17 A. In an IGCC facility, coal and/or petroleum coke along with oxygen typically
18 produced in an on site air separation unit, are fed into a closed vessel called a
19 gasifier in an oxygen limited (sub-stoichiometric) environment, where the
20 combination of heat, pressure, oxygen and steam breaks down the feedstock
21 and creates a chemical reaction that produces syngas. Feedstock minerals
22 become an inert, glassy slag product that can be used in roadbeds, landfill
23 cover, and other applications. The syngas is cooled to produce steam and is
24 cleaned to remove sulfur and other contaminants such as mercury (Hg) etc.
25 before it is burned in a combustion turbine to generate electricity.
26 Additionally, the heat from the combustion turbine exhaust and from the
27 gasifier coolers is recovered and used to produce steam to drive the steam

1 turbine similar to a conventional steam plant to generate electricity. Elemental
2 sulfur is recovered and may be marketed as a commodity.

3
4 Pressurized gasification is preferred to avoid large auxiliary power losses for
5 compression of the syngas. Most gasification processes currently in use or
6 planned for IGCC applications are entrained flow designs using oxygen-blown
7 instead of air-blown technology. This results in the production of a higher
8 heating value syngas. The air separation units provide oxygen for the
9 gasification process and nitrogen for the combustion turbine NO_x control and
10 for purging. In addition, since the nitrogen has been removed from the gas
11 stream in an oxygen-blown gasifier, a lower volume of syngas is produced,
12 which results in a reduction in the size of the equipment. High-pressure,
13 oxygen-blown gasification also provides advantages if CO₂ capture is to be
14 considered at a later date.

15
16 Entrained-flow gasifiers that deliberately operate in the higher-temperature
17 slagging regions have been selected for the majority of IGCC project
18 applications. These include the coal/water-slurry-fed processes of General
19 Electric (formerly ChevronTexaco) and ConocoPhillips (formerly
20 Dow/Destec E-Gas), and the dry-coal-fed Shell process. A major advantage
21 of the high-temperature entrained-flow gasifiers is that they avoid tar
22 formation and its related problems. The high reaction rate also allows a single
23 gasifier to be built with large gas outputs sufficient to fuel large commercial
24 gas turbines. A typical schematic of the IGCC process is as follows:



1
2
3 Q. WHICH PORTIONS OF AN IGCC PLANT WOULD YOU CONSIDER
4 CONVENTIONAL TECHNOLOGY?

5 A. Most of the systems, equipment, and plant components in an IGCC plant can
6 be construed as conventional proven technologies and have been used either
7 in the conventional gas turbine combined cycle/fossil steam turbine plants or
8 in the chemical/petrochemical industries. The only technology that is not
9 conventional is the use of syngas as the fuel for the advanced class
10 combustion turbine and the integration requirements associated with the
11 gasification plant.

12
13 Q. MESABA 1 LLC HAS PROPOSED A 603 MW PLANT. IS THERE A SIMILARLY
14 SIZED PLANT CURRENTLY OPERATING IN THE WORLD?

1 A. No, Mesaba Unit 1, if built, would be double the size of the next largest coal-
2 based IGCC electric generation plant currently in operation.

3
4 Q. PLEASE SUMMARIZE THE IGCC FLEET OPERATING HISTORY IN THE UNITED
5 STATES AND AROUND THE WORLD.

6 A. The basic IGCC concept was first successfully demonstrated on a commercial
7 scale at the Pioneer Cool Water Project in Southern California over twenty
8 years ago, from 1984 to 1989. The GE (formerly Texaco, ChevronTexaco)
9 gasification technology was used to produce Syngas. About 1150 TPD of
10 southern Utah (SUFCO) Bituminous coal was used to produce 100 MW of
11 power from a GE 7E combustion turbine based combined cycle.

12
13 The second IGCC demonstration project was the LGTI Gasification Project
14 (Dow Chemical Plant), in Plaquemine, LA from 1987-1995. The
15 ConocoPhillips E-Gas (formerly Dow, Destec, Dynegy, Global Energy)
16 gasification technology was used to produce syngas. About 2400 TPD of
17 Powder River Basin (PRB) Sub-Bituminous Coal was used to generate 160
18 MW of power utilizing two Westinghouse modified W501D5 combustion
19 turbines. The Gas turbines utilized a fuel blend of approximately 80% syngas
20 and 20% natural gas. More than 3.7 million tons of PRB fuel was processed
21 in the LGTI plant to produce syngas and electricity.

22
23 Around the world, currently there are four large (250 – 300 MW range, single
24 train) commercially sized, coal-based IGCC plants operating, two in the U.S.
25 and two in Europe. The two projects in the U.S. were supported initially under
26 the Department of Energy's Clean Coal Technology demonstration program,

1 but are now operating commercially. The following tables depict the four
2 coal-based IGCC electric generation plants that are currently in operation:

Coal Based IGCC Plants

Project/ Location	Combustion Turbine	Gasification Technology	Net Output MW	Start-Up Date
Nuon Buggenum Netherlands	Siemens V 94.2	Shell (Offered jointly with Krupp- Uhde)	253	Jan 1994
Wabash River, IN	GE 7 FA	E Gas (ConocoPhillips)	262	Oct 1995
Tampa Electric, FL	GE 7 FA	Texaco (GE Energy)	250	Sept 1996
ELCOGAS Puertollano Spain	Siemens V 94.3	Prenflo (Offered jointly with Shell)	300	Dec 1997

3
4
5 The first of the European IGCC plants was the 253MW NUON (formerly
6 SEP/Demkolec) project in Buggenum, the Netherlands, utilizing Shell's
7 gasification technology. It began operation in 1994.

8
9 The second European project, the 298MW ELCOGAS project in Puertollano,
10 Spain, uses the Prenflo (Krupp-Uhde) gasification technology and started
11 coal-based operations in 1998. In 2002, Shell and Krupp-Uhde announced
12 that henceforth their technologies would be merged and marketed as the Shell
13 gasification technology.

14
15 The 250 MW Tampa Electric Company Polk Power Station IGCC project in
16 Florida started up in September 1996 and is based on GE's (formerly

1 ChevronTexaco) gasification technology using bituminous coal and petroleum
2 coke as fuel.

3
4 The 262 MW Wabash River IGCC repowering project in Indiana started up in
5 October 1995 and uses the ConocoPhillips's E-Gas gasification technology
6 (formerly Dow, Destec, Dynegy, Global Energy). About 2,500 TPD of
7 Illinois No.6 Bituminous coal was used as the original design basis fuel.
8 Recently petroleum coke was also used as fuel.

9
10 Q. IS GASIFICATION A PROVEN TECHNOLOGY AS IT RELATES TO OTHER
11 APPLICATIONS?

12 A. Yes. There were 117 operating gasification plants with 385 gasifiers around
13 the world in 2004. The total capacity of these is equal to approximately
14 45,000MW_{th}. 49% of these plants utilize coal as a feed stock and 36% utilize
15 petro-residue fuel as feed stock. Of the total gasification plants, 73% are used
16 for chemical production of ammonia, urea, petrochemical products, and
17 synthesis fuels. 19% are used for power generation.

18
19 Q. SPECIFICALLY, WHAT ARE THE OTHER GASIFICATION APPLICATIONS?

20 A. With a gasification process, solid and liquid fuels such as coal, petroleum coke,
21 tar residue, crude oil/other similar hydrocarbon, biomass, or certain organic
22 liquid waste materials can be converted into syngas. The syngas can then be
23 converted into various products such as synthesis liquid fuel (Car fuel, Diesel
24 Truck/Ship fuel, Jet Fuel, Naphtha) using the Fisher-Tropsch process¹;

¹ The Fisher-Tropsch process is the method for the synthesis of hydrocarbons and other aliphatic compounds. It is named after two German coal researchers who discovered it in 1923. Source: Columbia Electronic Encyclopedia, Columbia University, 2005.

synthesis natural gas (SNG) using methanation process; and ammonia, urea, methanol, acetic acid and other chemical products. All of the technologies are established on a commercial basis to produce a variety of site-specific value added products.

Feedstock Options

Coal
Pet Coke
Ref Waste
Spent Cat
MSW
Sludge
Biomass
Waste oils
Plastics

Gasification Technology

Clean
Low-cost
Syngas

Product Options

GT-CC

Power
Steam
Hot Water

Chemical
Production

Hydrogen
CO
Methanol
Olefins
Acetic Acid
SNG

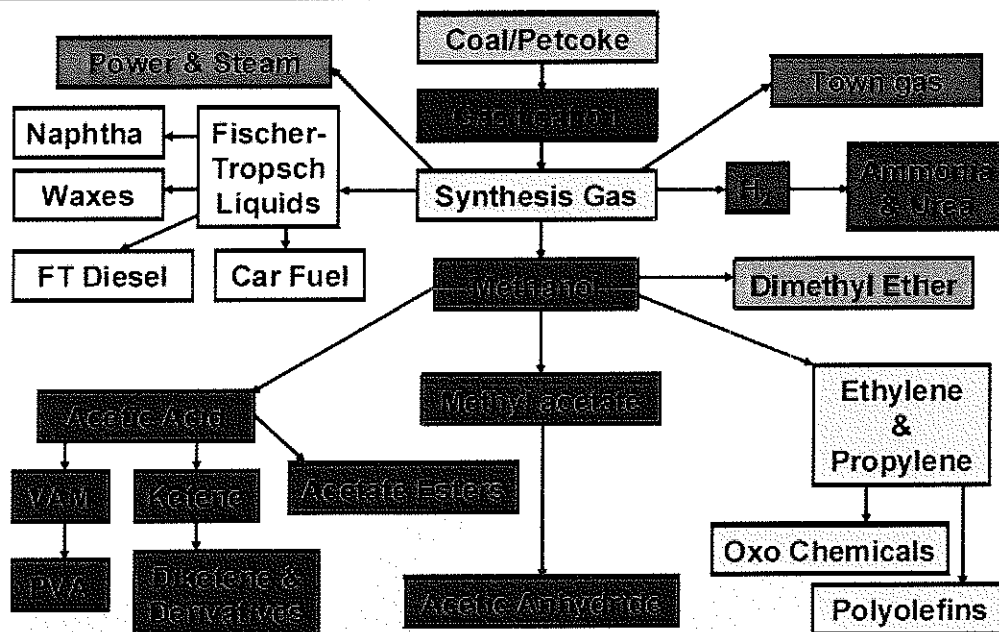
F-T
Synthesis

Diesel
Naphtha
Jet Fuel

Gasification Products

- Synthetic Aggregate
- Elemental Sulfur

Improved Economics via Polygeneration



EASTMAN

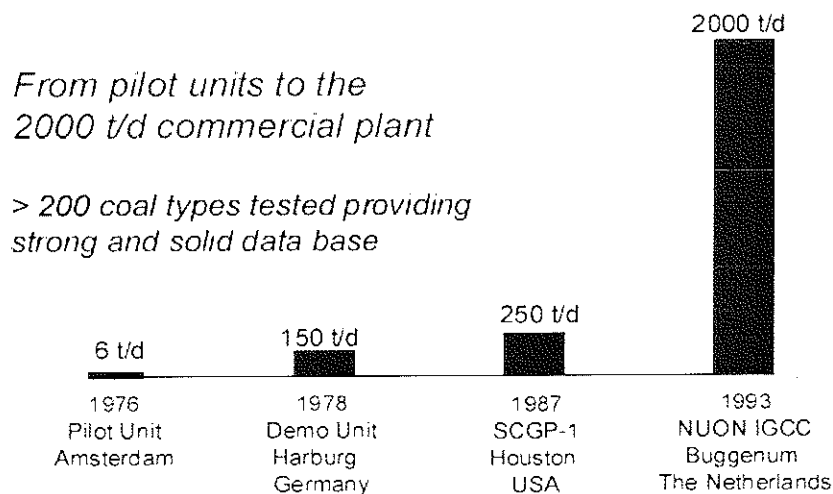
Q. CAN YOU PLEASE SUMMARIZE THE EVOLUTION OF PLANT SIZES FOR COAL BASED IGCC ELECTRIC GENERATION?

A. In the United States, from the first generation IGCC to the second generation coal feed IGCC plants like Wabash River, the plant's size has been scaled up from about 100MW to about 260MW per train power output using slurry feed ConocoPhillips ("COP") E-gas technology or GE gasification technology.

The largest coal based IGCC plant in the United States is the 260 MW Wabash River plant, which is less than half of the size being proposed by Mesaba 1 LLC. This plant uses the same E-Gas technology that Mesaba 1 LLC is proposing to use for Mesaba Unit 1.

The largest coal-based IGCC plant in Europe is the Buggenum Netherlands 300 MW plant, which is half the size Mesaba 1 LLC is proposing to build. It uses Shell gasification technology based on its development from 1976 to present, which is depicted below:

Shell Coal Gasification Process – development to commercialization



Q. HOW MANY PROPOSED IGCC PROJECTS ARE CURRENTLY BEING PLANNED IN THE UNITED STATES?

A. According to data in the public domain, as the 2004 table below shows, it appears there are approximately 16 announced IGCC projects in various stages of planning.

Announced USA IGCC Projects

Sponsor	State	Proposed location	Size, mw	Start-up	\$ millions
Orlando Utilities Comm.	Florida	Orange County	285	2010	\$750
Southeast Idaho Energy	Idaho	Pocatello	500	2010	\$850
Clean Coal Power Resources	Illinois	Fayette County	2,400	TBD	\$2,800
Madison Power Corp.	Illinois	Marion	500	TBD	\$2,000
Erora Group	Illinois	Taylorville	677	TBD	\$700
Steelhead Energy Co.	Illinois	Williamson County	545	TBD	\$600
Cinergy	Indiana	Edwardsport	600	TBD	\$900
Tondu Corp	Indiana	St. Joseph County	640	TBD	\$1,000
Global - Kentucky Pioneer	Kentucky	Clark County	540	TBD	\$520
Excelsior Energy, Mesaba Energy Project	Minnesota	Hoyt Lake	531	2010	\$1,200
American Electric Power	Ohio		600	2010	\$1,288
Global Energy	Ohio	Lima	580	2007	\$575
Synfuel	Oklahoma	Enid	600	2004	\$600
DKRW	Wyoming	Medicine Bow	350	2008	\$2,500
WMPI	Pennsylvania	Gilberton	41	2008	\$612
FirstEnergy/Consol	Ohio or PA	Undecided	TBD	TBD	TBD
Total			9,389		\$16,145

Highlighted projects have DOE funding

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Q. CAN YOU PLEASE SUMMARIZE THE CONOCOPHILLIPS E-GAS OPERATING HISTORY?

A. The E-gas technology development history is shown in the following:

E-GAS TECHNOLOGY HISTORY

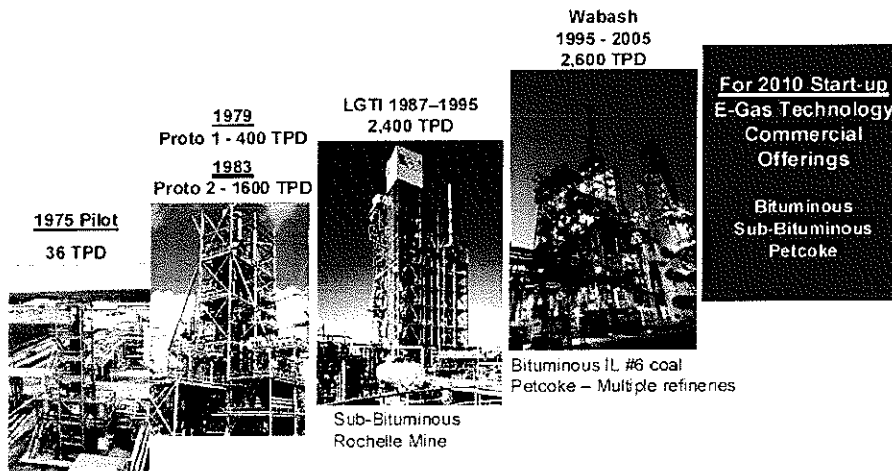
PILOT PLANT	36 TPD	1975
PROTO 1	400 TPD	1979
PROTO 2	1600 TPD	1983
LGTI	2400 TPD	1987-1995
WABASH - coal	2550 TPD	1995- 2000
WABASH – petcoke	2000 TPD	2000-2003

July 2003 - Millionth ton of Petcoke at Wabash

October 13, 2003

ConocoPhillips

E-Gas Gasification Commercial Feedstock Offerings and Gasifier Scale-up



Q. GIVEN THAT E-GAS HAS NOT BEEN USED IN A 603 MW PLANT, CAN YOU PLEASE DESCRIBE THE SCALE UP THAT WILL BE REQUIRED FOR MESABA UNIT 1?

A. Doubling the size of the plant may reveal previously unknown problems that are impossible to discuss in their entirety. However, generally, I believe that the scale up would be required with regard to the *Coal feed system and gasifier*. The coal feed system, rod mill capacity and gasifier vessel size and slurry

1 feeding capacity will be scaled up approximately 161%, from 2550 TPD of
2 coal feed at Wabash to about 4115 TPD required for Mesaba 1.

3
4 With regard to all other material aspects of the proposed facility, the
5 components should require little or no scale up. Specifically:

- 6
7 • *CT combined cycle*: The combustion turbine proposed for this plant is a
8 Siemens SGT6-5000F with syngas firing capability. No scale up of the
9 compressor section or turbine section is required for this machine.
10 Siemens has successfully completed the testing of burners for syngas
11 application. However, the integrated operation of this model combustion
12 turbine with syngas to demonstrate performance and emissions guarantees,
13 availability and reliability is yet to be accomplished in a commercial IGCC
14 plant application.
- 15
16 • *ASU (Air Separation Unit) system*: The largest ASU provided is by Air
17 Liquide. Its output is designed for 4000TPD, which is larger than the 2507
18 TPD output required for Mesaba 1. Therefore there is not a scale up
19 requirement.
- 20
21 • *Acid gas removal system*: The gas processing capacity of many acid gas
22 removal systems are much larger than Mesaba 1. Therefore there is not a
23 scale up requirement nor should there be a concern.
- 24
25 • *Other BOP (Balance of Plant) Systems such as the make-up water system,*
26 *water treatment systems, syngas filter, sulfur recovery system, cooling towers,*
27 *etc.* No scale up is required.

1
2 Q. WHAT CONCLUSION DO YOU REACH CONCERNING THE AMOUNT OF RISK
3 THAT THE SCALE-UP FOR THE MESABA UNIT 1 WILL REQUIRE?

4 A. Scale up is an accepted industry practice and has been successfully
5 implemented in the past on both power and process applications. But as
6 discussed above, there are always risks associated with incremental advances
7 to any technology such as here. The risk of the above-mentioned scale-up of
8 the coal feed system and gasifier may normally be determined by the project's
9 sponsor(s) or the financial institution (providing financing) and its consultants.
10

11 Q. DESCRIBE THE PROCESS OF CO₂ CAPTURE AND SEQUESTRATION FROM IGCC
12 PLANTS.

13 A. The CO₂ separation and capture technologies for power generation systems
14 are traditionally split into: (1) post-combustion technology- PC application;
15 and, (2) pre-combustion technology- IGCC application. My testimony will
16 focus on the pre-combustion CO₂ separation and capture technology as
17 applies to the IGCC plant.
18

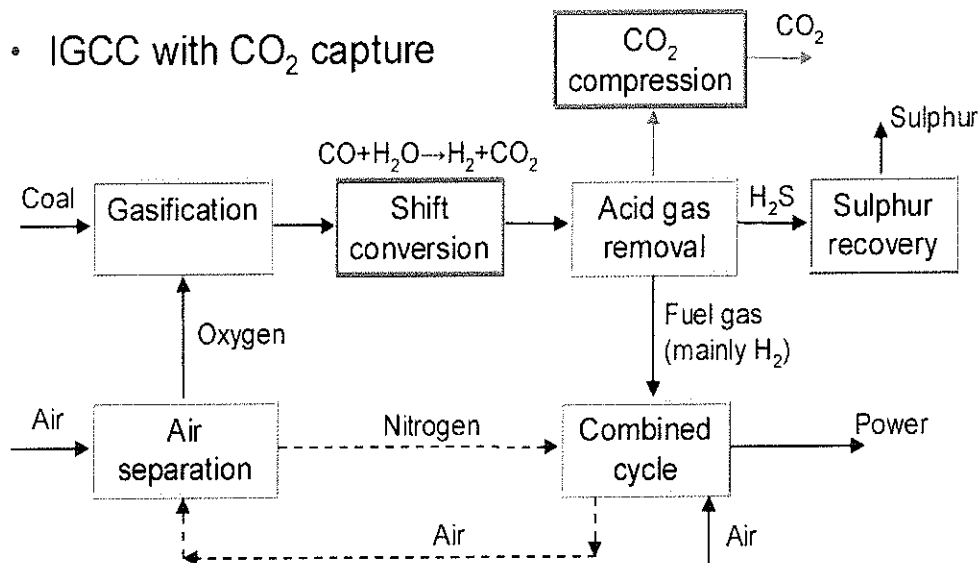
19 Pre-combustion CO₂ capture in an IGCC application usually means removal
20 of carbon oxides (CO and CO₂) from the syngas prior to sending the fuel to
21 the combustion turbines. In this application syngas is processed and treated to
22 convert CO to CO₂. The CO₂ is then removed and captured resulting in a
23 stream of hydrogen-rich fuel that can be used for various applications,
24 including power generation.
25

26 CO₂ capturing is generally accomplished using a physical or chemical
27 absorption process. The simplified diagram below illustrates a process for

IGCC with CO₂ removal. The process is similar to IGCC without CO₂ removal except that the syngas from the gasifier is sent to a CO shift converter prior to cooling, and the acid gas removal system (shown here as Selexol technology for representation purposes only) removes CO₂ as well as the sulfur compounds at high pressure. The other difference between the IGCC processes with and without CO₂ removal is the compression and drying of CO₂, for pipeline transportation for geological sequestration or other use.

Pre-Combustion Capture

- IGCC with CO₂ capture

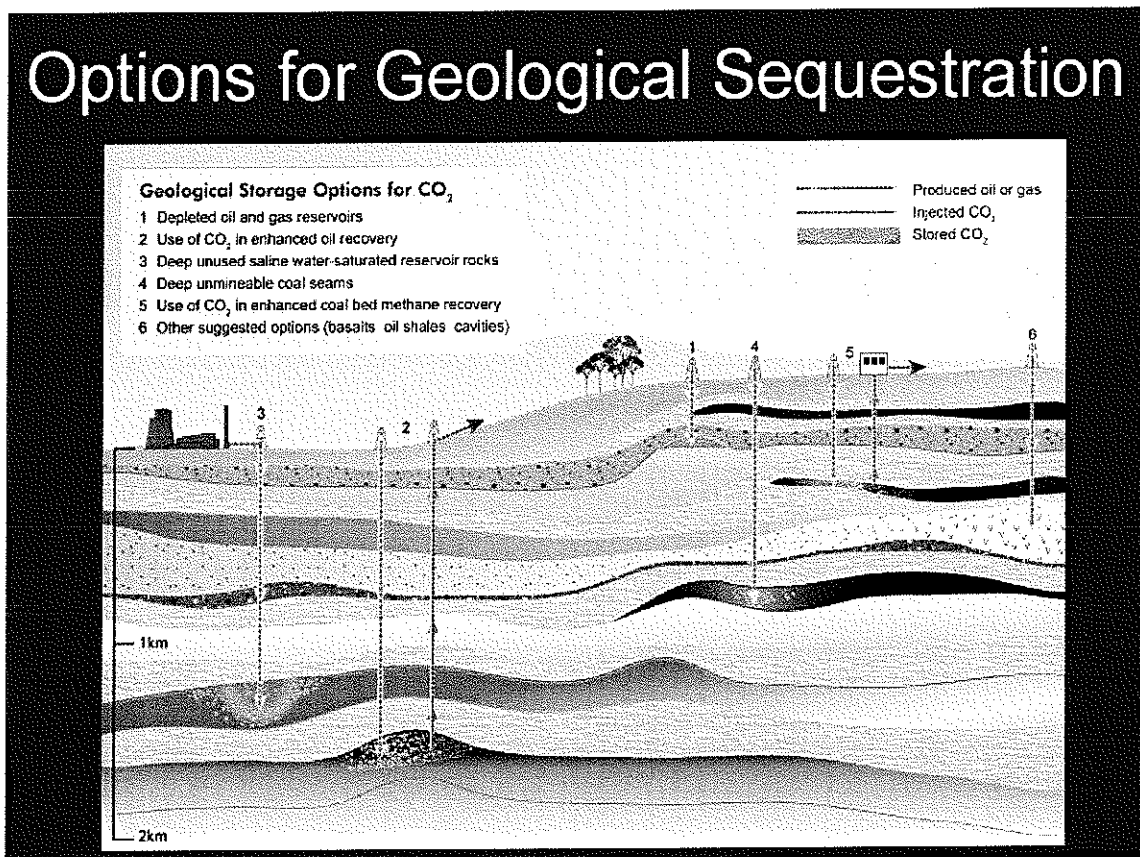


Geologic sequestration (also known as carbon capture and storage “CCS”) operations will compress the gas to a supercritical state and send it via a pipeline to an injection well, where it is pumped underground to depths generally greater than 800 meters (about 2,600 ft) to maintain critical pressures and temperatures. Candidate sites for geologic storage include:

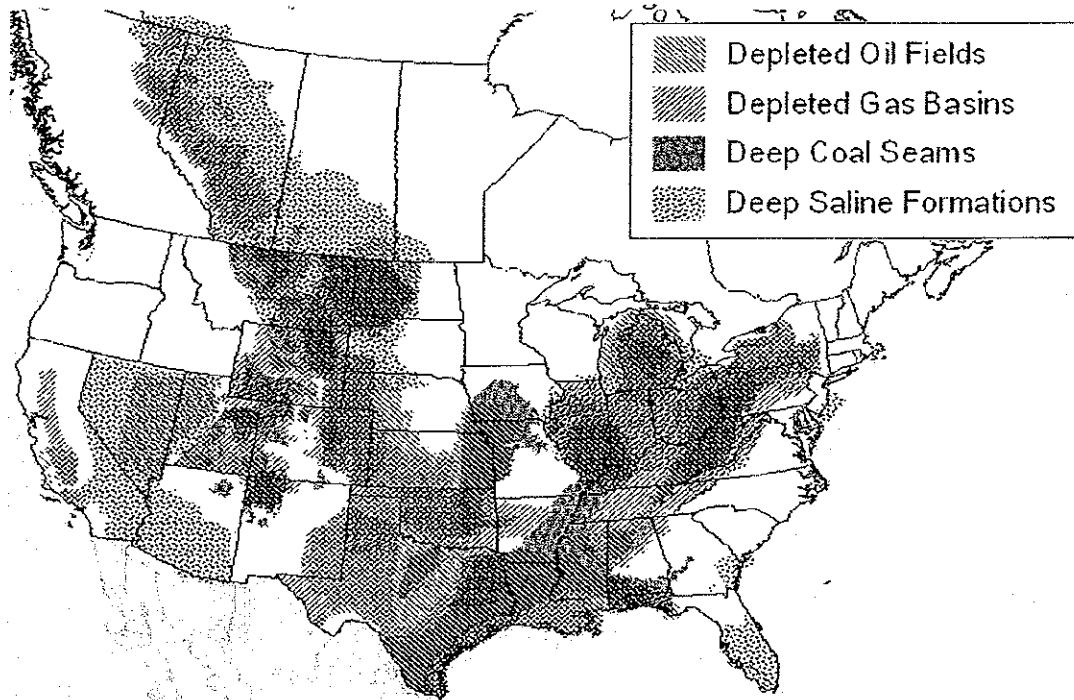
- 1) Deep saline formations,

- 2) Existing oil and gas fields and potential enhanced oil/gas recovery (EOR) conditions,
- 3) Depleted oil and gas reserves, and
- 4) Deep unmineable coal beds.

These options for geological sequestration are pictured in the below diagram.

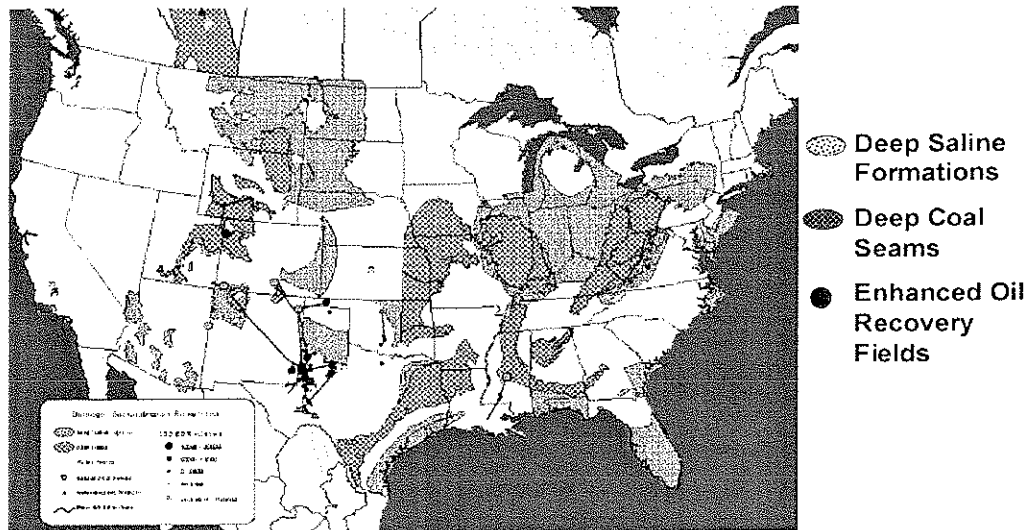


The maps below shows current identified potential geologic reservoirs for CO₂.



Source: J. Dooley et al., "A CO₂ Storage Supply Curve For North America and its Implications for the Deployment of Carbon Dioxide Capture and Storage Systems," GHGT-7, Sept 8, 2004.

Geologic Sequestration Options



SAFCEP Energy Worksheet - E6472/M-05-1993

Since there are no geologic storage sites currently identified in northeastern Minnesota for CO₂ sequestering, the CO₂ emitted from the Mesaba Unit 1 will, if it is to be sequestered or utilized, most likely be transported to western

1 North Dakota, Canada, or Iowa by pipeline. I note that Mesaba 1 LLC has
2 indicated that it may eventually sequester carbon and transport it by pipeline
3 to the Williston Basin in North Dakota.
4

5 Q. WHAT IS THE EXPECTED MAINTENANCE SCHEDULE OUTAGE RATE OF IGCC?

6 A. For an E-gas IGCC gasifier, there are two planned 21-day outages annually
7 followed by approximately five months of continuous operation. While the
8 combustion turbine maintenance schedules are common knowledge
9 (combustion inspection typically at about 8,000 hours interval, hot gas path
10 inspections typically at about 24,000 interval and major inspections typically at
11 about 48,000 hours interval at equivalent base load operation) the maintenance
12 schedule for the ASU and gasifier island equipment would have to be set
13 according to manufacturer's recommendations for their equipment. Major
14 outages during off-peak seasons are anticipated.
15

16 Q. WHAT IS THE START-UP DURATION (COLD, HOT AND WARM) AND THE RAMP-UP
17 RATE FOR IGCC?

18 A. According to ConocoPhillips (COP) the E-gas gasifier will require
19 approximately 48-60 hours for a cold start. A hot start can occur in as little as
20 one hour (because they have permanently installed natural gas [NG] burners as
21 part of their design). The gasifier can be kept hot indefinitely with a NG
22 burner. COP projects the gasifier ramp rate at 3-5% per minute. However,
23 some of the auxiliary systems in the gasifier plant may not ramp up at the
24 same rate as that of the gasifier. This hurdle can be overcome by increasing
25 the co-firing of natural gas.
26

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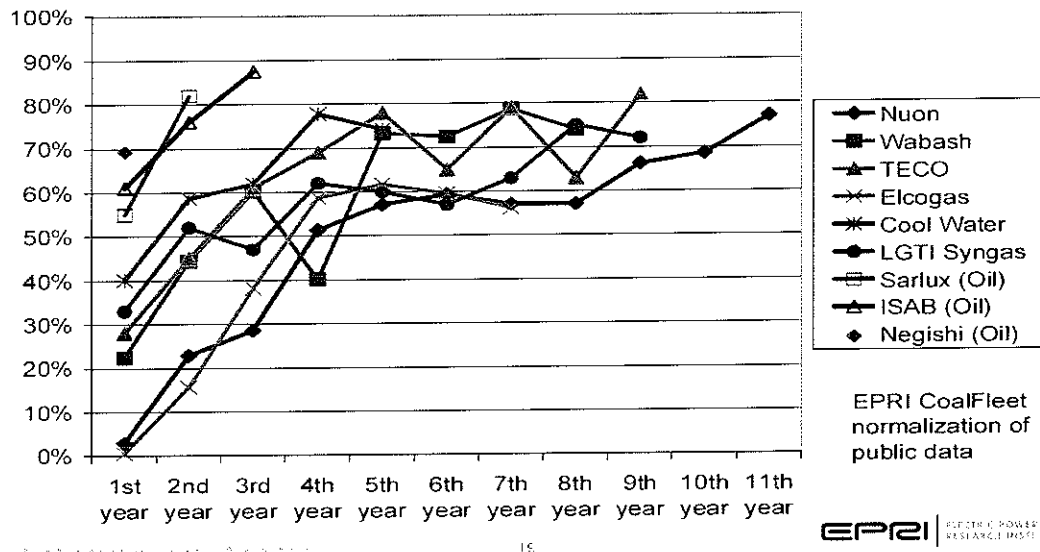
1 With NG as the backup fuel, the IGCC plant will startup with this fuel. If the
2 NG supply system is designed for the Combustion Turbine's ("CT") full
3 capacity, the CT combined cycle can start up and ramp-up with NG fuel. The
4 fuel switch from NG to syngas can occur at about [TRADE SECRET
5 BEGINS

6
7
8
9 TRADE SECRET ENDS] compared to
10 information available from ConocoPhillips which is 1 hour from a hot start
11 and 48 to 60 hours for a cold start.
12

13 Q. WHAT IS THE PUBLISHED EXPECTED AVAILABILITY FOR IGCC PLANTS?

14 A. The average availability factor for the last three years for all coal fueled IGCC
15 operations is approximately 80% excluding back up natural gas fueled power
16 island operation according to Stu Dalton from EPRI in his presentation dated
17 December 2, 2005 in the following exhibit. Based upon recent presentations
18 made by ConocoPhillips, the IGCC availability factor with a spare gasifier is
19 expected to be over 91% with their improved E-gas technology design. If a
20 spare gasifier is on hot standby during most IGCC operation time, it will
21 further reduce down time for IGCC plant and hence increase availability.
22

IGCC Availability History (excludes operation on back-up fuel)



If IGCC plants use natural gas as 100% back up fuel for the combustion turbine and power island backup natural gas feed system is designed for full combustion turbine demand, IGCC plants can have the same plant availability factor as conventional natural gas fueled combined cycle plants. A recent Siemens presentation indicated that a 12-month rolling average availability for the SGT6-5000F is about 95%.

III. MESABA UNIT 1 DESIGN CONSIDERATIONS

Q. WHAT CAN BE SAID ABOUT MESABA UNIT 1'S GENERATION PERFORMANCE AS COMPARED TO THE "STANDARD" IGCC PLANT'S PERFORMANCE?

A. I must qualify that my response is based only on the available Mesaba Unit 1 information that was provided and the "standard" IGCC plant information that is publicly available. Information that determines generation performance is based on the following parameters:

- 1) Site Ambient temperature.
- 2) Site Relative humidity.
- 3) Site Ambient pressure.
- 4) Site Elevation.
- 5) Fuel characteristics.
- 6) Fuel gas (syngas) characteristics.
- 7) CT (Combustion Turbine) inlet pressure loss, outlet draft loss. CT performance with Syngas and ASU (Air Separation Unit) integration.
- 8) HRSG (Heat Recovery Steam Generator) Design and stack temperature, blow down rate.
- 9) ST (Steam Turbine) cycle Heat & Mass balance.
- 10) Cooling water temperature.
- 11) Condenser pressure.
- 12) Gasifier BFW (Boiler Feed Water) rate and conditions and ST input, output conditions and rate.
- 13) ASU internal power load.
- 14) AGR (Acid Gas Removal) steam load and power load. Fuel gas pressure drop in AGR.
- 15) ZLD (Zero Liquid Discharge) steam load and power load.
- 16) Power Plant internal power load listing.
- 17) Transformer loss.
- 18) Gasifier coal conversion rate. Slag release conditions and rate.
- 19) Sulfur Recovery Unit steam generation rate, conditions.
- 20) Syngas cooler, BFW input rate and conditions, steam generation rate and conditions.

1 For Mesaba Unit 1 and the "Standard" IGCC plant only a few of the above
2 parameters are known. Therefore an engineering analysis could not be
3 performed at this time to provide a reasonable comparison.
4

5 Q. DO YOU HAVE ANY OTHER OBSERVATIONS REGARDING MESABA 1 LLC'S
6 PROPOSAL AS IT RELATES TO THE PLANT'S PERFORMANCE?

7 A. Yes. The performance of an IGCC plant will vary with respect to ambient
8 temperatures. Many times the economic analysis is performed on the basis of
9 average annual temperature conditions for simplicity. However, a power
10 purchaser's primary requirements are taken into consideration when
11 performing the project economics. For example, if the power purchaser has a
12 requirement for summer capacity or availability, then the performances
13 (outputs and heat rates) during the summer month conditions would be
14 calculated and included in the project economics. It does not appear that
15 Mesaba 1 LLC considered summer capacity in the project's economics. To
16 the contrary, it appears that all capacity numbers in the analysis are based on a
17 lower ambient temperature of 38F, which would be somewhat higher in
18 summer conditions.
19

20 Q. DOES THE EMISSION CONTROL SYSTEMS BEING PROPOSED FOR MESABA UNIT
21 1 APPEAR TO BE IN LINE WITH YOUR EXPERIENCE OR INDUSTRY STANDARDS
22 FOR PERMITTING REQUIREMENTS?

23 A. Yes.
24

25 Q. IS THE PROPOSED MESABA ENERGY PROJECT PROVIDED WITH THE NECESSARY
26 EQUIPMENT FOR CO₂ SEQUESTRATION?

1 A. No. Only the space for the future addition of CO₂ capture facilities and stub-
2 outs for process fuel gas supply and return to/from CO₂ capture facilities
3 have been provided in Mesaba Unit 1. No additional pre-investment for CO₂
4 capture facilities is provided. The following would be required for a future
5 CO₂ sequestering plant:

- 6 • A system for a CO shift reaction to CO₂,
- 7 • Ability for the acid removal system to be upgraded or switched to
- 8 alternate solvent for 90% CO₂ capture,
- 9 • Addition of another gas separation system to separate CO₂ with H₂S.
- 10 • Addition of a CO₂ drying and compression system
- 11 • Ability for combustion turbine to be upgraded or switched to run on
- 12 hydrogen rich fuel at a reduced flow rate.
- 13 • Addition of nitrogen blending in the fuel to limit the hydrogen content
- 14 within combustion turbine manufacturer's acceptable limits.

15
16 Q. WHAT WOULD IT COST TO ADD SEQUESTERING EQUIPMENT TO THE PROPOSED
17 MESABA UNIT 1?

18 A. In this case, I believe sequestration would require an additional \$760-850
19 million to install sequestration equipment at the plant and provide the pipeline
20 system necessary to transport CO₂ to a location where it could be sequestered.
21 This figure does not include any additional amounts for expenses related to
22 operations and maintenance of the sequestration equipment or the pipeline.

23
24 Q. PLEASE EXPLAIN.

25 A. Based on data presented in a July 2006 EPA Report, which is adjusted to
26 reflect 3Q2005 dollars, and indexed to Northern Minnesota, the cost of a
27 typical 600MW size IGCC plant, without a spare gasifier, would be about

1 \$1960/kW without CO₂ sequestering capability. This cost was evaluated at
2 the total project Cost (TPC) level and excludes facilities/systems outside the
3 battery limits, contractor's risk fee and event driven contingency, Minnesota
4 sales and use taxes, interest during construction, and Owner's costs. The cost
5 for the same plant with CO₂ sequestering capability will be in the range of
6 \$2640/kW to \$2790/kW using the same cost evaluation basis. This translates
7 into approximately \$410-500 million in capital for the plant itself (assuming a
8 603 MW size). Pipeline costs are additional.

9
10 For CO₂ pipeline transport, the pipeline construction cost is approximated at
11 \$17,800 per inch-mile ("inch" equaling pipe diameter and "mile" indicating
12 distance of transport) at 2006 dollar basis. The anticipated annual operations
13 and maintenance ("O&M") costs are about \$1,780 per mile independent of
14 pipe diameter.

15
16 It is estimated that for the Mesaba site, an approximate 24 inch diameter
17 pipeline would be required to transport the 90% of total CO₂ produced to one
18 of the previously named locations. As an example of costs for a 800 mile long
19 pipeline to transport CO₂ to Williston Basin for use in enhanced oil recovery,
20 the EPC cost would be approximately \$350 million. The annual O & M cost
21 would be approximately \$1.43 million. The capital cost is based on a straight
22 line route and is exclusive of right-of-way costs, permitting costs and other
23 development costs. In addition there could be difficulty and substantial time
24 delays in securing right-of-ways if there are a large number of landowners
25 involved in the route for the pipeline.

26
27 Q. WHERE IS THE PROPOSED STORAGE/DISPOSAL POINT FOR FUTURE CO₂?

1 A. No storage or disposal point has been indicated as being contracted for.

2
3 Q. HOW DO THE PUBLISHED VALUES OF IGCC PLANT AVAILABILITY COMPARE
4 WITH THE PROPOSED MESABA ENERGY PROJECT?

5 A. The project is consistent with information available in the public domain as
6 expressed by the project's gasifier supplier. According to ConocoPhillips,
7 Mesaba Unit 1 will be designed for an availability of 92% or 8059 operating
8 hours per year. Project economics have been based on an availability of 91%
9 7,972 hours after the first 3 years of reduced availability. I note, however, that
10 a plant of this size with the proposed gasifiers and combustion turbines does
11 not yet exist to verify whether this expected availability can be consistently
12 achieved.

13
14 Q. WHY DOES THE PROPOSED MESABA ENERGY PROJECT INCLUDE A SPARE
15 GASIFIER?

16 A. Based upon recent representations made by ConocoPhillips, the spare gasifier
17 is necessary in order for Mesaba Unit 1 to achieve an expected 91% availability
18 factor.

19
20 Q. WHAT WOULD MESABA UNIT 1'S AVAILABILITY FACTOR BE WITHOUT THE
21 SPARE GASIFIER?

22 A. According to ConocoPhillips published information the plant's availability
23 factor would be approximately 80%.

24
25 Q. BASED ON PUBLIC LITERATURE, HOW MIGHT THE PLANT AVAILABILITY BE
26 IMPACTED IN THE FIRST YEAR'S OF OPERATION?

PUBLIC DOCUMENT
TRADE SECRET DATA EXCISED

1 A. The DOE testing may have a material impact on the plant's operational
2 characteristics during the period of time needed for this testing. Secondly, all
3 plants normally go through a first year shakedown and teething period, which
4 may also have an impact on the operational characteristics.

5
6 Q. WHAT HAS MESABA 1 LLC INDICATED ITS INITIAL YEAR'S AVAILABILITY WILL
7 BE?

8 A. According to Mesaba 1 LLC's Volume I, Section III Report "Cost Analysis
9 and Comparison," the Mesaba 1 LLC has accounted for initial year
10 availabilities of [TRADE SECRET BEGINS

11 **TRADE SECRET ENDS]** thereafter. Mesaba 1
12 LLC's estimated Mesaba Unit 1's availabilities at [TRADE SECRET
13 **BEGINS** **TRADE SECRET ENDS]** or the 92% availability as used by
14 Fluor in their "Independent Analysis of Generation Technologies for a 600
15 MW Coal-Fired Power Plant in Minnesota" are [TRADE SECRET
16 **BEGINS** **TRADE SECRET ENDS]** than that shown below or as
17 indicated by ConocoPhillips in my testimony above. It should be noted that
18 the availability factors used by Mesaba 1 LLC in their [TRADE SECRET
19 **BEGINS**

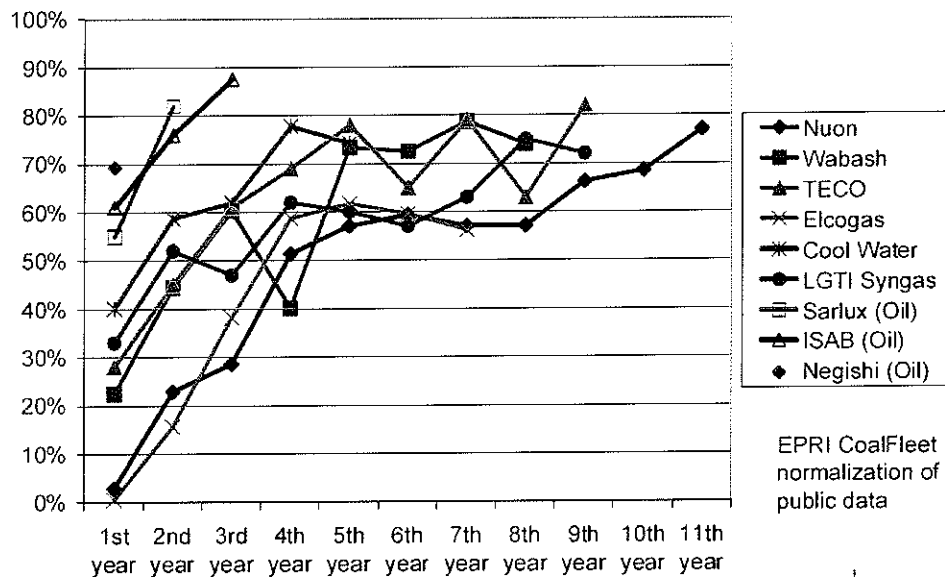
20
21 **TRADE SECRET ENDS]**.

22
23 Q. HOW CAN MESABA UNIT 1 ACHIEVE [TRADE SECRET BEGINS
24 **TRADE SECRET ENDS]** AVAILABILITIES THAN STATED IN THE PUBLISHED
25 ARTICLES?

26 A. The [TRADE SECRET BEGINS **TRADE SECRET ENDS]**
27 availabilities used by Mesaba 1 LLC and Fluor may be because the project has

the ability to fire NG as a back-up fuel and the spare gasifier. The published literature availability factors are exclusive of back-up fuel.

IGCC Availability History (excludes operation on back-up fuel)



Q. MESABA 1 LLC HAS INDICATED IN INFORMATION RESPONSE NO. 74, THAT IT IS REQUIRED TO PERFORM CERTAIN TESTS ON BEHALF OF THE DEPARTMENT OF ENERGY ("DOE"), IS THERE ENOUGH DETAIL IN MESABA 1 LLC'S PROPOSAL TO REVIEW THE DOE TESTING PROGRAM TO DETERMINE THE IMPACTS IT MAY HAVE ON MESABA UNIT 1'S OPERATING CAPACITY FACTOR?

A. There is insufficient information to quantify the extent and impact of DOE testing requirements. However, based on the information provided, it can be said that there will be a material impact to the Mesaba Plant's operations during the period that the DOE demonstration tests are to be performed.

Q. DOES THE LAYOUT AND LOCATION FOR THE PROPOSED MESABA ENERGY PROJECT APPEAR TO BE INLINE WITH YOUR EXPERIENCE OR INDUSTRY STANDARDS?

1 A. Yes. However, there is only a small storage area for slag since this by-product
2 is to be disposed of off site. If the project does not have a long-term
3 commitment for the permanent disposal or sale of slag, the financing entity
4 may require sufficient space be allocated on the site for its long-term disposal
5 or as an alternative, a long term dedicated off site landfill facility be identified
6 which is willing to accept this by-product. Disposal costs for slag should be
7 included in the project economics.

8
9 Q. DESCRIBE WHAT BY-PRODUCTS ARE BEING PRODUCED BY MESABA UNIT 1.

10 A. Beside electricity, Mesaba Unit 1 will also produce: sulfur from the acid gas
11 removal system, slag from the bottom of gasifier; ZLD cakes from the zero
12 liquid discharge system; small amounts of activated carbon adsorbed with Hg
13 as waste; and planned outage wastes such as used refractory and deposition
14 ash.

15
16 Q. DOES THE METHOD OF BY-PRODUCT REMOVAL AND DISPOSAL APPEAR TO BE
17 IN LINE WITH YOUR EXPERIENCE OR INDUSTRY STANDARDS?

18 A. No commitments as to by-product disposal have been made. The intent to
19 sell the by-products are in line with current industry plans and expectations.
20 The financial community may require that the "generic rule-of-thumb" cost
21 for disposal of ZLD salts be based on an actual proposed cost, verifiable
22 industry data or have adequate long-term disposal included on-site.

23
24 Q. DOES THIS CONCLUDE YOUR TESTIMONY?

25 A. Yes, it does.

REFERENCES

1. "ConocoPhillips Gasification 2004," presented at the Gasification Technologies Conference 2004, Washington DC October 4, 2004, by Phil Amick.
2. "Shell Gasification business in action" presented at the Gasification Technologies Conference 2005, by Thomas Chhoa.
3. "CONOCOPHILLIPS ENTERS GASIFICATION INDUSTRY," presented at the Gasification Technologies Conference 2003, Washington DC October 4, 2003, by Phil Amick.
4. "Coal Gasification: What are You Afraid of" POWER-GEN International Conference 2004 November 30 – December 2, 2004, Nathan Moock and William Trapp of Eastman Gasification Services Company
5. "Operational Experience at the Wabash River Project" presented by Thomas A. Lynch of ConocoPhillips at the IGCC Project Development and Finance Seminar at St. Lois, MO on November 14-16, 2005
6. "Siemens Advanced Gas Turbine Technology" presented at The Sixteenth Annual Burns and Roe Seminar 2006, by Rick Antos
7. "Technical Aspects of Clean Hydrogen Production" by Charles E. Taylor at GCEP Energy Workshop, Stanford University, Stanford, CA. April 26, 2004
8. "Evaluation of Innovative Fossil Fuel Power Plants with CO2 Removal, U.S." DOE/NETL and EPRI,
9. The Economics of CO2 Storage, Gemma Heddle, Howard Herzog & Michael Klett, MIT. August 2003.
10. "Environmental Footprints and Costs of Coal-Based Integrated Gasification Combined Cycle and Pulverized Coal Technology" EPA-430/R-06/006 July, 2006
11. "Cost Comparison IGCC & Advanced Coal", presented at the Roundtable on Deploying Advanced Clean Coal Plants, by Stu Dalton, Director Fossil, Emissions Control, and Distributed Energy Resources, EPRI, July 29, 2004.

- 1
2 12 “What is Geological Carbon Sequestration? Will it Work? How Will we
3 Know?” by Sally M. Benson, Advanced Coal Workshop, Portland, Oregon.
4 May 24, 2006.
5
6 13 “IGCC – Status, Comparisons, and R&D Other Advanced Coal Options
7 CO2 Capture and Storage Industry / EPRI Programs to Advance
8 Deployment” by Hank Courtright, Senior Vice President June 19, 2006 EPRI
9 Conference Call



Resume

Summary

Over 20 years experience in process engineering for power generation, oil and gas industries. Experience includes project management, business/proposal development, process engineering such as developing heat and material balances, PFDs and P&IDs, equipment specifications, datasheets and operating manuals.

• Experience

2004 - Present Supervising Process Engineer, WorleyParsons, Arcadia

- ConocoPhillips Alaska, Responsible for process and system integration evaluations, prepared equipment datasheets, developed P&ID and Heat & Material Balances of an oil and gas facility in the Alaska North Slope.
- BP Alaska Milne Point Alaska, Responsible for using ASPEN Hysis simulator for BP FEL-1 of process heat addition project simulation. Developed P&IDs, Heat & Material balance and datasheets. The heat addition solutions were proposed.
- Sonatrach, Algeria, Using SimSci Pipephase simulator, performed process simulation, hydraulics and equipment optimization of a pipe line network of Hassi-Massoud Oil and Gas production facilities. Over 900 production oil/gas wells in 12 satellite gas gathering centers with separators and pumps and compressors were evaluated. The improvements for the transmission systems were proposed.

1996 - 2004 Proposal Manager/Senior Consulting Engineer, Alstom Power (ABB Power Generation), Windsor

Project Engineering and Project Management

- Represented Alstom at ASME PTC47 Integrated Gasification Combined Cycle (IGCC) performance test code committee.
- Trouble shooting and technical supported ABB API/Texaco IGCC plant operation and system modifications.
- Project Manager and technical leader on Alstom steam-tail™ product lines development.
- Leading Engineer in HRSG thermal cycle development of Alstom/ABB Turnkey reference plants.
- Reviewed or designed HRSG thermal cycle system for GE, ABB, Siemens - Westinghouse and MHI gas turbines for domestic and international combined cycle and cogeneration turnkey applications.



Resume

- Reviewed and approved junior engineer's GA, PI&D, PFD drawings, data sheets, technical guarantees and other engineering documents
- Trained Alstom licensee on thermal cycle and power plant boiler design. Reviewing and approving Alstom licensee designs and proposals

1996 - 1997 **Technical Fellow/Senior Consulting Engineer, ABB Power Generation**

- Represented ABB at ASME PTC47 Integrated Gasification Combined Cycle IGCC performance test code committee. Wrote ASME PTC47 code with leading experts on IGCC field. Evaluated IGCC plant operation and performance testing
- Designed IGCC thermal cycle system with ABB GT26, GT24 and GT13 turbines
- Provided technical supported on ABB new gasification process development
- Project Manager in ABB distributed combined cooling, heating and power (CHP) system development project. Developed economic and technical computer evaluation tools
- Technical leader in plant cycle analysis and system design group of ABB PD&T
- Participated in ABB corporate business technology evaluation team on advanced solid fuel power plant system design and developments
- Provided technical support on ABB 600MW and 125MW reference plant cycle system design
- Leading thermal cycle engineer in ABB/DOE Low-emission Boiler System (LEBS) project for large scale coal fired power plant system

1995 - 1996 **Senior Engineer, Siemens Westinghouse Power Company, Orlando**

Project Engineering and Project Management

- Leading Engineer in Westinghouse, Shell Oil, Air Product joint feasibility study of highly Integrated Gasification Combined Cycle IGCC systems
- Developed W501FC and W501G plant thermal cycle systems for Shell gasification IGCC cogeneration process power plant applications
- Evaluated Texaco, Shell, Dow Destec, Gaskombinat Schwarze Pumpe (GSP), Lurgi, Noell, Koppers-Totzek (GKT), PRENFLO, BG/Lurgi, HT Winkler, IGC, ABB CE, KRW, IGT U-GAS gasification process for IGCC applications
- Represented Westinghouse at ASME PTC47 IGCC performance test code committee. Wrote ASME PTC47 code with leading experts on Integrated Gasification Combined Cycle (IGCC) field
- Designed thermal cycles; performed case studies; prepared major equipment specifications and data sheets, develop PFD, PI&D and Engineering Flow Diagrams for Westinghouse extended scope turnkey power plant projects



Resume

- Conducted trouble shooting and support for Westinghouse/CAPSA and Hanwha plant operations

1990 - 1995 Chemical Engineer, Gas Technology Institute, Chicago

- Supported engineering design of GRI N-Formyl Morpholine (NFM) gas processing process and conducted test on pilot plant operation
- Developed ASPEN Plus simulation model for NFM absorption system and gas processing plant
- Conducted research on gas purification processes for IGCC and natural gas processing applications
- Provided support on preparing proposal to several new gas processing projects
- Tested catalysts for sulfur tolerance methanation catalysts for DOE/GRI underground gasification coal to pipeline gas project
- Wrote the winning proposal and invented a new process — Novel Gas Conversion by Sulfur Process
- Tested catalyst for natural gas with sulfur to liquid applications for DOE Coal to liquid and Gas to liquid projects
- Prepared project monthly, annual and final reports. Prepared customer presentations and trade show papers
- Interfaced with customer, subcontractor and vendors
- Coordinated cross-functional project team members on project tasks, schedules and budgets
- Completed project on time and under budgets

1985 - 1986 Plant Engineer, SINOPC China

- Developed familiarity with the manufacture of ammonia and methanol processes
- Assisted plant engineers prepare new safety procedures manual for gas purification process
- Worked as plant operation engineer in ethylene glycol manufacture unit
- Provided trouble shooting and equipments maintenance support for EO and EG productions
- Developed a computer process simulation model for a p-xylene oxidation industrial process
- Performed optimization on p-xylene oxidation operation conditions

Education & Professional Affiliations

- Ph D in Chemical Engineering, Illinois Institute of Technology, Chicago



WorleyParsons

Frank Qun Miao

Supervising Process Engineer

Resume

- B.S. in Chemical Engineering, Beijing Chemical Technology University, Beijing
- Green Belt Quality Focus (QF) Six Sigma training at Alstom
- Gas Pipeline Operations, LNG Peakshaving, LNG base-load operation at IGT
- Power Plant and Products, Combustion Turbine, Steam Turbine at Westinghouse PGBU
- HRSG system design, Fossil Fuel Combustion Technology at ABB Power Generation

Registrations/Affiliations

- Committee of ASME Performance Test Code 47 in IGCC (Alstom representative)