Comparison of Nitrogen Oxides, Sulfur Dioxide, Particulate Matter, Mercury and Carbon Dioxide Emissions for IGCC and Other Electricity Generation.

The Minnesota Pollution Control Agency (MPCA) has been asked to analyze the emission profiles of electric generating facilities and compare integrated gasification combined cycle (IGCC) with other state-of-the-art coal-fired electric generating technologies. We compare the emission of the pollutants nitrogen oxides (NOx), sulfur dioxide (SO2), particulate matter (PM), and mercury (Hg) of various coal-fired electric generating units as specified in Minn. Stat. §§ 216B.1693 and 216B.1694. We also compute carbon dioxide emissions from each generating technology.

In air quality permits, emission limits for fossil-fuel fired generating stations are most often set on a heat input basis. The units typically used are pounds of emissions for each unit of heat fed to the combustion unit (million Btu or mmBtu). This type of limit allows for a determination of compliance irrespective of the utilitization rate of the unit. It does not, however, take into account the efficiency of a unit in converting the heat energy contained in the coal into electricity. Generating units that are more efficient will produce the same amount of electricity using less fossil fuel. Therefore, MPCA has evaluated pollutant emission rates on a pound per megawatt hour basis (lb/MWh).

Sources of information

We collected information about plant performance for coal gasification (IGCC) and three generations of pulverized coal (PC) technology: subcritical pulverized coal (steam quality of 2400 lbs/sq in and 1000/1000 degrees F), supercritical pulverized coal (steam quality of 3,500 lbs/sq in and 1,050/1,050 degrees F) and ultra-supercritical pulverized coal (steam quality of 4,500 lbs/sq in and 1,100/1,100 degrees F). Supercritical and ultra-supercritical PC represent the latest versions of traditional coal-fired electric generating technologies.

We first consulted U.S. EPA's recent publication "Environmental Footprints and Costs of Coal-Based Integrated Gasification Combined Cycle and Pulverized Coal Technologies" published in July 2006. This document compares the expected air emissions and solid waste generation of IGCC and pulverized coal technologies likely to be deployable by 2010.

We also sought the most recent air emission permit applications for subbituminous-fired pulverized coal facilities planned for construction in the same time horizon as the Mesaba Energy project. We identified two: Sithe Global Energy's Desert Rock plant in New Mexico, and Southwest Electric Power Company's proposed Hempstead County, Arkansas. These two plants represent very recent power plant permitting activity, and were identified by both Xcel Energy and Minnesota Power in their direct testimony[1,2]. US EPA is finalizing a new source review permit for Desert Rock, while Southwest Electric Power Company (a subsidiary of American Electric Power) has submitted a permit application to the state of Arkansas. Arkansas officials estimate having a draft permit by the end of the year[3].

[1] Direct Testimony, Roger A. Clarke, Xcel Energy. September 5, 2006
[2] Direct Testimony, Michael G. Cashin, Minnesota Power.
[3] Personal communication, Thomas Rheaume, Arkansas Department of Natural Resources September 28, 2006.

The MPCA did not choose to include Ottertail Power's Big Stone II project in this analysis, due to very recent announced project changes and pending amendments to its air emissions permit.

Because the purpose of this analysis is to compare technologies, we include Mesaba I in the analysis, assuming that it is burning 100% subbituminous coal, one of several operating fuel blend scenarios Mesaba Energy seeks to have permitted in its air emissions operating permit. In this way, identical fuel types are being compared for each technology.

Two factors must be considered when reviewing this comparison. Sub- and supercritical pulverized coal plants are well understood, and estimates of the performance of that technology are very reliable. By contrast, EPA's expected future performance of IGCC and ultra-supercritical plants is based on modeled predictions, not on widely deployed and understood technologies, and assumes expected thermal efficiencies. There are no ultra-supercritical and few IGCC plants operating in the United States. The Hempstead Co. facility is the first ultra-supercritical plant proposed for construction.

Second, permit limits represent a maximum allowed emissions level. Limits in air quality permits are based on an expected "worst case" performance level in order that the full range of operations is taken into account. Actual emissions are less than permitted emissions.

Results and Discussion:

Energy Conversion/Efficiency

The thermal efficiency of the generating technologies of interest is first reviewed. The thermal efficiency is the measure of the unit's ability to efficiently extract the heat from coal (or oil or gas) and convert it from thermal to mechanical to finally electrical energy. Improving thermal efficiencies means that more electricity is generated with the same amount of coal and depending on control technology, lower air emissions.

Figure 1 contains the comparison of thermal efficiencies for the technologies that were reviewed. Wabash Power is the operating demonstration IGCC plant in Indiana and selected gasification technology for Mesaba Energy. It achieves an efficiency of 40% on bituminous coal. The typical net thermal efficiency for an existing subbituminous subcritical pulverized coal generating unit is about 33%, shown as the third column of Figure 1. The thermal efficiency of the proposed Mesaba I plant (36.3%) is also compared to proposed Desert Rock (34.3%) and SWEPCO Hempstead Co. (35.9%) plants. Separately in Figure 2 Mesaba I is compared to EPA's modeled plants' performance-- supercritical (37.9%), IGCC (40%), and ultra supercritical (41.9%) plants all using subbituminous coal.

Figure 1. Net Thermal Efficiency for operating and proposed subbituminous-fired facilities.

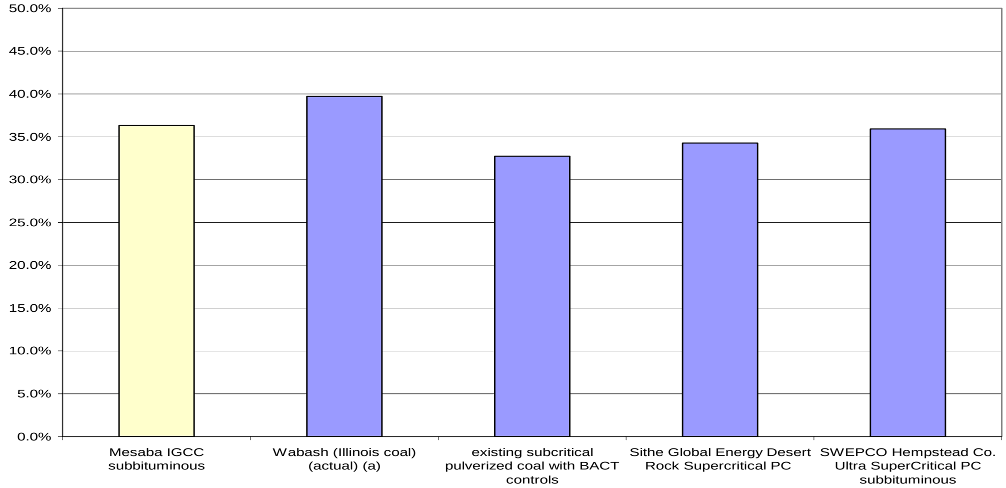
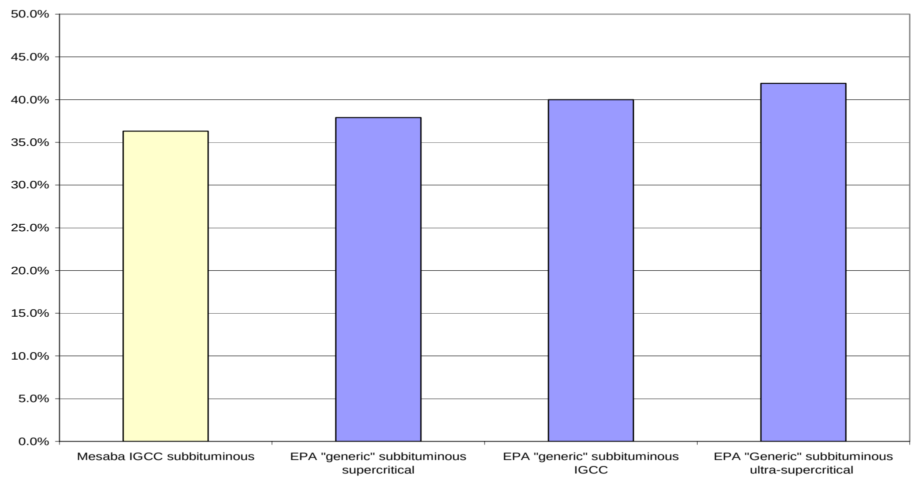


Figure 2. Thermal Efficiency of Mesaba Energy as compared to EPA modeled subbituminous-fired plant performance.



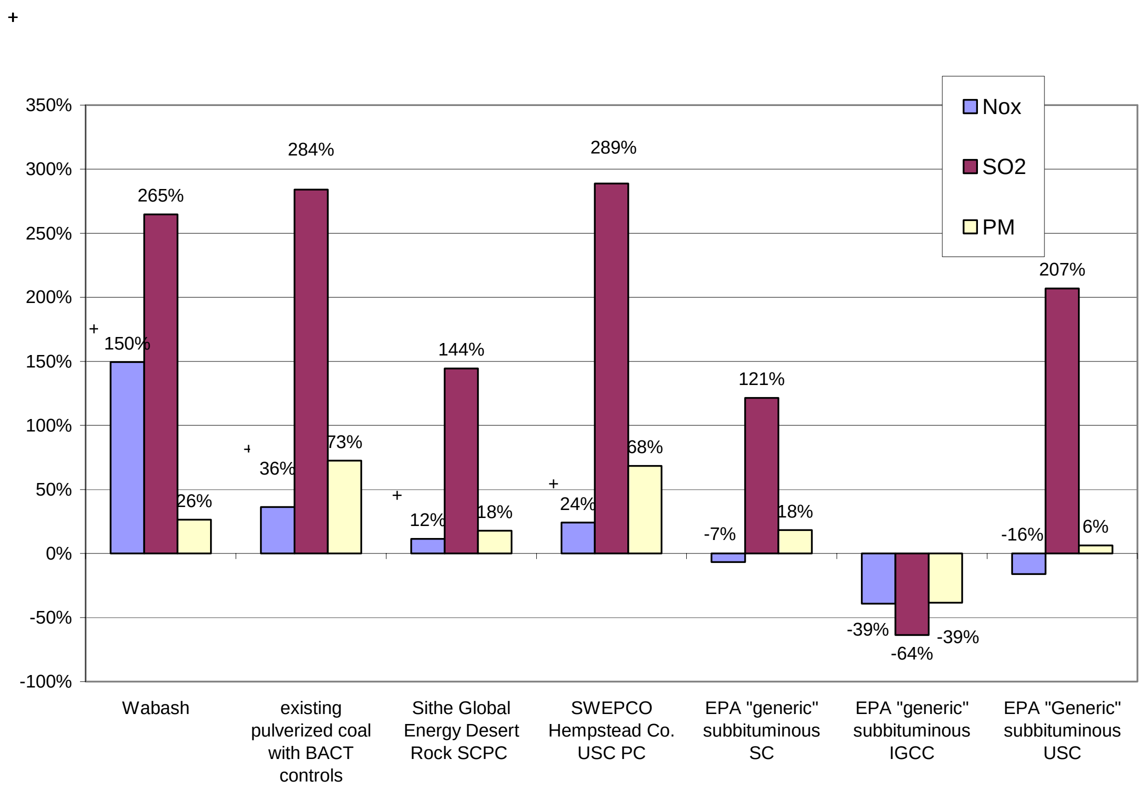
The reported efficiencies were extracted from permit applications or calculated from permit information and interviews[4]. For operating units, efficiency is determined using specific testing procedures.[5] The MPCA believes that actual performance of the proposed plants Mesaba, Desert Rock and SWEPCO Hempstead Co. is likely to show higher thermal efficiencies than represented here, and may achieve the thermal efficiencies that EPA predicts. Ultra-supercritical plants are located in Japan, Germany and Denmark. Denmark units are reported to achieve efficiencies greater than 40%.[6]

[4] Personal communication, Kris Gaus, American Electric Power. October 10, 2006
[5] The American Society of Mechanical Engineers (ASME) publishes very specific testing procedures for making such measurements.
[6] Burmeister & Wain Energy. www.bwe.dk/pdf/brochure-06%20USC.pdf Accessed October 24, 2006.

Air Pollutant Emissions

The MPCA calculated each facility's emissions rate (in lb/MWh), and compares them as a percentage of Mesaba Energy I's proposed permit limit. Figure 3 compares NOx, SO2, and PM[7]. In Figure 3 (and Figures 4 and 5), a positive (upward) bar means that the generating technology emits more pollutant for each megawatt generated than Mesaba; a downward bar means the technology emits less than Mesaba.

Figure 3. Nitrogen Oxides, Sulfur Dioxide and Particulate Matter emission rates per MWh as a percentage of Mesaba Energy I



Nitrogen oxide (NOx) emissions are a function of the generating technology and the efficiency of add-on control equipment. Units without specific NOx controls will have higher emissions (Wabash), but when advanced air pollution control equipment is used (such as selective catalytic reduction (SCR) at pulverized coal units) the difference between Mesaba Energy's performance and other types of generating technology is diminished. Note that EPA estimates that future performance of supercritical and ultra supercritical units will emit less NOx than Mesaba Energy for every megawatt generated.

Because of the ease in removing sulfur from the syngas prior to its combustion in a combustion turbine generator, IGCC plants (and Mesaba Energy I) emit far less SO2 than the other technologies. SO2 emissions are a result of the amount of sulfur in the coal and the removal

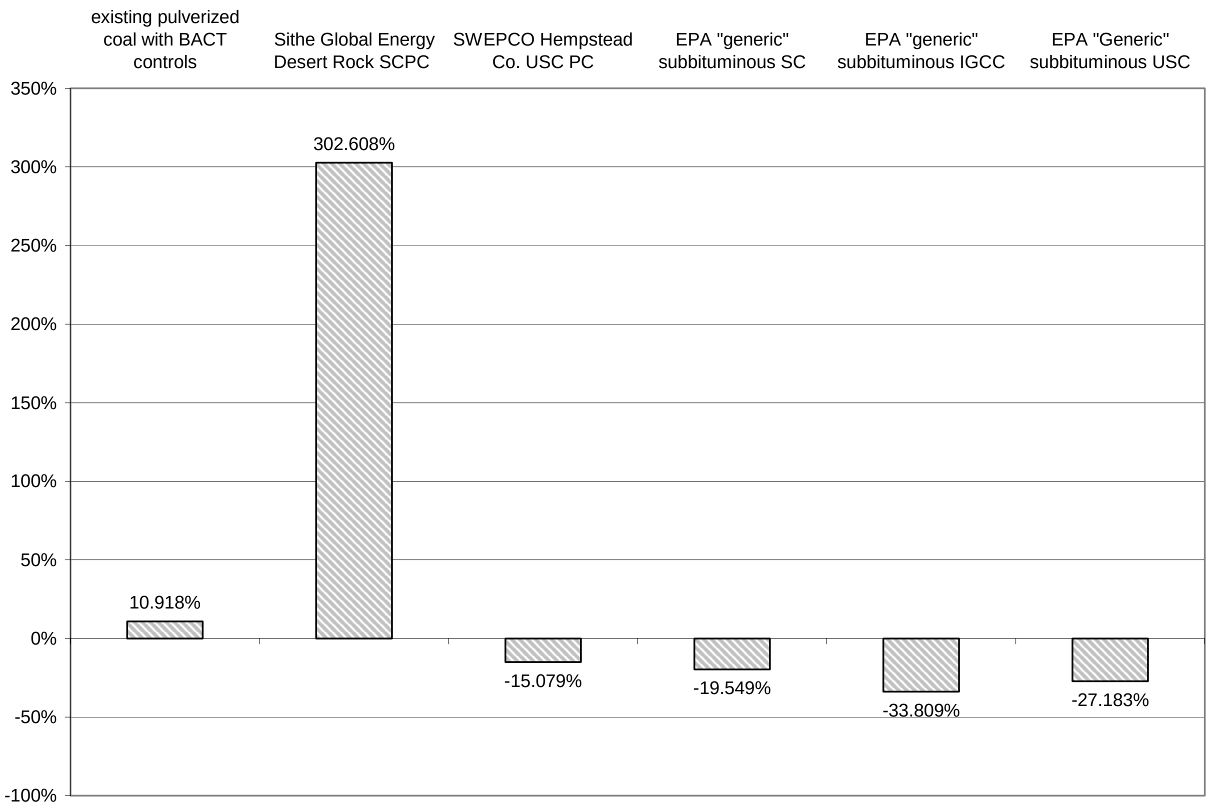
[7] Particulate matter is filterable particulate matter, measured by either Method 5 or Method 201A.

efficiency of the downstream control device. Efficiency improvements at pulverized coal facilities help lower the rate of SO_2 emissions. In comparison to Mesaba Energy, every generating technology has higher SO_2 emissions, some by a factor of 2.

Particulate matter emissions do not vary much with changes in generating technologies.

Because of the difference in scale, mercury emissions have been shown separately in Figure 4.

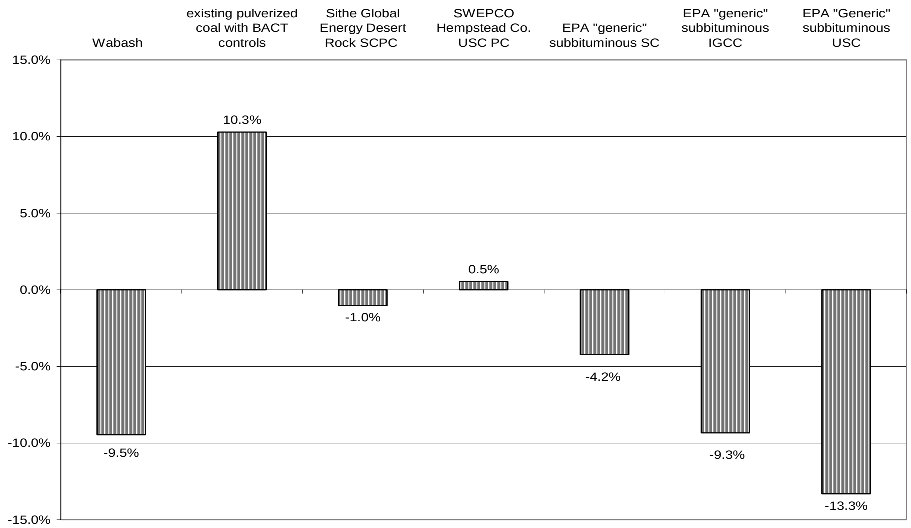
Figure 4. Mercury emissions as a percentage of mercury emissions per MWh from Mesaba Energy I



Like SO_2, the rate at which mercury is emitted during combustion depends critically on the presence or absence of mercury controls. Mesaba Energy is proposing 90% control in its permit; the Desert Rock facility is proposing 80% control and has not committed to activated carbon injection, the state of the art control technology for high levels of mercury control. The Hempstead Co. facility mercury emissions is assumed to achieve the same mercury emissions rate that EPA predicts for ultra supercritical boilers, and is shown to emit less mercury than Mesaba Energy I on a pounds of mercury emitted per net megawatt of electricity generated. Once controls are installed, mercury emissions appear to vary with thermal efficiency.

While the Minnesota statute is silent on carbon dioxide, the MPCA calculated likely CO_2 emission rates for all technologies, and shows them in Figure 5 as a percentage of Mesaba Energy's represented performance. In general, differences in CO_2 emission rates correspond to differences in plant thermal efficiency among the different technologies that we evaluated.

Figure 5. Carbon Dioxide Emissions per MWh as a percent of Mesaba Energy I



References:

U.S. EPA. Environmental Footprints and Costs of Coal-Based Integrated Gasification Comined Cycle and Pulverized Coal Technologies. EPA-430/R-06/006, July 2006.

Excelsior Energy. Mesaba Energy Project Application to the Minnesota Pollution Control Agency for a New Source Review Construction Authorization Permit. June 16, 2006.

Trinity Consultants, Little Rock, AK. PSD Permit Application, Coal-Fired Generation Facility, Southwest Electric Power Co, Hempstead Co Project. August 9, 2006.

U.S. EPA Region 9. Draft PSD permit for Desert Rock Energy Center Proposed Permit Conditions accessed 10/9/06 at www.epa.gov/region9/air/permit/desertrock/index.html

Facility Characteristics of EPA "Generic" Coal-fired Electric Generating Units, Currently Proposed EGUs, and Mesaba Energy I

	Net Thermal Efficiency % HHV	Net Heat Rate Btu/kWH	Gross Power MW	Internal power MW	Heat input mmbtu/hr	fuel required lb/hr	Net Power MW
Mesaba IGCC subbituminous (a)	36.3%	9,397	740	143	5616		598
EPA "generic" subbituminous IGCC (f)	40.0%	8,520	575	75		484,089	500
Wabash (Illinois coal) (actual) (b)	39.7%	8,910					192
EPA "Generic" subbituminous ultra-supercritical (f)	41.9%	8,146	543	43		460,227	500
existing subcritical pulverized coal with BACT controls (c)	32.7%	10,423			3355		350
Sithe Global Energy Desert Rock Supercritical PC (d)	34.3%	9,956	1500		6800	800,000	2 @ 683 net
SWEPCO Hempstead Co. Ultra SuperCritical PC subbituminous(e)	35.9%	9,500			6000 (b)	750,000	600
EPA "generic" subbituminous supercritical (f)	37.9%	9,000	541	41		517,045	500

Facility Emission Rates for Comparison

	NOx		SO2		PM		Hg		CO2	
	lb/MWh	lb/MMBtu	lb/MWh	lb/MMBtu	lb/MWh	lb/MMBtu	lb/MWh	lb/mmBtu	lb/MWh	lb/mmBtu
Mesaba IGCC subbituminous (a)	0.536	0.057	0.24	0.03	0.085	0.009	4.70E-06	5.00E-07	2005	213.34
EPA "generic" subbituminous IGCC (f)	0.326	0.044	0.09	0.01	0.052	0.007	3.58E-06	4.20E-07	1818	213.34
Wabash (Illinois coal) (actual) (b)	1.337	0.150	0.89	0.10	0.107	0.012			203.74	203.74
EPA "Generic" subbituminous ultra-supercritical (f)	0.450	0.060	0.75	0.10	0.090	0.012	3.42E-06	4.20E-07	1738	213.34
existing subcritical pulverized coal with BACT controls (c)	0.730	0.070	0.94	0.09	0.146	0.014	5.21E-06	5.00E-07	2211	212.14
Sithe Global Energy Desert Rock Supercritical PC (d)	0.597	0.060	0.60	0.06	0.100	0.01	1.89E-05	1.90E-06	1984	199.29
SWEPCO Hempstead Co. Ultra SuperCritical PC subbituminous (e)	0.665	0.070	0.95	0.10	0.143	0.015	3.99E-06	4.20E-07	2015	212.14
EPA "generic" subbituminous supercritical (f)	0.500	0.060	0.54	0.07	0.100	0.012	3.78E-06	4.20E-07	1920	213.34

References:

(a) Mesaba Energy I air emissions permit application, June 2006, p. 48. Excelsior Energy December 2005 Filing, Section IV, p. 51 Also, Robert Evans Rebuttal Testimony, October 10, 2006 p. 18.

(b) Wabash performance from www.clean-energy.us/projects/wabash_indiana.htm accessed on October 10, 2006

(c) Minnesota Power Boswell 3 retrofit, August 2006 permit application

(d) Desert Rock efficiency, heat rate calculated from PSD permit application accessed 10/9/06 at www.epa.gov/region9/air/permit/desertrock/index.html

(e) SWEPCO permit application indicates the boiler to be a supercritical boiler with a heat input rate of 6000 mmbtu/hr; AEP contact indicates the plant is being designed as an ultra supercritical plant, and design heat input rate is 5700 to 5800 mmbtu/hr, net electrical output 600 MW. This difference affects the net heat rate calculation and total boiler efficiency.

(f) EPA generic expected plant performance characteristics EPA-430/R-06-006 July 2006

MPCA ATTACHMENT 1