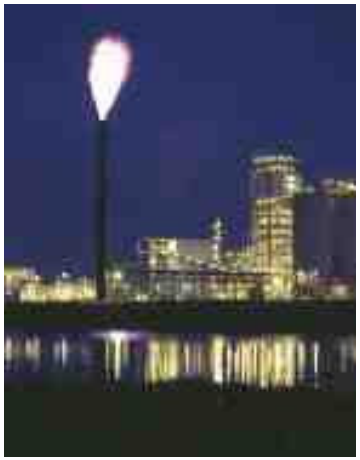
"IGCC 101"

Colorado's New Energy Economy: The Path Forward



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CH2M HILL

October 30, 2007
Denver, CO

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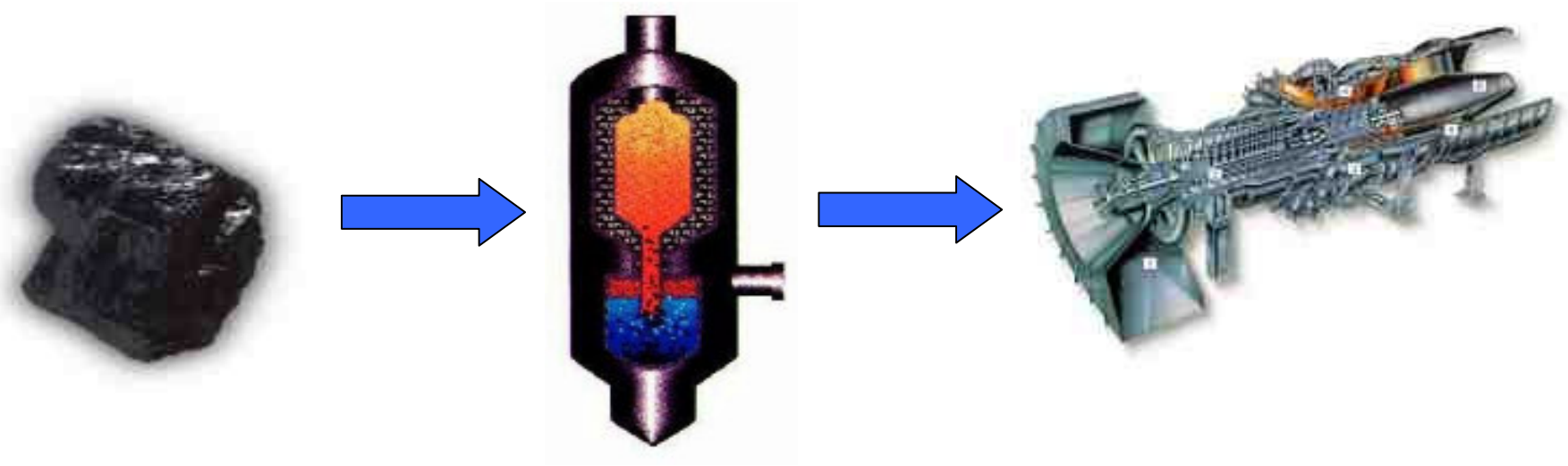
Topics

- IGCC “101”
- IGCC technology suppliers
- Environmental issues
- Proposed IGCC projects
- Costs
- CO_2 capture

What is IGCC?

Integrated Gasification Combined Cycle = IGCC



What is IGCC?

- Integrates two distinct technologies:
  - Coal gasification from the chemical industry
  - Combined cycle power generation from the power industry

- Advantages of IGCC
  - Can be designed to use a wide range of feedstocks
    - Coal, pet coke, biomass, blends
  - Takes advantage of high efficiency combined cycle power generation technology
  - Has low emissions and marketable byproducts
    - Slag, sulfur or sulfuric acid

What is Gasification?

- Thermal conversion of coal at 1,400-2,800°F, with a limited supply of air or oxygen, to a synthetic gas, or *syngas*
- It's not combustion!
- Gasification uses only a fraction of the air or oxygen that would be needed to burn the coal

What's in the Syngas?

- Syngas contains mostly hydrogen, carbon monoxide, carbon dioxide, and water
  - it's not methane, like natural gas
- Heating value is 125-300 Btu/ft^3
  - vs. natural gas at 1,000 Btu/ft^3
- Syngas can be used as a feedstock to make chemicals and fuels, or for generating power

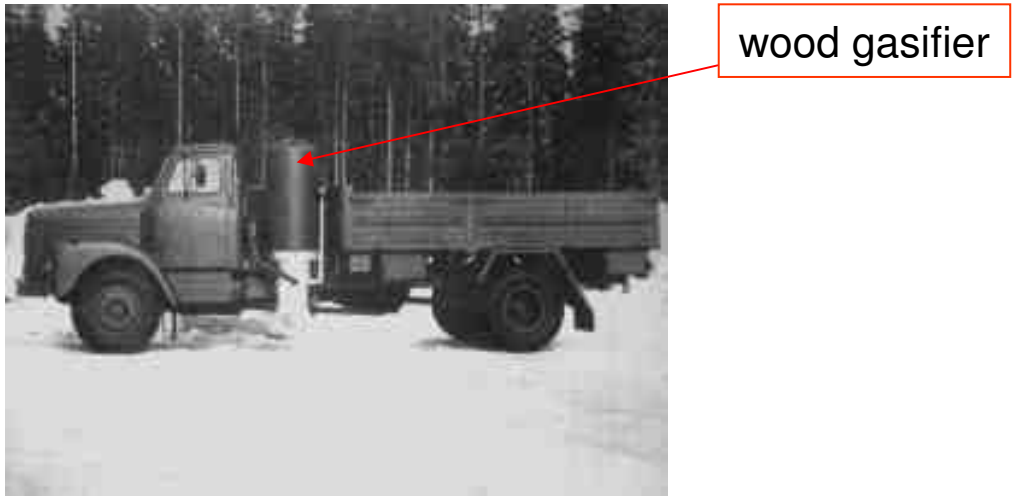
How has Gasification been Used?

- Making “town gas” from coal (1792)

- Manufactured gas plants – prior to discovery and widespread use of natural gas

How has Gasification been Used?

- Fuels
  - WWII: Germany – no access to oil, but lots of coal
  - "Fischer-Tropsch" process produced diesel and gasoline from syngas
  - Cars and trucks used small wood gasifiers for fuel



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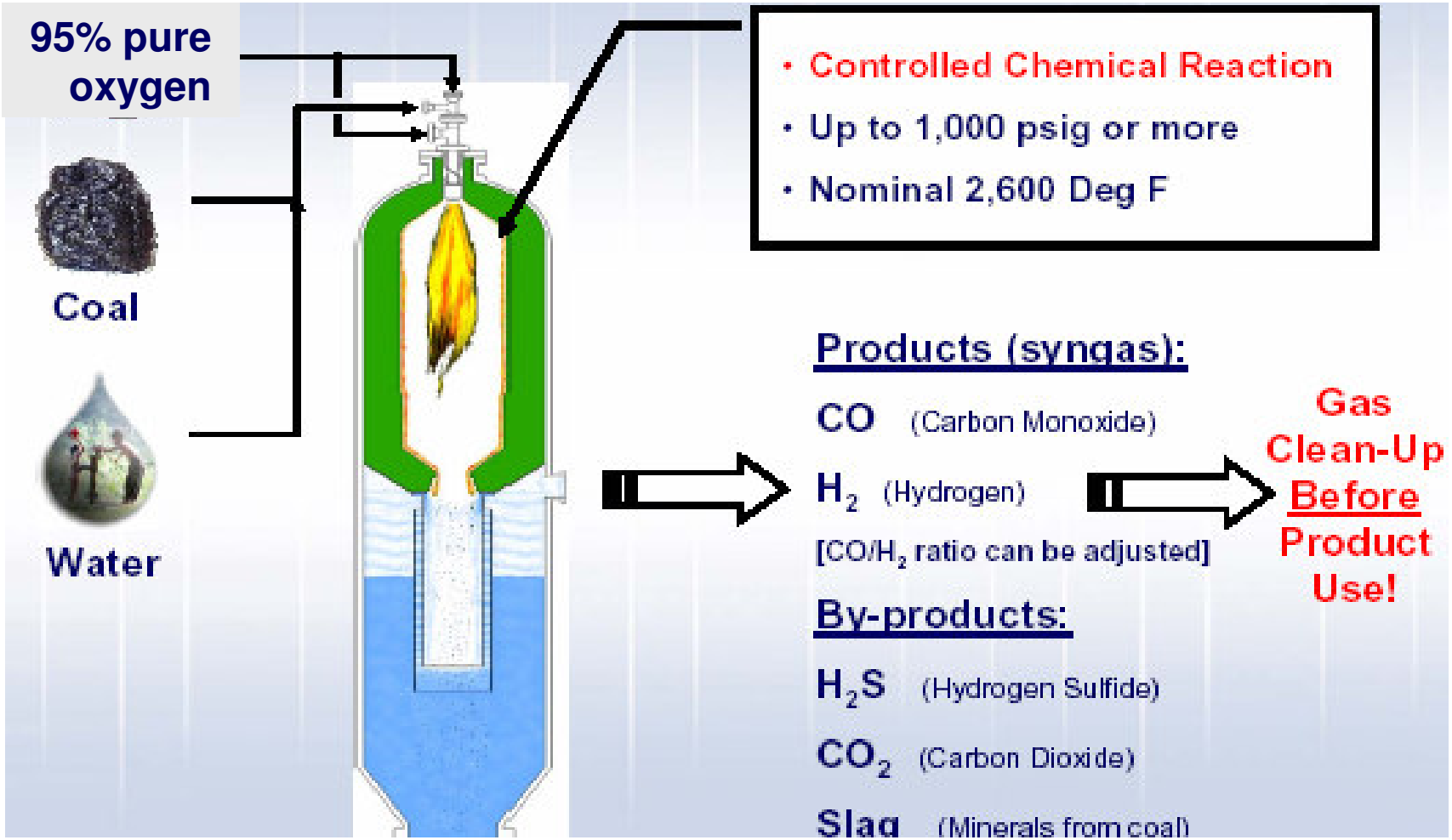
Modern Coal Gasification



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Dakota Gasification Company
Great Plains Synfuels Plant

- Beulah, North Dakota
- Started up in 1984
- Part of Basin Electric Power Cooperative
- Converts 16,000 tons/day of North Dakota lignite to synthetic natural gas (SNG)
- SNG is sold into local pipeline

Eastman Chemical
Coal to Chemicals

- Kingsport, Tennessee
- Started up in 1983
- Originally part of Eastman Kodak
- Texaco gasifiers
- Gasifies 1,200 tons/day Central Appalachian medium sulfur coal
- Sulfur compounds and ash are removed from the syngas
- Syngas is used to make methanol, acetic acid, acetic anhydride, methyl acetate and….

Consumer Products

CO and H_2 can be combined into long chain organic molecules

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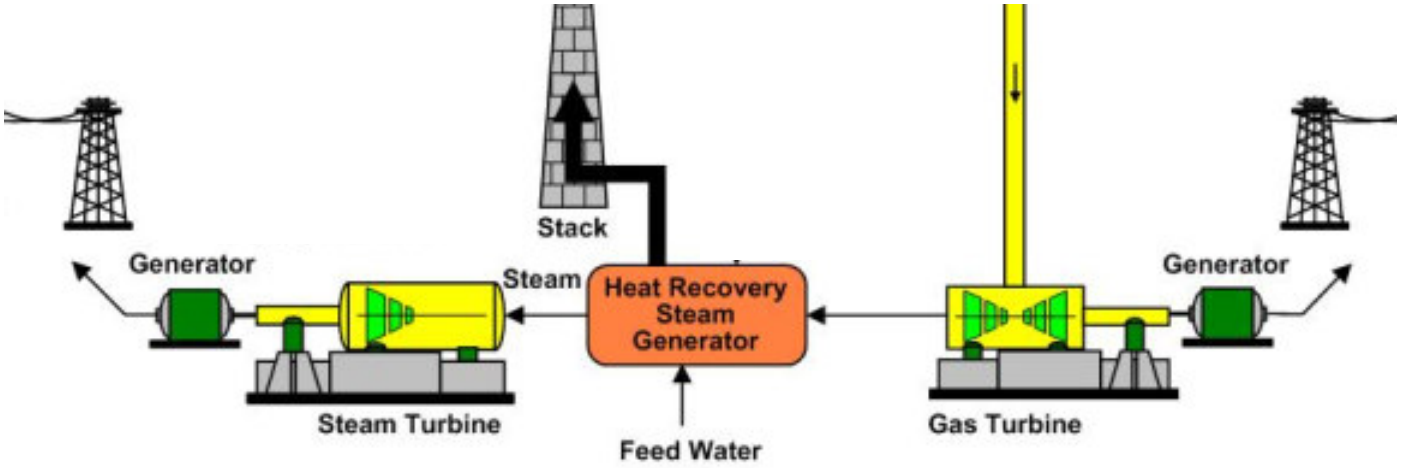
Gasification Plants

- Gasification is a commercially proven technology
- There are 138 operating gasification plants with a total of 417 gasifiers in operation worldwide
- They produce syngas for use in making chemicals, synthetic natural gas, hydrogen for ammonia, Fischer-Tropsch transportation fuels, and power

Combined Cycle Power Generation

What is Combined Cycle Power Generation?



- Hot exhaust gas from gas turbine is ducted through a boiler, where steam is produced
- Steam is piped to a conventional steam turbine-generator, producing more electricity
- Combined cycle plant efficiency = 55+%
- Commercially proven at hundreds of installations

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Combined Cycle – 2 Gas Turbines and 1 Steam Turbine

How Does IGCC Work?

- Integrate the coal gasification process with a combined cycle power plant
- Instead of using high-cost natural gas in the combined cycle power plant, convert low-cost coal to a clean-burning syngas and use it as the fuel for the gas turbines

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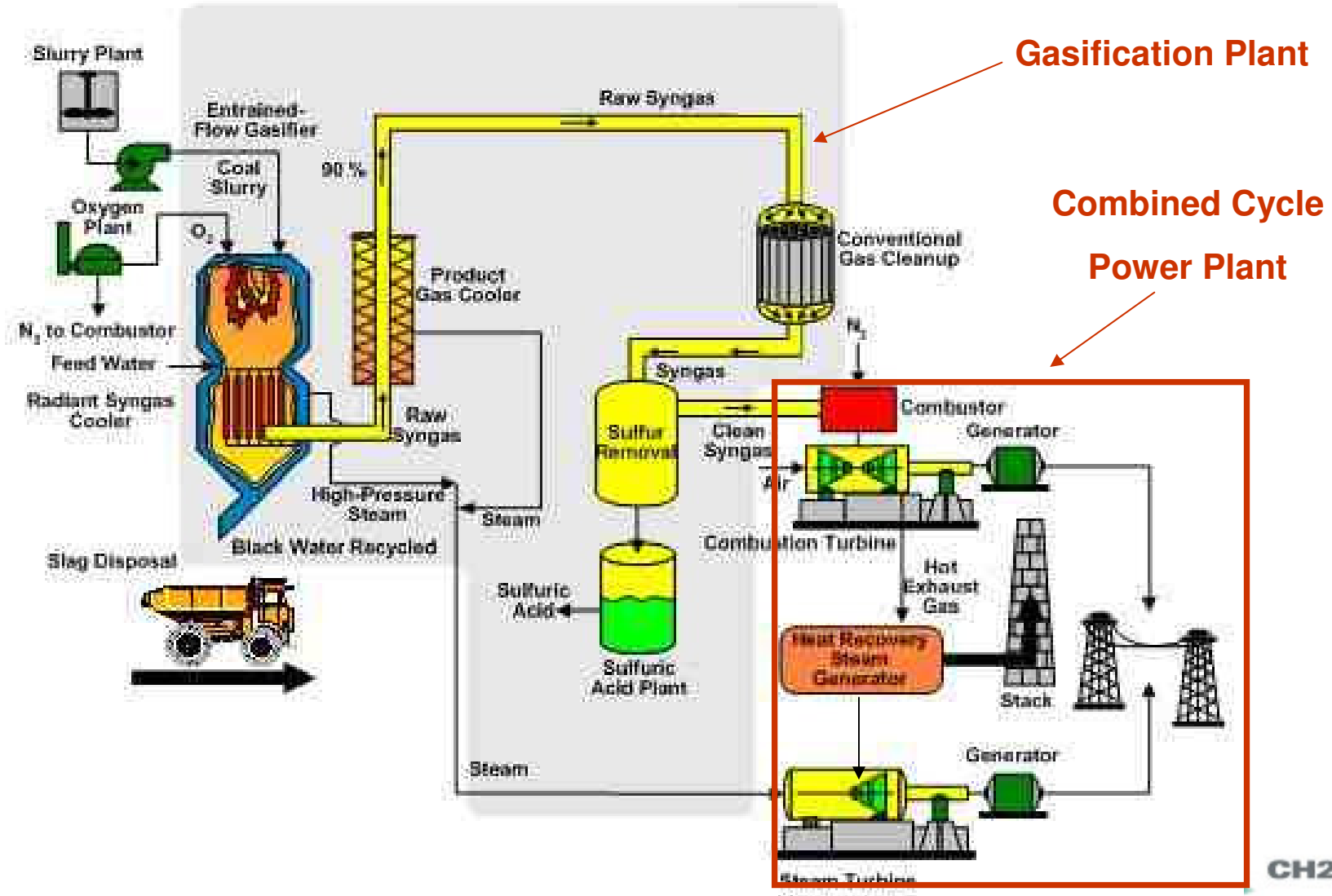

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Where has IGCC Been Used?

Cool Water IGCC Demonstration Plant Daggett, CA

- First demonstration of IGCC in the U.S.
- 1984-89 demonstration period
- 110 MW size
- Texaco gasifier and GE combined cycle
- 1,150 tons/day Utah coal
- Co-funded by Southern California Edison, Texaco, GE & EPRI

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Louisiana Gasification Technology, Inc. Plaquemine, LA

- Operated 1987-1995
- ConocoPhillips E-Gas™ Technology
- 2,400 tons/day subbituminous coal
- Gasified 3.7 million tons of coal during demonstration period
- Fueled two gas turbines and provided steam to Dow Chemical facility

Shell Deer Park Gasification Facility Deer Park, TX

- Operated 1987-1995
- Shell coal gasification technology
- 250-450 tons/day of feedstock
- Wide range of feedstocks from pet coke to Texas lignite
- Syngas burned in refinery boilers

Coal-based IGCC Plants

- Based on those facilities, coal-based IGCC demonstration plants were built in the U.S. and Europe
- All went into operation in the 1990s
- Today, there are four coal-based IGCC plants in operation, using a wide range of feedstocks and blends of feedstocks
  - Bituminous coal
  - Subbituminous coal
  - Pet coke
  - Biomass

Existing Coal-based IGCC Plants

Company	Facility	Location	Feedstock	Gasifier Technology
Nuon	Willem Alexander Centrale	Buggenum, The Netherlands	coal/biomass	Shell
SG Solutions	Wabash River	W. Terre Haute, IN	coal/pet coke	ConocoPhillips
Tampa Electric	Polk Power Station	Mulberry, FL	coal/pet coke	GE Energy
ELCOGAS	Puertollano	Puertollano, Spain	coal/pet coke	Prenflo

Nuon
Willem-Alexander Centrale
Buggenum, The Netherlands

- Started up in 1993
- Shell technology
- ~2,000 tons/day coal
- 253 MW net
- Now using blends of coal and biomass

SG Solutions
Wabash River Generating Station
W. Terre Haute, IN

- Started up in July 1995
- ConocoPhillips E-Gas technology
- ~2,000 tons/day coal, pet coke, blends
- DOE Clean Coal Technology Program
- 262 MW net output

Tampa Electric Company
Polk Power Station
Mulberry, FL

- Started up in July 1996
- GE Energy gasifier
- ~2,000 tons/day coal and blend with pet coke
- DOE Clean Coal Technology Program
- 252 MW net output

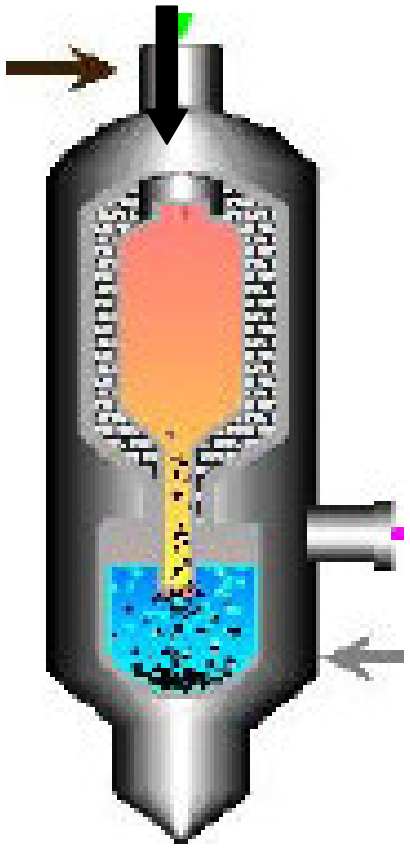
ELCOGAS
Puertollano, Spain

- Started up in 1998
- Prenflo technology
- ~2,000 tons/day of 50/50 blend of local subbituminous coal and pet coke
- 260-280 MW net output

IGCC Technology Suppliers

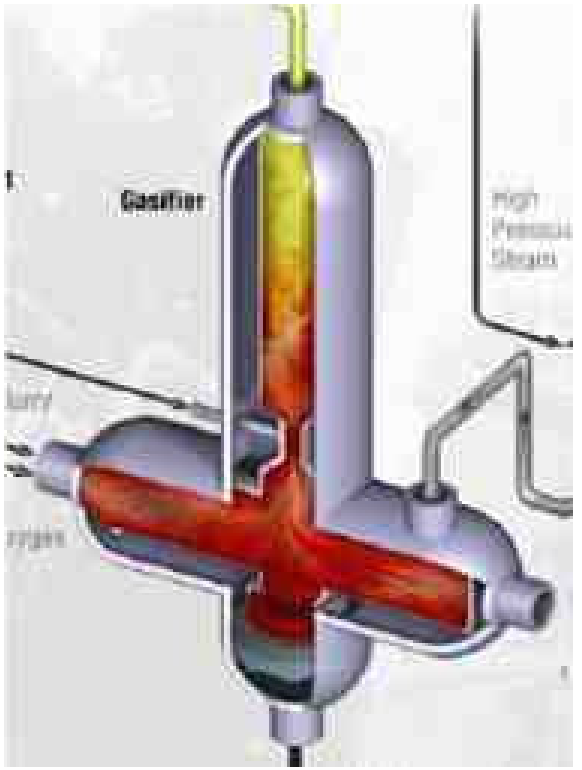
GE Energy (Texaco process)

- Coal-water slurry feed
- Oxygen-blown
- Refractory-lined gasifier
- Good for bituminous coal, pet coke, or blends of pet coke with low-rank coals
- Working on new design for subbituminous coals
- GE provides combined cycle



ConocoPhillips (E-Gas process)

- Coal-water slurry feed
- Oxygen-blown
- Refractory-lined gasifier
- Good for a wide range of coals, from pet coke to subbituminous, and blends
- Siemens or others provide combined cycle



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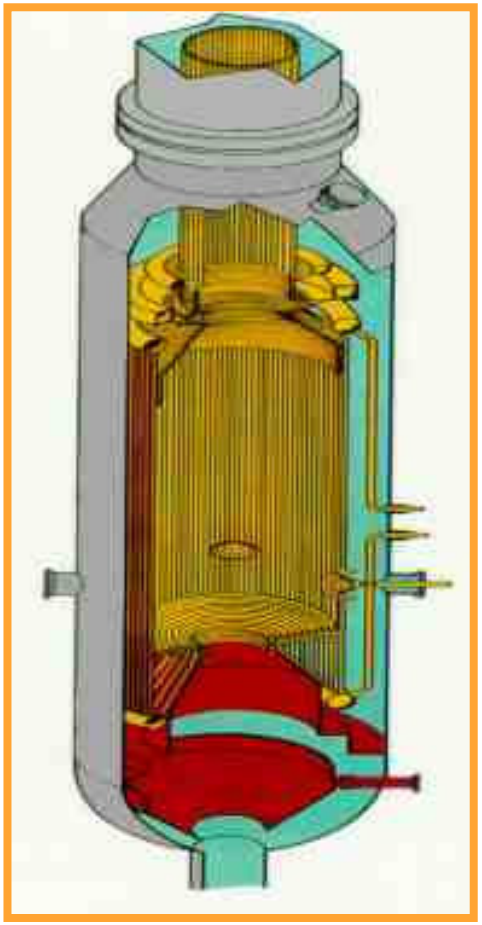
Shell

- Dry feed (coal is crushed and dried and then fed into gasifier)
- Oxygen-blown
- Waterwall (no refractory)
- Good for wide variety of feedstocks, from pet coke to subbituminous, and blends
- Various combined cycle suppliers



The New IGCC Reference Plant

- Based on eastern bituminous coal, producing sufficient syngas to fully load two 232 MW gas turbines, plus 320 MW steam turbine

- Gross output: 784 MW
- Internal load: -154 MW
- Net output: 630 MW

- Feedstock requirements: ~6,000 tons/day coal

IGCC Plant (with subbituminous coal at 4,000 feet altitude)

- Higher moisture, lower heating value results in slight reduction in output and efficiency
- Gas turbines have reduced output at higher altitudes

- Gross output: 670 MW
- Internal load: -120 MW
- Net output: 550 MW

- Feedstock requirements: ~7,400 tons/day coal

Proposed IGCC Projects – Air Permit Applications Filed or Permits Issued

Company	Facility	Location	Feedstock	Gasification Technology
AEP	Mountaineer	New Haven, WV	Coal	GE
Duke Energy Indiana	Edwardsport	Edwardsport, IN	Coal	GE
EnergyNorthwest	Pacific Mountain Energy Center	Port of Kalama, WA	PRB/pet coke	ConocoPhillips
ERORA	Cash Creek Generation	Owensboro, KY	Coal	GE
ERORA	Taylorville Energy Center	Taylorville, IL	Coal	GE
Excelsior Energy	Mesaba	Taconite, MN	PRB/Illinois #6/pet coke	ConocoPhillips

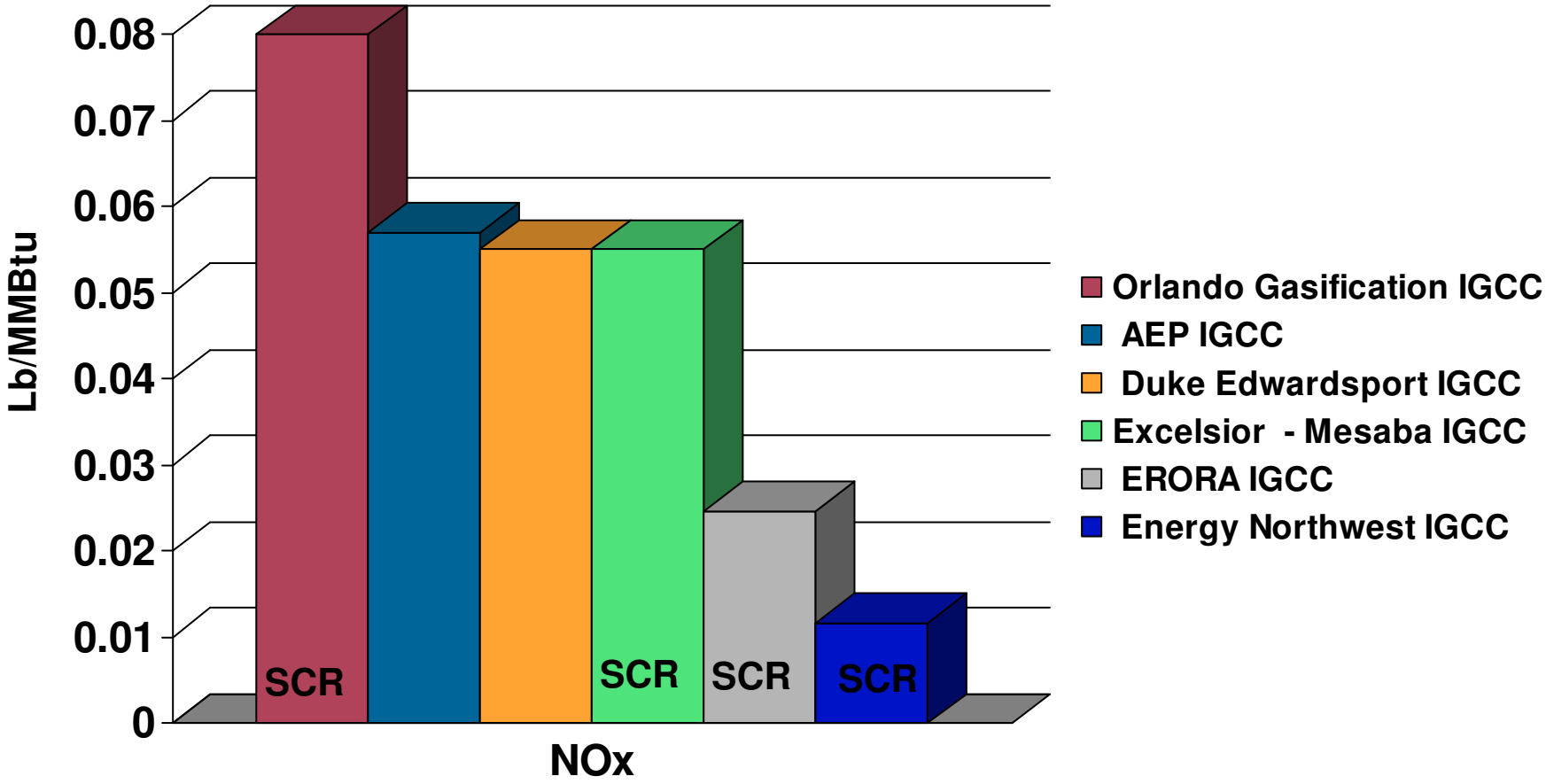
IGCC Availability Improvements

- IGCC plants being planned today will use lessons learned from 10+ years of IGCC experience
  - Better materials of construction
  - Spare systems and equipment
  - Improved gasifier refractory
  - Longer lasting gasifier burners
  - More efficient heat exchangers
  - Improvements in combined cycle technology
- Next generation of IGCC should achieve ~85% availability with two 50% gasifier trains

Environmental Issues

Air Emissions

Air Emission Comparisons - NOx



IGCC data is on gasifier heat input basis

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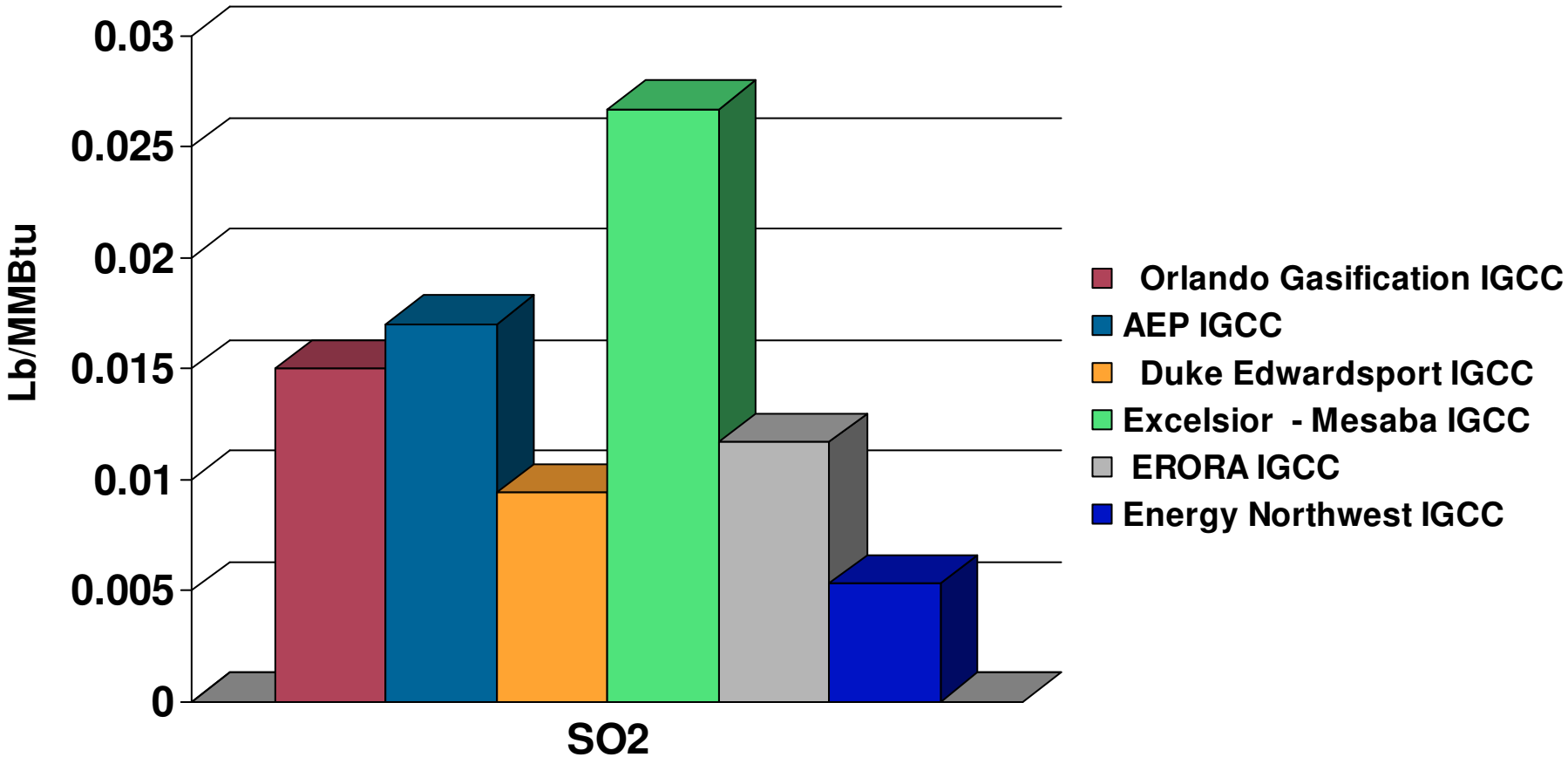
Air Emission Comparisons – SO_2



IGCC data is on gasifier heat input basis

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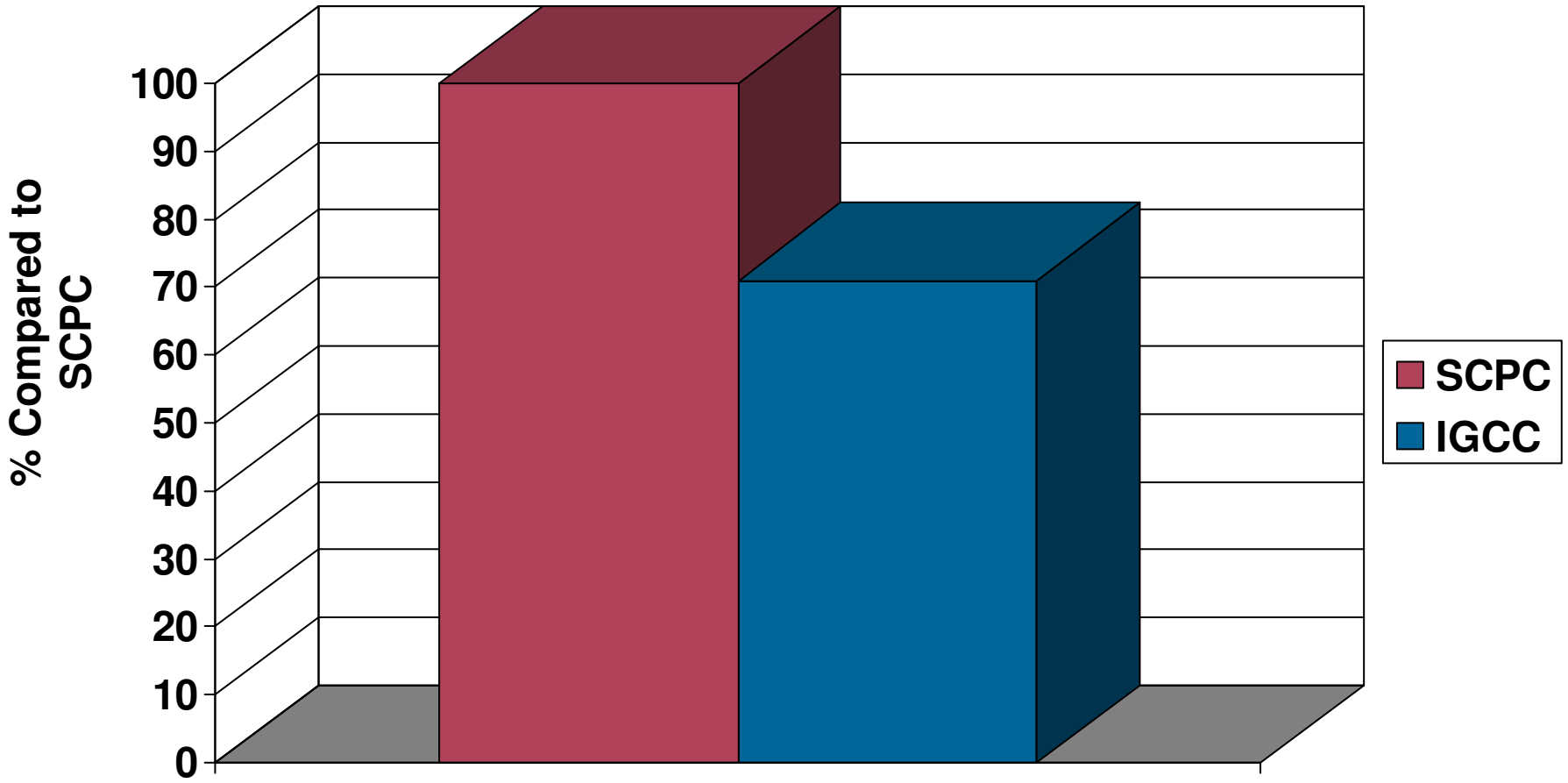
Mercury Removal

- Pre-sulfided carbon beds
- >94% removal of vapor-phase mercury at Eastman Chemical
- Forms a mercury-sulfur complex
- Spent carbon disposed of in drums once/year
- Proposed IGCC plants plan to use this technology

Source: Eastman Chemical

Water Issues

Comparison of Water Use



Source: DOE

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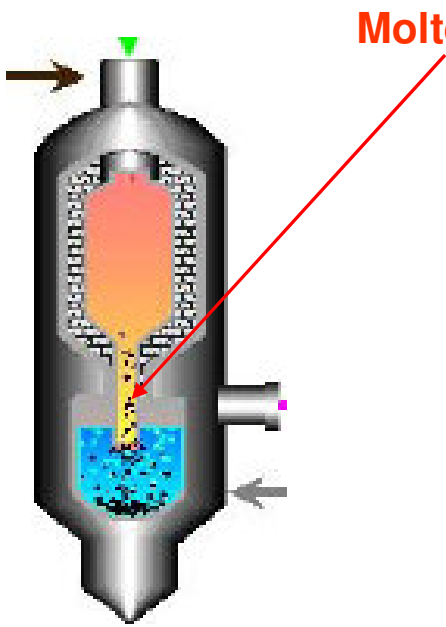
Solid Byproducts

- Ash is removed in molten form, then quench-cooled to form glassy, inert, marketable slag



Slag Use

- Used for making
  - Cement
  - Asphalt filler
  - Roofing shingles
  - Sand-blasting grit

Other Byproducts

- Sulfur
  - Recovered in molten form
  - Commercially proven processes from refinery industry
  - Transported by rail or truck

- Sulfuric acid
  - Commercially proven in many industrial processes
  - Transported by rail or truck

Cost

Cost Basis

- Be careful when comparing costs
- Size (MW)
- IGCC technology supplier
- Location
- Feedstock
- Published costs or cost estimates usually do not include owner's costs
  - Permitting
  - Interest during construction (AFUDC)
  - Transmission lines and substation
  - Site
  - Escalation to actual in-service date
  - These can add 30% to overnight "Total Project Cost"

IGCC Capital Costs as Reported to State Agencies (no CO_2 Capture)

IGCC Plant	In-service Date	$ Billion	$/kW
AEP - Mountaineer	2012	$2.23	$3,454
Duke Energy Indiana - Edwardsport	2011	$1.98	$3,150
Excelsior Energy – Mesaba IGCC Project	2011	$2.156	$3,594
Tampa Electric Co. – Polk Unit #6	2013	$2.0	$3,180

CO_2 Capture Technology for IGCC

- IGCC process does not inherently "capture" CO_2
- CO_2 capture requires additional equipment, and results in increased capital and O&M expense, as well as a decrease in the unit's output and efficiency
- None of the 4 coal-based IGCC units capture CO_2
- CO_2 capture technology utilized on gasification plants needs to be modified for use on IGCC, then proven at larger scale
- Once the CO_2 is captured, you must have a place to use or sequester it

Dakota Gasification

- SNG production process produces concentrated CO_2 stream
- CO_2 used to be vented
- Now, >50% of the CO_2 (2 million tons/year) is captured, compressed and piped 205 miles to Saskatchewan and sold for EOR by EnCana and Apache Canada

Impacts of CO_2 Capture

- IGCC plant designed for CO_2 capture is larger/different than a standard IGCC plant
  - Higher plant gross output to provide internal power for CO_2 capture system and CO_2 compressors
  - More steam needed to provide requirements in CO_2 capture system (instead of being used to generate electricity)
  - Syngas has a high concentration of hydrogen
    - Industrial-sized gas turbines are presently burning high-hydrogen syngas streams, but
    - IGCC-sized gas turbines to combust high-hydrogen syngas are still in commercial development

Conclusions

- Coal gasification and combined cycle technologies are commercially proven
- Coal-based IGCC has been demonstrated at the 250 MW scale
- Coal-based IGCC plants are being developed nationwide at the 630 MW size designed for a wide range of coals
- CO_2 capture technology has been used on gasification plants, but not yet on IGCC plants
- Total Capital Requirement for IGCC is in the range of $3,150-3,600/kW for new plants (no CO_2 capture)
- CO_2 capture results in additional IGCC plant cost and decreased IGCC performance and output

Questions?

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