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ENVIRONMENTAL PERFORMANCE OF IGCC POWER PLANTS

Steve Jenkins
CH2M HILL, Inc.
&
George Booras
Electric Power Research Institute

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Topics

- IGCC environmental performance
  - Air
  - Water
  - Wastes
- Impacts of adding CO_2 capture
- Hybrid IGCC configuration
- Conclusions

Permits/Permit Applications for Actual IGCC Projects

Excelsior Energy, Mesaba Energy Project, MN

600 MW_e, No CO_2 Capture
E-Gas/MDEA

Duke Energy, Edwardsport, IN

630 MW_e, No CO_2 Capture
GE RQ/Selexol

Taylorville Energy Center, IL

542 MW_e, Hybrid
Siemens/Rectisol

Cash Creek Generation, KY

566 MW_e, Hybrid
GE Quench/Selexol

Hydrogen Energy California

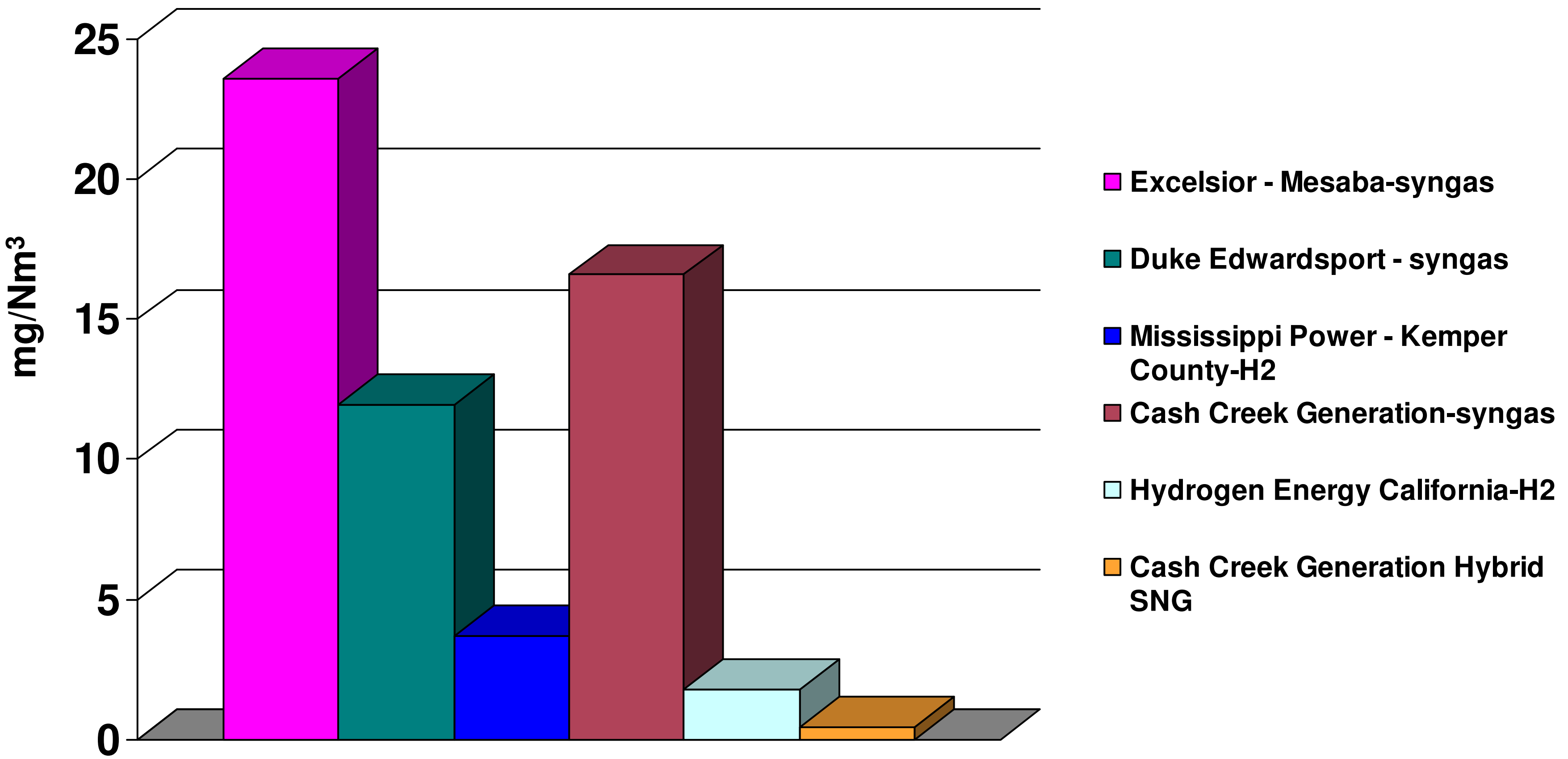
250 MW_e, 90% CO_2 Capture
GE Quench/Rectisol

Mississippi Power, Kemper County IGCC

582 MW_e, 65% CO_2 Capture
KBR TRIG/Selexol

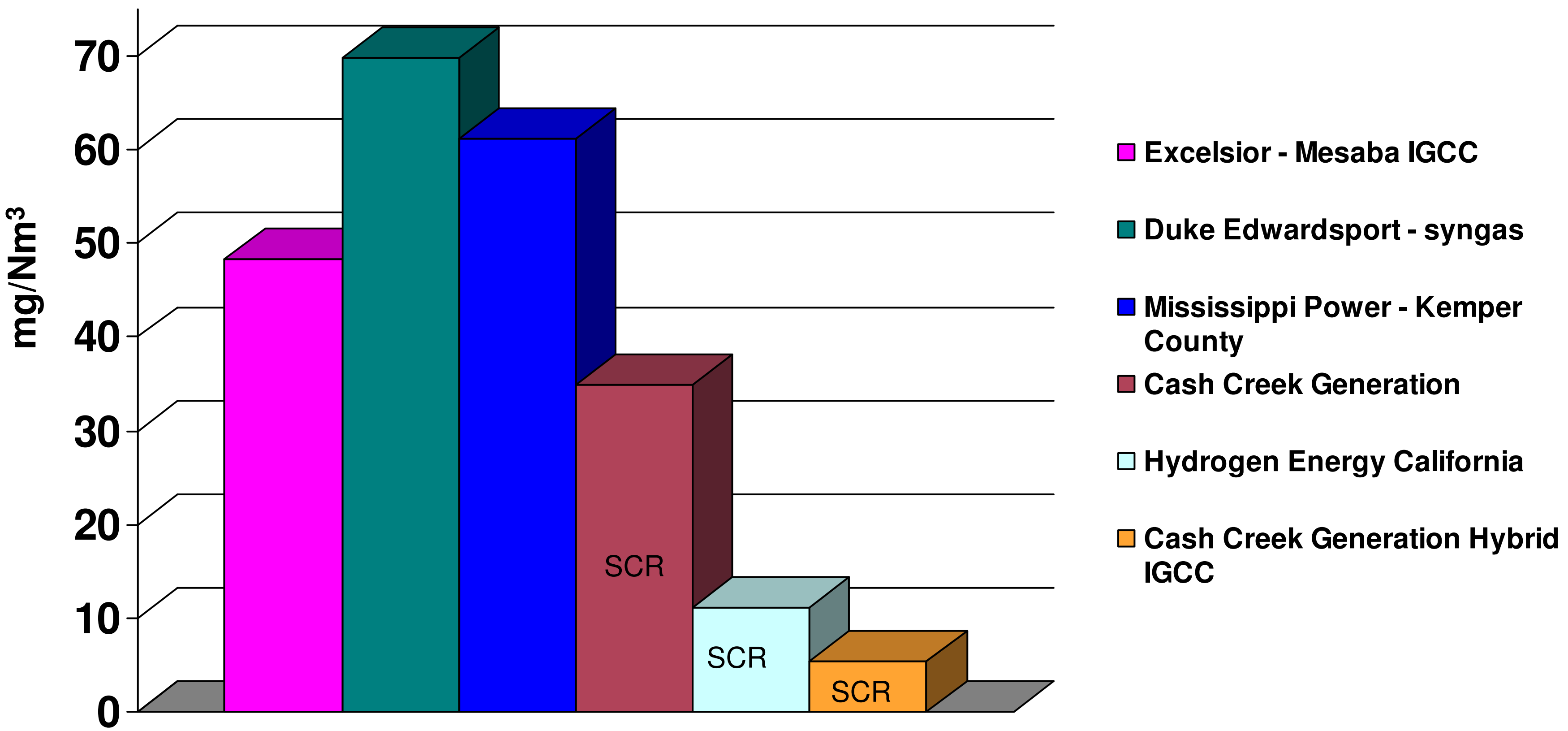
Air Emissions

SO_2 Emission Rate Comparison



Data from public submittals

NOx Emission Rate Comparison



Data from public submittals

Mercury Removal

- Pre-sulfided activated carbon beds
- >94% removal of vapor-phase mercury at Eastman Chemical
- Spent carbon disposed of in drums once/year
- Proposed IGCC plants will use this technology

Source: Eastman Chemical

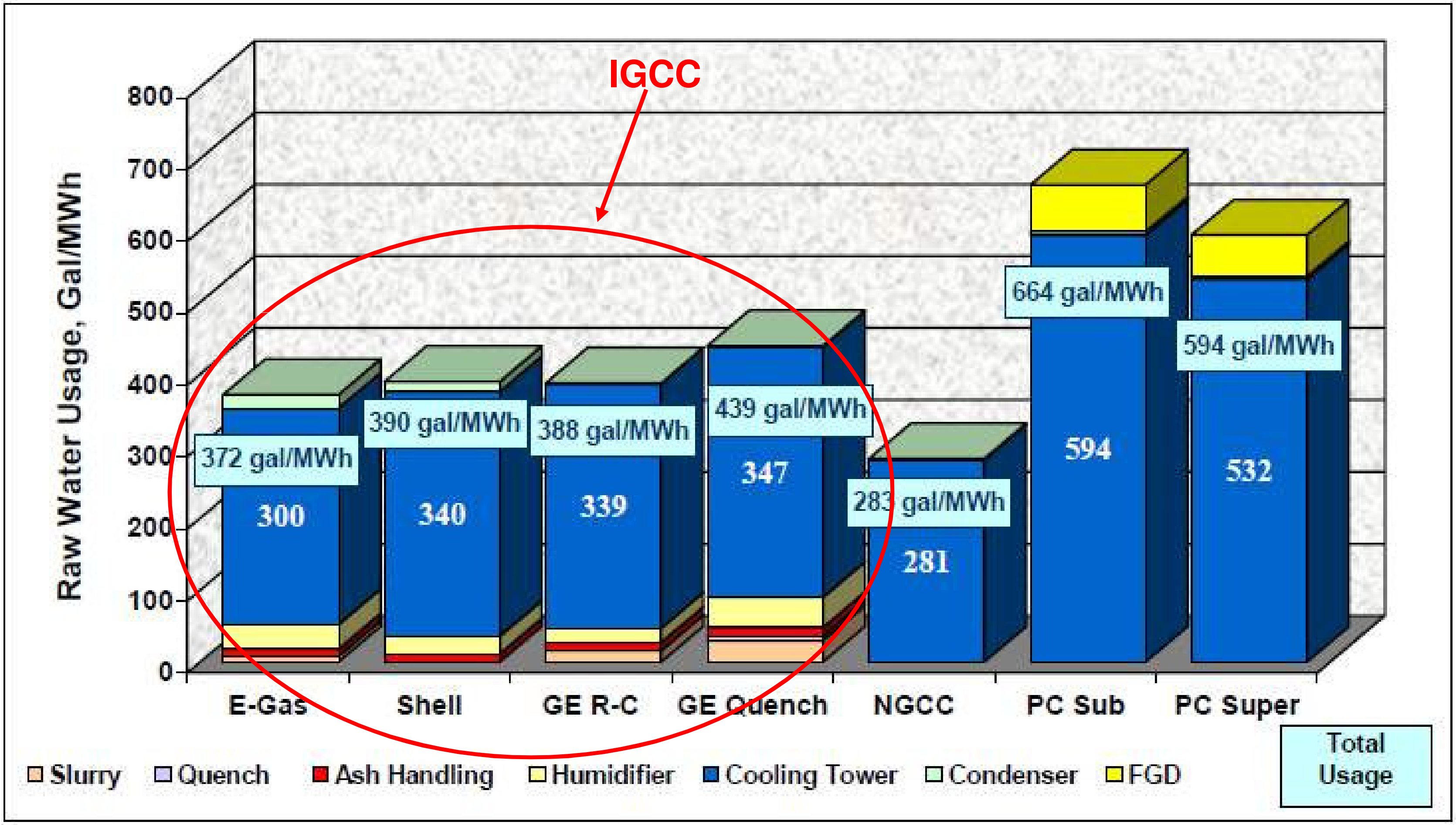
Water Consumption IGCC vs PC

- For IGCC reference plant:
  - 784 MW (gross) unit, 464 MW is from CTs and 320 MW is from the ST
  - Only ~1/3 of total output is from steam turbine, so condenser cooling water make-up needs are decreased by ~2/3
- No FGD system with IGCC, so no need for water to produce limestone slurry

IGCC Water Consumption

- Water requirement for slurry-feed gasifiers to produce slurry of about 65% solids that is pumped to the gasifier
- Syngas coolers have pure water needs for producing steam
- Gasification plants usually include a combined cycle power block
  - Cooling tower makeup

Raw Water Usage for Power Plants IGCC is ~40% less than for PC



Source: U.S. DOE

Wastewater Production – Sources of Contaminants

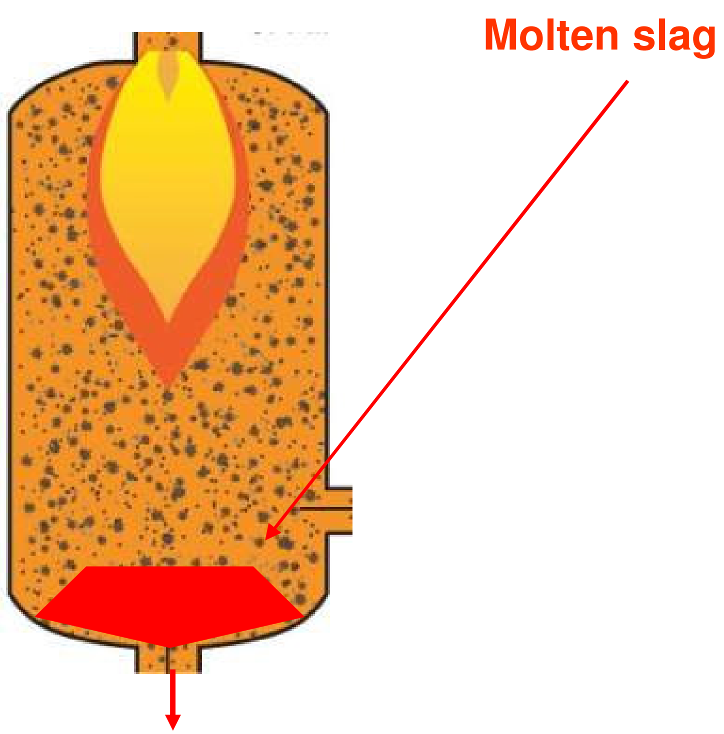
- Ash in the feedstock
  - Slag (for high temperature gasification)
  - Bottom ash (for low temperature gasification)
  - Fly ash
- Chlorides in the raw water and feedstock
- Sulfur in the feedstock
- Compounds formed in the gasification process
  - Ammonia
  - Sulfides
  - Formates
  - Cyanides

Water and Wastewater Discharges

- IGCC design typically based on significant re-use and recycling of process water discharges
- Zero liquid discharge systems are common
  - Vapor recompression systems
  - Evaporator-crystallizers
  - Ammonium chloride brine cake for disposal
    - May be a hazardous material depending on contaminants, requiring appropriate disposal,

Solid Byproducts

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



Slag Use

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




Other Byproducts

- Sulfur
  - Recovered in molten form
  - Transported by rail or truck

- Sulfuric acid
  - Various concentrations can be produced, depending on local markets
  - Transported by rail or truck

CO_2 Capture

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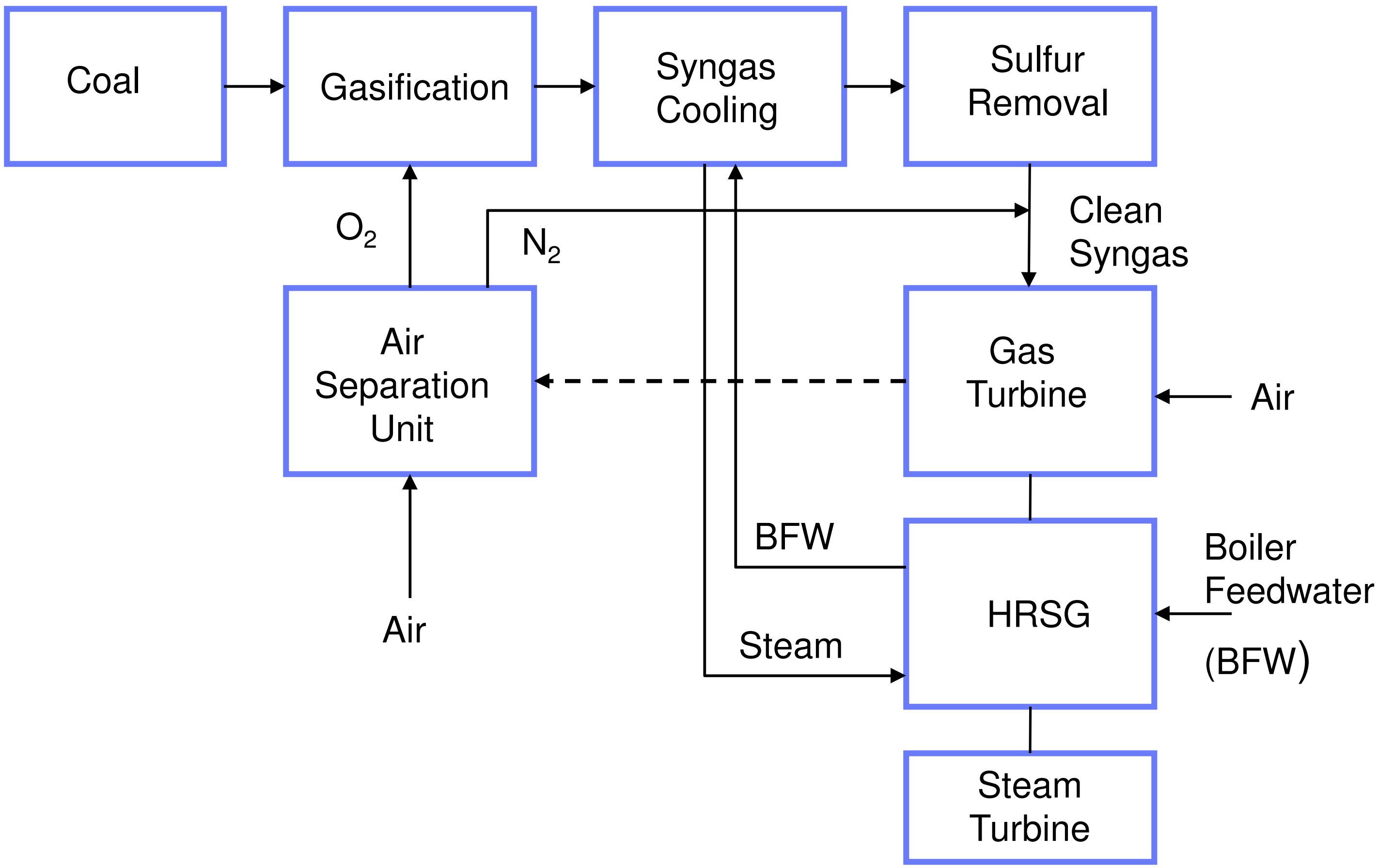
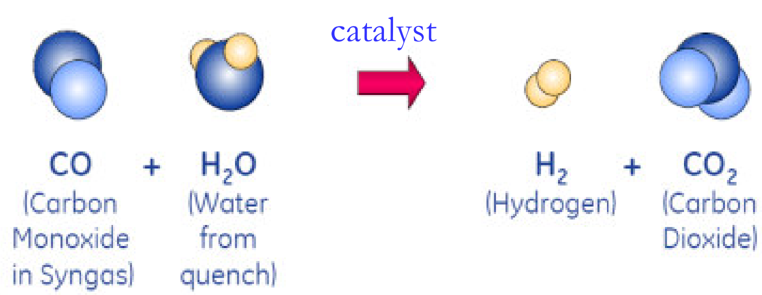
IGCC Reference Plant Block Flow Diagram
No CO_2 Removal

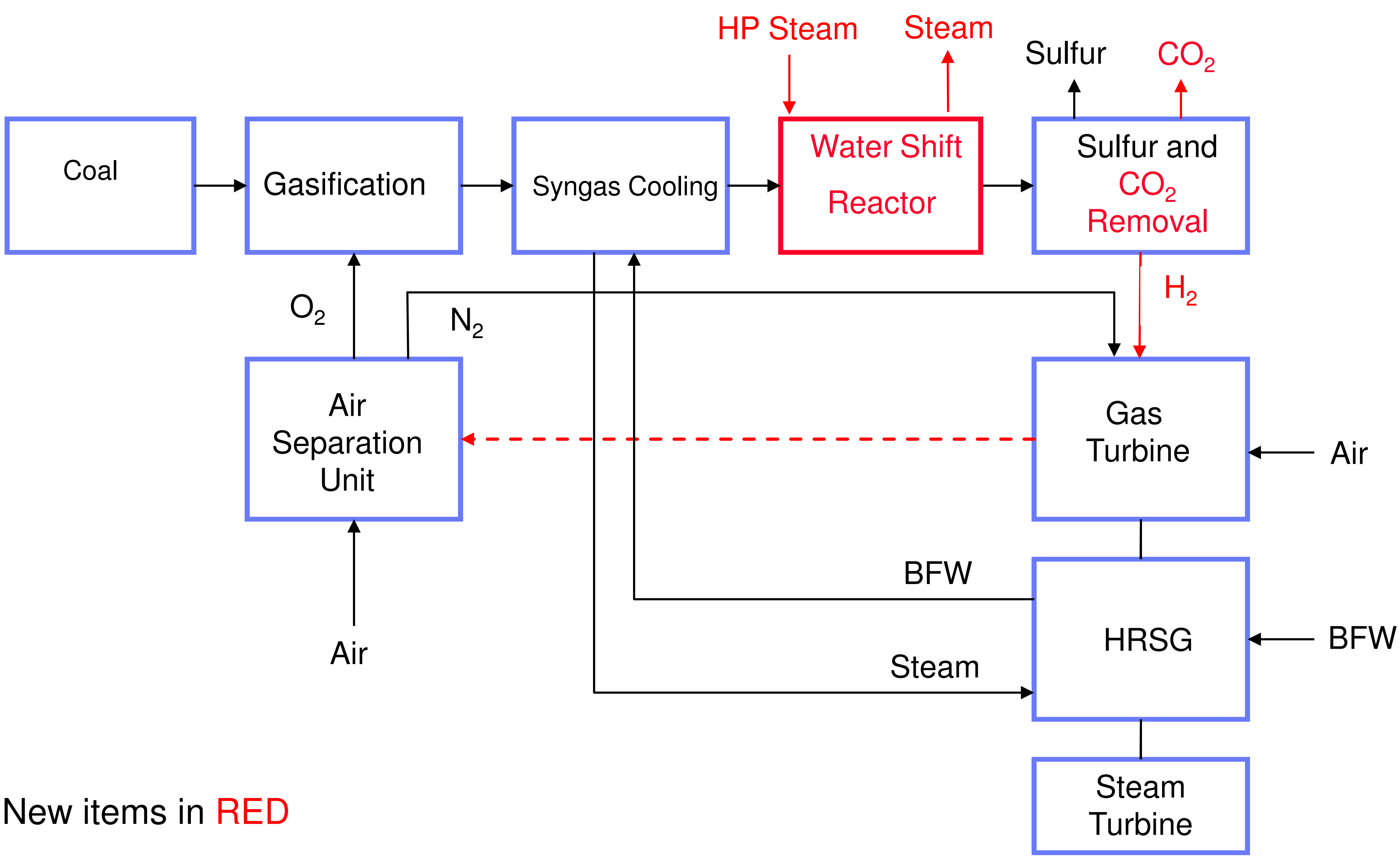


Water Shift Reaction

- Low concentration of CO_2 in syngas
- Must be increased for efficient removal
- By adding steam to the syngas, over a catalyst bed, the CO in the syngas is converted to CO_2, raising the concentration in the syngas to >50%



IGCC Reference Plant Block Flow Diagram w/Water Shift Reactor and CO_2 Capture



New items in RED

Impact of CO_2 Pipeline Specification on Sulfur Removal

- Pipeline specification for H_2S/COS may require additional capacity in acid gas removal system or CO_2 capture stage

	Dakota Gasification	FutureGen	Kinder Morgan	Hydrogen Energy CA
CO_2	> 95%	95%	> 95%	>97%
H_2S	< 20,000 ppmv	100 ppmv	20 ppmw*	-
Total S	-	-	35 ppmw**	<30 ppmv

- Options for increasing CO_2 purity include:
  - Increase pressure to improve Selexol CO_2 capture efficiency
  - Add post-capture purification of CO_2 through compression / liquefaction / gas separations / pumping
  - Use Rectisol process

What Happens When CO_2 Compressor or CO_2 Pipeline is Out of Service?

- Option 1 - CO_2 stream could be vented
  - CO and H_2S/COS in stream may require thermal oxidizer ($$$ for capital and operation)

- Option 2 - Inject CO_2 as diluent in CTs (instead of N_2)
  - need to maintain Modified Wobbe Index
    - control heating value, specific gravity and temperature of fuel/diluent mixture

- Option 3 - Shut down/bypass water shift reactor and combust "normal" syngas (with N_2 diluent) in CTs
  - need capability to switch from H_2 to syngas at full load
  - steam flow imbalances

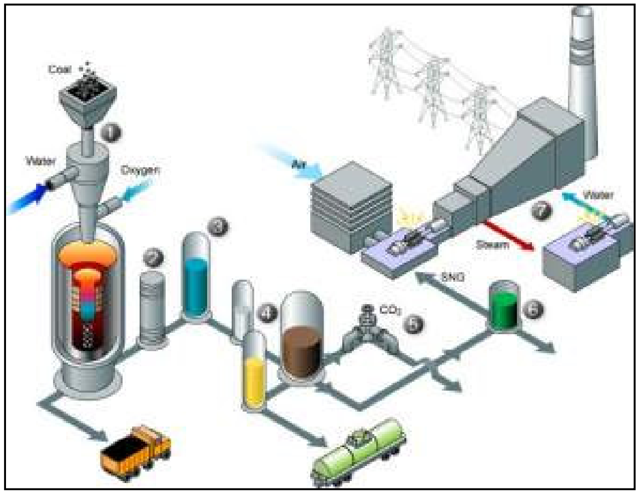
Hybrid IGCC

Hybrid IGCC – an Option for IGCC with CO_2 Capture

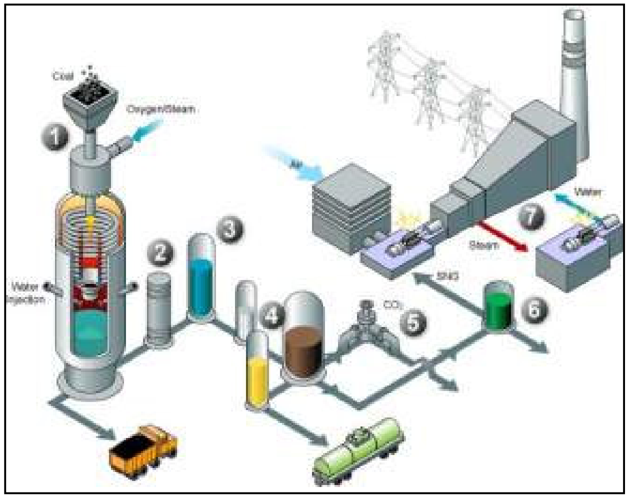
- Produce syngas in gasification area
- Use water shift reaction to produce high concentrations of H_2 and CO_2
- Capture the CO_2 from the syngas
- Methanate the syngas to synthetic natural gas (SNG)
- Combust SNG in conventional combined cycle or send to pipeline
- Compress the CO_2 for sequestration or use in enhanced oil recovery

Hybrid IGCC

- Cash Creek Generation (Kentucky)
  - GE Energy quench gasification technology
  - 566 MW (net)



- Taylorville Energy Center (Illinois)
  - Siemens quench gasification technology
  - 542 MW (net)



Source: Taylorville Energy Center

Hybrid IGCC

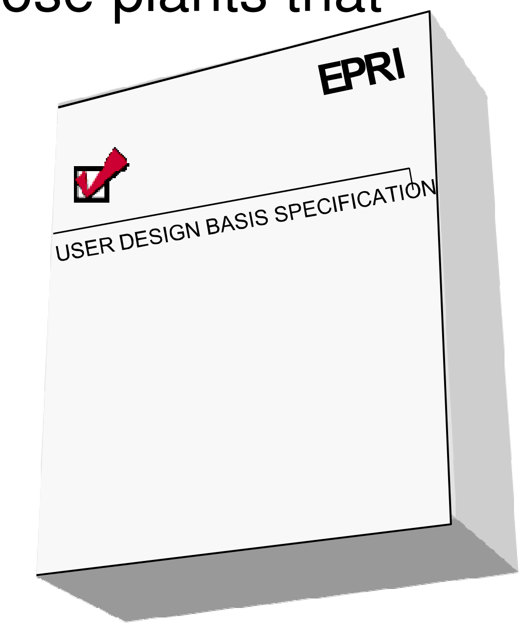
- Overall conversion rate of coal to gaseous fuel is lower than for conventional IGCC
- Two-thirds of the carbon in the coal is removed in a concentrated CO_2 stream
- Limited ability to respond to CO_2 compressor or CO_2 pipeline outages
  - CTs are designed for NG/SNG, but not syngas
  - CO_2 capture system must stay in service
  - CO_2 not viable as diluent in CT
  - CO_2 stream must be vented; thermal oxidizer may be required

Change from IGCC to Hybrid IGCC - Cash Creek Generation

	IGCC No CO_2 Capture	Hybrid IGCC w/CO_2 Capture	Change
Gasifiers	2 x 50% radiant quench	3 x 33% quench	-
Heat input to gasifiers	5,834 MMBtu/hr	7,393 MMBtu/hr	+27%
Tons coal/year	2.36 million	2.98 million	+26%
CTs	2 x 7FB @ 464 MW	2 x 7FA @ 376 MW	-19%
ST	306 MW	385 MW	+26%
Total gross output	770 MW	761 MW	-5%
Internal load	140 MW	195 MW	+55%
Total net output	630 MW	566 MW	-10%
Efficiency	36.8 %	26.1 %	-10.7 points or -29%

CoalFleet IGCC User Design Basis Specification (UDBS)

- Defines power company **technical requirements** for a site-specific IGCC plant; supplier alliances to propose plants that meet the UDBS
- UDBS represents **major collaborative effort**
  - All sectors of industry engaged
  - 40+ people developed UDBS
  - Approved by all CoalFleet members
- Robust, 1200-page industry-developed and tested **guideline, primer, and lessons-learned compendium**



- **Flexible**, yet promoting of standardized, optimized designs
- **Already in use** by numerous CoalFleet participants

Conclusions

- IGCC plants produce very low quantities of air pollutants.
- IGCC plants use significantly less water than traditional coal-based power generation, and can be designed to recycle the process water.
- Gasification slag and sulfur byproducts are non-hazardous and are readily marketable.
- CO_2 can be captured from IGCC plants using commercially proven technologies.

Contact Info

Steve Jenkins
CH2M HILL
Tampa, FL
813-874-6522, ext. 4141
steve.jenkins@ch2m.com

George Booras
EPRI
Palo Alto, CA
650-855-2471
gbooras@epri.com