Study on H_2 Production from Low BTU Western Coal Incorporating CO_2 Sequestration and Coalbed Methane Recovery - Economics and Environmental Aspects

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Purpose - to examine the technoeconomic feasibility and environmental aspects of using low BTU western coal for H_2 production incorporating CO_2 sequestration and coalbed methane recovery

Cases Studied:

- **Base case**
- **CO_2 sequestration & no CH_4 recovery**
- **Maximum H_2 production**
- **H_2/power co-production**

Assumptions

- Wyodak coal

  Ultimate analysis (wt%, dry basis)

Carbon	67.6
Oxygen	17.7
Hydrogen	4.8
Nitrogen	1.2
Sulfur	0.8
Ash	7.9

  - Moisture = 26.6 wt%, as received
  - Heat of combustion, HHV = 20,073 J/g, wet basis
  - Delivered coal price = $12.85/tonne, as received
  - Mine mouth coal price = $5.45/tonne, as received
    (from EIA - avg to electric utilities & avg mine mouth from Wyoming in 1997)

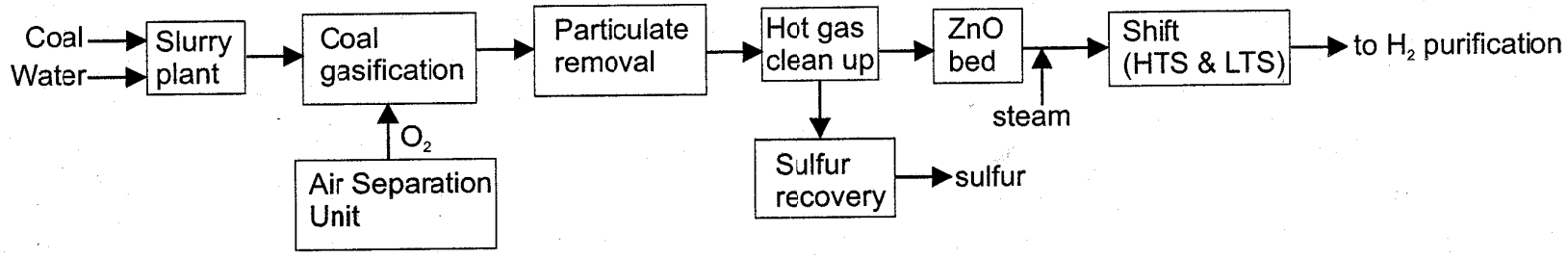
Destec gasifier

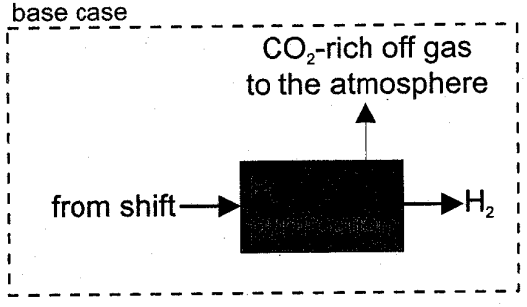
- Two stage entrained upflow
- Demonstrated under NETL's Clean Coal Technology at Wabash River Coal Gasification Repowering Project in Indiana
- temperature = 1,038 C (1,900 F)
- pressure = 2,841 kPa (412 psia)
- coal water slurry
- oxygen blown

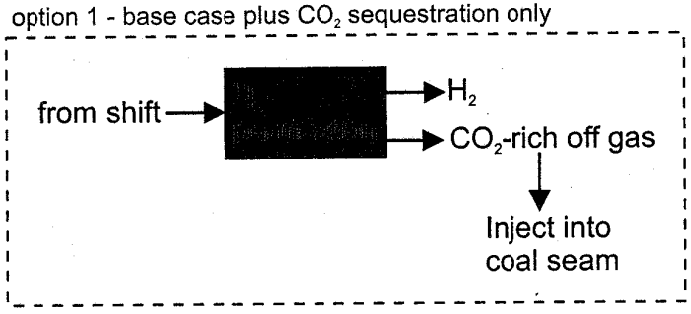
Additional Assumptions

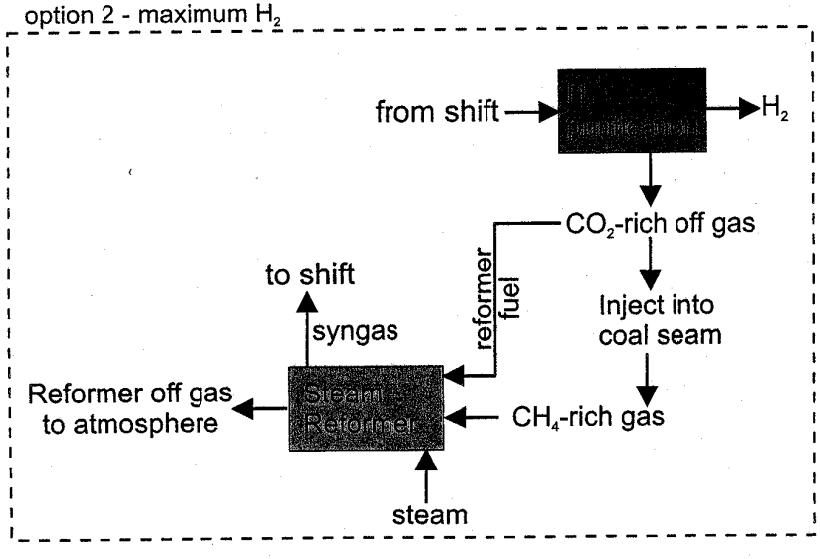
- base case not mine mouth
- all other cases mine mouth (must be located near coalbed)
- price of electricity = $0.05/kWh ($0.04 & $0.07/kWh for sensitivity)
- natural gas price = $2.07/GJ (used in ratioing HHV of offgas for base case)
- credit taken for selling excess steam (100 & 500 psi)

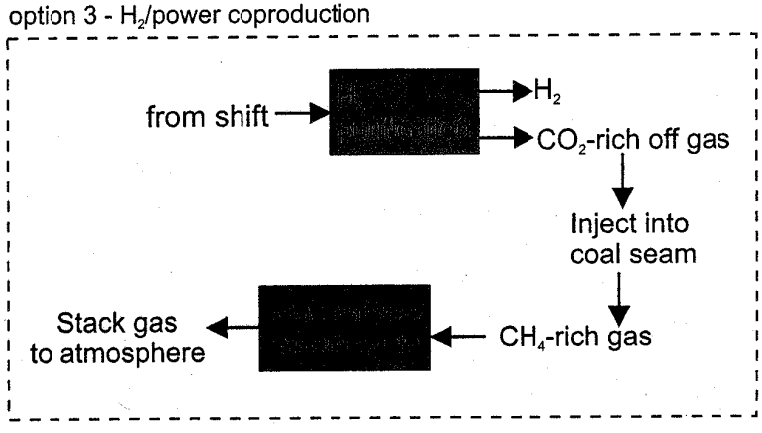
Systems Analyzed











Material & Energy Balance Summary

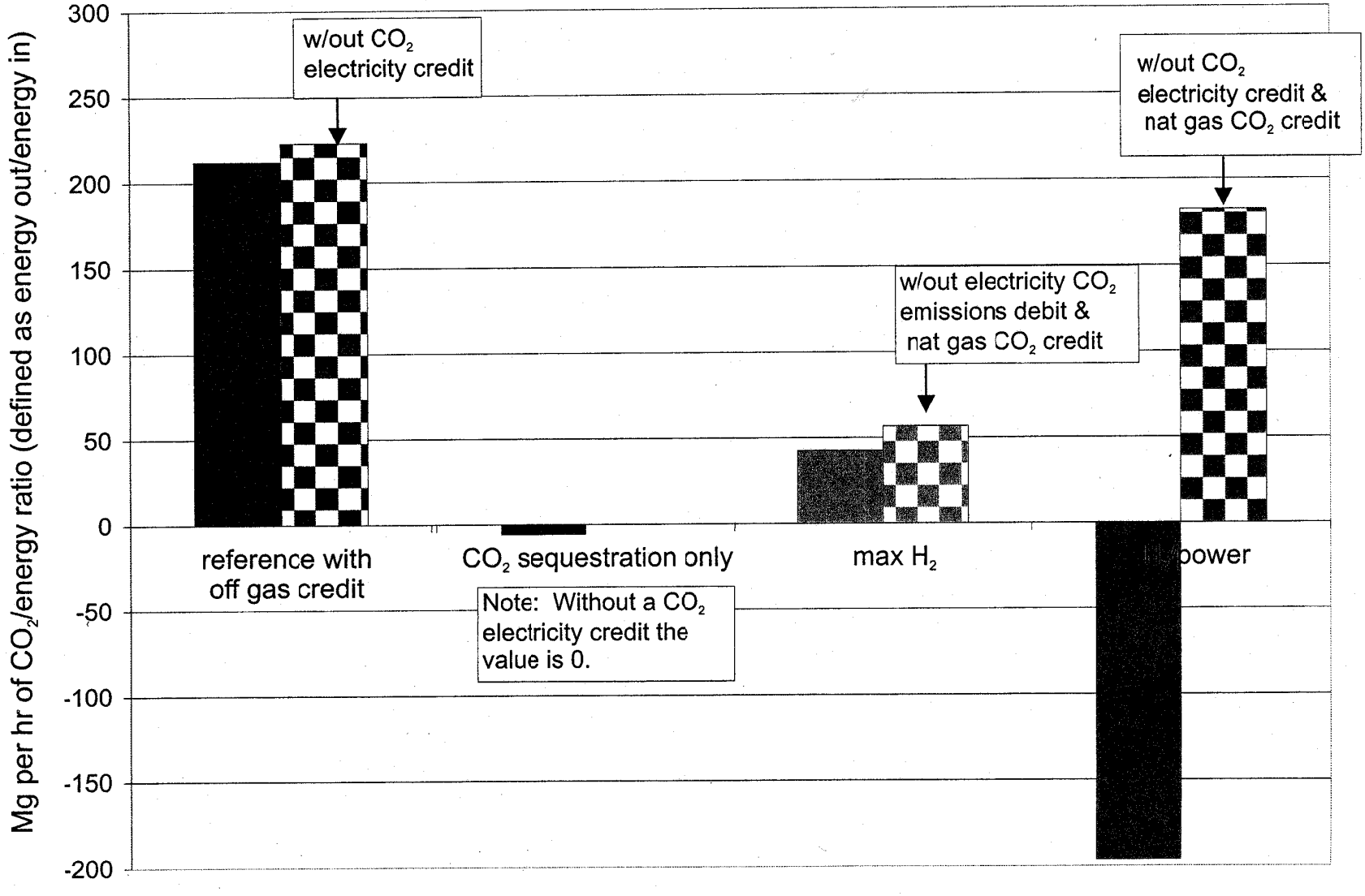
Case	coal (as received) (kg/hr)	H_2 production (kg/hr)	electricity required (MW)	Coalbed methane (kg/hr)	Energy ratio
base	113,393	8,011	-12	0	0.83
seq only	113,393	8,011	-4	0	0.57
all H_2	113,393	18,739	3	47,366	0.67
H_2/pwr	113,393	8,011	-241	36,419	0.50

without offgas energy credit energy ratio = 0.58

Break down of CO_2 emissions

Case	CO_2 to atmosphere (kg/hr)	avoided electricity CO_2 (kg/hr)	avoided natural gas CO_2 (kg/hr)	electricity CO_2 (kg/hr)	process CO_2 (kg/hr)
base	195,707	-10,037	N/A	N/A	205,744
seq only	-3,667	-3,667	N/A	N/A	0
all H_2	65,985	N/A	-12,694	2,619	43,070
H_2/pwr	-109,065	-200,575	-9,760	N/A	101,270

CO_2 Emissions per Energy Ratio @ 90% Capacity Factor



(For these systems, looking at the CO_2 emissions per the amount of hydrogen produced is NOT correct)

Storage & Transport Options for Delivered Cost of Hydrogen

Because the plant is assumed to be sited far from any users, examined 2 likely storage and transport scenarios:

- **bulk delivery: 1,610 km one way**
- **pipeline: 3 km to nearest infrastructure; 160 km to end user (shared by 5 companies)**

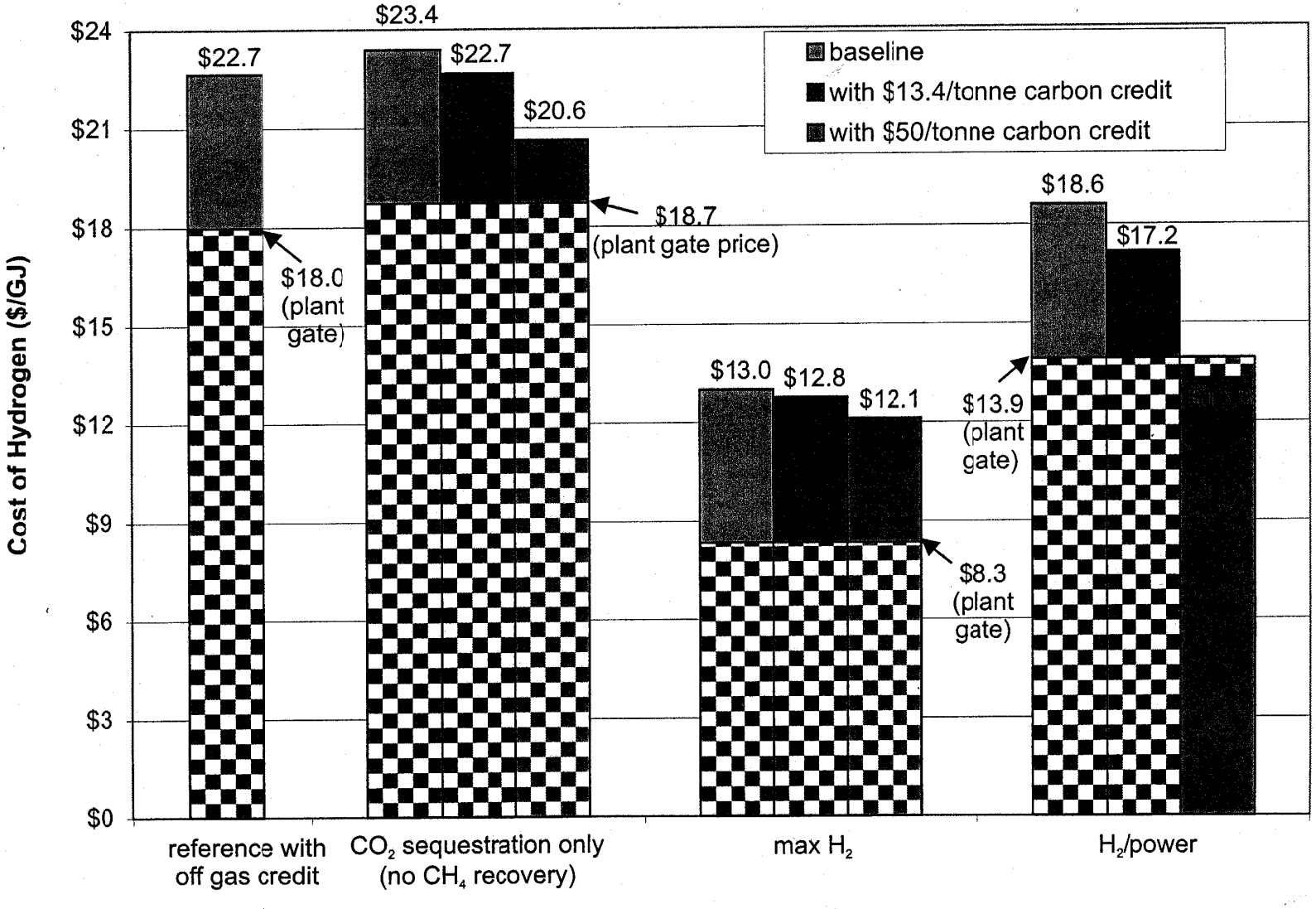
Cost of Hydrogen

Case	Plant Gate selling price ($/GJ)	Bulk delivery (liquid/rail) ($/GJ)	Pipeline delivery ($/GJ)
base	17.98	26.76	22.65
seq only	18.72	27.50	23.40
all H_2	8.34	17.12	13.01
H_2/pwr	13.92	22.70	18.59

Bulk delivery = $8.78/GJ

Pipeline delivery = $4.67/GJ

Delivered Cost of Hydrogen (Pipeline -1,610 km) with a Carbon Tax



Other Coal Types

3 regions:

- Western (44% of total)
- Interior (15% of total)
- Appalachian (41% of total)

Tested higher rank coal assuming:

- 50% more hydrogen
- additional sulfur removal
- more ash disposal
- delivered coal price of $25.87/tonne (as received)

Result: plant gate H_2 price = $13.62/GJ
($4 less than Wyodak - $17.98/GJ)

Conclusions

- economics favor sequestering CO_2, recovering CH_4, and making H_2 or power
- storage & delivery will add $5 - $9/GJ to plant gate cost (bulk & pipeline)
- a carbon tax as low as $13.4 would make the economics of the CO_2 sequestration only case equivalent to the base case
- H_2/power and max H_2 cases looks best:
  - cheapest H_2
  - lowest CO_2 emissions