Northwest Power and Conservation Council

January 29, 2009

MEMORANDUM

TO: Power Committee

FROM: Jeff King, Senior Resource Analyst

SUBJECT: Assessment of coal gasification combined-cycle generating resource potential

Coal is found in abundance in the Northwest and adjacent states and is forecast to be available at low cost and with low price volatility through the 20-year period of the Sixth Power Plan. The principal problem to future use of this resource is dealing with the relatively high carbon dioxide production of coal combustion. Established limits on CO_2 production from new power plants in Montana, Oregon and Washington, *de facto* constraints on the construction of coal-fired power plants in Idaho, and increasing prospects of greenhouse gas regulation at the federal level either preclude or increase the risk of constructing new coal-fired generating stations without provision for separating and storing a substantial portion of the CO_2 produced during operation.

One approach to continued use of coal is by use of coal gasification power plants. The design of these plans facilitates the separation of CO_2 prior to the power generation process using commercially-proven technology. Advantages of coal gasification power plants would include low and stable fuel costs, operational flexibility, potential for synfuels co-production and inherent sustained peaking capacity. High and uncertain capital cost, uncertainties regarding operating availability and costs and long lead times are risks associated with these plants. The principal issue, however, is the availability of large-scale CO_2 sequestration facilities. Though CO_2 sequestration by injection into depleting oil or gas fields is proven, the availability of these formations for development as sequestration facilities is very limited, especially in the Northwest. Commercial availability of suitably large sequestration facilities using alternative geology and technologies may be a decade or more in the future

Staff will describe an assessment of the potential cost and performance of integrated coal gasification combined-cycle (IGCC) plants, equipped with or capable of being equipped with CO_2 separation. The cost and availability of CO_2 sequestration will also be described.

851 S.W. Sixth Avenue, Suite 1100
Portland, Oregon 97204-1348
www.nwcouncil.org

Steve Crow
Executive Director

503-222-5161
800-452-5161
Fax: 503-820-2370

Sixth Northwest Conservation & Electric Power Plan

Coal Gasification Resource Assessment

Jeff King

Northwest Power and Conservation Council

Power Committee

Portland, OR

February 10, 2009

General take on IGCC

Lots of interest 2000-07; many (10 - 20) proposed projects in NA

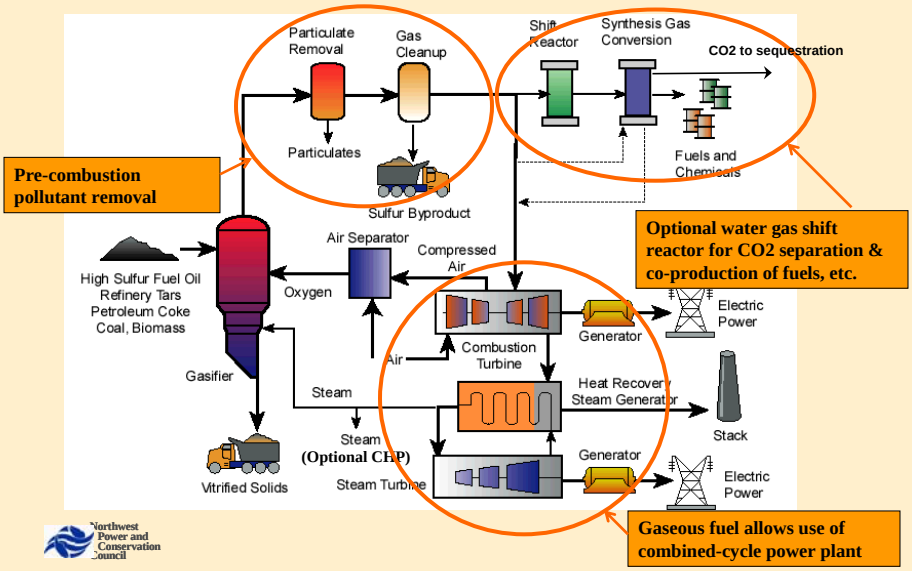
- ✓ An avenue to continued use of coal in face of GHG policy uncertainty
- ✓ Proven CO2 capture technology; retrofit potential
- ✓ Perception that IGCC efficiency and emissions performance would be markedly better than pulverized coal though at somewhat greater cost
- ✓ EPAct 2005 incentives.

Post-2007 decline in enthusiasm; realism arrives; 3 - 5 healthy projects

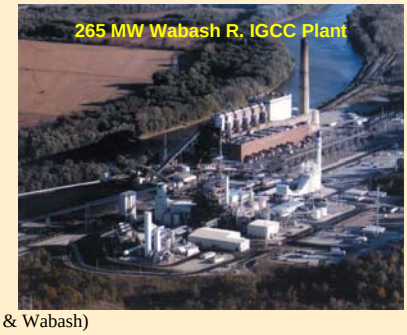
- ✓ Efficiency lower, costs higher than anticipated, not that much better than supercritical PC
- ✓ Construction cost escalation + capital-intensive technology
- ✓ Sequestration not slam-dunk, proven sequestration media (gas & oil fields) limited in capacity
- ✓ Lawyers arrive on scene - sequestration liability/rights
- ✓ Decade until sequestration options other than gas & oil fields are operational

Remaining big advantage vs. PC: proven and lower cost CO2 separation technology

Integrated Coal Gasification Power Plant



Reference plant design*



Gasification & synthesis gas cleanup:

- Two Conoco-Phillips E-Gas gasification trains
- Oxygen-blown entrained-flow two-stage slagging gasifier
- Sulfur recovery, particulate filters, carbon bed Hg control
- Operating experience w/subbituminous coals (Plaquemine & Wabash)
- Shorter refractory life (high operating temps) - lower availability, higher operating cost
- High CH_4 content of product gas (somewhat reduced CO2 separation capability)

Power block:

- Two 232 MW GE 7FB gas turbine generators w/heat recovery steam generators
- One 279 MW steam turbine generator

Other major components:

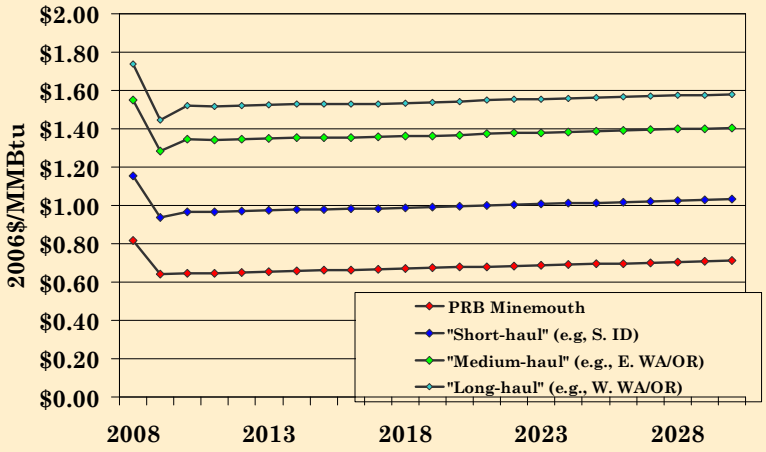
- Coal handling & preparation plant
- Air separation unit (oxygen plant)
- Water gas shift reactor
- CO2 compression & dehydration

} Case w/CO2 separation

* DOE/NETL-2007/1281 Cases 3 & 4

February 10, 2008

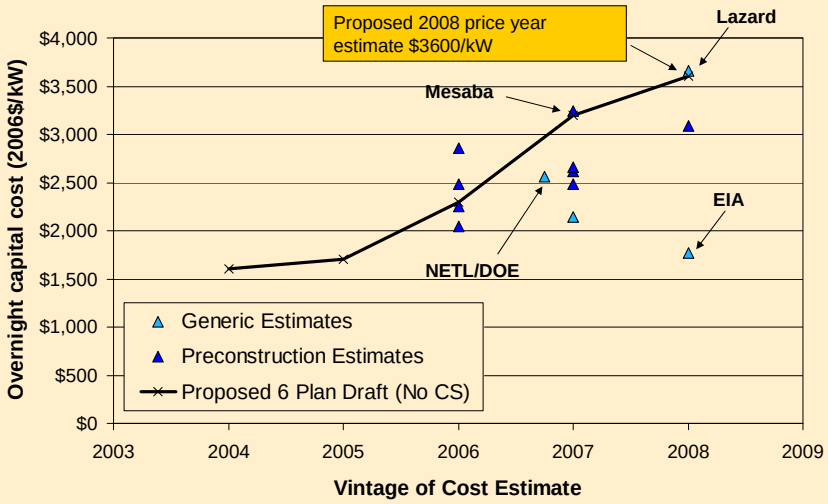
The cost of fuel is expected to be low & stable



Northwest Power and Conservation Council

February 10, 2008

Capital cost estimates: IGCC plants (no CS*)

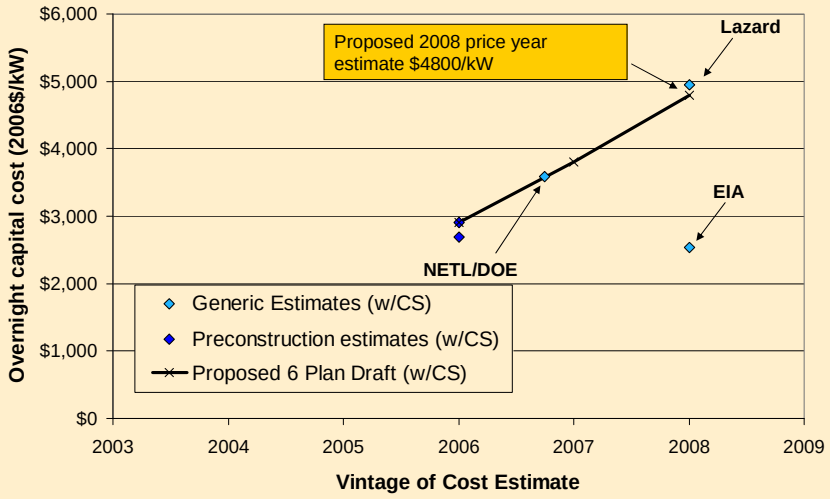


* CO2 separation

Northwest Power and Conservation Council

February 10, 2008

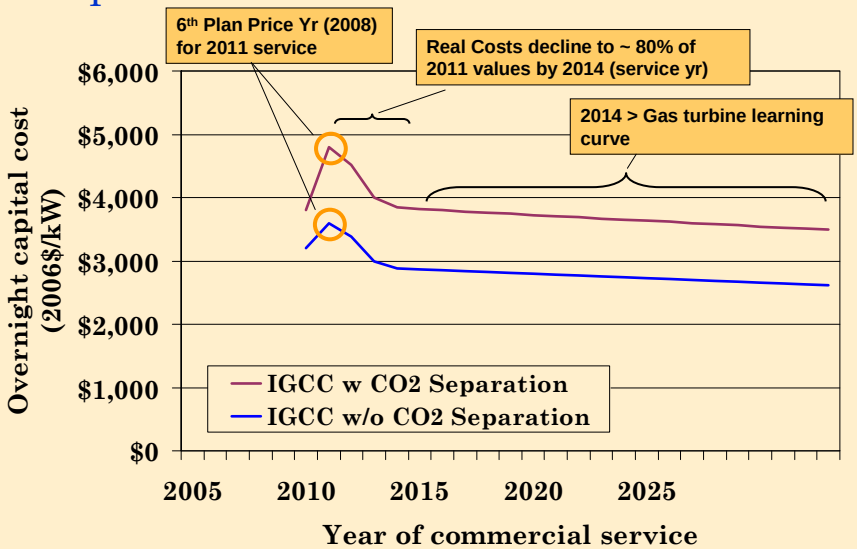
Capital cost estimates: IGCC plants (w/CS)



Northwest Power and Conservation Council

February 10, 2008

Capital cost forecast



Northwest Power and Conservation Council

February 10, 2008

A brief digression:

CO2 Transport & Sequestration

No lack of ideas for CO_2 storage

Enhanced oil or gas recovery

- EOR practiced for three decades on a limited scale (3% of world oil production)
- "Byproduct" credit
- Long-term reservoir integrity an issue
- One EGR demonstration project (North Sea)
- EGR economics less favorable than EOR

Depleted oil or gas fields

- Not demonstrated for CO_2 storage, but technology is commercially available
- Integrity an issue
- Some existing facilities (e.g, wells) could be reused

Unmineable deep coal seams

- CO_2 preferentially adsorbed on coal vs. methane
- Methane byproduct credit
- Scattered potential in Northwest
- Demonstration projects underway

Saline formations

- Very large potential
- Substantial Northwest potential near load centers
- Uncertainty regarding capacity and long-term integrity
- Effective storage capacity may be much less than theoretical
- Demonstration projects (North Sea, Algeria)

More ideas for CO_2 storage; these less well-understood

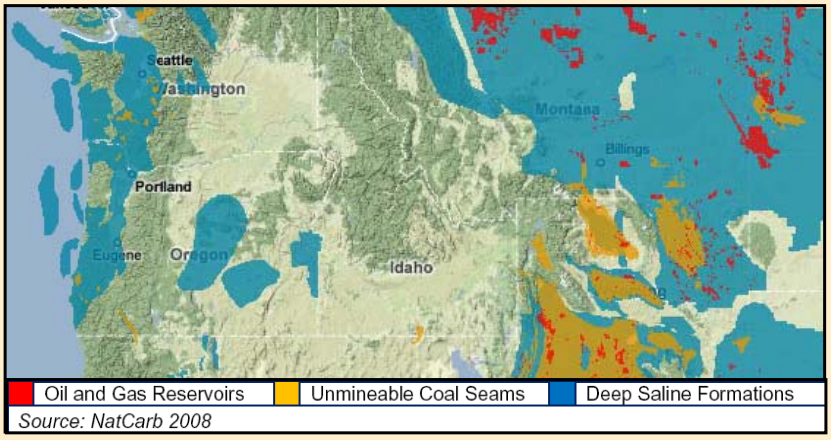
Basalt formations
- Potentially high integrity
- Extensive Northwest potential near load centers
- Demonstration project underway (Wallula)

Algae biosequestration
- Potential source of biofuel
- Demonstration project at Redhawk power plant in AZ

Terrestrial sequestration (uptake by soils and plants)
- Potential and effectiveness difficult to quantify

Other processes considered infeasible at this time
- Organic rich shales - Low permeability appears to preclude practical application
- Mineral carbonation - Unfeasibly large quantities of product carbonate
- Ocean storage - Potential acidification of ocean environment
- Limestone ponds - Size of ponds appear prohibitive
- Industrial use - Demand inadequate compared to requirements, short residence time

Potential CO2 storage sites - leading technologies



Theoretical CO2 storage potential (yrs at PNW 2005 coal-fired generation rate assuming IGCC w/88% CO2 separation)

	ID	MT	OR	WA	Total
Oil or gas fields	--	28	--	0	28
Unmineable coal seams	--	7	--	63	70
Deep saline formations	??	6,000 - 22,000	375 - 1500	2000 - 8000	8300 - 32000

Cost of CO2 transport & sequestration

Transport

- Commercially proven and in use for EOR
- $1 - $8 per tonne CO2 ($0.90 - $7.25/ton CO2)
- Sensitive to terrain, land use, volume

Injection & Storage

- Depleted oil or gas fields:
  - Oil: $0.50 - $4.00 per tonne CO2 ($0.45 - $3.30/ton CO2)
  - Gas: $0.50 - $12.00 per tonne CO2 ($0.45 - $10.90/ton CO2)
  - Possible secondary revenue through enhanced oil or gas recovery
- Deep unmineable coal seams
  - Reliable estimates not available, highly variable
  - Possible secondary revenue through methane recovery
- Saline formations:
  - $0.40 - $4.50 per tonne CO2 ($0.36 - $4.10/ton CO2)
- IEA estimates overall North American cost of $15 - 25/tonne CO2 ($14 - 23/ton CO2) (depleted hydrocarbon fields, unminable coal, saline formations)

Back to the main topic...

Proposed IGCC power plant ass

Note capacity & efficiency penalty of CO2 separation & compression

	w/o CO_2 Separation	w/CO_2 Separation
Net capacity (MW)	623	518
Heat Rate (Btu/kWh)	8680 (39%)	10760 (32%)
Overnight capital ($/kW)	$3600	$4800
Fixed O&M ($/kW/yr)	$45	$60
Variable O&M ($/MWh)	$6.30	$8.50
CO2 dispos	ed CO2 st)	Transportation: $4 Sequestration: $15 - 30
Preconstruction		36 mo
Preparation		12 mo
Committed construction	36 mo	36 mo
Earliest service in PNW	2017	2019

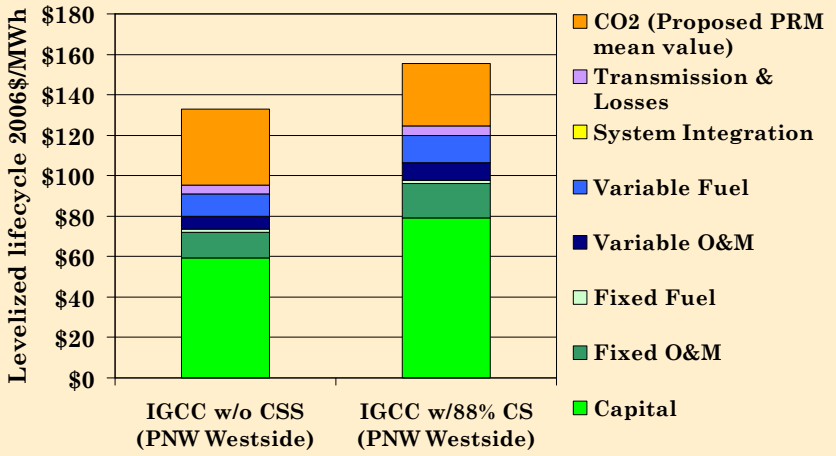
Cost of transporting and sequestering CO2 in addition to plant construction & operating costs

Earliest availability of CO2 separation option assumes a decade until commercially-available large-scale sequestration

February 10, 2008

IGCC cost elements ca: 2020

IOU financing
2020 service
80% CF



Northwest Power and Conservation Council

February 10, 2008

Possible action items

Support R&D for CO2 sequestration options applicable to the Northwest

- Flood basalts
- Deep saline aquifers
- Algae biosequestration
- Terrestrial sequestration

Establish legal framework for geological CO2 sequestration

Northwest Power and Conservation Council

February 10, 2008