Gasification Repowering, The Innovative Option for Old Existing Coal-Fired Power Plants

Presentation at the Annual

NEMS/Annual Energy Outlook 2003 Conference

March 18, 2003

Washington, D.C.

by

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Presentation Overview

Background

- SFA Pacific
- Fundamental changes in electric power generation
- Aging coal power plant fleet generating over 50% of total power
- Multi-Pollutant reductions - to 3P or to 4P, that is the question

Why power generation will be forced to meet a disproportionate share of any CO_2 reductions

- CO_2 capture & storage could favor coal gasification combined cycle (CGCC) over traditional pulverized coal (PC) steam boiler systems

Power generation CO_2 mitigation economics

- Both new & especially retrofit of existing coal-fired power plants

Conclusions

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SFA Pacific Background

Founded in 1980

Performs technical, economic & market assessments for the major international energy & engineering companies

Principal work involves residual oil upgrading, electric power generation & emissions control

Niche is objective outside opinion and comparative analysis before companies make major decisions or investments

Unique perspective, as we have no vested interest in resources, technologies, R&D or project development

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Representative SFA Pacific Clients

UTILITIES	*INDUSTRIALS*	*MANUFACTURERS + E&C*
Epcor	BHP	ABB/Alstom
EdF	BP (Amoco Arco Veba Oil)	B&W/McDermott
Electrabel	Chevron Texaco	Black & Veatch
EPDC (Japan)	Conoco Phillips	Bechtel
EPRI	Dow Chemical	Chiyoda
Eskom (South Africa)	ENI	Cummins
National Power	Exxon Mobil	Fluor Daniel
Nova Scotia Power	PDVSA	Foster Wheeler
Ontario Power	Rio Tinto (Kennecott Energy)	General Electric
Power Gen	Saudi Aramco	Kellogg Brown & Root
RWE/Rheinbraun	Shell International	JGC
Taiwan Power	Sinopec	MHI
Tokyo Electric Power	Statoil	Siemens/Westinghouse
TransAlta	Total Fina Elf	Snamprogetti
Vattenfall	Weyerhaeuser	Toyo

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Fundamental Changes in Power Generation

Deregulation, increased competition & globalization

- **IPP subsidiaries, power marketers & convergence of power & gas**
- **Restructuring: staff reductions, takeovers, asset resales to create large, more economically efficient Genco's, Transco's & Disco's**

Greatest uncertainties in Genco's (power generation)

- **Applications, markets, technology, regulations, fuel availability & price**
- **SO_2, NO_x, $PM_{2.5}$, & Hg regulations constantly changing - quite stringent for new power plants favoring NGCC & can even apply to old "grandfathered" coal plants if modified or upgraded**
- **However the CO_2 issue will be the greatest uncertainty & challenge**

Best option for "grandfathered" old coal power plants is to do as little as required due to risks from above uncertainties

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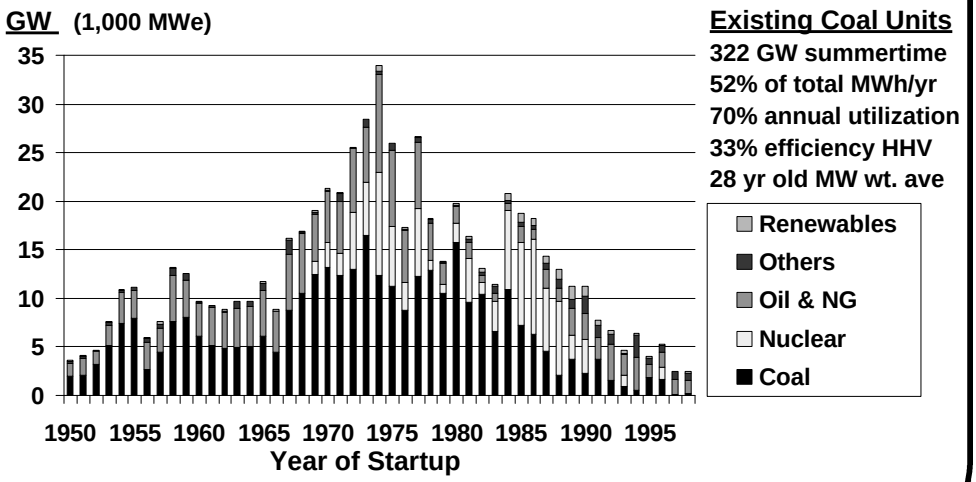
Operating U.S. Power Plants in 2000 By Year of Startup for the Last 50 Years



Source: SFA Pacific, Inc.from EIA, FERC, NETL & EPA power plant data bases

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EIA 2000-2020 Facts & Projection of U.S. Electricity Generation & Capacity Additions

Most new capacity is natural gas GT or CC, however, still a 25% coal generation increase, but only 10% new coal capacity

Figure 52. Projected electricity generation by fuel, 2000 and 2020 (billion kilowatthours)

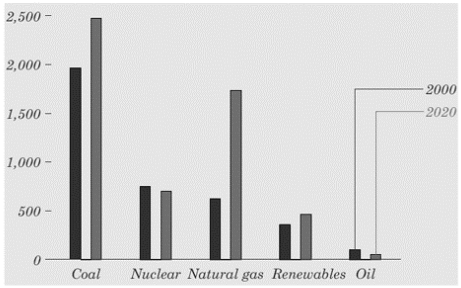

Table A8.

Figure 48. Projected electricity generation and capacity additions by fuel type, including cogeneration, 2000-2020 (gigawatts)

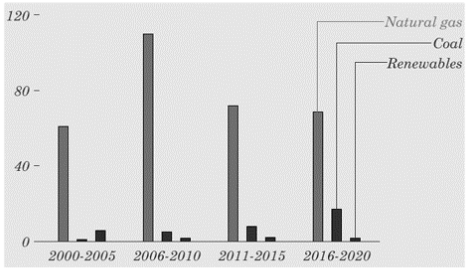

Table A9.

Source: Figures from U.S. DOE's EIA Annual Energy Outlook 2002

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Options for the Over 300,000 MW of Life-Extended Existing U.S. Coal Power Plants

Emphasis on maintaining grandfathering of "big dirties" while knowing they will eventually need rebuilds & flue gas retrofits

- **Improved flue gas desulfurization (FGD), selective catalytic reduction (SCR) of NO_x, mercury control via dry carbon scrubbers & bag houses**
- **Lower capital & fewer permitting hassles than new "greenfield" plants**
- **However, low efficiency of existing coal power plants gets even lower with these add-on retrofit flue gas emission controls**

Delays with eventual flue gas retrofits are clearly cheaper for the short-term, but lack strategic long-term flexibility

- **Deregulation, surge in NGCC capacity, efficiency advantage of cogen & especially the CO_2 issue may ultimately work against infinite life-extension & rebuilds of old existing inefficient coal power plants**

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To "3P" or To "4P" - That is the Question

Republicans propose the Clear Skies Initiative "3P" reductions

- 73% SO_2, 67% NO_x & 69% Hg reductions by 2018, but back-end loaded
- However, key is elimination of the Clean Air Act & New Source Review allowing upgrades & rebuilds without emission reductions till later
- Likely favors rebuilding "big dirties" then flue gas retrofits after 2010

Democrats propose "4P" reductions that also include CO_2

- SO_2, NO_x & Hg caps slightly lower but sooner than Republicans, however caps CO_2 at 1990 level or about 21% reduction from current
- Likely favors repowering "big dirties" with NG or CGCC depending on how high NG prices go in a carbon constrained world
- Higher capital cost, but also new, efficient power plants at old sites with much better CO_2 capture & storage potential than flue gas retrofits of old life-extended steam units with inevitable reliability issues

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Existing Power Plant Repowering

Defined as adding new gas turbines to existing steam plants

- Usually best to let the GT determine the size & add a new steam system

Many advantages to repowering existing steam cycle plants

- Large capacity increase, up to 3 times the original power plant capacity
- Large efficiency increase, usually from about 30-35% to 45-55% if NGCC or about 40-42% if CGCC ("real" HHV efficiency)

Great potential due to location of old existing power plants

- Strategically located in existing grid system with significantly less siting or permitting problems relative to a new "green field" power plant
- NGCC repowering of NG & oil boilers now & later CGCC repowering of coal boilers depending on future of: NG prices,"grandfathering" & CO_2

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Why Traditional Power Generators Are Skeptical of Coal Gasification Combined Cycle

Successful CGCC requires chemical process expertise

- **Little or no chemical process expertise at most coal utilities & will usually not pay the price required to attract personnel with essential oil & chemical industry gasification expertise even if considering CGCC**
- **Embarrassingly poor history with the simplest chemical process - wet limestone SO_2 scrubber FGD - why FGD costs have dropped in half due to outrageously poor starting baseline costs & performance**

Any risk is a "lose-lose" for traditional regulated power generators & CGCC is clearly a much greater risk than PC

- **If it does not work well, will not get all the costs covered by rate payers**
- **If it works quite well & greatly reduces costs, most of the savings are passed on to the rate payers**

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CGCC vs PC for New Coal-Based Power Plant

CGCC verses supercritical PC boilers for new coal power plants

- **CGCC can have slightly better efficiency (40-42% HHV - U.S., <u>not</u> European basis) & slightly lower SO_2, NO_x & $PM_{2.5}$ emissions than PC**
- **However, CGCC is likely 10-20% higher capital costs plus potentially poorer availability than a PC boiler coal unit**

Highly integrated CGCC demonstration plants even worse

- **European CGCC demos confused "efficiency with honor" by integrating CGCC to death - 25% extra capital to be 2% more efficient but about 50% (coal only) availability of these complex CGCC demos**

Promotion of similar highly integrated CGCC projects in China, India, Taiwan & Korea could be a major set-back to CGCC

- **Utility promoters are totally ignoring the extensive chemical process expertise within their nations - existing gasification ammonia plants**

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Most Successful CGCC Demo is not Integrated

Wabash River CCT: E-Gas (Destec) 262 MW_e CGCC repowering

- Coal to clean syngas "over the fence" by chemical process experts originally from Dow Chemical (then called Destec)
- Clean syngas to utility owned CC at an existing coal-fired power plant - reused old ST/gen & coal handling as a CGCC repowering of an existing PC

- **The most successful of the five CGCC demonstration plants**
  - Lowest capital cost ($1,590/kW all costs), simplest design (only steam SH integration), highest efficiency (> 39%HHV) & highest availability (85-90%)
  - Now successfully operating on 100% pet coke with even better performance
- **Based on the original Dow Chemical later called Destec gasifier**
  - Two stage water slurry gives the ease of high pressure feeding with high cold gas efficiency & low cost fire-tube type syngas cooler
  - One of the best coal & coke gasification technologies, however current weak ownership with E-Gas technology now up for sale

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Advantages of CGCC Over PC Boilers

NGCC beats both CGCC & PC until NG - coal price >$3/MM Btu

- However, uncertainty of future NG prices/supplies makes gasification strategic as clean syngas can replace NG in existing NGCC units

Deregulation increases uncertainty of future power generation

- Favors higher efficiency & much lower capital of NGCC
- Favors higher efficiency, revenues & load factors of polygeneration

Environmental requirements is likely the greatest uncertainty of future coal-based power generation

- Only CGCC can obtain the same low emission as NGCC, including Hg
- Key flexibility of CO_2 capture (new or retrofit) at low incremental costs

CGCC has greater flexibility than PC boiler to face the many uncertainty challenges of future power generation

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Gasification Projects Without Subsidies

Chemicals from coal or pet coke	MW_{th} syngas
• Ube Ammonia - Japan	294
• Farmland - Kansas, USA	293
• Eastman Chemicals - Tennessee, USA	219
Oil refinery <u>polygeneration</u> from pitch or pet coke	
• Port Arthur*, Texas - USA	2,029
• Repsol* - Spain	1,654
• Lake Charles*, Louisiana - USA	1,407
• Deer Park*, Texas - USA	1,400
• Total/EdF/Texaco - France	1,043
• Nippon Oil - Japan	793
• Exxon - Texas, USA & Singapore	711
• Shell - the Netherlands	637

* Planned

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Polygeneration

Defined as gasification to synthesis gas (H_2 & CO) for GT-based cogen steam/power + syngas chemicals & premium fuels

Shell Oil Pernis oil refinery in Holland is a good example: no subsidies & high availability <u>without</u> a spare gasifier

- Pitch gasification - 3 units total 640 MW_{th} with 2 gasifiers for oil refinery H_2 & 1 gasifier for GCC cogeneration with NG as GT back-up

Great potential for polygeneration in the future due to ongoing deregulation of electric power generation

- Low value feedstock, thereby ultra-low marginal load dispatch costs
- Offers greater flexibility than traditional power plants relative to fuels, products, revenues, emissions, efficiency & annual load factors
- Low marginal costs for CO_2 capture (will likely be added at Pernis)

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Power Generation Will Be Forced to Meet a Disproportionate Share of Any CO_2 Reductions

Transportation fuel users have more votes than CO_2 intensive industries as demonstrated in June 2000 in the U.S. & Europe

Power plants can not move to China, as other CO_2 intensive industries in Annex 1 nations will, if faced with carbon taxes

Large potential for improvements in power generation

- **Increase old coal-boiler power plants efficiency - NG/CGCC repowering**
- **Replace coal with: co-firing biomass, natural gas or wind turbines**
- **New NGCC or CGCC - central power plant & especially cogeneration**

Large point sources of power generation reduces both CO_2 mitigation & capture/storage costs

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CO_2 Capture Can Save Coal

Transforming the GHG debate as CO_2 capture & storage is generally more effective than renewables or efficiency gains

- **Cycling-load wind turbines cannot replace large baseload coal power**
- **$/ton for CO_2 avoided is lower than just efficiency due to much larger CO_2 reductions of 90% vs only 20% for efficiency improvements**

Effective CO_2 capture requires large CO_2 point source, high purity recovery, compression to high pressure & injection:

- **First in enhanced oil recovery (EOR), then coal bed methane (CBM) recovery, but ultimately deep aquifers (like current H_2S injections)**

CO_2 capture options in order of increasing costs

- **High purity CO_2 vents from existing NG & syngas (H_2 & CO) purification**
- **CGCC repowering of existing PC boiler central power plants**
- **New CGCC & polygeneration**

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Geologic CO_2 Storage is Already a Large Commercially Well Proven Industry

Over 20 years & currently > 30 million ton/year of commercial geologic CO_2 storage for enhanced oil recovery (EOR)

- **Extensive existing CO_2 pipeline systems of > 2,000 miles**
- **If CO_2 were supplied from coal power plants would be > 4,500 MWe**
- **Expect man-made CO_2 use in EOR to grow significantly in the future**

Over 20 years of commercial acid gas (H_2S & CO_2 from natural gas purification) injection into various geologic formations

- **Significant because H_2S is a lighter, more dangerous gas than CO_2 & H_2S has a strong smell at only a few parts per million (ppm) in air**
- **Therefore, just the smallest H_2S leakage would have been easily detected if there were any leakage problems years ago**

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Status of Gasification & H_2 + CO_2 Generation

Worldwide commercial gasification capacity

- **Almost 50,000 MW_{th} (syngas) operating & growing at 5,000 MW_{th}/yr**
- **New projects are mostly petroleum coke or pitch gasification in oil refineries for export power + cogen steam & syngas - polygeneration**

Extensive successful commercial experience with coal & heavy oil gasification producing pure H_2 & CO_2 streams

- **Over 15 solid & 40 liquid fuel gasification plants making pure H_2**
- **Mostly for ammonia fertilizer plus some for oil refinery H_2**
- **Most are in China, some in USA, Germany, Japan, India & Brazil**

General Electric has tested & will give commercial performance guarantees for H_2- fired "F" type gas turbines

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Farmland in Kansas - Commercial (no subsidies) Coke to H_2 Gasification Plant for Ammonia & CO_2

CO_2 Capture Clearly Favors CGCC over PC

PC boiler & low pressure flue gas amine CO_2 scrubber

- **Increases relative capital costs of PC by 70-80% while reducing relative capacity & efficiency by 20-30%**
- **Large amine stripping requirements of 1.5 ton steam per ton CO_2 followed by compressing CO_2 from 1 atm pressure are the problems**

CGCC + shift: H_2O+CO to H_2+CO_2 & high pressure CO_2 scrubber

- **Favors simple high pressure direct water quench & sour shift designs**
- **Increases relative capital cost of CGCC by 30-40% while reducing relative capacity & efficiency 10-15%, <u>both half that of PC</u>**
- **Physical solvents with little CO_2 stripping steam + flashing CO_2 at moderate (3-12 atm) - greatly reduce costs & efficiency/capacity loses**
- **<u>2-3 orders of magnitude</u> higher CO_2 partial pressure of CGCC vs PC**

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Cost of New Power Plants with CO_2 Control

Natural gas combined cycle (NGCC) baseline

- **NG price set where coal becomes competitive <u>without</u> CO_2 capture as current NG prices favor NG over coal even if ignoring the CO_2 issue**

Best option is cogeneration or polygeneration vs a new central power plant with or without CO_2 capture

Best options if just new central power plant with CO_2 capture

- **NGCC with amine flue gas scrubber if low NG prices or coal gasification to H_2 combined cycle (H_2-CGCC) if higher NG prices**

Overall CGCC CO_2 capture costs are about 50% for recovery to pure CO_2 , 25% for compression & 25% for disposal charge

- **Thereby, slight byproduct credit (EOR & CBM) or incentive for CO_2 reduction can significantly reduce net CO_2 control costs**

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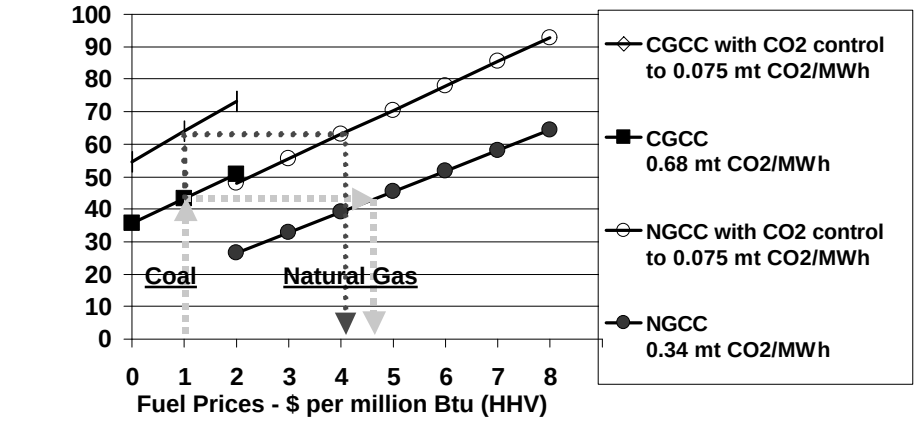
Electric Power Costs of Coal Verses Natural Gas For Various Fuel Prices & CO_2 Emissions

<u>$ per MWh</u> Electric Price with capital charges & CO_2 <u>disposal charge of $37/ton C</u>



Source: SFA Pacific, Inc

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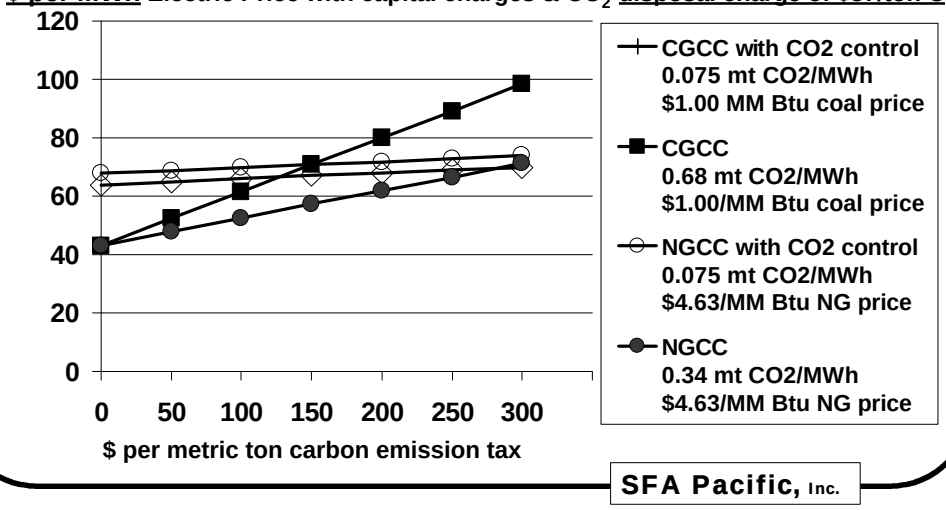
Electricity Costs for New Coal vs New NG Power Plants at Various CO_2 Emissions & Carbon Taxes



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Economics of Existing Coal Power Plants

Baseline: older & less efficient existing coal power plant with high CO_2 emissions (1 ton CO_2 per MWh net power)

- Much lower $/ton CO_2 avoided costs than with a new NGCC baseline
- Many cost & CO_2 mitigation advantages relative to a new power plant

NG repowering & no CO_2 control if low NG prices or CGCC repowering to H_2 with CO_2 capture if higher NG prices

- NG prices will likely rise if a carbon constrained world develops
- Options of retrofit O_2 combustion or flue gas amine CO_2 scrubber to existing coal boiler suffers from large capacity & efficiency losses
  - NGOs oppose these CO_2 capture options due to large efficiency losses
- Gasification repowering increases both capacity & efficiency while reducing all emissions to near zero while staying on coal
  - Only major CO_2 capture application that can make this important claim

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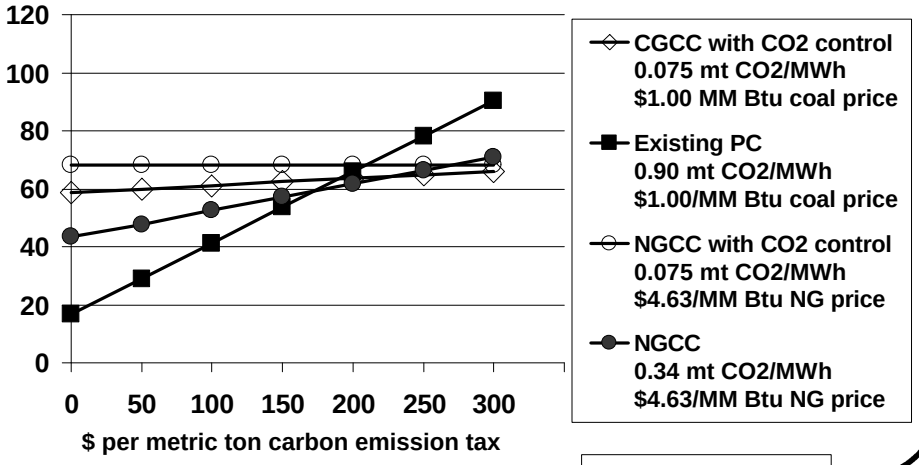
Existing Coal Power Plants if Carbon Taxes

No Impact at Politically Acceptable Carbon Taxes

$ per MWh Electric Price with capital charges for new investments & CO_2 disposal charge



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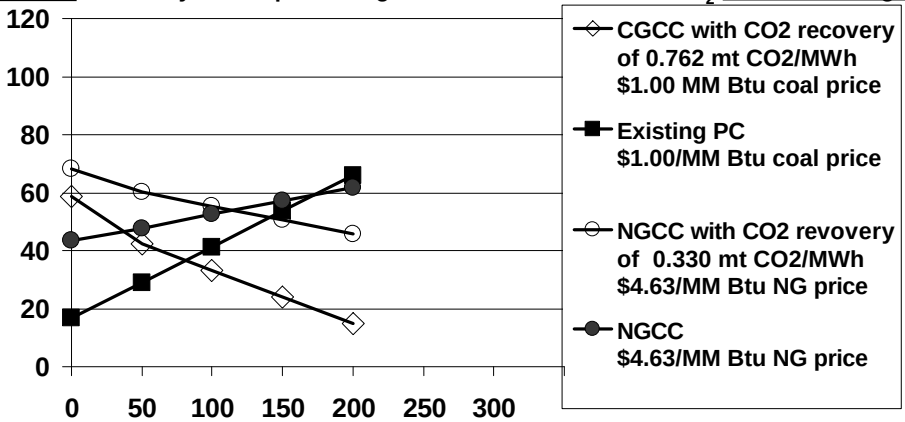
Existing Coal Plants if CO_2 Reduction Credit or Emission Tax (credits paid by tax for zero net sum)

$ per MWh Electricity with capital charges for new investments & CO_2 credits or charges



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Conclusions

Uncertainties in future emission regulations & grandfathering encourages continued life-extension of the old coal plants

- To 3P or to 4P, that is the question: CO_2 hangs in the balance
  - Republican 3P being back-end loaded likely favors rebuilding old coal units & then flue gas retrofit after 2010 - will increase CO_2 emissions

Electric power generation will be forced to meet a disproportionate share of any CO_2 reductions

- SUV owners have more votes than CO_2 intensive industries
- Cannot move electric generation to China
- Lowest CO_2 reduction costs at large point sources (coal power plants)

New capacity additions will favor high-efficiency technology

- Deregulation clearly favors gas turbines for maximum power-to-heat ratio cogeneration & polygeneration for new baseload capacity

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Conclusions

Electric power generators must more objectively assess all CO_2 mitigation options to assure strategic long-term flexibility

- Support reforestation & renewables with honest economics
- Support existing nuclear plant life-extension with uprating
- Consider NGCC or CGCC repowering of existing coal power plants depending on how high NG prices go in a carbon constrained world
- Longer term will require CO_2 capture which likely favors CGCC for repowering of existing coal power plants & polygeneration

Keys to effective CO_2 reduction in U.S. power generation

- Policy to create incentives for CO_2 reduction, capture & replacement of increasingly inefficient old coal plants currently being life-extended
- Gasification repowering old coal plants increases both capacity & efficiency while reducing all emissions to near zero, including CO_2; only major CO_2 capture application that can make this important claim

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