Are You CO_2 Capture Friendly? "Gaming" the Climate Change Issue

Noon Luncheon Presentation and Discussion of the

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by

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Presentation Overview

Background

- SFA Pacific's recent activities on CO_2 capture
- Overview of global warming & man-made greenhouse gas (GHG) issues plus the impacts of the Kyoto Protocol, <u>without</u> the USA
- <u>If</u> a carbon constrained world ever develops, CO_2 capture & storage (CCS) will become strategic, especially for coal-based power

CCS economics for new and existing power plants

Our insightful views of "gaming" & political agendas on CO_2 capture & storage (CCS) for coal-based power generation

- What I learned working on the IPCC special report on CCS
  - Appears an IEA driven gaming of CCS costs to get their agenda - advanced technologies showing <u>all</u> CCS options have about the same costs & performance to "save the boilers"

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SFA Pacific Background

Founded in 1980

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

- **Over a third of our work is consistently outside the United States**

Principal work involves residual oil upgrading, syngas (H_2 & CO), electric power generation & emissions control

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

Unique perspective with no vested interest in engineering, resources, technologies, R&D or project development

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Representative SFA Pacific Clients

UTILITIES	*INDUSTRIALS*	*MANUFACTURERS + E&C*
EdF	BP (Amoco Arco Veba Oil)	All industrial gas companies
Electrabel	Chevron Texaco	Babcock Hitachi
EPDC (Japan)	Conoco Phillips	Black & Veatch
EPRI	Dow Chemical	Bechtel
Eskom (South Africa)	ENI	Chiyoda
National Power	Exxon Mobil	Fluor
PG&E	PDVSA	Foster Wheeler
Power Gen	Petrobras	General Electric
RWE/Rheinbraun	Pemex	Kellogg Brown & Root
So CA Edison	Rio Tinto (Kennecott Energy)	Krupp-Uhde
Suez	Shell Oil	JGC
Taiwan Power	Sinopec	MHI
Tokyo Electric Power	Statoil	Siemens/Westinghouse
TransAlta	Suncor, Syncrude & OPTI	Snamprogetti
Vattenfall	Total Fina Elf	Toyo

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Background of SFA Pacific CO_2 Capture Related Projects

1989 - CO_2 Capture analysis for EPRI

1992 - CO_2 Capture analysis for DOE

2001 - Private Mulitclient Analysis of CO_2 Mitigation Options sponsored by over 25 major international energy companies

2002-2004 - Technical Advisory Board (TAB) to the oil industry CO_2 Capture Project (CCP)

2002-2004 - Canadian Clean Power Coalition (CCPC)

2003-2005 - Lead author on the IPCC Special Report on CO_2 Capture & Geologic Storage - to be made public in Nov 2005

Most of our recent CO_2 mitigation work is for private industry

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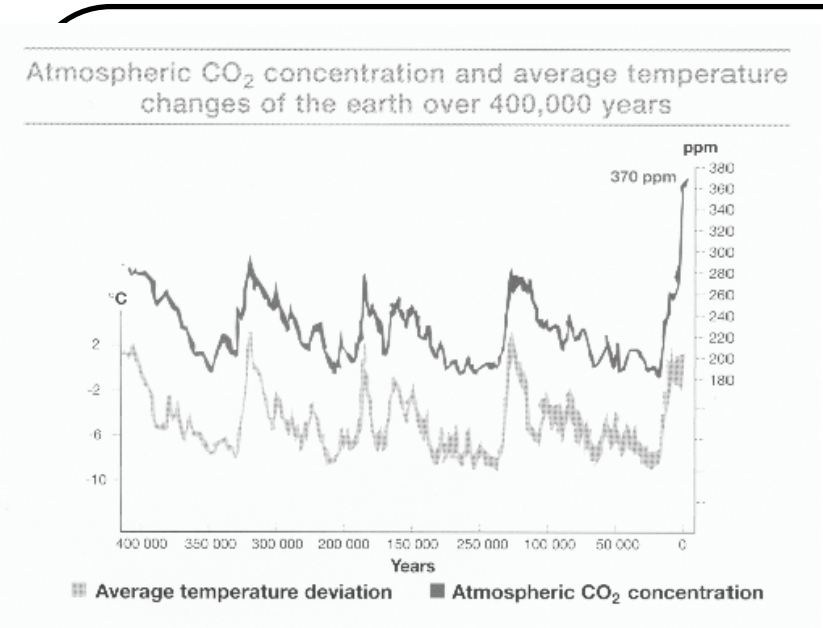

Global Warming: What is the Problem

Atmospheric CO_2 ppmv the main greenhouse gas (GHG) is <u>accelerating</u> every year

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Kyoto Protocol Has Gone Into Effect

Goal is about 5.2% reduction of GHG emissions (mostly CO_2) below 1990 levels in just the industrial nations by 2008-2012

- Vague definition of "additionalities" used by environmentalists to bias toward renewables over fossil fuel reductions via efficiency or CCS

Went into in effect in 2005 without the USA involved due to the 55% rule of GHG emissions from industrial nations that ratify

- Japan appears to have signed mainly due to Protocol's name
- The European Union (EU) signed because they are more concerned and generally more socialistic than North America
- Canada signed, with capped reductions costs < $15 Canadian / t CO_2
- Russia signed via a deal with the EU to get them into the WTO + Russia wants to make money selling "hot air" & more NG to the EU

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Impact of Kyoto Protocol

From a global GHG growth perspective, almost no impact as:

- 80-85% of GHG growth in developing nations not bound by Kyoto
- The USA with about 36% of industrial nation's (25% of entire world's) current GHG emissions is not bound by Kyoto
- Many industrial nations that signed will not meet their reductions
- Most of the reductions will be just "hot air" followed by low-cost CH_4 flare & vent reductions + only "token" renewables & efficiency gains

However, the positive spin is that we have to start somewhere & the longer we wait the larger the reduction will have to be to stabilize atmospheric CO_2 at double pre-industrialization level of 550 ppmv - the original objective of The Rio Accord

- Assuming we do not reach the peak in the fossil age in less than 30-40 years as most respected experts project

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Impact of Kyoto Protocol - continued

Impact of the USA not signing?

- **Unclear due to nations that signed Kyoto but will not meet their reductions, as this makes the USA look more honest or realistic about the economic impacts & limitations of Kyoto**
- **Perhaps the USA loses out or is slower to establish: effective, fungible, low transaction cost & most of all, transparent GHG trading systems**
  - **EU "claims" failing to comply face penalties starting in 2005 of 40 Euro/t CO_2 for going over their limits until 2008 & 100 Euro/t CO_2 thereafter**
  - **Current EU market trading of CO_2 is about 20-25 Euro per metric ton CO_2**

The real issue is "beyond Kyoto" behind the scene negotiations

- **While publicly claiming Kyoto is a success, understand why it mostly failed, to try to negotiate something that might work for the next phase**
  - **Assuming global warming really becomes a major problem, it is clearly due to GHG & we have the fortitude to address it rather than just adapt & talk**

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Do We Have The Resolve & Economic Fortitude to Address the Potential GHG Challenges

Not likely in the foreseeable future, thanks to several groups

- **Consumers that demand big vehicles & houses + cheap energy**
- **"White collar welfare" telling consumers there is a "free lunch" (low cost big GHG reductions) provided they get paid to prepare this "lunch"**
- **Those taking advantage of the white collar welfare by promoting only "leap-frog" advanced technologies claiming just 10 years away forever**
  - **Partnership for the Next Generation Vehicle - $3.1 billion failure & Pinon Pine - $0.5 billion IGCC failure: effective "delay & fail" status quo strategy**

Real technology time frames, real higher costs & fundamental lifestyle changes to significantly impact world GHG emissions

- **Still unclear how big of a problem global warming could be & when**
- **It might even be politically easier + cheaper to adapt to global warming especially if we love our current lifestyle more than our grandchildren**

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CO_2 Mitigation Options

Man-made CO_2 emissions & growth rate are simple to calculate via the *Kaya Identity* where CO_2 emissions =

people x GDP/person x energy/unit GDP x CO_2/unit energy

Only four options:

- **Population** (number of people)
- **Standard of living** (GDP/person)
- **Energy intensity** (energy/unit of GDP)
- **Carbon intensity** (CO_2 /unit energy)

Any meaningful worldwide CO_2 reduction requires focus on carbon intensity & energy intensity in the USA & China

- **USA is 25% of world GHG emissions, but also over 25% of world GDP**
- **China will pass the USA in GHG emissions in only 20-25 years**

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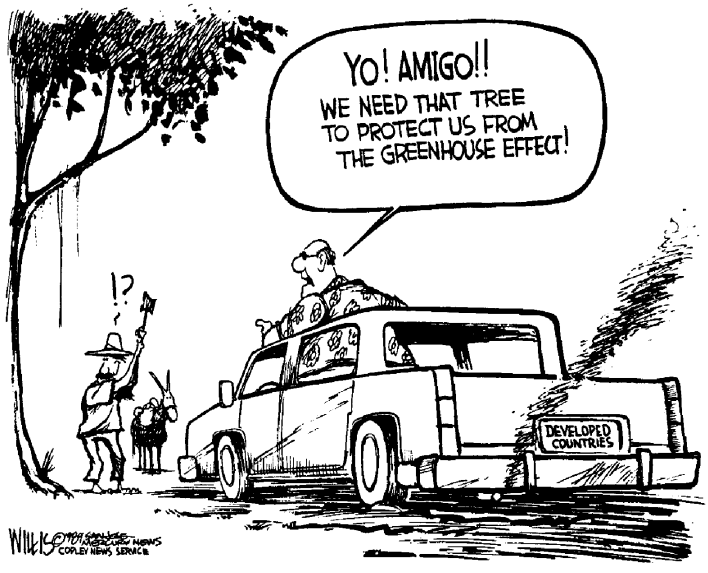

Source: Scott Willis of the San Jose Mercury News (California)

The Classic Ugly American: Confuses "US" with U.S.

Standard of Living & Fossil Fuels Consumption

The fundamental greenhouse gas (GHG) issue of fairness

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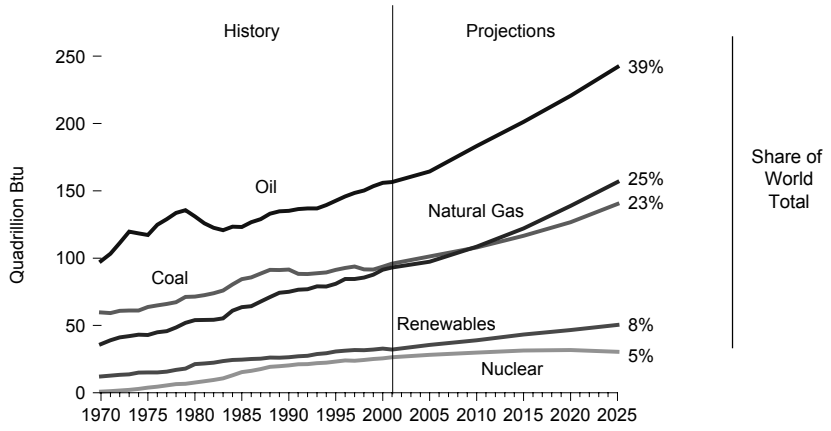
World Primary Energy Consumption by Fuel Type, 1970-2025



Source: EIA, *International Energy Outlook 2004*

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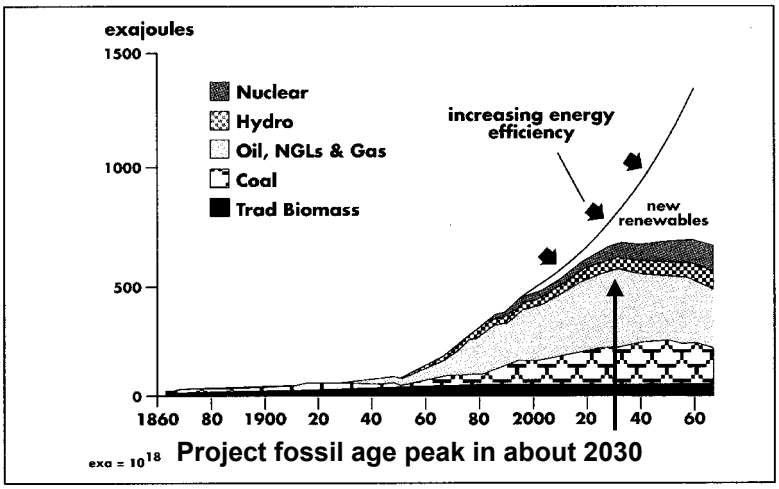
Shell's Famous 1996 World Energy Supply/Demand Projection

Massive expensive new renewables or increased energy efficiency? - DA!



Source: Paper by C.A. Herkstroter (managing director of Royal Dutch Shell), "A Continuing Contribution-- Oil and Gas in the 21st Century", presented at Nymphenburg Talk, Munich, June 19, 1996

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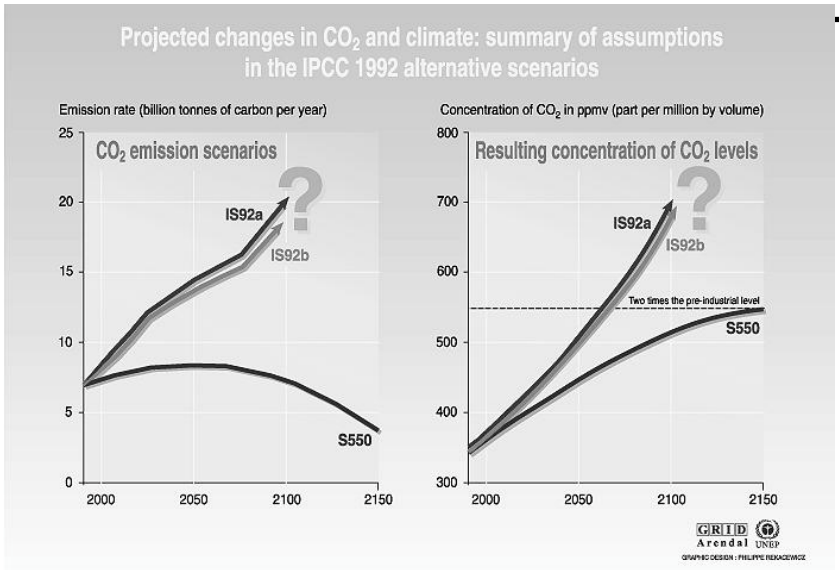

Sources: Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 199; Hadley center for climate prediction and research, United Kingdom, in Climate change information kit, Information unit for convention (IUC), UNEP, Geneva, 1997.

IPCC Projects No Peak in the Fossil Age Before 2100 Which Is Almost Impossible

Above units are in Giga metric ton carbon equivalent per year of CO_2

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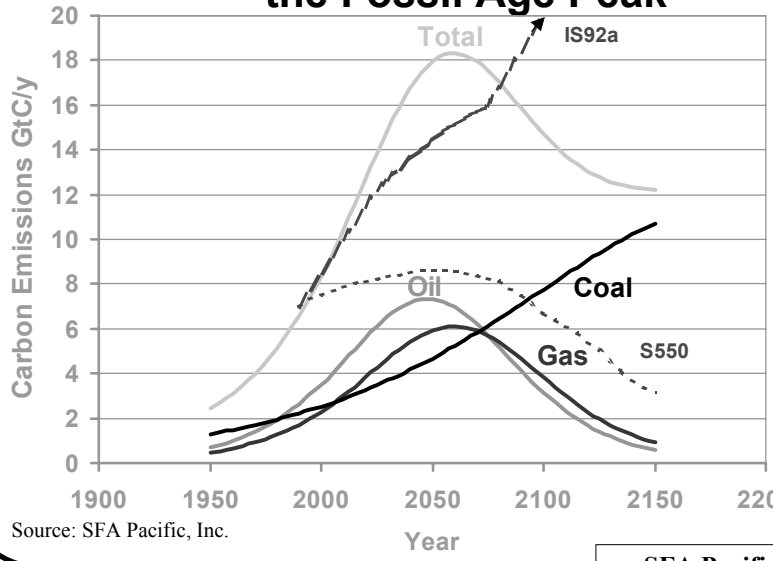
SFA Pacific's Latest Possible Projection of the Fossil Age Peak



Source: SFA Pacific, Inc.

Note:

CO_2 emissions as carbon not units of energy

Also the IPCC IS92a Gt/y carbon beyond 2075 projection is highly questionable

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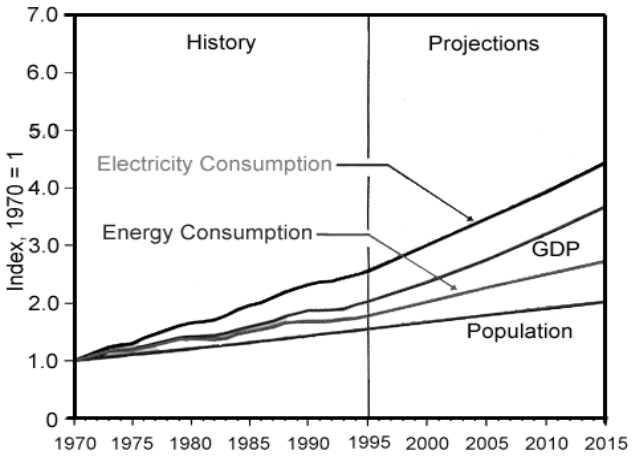
World Energy, GDP & Population Trends
Clearly Show Electricity is the Energy of the Future



Electricity grows at the same rate as GDP where as other end-use forms of energy only grow at half the GDP rate

Source: 1997 EIA International Energy Outlook

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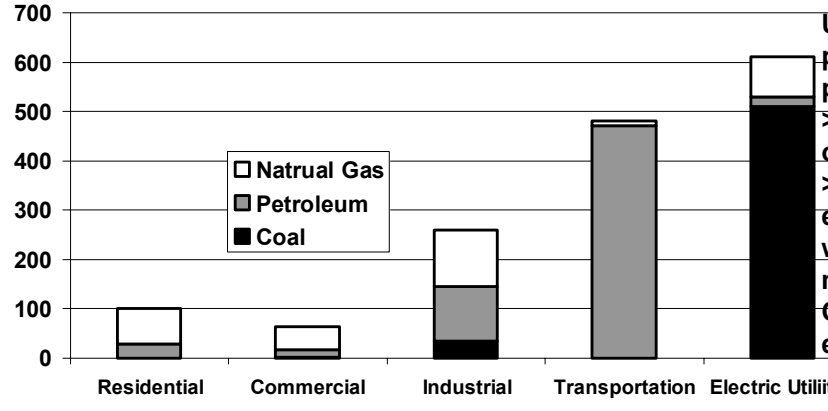
United States CO_2 Emissions as Carbon Equivalent by Sector and Fuels in 2002

Millions of metric tons per year carbon equivalent (x 3.67 for CO_2)



U.S. coal power plants ave. > 32 years old & are >9% of entire world's man-made CO_2 emissions

Source: U.S. EPA Inventory of Greenhouse Gas Emissions, April 2004

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

- Transportation fuel users have more "voting power" than the CO_2 intensive power industries as demonstrated in June 2000 when gasoline taxes were reduced in both 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 plant efficiencies
  - Replace coal with: co-firing biomass, natural gas or wind turbines
- Large point sources of power generation reduces both CO_2 mitigation & capture/storage costs

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What If We "Really" Moved Into a "Carbon Constrained World"

- Conservation & energy efficiency significantly increase as energy prices rise to reflect increasing realization the oil/NG age could peak in <25 yr.
- Natural gas demand/prices go up while coal & oil residue demand/prices go down as CO_2 avoidance & emission cost gains "real" market values
- Nuclear will eventually make a big comeback, however, not for 20-30 years, until life-extensions & upgrades + eventual decommissioning of current fleet + we honestly assess why nuclear power failed the 1st time
- Renewables become increasingly important but still have limitations
  - Intermittent solar PV & wind turbines cannot replace baseload coal power which currently supplies >50%of total USA & 40%of total world electricity
  - Beyond waste biomass, bioenergy requires cheap land & ultra-cheap labor
- CO_2 capture & storage (CCS) of fossil fuels becomes strategic for technical, economic, energy resource & overall reduction perspectives
  - Once big coal CCS units can co-process biomass for "double reductions"

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CO_2 Capture & Storage (CCS) is Already a Large Commercially Well Proven Industry

Over 20 years & currently > 35 million t/yr commercial geologic CO_2 storage for 200,000 bbl/d enhanced oil recovery (EOR)

- **Extensive existing CO_2 pipeline systems of > 2,000 miles**
- **Already 30% from man-made CO_2 capture: NG, gasification, ammonia**
- **<u>If</u> all current CO_2 supplied by coal power plants - about 4,500 MWe**
- **New DOE report by ARI estimates 84 billion barrels of additional recoverable oil via CO_2 EOR in just the 6 major USA oil fields or about 8 million bbl/d oil + 1.4 Giga-tons/year CO_2 storage for 30 years**

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**

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Energy Efficiency - Large Cogen Potential

The European cogen experience clearly shows there is significantly more cogen potential than many believed

- **The Netherlands is delaying large cogen projects due to excess power**
- **Small distributed cogen suffers from high costs & low annual load**

Large potential for cogen in North America <u>once</u> start replacing old coal units & utility reforms toward <u>twice</u> as efficient cogen

The Japanese Gas Association 1991 Industrial Repowering Analysis showed big potential (17,500 MW_e), large power efficiency gain (16%), & major CO_2 reduction (50 MM t/yr)

Biggest cogen opportunities are in China <u>once</u> utility reforms

- **40 % of China's total coal use is in small inefficient industrial boilers**

Need industry & electric utility cooperation & <u>utility</u> incentives

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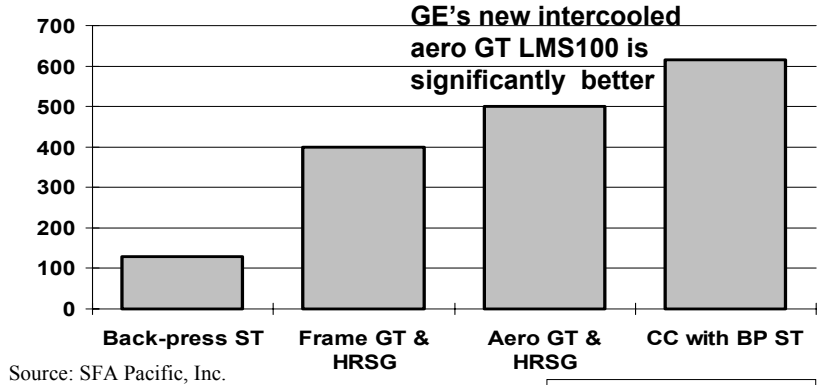
Maximum Power in Total Cogeneration Clearly Favors Gas Turbines Over Steam Turbines

For a given heat host, 3-5 times more power with GT vs ST
This is the key issue as true cogeneration is heat host limited

Power-to-Steam ratio: kWe per ton/hr 150 psig cogen steam (no steam to condenser)



Source: SFA Pacific, Inc.

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What is Polygeneration

Defined as gasification to "syngas" (H_2 & CO) for high power/heat GT-cogen + syngas chemicals & ultra-clean fuels

Shell Oil Pernis refinery in The Netherlands is a good example - no subsidies & high availability without a spare gasifier

- **Pitch gasification - 3 units total 640 MW_{th} with 2 gasifiers for refinery H_2 and 1 gasifier for IGCC cogeneration with NG as GT back-up fuel**

Large potential for polygeneration in the future due to ongoing deregulation of electric generation + higher oil & NG prices

- **Economy of scale plus high H_2 availability without spare gasifiers**
- **Offers greater flexibility than traditional power plant relative to fuels, products, revenues, emissions, efficiency & annual capacity factors**
- **Low incremental costs of CCS as CO_2 already recovered & just vented**
- **Steam assisted gravity drain (SAGD) oil sands polygen & CO_2 EOR**

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Polygeneration is the Best Use of Gasification

Many advantages of clean syngas as an intermediate which are lost in the supercritical boiler PC vs. IGCC power debate

- Many high value uses of syngas such as F-T ultra clean diesel, methanol, ethanol, DME, SNG, NH_3 (fertilizer) & hydrogen (H_2)
- Most syngas applications make a high purity CO_2 vent thus reducing CCS costs in about half - to just the CO_2 compression & storage
- Central coal power plant about 40-43% "real" HHV efficiency where as gasification cogen will be almost double (70-75%) that efficiency
- Polygeneration by oil, chemical or minerals processing industry experts avoids the lack of chemical process expertise problem of most regulated electric utilities, which we consider a major issue
  - Look at cost, performance & availability of Wabash River (Dow owned gasifier & PSI owned CC) + Dow Plaquemine vs the other 4 IGCC demos

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What is Holding Back Polygen if so Great

Paid-off, life-extended old coal power plants assures market price for any new cogen power sales to the grid are too low

- Only relative to new or replacement baseload capacity (fully capital charges loaded new power plant power costs) is polygen/cogen significantly more economical besides much more efficient

A regulated electric utility's worst nightmare is clean, cost-effective & ultra-high efficiency cogen power sales in the grid that is generated by industrial cogenerators

- Most regulated utilities make much less money reselling + T&D of polygen power by other vs guaranteed return on investments in their own central power plants at half the efficiency of polygen
- Regulated utilities & private energy companies distrust each other & have not worked together for effective polygen - that must change in the future if climate change due to GHG is a real problem

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Cost of New Power Plants CO_2 Reduction

Natural gas combined cycle (NGCC) baseline - vary NG price

- Most effective to vary NG price to where new coal vs. new NGCC power plants without CO_2 capture have the same electricity cost

Best option: cogen/polygen vs. new central power plant with or without CO_2 capture, why: efficiency & incremental CCS cost

Best options if just new central power plant with CO_2 capture is a NGCC with post-combustion (amine scrubber) if low NG prices or coal pre-combustion (H_2-IGCC) if higher NG prices

CO_2 capture & storage (CCS) costs: best matrix is electricity costs increase, as $/t CO_2 costs vary too much with baselines

- $/t CO_2 avoided = ($/MWh$_{CCS}$ - $/MWh$_B$) / (to atm t CO_2/MWh$_B$ - t CO_2/MWh$_{CCS}$)
- About $ 80/t CO_2 ($293/t carbon equivalent) avoided if new NG as baseline
- Only about $30/t CO_2 ($110/t carbon equiv.) avoided if new coal as baseline

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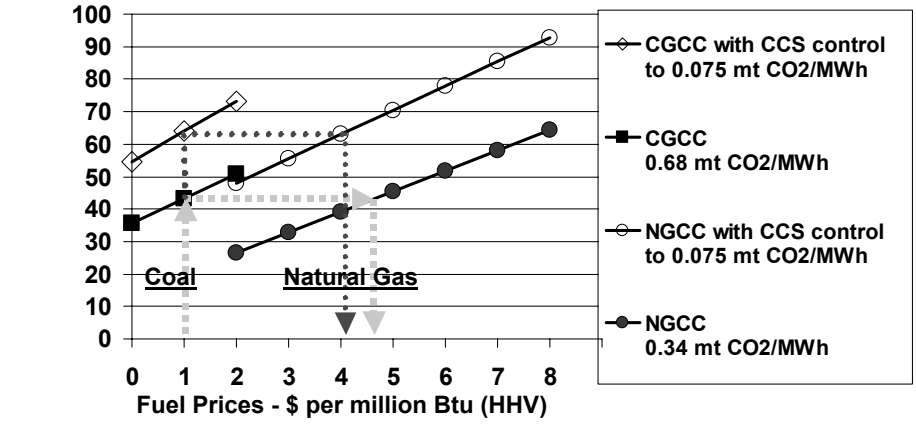
Electric Power Costs of Coal Verses Natural Gas For Various Fuel Prices & CO_2 Emissions

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



Source: SFA Pacific, Inc.

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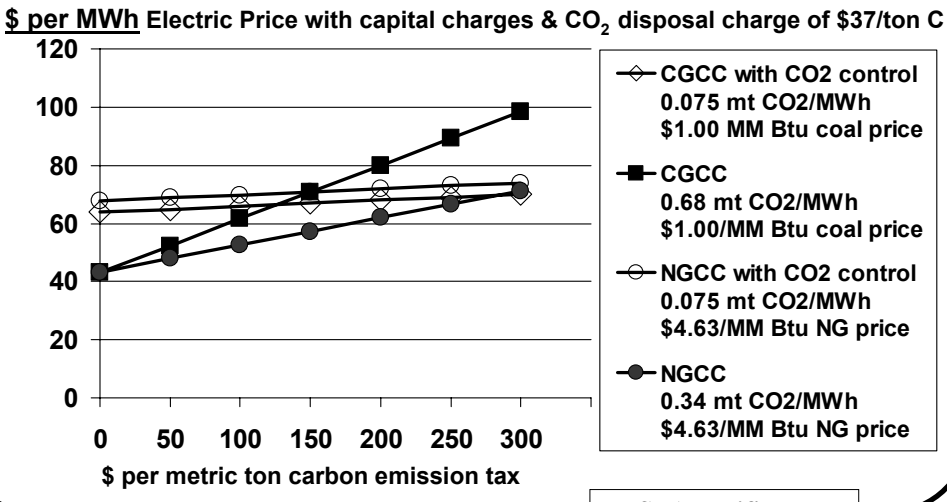
Electricity Costs for New Coal vs New NG Power Plants at Various CO_2 Emissions & Carbon Taxes



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Existing Coal Power Costs of CO_2 Reduction

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 CCS if low NG prices, however NG prices will certainly rise if a carbon constrained world develops

USC PC rebuild or CGCC repowering with CCS if high NG prices

- Only via USC boiler replacement/rebuilds can post combustion & oxyfuel CCS effectively compete with gasification for CO_2 capture
  - For old, dirty & inefficient existing PC rebuilds, likely not for new capacity
- Can increase both capacity & efficiency while reducing all emissions to near zero while staying on coal - due to the poor existing baseline
  - Only major CO_2 capture application that can make this important claim

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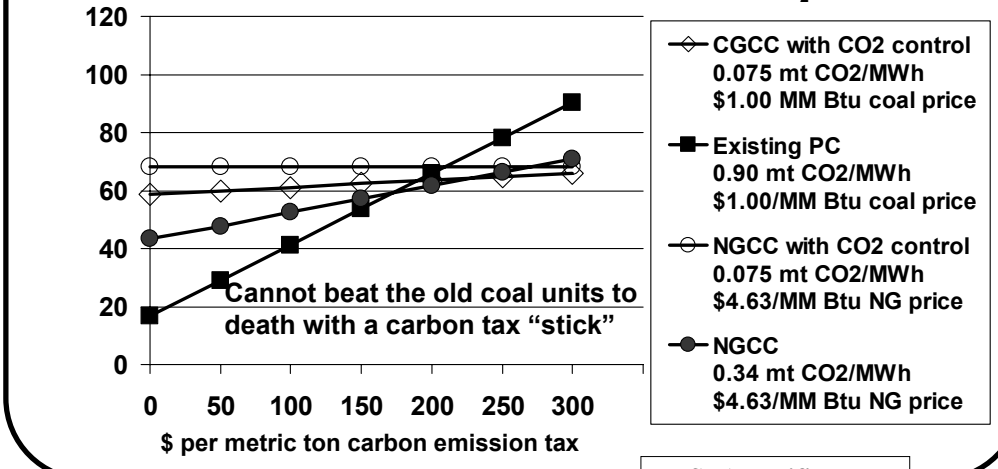
Electricity Costs for Existing Coal Power Plant Upgrades if Carbon Taxes

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



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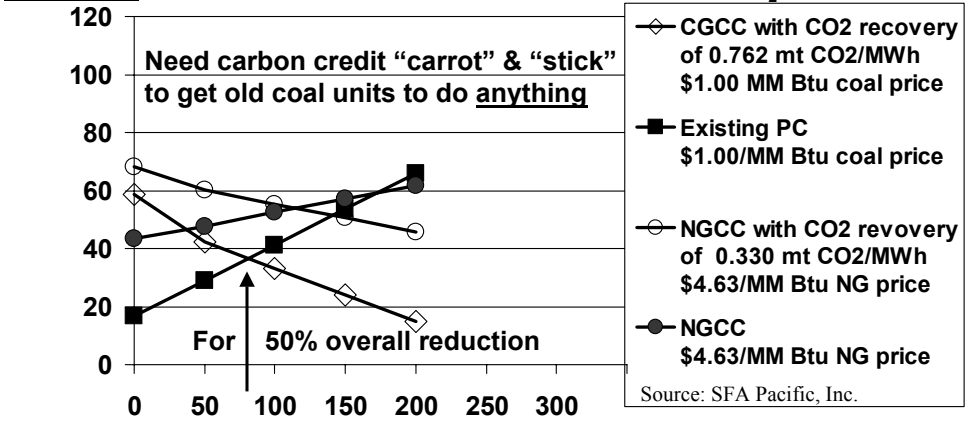
Electricity Costs for Existing Coal Plant Upgrades if Combined CO_2 Recovery Credit & Emission Tax

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



Source: SFA Pacific, Inc.

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Why CO_2 Capture Should Focus on Existing Coal Power Plant Retrofits

Most new power plants (except China) are NGCC, not coal

- Essentially none of the old existing dirty inefficient coal power plants (including China) are being replaced by new power plant capacity

Even if CO_2 capture on new fossil power plants, this would only reduce the growth rate of CO_2 emissions in power gen

Existing coal power plants are the big CO_2 reduction potential

- Largest point sources & >1/3 of total world man-made CO_2 emissions
- Plan to run forever due to paid-off investments & low operation costs
- CO_2 capture would significantly reduce CO_2 emissions
- If CCS with boiler rebuild of old PC avoids net efficiency & capacity loses + can also significantly reduce traditional emissions - SO_2 & NO_x

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How to "Game" CCS Costs

Advanced R&D & technologies are the only answer!

- Sell well with politicians & are the life blood of the white collar welfare
- Set overly optimistic cost & performance "targets" or "goals" to force the white collar welfare to grossly under estimate costs & over estimate performance to obtain & maintain funding (feed their families)
  - Compare ultra optimistic "green lemon" advanced technology estimates with ultra conservative "rotten red apple" commercial technology estimates to assure large cost reductions if we only wait forever

Use low capital est. & returns due to high capital costs of CCS

- Some analyses use only 10% DCF ROI before taxes that converts to only a 11-12% of total capital per year "capital charge rate" which is clearly too low for even high debt leveraged utility type investments
- Never update to 2005 dollars due to big increases in steel most impact: post-combustion CCS, ultrasupercritical (USC) boilers & wind turbines

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Oranges vs. Applies Efficiency Bases

European electric utilities overstate efficiency & capacity

- Assume winter rating at sea level with once-through 1°C cooling water & LHV definition that real coal drying energy "comes for heaven"
- Sometime efficiencies are for gross or net & without emission controls
- Therefore typical efficiency & capacity are overstated by about 1-3% with annual averages much less
- Rationale - winter peak & associate "efficiency with honor"

American electric utilities understate efficiency & capacity

- Assume hottest summer rating at elevation with cooling towers & HHV including real coal drying energy
- Therefore except on the hottest day understate efficiency by 1-3% to assure annual averages are what the regulators expects
- Rationale - summer peaking & understand economics vs. efficiency

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Examples of How to Game Efficiency

Same GE 9F turbine combined cycle shown two ways

- ISO rating - 59°F 60% relative humidity, 14.696 psia, LHV & once-through cooling water
  - 390.8 MWe & 56.7% efficiency
- Summertime rating, same ultra-high psia, HHV & cooling tower
  - 343.3 MWe & 48.9% efficiency - differences: 47.5MWe & 7.8%efficiency
- European to American coal design bases - even greater difference

European gaming of ultra supercritical (USC) steam cycle pulverized coal (PC) boiler power plants is very effective

- European's unique LHV definition of assuming the very real energy for coal drying "comes from heaven" is usually not noticed
  - For lignites & brown coals this trick over-states efficiency by 5-8%
- Compare European design basis to American design basis without mentioning the major impacts on efficiency & net capacity

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Gaming CO_2 Capture-Ready or Friendly

Old electric utility trick to get approval of what ever they want to build with little or no real intention of ever doing the later retrofits or next phase "ready" promised

- **"Phased construction IGCC" claim to get NGCC approval during the old Fuel Use Act days**
- **Original 1970 Clean Air Act "grandfathering" claiming now 35 years older coal "big dirties" would have been shutdown 15 years ago**
- **Same effect with the new Clean Air Interstate Regulations as might allow rebuild of old boiler for capacity creep & life extension then new excuses in 10 yrs when promised emission reductions are due**

Nevertheless could be a great idea if done right & not gamed

- **However, the "save the boiler" people have turned some good CCS ready ideas for IGCC into a gaming trick as in the past**

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"Save the Boiler" Appears to be an IEA Agenda

Boiler people never originally took Kyoto or CCS seriously

- **Never commented on the many EPRI studies of CCS showing IGCC had clear cost/efficiency advantages over PC with post or oxyfuel CCS**
- **However Kyoto going into effect in Europe quickly changed that**

Save the boiler <u>with</u> CCS now aggressively promoted by mostly the European coal boiler people via IEA studies

- **Likely due to the EU commitment to Kyoto + the massive funding of advanced USC PC boilers in Europe under the EU "Therme" project**
- **Recent IEA GHG R&D & IEA Clean Coal reports are highly questionable**
  - **Claim current PC flue gas MEA CO_2 scrubber has same $/kW as FGD**
  - **Claim long-term improvements in CCS for PC much greater than for IGCC**
  - **Claim USC PC with CCS has lower capital than IGCC & same efficiencies**

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Summary of CO_2 Capture Options

Coal-based power gen will be forced to meet a disproportionate share of any CO_2 reductions, as they cannot move to China

- If a carbon constrained world ever develops, CO_2 capture & storage (CCS) becomes strategic, especially for coal power plants

Successful demos of CO_2 capture & especially long-term geologic storage is too important for usual "delay & fail" tactic

- Must prove & convince NGO CCS is a real GHG mitigation option ASAP
- EOR could become a quite significant new oil source & big CCS option

Post-Combustion CO_2 Capture

- Clearly favored by the traditional coal boiler engineers as it "saves the boiler" & they think this is just another flue gas scrubber (i.e., like FGD)
- Focus on ultrasupercritical (USC) boiler rebuilds of existing old subcritical boilers already with high efficiency FGD & SCR add-ons

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Summary of CO_2 Capture Options

Oxygen Combustion CO_2 Capture

- Favored by "saves the boiler" researchers
- Focus on USC rebuild of old existing subcritical boilers without SO_2 & NO_2 emission controls if "raw" dirty CO_2 storage is possible

Pre-Combustion CO_2 Capture is most strategic & likely the lowest cost & more efficient CCS option, if done right

- Focus on IGCC CCS repowering of older coal boilers for maximum reduction of all emissions while increasing both capacity & efficiency
- Gasification with CCS via polygeneration the biggest & best longer-term potential if we can get industry & utilities working together

GHG reduction & CCS might become too important for just gaming by the save the boiler & white collar welfare groups

- "Learn by doing" commercial systems + kiss the "leap-frog" advanced technologies to see which are really turkeys in frog's clothing

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