Carbon Reduction Options in Power Generation

Federal Reserve Bank of Chicago

Detroit Branch

Conference on Cost-Effective Carbon Reduction

Detroit, MI

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Disclaimer

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Overview

- What needs to be done
- When does it need to be done
- Where does electrical generation fit
- What are the options in generation
- US Generation Fleet Characteristics
- Retrofitting Existing PC Plants
- Fleet Impact of Retrofit CO_2 Capture
- Issues Outside the Plant Gate
- Regional Considerations

What Needs to be Done about CO_2

- **UK's Stern calls on 'rich' nations for 75% cut in greenhouse gases**
  - September 27, 2007 (**Emissions Daily**) -- Sir Nicholas Stern, told US congressional staff on September 21 that the United States, EU countries and other industrialized nations should agree this year to cut emissions 75% below 1990 levels by 2050.

- What constitutes an appropriate level of GHG in the atmosphere remains open to debate, but even modest scenarios for stabilization would eventually require a reduction in worldwide GHG emissions of 50 to 90 percent below current levels. Source: “Carbon Sequestration Program Environmental Reference Document”, August 2007, DE-AT26-04NT42070 **National Energy Technology Laboratory**

When Should CO_2 Capture be Required

- **"The Future of Coal",** MIT, 2007
  - *Recommendation #6b:* Congress should act to close this potential "grandfathering" loophole before it becomes a problem for new power plants of all types that are being planned for construction. (Page 100)
- EPRI, "**The Power to Reduce CO_2 Emissions", 2007**
  - The technology development pathways outlined in this section are intended to achieve two key targets: first, increase the efficiency of PC and IGCC baseload plants (with CO2 capture) to the 43-45% range by 2030; and second, ensure that all coal plants built after 2020 have the capability to capture and store 90% of the CO2 produced.

Carbon Dioxide Sources

- US 2005: 5945 million tonnes CO_2 all sectors
- Electrical generation: 2375 million tonnes
- Transportation: 1953 million tonnes
- Electric power and transportation are roughly ¾ of the total

Source: EIA Annual Energy Review 2006

Why Electricity Generation is a Target

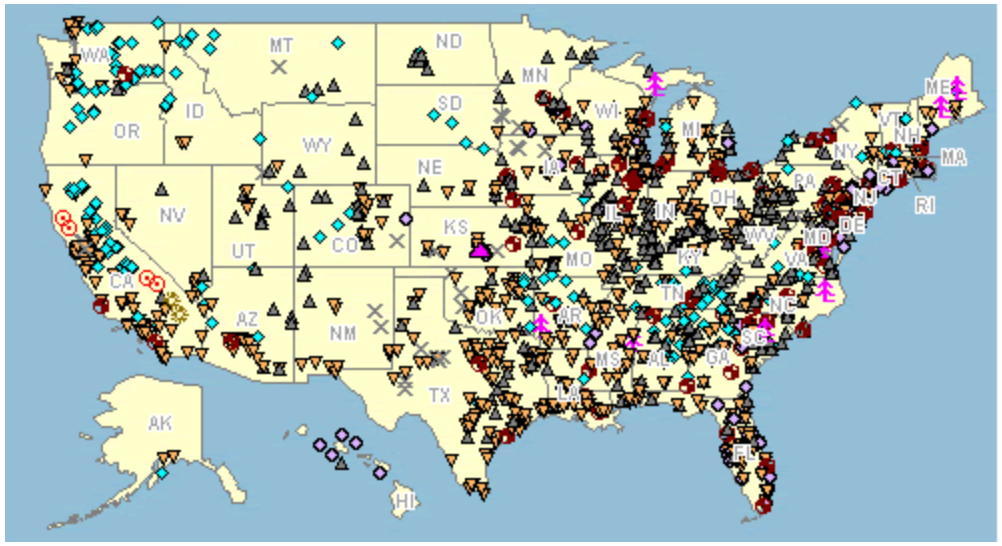
- Transportation and coal-fired generation have similar CO_2 emissions
  - 1953 Million tonnes – coal 2005
  - 1944 Million tonnes – transportation sector 2005
- There are about 1500 coal-fired generators, about 240 million cars and trucks
- The average coal plant emitted 1.6 million tonnes, the average vehicle emitted 8.1 tonnes

Sources: Emissions: EIA Annual Energy Review 2006

Transportation: Transportation Energy Data Book, 26th Ed., ORNL, 2007

Electricity and Transportation

- US Power Plants > 100 MW



Electric Power Plants

Min. net summer capacity of
100 megawatts
(Values below are U.S. totals)

- Natural Gas (731)
- Coal (401)
- Hydro (183)
- Petroleum (108)
- Nuclear (66)
- Wind (31)
- Wood (8)
- Geothermal (4)
- Biomass (2)
- Solar (2)

Source: EIA Website

1536 total power plants greater than 100 MW

What are the Options in Electricity

- Fuel switching
  - Substituting natural gas for coal
- Post combustion capture
  - Conventional PC with amine scrubbing of flue gas
  - Oxyfuel PC with amine scrubbing of flue gas
- Pre-combustion capture
  - IGCC
    - *FutureGen prototype*
- Chemical looping and other approaches
- Nuclear and renewables
  - These are subjects of other presentations today

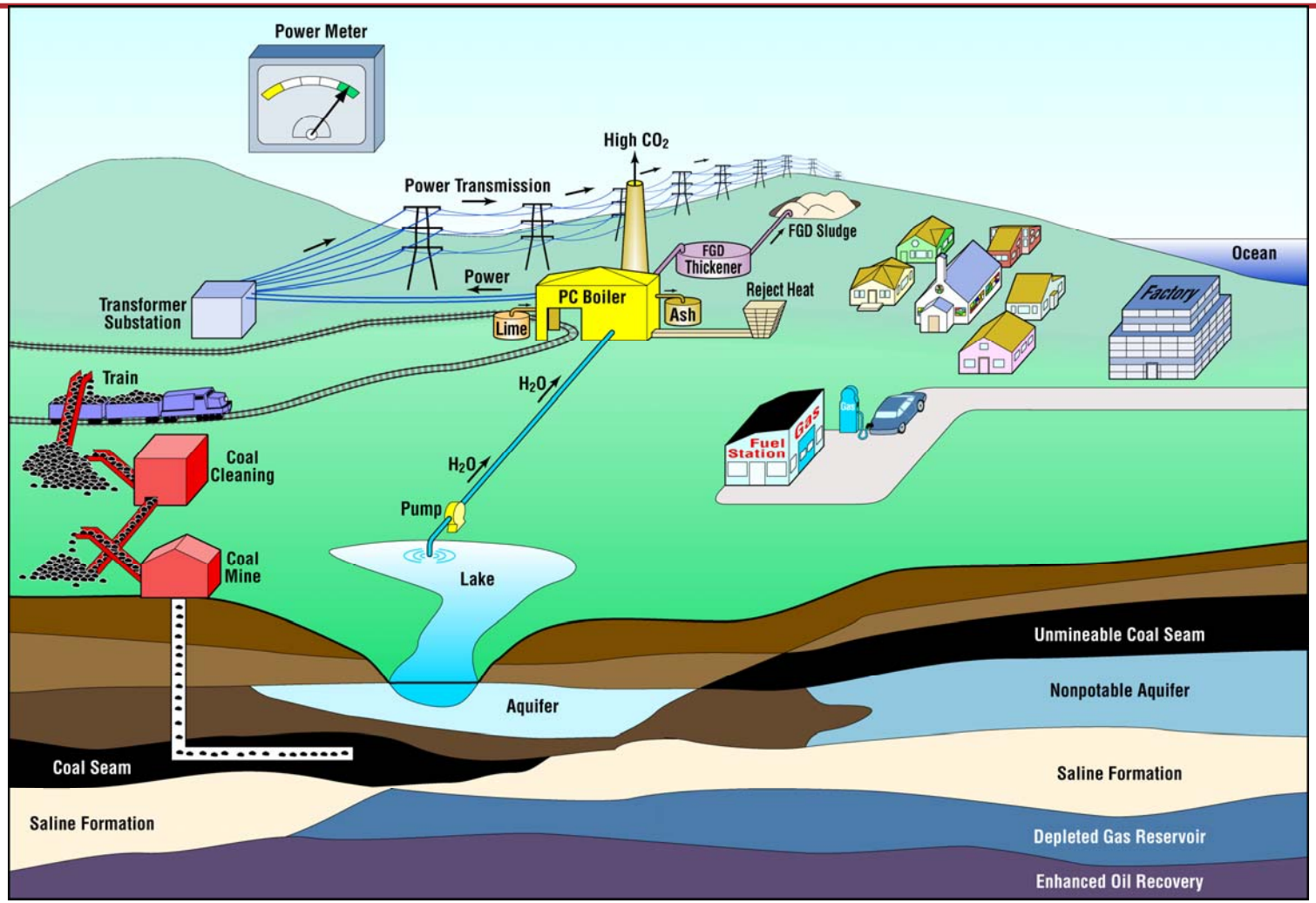
Fuel Switching – Coal to Natural Gas

- Existing coal fleet has 72.2% capacity factor, 32.8% thermal efficiency
- Existing gas fleet has 23.7% capacity factor, 39% thermal efficiency
- Substituting gas for coal reduces emissions about 53%, not 70-90% needed
- ***We don't have either the gas resources or deliverability to make this substitution***

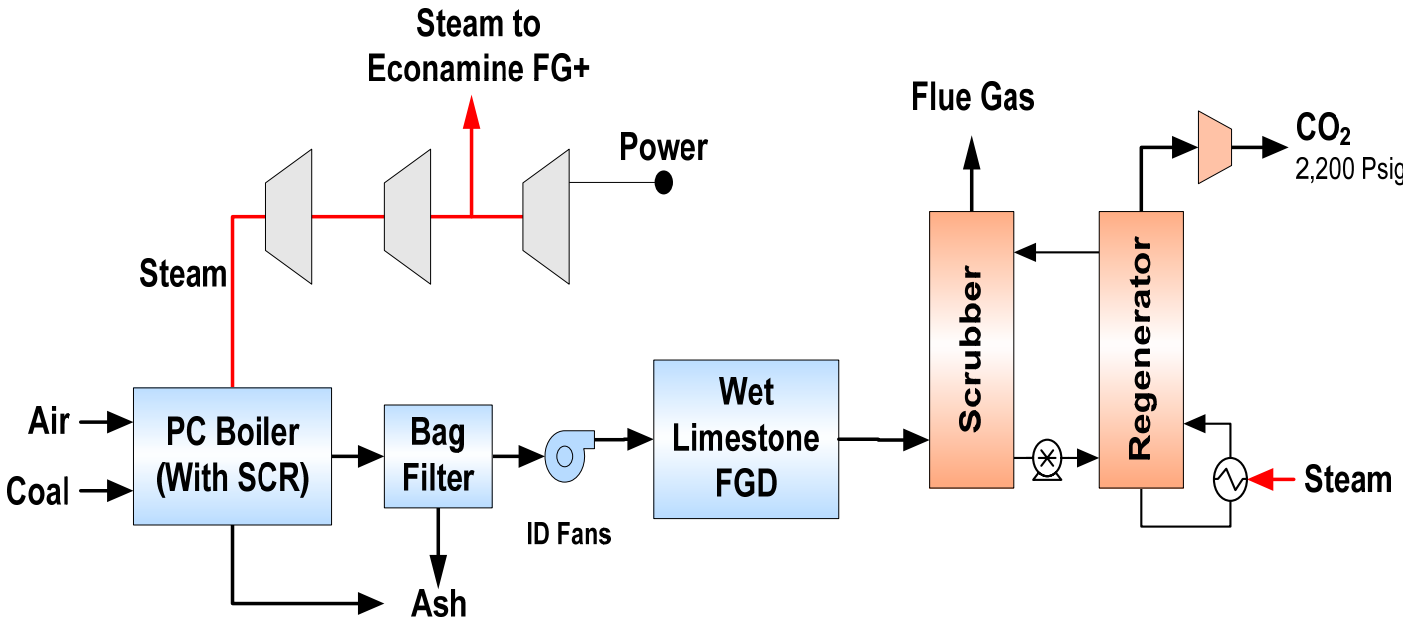
Post Combustion Capture

- **Conventional PC with Scrubbing**
  - **Costs**
  - **Derating, Efficiency reduction**
  - **Lack of utility-scale experience**
- **Oxyfuel PC with Scrubbing**
  - **Cost, complexity**
  - **Air separation reduces efficiency, derates output**
  - **Lack of experience base**

Pulverized Coal – No Capture



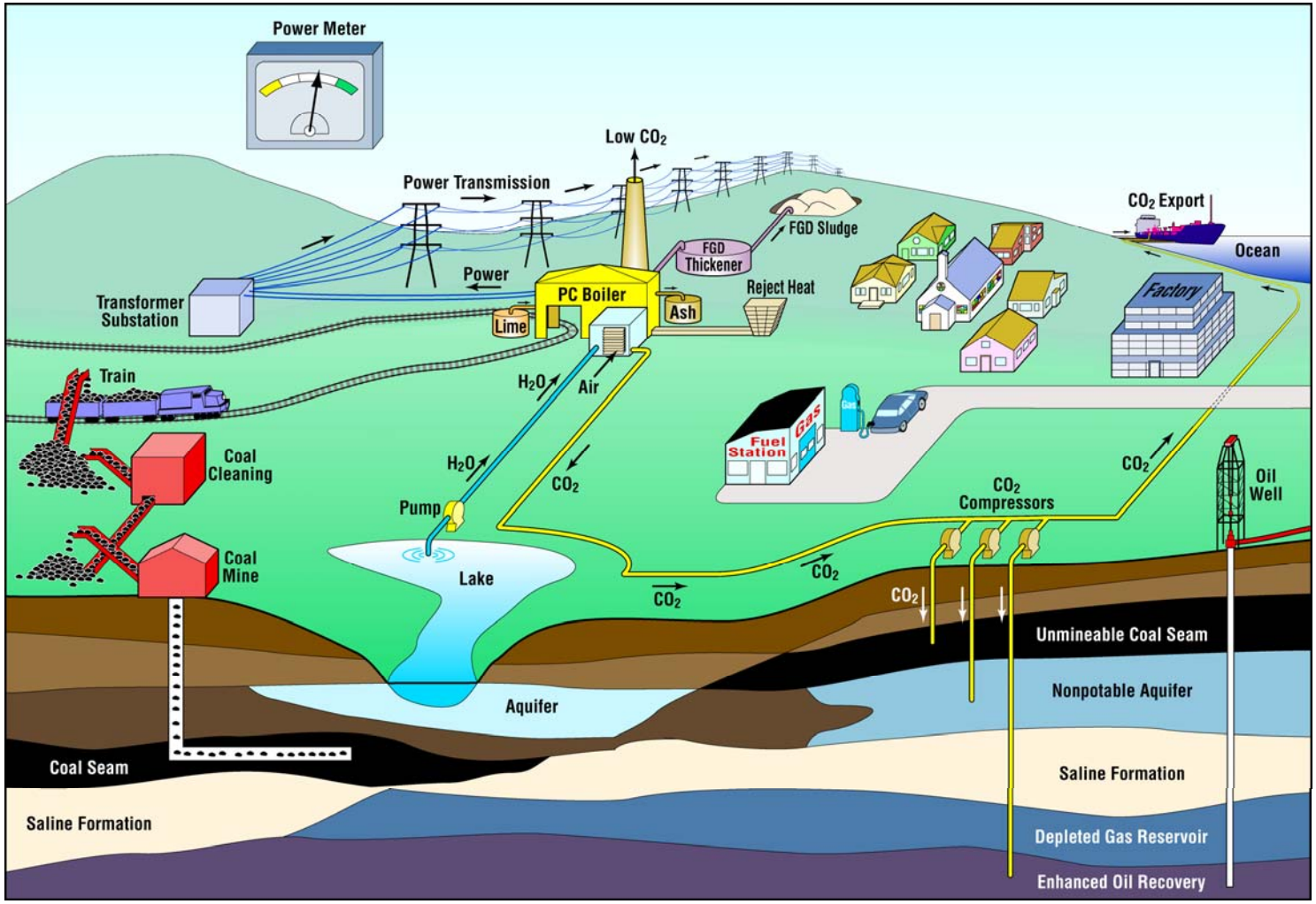
Current Technology
Pulverized Coal Power Plant



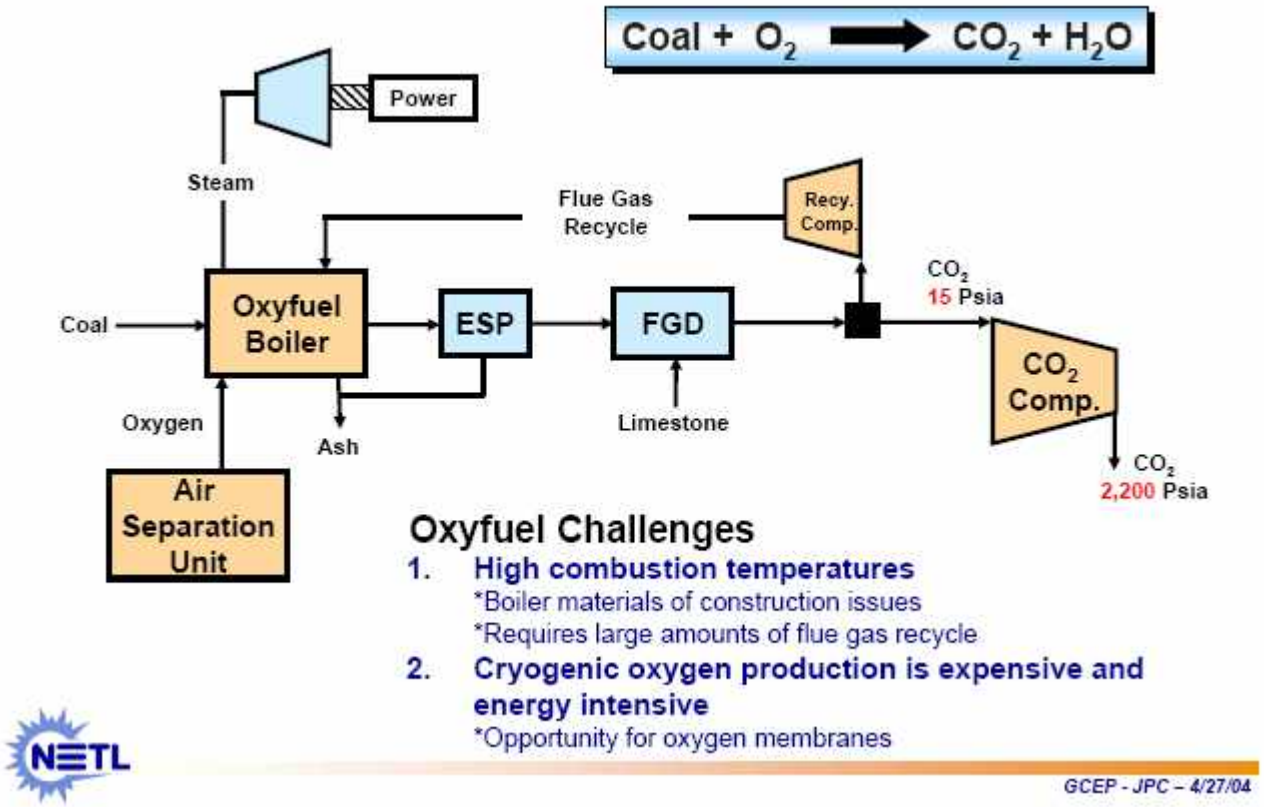
Orange blocks added for carbon capture

Source: **Cost and Performance Baseline for Fossil Energy Plants,** National Energy Technology Laboratory, ***April 10, 2007***

Oxyfuel PC with CO_2 Capture

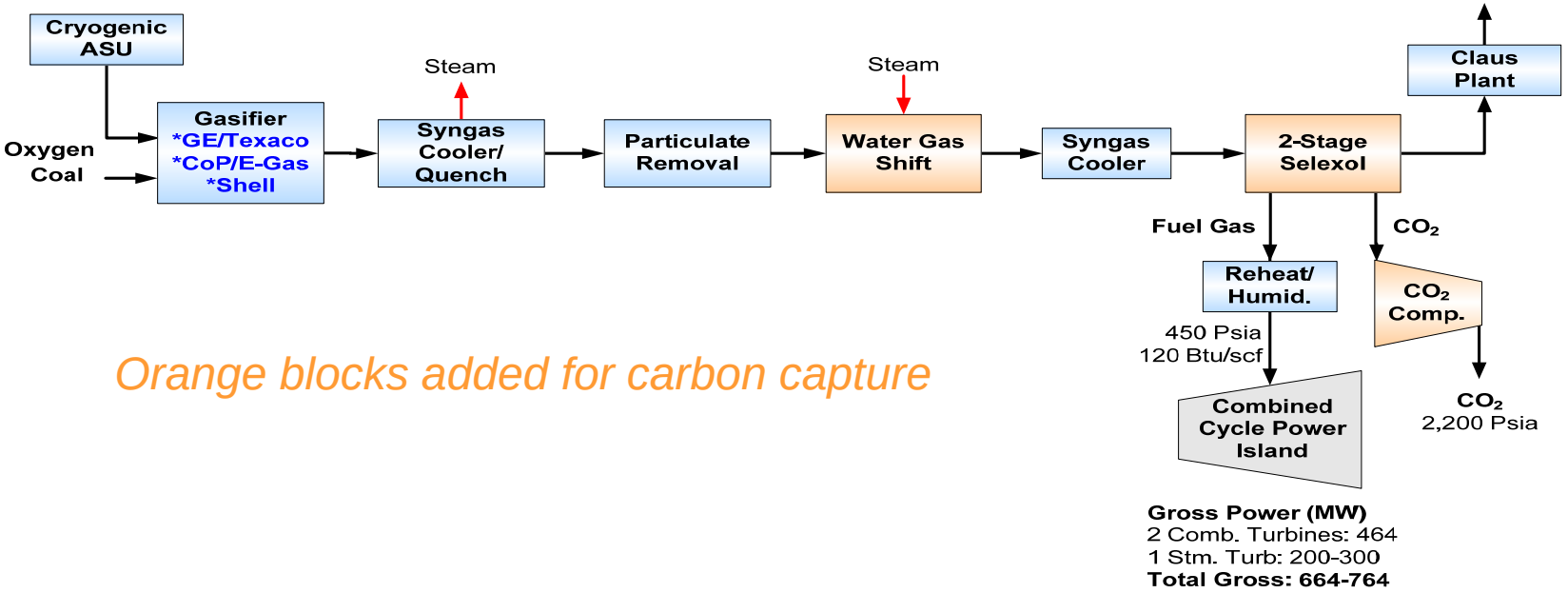


Oxyfuel Combustion



Source: NETL Carbon Sequestration Program
***US Perspective on CO2 Capture and Separation,* Jared P. Ciferno,**
April 27, 2004
Stanford University

IGCC with Carbon Capture



Orange blocks added for carbon capture

Source: **Cost and Performance Baseline for Fossil Energy Plants,** **National Energy Technology Laboratory,** ***April 10, 2007***

Existing US IGCC Plants

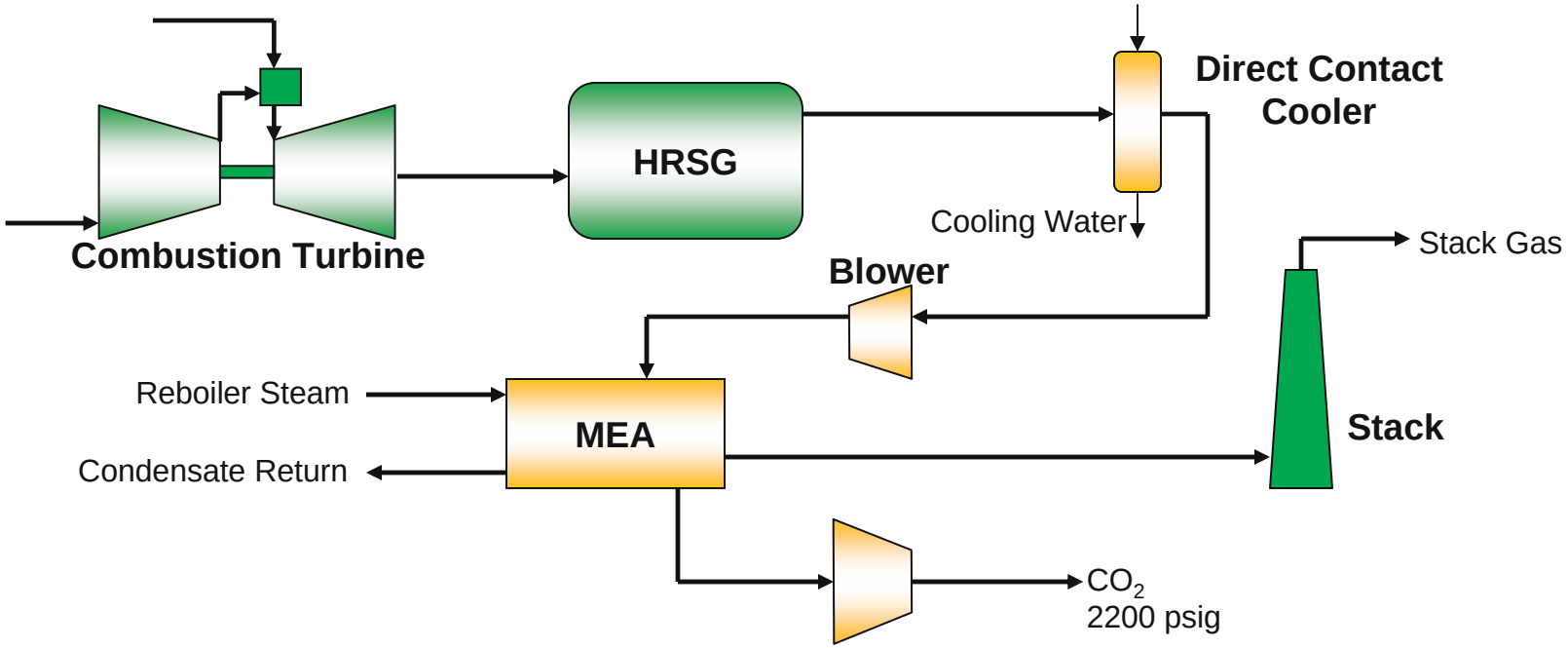
Wabash River

Source:
http://www.netl.doe.gov/technologies/coalpower/gasification/pubs/photo.html

Both plants were built under the Clean Coal Technology Program of DOE

Tampa Electric

NGCC with Carbon Capture



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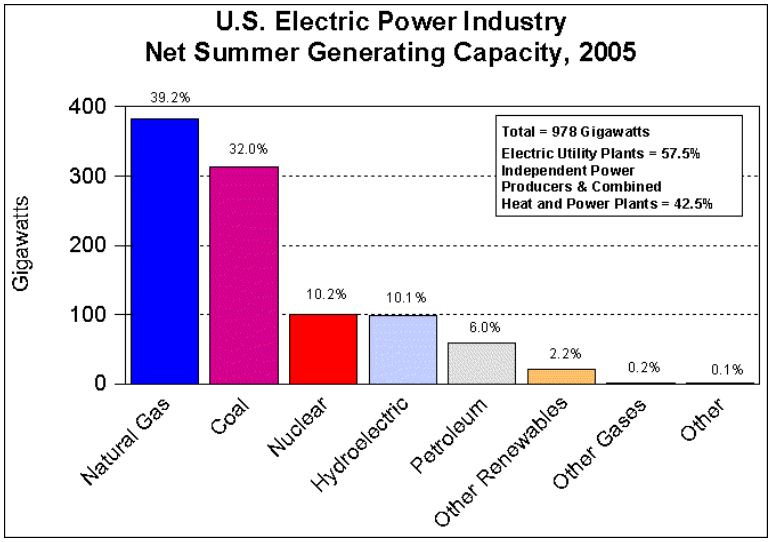
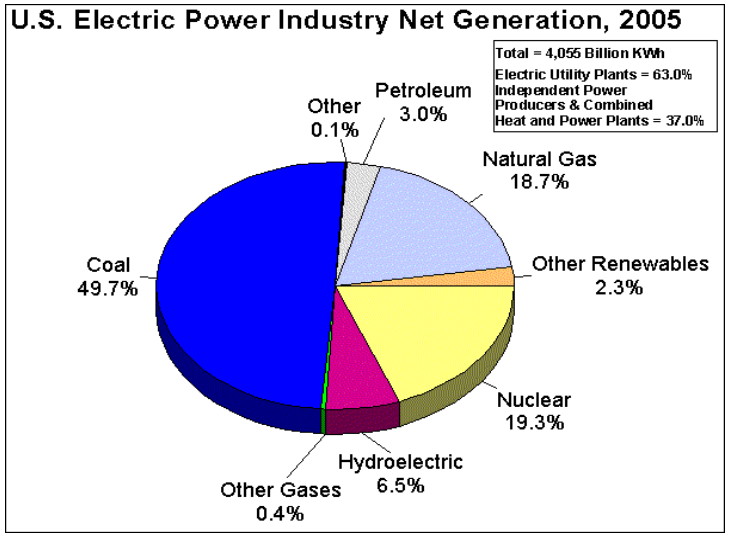
Source: **Cost and Performance Baseline for Fossil Energy Plants, National Energy Technology Laboratory, *April 10, 2007***

Current Generation Capacity

- **Scale of current generation fleet**
  - **970+ GW capacity, 16,000+ units**
  - **1500 >100 MW plants, 400+ are PC**
  - **Pre-combustion fleet very small**
    - ***Wabash River, IN***
    - ***Tampa, FL***
- **Oxyfuel is a possible path from PC to IGCC with CCS**
  - **No utility-scale currently**

US Generation Fleet Characteristics



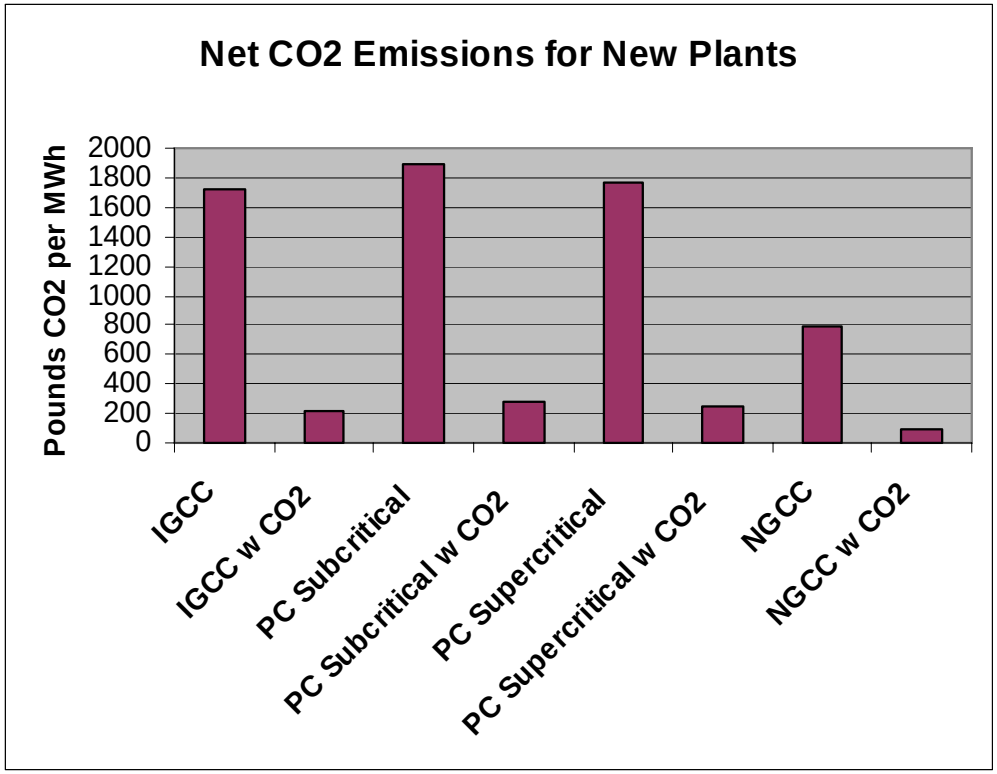


U.S. Electric Power Industry Consumption & Cost of Fossil Fuels for Electricity Generation, 2005

	Consumption	Cost (cents/million Btu)
COAL (thousand tons)	1,045,878	154
PETROLEUM (thousand barrels)	211,256	644
NATURAL GAS (million cubic feet)	6,486,761	821

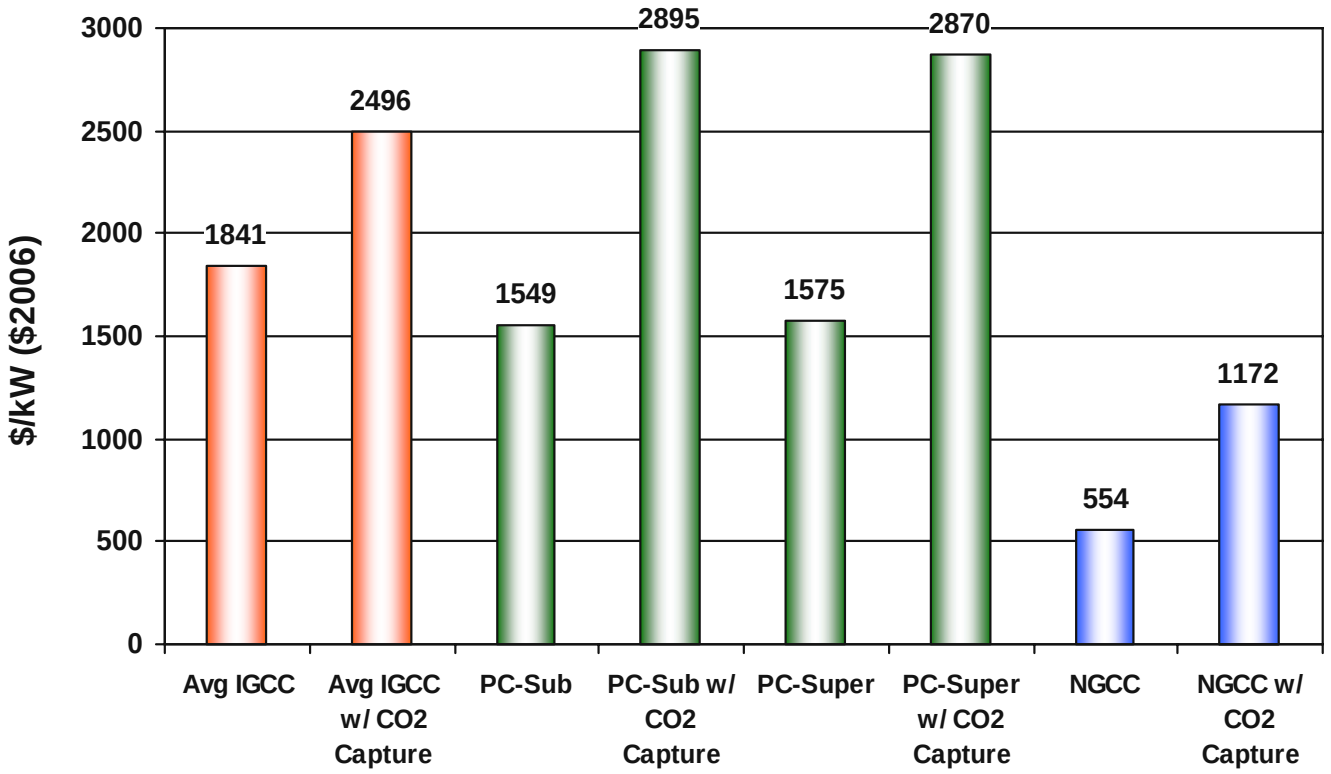
Source: EIA Electricity Website, http://www.eia.doe.gov/neic/brochure/elecinfocard.html

CO_2 Emission from Generation Plants



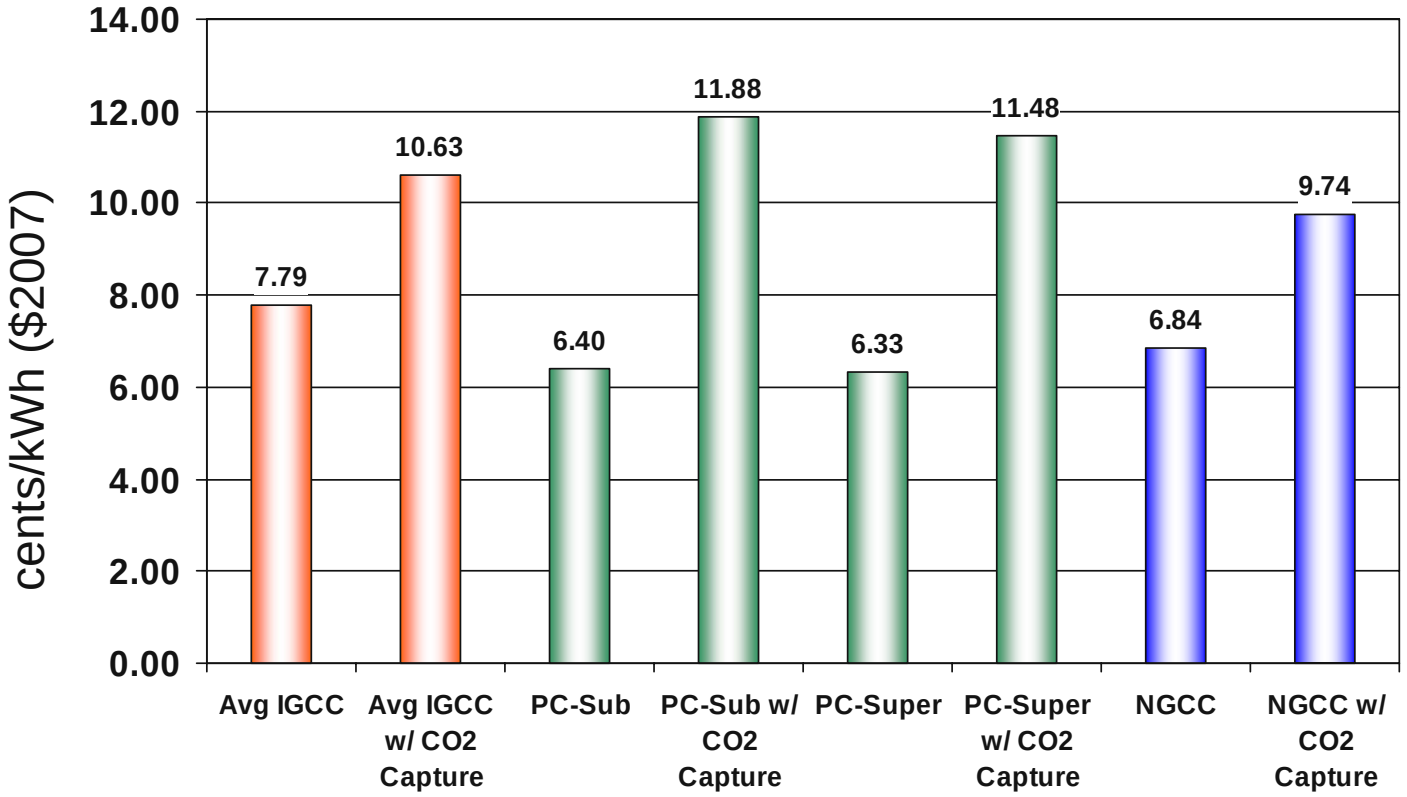
Data Source: Exhibit ES-2, Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity Final Report, May 2007, National Energy Technology Laboratory, DOE/NETL-2007/1281

Plant Cost Comparison



Source: Cost and Performance Baseline for Fossil Energy Plants, *May 15, 2007 Revised August 2007,* National Energy Technology Laboratory

Cost of Electricity Impacts



January 2007 Dollars, Coal cost $1.80/106Btu. Gas cost $6.75/106Btu

Source: Cost and Performance Baseline for Fossil Energy Plants, *May 15, 2007* *Revised August 2007,* National Energy Technology Laboratory

Retrofitting an Existing PC Plant

Conesville Unit #5 studied

Subcritical steam cycle

463 MW gross, 430 MW net

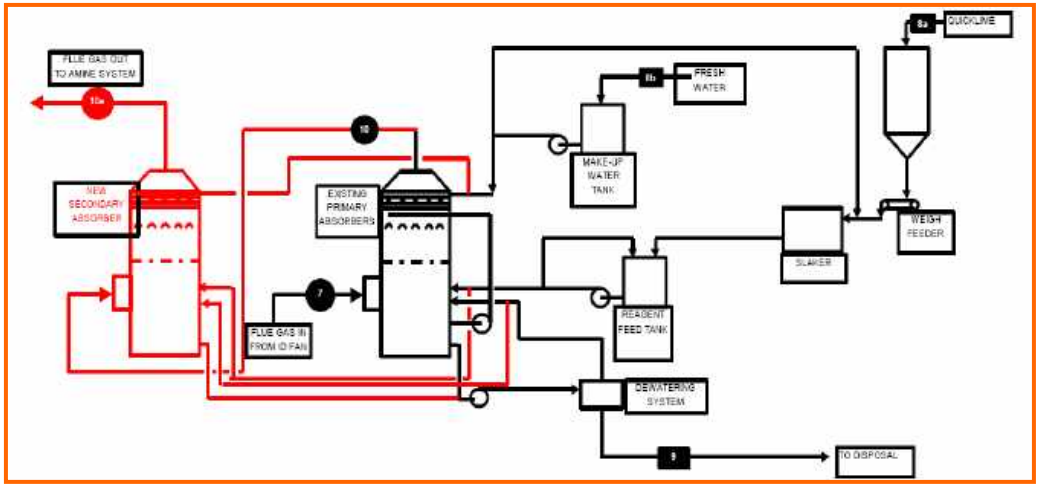
Bituminous coal

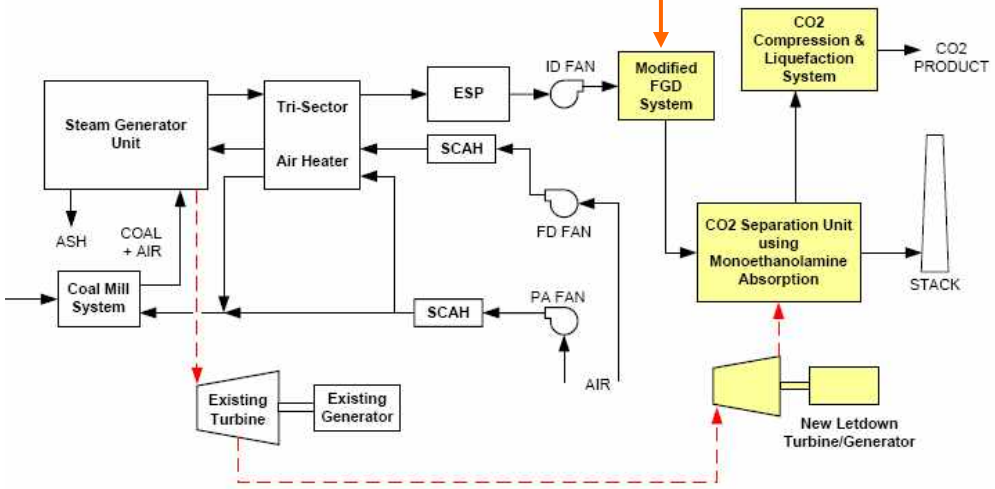
ESP and wet lime FGD

Source: CO2Capture From *Existing Coal*-Fired Power Plants,
Jared P. Ciferno -National Energy Technology Laboratory, *April 2007*

Schematic of Plant Modifications

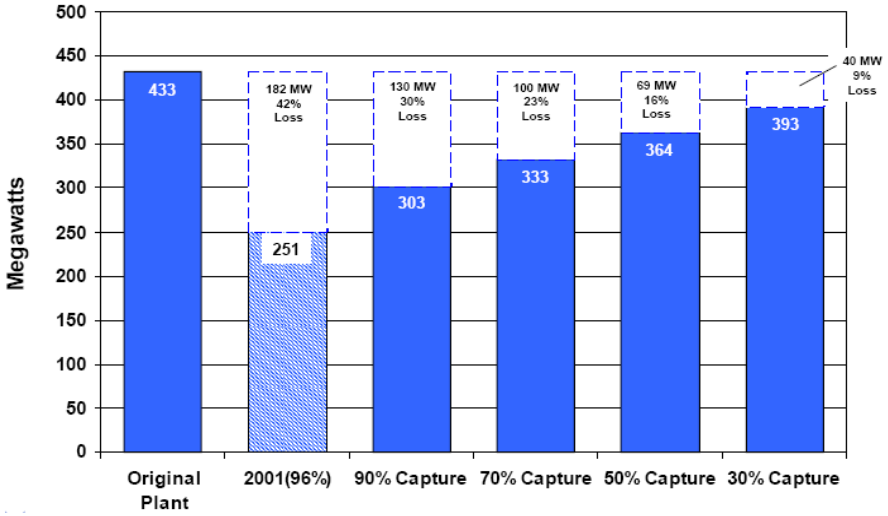
This type of FGD would be needed for most coals, retrofit or new



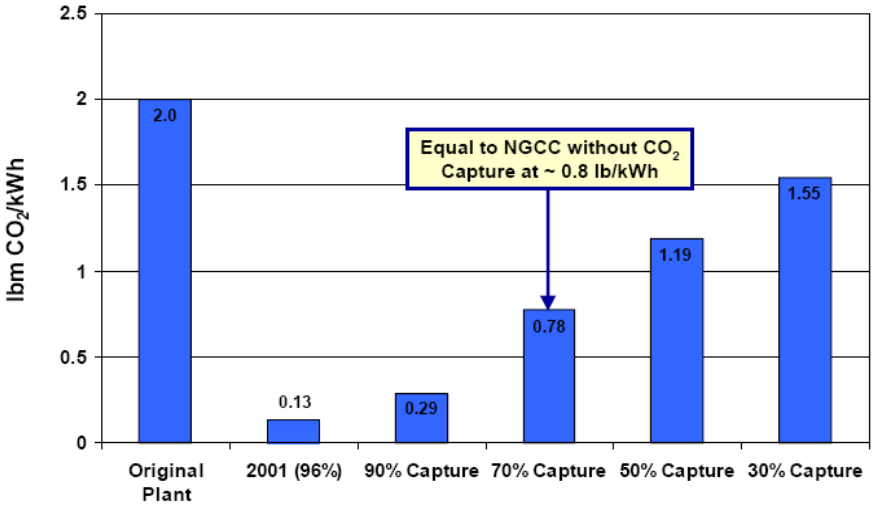


Source: CO_2Capture From *Existing Coal*-Fired Power Plants,
Jared P. Ciferno -National Energy Technology Laboratory, *April 2007*

Impacts on Net Output and CO_2 Emissions



Capital costs ranged from 417 $/kW at 30% capture to 1010 $/kW at 90% capture



Source: CO_2 Capture From *Existing Coal*-Fired Power Plants,
Jared P. Ciferno -National Energy Technology Laboratory,
April 2007

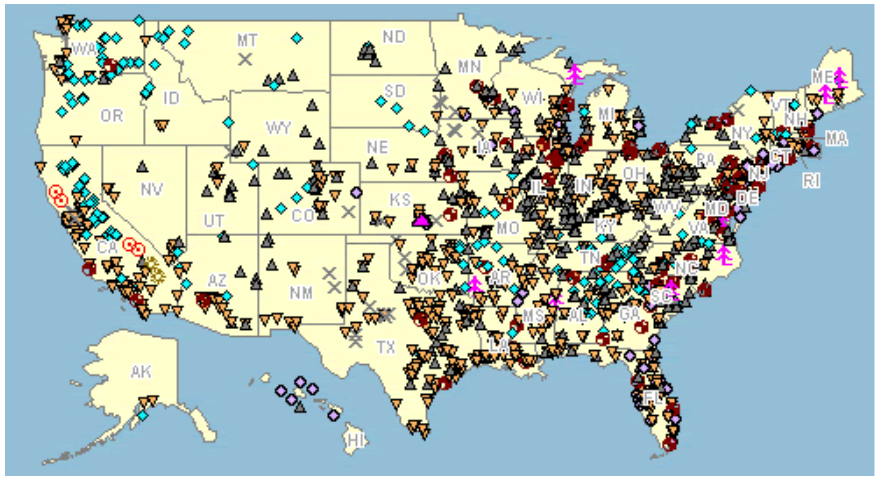
Fleet Impact of Retrofit CO_2 Capture

- **Roughly 250 MW of incremental capacity needed for every 1000 MW of capacity retrofitted at 70% carbon capture**
- **NETL and Argonne are beginning a joint study to better understand the grid-level implications of retrofitting significant levels of generation capacity with CO_2 capture**
  - **Midwest will be initial focus**
  - **Least-cost replacement power sources and impacts will be examined**

Issues Outside the Plant Gate

- **Pipeline costs, rights-of-ways, regulations**
- **Availability of adequate storage (sequestration) capacity**
- **Unsettled legal and regulatory issues**
  - **Who owns the CO_2**
    - ***Is the CO_2 a 'waste' or a product***
  - **Who owns the mineral rights and/or property rights at the sequestration site**
  - **What will the monitoring requirements be**
    - **How long will they run**
  - **If cap and trade, how will the trading regimen work**
  - **Who owns the short-term and long-term liabilities**

US Power Plants and CO_2 Pipelines



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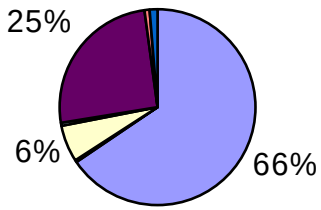
Top map from EIA website
Bottom map from “Prospects for Early Deployment of Power Plants Employing Carbon Capture”, Electric Utilities Environmental Conference Tucson, AZ January 22-25, 2002, National Energy Technology Laboratory,

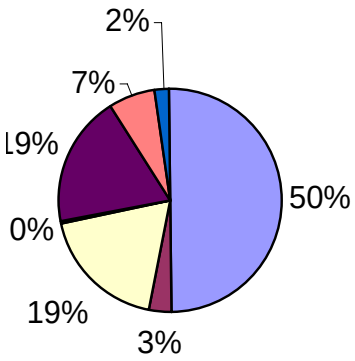
How does the Chicago FRB Region Compare to US

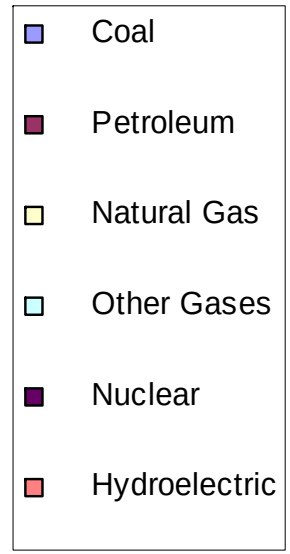
- States of Illinois, Indiana, Iowa, Michigan, and Wisconsin taken as surrogate for FRB region

Illinois, Indiana, Iowa, Michigan, Wisconsin

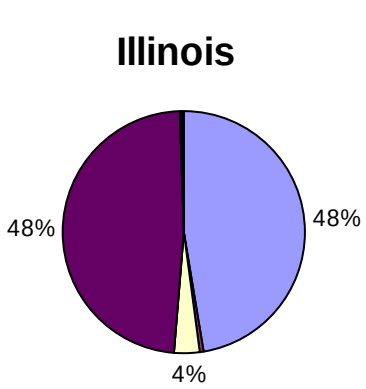


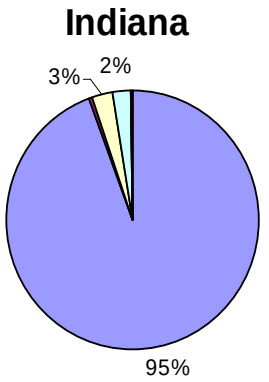
US Total

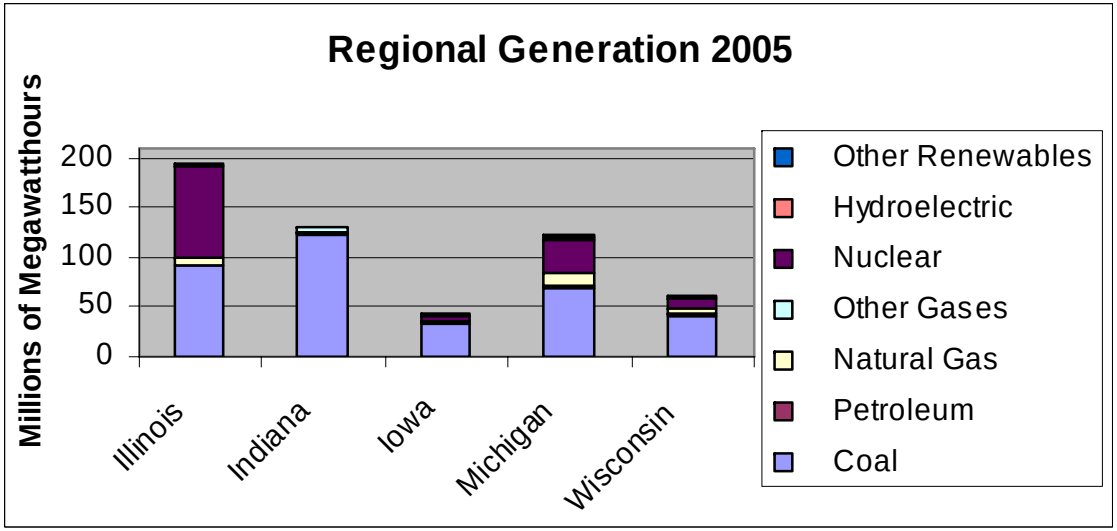




Regional Capacity and Generation







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