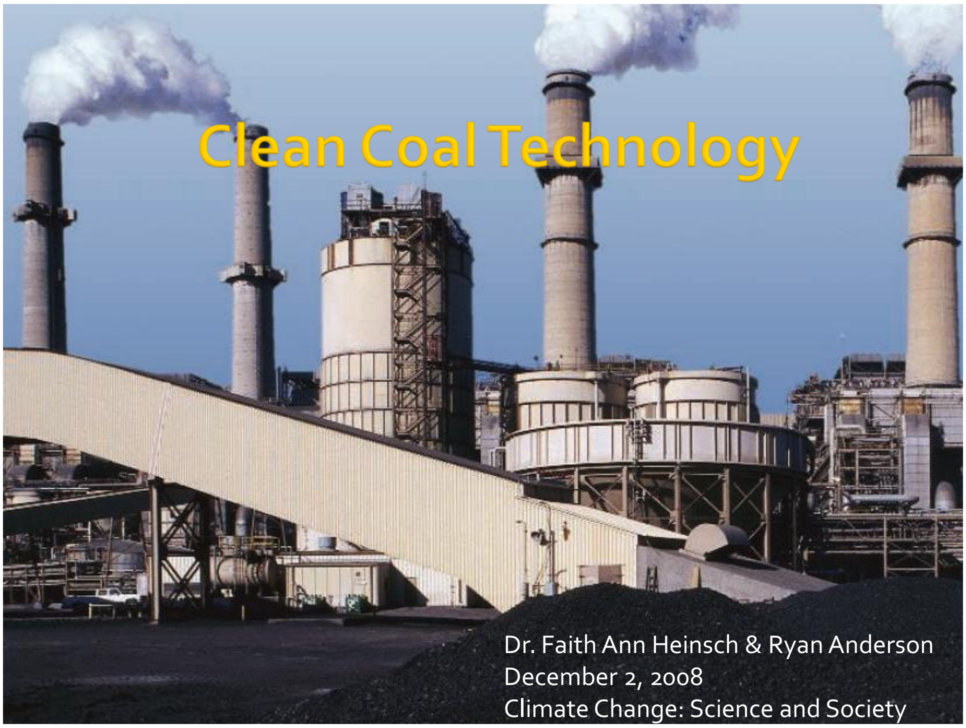


Fuel needed to run a 100-W light bulb for one year (876 kWh, or 3153.6 MJ)

(The fuel quantities below assume 100% conversion efficiency. As most power generation/distribution systems only achieve 30% - 35% efficiency, the actual quantity of fuel used to power a 100 W light bulb in your home will be about three times the quantity shown.)

- 166 kg of wood
- 117 to 210 kg (257 to 462 lb) of coal
- 73.34 kg (161.6 lb) of kerosene
- 78.8m^3, of natural gas
- 58 kg of Methane
- .006 kg (.014 lb) of uranium

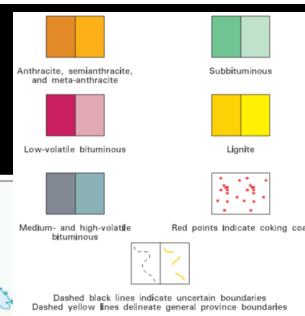
Types of Coal (in order of C Content)

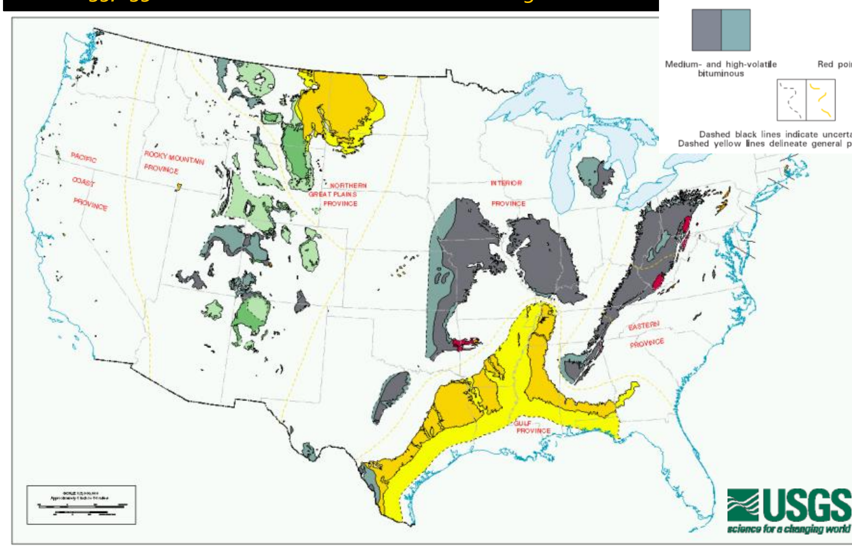
- Anthracite
  - Carbon content (86-98%); Heat value = 15,000 BTUs/lb
  - Most frequently associated with home heating
  - 7.3 billion tons of reserves in the U.S.; mostly in 11 northeastern PA counties
- Bituminous
  - Carbon content = 45-86%; Heat value = 10,500 – 15,500 BTUs/lb
  - Most frequently used to generate electricity and make coke for steel industry
  - Most plentiful form of coal in U.S.
- Sub-bituminous
  - Carbon content = 35-45%; Heat value = 8,300 – 13,000 BTUs/lb
  - Lower sulfur content than other types = cleaner burning
  - Reserves in half-dozen Western US states and Alaska
- Lignite
  - Carbon content = 25-35%; Heat value = 4,000-8,300 BTUs/lb
  - Mainly used for electric power generation
  - Sometimes called brown coal; Geologically young

U.S. Coal Regions

U.S. Proved recoverable coal reserves at the end of 2006

- 111,338 million tonnes of Bituminous & Anthracite
- 135,035 million tonnes of Sub-Bituminous & lignite





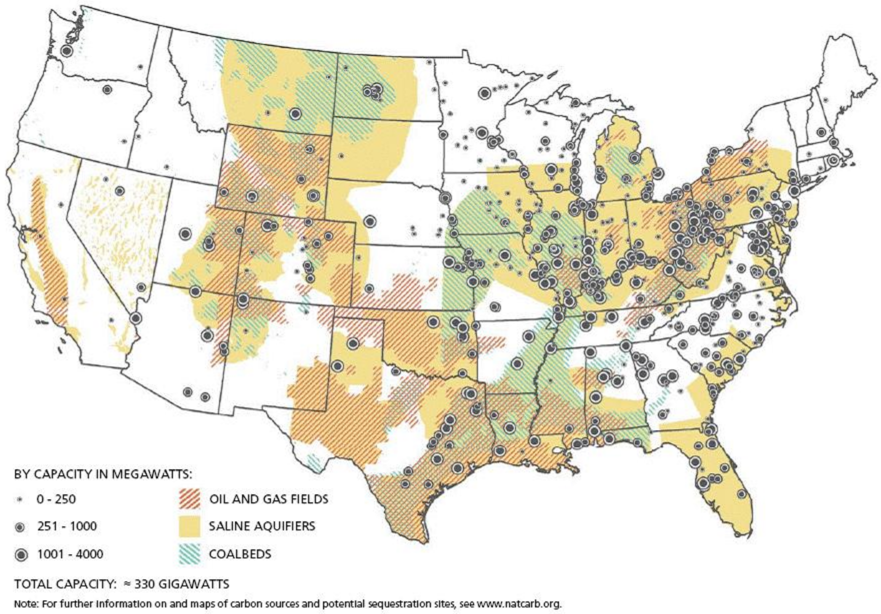
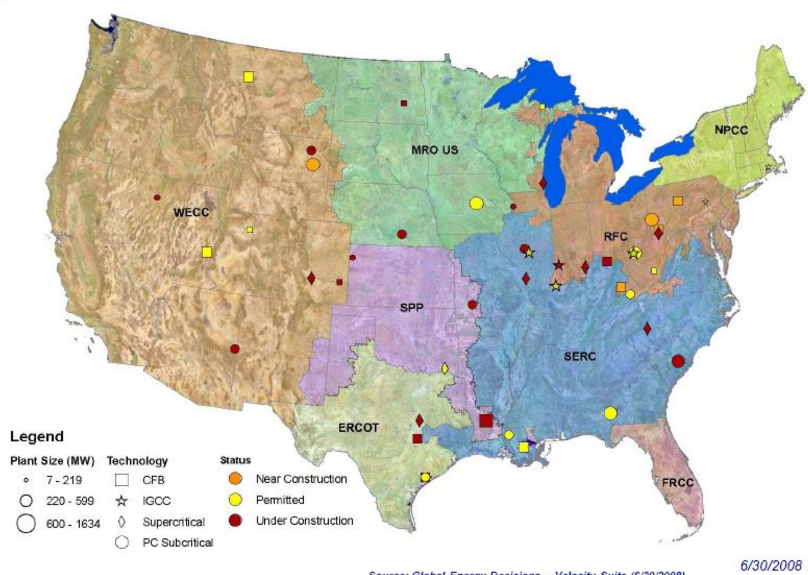


FIGURE 5-3. U.S. Coal-Fired Power Plants (2000) and Potential Sequestration Sites

Geographical Map by NERC Regions: Coal-Fired Plants

(Permitted, Near Construction, and Under Construction)

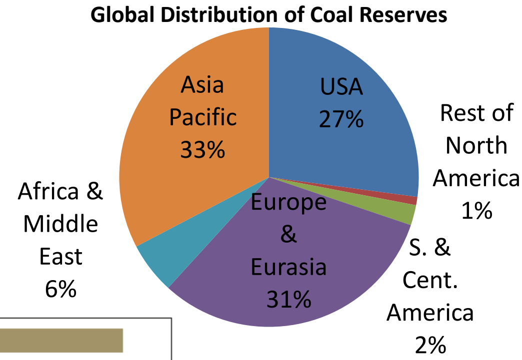
Figure 4

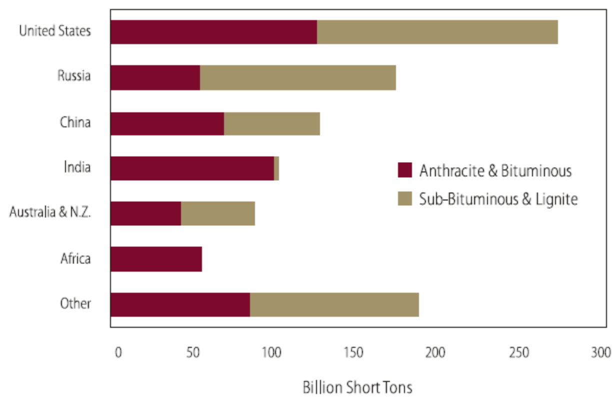


NETL 11

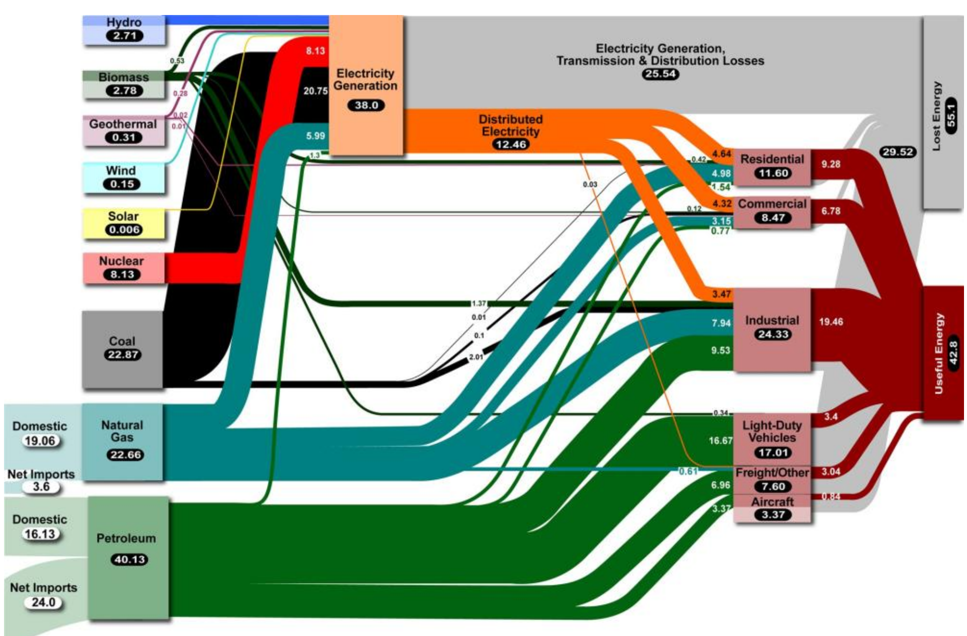
6/30/2008

Source: Global Energy Decisions – Velocity Suite (6/30/2008)

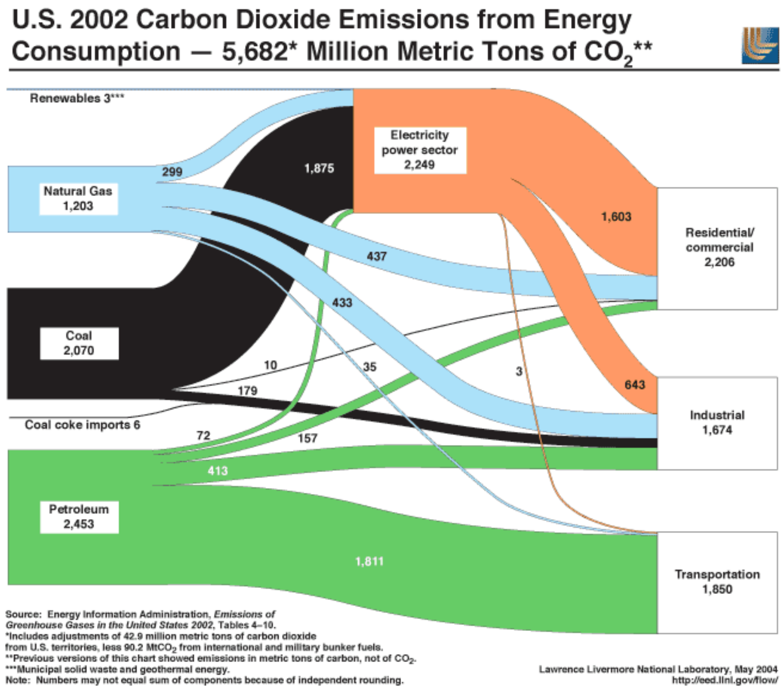


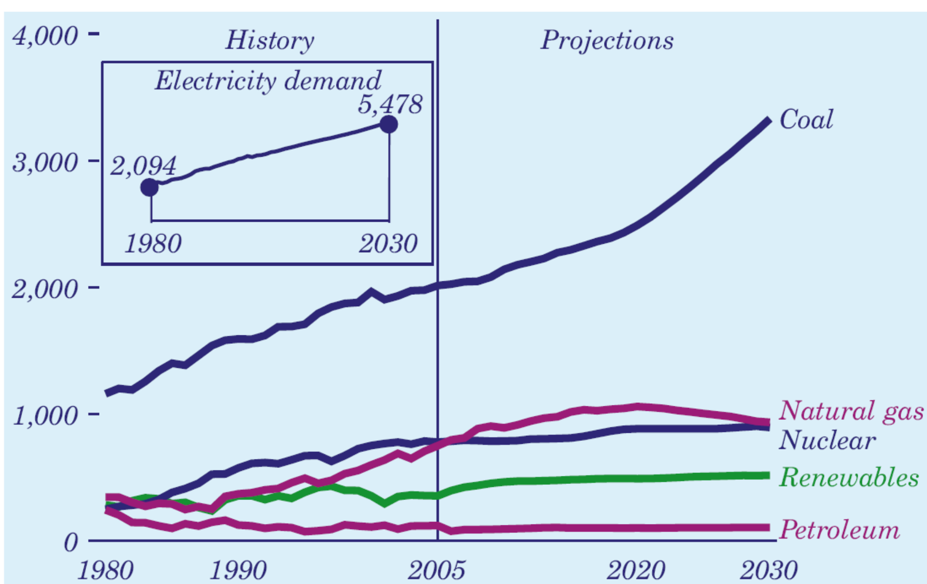


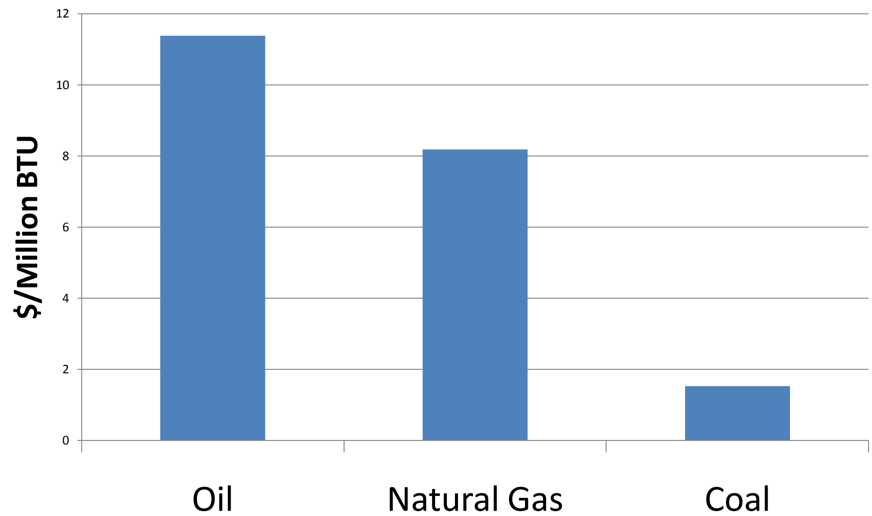
The Future of Coal, MIT, 2007



https://eed.llnl.gov/flow/images/LLNL_Energy_Chart300.jpg


U.S. 2002 Carbon Dioxide Emissions from Energy Consumption — 5,682* Million Metric Tons of CO_2**
Renewables 3***
Natural Gas 1,203
Coal 2,070
Coal coke imports 6
Petroleum 2,453
Electricity power sector 2,249
Residential/ commercial 2,206
Industrial 1,674
Transportation 1,850
299
1,875
1,603
437
433
10
35
3
179
643
72
157
413
1,811
Source: Energy Information Administration, Emissions of Greenhouse Gases in the United States 2002, Tables 4–10.
*Includes adjustments of 42.9 million metric tons of carbon dioxide from U.S. territories, less 90.2 $MtCO_2$ from international and military bunker fuels.
**Previous versions of this chart showed emissions in metric tons of carbon, not of CO_2.
***Municipal solid waste and geothermal energy.
Note: Numbers may not equal sum of components because of independent rounding.
Lawrence Livermore National Laboratory, May 2004
http://eed.llnl.gov/flow/


4,000
3,000
2,000
1,000
0
History
Projections
Electricity demand
5,478
2,094
1980
2030
Coal
Natural gas
Nuclear
Renewables
Petroleum
1980
1990
2005
2020
2030



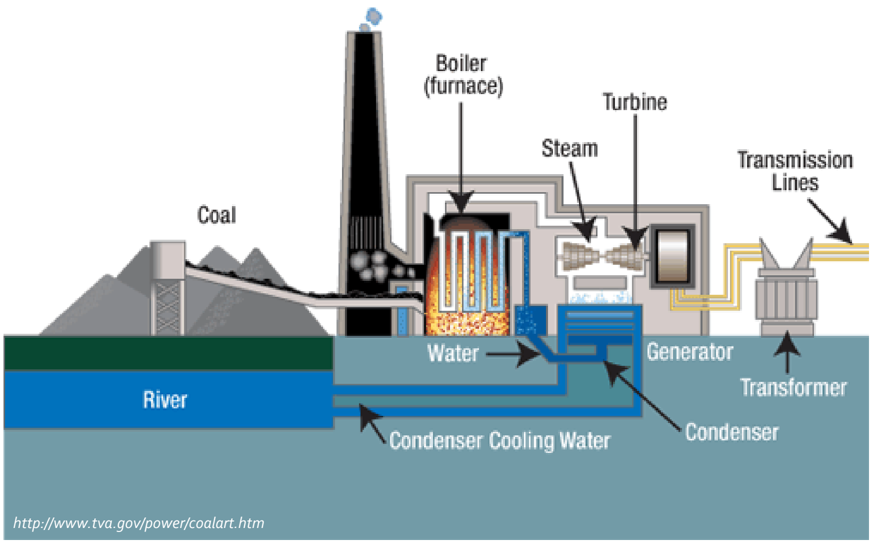
The Future of Coal, MIT, 2007

But…

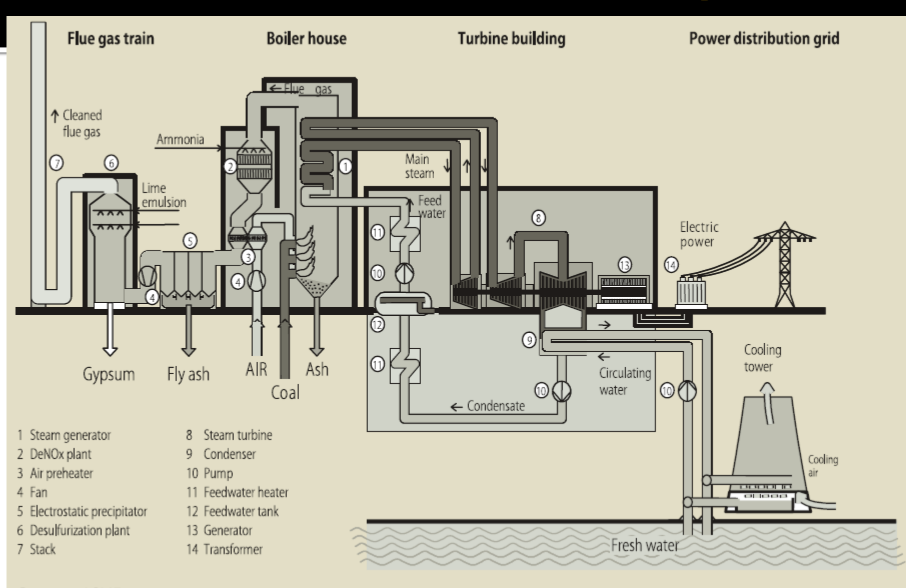
- Carbon intensity of Coal is Very High ($92g\ CO_2/MJ$)
- One typical plant = 3 million tons/year CO_2
- US produces 1.5 billion tons/year from coal burning power plants
- If 60% of the US CO_2 from coal were captured for sequestration, it would be **20 million barrels a day**

The Future of Coal, MIT, 2007

Sub-critical Coal-Fired Power Plant



Sub-critical Pulverized Coal System



Generating Efficiency

$$\frac{\text{Thermal Energy in Fuel}}{\text{Electricity Produced}}$$

Influenced By:

- Fuel Source
- Plant Design
- Environment

Lower efficiency = More coal burned per unit electricity produced.

Coal Types

	Higher Heating Value (kJ/kg)	Moisture Content (%wt)	Carbon Content (%wt)	Ash Content (%wt)	Sulfur Content (%wt)	Minemouth Coal Cost (2005 $/ton)
Anthracite	30,000[1] – 31,500[2]	2.1[2]–12[1]	72[1]–87[2]	6.9[2]–11[1]	0.5[2]–0.7[1]	44–87[5]
Pittsburgh # 8	30,800[3] – 31,000[4]	1.1[4]–5.13[3]	73[4]–74[3]	7.2[3]–13[4]	2.1[3]–2.3[4]	45–55[5]
Illinois #6	25,400[3]– 25,600[4]	8.0[4] –13[3]	60[4]–61[3]	11[3]–14[4]	3.3[3]–4.4[4]	32–39[5]
Chinese Coal	19,300– 25,300[6]	3.3–23[6]	48–61[6]	28–33[6]	0.4–3.7[6]	N/A
Indian Coal	13,000– 21,000[7]	4[7]–15[6]	30–50[8]	30–50[7]	0.2–0.7[7]	14–19[7]
WY Powder River Basin	19,400[3]– 19,600[4]	28[4] –30[3]	48[3]–49[4]	5.3[3]–6.3[4]	0.37[3] –0.45[4]	6–17[5]
Texas Lignite	14,500[9]– 18,300[10]	30[10]–34[9]	38[9]–44[10]	9[10]–14[9]	0.6[10]–1.5[9]	14[11]– 15[12]
ND Lignite	14,000[3]– 17,300[4]	32[4]–33[3]	35[3]–45[4]	6.6[4]–16[3]	0.54[4]–1.6[3]	9[12]

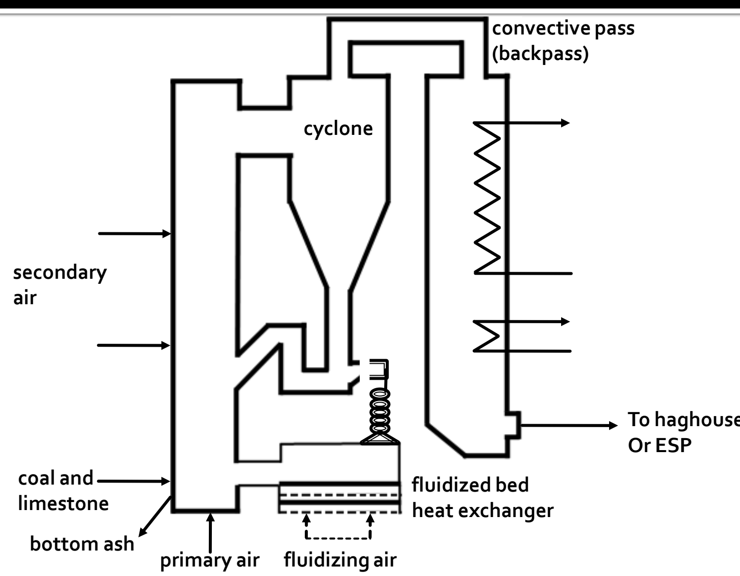
The Future of Coal, MIT, 2007

Plant Design

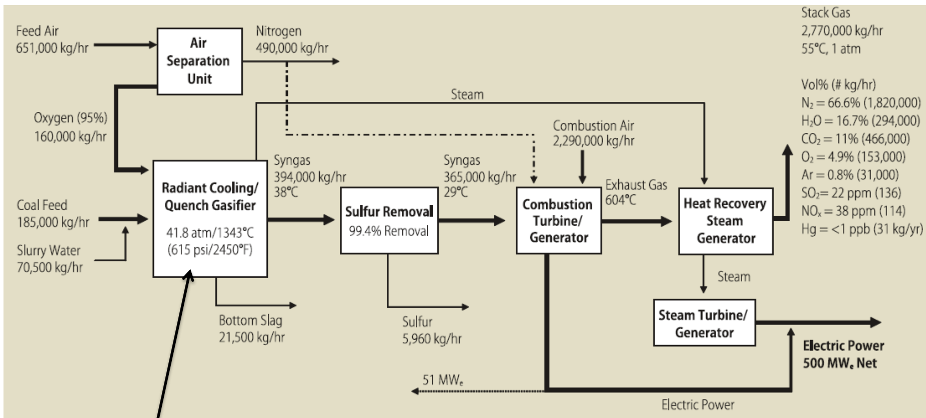
	Pressure	Temperature	Efficiency
Subcritical	<22.0 Mpa (16.5)	550C (540C)	33%-37% (34%)
Supercritical	>22.0 Mpa (24.3)	>550C (565C)	37%-40% (38%)
Ultra-Supercritical	Up to 32 Mpa	610C	43.30%

The Future of Coal, MIT, 2007

Fluidized Bed Combustion



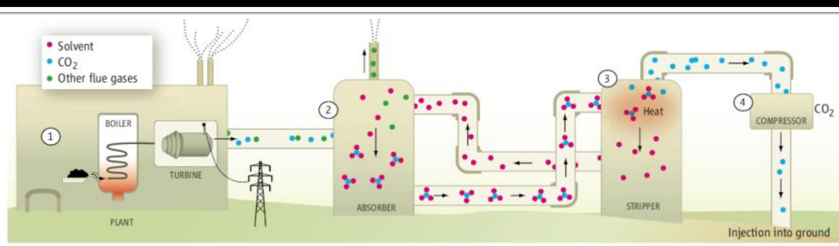
Gasification (IGCC)



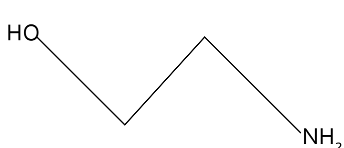
Coal + H_2O → H_2 + CO

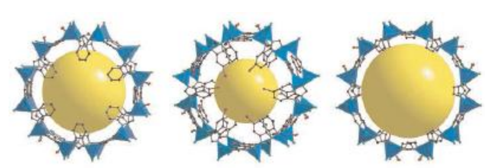
The Future of Coal, MIT, 2007

Post – Combustion CO_2 Capture



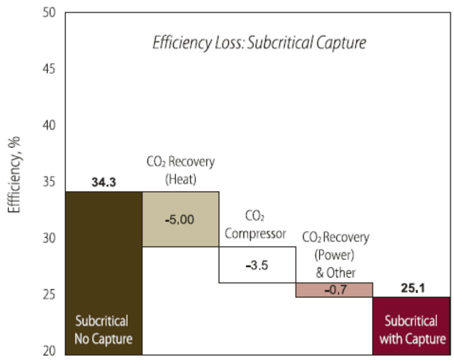
*Kintisch Science **317**:184-186*



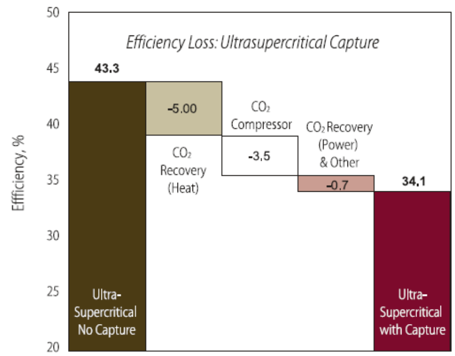


*Banerjee et al. Science **319**:939-943*

Energy Cost of CO_2 Capture



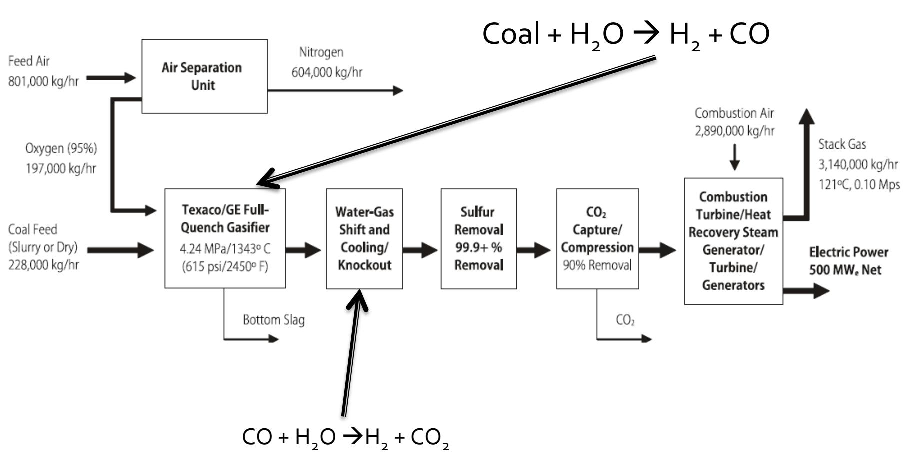
73 % of original efficiency



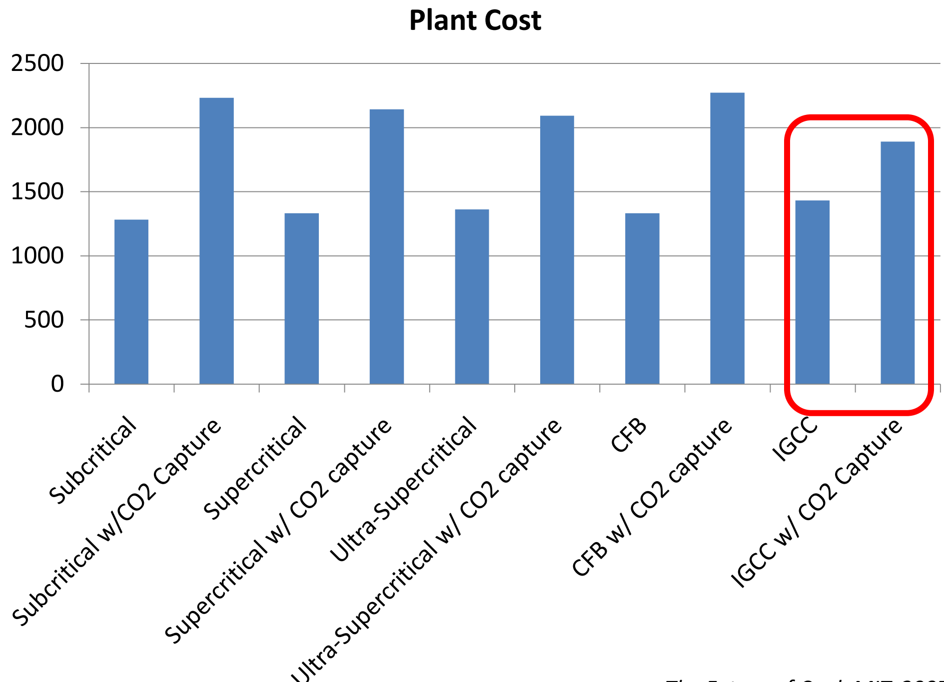
79% of original efficiency

The Future of Coal, MIT, 2007

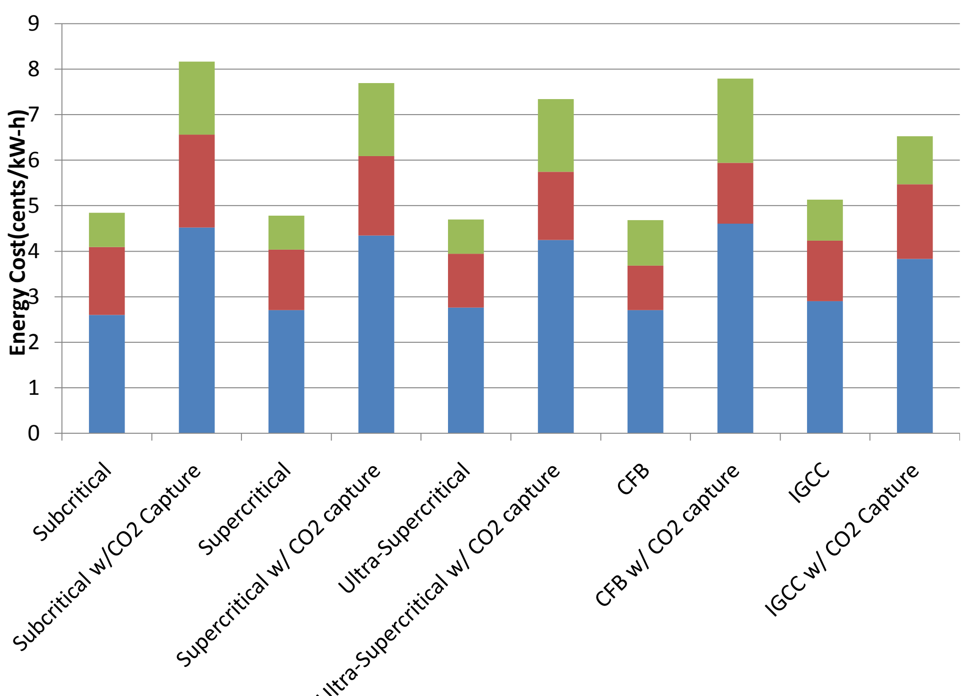
IGCC Pre-Combustion CO_2 Capture



The Future of Coal, MIT, 2007



The Future of Coal, MIT, 2007

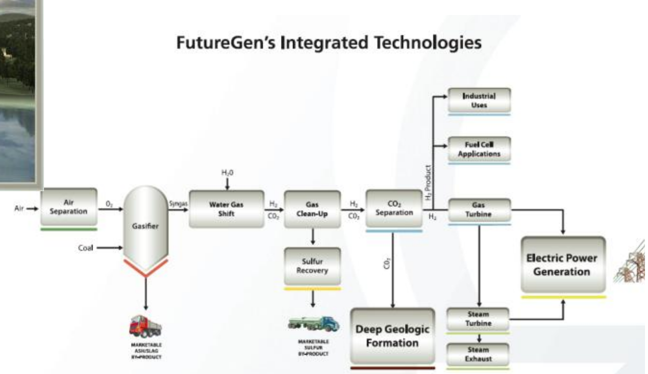


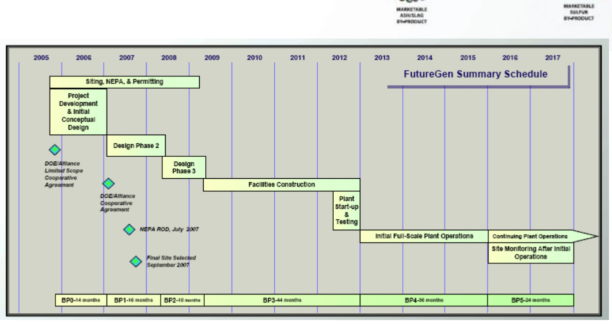
The Future of Coal, MIT, 2007

Carbon Cost at Which Capture Becomes Competitive

- Subcritical : $41.3/ton
- Supercritical: $40.4/ton
- Ultra-supercritical: $41.4/ton
- Fluidized bed combustion: $39.7/ton
- IGCC:$19.3/ton

The Future of Coal, MIT, 2007





NATURE|Vol 451|14 February 2008 NEWS

Natural gas back in favour with US power companies

Electric utilities in the United States are quietly shifting their sights from coal to natural gas as the lower-risk fuel while they wait for the nation's carbon policy to be decided.

But given the major up-front costs and a lack of certainty about long-term economics owing to impending climate regulation, neither coal nor nuclear power look terribly attractive from an economic standpoint at the moment, says Revis James, a researcher at the Electric Power

Carbon burial buried

The US Department of Energy has pulled out of a flagship project to build the first 'clean' coal-fired power plant in the United States, a move that will kill the project unless supporters can rouse Congress on its behalf.

The FutureGen project was intended to demonstrate technologies for capturing and burying carbon dioxide from coal-fuelled power plants; it was doubled to $1.8 billion in recent years, and last week the department pulled out of the deal after failing to reach a new funding agreement with its private partner, the FutureGen Industrial Alliance, which consists of more than a dozen energy companies. The energy department had been slated to pick up three-quarters of the bill for the 275-megawatt plant.

"I'm disappointed because

Soaring costs mean the FutureGen power plant may never be built.

says Howard Herzog, a carbon-sequestration expert at the

"It's hard for me to see this not delaying overall progress."

In the project's place, the administration says it will help companies add carbon-capture and -sequestration equipment to new or existing coal plants that have at least 300 megawatts of capacity. Officials say this will ultimately save taxpayers money while allowing the technology to spread more quickly.

The abrupt decision has infuriated

nature Vol 449|6 September 2007

BUSINESS

King coal constrained

Sustained high oil prices won't be enough to make coal liquefaction economically viable without large-scale public investment. Katharine Sanderson reports.

Turning dirty coal into a clean-burning liquid fuel remains something of a challenge for the energy industry. As scientists heard last month at the annual meeting of the American Chemical Society in Boston, Massa-

Economic isolation forced South Africa to refine the coal technology used today at Secunda, Mpumalanga.

Spremberg, Germany

- First test plant for CCS
- 30 MW plant, cost $70m Euros
  - U.S. Average = 976 MW
- CO2 separated, condensed, transported to gas field, forced 1,000 m underground
- Larger demonstration project slated for 2015

Conclusions

- World power demands are expected to rise 60% by 2030.
- Coal is a huge part of global energy use and is likely to remain important
- Technology exists to remove 90% of CO_2, 99% of sulfur dioxide, 99% of particulates, and 90% No_x
- Costs of implementing these technologies are large and possibly prohibitive