The Future of Coal

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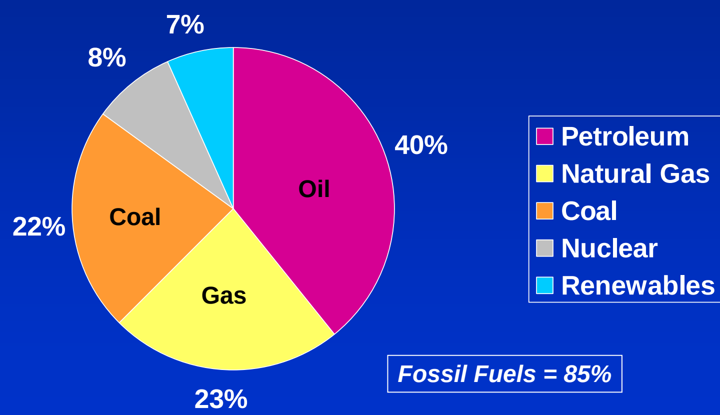
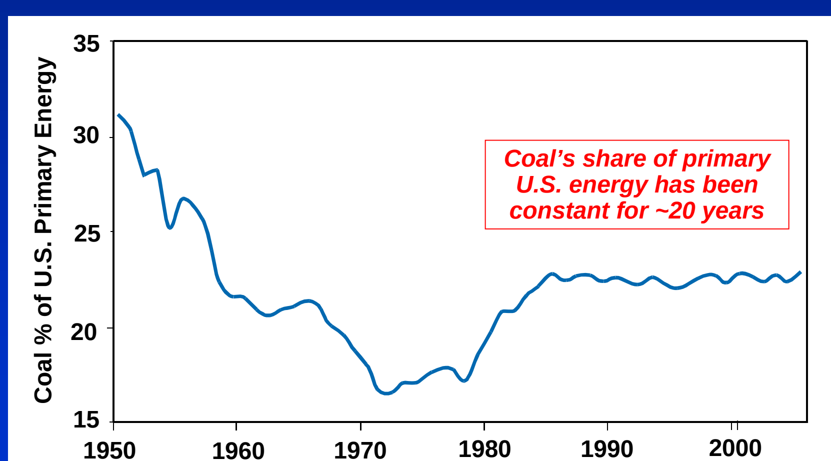
Coal use in the U.S.

Primary U.S. Energy Supplies, 2007



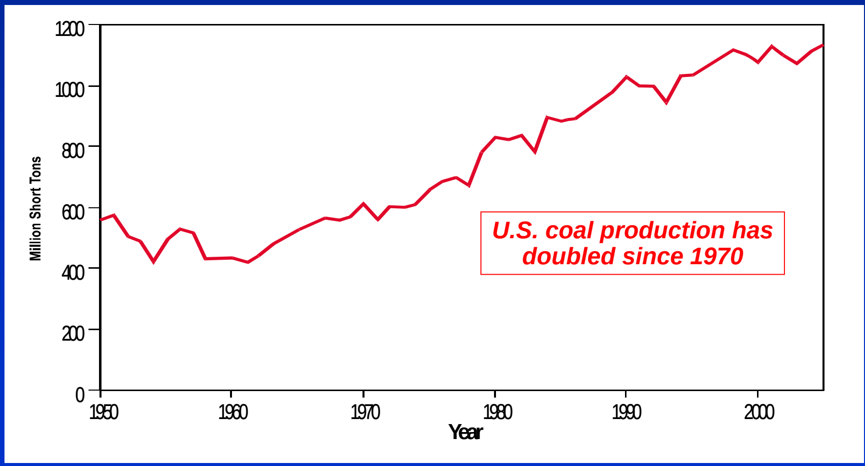
Fossil Fuels = 85%

Coal Use as a Percentage of U.S. Primary Energy Consumption



Source: NRC, 2007

U.S. Coal Production, 1950-2005



Source: NRC, 2007

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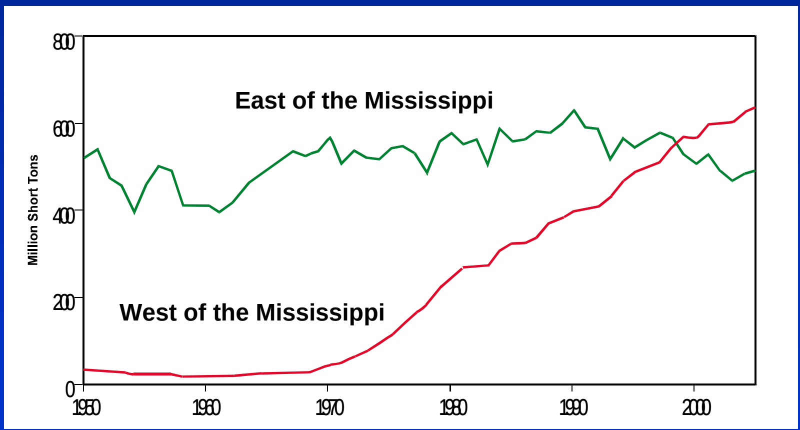
U.S. Coal Production by Region, 1950-2005



Source: NRC, 2007

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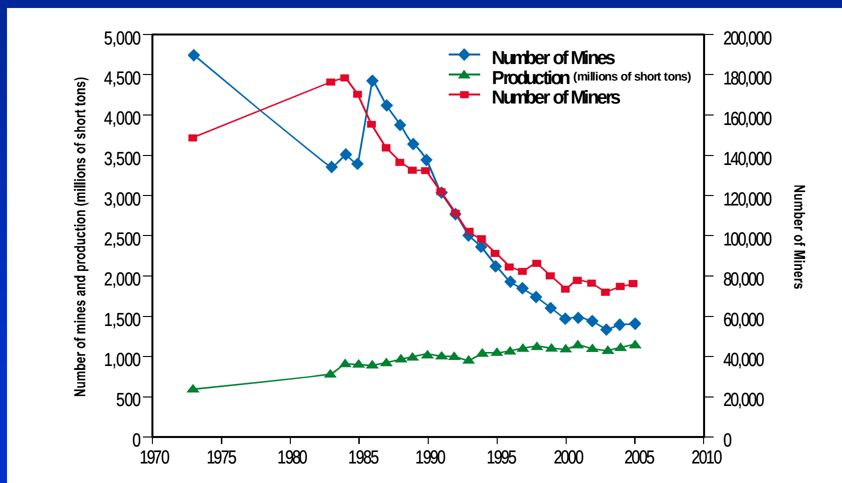
Trends for U.S. Coal Production, Mines and Employment



Source: NRC, 2007

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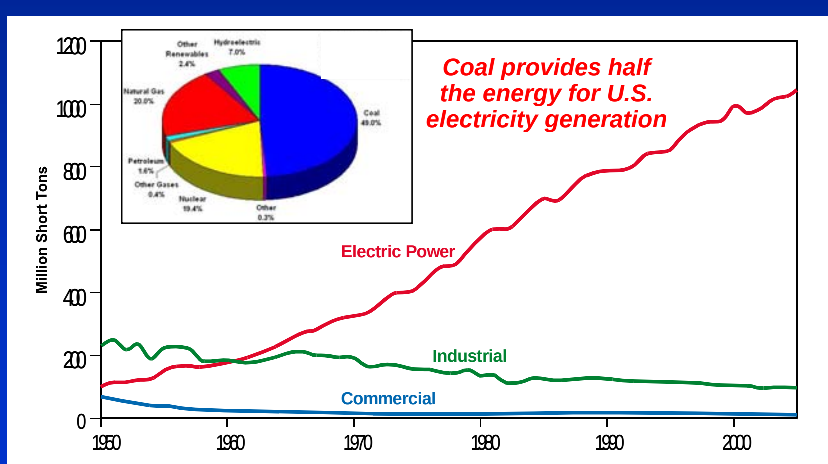
U.S. Coal Use by Sector



Source: NRC, 2007

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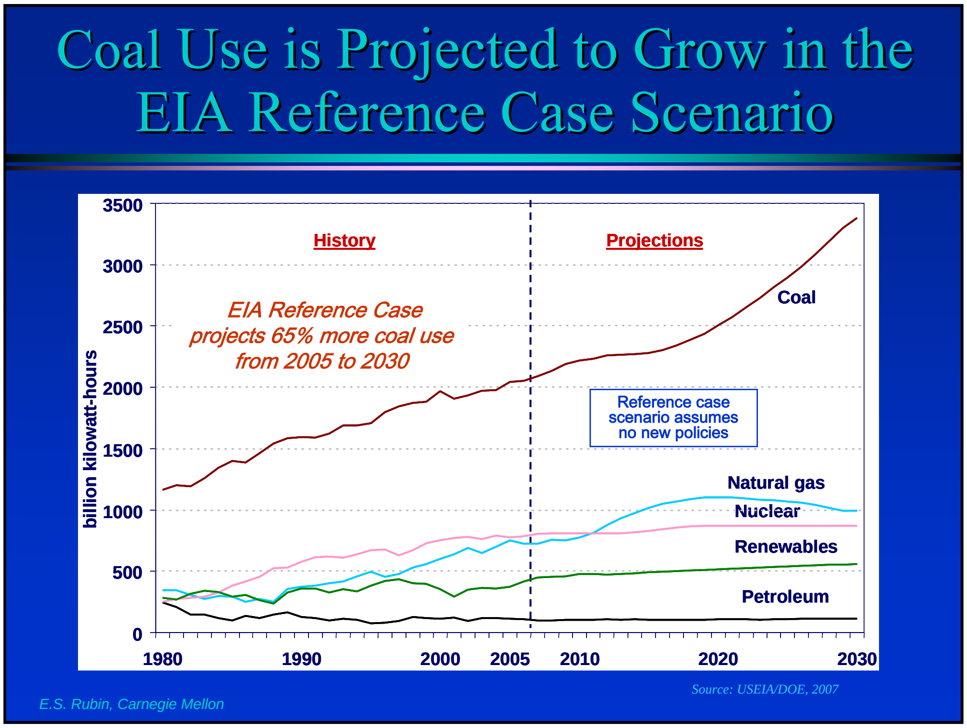
Coal Use is Projected to Grow in the EIA Reference Case Scenario
History
Projections
EIA Reference Case projects 65% more coal use from 2005 to 2030
Reference case scenario assumes no new policies
billion kilowatt-hours
3500
3000
2500
2000
1500
1000
500
0
1980
1990
2000
2005
2010
2020
2030
Coal
Natural gas
Nuclear
Renewables
Petroleum
Source: USEIA/DOE, 2007
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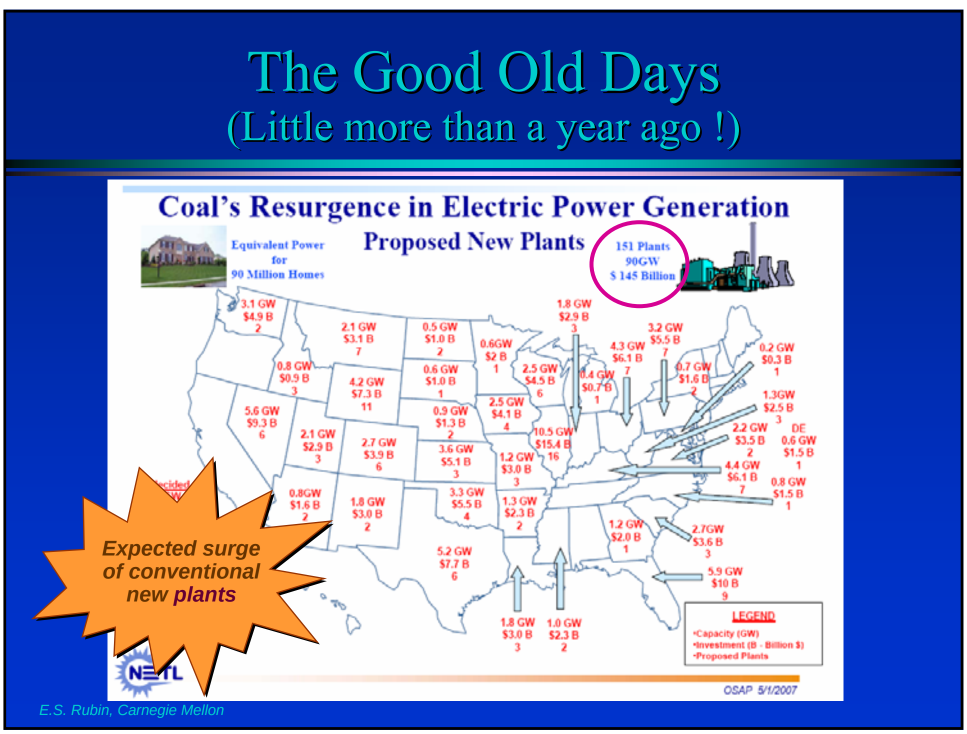
The Good Old Days
(Little more than a year ago !)
Coal's Resurgence in Electric Power Generation
Equivalent Power for 90 Million Homes
Proposed New Plants
151 Plants 90GW $ 145 Billion
Expected surge of conventional new plants
LEGEND
•Capacity (GW)
•Investment (B - Billion $)
•Proposed Plants
OSAP 5/1/2007
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But what a difference a year can make

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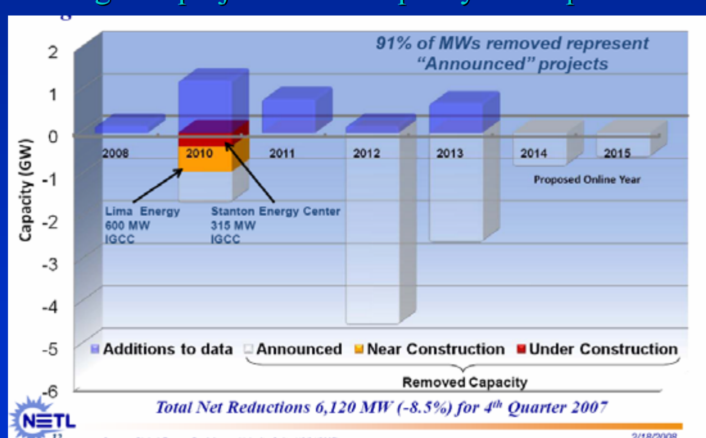
Many projects have been cancelled due to escalating costs and other factors

Changes in projected U.S. capacity in 4th quarter 2007



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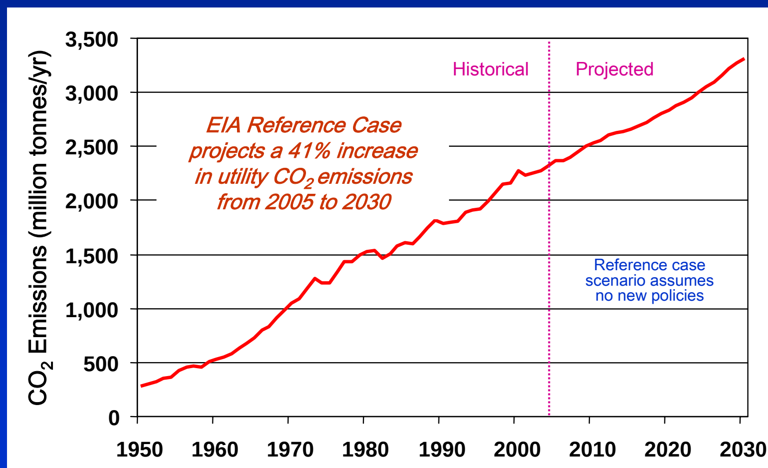
U.S. Power Sector CO_2 Emissions

(historical trend with EIA 2007 Reference Case projections to 2030)



Source: USEIA/DOE, 2007

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IPCC says prompt action needed to avoid serious climate impacts

Fourth IPCC assessment indicates potentially serious impacts for more that a 2ºC rise in average global temperature

Global avg. temperature increase over pre-industrial	Atmospheric stabilization $CO_{2\text{-equiv}}$ (ppm) *(2005=375 ppm)*	Required change in global CO_2 emissions from 2000 to 2050
2.0 – 2.4º C	445 – 490	**-85% to -50%**
2.8 – 3.2 ºC	535 – 590	-30% to +5%
4.0 – 4.9 ºC	710 – 855	+25% to +85%

Source: IPCC, 2007

Lower stabilization levels require earlier action to reduce emissions

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Opposition to conventional coal has become more vocal

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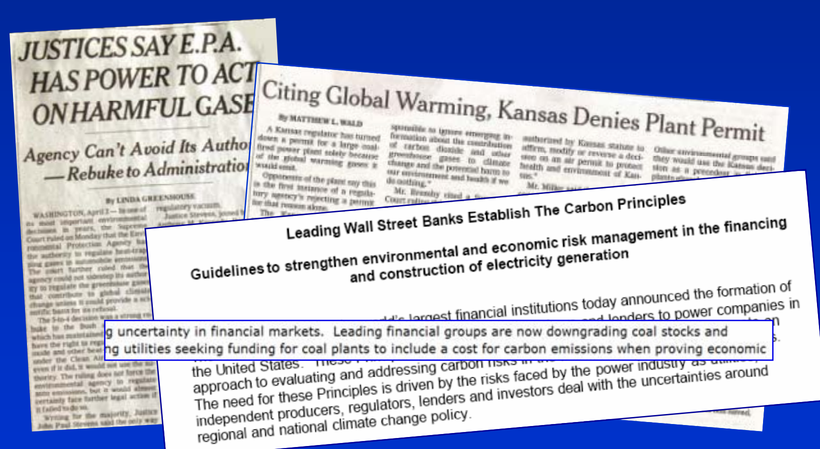
Calls for carbon controls are mounting



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Current U.S. Outlook

- I believe it will be very difficult—and perhaps impossible—to undertake new large coal-fired power projects that do not include provisions for CO_2 capture and storage (CCS)
- *CCS is critical to the future of coal*

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The potential role of CCS

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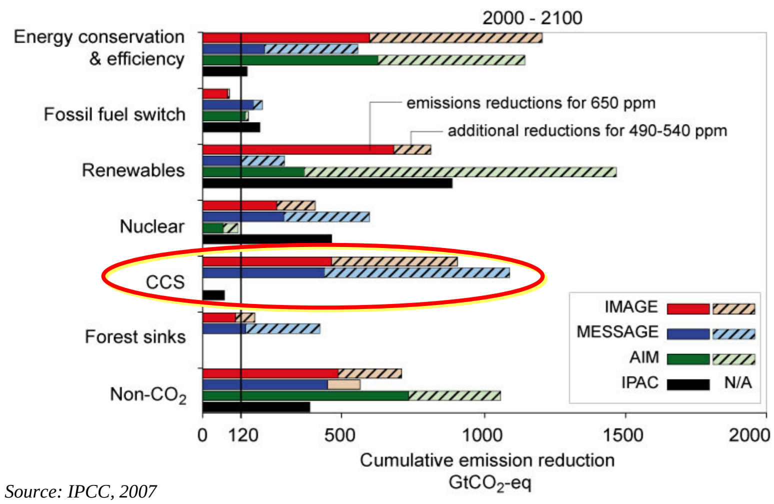
IPCC Assessment of Cost-Effective Global Energy Strategies



Source: IPCC, 2007

Status of CCS Technology

- Pre- and post-combustion CO_2 capture technologies are commercial and widely used in industrial processes; also at several gas-fired and coal-fired power plants, at small scale (~50 MW); CO_2 capture efficiencies are typically 85-90%. Oxyfuel capture still in development.
- CO_2 pipelines are a mature technology
- Geological sequestration is commercial on a limited basis, mainly for enhanced oil recovery (EOR); several projects now in operation at scale of ~1 Mt CO_2 /yr
- Integration of CO_2 capture, transport and geological sequestration has been demonstrated in several industrial applications—but not yet at an electric power plant, and not yet in the U.S.

Examples of Post-Combustion CO_2 Capture at Coal-Fired Plants

(Source: ABB Lummus)

Shady Point Power Plant

(Panama, Oklahoma, USA)

(Source: IEA GHG)

Warrior Run Power Plant

(Cumberland, Maryland, USA)

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Examples of Pre-Combustion CO_2 Capture Systems

(Source: Chevron-Texaco)

Petcoke Gasification to Produce H_2

(Coffeyville, Kansas, USA)

(Source: Dakota Gasification

Coal Gasification to Produce SNG

(Beulah, North Dakota, USA)

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Oxy-Combustion Pilot Plant

Vattenfall Schwarze Pumpe Station (Germany)

Source: Vattenfall, 2008

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CO_2 Pipelines for Enhanced Oil Recovery

Source: USDOE/Battelle

Source: NRDC

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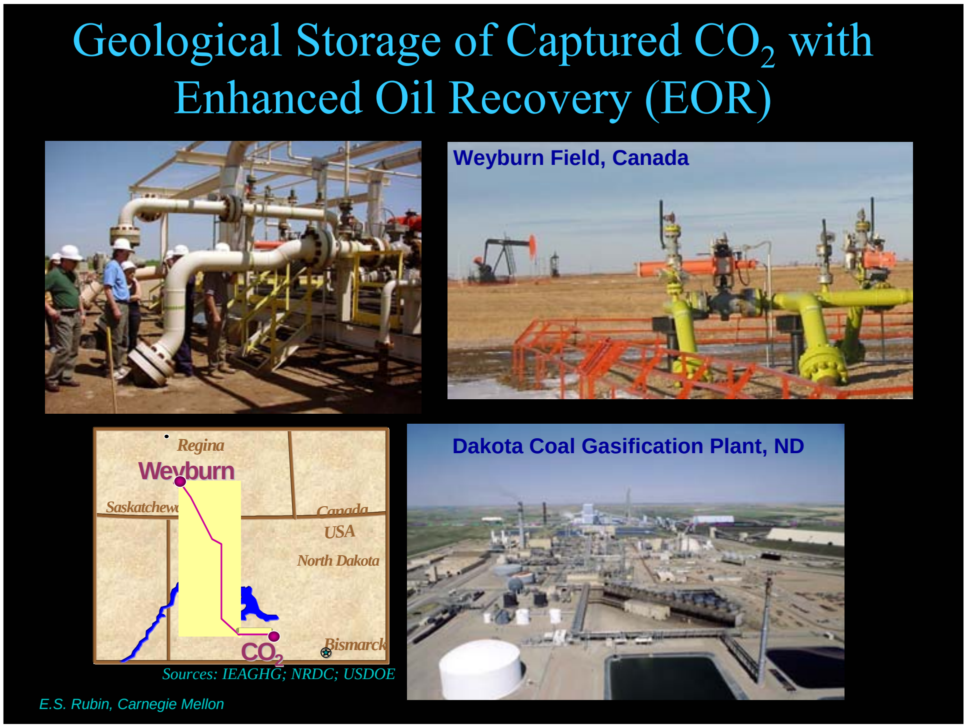
Geological Storage of Captured CO2 with Enhanced Oil Recovery (EOR)
Weyburn Field, Canada
Regina
Weyburn
Saskatchew
Canada
USA
North Dakota
CO2
Bismarck
Dakota Coal Gasification Plant, ND
Sources: IEAGHG; NRDC; USDOE
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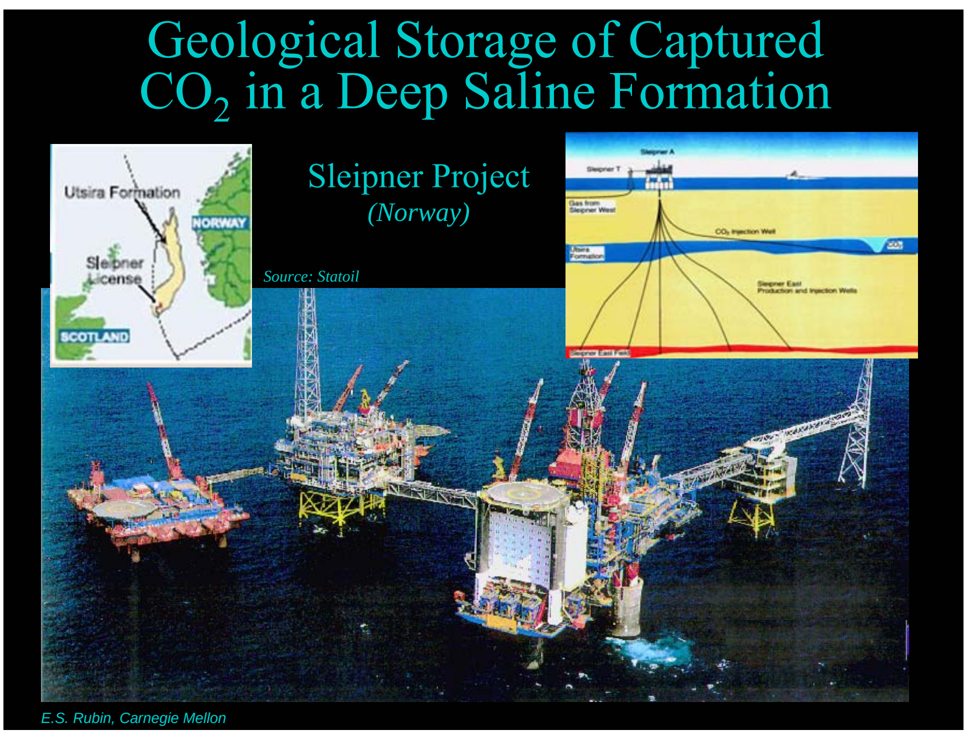
Geological Storage of Captured CO2 in a Deep Saline Formation
Utsira Formation
NORWAY
Sleipner License
SCOTLAND
Sleipner Project
(Norway)
Source: Statoil
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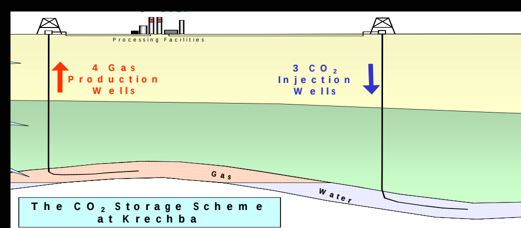
Geological Storage of Captured CO_2 in a Deep Saline Formation

In Salah /Krechba *(Algeria)*

Source: BP



CCS Activity Worldwide

- Approximately 65 CCS projects currently planned or proposed in different parts of the world

(here is a sample)

Project Name	Location	Feedstock	Size MW	Capture Process	CO2 Fate	Start-up
Total Lacq	France	Oil	35	Oxy	Seq	2008
Vattenfall Oxyfuel	Germany	Coal	30/300/1000	Oxy	Undecided	2008
AEP Alstom Mountaineer	USA	Coal	30	Post	Seq	2008
Callide-A Oxy Fuel	Australia	Coal	30	Oxy	Seq	2009
GreenGen	China	Coal	250/800	Pre	Seq	2009
Williston	USA	Coal	450	Post	EOR	2009-15
NZEC	China	Coal	Undecided	Undecided	Seq	2010
E.ON Killingholme	UK	Coal	450	Pre	Seq	2011
AEP Alstom Northeastern	USA	Coal	200	Post	EOR	2011
Sargas Husnes	Norway	Coal	400	Post	EOR	2011
Scottish& So Ferrybridge	UK	Coal	500	Post	Seq	2011-2012
Naturkraft Kårstø	Norway	Gas	420	Post	Undecided	2011-2012
ZeroGen	Australia	Coal	100	Pre	Seq	2012
WA Parish	USA	Coal	125	Post	EOR	2012
Coastal Energy	UK	Coal/Petcoke	800	Pre	EOR	2012
UAE Project	UAE	Gas	420	Pre	EOR	2012
Appalachian Power	USA	Coal	629	Pre	Undecided	2012
Wallula Energy	USA	Coal	600-700	Pre	Seq	2013
RWE npower Tilbury	UK	Coal	1600	Post	Seq	2013
Tenaska	USA	Coal	600	Post	EOR	2014
BP Rio Tinto Kwinana	Australia	Coal	500	Pre	Seq	2014
UK CCS project	UK	Coal	300-400	Post	Seq	2014
Statoil Mongstad	Norway	Gas	630 CHP	Post	Seq	2014
RWE Zero CO2	Germany	Coal	450	Pre	Seq	2015
Monash Energy	Australia	Coal	60 k bpd	Pre	Seq	2016
Powerfuel Hatfield	UK	Coal	900	Pre	EOR	Undecided
ZENG Worsham-Steed	USA	Gas	70	Oxy	EOR	Undecided
Polygen Project	Canada	Coal/Petcoke	300	Pre	Undecided	Undecided
ZENG Risavika	Norway	Gas	50-70	Oxy	Undecided	Undecided
E.ON Karlshamn	Sweden	Oil	5	Post	Undecided	Undecided

Source: MIT, 2008

Is CCS ready for prime time ?

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Barriers to CCS Deployment

- No current policy mandate or strong incentives for large reductions in CO_2 emissions
- High cost of current technology
- Lack of a regulatory framework for licensing large-scale geological sequestration projects
- Unresolved legal issues related to sub-surface property rights and long-term liabilities
- Uncertainties about public acceptance
- Lack of experience in utility applications

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Several anticipated CCS projects were recently cancelled

CCS Project Cancellations, 2007–2008

Project	Location	Technology	CCS	Developers
FutureGen	USA	275 MW coal IGCC	Pre-/ Aquifer	FG Alliance, DOE
Clean Coal	Canada	450 MW lignite PC	Oxy-/ Geol.	SaskPower + others
Peterhead	UK	475 MW gas IGCC	Pre-/ EOR	BP, SSE
Halten	Norway	860 MW gas NGCC	Post-/ EOR	Statoil, Shell
Carson *	USA	500 MW petcoke IGCC	Pre-/ EOR	BP, Edison Mission

**Project cancelled at this location; a similar project is now planned elsewhere.*

No certainty that currently proposed projects will be fully funded and completed as planned

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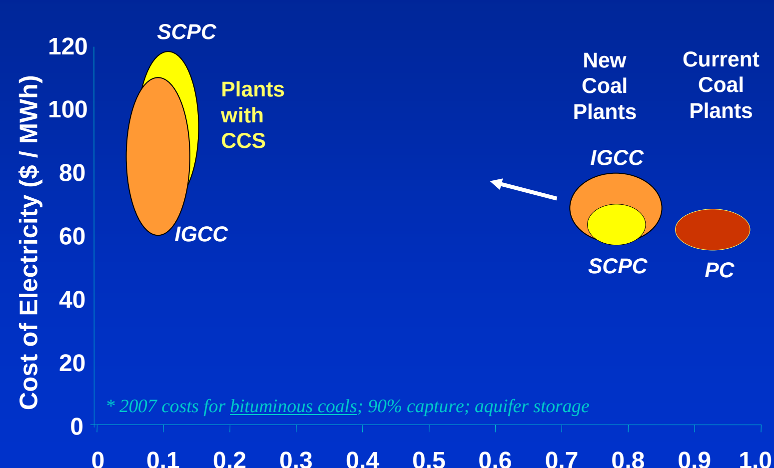
Cost of New Power Plants with and without CCS



CO_2 Emission Rate (tonnes / MWh)

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Typical Cost of CO_2 Avoided

(Relative to a SCPC reference plant w/o CCS)

Levelized cost in 2007 US$ per tonne CO_2 avoided
(based on current technology w/ bituminous coals)

Power Plant System *(relative to SCPC plant without CCS)*	New Supercritical Pulverized Coal Plant	New Integrated Gasification Combined Cycle Plant
Deep aquifer storage	**~ \$70 /tCO_2**	**~ \$50 /tCO_2**
Enhanced oil recovery (EOR) storage	Cost reduced by ~ \$20–30 /tCO_2	

Source: Based on IPCC, 2005; Rubin et al, 2007; DOE, 2007

Different choices of reference plant without CCS will yield different avoidance costs

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What's needed to move ahead ?

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Everyone Agrees: Multiple large-scale projects are needed …

- To establish the reliability and true cost of CCS in utility applications at commercial scale, for:
  - Alternative technologies (PC, IGCC; new, retrofit)
  - Different coal types (bituminous, sub-bit, lignite)
  - Different geological settings
- To help resolve the legal and regulatory issues of large-scale geological sequestration
- To begin reducing future costs of CCS (via learning-by-doing together with sustained R&D)

~10 full-scale projects are needed

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Many Government Programs and Public-Private Partnerships Working on CCS

Some of the government programs supporting CCS:

- Australia
- Canada
- China
- European Union
- United Kingdom
- United States

Funding levels and scale of projects vary widely

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What Does a Full-Scale CCS Project Cost?

- Total incremental cost of building and operating CCS at a 400 MW_{net} coal-based power plant (PC or IGCC)—including cost of the “energy penalty” (replacement power), plus costs of CO_2 transport and deep aquifer storage (for 5 years):

≈ 0.7 to 1.0 billion USD
per project

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As Best I Can Tell …

- … None of the national programs now in place have firm commitments (“money in the bank”) for this level of support for multiple CCS projects at a coal-based power plants
- Only a small number of programs come close to the commitment needed for large-scale projects; in most cases, certainty of full funding is still years away, hence, uncertain

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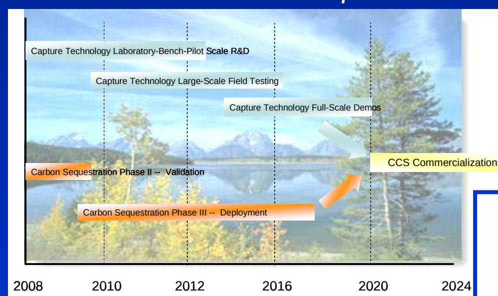
CCS Technology RD&D Timelines

DOE/NETL Roadmap



Current CCS roadmaps envision commercialization by ~2020

This will require significant new funding commitments, plus resolution of regulatory and legal issues related to CCS

EPRI Roadmap

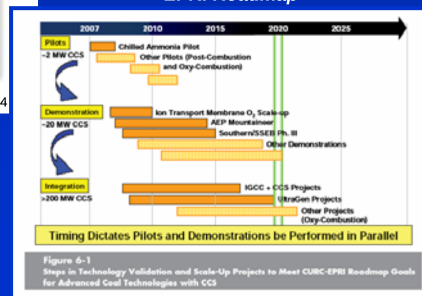


Figure 6-1
Steps in Technology Validation and Scale-Up Projects to Meet CURC-EPRI Roadmap Goals for Advanced Coal Technologies with CCS

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Options for Accelerating CCS

Carrots:

- Expand traditional "technology policy" options (e.g., tax credits, loans, subsidies, etc.)
  (as in Energy Policy Act, USDOE CCTI program, etc.)
- Establish a CCS Trust Fund with fees used to pay full added cost of early CCS projects
  (as per Pew Center, EPA ACT committee, Boucher bill)

Sticks:

- Adopt sufficiently stringency cap-and-trade program w/ CCS bonus allowances and/or a tech. fund (e.g., from auction of allowances)
  (as in Lieberman-Warner bill and others)
- Set new regulations requiring CCS (e.g., generator CO_2 performance standards)
  (as in California CO_2 stds, NSPS for major pollutants, etc.)

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One Recent U.S. Proposal

- In addition to current DOE programs for CCS, the Boucher Bill would:
  - Establish a non-governmental corporation to support commercial-scale demonstrations of CCS for new or retrofit applications for a range of coals and regions
  - Raise ~$10 billion over 10 years **(~$1B/yr)**, via fees on all fossil-based electricity delivered by distribution utilities to retail consumers ($0.43/MWh for coal)

Program would require approval of qualified industry organizations and State regulatory agencies; Revised bill is still pending Congressional action

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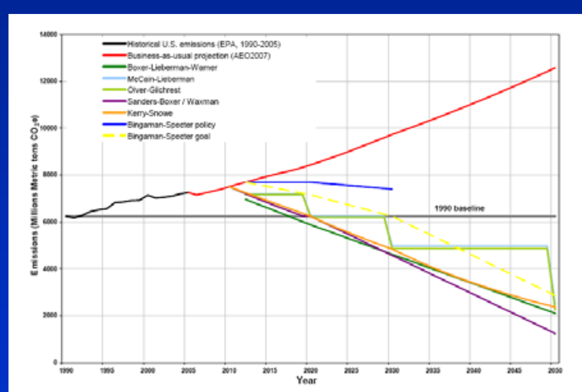
Recent Cap & Trade Bills Included Incentives for CCS



Source: Pew Center on Global Climate Change, 2008

But <u>no agreement on policy</u> in 110th Congress; Action on climate change will take time

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Will CCS Come to the Rescue ?

- We are very likely to see successful demonstrations of CCS technology; but …
- Widespread deployment will not occur without a sufficiently strong policy driver

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Thank You

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