Clean Coal and Carbon Sequestration
National Congress of American Indians
Panel on Carbon Trading and Sequestration
October 22, 2008

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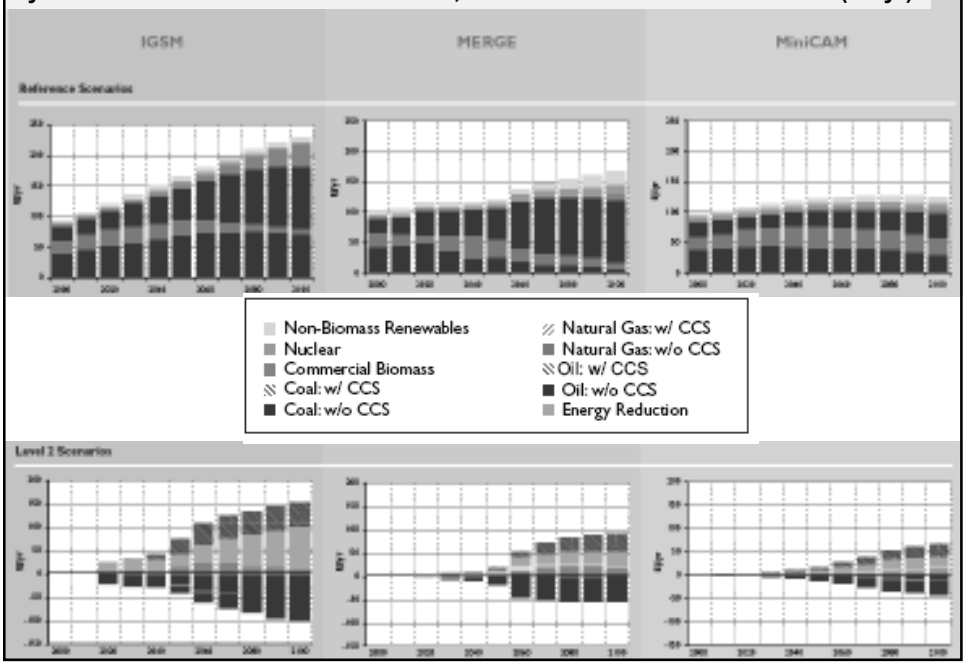
Changes in U.S. Primary Energy Consumption by Fuel Across Stabilization Scenarios, Relative to Reference Scenarios (EJ/yr).



What is Clean Coal

- **Air Emissions**
  - **SO2**
  - **NOx**
  - **Particulate**
  - **Hg**
- **CO2 Management**
- **By-Product Utilization**
- **Water Use and Discharge**
- **Plant Efficiency**
- **Reliability/Availability**
- **Capital and Product Cost**
  - **(power and fuels production)**

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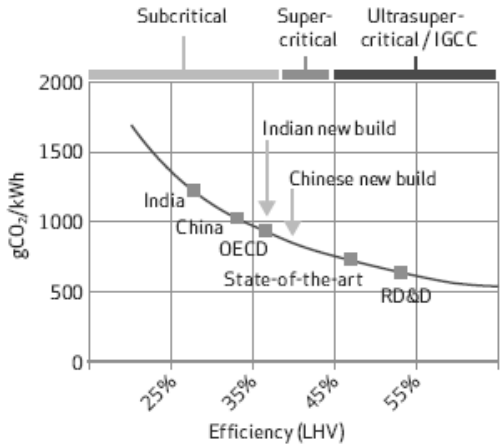
Figure 5: CO_2 Emissions from Coal-fired Power Plants

■ Fleet averages

■ Single plants

Source: IEA 2006c



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Supply Side Options Available for IRP

Options	Option Size MW	Capital Costs $/kW	Includes a 10% Process Contingency	Capacity Factor %	2008 Fuel Price $/mmBtu	Heatrate Btu/kWhr	Levelized Capital $/MWhr	2008 O&M $/MWhr	2030 Fuel $/MWhr	Total** $/MWhr
COAL										
Pulverized Coal	200	2,845	no	85%	2.20	8,990	33	8	30	91
IGCC***	200	3,357	yes	85%	2.20	8,221	55	12	18	85
Pulverized Coal with CO_2 removal	200	3,648	no	85%	2.20	10,909	52	10	24	86
IGCC*** with CO_2 removal	200	4,072	yes	85%	2.20	10,000	67	14	24	105
NATURAL GAS (all combustion turbine technologies are derated for an elevation of 4,500 feet)										
Aeroderivative	40	1,814	no	95%	7.80	9,980	58	15	69	171
Combustion Turbine	81	963	no	95%	7.80	9,395	63	10	95	168
Combustion Turbine	158	943	no	95%	7.80	10,297	69	10	72	132
Combined Cycle (1x1)	248	1,002	no	40%	7.80	7,114	34	7	50	91
Combined Cycle (2x1)	496	936	no	40%	7.80	7,175	32	7	50	90
OTHER										
Nuclear	200	2,858	yes	85%	0.40	10,510	48	16	5	71
Wind	100	1,833	no	33%		N/A	77	8		85
Solar - Parabolic Trough (solar only)	100	3,800	yes	23%		N/A	191	28		219
Solar - Photovoltaic (two axis tracking)	50	5,909	no	25%		N/A	221	8		229
Biomass	25	3,251	no	85%	2.80	13,984	53	22	28	102
Geothermal *****	24	2,348	no	85%		29,080	39	7	5	46
STORAGE										
Compressed Air Energy	100	1,226	yes	30%	7.80	4,590	61	12	32	104

Costs are derived from EPRI TAG which have been modified in NYISO financial assumptions and site conditions. Not included are site specific owners costs such as water acquisition, site development, transmission infrastructure upgrades, community outreach costs and fuel infrastructure which may vary significantly depending upon site location. O&M estimates are derived from Dominion & Bernard Gut Estimates Study for combustion turbine technologies

*Levelized costs for solar includes 10% federal ITC, any state ITC, 5 years accelerated depreciation, 10 year state PTC, for windfarm costs include 10 year federal PTC)

**IGCC costs have been modified to account for elevation effect at 4,500 feet

*** Options with carbon removal do not include sequestration, estimated in the $14/MWh adder

***** Represents maximum potential, smaller projects may be feasible

DRAFT - Updated 1/15/09

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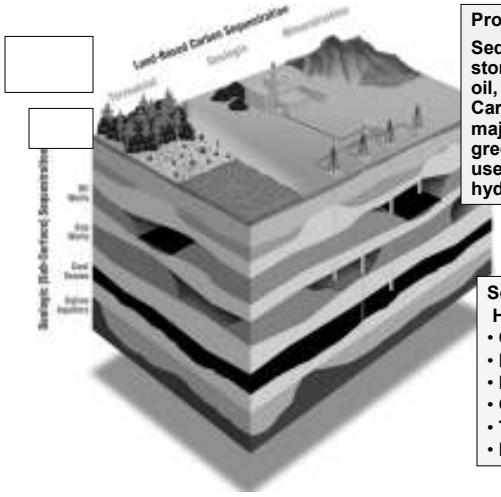
Carbon Sequestration



Problem Description:

Sequestration is the capture and storage of CO2 from the combustion of oil, natural gas, coal and biomass. Carbon sequestration could play a major role in the reduction of greenhouse gases through increased use of clean coal, natural gas and hydrogen

Sequestration Capacity:
Herzog (MIT)
- **Oceans 1000s Gt,**
- **Deep saline aquifers 100s to 1000s Gt**
- **Depleted oil and gas reservoirs 100s Gt**
- **Coal Seams 10s to 100s Gt**
- **Terrestrial (e.g., trees and soils) 10s Gt**
- **Reuse <1Gt/yr. (can this increase?)**

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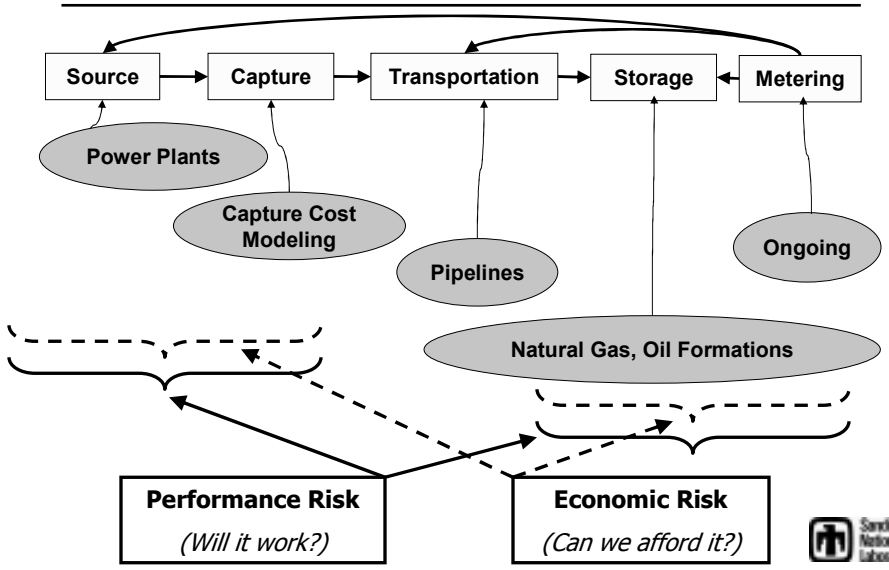
Systems Models' Structure
(e.g., 'String of Pearls' (SOP))



Full Scale Projects

- **Demonstrated on a full scale by the Alberta Energy Board in the 1980's at the Sunshine and Boundary Dam PC plants**
- **Combined Cycle Natural Gas Plants for Power and CO2 for Enhanced Oil Recovery, Scotland and North Africa, initiated by BP**

Major Issues for Sequestration

- **Parasitic Losses**
  - **10 existing PC (pulverized coal) coal plants with sequestration added will need 4 additional plants installed**
  - **10 existing Natural Gas plants with sequestration added will need 2 additional plants installed**
- **How will sequestration be regulated?**
- **Can projected sequestration capacities be achieved?**
- **Can separation and capture costs be reduced by a factor of 10?**

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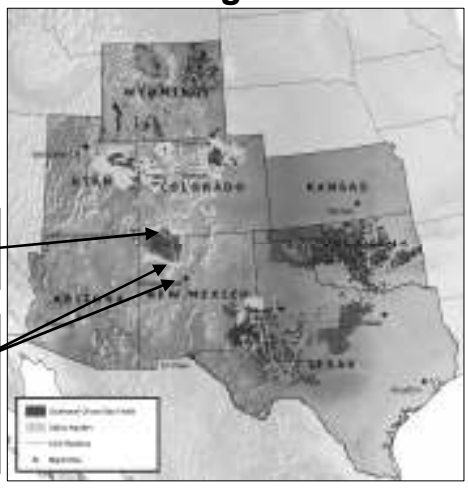
The Southwest Regional Partnership on Carbon Sequestration (SWP)

'The String of Pearls'

CO_2 pipelines in NM, TX, CO, WY, UT

Potential Sequestration:
- Oil Fields
- Natural Gas Fields
- Saline Formations



- ***One of seven*** regional partnerships throughout the U.S.
- Evaluating ***available technologies*** to capture and to reduce CO_2 emissions
- ***Source to Sink*** matching (Power plants to Geological Formations)
- String of Pearls Model ***'Tells the Story'*** for the SW Partnership
  - → Technology
  - → Economics
  - → Scale of the Issues

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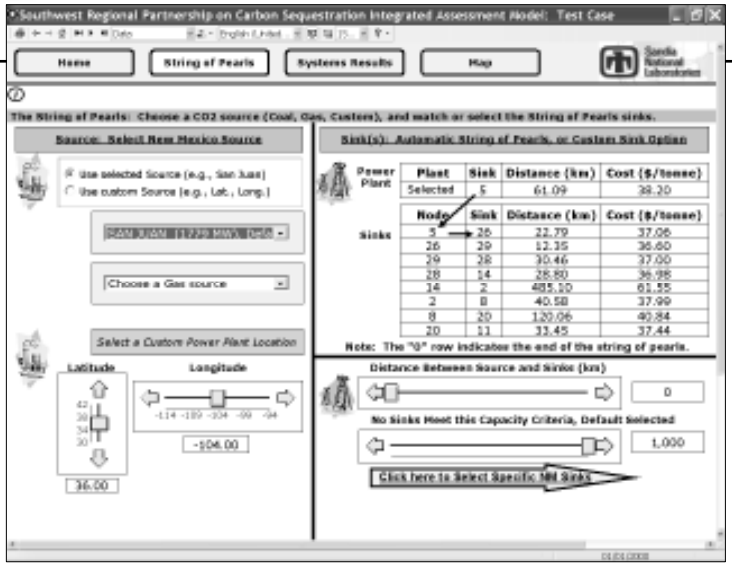
Southwest Regional Partnership on Carbon Sequestration Integrated Assessment Model: Test Case
Home
String of Pearls
Systems Results
Map
The String of Pearls: Choose a CO2 source (Coal, Gas, Custom), and match or select the String of Pearls sinks.
Source: Select New Mexico Source
Use selected Source (e.g., San Juan)
Use custom Source (e.g., Lat., Long.)
Choose a Gas source
Select a Custom Power Plant Location
Latitude
Longitude
36.00
-104.00
Sink(s): Automatic String of Pearls, or Custom Sink Option
Power Plant
Plant | Sink | Distance (km) | Cost ($/tonne)
Selected | 5 | 61.09 | 38.20
Sinks
Node | Sink | Distance (km) | Cost ($/tonne)
5 | 26 | 22.79 | 37.06
26 | 29 | 12.35 | 36.60
29 | 28 | 30.46 | 37.00
28 | 14 | 28.80 | 36.98
14 | 2 | 485.10 | 61.55
2 | 8 | 40.58 | 37.99
8 | 20 | 120.06 | 40.84
20 | 11 | 33.45 | 37.44
Note: The "0" row indicates the end of the string of pearls.
Distance Between Source and Sinks (km)
0
No Sinks Meet this Capacity Criteria, Default Selected
1,000
Click here to Select Specific NM Sinks
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