

Reinhold Environmental Ltd.



2008 NOx-Combustion Round
Table & Expo Presentation

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Impact of Carbon Dioxide Capture and Storage (CCS) on Fossil Fired Power Plants

**Christopher Wedig – Shaw Power Group
February 4, 2008**

**Reinhold Environmental
2008 - NOx Round Table – PCUG Conference
Carbon Capture Panel
Richmond, VA**

Topics

(Applications and Implications of CCS)

- Overview
- Process Options and Feasibility
- Integration and Impacts
- Re-Use and Storage of CO₂
- Economics
- Summary



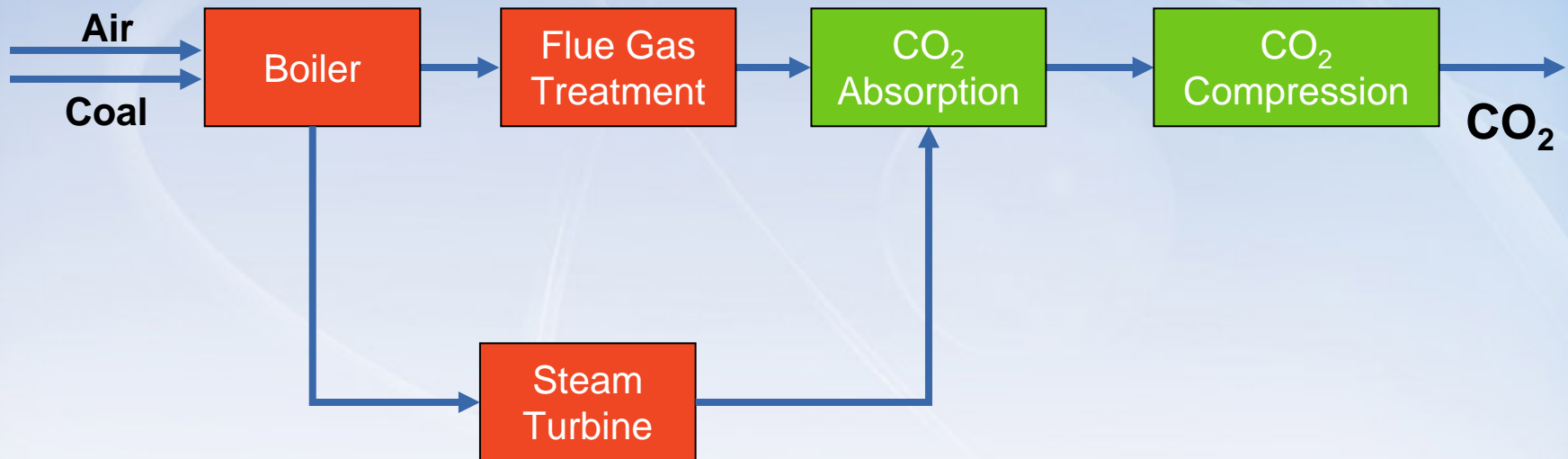
Carbon Dioxide Capture Various Types of Power Plants

- Post-Combustion (flue gas) CO₂ Capture Processes
- Pre-Combustion CO₂ Capture Technologies for IGCC
- Oxy-Fuel Combustion Technology with CO₂ Capture

Post-Combustion Carbon Dioxide Capture

**Process Options and Feasibility
(Applications and Implications of CCS)**

Pulverized Coal Post-Combustion Process CO₂ Capture



Technology Options for Post-Combustion CO₂ Capture

- Amine-based absorption (generic and advanced amines)
- Ammonia absorption process (not chilled)
- Chilled ammonia absorption
- Solvent-based absorption (non-amine-solvents)
- Algae-based process
- Enzyme-based process
- Membrane-type processes
- Physical adsorption of CO₂ in solvents
- Other technologies (being developed, R&D, piloted)

Technical Feasibility of PC CO₂ Capture

- Most individual equipment components are demonstrated
- Most unit operations are demonstrated
- CO₂ Capture Systems need to be demonstrated (various scales)
- PC CO₂ Capture – Future Pilot and Demonstrations (based on announcements and descriptions from internet)
 - Algae-based CO₂ capture process
 - Amine CO₂ capture process
 - Ammonia CO₂ capture process
 - Chilled Ammonia CO₂ capture process
 - Solvent-based absorption (non-amine-solvents)
 - Other

Post-Combustion Carbon Dioxide Capture Integration

**The Impact of CCS on Pulverized Coal Plant
(Applications and Implications of CCS)**

Impacts and Integration of CO₂ Capture and Storage System

- Real estate for deep FGD equipment (if required)
- Real estate required for CO₂ capture system equipment
- Real estate for CO₂ cooling, drying, and compression equipment
- Real estate for CO₂ transport (pipeline)
- Real estate for interconnecting piping, roads, ductwork, BOP equipment, etc.
- Real estate for CO₂ sequestration or re-use system (if onsite)
- Electrical power usage and impact on plant electrical system
- Steam requirement and impact on plant steam turbine system
- Cooling water usage

Impacts and Integration of CO₂ Capture and Storage System (cont.)

- Impact on flue gas cleaning system (e.g. deep FGD, if required)
- Impact on stack for the processed flue gas
- Water balance issues
- O&M personnel requirements
- Maintenance and spare part requirements
- Disposal or regeneration of the spent CO₂ sorbent/material
- Permit issues
- CO₂ by-product reuse or CO₂ storage
- Other impacts

Integration of CO₂ Capture into Pulverized Coal or Natural Gas Combined Cycle Plant

- New Plant – CO₂ capture-ready vs. enhanced-ready
- New Plant – CO₂ initially installed – demo or pilot
- Retrofit CCS (possible) – demo or pilot

Disposition of the Captured CO₂

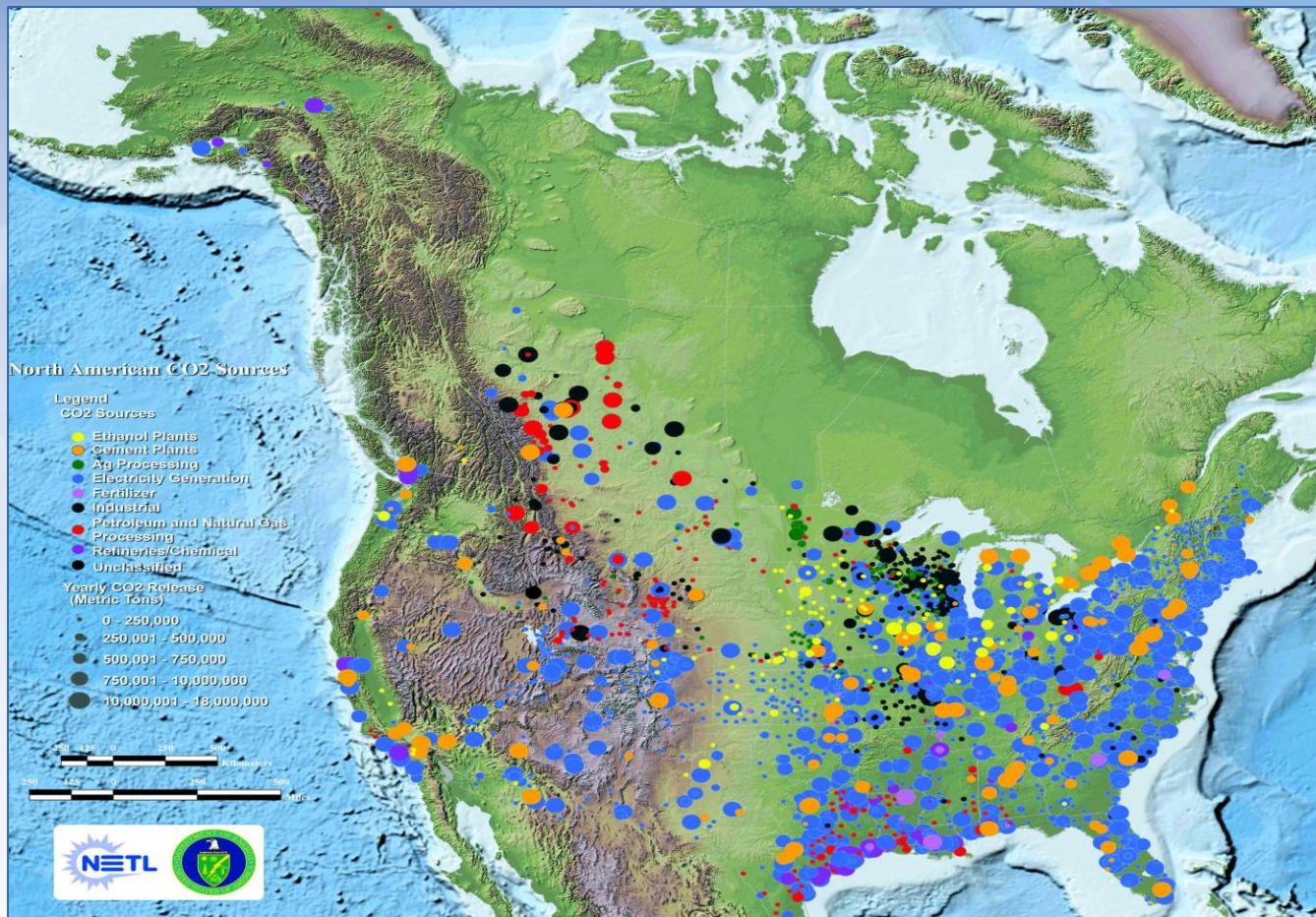
**Where will 12,000 tons CO₂/day
of liquid CO₂ product be sent?**

Mass Balance Concerning CO₂ Issues

Fossil fuels are readily available to generate electricity reliably, efficiently and cost-effectively, while meeting environmental regulations

- Combustion Chemistry (related to carbon):
Coal (carbon) + air (O₂) → CO₂
- Example (typical coal containing ~ 70% carbon):
 - ▶ 1.0 ton Coal
 - ▶ 2.5 ton CO₂

USA and Canada – CO₂ Sources and Size

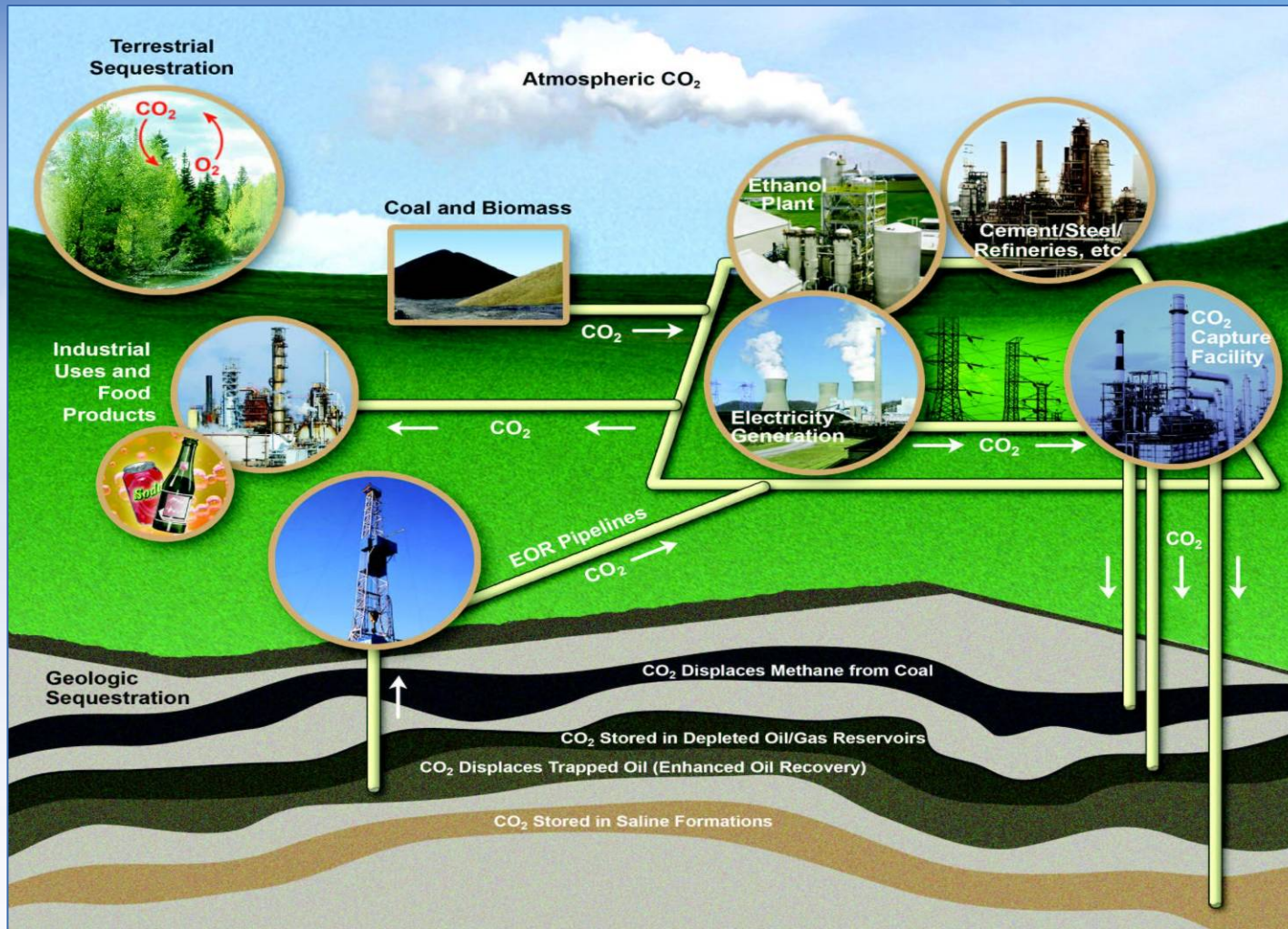


Re-Use of Carbon Dioxide

Potential Methods (partial list)

- Enhanced oil recovery (EOR) with CO₂ sequestration (storage)
- Manufacture of chemicals (e.g. urea, methanol, etc.)
- Carbonated beverages
- Refrigeration medium and dry-ice refrigerant
- Algae based bio-diesel fuels
- Algae based bio-mass fuel
- Algae based fish-food
- Other methods to re-use the CO₂ (e.g. propellants, health care, cast molds, transport fluid, etc.).

Carbon Capture and Storage (CCS)

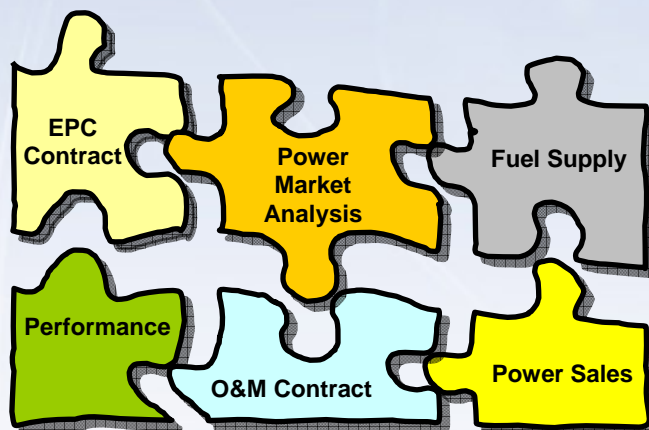


US DOE

Economics and Managing Risk (Applications and Implications of CCS)

Project Economics and Managing Risks

- Technology scale-up
- Installed capital cost (material and labor)
- Annual Operation & Maintenance costs
- Carbon dioxide value (\$/ton) and disposition



Process Parameters Influencing Installed Capital Cost of Post-Combustion CO₂ Capture Systems

- Percent (%) of total flue gas that is treated
- Percent (%) removal of CO₂ removed from flue gas
- Total mass of CO₂ (tons/day) removed from flue gas
- Type of CO₂ capture process chosen
- Disposition of CO₂ product

Process Parameters Influencing Annual Operation and Maintenance Costs of Post-Combustion CO₂ Capture Systems

- Total mass of CO₂ removed (tons/day) from flue gas
- Type of CO₂ capture process chosen
- Steam unit cost and usage rate
- Electricity unit cost and usage rate
- Cooling water unit cost and usage rate
- Reagent(s) unit cost and make-up rate
- Waste by-product(s) disposal cost
- Corrosion issues
- Solar flux, air humidity & temperature (e.g., algae process)
- Disposition of CO₂ product
- Other issues

Summary

Post-Combustion CO₂ Capture Options (Application and Implications of CCS)

- CO₂ capture technologies are available for pilot or demonstration
- CO₂ capture technology demonstration systems are being installed
- CO₂ capture process greatly impacts PC plant or NG CC power plant
- Long term operating experience is needed (steady state & upset)
- Significant cost issues (capital and annual O&M)
- CO₂ can be used in Enhanced Oil or Gas Recovery projects
- CO₂ storage projects (geological, saline, or depleted oil/gas reservoirs)
- New and/or improved PC CO₂ capture technologies being developed

Contact Information

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Thank You

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