Reinhold Environmental Ltd.

2010 NOx-Combustion Round Table & Expo Presentation

February 8 & 9, 2010 Chattanooga, TN


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Carbon Dioxide Capture and Storage (CCS) Technology Advancements

Christopher Wedig – Shaw Power Group

February 8, 2010

Reinhold Environmental
2010 - NOx Combustion Round Table – PCUG Conference
Session Workshop 3
Chattanooga, Tennessee

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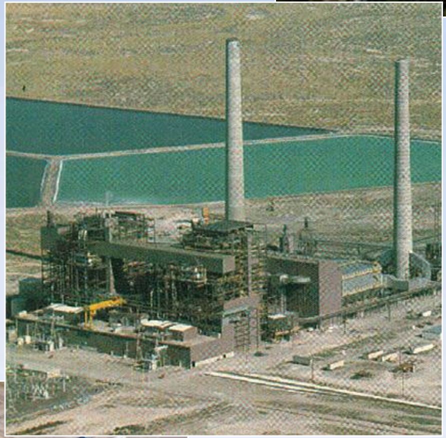
Topics
(advancements)

- Introduction
- Energy Efficiency Discussion – Power Plants
- CO_2 Capture and Storage Systems
- Impact of Air Quality Control Systems
- Summary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Advancements in Energy Efficiency and Carbon Dioxide Reduction for Power Plants

CO_2 Reduction

- Heat rate and power plant efficiency improvements
- Co-fired alternative fuels with coal
- Repowering
- Other methods

CO_2 Capture

- Pre-combustion CO_2 capture technologies for Integrated Gasification Combined Cycle (IGCC)
- Oxy-fuel combustion technology with CO_2 capture
- Post-combustion (flue gas) CO_2 capture processes

Power Plant Efficiency Discussion

(advancements)

Topics Concerning Efficiency Improvements in Fossil-Fired Power Plants

- Heat rate and power plant efficiency improvements
- Definitions of efficiency
- Boiler steam pressure and temperature
- Improved integration of power plant auxiliary systems
- Different fuels
- Co-fired alternative fuels with coal
- Repowering
- CO_2 production, capture, and storage
- Other issues

Boiler Steam Pressure and Temperature

(impacts plant efficiency, flue gas and CO_2 production, etc.)
(advancements)

- Ultra supercritical boilers
- Supercritical boilers
- Subcritical boilers
- Other

Efficiency Definitions

(there are numerous definitions)

Net Electrical Efficiency is

net electrical energy divided by total heating value energy of input fuels

- Examples of why efficiency definitions and values vary:
  - Where and how net electrical energy is measured (generator vs. transmission tower)
  - Type of fuels (coal, biomass, natural gas, oil, hydrogen, etc.)
  - Higher or Lower heating value of fuels (HHV vs. LHV)
  - Auxiliary plant equipment in *or* out of service (feed water heaters, cooling, AQCS, CCS)
  - Weather conditions (summer or winter cooling loads)
  - Test methods and procedure (ASME, international standards)
  - Other reasons why efficiency definitions and values can vary

Different Types of Fossil Fuels

(impact plant efficiency, flue gas and CO_2 production, etc.)

Fossil Fuel Type	Total Carbon Content (% carbon weight)	Higher Heating Value (HHV, Btu/pound fuel)	CO_2 Production Rate (lb CO_2 per million Btu, HHV)
Coal – A	83.7	11,890	258
Coal – B	74.0	12,540	216
Coal – SB	70.3	9,190	280
Coal – L	63.3	7,090	327
Bagasse	23.4	4,000	214
Fuel Oil – # 2	87.2	19,460	164
Fuel Oil – # 6	88.4	18,200	178
Natural Gas –1	75.2	23,170	119
Natural Gas –5	64.8	20,160	118
MSW	27.9	5,100	200
RDF	36.1	6,200	213

Mass & Energy Balance
CO_2 Issues

Coal is readily available to generate electricity reliably, efficiently and cost-effectively, while meeting environmental regulations.

- Combustion Chemistry (related to carbon):

  Coal (carbon) + air (O_2) → CO_2

- Example (typical coal containing ~70% carbon):

  1.0 ton Coal
  2.5 ton CO_2
  24 million Btu (HHV) total energy
  ~85% of energy is from carbon

Carbon Dioxide Capture

(Advancement in CCS)

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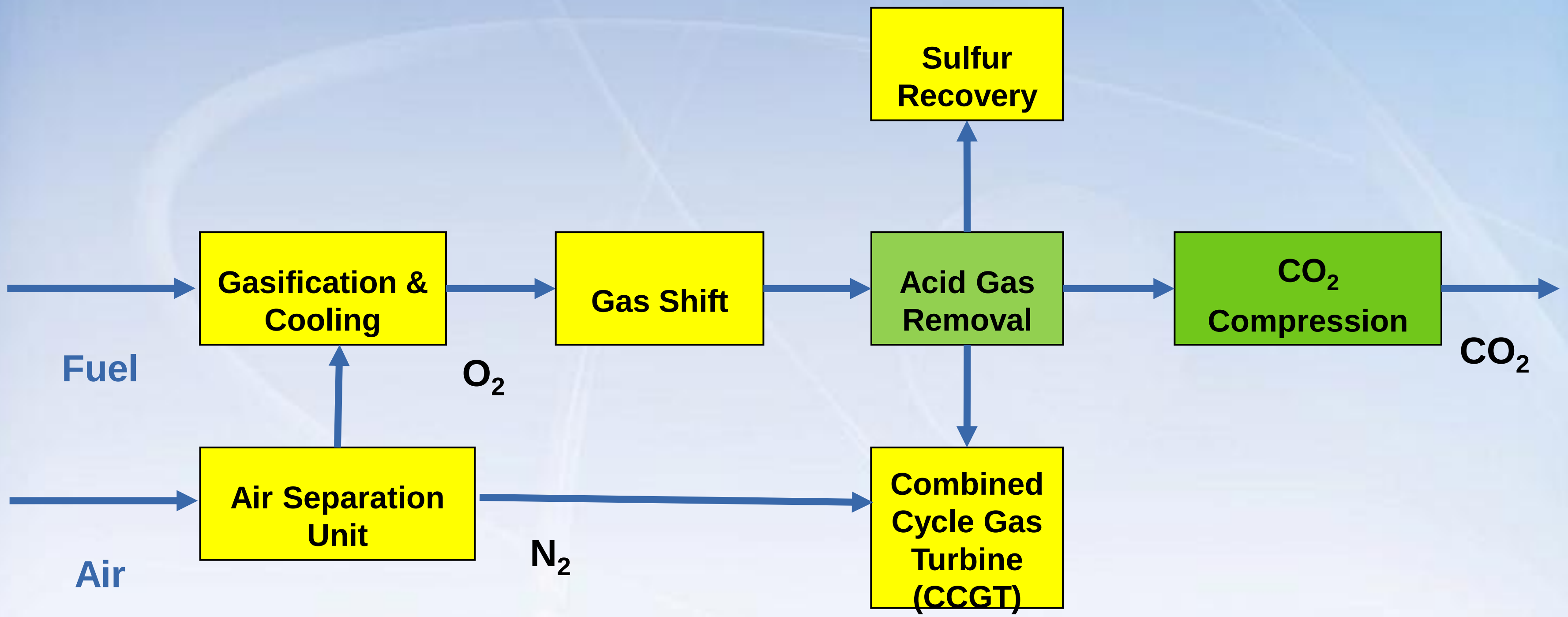
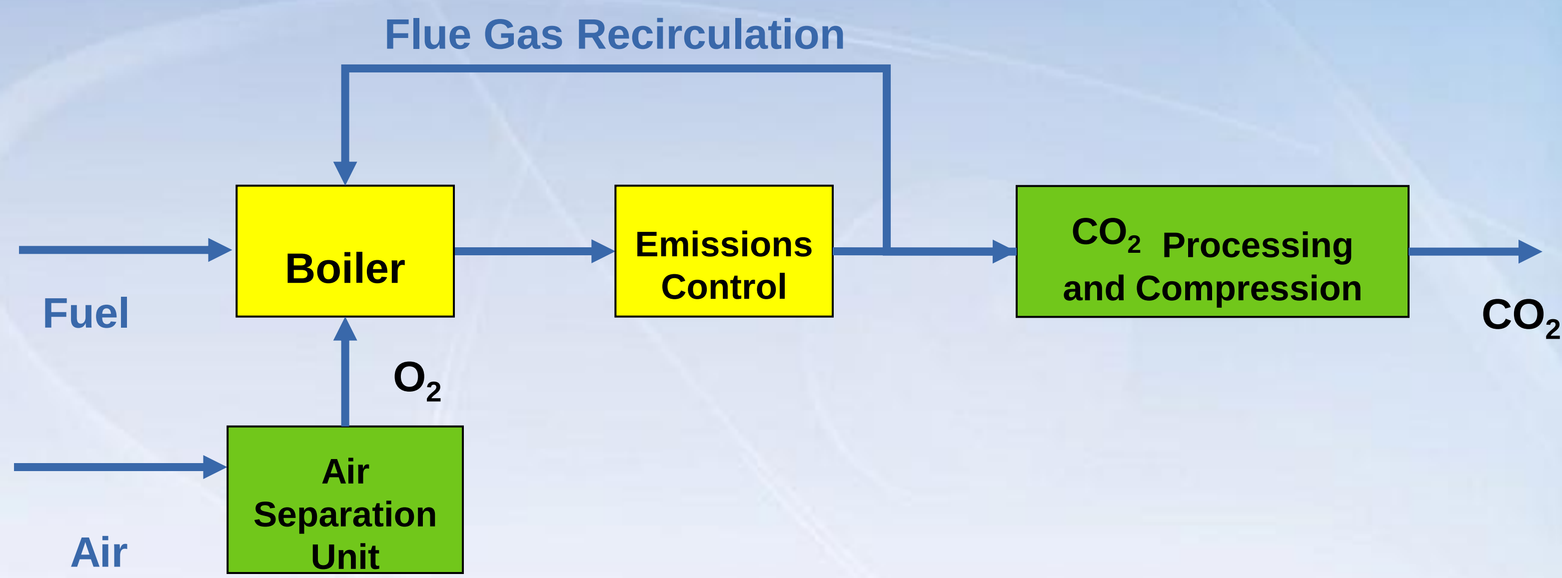
IGCC Process with Pre-Combustion Carbon Dioxide Capture

(advancements in CO2 capture and GT designed for H2)



OxyFuel Process with Carbon Dioxide Capture

(advancements in demonstrations, minimizing air leaks, etc)



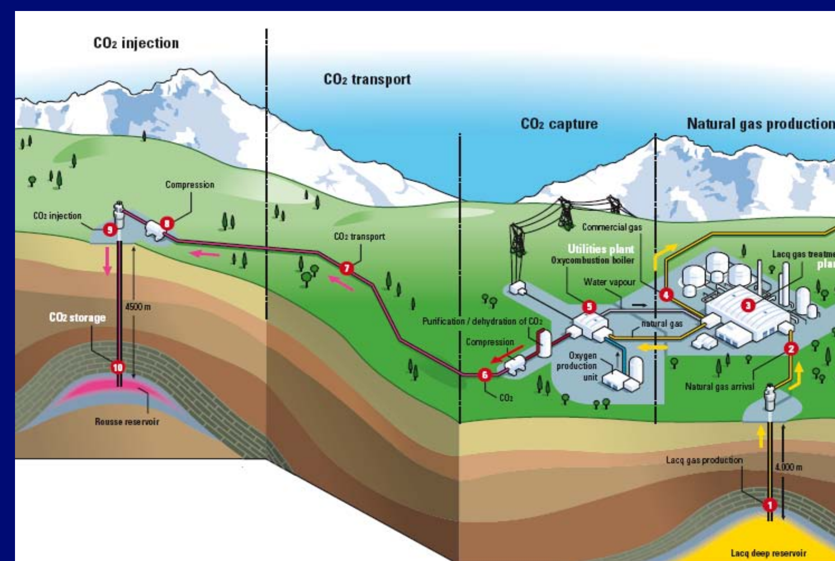
Example of Advancements Oxy Fuel CO_2 Capture & Storage Demonstrations

Oxy Coal Pilot Plant – Vattenfall

30 MW thermal pilot plant at Schwarze Pumpe in Germany

Oxy Fuel Pilot Plant – Total

150,000 tones CO2 over two years
Lacq Basin, Southwestern France



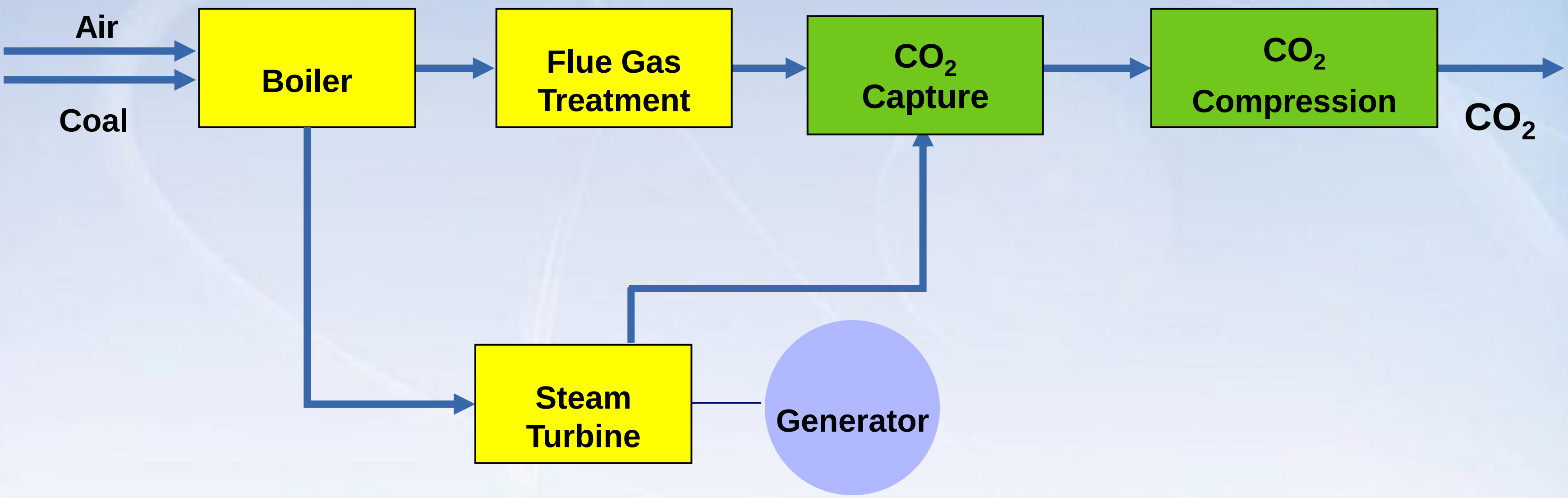
Example of Advancements
Oxy Fuel Demonstrations

No	Demo/pilot-plant name	Scale (Demo/Pilot plant)	MW e	New Retrofit	Startup/ Duration	Main Fuel	Electricity generation Yes/No	CO2 Compression (Yes/No)	CO2 use/Seq	CO2 purity	Gas clean up
1	Vattenfall pilot plant, Germany	P	10	N	2008	Coal	N	Y	Y	99.90%	FGD ESP
2	Callide (CS Energy, Australia)	D	30	R	2011	Coal	Y	Y	Y		FF
3	TOTAL, Lecq, France	D	10	R	2009	NG	N	Y	Y	99.90%	
4	CIUDEN, Spain	P (PC/CFB)	17	N	2010	Coal	N	Y	Y		SCR FF FGD
5	Youngdong, South Korea	D	100	R	2016	Coal	Y		Y	98%	SNCR FF
6	Jamestown/Praxair Plant, USA	D(CFB)	50	N	2013	Coal	N	Y			
7	Jupiter Pearl plant, USA	D	22	R	2009	Coal	N	N			
8	Babcock&Wilcox pilot plant, B&W, USA	P	10	R	2008	Coal	N		N	70% dry	FGD ESP
9	Doosan Babcock, UK	P	30	N/A	2008	Coal	N		N		

Post-Combustion Carbon Dioxide Capture

(Advancements in CCS)

Pulverized Coal Post-Combustion Process CO_2 Capture
(advancements in demonstrations, energy efficiency, etc)



Technology Options for Post-Combustion CO_2 Capture

(each process has had its own advancements)

- Amine-based absorption (generic and advanced amines)
- Ammonia absorption process (aqueous ammonia, not chilled)
- Chilled ammonia absorption (aqueous ammonia)
- Solvent-based absorption (non-amine-solvents)
- Algae-based process using solar energy
- Enzyme-based process
- Membrane-type processes
- Physical adsorption of CO_2 in solvents
- Solid sorbents for CO_2 absorption and/or adsorption.
- Frosting or anti-sublimation processes
- Other technologies (being developed, R&D, piloted)

Technical Feasibility of Pulverized Coal CO_2 Capture

- Most individual equipment components are demonstrated
- Most unit operations are demonstrated – (but some under conditions not typical for most coal-fired power plants)
- CO_2 capture systems need to be demonstrated (various scales)
- PC CO_2 capture – future pilot and demonstrations - (with lessons learned with regard to design, energy usage, operation, and maintenance)
  - Amine CO_2 capture process
  - Ammonia CO_2 capture process
  - Chilled ammonia CO_2 capture process
  - Solvent-based absorption (non-amine-solvents)
  - Algae/sunlight-based CO_2 capture process
  - Frosting or anti-sublimation process
  - Other

Examples of Advancements
Post Combustion CCS Demonstrations

DOE Announcement ***Project Title: Mountaineer Carbon Dioxide Capture and Storage Demonstration*** **American Electric Power (AEP) will retrofit a Alstom CO2 capture chilled ammonia process, in a 235 megawatt flue gas stream.**	***DOE Announcement*** ***Project Title: Southern Company Carbon Capture and Sequestration Demonstration*** **Southern Company Services (SCS) will retrofit a MHI CO2 capture plant on a 160 megawatt flue gas stream at Plant Barry.**
Scottish Power (UK) performed testing of carbon dioxide capture pilot unit demonstration at the Longannet Station.	**Powerspan announced test results of a carbon dioxide capture pilot unit (ammonia based) demonstration at the R.E. Burger Plant.**

Examples of Algae CO_2 Capture
(advancements)

Algae CO2 Capture Demonstration
Redhawk Power Plant - APS

Algae CO2 Capture Demonstartion
Niederaussem Power Plant - RWE

Examples of Advancements
CO_2 Capture

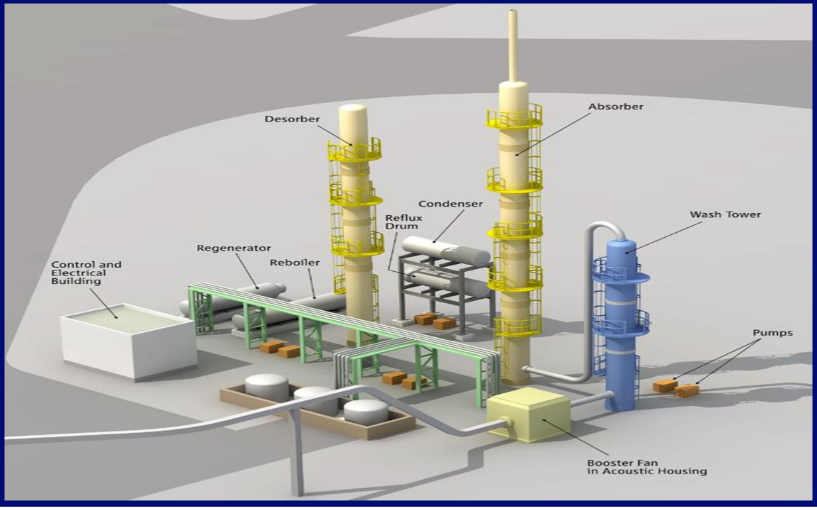
Babcock & Wilcox has begun capturing carbon dioxide (CO_2) from a pilot-scale Regenerable Solvent Absorption Technology (RSAT) process at the coal-fired boiler of the company's research center in Ohio.	HTC Purenergy and Doosan Babcock have signed an agreement to do process design and engineering work for a proposed carbon capture project at Basin Electric's Antelope Valley power plant in North Dakota.
The Australian government has committed A$2.425 billion (US$2.22 billion) over nine years for the CCS Flagships program to fund two to four large scale CCS demonstration projects.	Lawrence Livermore National Laboratory has developed new carbon nano tube permeable membranes for CO2 separation and capture.

Examples of Advancements
Post Combustion CO_2 Capture

Cansolv CO2 Capture Demonstrations

Application	Date	Site	CO2 in the gas	Removal
Natural Gas Fired boiler	March-June 2004	Paprican, Montreal, Canada	8% vol	75%
Coal fired Boiler	November 2004	Pulp Mill Boiler, US	11.5% vol	65%
Coal fired Power Plant	July – Sept 2006	Saskpower, Poplar River, Canada	12% vol	90%
Blast Furnace	April 2007 - 2008	Japan	22% vol	90%
Natural Gas Fired Boiler	May - Sept 2007	Shell-Statoil, Norway	4.5 %vol	85%
Cement Kiln	Jan – Feb 2008	USA	20 %vol	90% and 45%

RWE Aberthaw (UK) CO2 Pilot - 1 MW



Germany's E.ON and Siemans are putting a pilot CO2 capture plant into operation at the hard coal-fired power plant Staudinger Unit 5 in Germany.

RWE is operating a CO2 pilot plant at the BoA 1 Niederaussem Station in Germany with Linde and BASF sized at 300 kg CO2/hour.

Post-Combustion Carbon Dioxide Capture Integration and O&M Considerations

Advancements CCS for Fossil-Fired Power Plants

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Integration of CO_2 Capture into Pulverized Coal or Natural Gas Combined Cycle Plant

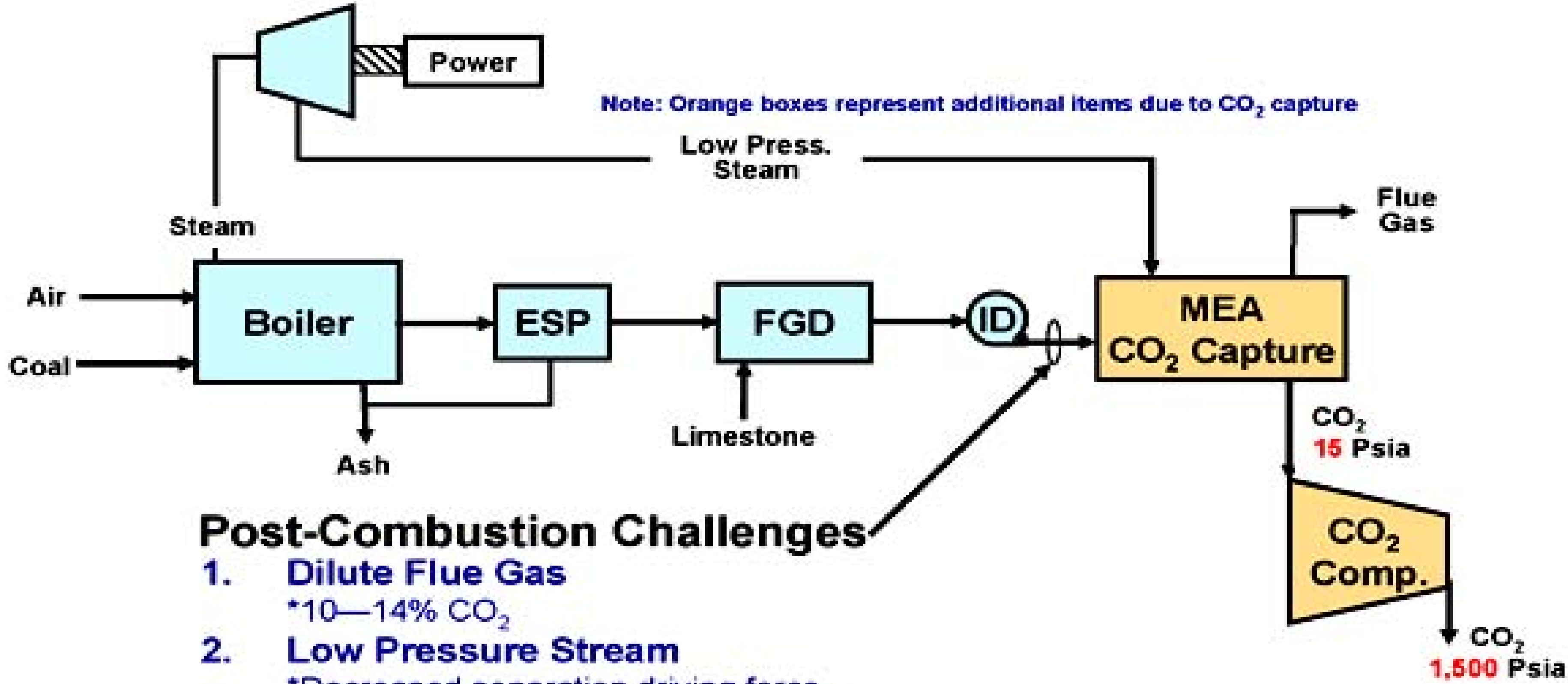
(advancements in design and demonstrations)

- New Plant – CO_2 capture-ready vs. enhanced-ready
- New Plant – CO_2 initially installed – demo or pilot
- Retrofit CCS (possible) – demo or pilot

Example of Planned New Coal-Fired Power Plant Carbon Capture Ready Real Estate

(advancements in design and CCS integration into plant)

Post-combustion Capture

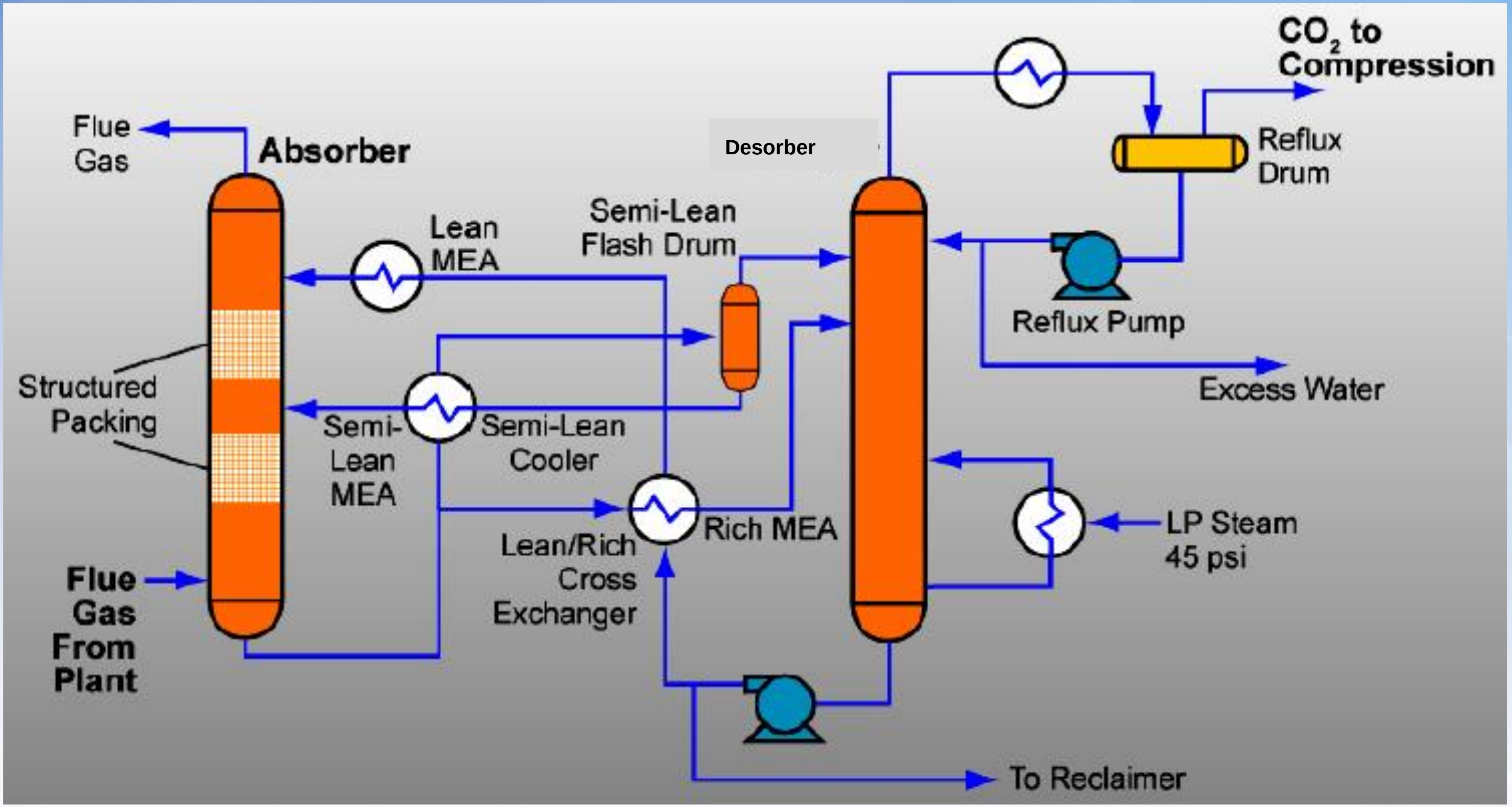


Post-Combustion Challenges

1. **Dilute Flue Gas**
   *10—14% CO_2
2. **Low Pressure Stream**
   *Decreased separation driving force
3. **Contaminants**
   *SO_2, Particulates, etc.
4. **Large Parasitic Load (regeneration steam)**

Source: US DOE report

Sorbent Based – Flue Gas CO_2 Capture Process Schematic – Generic Example



Source: US DOE report

Typical CO_2 Capture and Storage Equipment

(Designed for Proper Energy Efficiency, O&M, Layout)

- Flue gas booster fan
- Deep FGD equipment (if required)
- CO_2 absorber column
- Heat exchangers (cooling water)
- CO_2 capture solvent delivery, storage, and handling equipment
- CO_2 desorber column
- Steam generator (reboiler) for CO_2 desorber column
- Spent CO_2 solvent storage, handling, and disposal equipment
- CO_2 coolers, dryers and compressors
- CO_2 pipeline and storage equipment

Impacts and Integration of CO_2 Capture and Storage System

(Design in Advance for Energy Efficiency O&M, and Layout Considerations)

- Real estate (land area) for deep FGD equipment (if required)
- Real estate for additional NO_X and PM reduction systems (if required)
- Real estate required for CO_2 capture system equipment
- Real estate for CO_2 cooling, drying, and compression equipment
- Real estate for CO_2 transport (pipeline)
- Real estate for interconnecting piping, roads, ductwork, BOP equipment, etc.
- Real estate for CO_2 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
- Route for interconnections

Impacts and Integration of CO_2 Capture and Storage System

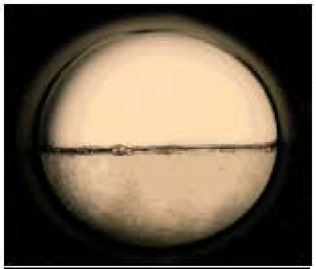
(Design in Advance for Energy Efficiency, O&M, and Layout Considerations)

- 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 CO_2 sorbent/material
- Permit issues
- CO_2 by-product reuse or CO_2 storage
- Safety, environmental and other issues

Example of Potential Heat Integration

RAMGEN POWER SYSTEMS™

PT Diagram & Supercritical Phase



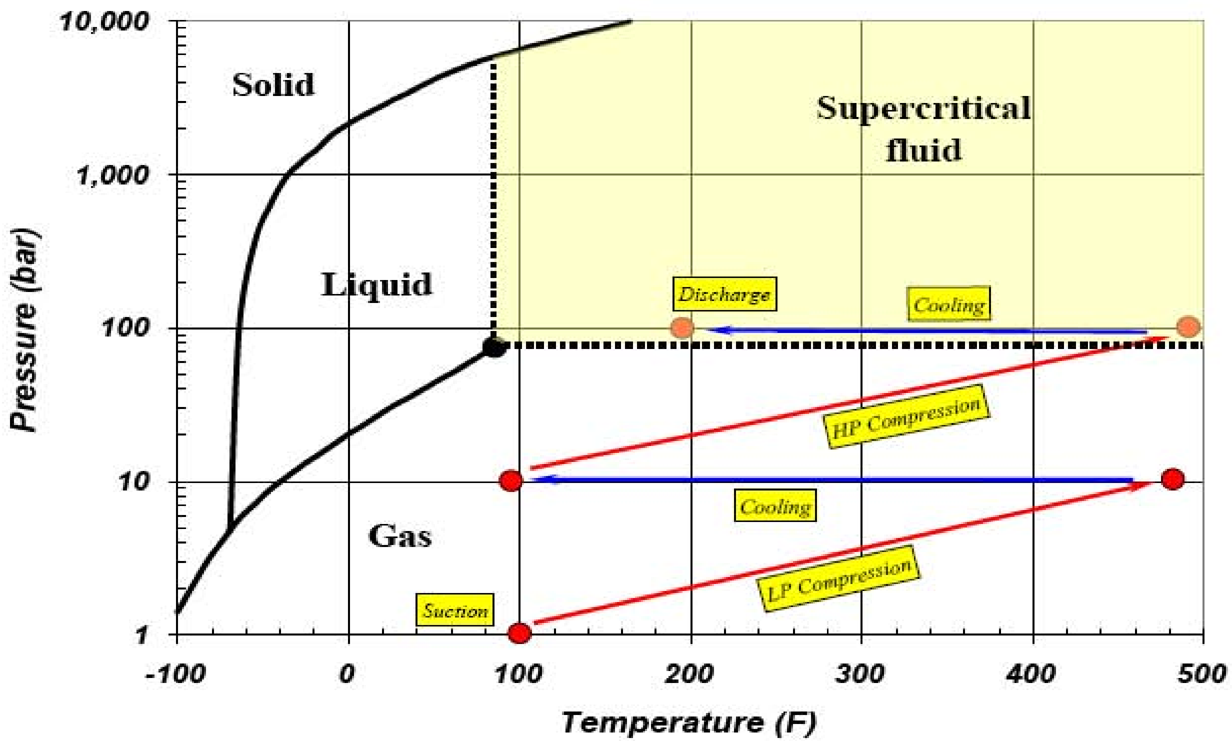
Separate Phases Visible- Meniscus Clearly Observed

Increase in Temperature- Diminished Meniscus

Further Increase in Temperature- Gas & Liquid Densities more Similar

At Critical P & T- Distinct Gas & Liquid Phases no Longer Visible "Supercritical Fluid" with Properties of Both Liquids & Gases

- Compression process transitions from superheated to supercritical phases
- Avoids liquid (sub-cooled) phase



Disposition of the Captured CO_2

(advancements)

Where will 12,000 ton CO_2/day of liquid CO_2 product be sent?

Mass Balance
CO_2 Issues

Coal is readily available to generate electricity reliably, efficiently and cost-effectively, while meeting environmental regulations.

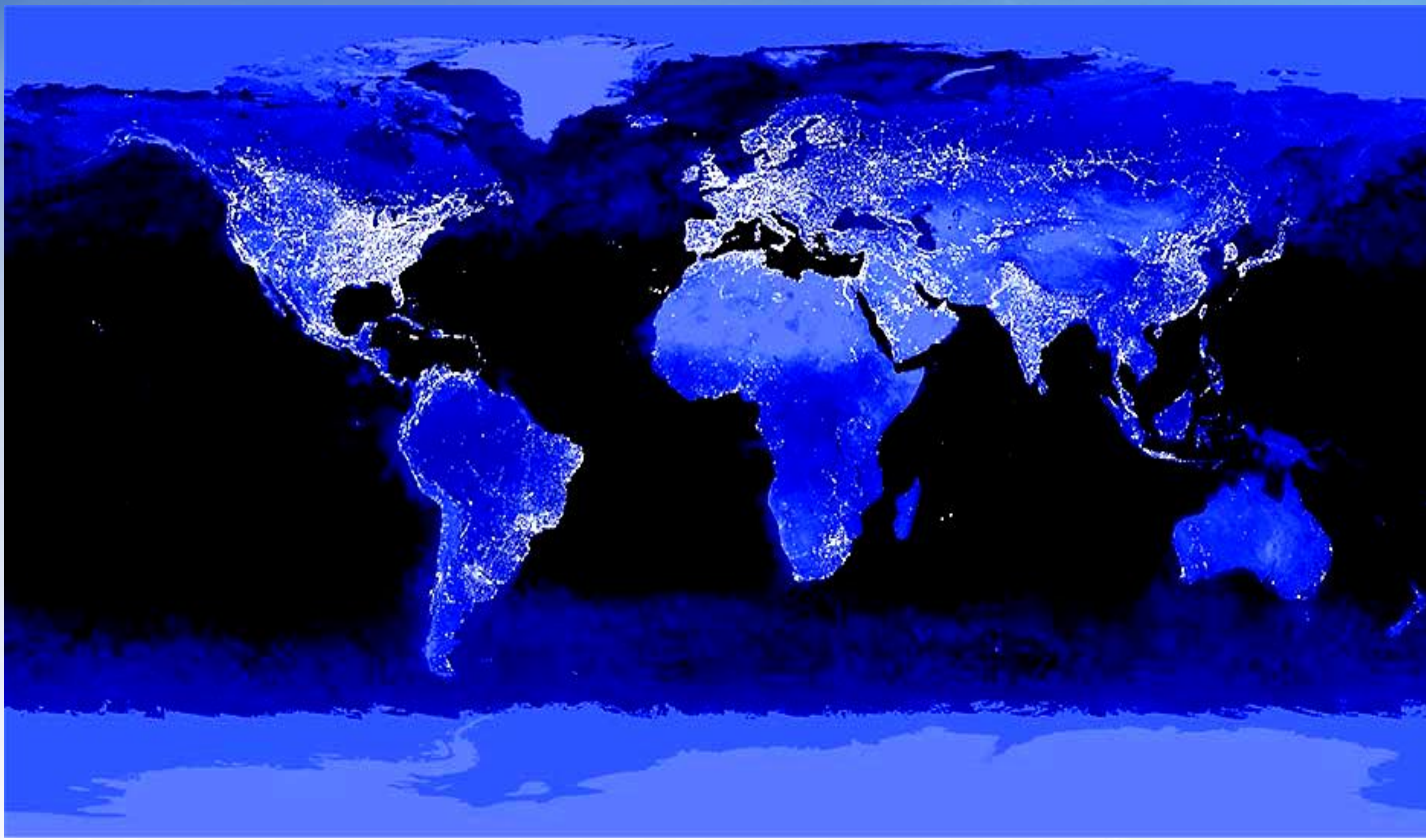
- Combustion Chemistry (related to carbon):

  Coal (carbon) + air (O_2) → CO_2

- Example (typical coal containing ~ 70% carbon):

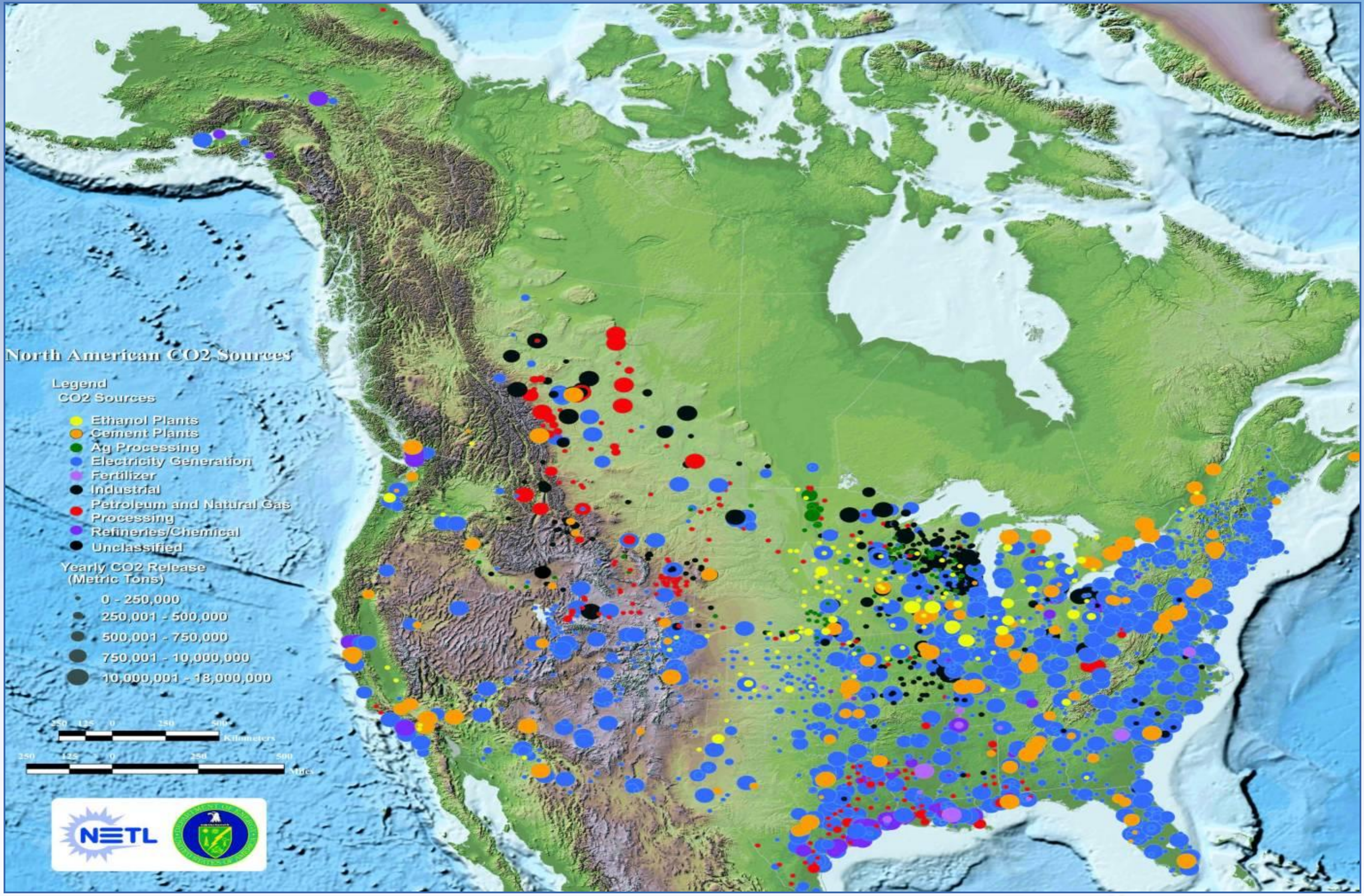
  500 MW(e)
  200 ton per hour of coal
  12,000 ton CO_2 per day

Earth at Night



Internet Source: Sky Image Lab – Earth at Night Photo – http://www.skyimagelab.com/earatnitlar.html

U.S. and Canada – CO_2 Sources and Size



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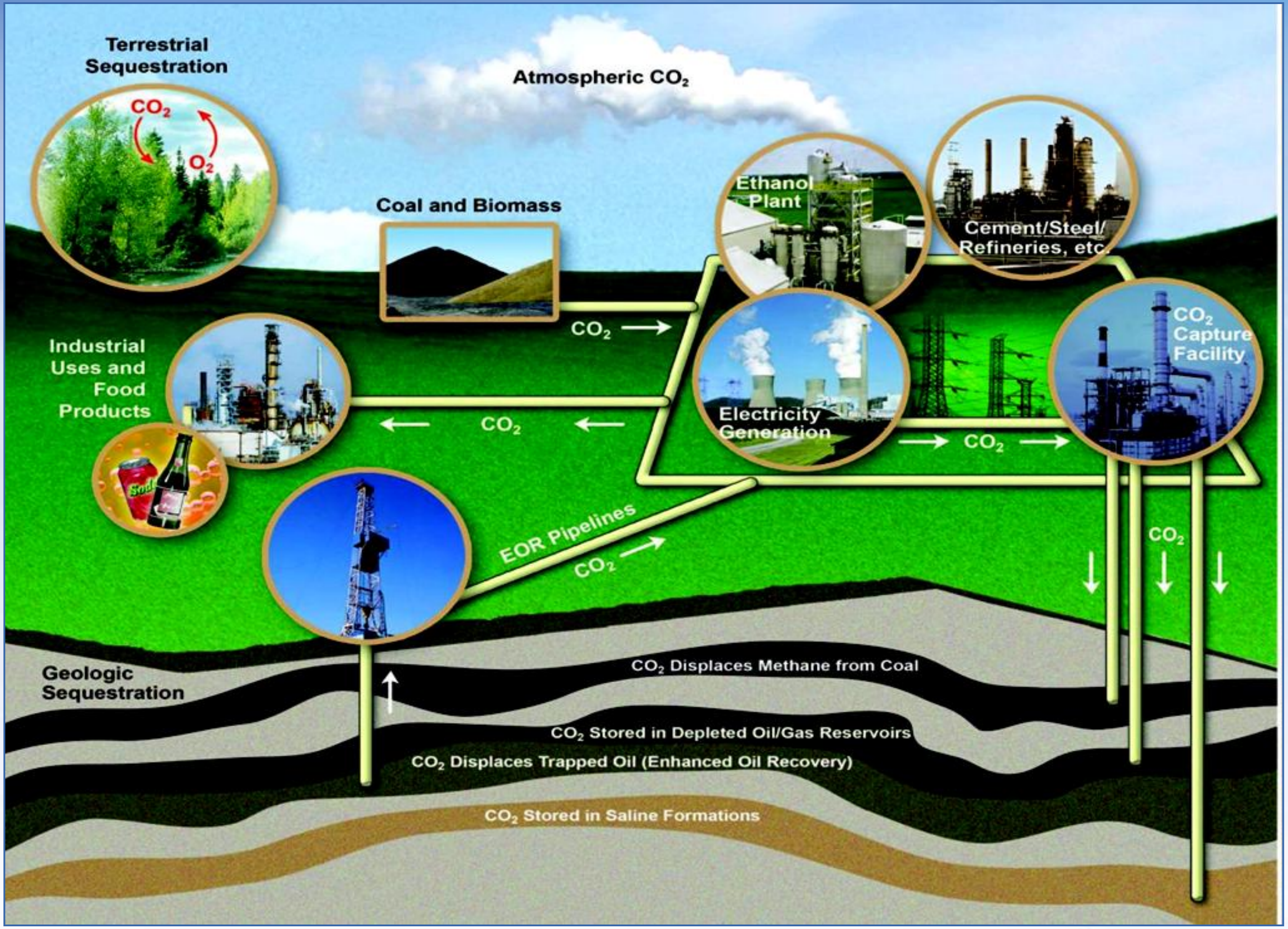
Re-Use of Carbon Dioxide
(advancements)

- Enhanced oil recovery (EOR) with CO_2 sequestration (storage)
- Enhanced gas recovery (EGR) with CO_2 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
- Ammonia-based fertilizers
- Other methods to re-use the CO_2 (e.g., propellants, health care, cast molds, transport fluid, etc.)

Carbon Capture and Storage (CCS) Options

(each option has its own advancements)



US DOE

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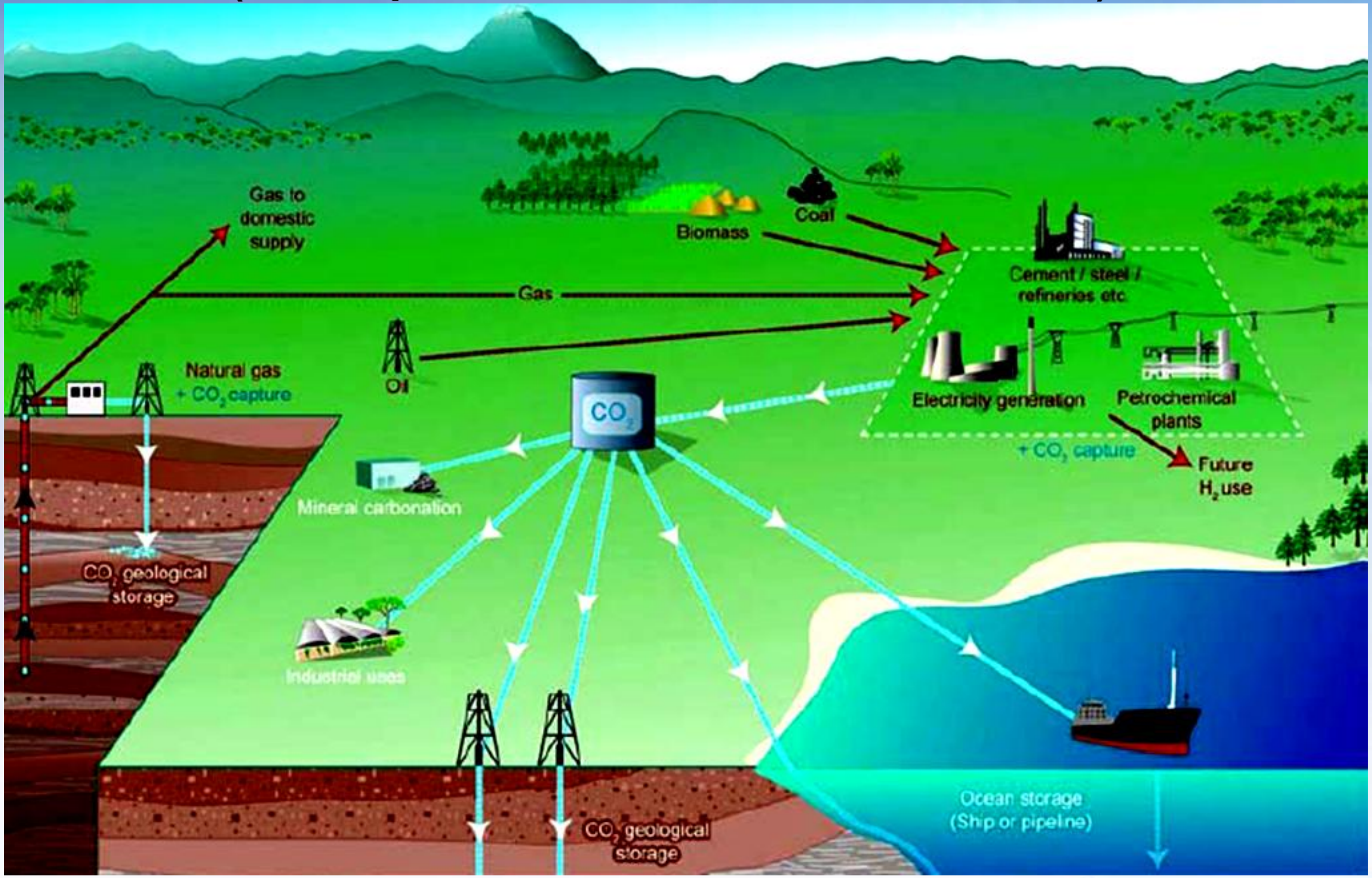
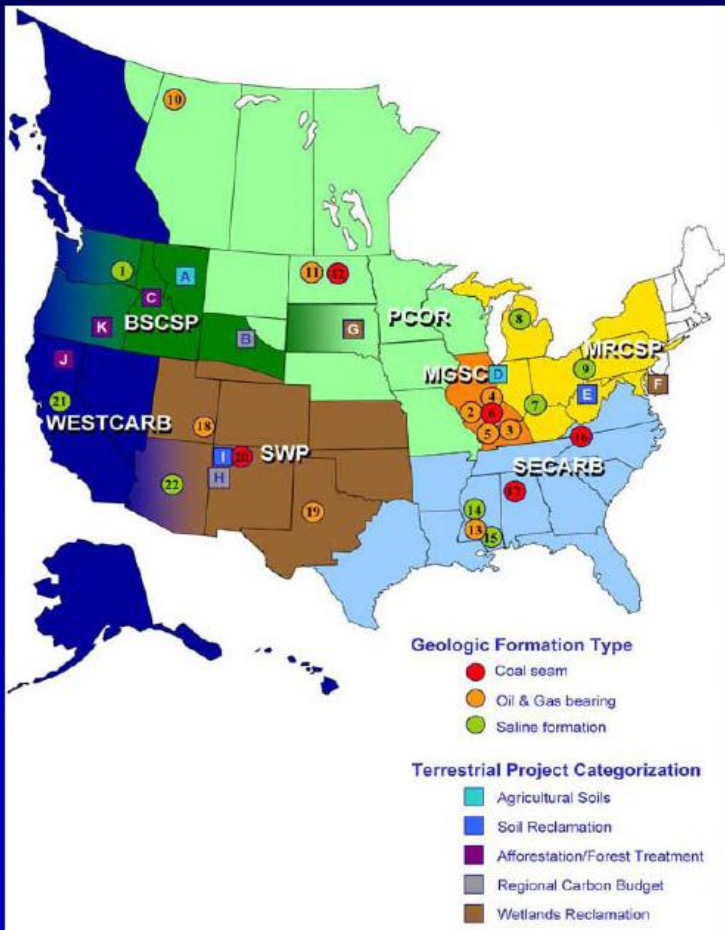
Carbon Dioxide Storage Options

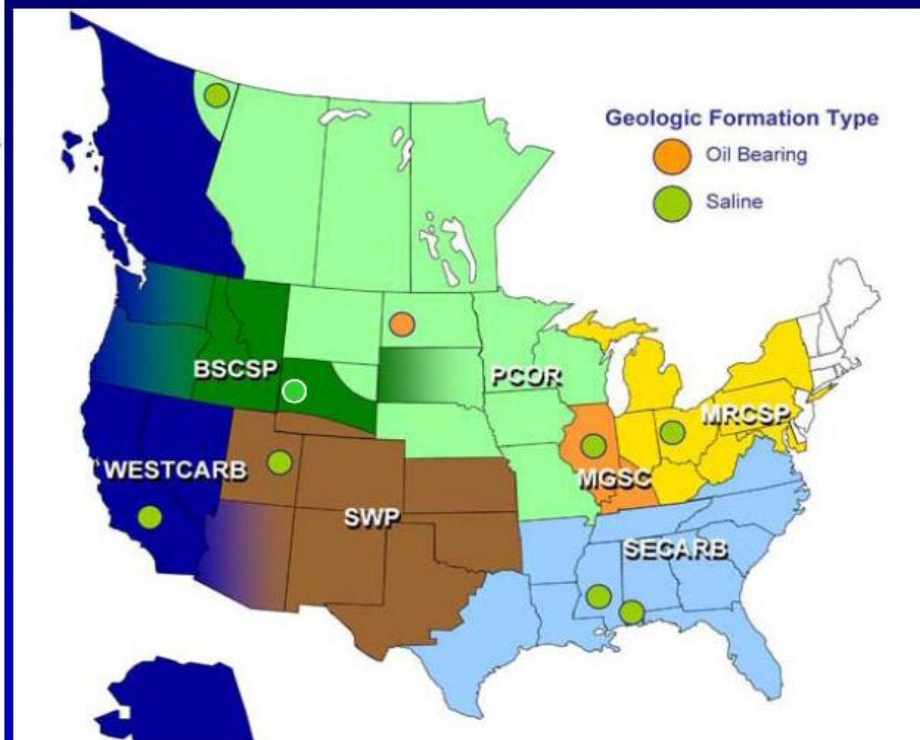
(each option has its own advancements)



IPCC Special Report, Carbon Dioxide Capture and Storage, Technical Summary

Department of Energy (DOE)
Regional Carbon Sequestration Partnership
(advancements)





DOE

Carbon Dioxide Properties

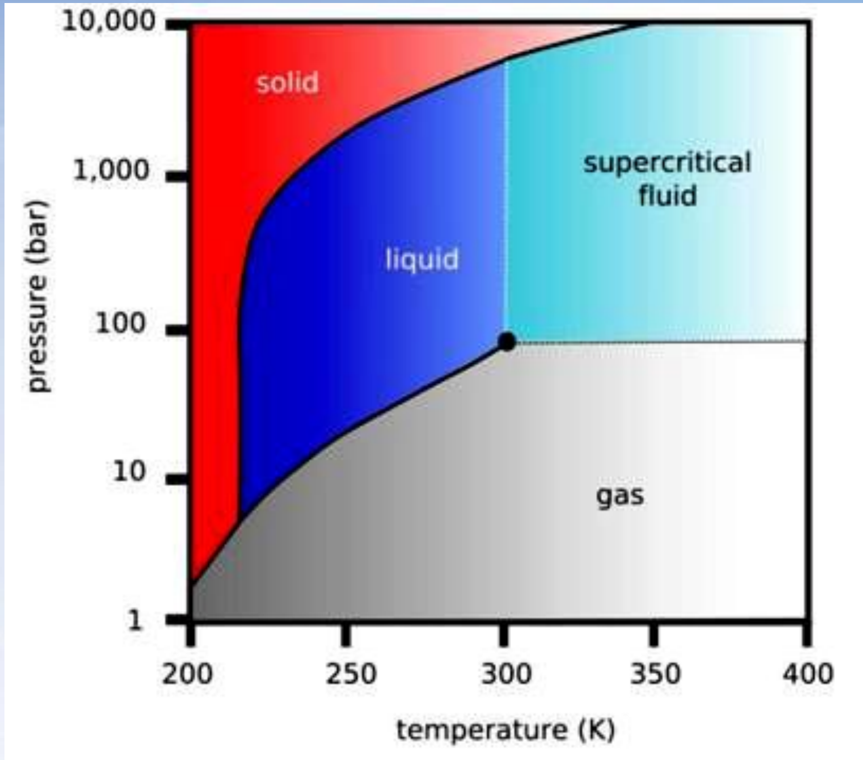
(advancements also made in properties of CO_2 sorbents)

- Molecular weight CO_2 = 44.01 lb/lb-mole (grams/gram-mole)
- Triple Point = -56.6°C at 5.11 atm
- Critical Temperature = 31.0°C
- Critical Pressure = 72.80 atm (1070.16 psia)
- Critical Point = 87.8°F and 1,071 psia
- Sublimation Temperature of CO_2 = -109.3°F (equals -78.5°C), (@ 1atm)
- Melting Point CO_2 = -56.6°C (@ 5.2 atm)
- Density as CO_2 gas = 0.001977 grams/cubic centimetre (@ 1 atm pressure, 0°C)
- Density as CO_2 liquid = 1.101 grams/cubic centimetre (@ -37°C)
- Density as CO_2 liquid = 0.914 grams/cubic centimetre (@ 0°C and 34.3 atm)
- Density as CO_2 solid = 1.56 grams/cubic centimetre (@ -79°C)
- Density as CO_2 solid = 1.512 grams/cubic centimetre (@-56.6°C)
- Latent Heat of Vaporization = 149.6 Btu/lb CO_2 (equals 83.12 gram-cal per gram CO_2) at the triple point and 101.03 Btu/lb at 0°C
- Solubility in cold water = 0.348 grams CO_2/100 cubic centimetres water (@ 0°C)
- Solubility in warm water = 0.097 grams CO_2/100 cubic centimetres water (@ 40°C)
- Heat of combustion of carbon to CO_2 = 14,093 Btu per lb of carbon.

Source: "Impact of CO2 Capture on Fossil-Fired Power Plants" – Power-Gen Asia, 2008

Carbon Dioxide Phases

Pure CO_2 can exist as a gas, liquid, or solid depending on its pressure and temperature.



Phase Diagram for CO_2

- **Carbon dioxide exists in four phases: gas, liquid, solid, and supercritical.**
- **Supercritical is important as CO_2 acts both as a gas and a liquid.**
- **In the supercritical phase, CO_2 acts like a gas, but has the density of liquid.**
- **The supercritical phase occurs at 31°C (88°F) and at 73 atm (1,070 psi).**

Carbon Dioxide Properties
(ground level and deep earth)
(useful for design and predicting energy related parameters)

CO_2 Properties at Two Different Nominal Representative Conditions				
Property P (bar), T(°C)	Depth in Earth (approximate)	Units	Brine	CO_2
Density @ 201 bar and 60 C	2 km	kg/m^3	1191	725
Density @ 1 bar and 10 C	0 km (ground level)	kg/m^3	1205	1.9
Viscosity @ 201 bar and 60 C	2 km	10^{-6} Pa s	940	60
Viscosity @ 1 bar and 10 C	0 km (ground level)	10^{-6} Pa s	1800	14

“Carbon Capture and Sequestration, Integrating Technology Monitoring and Regulation,” edited by Elizabeth J. Wilson and David Gerard, published by Blackwell Publishing, 2007.

Examples: CCS Demonstration Projects

(O&M experience, although not on pulverized coal applications)

Weyburn

- Project launched in 1999
- Enhanced oil recovery
- Expected - 22 Million tonne CO_2
- Dakota Gasification Company
- 320 km pipeline

Sleipner

STATOIL

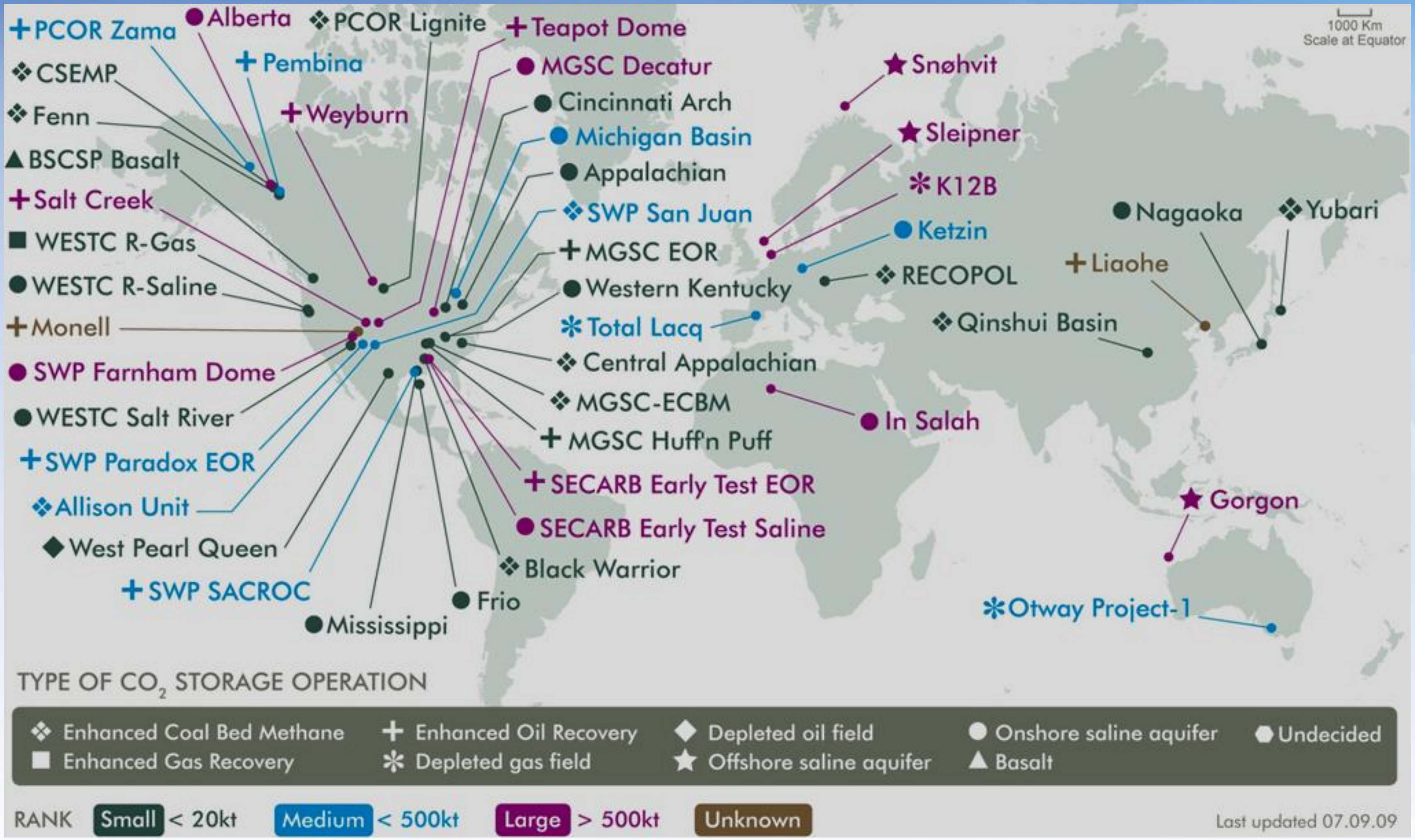
- Field on stream since 1996
- Contains 4 to 9.5% CO_2
- Need to reduce to 2.5%
- Elf – amine technology
- CO_2 – saline aquifer injection

In Salah

bp

- Field on stream since 2004
- Largest dry gas field in Algeria
- Jointly operated with Statoil
- 1,200 km south of Algiers
- 1 Million tonne CO_2 / year

Worldwide CO_2 Storage Programs – Examples



"CO2CRC Fact Sheets", www.co2crc.com.au, September 27, 2009.

Ongoing or Planned CCS Programs
(each program will develop valuable CCS advancements)

United States	Japan
Canada	Germany
United Kingdom	China
Italy	Australia
Norway	Netherlands
United Arab Emirates	Finland
France	Denmark
Sweden	Belgium
Spain	Other

Air Quality Systems on Fossil Power Plant and Carbon Capture Systems

(advancements in AQCS-CCS)

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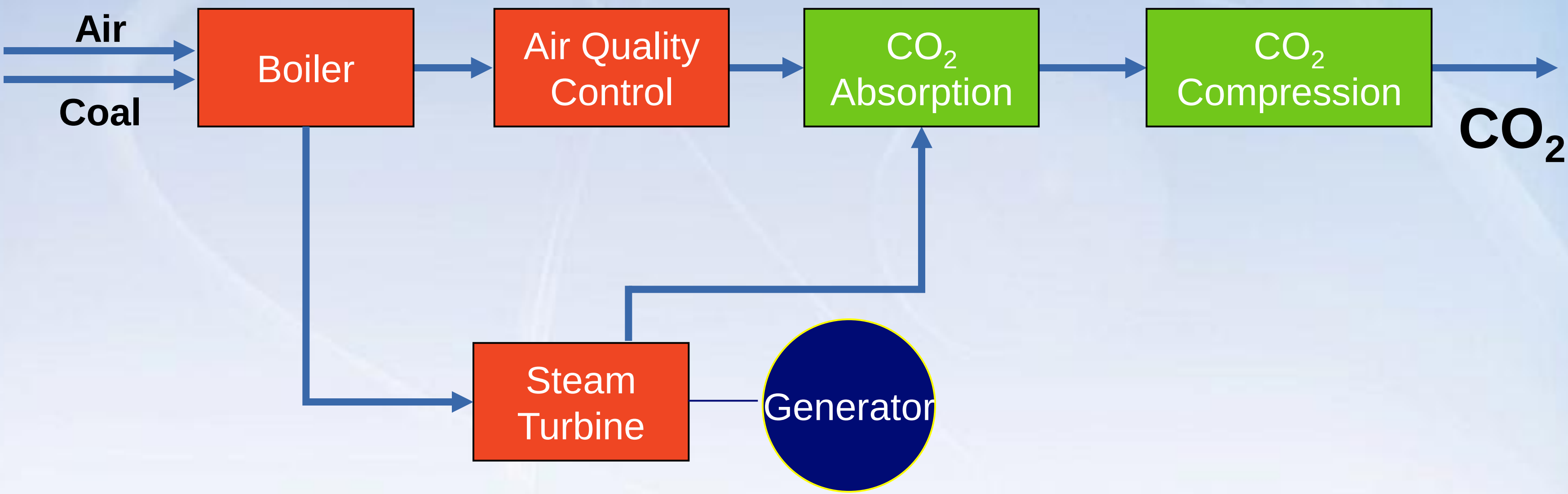
Coal – Fired Power Plant
Post-Combustion CO_2 Capture
(advancements of AQCS integration into CCS)



Air Quality Control Systems (AQCS) for Carbon Capture Ready (CCR) Fossil fired Power Plants

- AQCS primary purpose is to clean the flue gas to meet environmental stack emission limits
- Most CO_2 capture systems require (or can be optimized with) a relatively clean gas stream (e.g., PM, SO_2, HCl, NO_X, Hg, etc.)

Air Quality Control Systems (AQCS) for Carbon Capture Ready Fossil Fired Power Plants

(O&M, cost, and energy efficiency considerations)

- Nitrogen Oxides (NO_X)
- Particulate Matter (PM)
- Sulfur Dioxide (SO_2)
- Sulfur Trioxide (SO_3/H_2SO_4)
- Mercury (Hg)
- HAPs (future MACT, including HCl)

Nitrogen Oxide (NO_X) Control for CCR Coal-Fired Power Plants

(advancements to reduce NO2 heat stable salts in CCS)

- Boiler low NO_X burners
- Boiler staged combustion
- Selective non-catalytic reduction (SNCR)
- Selective catalytic reduction (SCR)
- Other systems

Particulate Matter (PM) Control for CCR Power Plants

(advancements to reduce solids in CCS system)

- Electrostatic precipitators (ESP)
- Fabric filters (PJFF)
- Other types

Acid Gas Control (SO_2 and HCl) Control for CCR Coal-Fired Power Plants

(advancements to reduce acid gases caused heat stable salts in CCS)

- Circulating dry scrubbers (CDS) flue gas desulfurization (FGD)
- Spray dryer absorber (SDA) FGD
- Limestone or lime wet FGD (LSFO)
- Sea water wet FGD (SWFGD)
- Other systems

Sulfur Trioxide (SO_3) Control for CCR High-Sulfur Coal-Fired Power Plants

- Low oxidation SCR catalyst
- Sorbent injection (dry chemical or wet chemical injection)
- Wet electrostatic precipitators (WESP)

Mercury (Hg) Control for CCR Coal-Fired Power Plants

- Additives for coal fuel (convert neutral mercury to ionic mercury during fuel furnace combustion)
- SCR catalyst mercury oxidation (convert neutral mercury to ionic mercury)
- Sorbent injection into flue gas (such as powdered activated carbon or other types of sorbents)
- Wet or dry type FGD systems to remove ionic mercury
- Wet FGD system chemical additives (to minimize neutral mercury re-emission)

Multi-Pollutant (NOx, PM, SO_2, Hg) Control CCR Coal-Fired Power Plants

- ReACT™
- Powerspan™
- Other types

Air Quality Control Systems for CO_2 Capture & Storage (CCS) Systems

(advancements)

- The potential benefits of AQCS on CCS include:
  - optimized energy efficiency,
  - reduced operation & maintenance (O&M) costs of CCS,
  - decreased equipment size and real estate of CCS system,
  - decreased installed capital cost of CCS,
  - improvement in reliability of CCS operation.

- **Question**: Does the CCS system require additional gas cleaning beyond what the CO_2 Capture Ready (CCR) power plant AQCS has already provided (e.g., upgraded FGD, CCS deep FGD, reduced PM, flue gas cooling, etc.)?

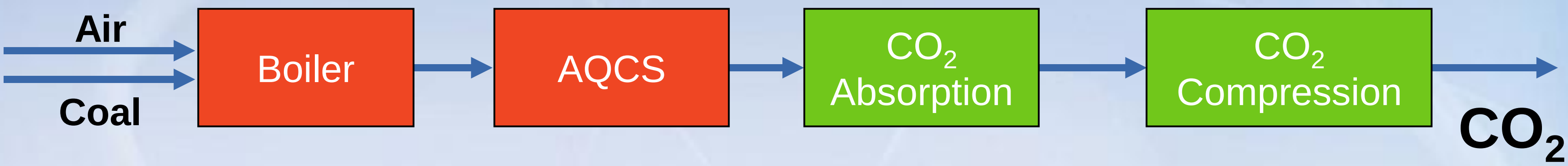
Stack Flue Gas Composition after AQCS and Post-Combustion CO_2 Capture

(advancements)

- AQCS significantly reduces stack emissions (e.g. NO_X, PM, SO_2, SO_3, H_2SO_4, HCl, and Hg).
- CO_2 capture system further reduces stack emissions, depending on % of total flue gas treated by CO_2 capture system (e.g., CCS bypass).
- CO_2 capture system may further lower the flue gas temperature (e.g., stack flue gas dispersion issues).
- Stack flue gas from CO_2 capture system is N_2, O_2, H_2O, CO_2, and trace components (e.g. CCS solvent).
- CCS may have its own stack (depends on site specifics)

Carbon Dioxide Product Composition from a CO_2 Capture System

(AQCS considerations)



Type of AQCS can influence the composition of the CO_2 product and byproducts produced from CO_2 capture system.

Liquid compressed CO_2 product from a CO_2 capture system consists of mostly CO_2, some N_2, and trace O_2, H_2O, and other components.

Energy Efficiency, Economics and Managing Risk

(advancements)

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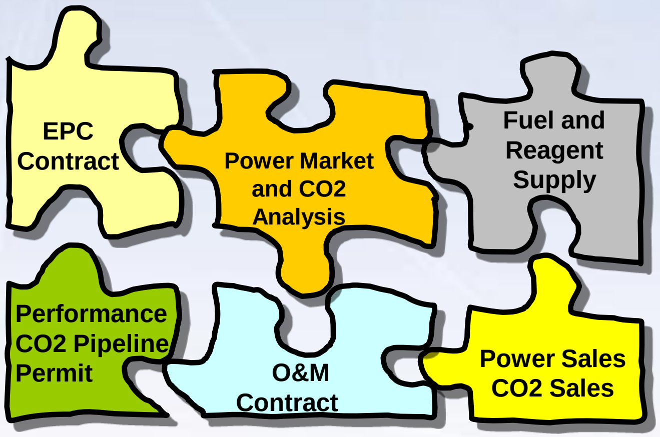
Project Economics and Managing Risks

(advancements in CCS energy efficiency are important, but not the only issue)

- Technology scale-up (advancements)
- Installed capital cost (material and labor)
- Annual energy and operation & maintenance costs
- Carbon dioxide value or liability ($/ton, sale price, carbon credits, disposal cost, etc.) and disposition



Process Parameters Influencing CO_2 Capture Systems

(advancements)

- Percent (%) of total flue gas that is treated
- Percent (%) removal of CO_2 removed from flue gas
- Total mass of CO_2 (tonnes/day) removed from flue gas
- Type of CO_2 capture process chosen
- Degree of flue gas pre-treatment (if required)
- Storage of CO_2 product

Process Parameters Influencing Annual O&M and Energy Costs of CO_2 Capture Systems

- Total mass of CO_2 removed (tonnes/day) from flue gas
- Type of CO_2 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)
- O&M costs of flue gas pre-treatment (if required)
- Storage of CO_2 product
- Other issues

Key Issues Concerning CCS
(advancements)

- CO_2 capture system design **must** address energy issues.
- CO_2 capture technologies are available for pilot or demonstration
- CO_2 capture technology demonstration systems are being installed
- CO_2 capture process **greatly impacts** PC plant or NGCC power plant
- Long-term operating experience is needed (steady-state, load-following, & upset conditions)
- ***Significant*** cost issues (capital and annual O&M, including energy)
- CO_2 can be used in enhanced oil or gas recovery projects
- CO_2 storage projects (geological, saline, or depleted oil/gas reservoirs)
- New and/or improved power plant designs and CO_2 capture technologies being developed

Summary – Advancements

- Advanced efficient electric power production technologies are available.
- Improved Air Quality Control Systems (AQCS) are available for Carbon Capture Ready (CCR) coal fired power plants.
- CCS demonstration programs are being conducted, providing technology advancements, including addressing energy efficiency issues.
- Long-term operating experience is needed (steady-state, load-following, & upset conditions)
- New and/or improved power plants and CCS technologies are being developed.

Contact Information

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Thank You

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Carbon Dioxide Capture and Storage (CCS) Technology Advancements

Christopher Wedig – Shaw Power Group

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Reinhold Environmental
2010 - NOx Combustion Round Table – PCUG Conference
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Chattanooga, Tennessee

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