Carbon Dioxide Sequestration Potential in Coalbed Deposits

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Introduction

The concept of using gassy unmineable coalbeds for carbon dioxide (CO2) storage while concurrently initiating and enhancing coalbed methane production may be a viable near-term system for industry consideration. Coal is our most abundant and cheapest fossil fuel resource, and it has played a vital role in the stability and growth of the U.S. economy. The energy source is also one of the fuels causing large CO2 emissions with the burning of coal in power plants. In the near future, coal may also have a role in solving environmental greenhouse gas concerns with increasing CO2 emissions throughout the world. Coal resources may be an acceptable "geological sink" for storing CO2 emissions in amenable unmineable coalbeds while significantly increasing the production of natural gas (CH4) from gassy coalbeds. Industry proprietary research has shown that the recovery of coalbed methane can be enhanced by the injection of CO2 via well bores into coal deposits. Gassy coals generally have shown a 2:1 coal-sorption selectivity for CO2 over methane which could allow for the potential of targeting unmineable coals near fossil fueled power plants to be utilized for storing stack gas CO2. Preliminary technical and economic assessments of this concept appear to merit further research leading to pilot demonstrations in selected regions of the U.S.

Background

On a worldwide basis, fuel use and carbon emission increases derive principally from increased generation of electric power and increased use of motor fuel for transport. In both developed and developing areas of the world, electricity demand has increased faster than economic growth. In developed countries, electricity demand doubled between 1970 and 1990. In developing areas, the increase was 300 percent. For most countries, fossil fuels continue to represent the main incremental fuel source to meet increased electric power needs.[1]

Estimated coal resources in the U.S. total nearly six trillion tons (Figure 1) to a depth of 6,000 feet with 90% of this amount considered unmineable with current technology.[2] Unmineable coals are either too thin, too deep, or too unsafe. In recent times, historically mined coals may also be too high in sulfur or ash or too low in Btu value to be economically profitable. These coals, however, represent a widely dispersed potential sink for CO2 storage while at the same time recovering methane for commercial use.

For the past 25 years the U.S. Department of Energy has been facilitating the evolving recognition and development of coalbed methane resources and technologies. The concept of using gassy unmineable coalbeds for CO_2 storage while increasing coalbed methane production is already being field tested by industry. The CO_2 used in this concept has positive economic value in this approach. Unlike CO_2-enhanced oil recovery, the CO_2 is subsequently co-produced, injected CO_2 is sequestered in the reservoir by sorption to the coal surface. The mechanism is that the CO_2 displaces the sobbed CH_4 from the coal surface, two molecules of CO_2 being trapped for every molecule of CH_4 released. Initial field projects of CO_2 injection into coalbeds have shown increased yields of produced CH_4 over conventional coalbed methane recovery efforts.[3]

Approach

Coal is formed over thousands of years by the biochemical decay and metamorphic transformation of the original vegetable matter. This process, known as "coalification, " produces large quantities of by-product gases. The volume of by-product gas increases with the rank of coal, and is the highest for anthracite coal. Most of these gases escape to the atmosphere during the coalification process, but a small fraction is retained in the coal. This source of methane has been a "rediscovery" of a natural energy resource in during recent decades. During the last decade, coalbed methane has been commercially produced in many of the coal bearing counties, most notable the U.S. and Australia. In the U.S. more than one trillion cubic feet (Tcf) of coalbed methane is now being produced (Figure 2) and meeting about 6% of the total natural gas demand.[4]

Coals are both source and reservoir rocks for major quantities of natural gas. Large amounts of natural gas are generated in coalbeds throughout their burial history by both biogenic and thermogenic process. Coalbed gas is variable in molecular and isotopic composition. In addition to methane, they can contain significant amounts of heavier hydrocarbons and CO_2. The primary controls of hydrocarbon gas composition are coal rank and composition, and depth/temperature. Coalbed gas is stored (sorbed) upon and within the molecular structure of the coal. As a result, coal has the ability to hold much more gas than the same rock volume of a conventional reservoir in which gas occurs as a free or dissolved phase. The amount of gas stored is a function of rank, pressure, and temperature.[5]

Matrix permeability is essentially nonexistent in coal and flow pathways for gas are provided by the fracture (cleat) system (Figure 3). Nearly all coals contain at least some water either from inherent or from adjacent aquifers. Economic quantities of natural gas can be produced from coalbed reservoirs; desorption results from dewatering and subsequent depressurization of the coalbeds. The main environmental concerns about coalbed gas extraction are related to methane emissions from coal mining and disposal of produced water. However, significant amounts of methane can be captured prior to and during mining, and the water produced and disposed of in an environmentally acceptable manner, such as in injection wells. The US DOE is sponsoring evolving submerged evaporation technology which utilizes coalbed methane as a fuel source to evaporate produced brine waters from gas wells or mining operations.

World Wide Resource

Coal is the most abundant energy source in the world with reserves estimated to be more than one trillion metric tons. With the expansion of global economics, particularly in underdeveloped countries, world coal production has been increasing rapidly on a yearly basis. Total production total more than five billion metric tons in (1990) with China alone producing more than one billion metric tons.[6] The presence of methane-rich gas in coal has been recognized for a long time because of mine explosions and gaseous outbursts associated with underground mining. Only recently has coal been recognized as a reservoir rock as well as a source rock for natural gas.

Production for coalbed methane can be traced back to Europe during the late 19th century. The Big Run gas field in north-central West Virginia began during the 1930's and is known for early historical production of natural gas from a coalbed in the U.S. This field today is still producing after 65 years from the Pittsburgh coalbed. By the late 1970's some commercial production of coalbed gas had also been established in the Black Warrior (Alabama) and San Juan (Colorado and New Mexico) basins in the U.S.

The U.S. Department of Energy began extensive coalbed methane research, development, and demonstration efforts in 1977 and has been involved for the past twenty years in supporting expanding development of this large energy resource. Significant exploration for and production of coalbed gas in the U.S. began in the mid-1980's mainly because of a Federal tax credit given for the production of coalbed gas. The tax credit (Section 29) not only increased drilling activity, but was also responsible for the development of new drilling and completion technology.

Worldwide coal resources with a high affinity for CO2 may be an attractive “natural sink” for sequestering emissions of CO2 as disposal options are evaluated. Each of the coal bearing and coal producing countries throughout the world may have a feasible opportunity for CO2 disposal with their own borders. Unmineable coalbeds may present a viable option for long-term CO2 storage possibilities while providing the potential for producing more coalbed methane as a valuable energy source.

Description of Technologies

The underground (geological) disposal of industrial quantities of carbon dioxide (CO2) offers a path for continued use of fossil fuels, especially coal, with greatly reduced emissions of CO2 from fossil fuel fired power plants is its cost. Most of the cost is incurred by the necessity to separate the CO2 form, or concentrate it in, the flue gas. This cost is expected to vary widely, depending on the type of power plant and separation technology considered, but is in the range of $27-65 per ton CO2 avoided. A realistic cost of $40 per ton of CO2 collected and sequestered would increase the cost of electricity generation by at least 2 cents/kWh, 40% above current levels.[7]

The preferred underground storage concept is injection via wells into deep reservoir rocks capped by very low permeability seals such as shales or claystones. Much of the CO2 will be stored in a free state, or dissolved in the formation water of the reservoir. However, a natural mineral trapping mechanism may exist in certain sandstone reservoirs. Advantages of underground disposal include retention of the CO_2 for times scales of tens of thousands of years. In reality, the potential effects of leaks from the storage reservoir would have to be assessed on a site-specific basis. At a minimum, it may be possible to store CO_2 for several hundred years, with confidence that almost all of it will stay where it is put. These factors form the basis for distinguishing between the various technical possibilities. (Figure 4)

The concept of using gassy unmineable coalbeds for CO_2 storage while initiating and enhancing coalbed methane production is a viable near-term economic system for industry consideration. This geological "sink" option for CO_2 storage while increasing CH_4 production enhances the economics of "co-firing" or "re-burning" methane and coal or solely methane for power at nearby coal-fired power plants while furthering reduction in emissions from the stack. (Figure 5)

Application

The coupling of existing and evolving CBM technologies with innovative strategies for a CO_2 disposal into unmineable coalbeds is considered by the US DOE an important technical and economic option to be considered for CO_2 sequestration. The goals and objectives of this unique approach complement the U.S. Department of Energy's Climate Change Action Plan as well as overall efforts to reduce greenhouse gas (GHG) emissions in accordance with the Framework Convention on Climate Change (1992).

The benefits for considering and using unmineable coalbeds for a system concept of CO_2-CH_4 cycle include the following:

- CO_2 is captured from power plant flue gas, pressurized, and transported to injection well completed in deep unmineable coals.
- Coals near existing power plants have enormous capacity to store CO_2 while enhancing CH_4 production.
- Coal reserves underlie many U.S. power plants with as many as 90% estimated as unmineable.
- Power plants near gassy coalbeds have the potential for injection of CO_2 from the flue gas into coalbeds while enhancing the methane production to be used in co-firing strategy.
- Injection of CO_2 into unmineable gassy coals allow for displacement of one molecule of the sorbed CH_4 while two or more molecules of CO_2 are sequestered on the coal surface.
- Subsequent concept meriting R & D should focus on direct flue gas injection into coals - possible revealing new problems but having additional advantages.

International Cooperative CO_2- CH_4 Project Well

An international consortium of Canadian and U.S. organizations have entered into an agreement to develop new technology to reduce greenhouse gas emissions. The technology also shows promise in enhancing the production of Canada's large coalbed gas reserves, potentially making it an economically attractive approach to limiting CO_2 emissions. The work, being led by the Alberta Research Council, is attracting international attention. It is being supported jointly by the U.S. Department of Energy and Environment Canada, as well as a number of industry partners. It was one of several projects recognized as part of the International Energy Agency's (IEA) Climate Technology Initiative (CTI), at the Third International Conference of the Parties (COP3) recently held in Kyoto, Japan, in December 1997.

The project is testing the process of injecting CO_2 into Alberta's vast deep unmineable coalbeds. The concept focuses on CO_2 being adsorbed on the coal surface while displacing the trapped coalbed methane. Application of this new process by the utility industry would lower their CO_2 emissions and produce methane, a valuable energy source. An abundance of deep coalbeds in the U.S. and Canada make geological sequestration of CO_2 in coalbeds applicable to many regions where coal-burning power plants are located.

Future Activities

Climate change technology advances are key to: 1) Keeping energy prices as low as possible for consumers, and 2) maintaining the profitability and long-term survival of the fossil fuel industry while improving the environmental and climate conditions in the U.S. Affordable electricity and other forms of energy from fossil fuels is critical to our Nation's competitiveness in the global marketplace. The U.S. will continue to rely heavily on lowcost fossil fuels to power the commercial, residential, industrial, and transportation sectors of our economy. In the future, technology advances can lead the U.S. toward more cost-effective disposal of carbon dioxide, particularly from geologically targeted strata which heretofore may not have been of any significant usefulness until the climate change issue gave value to their ability to store CO_2.

The near-term economic viability of CO_2 sequestration strategy to be considered by the utility energy industry (electric, coal and gas) will potentially hinge on the continued economic production / transportation of electricity from coal, and also on the concurrent economic production of nearly coalbed methane reserves. The economic profit from the coalbed methane production is an integral economic part of a "co-firing - re-burning system" in order to pay (not counting any yet-to-be allocated CO_2 - CH_4 reduction credits) for the expense of the CO_2 infrastructure (separation / recovery technology from flue gas, pipeline transportation, and well-injection technology) will be required to make this "CO_2-CH_4 system" concept operate effectively and efficiently.

Widespread acceptance by industry of these applied and evolving technological efforts may require demonstrations in many phases of the energy production / utilization. Also, some applied scientific R&D for system characterization may be necessary. Commercialization of these technologies may require several years of pilot demonstration partnerships with industry. The federal - industry partnership program will be an opportunity for helping to instill confidence in these evolving technologies which have worldwide application.

References

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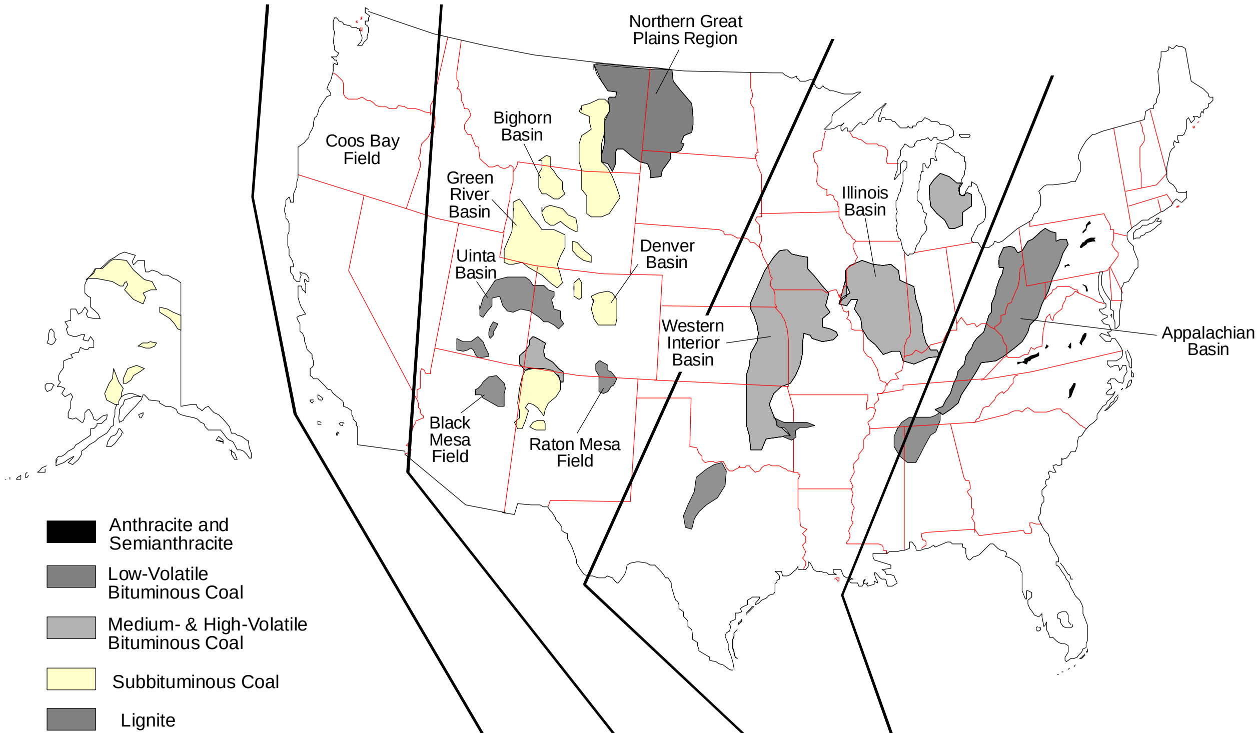
Illustrations

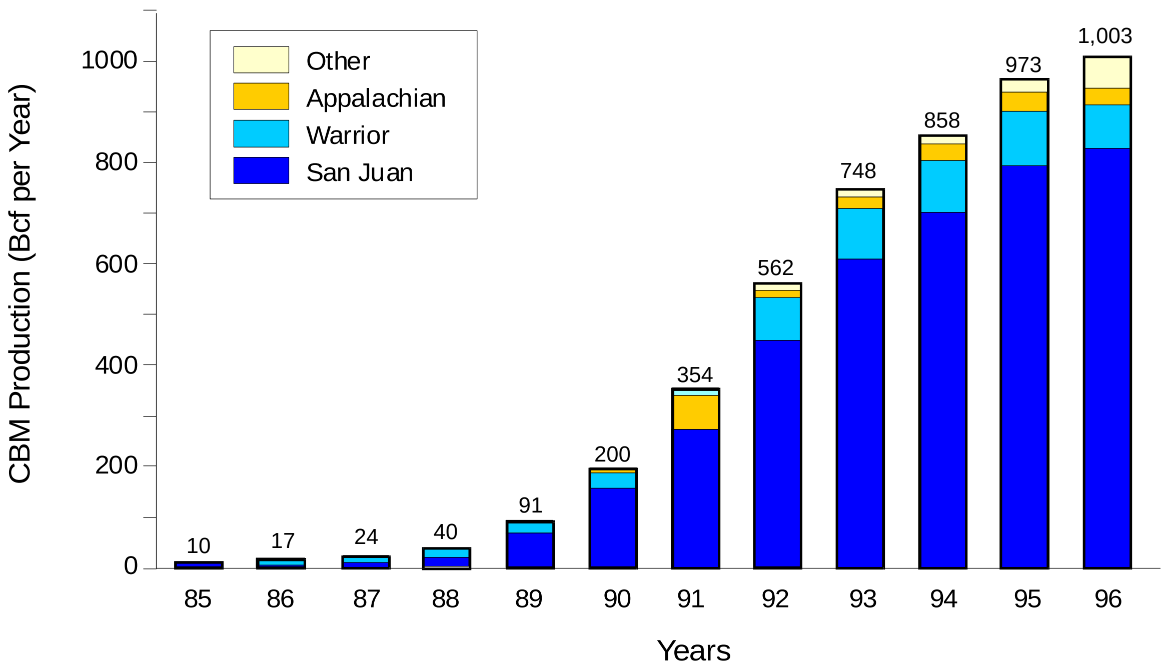
Estimated Coal Resources in the United States

- 90% is Considered Unminable



Total Coal to 6000 Feet	2030	100	3260	620	350	Total = 6360
Mineable Reserves	12	2	200	110	110	Total = 430
UCG Resource	640	20	920	140	80	Total = 1800

Coalbed Methane Production in the U.S. Has Grown Rapidly, Now Accounts for 6% of Total U.S. Gas Production



Source: Advanced Resources International, Inc.

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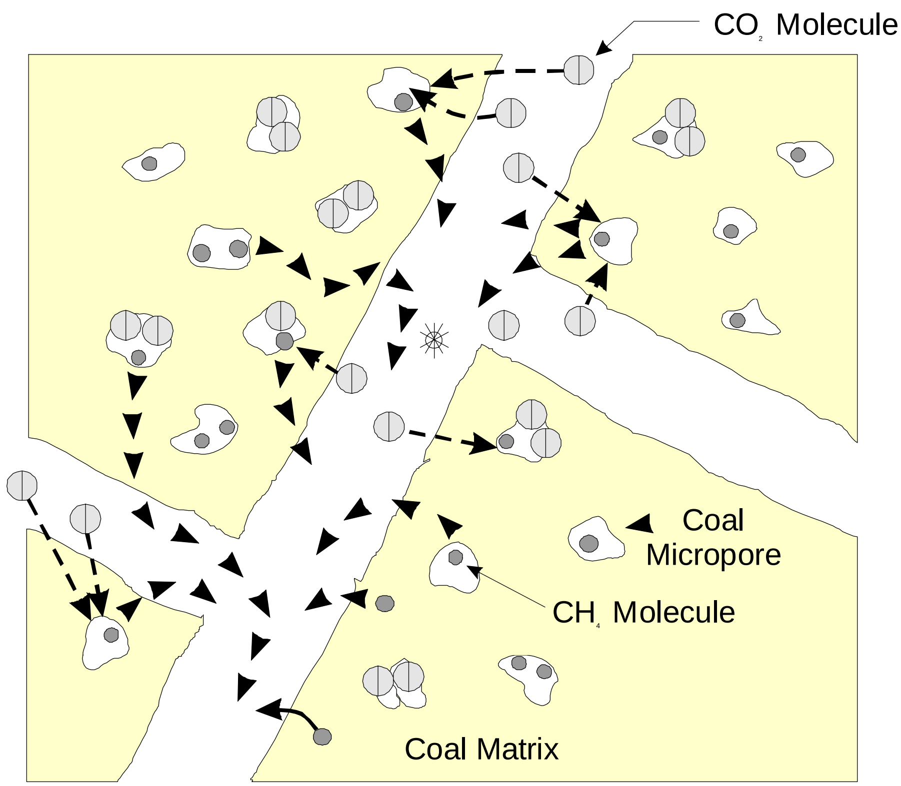
Sorption /Affinity Exchange CO_2 - CH_4



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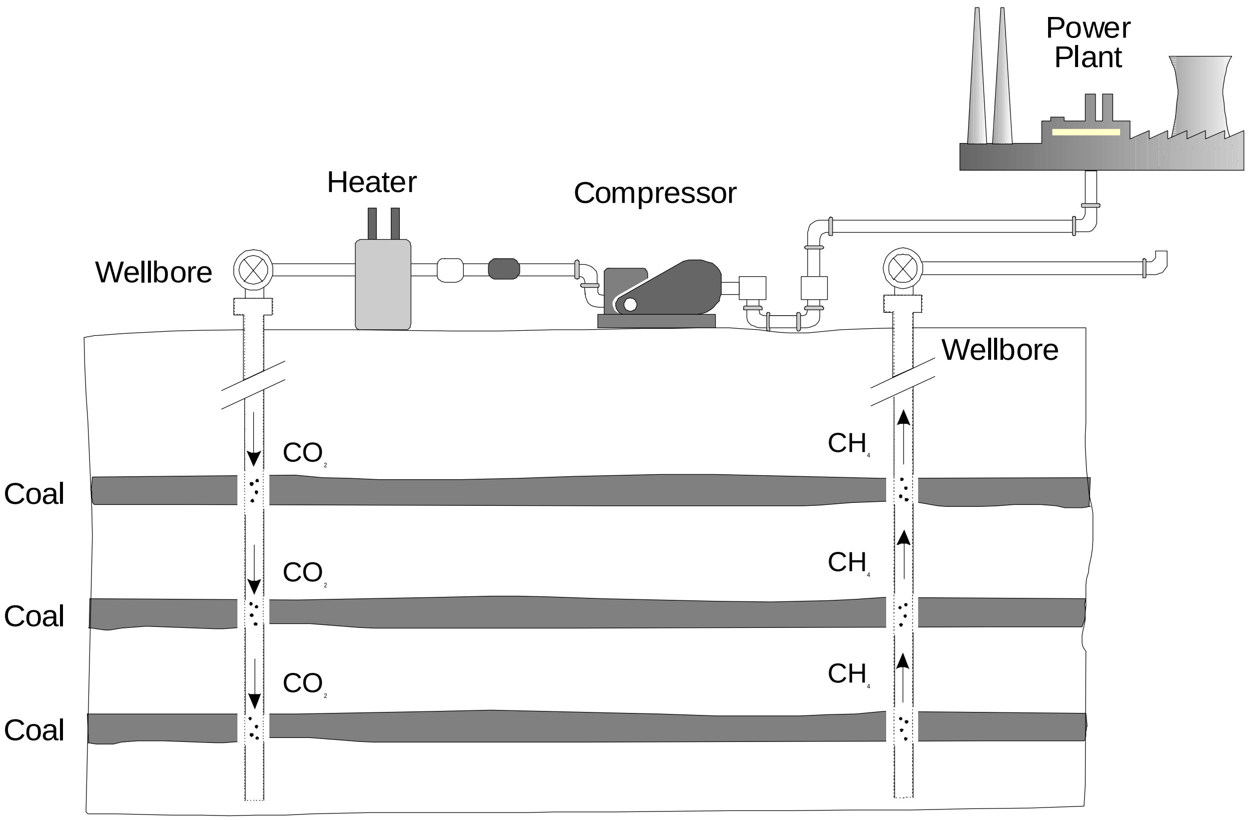
Sequestering CO_2 in Coalbeds



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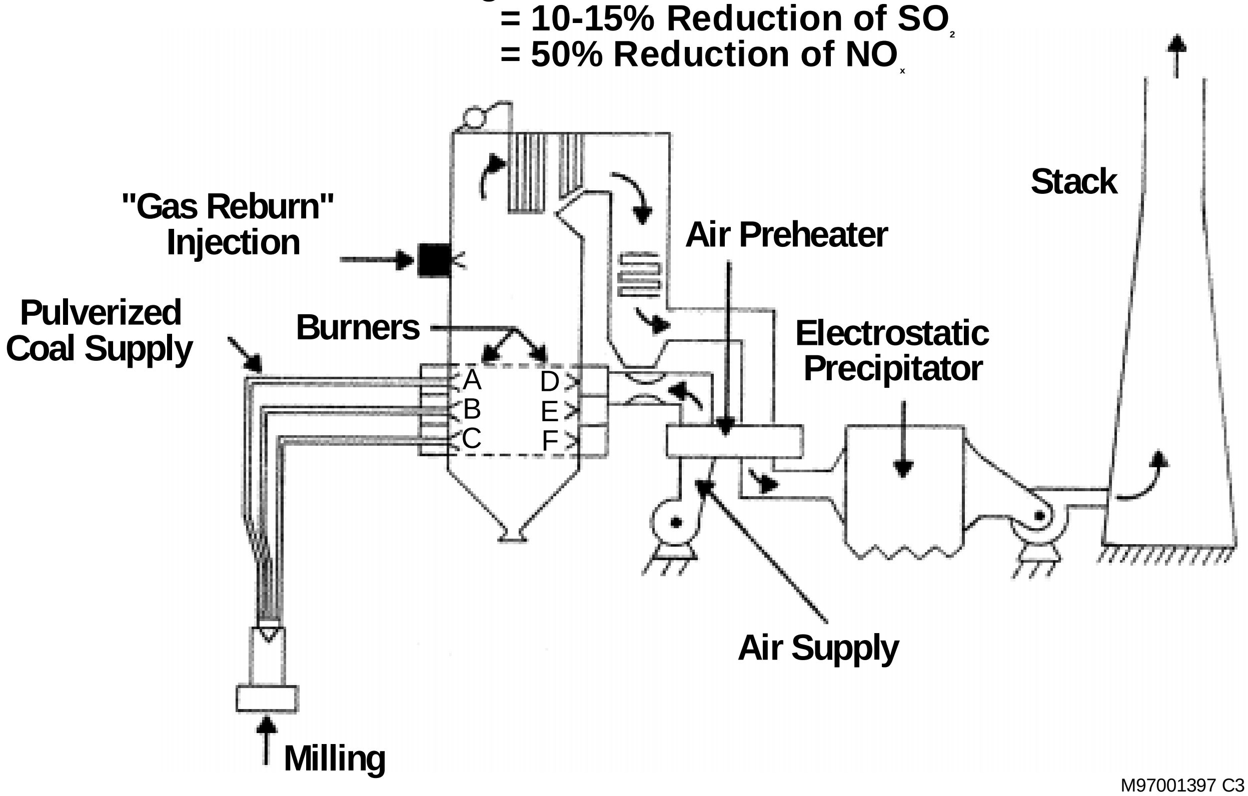
Near-Term Use of Coalbed Methane: Co-firing and Reburning Potential

Co-Firing = 90% Coal and 10% Gas
= 10-15% Reduction of SO_2
= 50% Reduction of NO_x



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