

Economical Point in Sequestering CO₂ into Coal Bed - Methane Production on Based Turkish Coal Mines

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Abstract—Unmineable coal seams can be used to store CO₂ because the CO₂ molecules fill the pores and attach to the surface of coal. The technical feasibility, however, depends on the permeability of the coal bed. In the process of filling pores and absorption to the coal surface, the sequestering the CO₂ in coal mines releases methane in Turkish coal mines. Burning the resultant methane, however, would negate some of the economic view of sequestering the CO₂. Economic advantages of the sequestering the CO₂ were defined for economical view by coal bed methane gas production and green energy production in Turkey. Also economic view of designed work was comprising sequestering the CO₂ into the coal bed in order to improve coal bed methane production in Sırnak Asphaltite Coal Mines. CO₂ capturing, transporting and sequestering costs with methane drainage decreased from original cost of 14 \$/ton CO₂ to near 11\$/ton of CO₂.

Keywords- CCS; capturing and storing CO₂; sequestering the CO₂; Cost of CO₂; coal bed methane

I. INTRODUCTION

Turkish Energy Agency adopting clean coal to fill the immediate energy gap would also help us set the right example internationally and encourages the meeting of emissions targets globally. Countries such as China, India and the US produce more than 30 times more carbon emissions than the UK and must be encouraged to clean up their coal powered plants. Clean coal technology is the best solution for the short-term if we are to avoid overdependence on imported gas. Clean coal provides the means to achieve the economical objectives set out in the energy production. The green energy is just the required step in coal power plants. The power plant firms must take serious actions now, or the costs will go up.

The absorption technology for capturing carbon dioxide from natural gas streams was developed more than 60 years ago to produce a more pure natural gas stream. The technology of sequestering carbon dioxide from a power plant's flue gas was first implemented more than 20 years ago. When the price of oil rose in the late 1970s, owners of oil wells created a demand for carbon dioxide for use in enhanced oil recovery (EOR). Carbon dioxide's ability to increase the productivity of an oil reservoir created value for the CO₂. In response, several commercial CO₂ capture plants were constructed in the United States [1]. As the price of oil fell in the mid-1980s most capture plants shut down. However, the North American Chemical Plant in Trona, CA, which was built in 1978, still produces CO₂ to carbonate brine

for the use in producing soda ash. Other plants have been subsequently built for other commercial purposes and over a dozen are in use today for various purposes across the globe [2]. Electricity generation and industrial processes release large amounts of carbon dioxide (CO₂), the primary greenhouse gas (GHG). In 2010, coal- and natural gas fueled electricity generation accounted for approximately 80 percent and 18 percent, respectively, of CO₂ emissions from the U.S. electricity sector; together, they accounted for almost 33 percent of all U.S. GHG emissions [3-6]. Not including its electricity use, the industrial sector's CO₂ emissions accounted for an additional 14 percent of total U.S. GHG emissions. The combustion of fossil fuels accounted for approximately 82 percent of the industrial sector's CO₂ emissions, while industrial processes accounted for approximately 18 percent. Going forward, coal and natural gas will remain major sources of energy for Turkey and global power and industrial sectors. In Turkey, both coal and natural gas are in relatively abundant supply and are relatively inexpensive electricity generation sources [6]. In 2011, Turkey generated approximately 26 percent of its electricity from coal and 48 percent from natural gas. Globally, coal and natural gas will continue to meet growing energy demand, particularly in emerging market countries, such as China and India [2, 4]. From 2007 to 2011, China's total coal consumption increased by nearly 50 percent, while India's increased by nearly 33 percent. During that same time period, China's total natural gas consumption increased by more than 85 percent, while India's increased by approximately 48 percent. CCS technology has the potential to yield dramatic reductions in CO₂ emissions from the power and industrial sectors by capturing and storing anthropogenic CO₂ in underground geological formations. Given the magnitude of CO₂ emissions from coal and natural gas fired electricity generation, the greatest potential for CCS is in the power sector.

Currently, CCS has been deployed at commercial-scale natural gas processing, fertilizer production, and synfuel production facilities. Many great researches are carried out in order to determine suitable CCS fields. The first commercial-scale natural gas storage fields were determined and gas storage plants were built in Turkey. However many old coal mine sites may be expected to be searched in operation by 2014.

Our main contribution is in analyzing the economic issues related with methane drainage enhancement, which can be seen as a follow-up to the technical issues. CCS technology may become available in the Turkish market and that current cost

projections and expected efficiencies may be rational values. We may see profit-maximizing conditions in the methane drainage and gas market. Methane production may retrofit to install CCS in power plants under plausible values of an environment tax.

A. Transfer CO₂ to Coal Seam

The physical absorption process is a better option due to the lower energy requirements. It can be used in the gasification processes because of the higher partial pressure of CO₂ compared to flue gases. Other processes like membrane separation, cryogenic fractionation, and adsorption technologies are also possible to separate the carbon from the flue gases (Figure 1) [2,6,7].

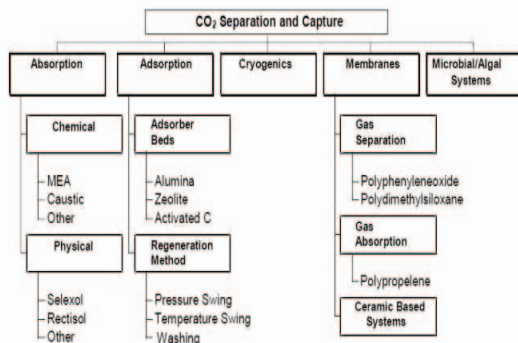


Figure 1. CO₂ separation options using membrane separation, cryogenic fractionation, absorption and adsorption [3].

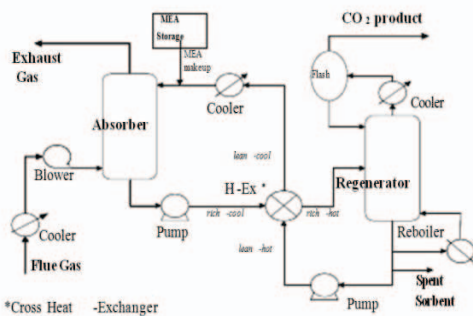


Figure 2. CO₂ capturing process with amine solutions[3].

However, those are even less energy efficient and more expensive than chemical absorption [3]. In absorption processes (Figure 1), the flue gas is continuously passed through the liquid solvent, which absorbs the CO₂. The CO₂ is then released by raising the temperature or lowering the pressure. Typical chemical solvents are amine or carbonate based, such as monoethanolamine (MEA), diethanolamine (DEA), ammonia and hot potassium carbonate [3]. The physical absorption process is similar and typically uses solvents such as Selexol® (dimethylether of polyethylene glycol) and Rectisol® (cold methanol). These processes are known to be the most

economical and energy efficient of the capture technologies [8-11].

B. Storage to Geo Deposits

Enhanced oil recovery would be an inexpensive option with good storage integrity, and it has been used in the past. Part of the sequestration costs would be offset by the value of the oil recovered, which depends on the price of oil. The amount of CO₂ that could be sequestered this way is small. The IPCC estimated that about 1% of annual anthropogenic CO₂ emissions could be used for enhanced oil recovery. These reservoirs have already proven their ability to contain pressurized fluids for a long period of time and worldwide capacity is judged to be on the order of 100 GtC (100 billion tons) of atmospheric carbon [12]. The cost estimations rationally reach to certain limits of 35-80\$/t CO₂ [13-17]. In fact, depleted oil and gas reserves appear to be the most promising land storage option in the near term [18-20]. In the longer term, deep saline aquifers may be the best storage option [21, 22]. These aquifers are almost ubiquitous. Sequestration costs have been estimated to range from 7\$ to 30 \$/t C [21]. However, the storage integrity is uncertain [18-22].

II. PROJECT WORK

Methane recovery will be a less cost integrated option in coal mining with even good storage of CO₂ in old mine space. Low quality coal seams excavated and left behind production site are becoming suitable for CO₂ storage and even methane drainage can be made. The amount of CO₂ that could be sequestered this way is small. Hence, storage in coal seams is a viable option in terms of its cost, storage integrity, and improved methane drainage capacity. The cost is judged to be less than \$3/t CO₂. In this experimentation, the coal mine in Sırnak was evaluated for enhanced coal methane drainage and production (Figure 3).



Figure 3. 1/10000 Coal Bed Methane Drainage Site in Coal Mine Site, Sırnak, Turkey.

CO₂ capturing and transport costs are widely changed in various industrial CO₂ sources (Table 1). Hence, CO₂ source of coal power stations will be benefited in this site for drainage. Almost CO₂ capturing and transporting cost will be lowered on that local coal combustion. CO₂ capturing and transporting costs

of Power station in Silopi, almost 30km near to Sırnak Coal Mine was lower than those of other industries such as cement plant in Mardin almost 350km far to Sırnak Coal Mine.

TABLE I. INDUSTRIAL COST OF CO₂ CAPTURE AND TRANSPORT.

Industrial CO ₂ Source	Cost of CO ₂ Capture and Transport (\$/ ton CO ₂)
<i>Coal and biomass-to-liquids</i>	36.10
<i>Natural gas processing</i>	36.29
<i>Hydrogen plants</i>	36.67 to 46.12
<i>Refineries (Hydrogen)</i>	36.67 to 46.12
<i>Ammonia plants</i>	39.69
<i>Ethanol plants</i>	42.15
<i>Cement plants</i>	81.08

Methane drainage is carried out in 5km wide area and every drilled drainage holes are separated in 80m length and all the holes are connected to central methane collection tank. The methane coal seam gas and biogas collected in the site will separately put into 2 tanks after drainage and evaluated with the lower phase in electricity generator. Costs of coal seam methane drainage and drills are fundamentally determined with scale up calculations.

A. Probable Cost

The method used for cost estimation is independent of fuel cost and depended on variables such as coal mining parameters and coal seam parameters. After serial addition of costs, the main CO₂ capturing and transporting and sequestering costs for 135MW power station are given in Table 2.

TABLE II. PARAMETRICAL COST OF PLANT

Parameter	Units	Sırnak Plant	w/CO ₂ Control
Net plant capacity	MW (net)	135	75
CO ₂ emission rate	g CO ₂ /kWh (net)	750	83
SO ₂ emission rate	g SO ₂ /kWh (net)	15	0.003
NO _x emission rate	g NO _x /kWh (net)	0.4	0.5
CO ₂ sequestered	60 tonne CO ₂ /yr	-	5
Cost of electricity	\$/MWh (net)	39.2	57.0
CO ₂ mitigation cost	\$/tonne CO ₂ avoided	-	39.1

The precursors which are used for both flue gas desulphurization and CO₂ capturing are evaluated in cost. Power plant commonly manages desulfurization in combustion boiler chamber. However, amine capturing method used in CO₂ capturing can also desulfurize exhaust gas of power station. The main parametric costs of plant are given in Table 3 for MEA, MEA+FGD and MEA+FGD upgrade conditions.

III. COST BY COAL BED METHANE GAS

According to the proposed project studies over coal bed methane drainage, it is calculated that at almost 40% drainage

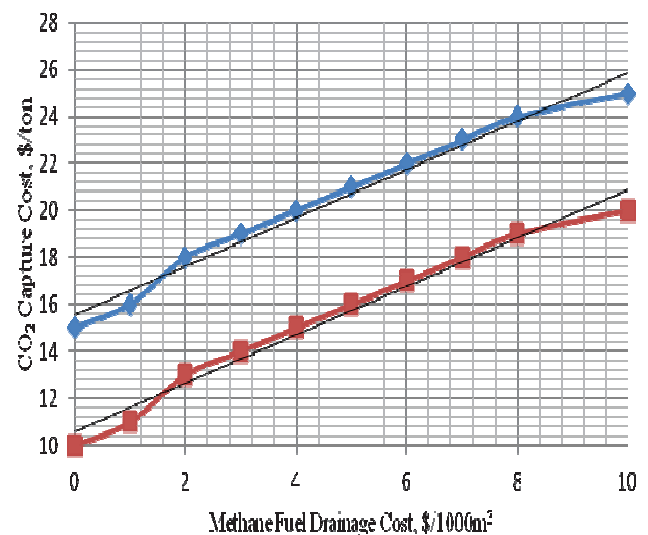
performance methane gas could be received in the mine site and methane gas collected at average near 2,7m³/ton coal in Sırnak Coal Mine. Coal seam gas production may reach to 200.000m³/yr. Hence optimized resource usage in cost minimization could just be managed by iterative calculations.

TABLE III. PARAMETRICAL COST OF PLANT

Quantity	SırnakPlant no CO ₂ control	MEA only	MEA +FGD	MEA +FGD upgrade
Net power (MW)	135	100	75	75
COE (\$/MWh)	38.0	57	60	60
SO ₂ emission rate (g/kWh)	7.5	0.02	0.002	0.002
TotalSO ₂ emission(tonne/yr)	6,506	12	2	2
SO ₂ captureinFGD(tonne/yr)	0	0	5,600	5,600
SO ₂ captureinMEA(tonne/y)	0	6,300	250	250

At projected capacity at near 200.000 m³/yr of coal seam gas per year we can manage proposed 40% gas yield and the cost of methane drainage mainly was changed on drainage performances in coal production method in-situ excavation site (Figure 4).

CO₂ capturing and transporting and sequestering costs are decreased with flue gas desulfurization cost and even legal environmental taxes. Methane drainage will be enhanced with CO₂ capturing and transporting and sequestering in the old excavated coal seams. As given in Figure 4, it could be revealed that CO₂ capturing, transporting and sequestering costs with methane drainage decreased to near 11\$/ton of CO₂.

Figure 4. Effect of Methane drainage on CO₂ capturing transporting and sequestering costs with transporting and sequestering costs.

IV. RESULTS AND DISCUSSIONS

At projected capacity at near 200.000 m³/yr of coal seam gas per year we can manage proposed 40% gas yield by CO₂ capturing and sequestering. The sequestering cost with methane

drainage decreased from original cost of 14 \$/ton CO₂ to near 11\$/ton of CO₂.

Storage of CO₂ is necessarily designed with an extremely long term perspective. This raises issues of liability for the storage, particularly in the case that leaks that may occur in Turkish coal mines in future. In order to detect a leak in the storage or pipelines, a monitoring and regulatory body would need to be developed to assume responsibility of these roles. Funding required for these sorts of organizations need to be acquired, raising additional concerns over private industry should pay in Turkey. Owners of generating stations, the government or a private company could legally charge a fee to emitters. Considering that the actual storage duration remains far longer than the typical lifetime of a company, it would be ideal for coal companies to take on the serious precautions.

Turkish coal miner thinks that CO₂ could be classified as waste, depending on the purity of the CO₂ stream. A high purity requirement would greatly increase the cost of CCS. If legally classified as waste product, major obstacles would arise in developing transport and storage capacity for CO₂.

Carbon pricing or a carbon market should take in place in Turkey. There is a lack of guidelines to estimate the CO₂ emission savings associated with CCS. This makes it difficult to approximate the true value of CCS technologies. CO₂ may also be captured in one country, province or state and stored in another with differing commitments to CO₂ abatement and accounting practices. Rules and methods need to be adjusted to each coal miners in Turkey.

V. CONCLUSION

The present study has established a framework for quantifying amine (MEA) based absorption systems applied to coal fired power plants. The present study has confirmed that fuel methane cost especially depended on coal seam parameters such as methane drainage depth and local coal seam methane content and also applied to coal fired power plants.

Carbon dioxide capture and storage is politically attractive in the sense that it reduces emissions from reliable, demand-following energy supplies such as coal or natural gas-fired generating stations. This allows for progress in CO₂ emissions reduction, without significant implications to the power grid available to a specific jurisdiction. For CCS to be successful, government support is vital in order to provide funding and education to the general population. It is recommended that such initiatives be operated as experimental pilot projects with extensive public exposure. This would form a basis to move forward with research into legal strategies which would ease the implementation of future systems. The long term cost of CCS is expected to decrease due to the learning effect from earlier projects, its economies of scale, carbon pricing, increased public support and development of clusters with common interests.

ACKNOWLEDGMENT

The authors would like to thank Giresun University instrumental analysis support. The authors also gratefully acknowledge Prof. Dr. Aygün Attar their helps on analysis.

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