CO_2 EMISSION AND CARBON CAPTURE FOR COAL FIRED POWER PLANTS IN MALAYSIA AND INDONESIA

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ABSTRACT

Coal consumption in Malaysia and Indonesia is growing at the rate of 9.7 and 4.7% per year since 2002, respectively. The increase in coal utilization usually tallies fairly well with the increase in CO_2 emission. The present study attempts at predicting the emissions of CO_2 from coal fired power plants from 2005 until 2020. The paper also analyzes the potential of carbon capture (CC) program as a source of foreign direct investment in Malaysia and Indonesia. The perceived emission rate is based on the percentage of coal for energy mix and coal consumption for electricity generation. Results from the study shows that CO_2 emission from coal fired power plants will grow at 4.1% per year to reach 98 million tons in Malaysia and 171 million tons in Indonesia by 2020. It is learnt that adsorption technology can be applied in coal fired power plants to reduce CO_2 emissions in Malaysia and Indonesia. Integrated Gasification Combined Cycle (IGCC) power plants incooperating a pre-combustion capture with the adsorption technology is one of the available options for new plants in Malaysia and Indonesia.

Keywords: Malaysia; Indonesia; Coal fired plant; Carbon capture.

INTRODUCTION

In 1896, a Swedish chemist, Svante Arrhenius put forth the idea that carbon dioxide (CO_2) emissions from combustion of coal could enhance the greenhouse effect and lead to global warming [1-2]. Now, the contribution of CO_2 towards global warming has been well known and taken as a fact. In Malaysia and Indonesia, the highest contributor to the emission of the gas reportedly came primarily from the energy sector [3-5]. Malaysia and Indonesia contributed 161.92 and 595.6 million tons of CO_2, respectively, last year.

In Malaysia, coal consumption for electricity generation grows at a rate of 9.7% per year, and is expected to increase substantially to meet the rising demand for energy. The electricity demand will increase by 4.7% per year. The growth in electricity demand is heavily influenced by strong demand from the industrial sector, which increases at 5.4% annually. Electricity demand for the residential sector will also experience strong growth of 4.9% per year. Per capita electricity demand is projected to be more than double from 2002 to reach 7,571 kWh/person in 2030. In Indonesia, coal consumption grows at 4.7% per year. Electricity demand grows annually at 4.6% to reach 108 GW in 2030 [6].

Considering the ever increasing demand for coal fired electricity, it would be interesting to understand and analyze the pattern of CO_2 emissions from the two countries. Thus, this study is carried out in order to predict the emissions of CO_2 from coal fired plants from 2005 to 2020, by correlating the percentage of coal for energy mix and coal consumption for electricity generation. The study also reviews some of the available technologies for carbon capture for new coal fired power plants in Malaysia and Indonesia.

SURVEY DATA

The data used for this study are the percentage of coal for energy mix data, coal consumption for electricity generation data and emissions of CO_2. These data are collected from various researches reported in the past and present [6-11].

Methodology. This study uses the scenario approach for the analysis. Schwartz [12] states that scenarios are tools for ordering perceptions about alternative future environments. Although the end result might not be an accurate picture of tomorrow, it can be utterly useful for making decision about the future. No matter how things might actually turn out, both the analyst and the policy maker will have a scenario that resembles a given future and that will help one think through both the opportunities and the consequences of that future.

This analysis is based on the pattern of coal consumption for electricity generation. Some of the data are readily available but other unavailabe data have to be calculated with respect to the countries electricity consumption trend. All the computation is performed using curve fitting toolbox (cftool) of Matlab® R2008a.

RESULTS AND DISCUSSION

In 2008, the total coal consumption for electricity generation in Malaysia is 21.15 million tons calculated based on 7 power plants, with 8120 MW installed capacity. Figure 1 shows the consumption of coal from 2005 to 2020 increases from 12.4 to 36 million tons.

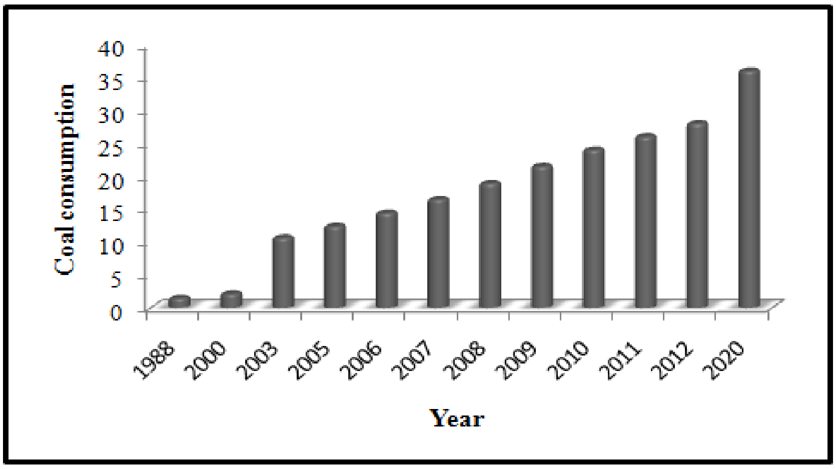


Figure 1: Coal Consumption for Electricity Generation in Malaysia (Million tons)

The increase in coal consumption has contributed to the changes in CO_2 emissions pattern in Malaysia. As a direct consequence, the total CO_2 emissions from coal fired power plants will reach 98 million tons by 2020, a two point sixty five-fold increase from 2005 as shown in Figure 2. The emission will continuously increase with the construction of new coal fired power plants and the increase on the capacity of existing coal fired power plants.

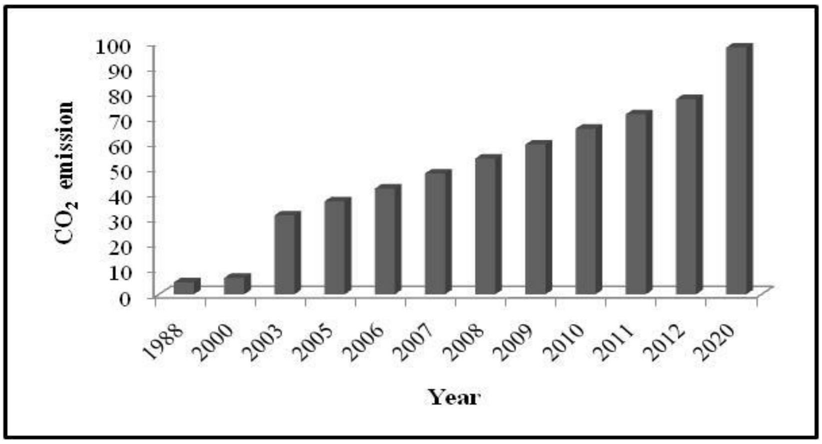


Figure 2: CO_2 Emissions from Coal Fired Plant in Malaysia (Million tons)

In Indonesia, the consumption of coal for electricity generation is 39.7 million tons (computed based on 25 power plants in 2008, with 11376 MW installed capacity). Figure 3 shows that the total consumption of coal from 2005 to 2020 grows from slightly over 12 to about 75 million tons.

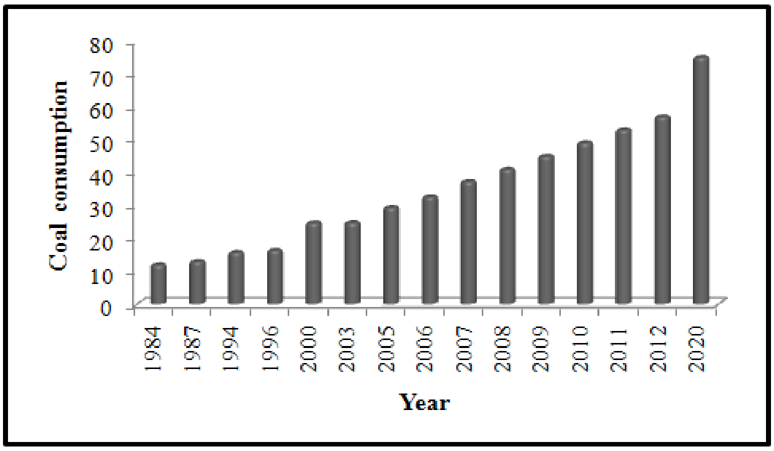


Figure 3: Coal Consumption for Electricity Generation in Indonesia (Million tons)

The total CO_2 emissions from coal fired power plants in Indonesia is expected to increase from 69.4 million tons in 2005 to 171 million tons in 2020 such as as shown in Figure 4. Similarly, this CO_2 emission will continuously increase with the construction of new coal fired power plants and the increase on the capacity of existing coal fired power plants in Indonesia.

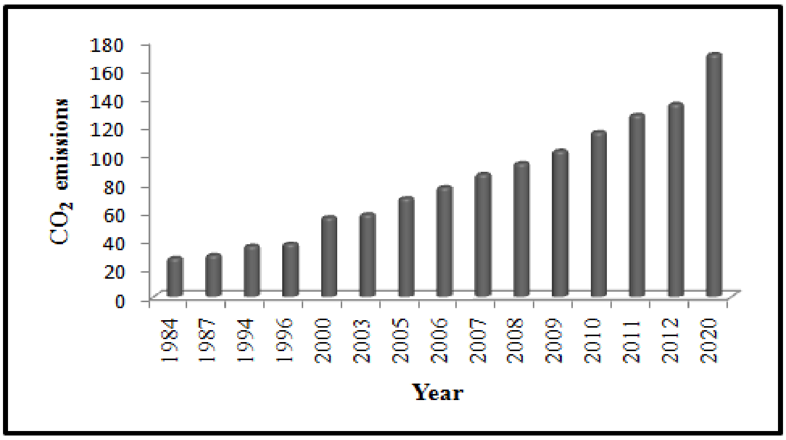


Figure 4: CO_2 Emissions from Coal Fired Plant in Indonesia (Million tons)

Carbon Capture and Storage. There are three alternatives to reducing CO_2 emissions without hampering economic growth. One is to use energy more efficiently, thereby reducing the energy consumption. The second option is to employ renewable energy sources that do not emit CO_2. The third option is to burn fossil fuels while capturing and storing the CO_2 instead of releasing it into the atmosphere. The option of burning fossil fuels while storing the CO_2 instead of releasing it is referred to as "CO_2 capture and storage (CCS)", "Carbon capture and storage (CCS)" or "CO_2 sequestration". CCS involves three distinct processes: (i) capturing CO_2 from the gas streams; (ii) transporting the captured CO_2; and (iii) storing CO_2 in geological formation [13-15].

The capture and storage of CO_2 presents one of the promising options for large-scale reductions in CO_2 emissions and is considered as competitive with other future carbon mitigation options. The cost to reduce CO_2 emissions from CCS technology is 2.5 €c/kWh as shown in Table 1.

Table 1: Cost of CO_2 Emissions Reduction [16]

Cost of CCS	3 USc/kWh (2.5 €c/kWh)
Current buy-out price for UK renewables	over 5 €c/kWh
Premium for wind power under the German Renewable Energy Law	9 €c/kWh

CO_2 Capture. CO_2 capture systems refer to the integration of CO_2 capture in pre-combustion capture routes with the best suited capture technologies (i.e. absorption, adsorption, membranes and cryogenics) to mitigate CO_2 emissions from coal-fired power plants. The most demanding part of this approach is the capture and separation of CO_2 from other exhaust gas components. There are three main routes to CO_2 capture from combustion processes as shown in Figure 5 [17-20]:

(i) *Post-combustion capture*, where the CO_2 in the exhaust gas coming from a standard gas turbine combined cycle, or a coal-fired steam power plant is captured through the use of chemical or physical solvents [17, 20-21].

(ii) *Oxy-fuel combustion*, using concentrated oxygen rather than air for combustion has the advantage of increasing the CO_2 concentration in the flue gas (>80%), eliminating the need for expensive downstream separation equipment. Oxygen can be supplied from cryogenic air separation and fed to either a boiler or a gas turbine. In order to avoid high flame temperatures, the CO_2-rich flue gas is often recycled to make the flame temperature similar to a normal air blown combustor. NO*x* formation is also suppressed by using oxygen rather than air. The main disadvantage of oxy-fuel combustion is the large amount of O_2 required, which is energy consuming and expensive to produce [15].

(iii) *Pre-combustion,* as the name indicates, captures CO_2 before the combustor by separating it from a synthesis gas mixture (H_2/CO). The fossil fuel is mainly converted to CO and H_2 by gasification, partial oxidation or reforming. CO is reacted with steam and catalytically converted to CO_2 and more H_2 in a water gas shift (WGS) step. CO_2 is then separated from hydrogen by chemical or physical absorption, membranes, cryogenic or pressure swing adsorption. The advantage of doing the separation before the combustor relates to the much higher partial pressure of CO_2 obtained compared to post-combustion, hence reducing the size of the equipment. This approach gives valuable hydrogen as product [20,22].

While post-combustion capture is considered practical, it requires large-scale equipment for the CO_2 removal, consumes process heat which leads to additional exhaust-gas pressure losses, causing the thermal efficiency to be significantly reduced [17-18, 21]. Post combustion is commercially available only on medium scale. At present, it is the most expensive in industrial application [23-24].

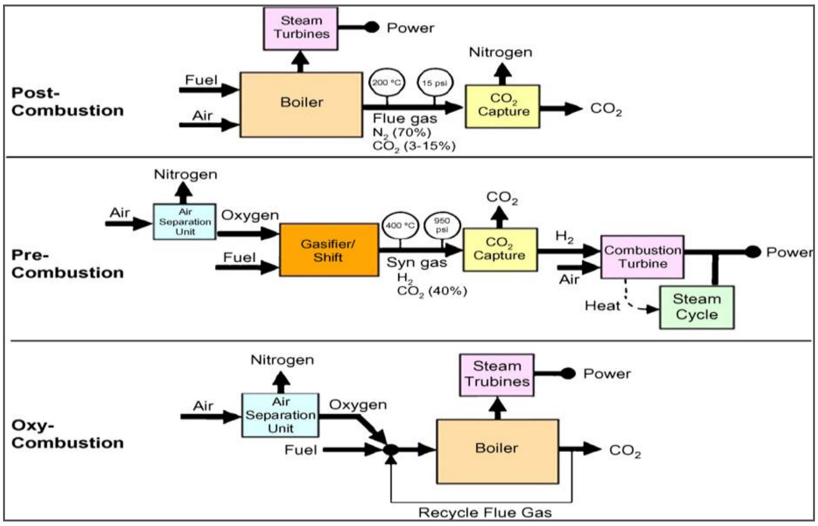
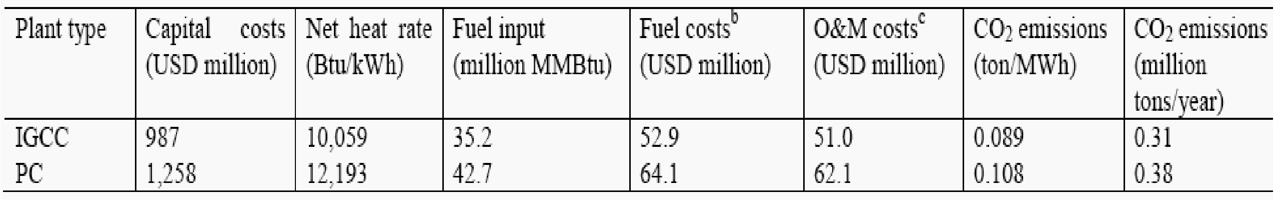


Figure 5: Schematic of Main CO_2 Capture Routes [20]

Choices of Coal Fired Power Plants. There are two types of coal fired power plants; pulverised coal (PC) and IGCC fired plants. IGCC power plants applying pre-combustion capture are more efficient than PC fired plants and would be an attractive choice for new plants [24]. Net efficiency for IGCC in existing plants is around 40 to 43% (LHV) and 38 to 41% (HHV). Recent gas turbines would enable this to be imporved, and future developments should take efficiencies beyond 50% [25].

Unlike the ordinary coal-fired power plants, IGCC does not need to deal with low concentration pollutants in a large volume of flue gas. In a coal IGCC system, the gas coming out of the gasifier (syngas) is under high pressure and contains higher concentrations of pollutants than the exhaust gas of coal combustion does. Therefore, the cost of removing pollutants is comparatively lower [26]. Table 6 lays out the key technical and economic parameters for these two plants types with carbon capture. This comparison is based on total capital, fuel, operating and CC costs for a hypothetical power plant with 500MW capacity operating at a factor of 80%.

Table 2: Comparison of Costs and Performance for a PC Plant and an IGCC Plant[a] [27]



Plant type	Capital costs (USD million)	Net heat rate (Btu/kWh)	Fuel input (million MMBtu)	Fuel costs[b] (USD million)	O&M costs[c] (USD million)	CO_2 emissions (ton/MWh)	CO_2 emissions (million tons/year)
IGCC	987	10,059	35.2	52.9	51.0	0.089	0.31
PC	1,258	12,193	42.7	64.1	62.1	0.108	0.38

a-capacity 500MW; capacity factor 80%; discount rate 6%.

b-assume a coal price of USD1.5/MMBtu

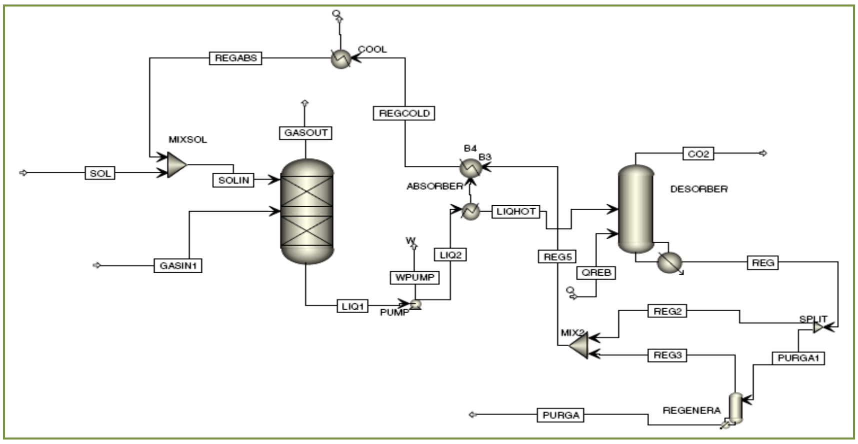
c-O&M costs with CO2 capture include transportation and storage of captured CO2 at USD 5/ton.

Capture Technologies. There are four main capture technologies namely absorption, adsorption, membranes and cryogenic separation. Cryogenic separation (low temperature distillation) requires much energy, thus expensive. Separation by membranes is attractive (a principle similar to filtration) but most membranes are under development and do not yet exist for an industrial scale [28].

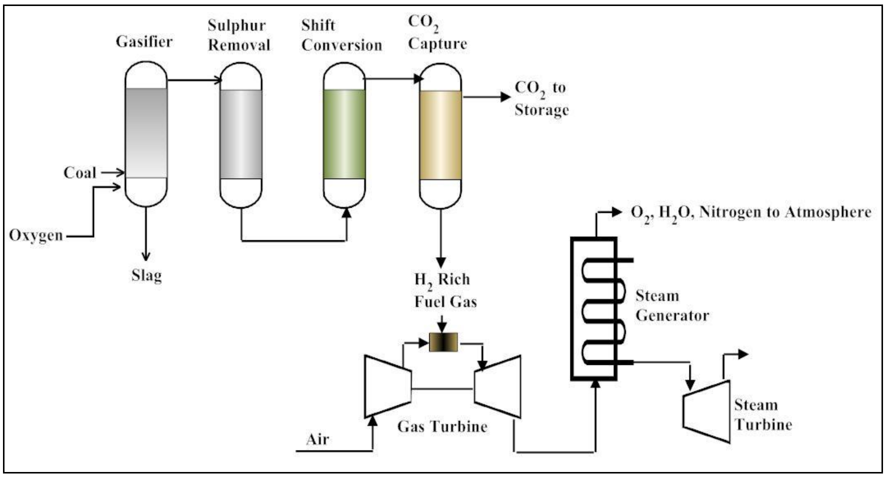
In the end, only absorption and adsorption technologies appear suitable for large power plants. Absorption is considered as a proven technology to capture GHGs, and has been widely used in industry and widespread application in many different sectors. The mechanism of this technology in separating CO_2 is by employing solvents. The solvents work by either, reacting with the CO_2 and producing a chemical which is subsequently dissociated by heating to recover the solvents and CO_2 (i.e. chemical absorption), or by physically absorbing the CO_2 under the pressure and recovering the solvent and CO_2 by subsequently dropping the pressure (i.e. physical absorption). A typical absorption process utilizing monoethanolamine (MEA) is shown in Figure 6a.

On the other hand, adsorption (physical adsorption) process is based on the same principle but using porous solid adsorbents such as zeolites and actived carbon, and chemical reactions between adsorbent and CO_2 may or may not occur during the separation process [24]. Figure 6b shows a typical adsorption process.

An adsorption process consists of two major steps: adsorption and desorption. The technical feasibility of a process is dictated by the adsorption step, whereas the desorption step controls its economic viability. Strong affinity of an adsorbent for removing the undesired component from a gas mixture is essential for an effective adsorption step. The stronger the affinity, however, the more difficult it is to desorb the gas impurity and the higher the energy consumed in regenerating the adsorbent for reuse in the next cycle. The desorption step, therefore, has to be very carefully balanced against the adsorption step for an adsorption step to be successful [31-32].



(a) MEA Absorption Process flowsheet [29].



(b) An Adsorption Process Flowsheet [30]

Figure 6: A Coal Fired Power Plant Project Process Flowsheet.

The main advantage of physical adsorption over chemical or physical absorption is its simple and energy efficient operation and regeneration, which can be achieved with a pressure swing [31-34]. The appropriate operating condition for each capture technology is presented in Table 3. It is crucial that they are applied in compatible operating condition in order to reduce the cost such as shown in Table 4 and 5.

Table 3: Operating Condition [34]

Capture technologies	Gas flow[a]	CO_2 partial pressure[b]	CO_2 concentration[c]
MEA absorption	High	Low	Low
Adsorption	Low	High	High

a-A high gas flow is considered over 150 m3/s

b-A high CO2 partial pressure is considered over 7 bar

c-A high CO2 concentration is considered over 15% volume dry.

Table 4: Cost of Reduction Capture Technologies[a] [35]

Capture technologies	Capital cost (million won/MW)	Fixed O & M (thousand won/MW)
MEA Absorption	736	29,425
Adsorption	702	28,087

a-1 US $ = 1200 won

Table 5: Efficiency and CO_2 Emission Reduction [32]

Power plants	Efficiency penalty (% points)	Emission rate of CO_2 (gCO_2/kWh)	CO_2 emission reduction (%)
IGCC plus MEA chemical absorption	11	199	75
IGCC plus PSA adsorption	15	61	92

a-Based on lower heating value (LHV)

CONCLUSION

CC installation to accommodate large-scale CO_2 mitigation projects to reduce CO_2 emissions without hampering economic growth should be incorporated in all coal fired power plants. This is to prepare Malaysia and Indonesia to conform to the emission standards promulgated in the Kyoto Protocol in the future and reap the benefit from carbon trading along the process.

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