

A STUDY ON GREENHOUSE GAS EMISSIONS FROM FOSSIL FUELS AND ITS SEPARATION

Basavaraja R J*, Kiran Kumar Nayaka V S

R V College of Engineering, Bengaluru

Department of Chemical Engineering

RV College of Engineering, Bengaluru-560059, INDIA

Abstract: Emission of carbon dioxide from various thermal power plants is a major concern for energy providers, policymakers and environmentalists all around the world. The present work reports on a detailed analysis of power plant lay-outs which use almost pure oxygen instead of air to oxidise the hydrocarbon fuel. Flue gas after combustion from these power plants contains mainly carbon dioxide and water vapour. CO₂ is separated from flue gas after condensing water. Carbon dioxide absorption or separation at the source and sequestration is the possible options to control its emission to atmosphere.

Keywords: Carbon dioxide, oxy-fuel combustion, power plant, CO₂ sequestration, lay-outs

1.1 CARBON DIOXIDE EMISSIONS FROM FOSSIL FUELS

Increase in energy needs day by day results an increase in greenhouse gas (GHG) emissions due to fossil fuel combustion. It is observed that CO₂ concentration in the atmosphere has been increasing significantly for the past two decades. The 2012 concentration of CO₂ is 394 ppm and this is about 40% higher when compared to mid-1800s. The average growth of CO₂ concentration is 2 ppm/year for the last 10 years. Despite the growth of non-fossil energy (such as nuclear and hydropower), considered as non-emitting, the share of fossil fuels within the world energy supply is relatively unchanged over the past 40 years and is shown in Figure 1.1 below.

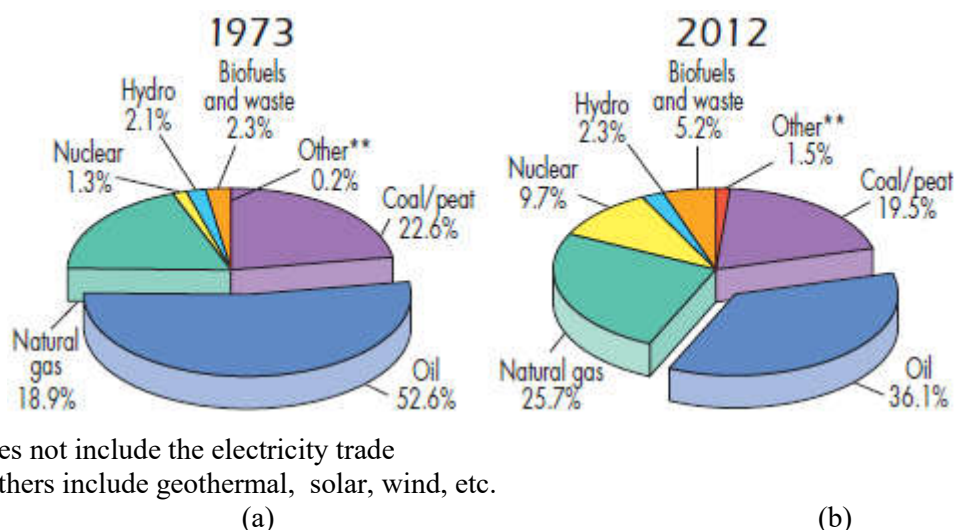


Figure 1.1: World energy production from type of energy source (a) in the past and (b) present (IEA 2013).

In Figure 1.1, the energy share of hydropower is 2.1 % in 1973 compared to that of 2.3% in 2012. Similarly the share of nuclear has improved from 1.3 to 9.7 %. These changes are relatively low when compared hydrocarbon fuel based energy shares. Among the energy sectors shown in Figure 1.1, CO₂ resulting from the combustion of carbonaceous fuels dominates the total GHG emissions. At present, combustion of fossil fuels based sectors provides around 82% of primary energy production (IEA 2013). There are several

advantages with fossil fuels from a power generation point of view and while efforts are going on to make power generation greener (see the recent summary of Yan et al. 2013), it is expected that countries such as India will continue to depend significantly on coal-based power generation for the next few decades (Chikkatur and Sagar 2007; Jayanti et al. 2012; Krishna Priya and Bandopadhyay 2013). Major emission sources of CO₂ include fossil fuel or biomass fired power plants, synthetic fuel plants, natural gas based energy industry (see Table 1.1). Apart from thermal power stations, energy-intensive industries such as steel plants and cement plants also release significant amounts of CO₂ into the atmosphere (IPCC 2005).

Table 1.1: Profile by process or industrial activity of worldwide large stationary CO₂ sources with emissions more than 0.1 MtCO₂ per year (IPCC Special Report on CCS 2005)

Process	Total installed MW capacity	Emissions (MtCO ₂ yr ⁻¹)
Fossil fuels		
Power plant	4,942	10,539
Cement production	1,175	932
Refineries	638	798
Iron and steel industry	269	646
Petrochemical industry	470	379
Oil and gas processing	N/A	50
Other sources	90	33
Biomass		
Bioethanol and bioenergy	303	91
Total	7,887	13,468

Increasing energy demand from fossil fuels plays a key role in the upward trend in CO₂ emissions. Since the onset of large scale industrialization in the late 1800s, CO₂ emissions have been increasing significantly from 1 GtCO₂ in 1870 to over 31 GtCO₂ in 2011 as seen in Figure 1.2 (a). Depending on the availability of the fuel, various countries have built up their energy sector, automobile and power stations using gas, liquid and solid hydrocarbon fuels. Coal provided around 29% of the world total primary energy supply (TPES) in 2011 but as shown in the Figure 1.2(b) it contributed 44% of the global CO₂ emissions from combustion. As compared to gaseous fuels, CO₂ emission from coal is nearly twice per MW, and the total CO₂ emission from coal stands at 13.7 GtCO₂ in the year 2011. Currently, coal fills much of the growing energy demand of those developing countries (such as China and India) where energy-intensive industrial production is growing rapidly and large coal reserves exist with limited reserves of other energy sources. Adopting pathways to limiting long term temperature rise to 2°C (WEO 2013), for example, by using more efficient plants and end-use technologies as well as increased use of renewables, nuclear and carbon capture and storage (CCS) technologies, could see coal consumption drop, thereby reducing CO₂ emissions from coal to 5.7 Gt by 2035.

CO₂ emissions from oil rose to 11.1 GtCO₂ in 2011, an increase of 0.6% than in previous year. World Energy Outlooks (WEO 2013) projects that emissions from oil will grow to 12.5 GtCO₂ in 2035, due to increased transport demand. Emissions of CO₂ from gas were 6.3 GtCO₂ in 2011, 1.7% higher than in the previous year. Again, the WEO 2013 projects emissions from gas will continue to grow, rising to 9.1 GtCO₂ in 2035.

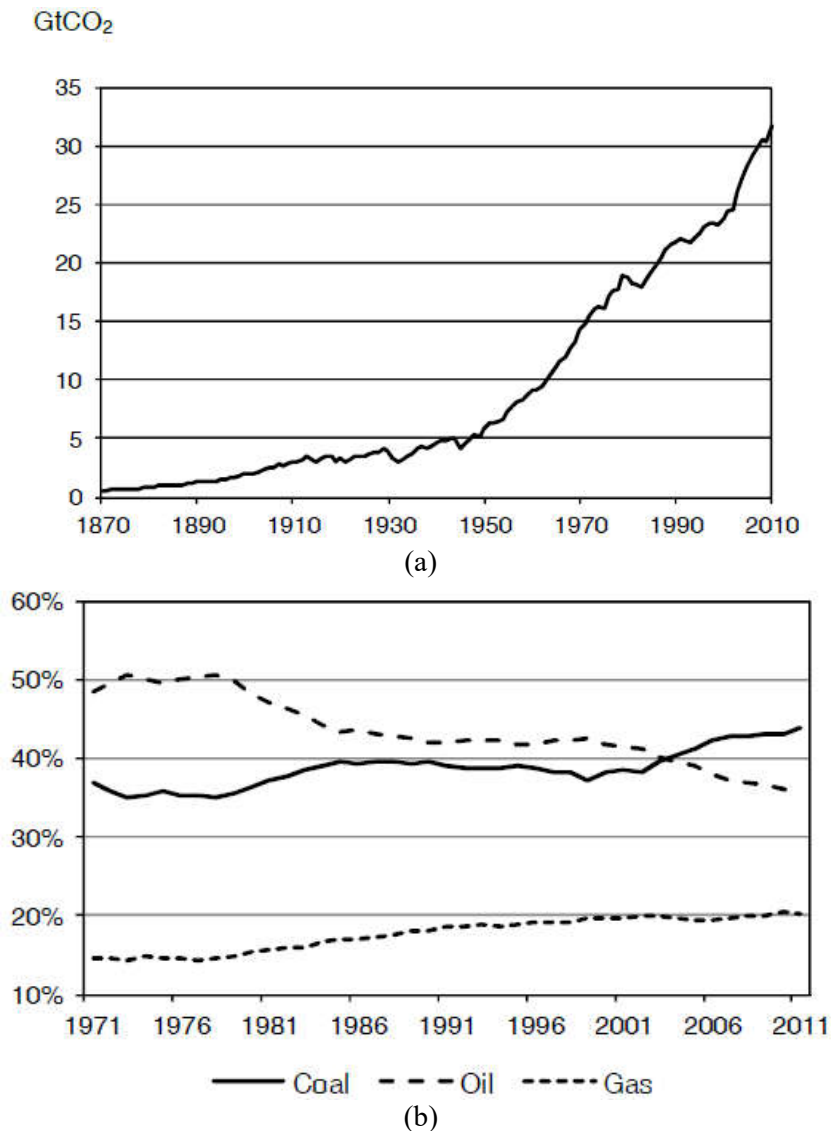


Figure 1.2: Fossil fuels: (a) CO₂ emission by combustion and (b) Fuel share in global CO₂ emissions (IEA Statistics 2013)

1.2 GREENHOUSE EFFECT AND CLIMATE CHANGE

Increasing concentration of GHGs (including water vapor, carbon dioxide, methane, nitrous oxide, and others) in the atmosphere strengthens the greenhouse effect, especially the so-called additional greenhouse effect. This leads to an increase of global surface and atmospheric temperatures; this is referred to as the global warming. Global warming causes different changes such as increase in extreme weather events, rising sea levels, ecosystem migrations. More generally, interactions between the atmosphere, the biosphere and the oceans are disturbed by global warming. The atmospheric carbon dioxide concentrations were reasonably stable (typically quoted as 278 ppm) before industrialization (IPCC 2005). The growth rate of the atmospheric carbon dioxide has averaged about 1.68 ppm per year over the past 31 years (1979-2010), averaging about 1.43 ppmv per year before 1995, and 1.94 ppm per year thereafter. Carbon dioxide increase from pre-industrial mixing ratio has induced a radiative forcing of +1.66 (± 0.17) W/m². Past emissions of fossil fuels and cement production have likely contributed about three-quarters of the current radiative forcing, with the remainder caused by land use changes (IPCC, 2007). Concentrations of the greenhouse gases (GHGs) such as carbon dioxide, methane and nitrous oxide, have increased, steadily since 1750 due to human activity. In 2011 the concentrations of these greenhouse gases were 391 ppm (CO₂), 1803

ppb (CH₄), and 324 (N₂O) ppb, and exceeded the pre-industrial levels by about 40%, 150%, and 20%, respectively. Figure 1.3 gives an overview of CO₂ emissions, temperature change and sea level rise resulting from human activities (IPCC 2013). Studies indicate that there is rise in atmospheric CO₂ concentration from 278 ppm in 1750 to 391 ppm in 2011 as shown in Figure 1.3(a). In Figure 1.3 (b), multi-model results from a hierarchy of climate-carbon cycle models for each RCP (Representative Concentration Pathways) until 2100 are shown with coloured lines and decadal means (dots). Model results over the historical period (1860 to 2010) are indicated in black.

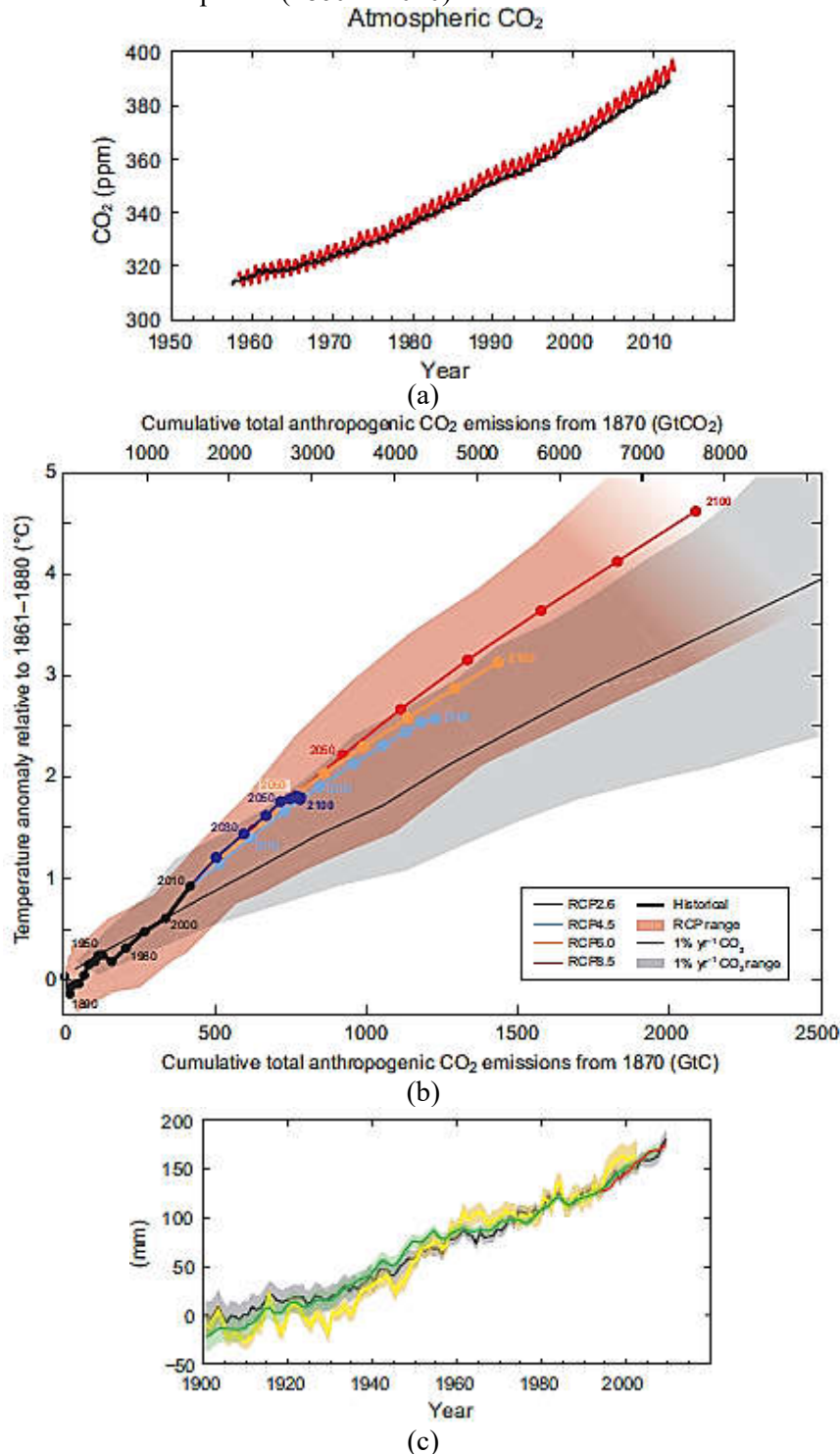


Figure 1.3: CO₂ emissions and its effect on global changing, (a) atmospheric concentrations of carbon dioxide, (b) mean surface temperature increase as a

function of cumulative total global CO₂ emissions from various lines of evidence and, (c) average sea level change (IPCC 2013)

The coloured plume illustrates the multi-model spread over the four RCP scenarios. CO₂ increase of 1% per year (1% yr⁻¹ CO₂ simulations), is given by the thin black line and grey area.

Temperature values are given relative to the 1861–1880 base period, emissions relative to 1870. Decadal averages are connected by straight lines. The various models shown in Figure 1.3 (c) with different colors indicate that global mean sea level rise is less than 0.6 m for a forcing that corresponds to CO₂ concentrations that peak and decline and remain below 500 ppm. For a radiative forcing that corresponds to a CO₂ concentration that is above 700 ppm but below 1500 ppm, as in the scenario RCP8.5, the projected rise is 1 m to more than 3 m. Sea level rise due to global warming for last 100 years is shown in Figure 1.3(c).

1.3 POSSIBLE OPTIONS TO CONTROL CO₂ EMISSIONS

Control of GHG emissions can be achieved by taking measures in industry, power stations, forest sectors and agriculture. Reducing the CO₂ emissions to atmosphere is achieved by adopting following technological options (IPCC 2005) : 1) switching to less carbon intensive fuels (e.g., natural gas or use of coal-derived syngas instead of coal); 2) increasing efficiency of conversion; 3) increasing the use of renewable energy sources (solar, biofuels, wind power, etc.) or nuclear energy, and 4) the use of combustion technologies with carbon capture and sequestration (CCS), see below, which also appears to be a relevant option to reduce the emissions of GHG while continuing to use fossil fuels. Based on the analysis made by IPCC (2005) and IEA (2006), the required world-wide cumulative mitigation of CO₂ through CCS is 15-55% until 2100 in order to stabilize climate changes at reasonable cost. CCS must provide 20% of the global CO₂ cuts required by 2050, according to the IEA (IEA 2006). It appears that there is enough technical potential for geological storage. The technological challenge therefore is to do it economically and safely.

1.4 CONCLUSIONS

Carbon dioxide released from industries and energy sources is either to be treated chemically or stored in suitable locations. Since chemical adsorption of large quantity of CO₂ is not feasible the only feasible option is to store CO₂ away from the atmosphere at suitable locations. Storage of high volume impure CO₂ gas is not practical due to high cost of compression and transportation. Therefore CO₂ gas should be nearly pure prior to compression and sequestration.

Acknowledgments

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