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Recommended Citation


Available at: http://www.iucn.org/about/union/commissions/ceesp/what_we_do/wg/temti.cfm

International Union for the Conservation of Nature (IUCN)
Commission on Environmental, Economic and Social Policies (CEESP)
Effectiveness of clean coal technologies in global carbon emission mitigation: evidence and summary

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Abstract

The need to balance the goals of economic growth and environmental protection is one of the major challenges faced by policy makers today. Energy is crucial for economic growth, global prosperity and equity, but unsustainable use of energy resources is also associated with environmental pollution and greenhouse gas emissions, which is largely responsible for global warming and climate change. As a result, various measures are being proposed by stakeholders to proffer means of sustaining the current level of development while stemming the pace of global warming through greenhouse gas emissions reduction. One of such measures is the development of clean coal technologies. Given the importance of coal in the global energy framework, and the difficulty in phasing out its use, at least in the foreseeable future, the development of clean coal technologies has been pressed as an appropriate way to achieve both coal-driven energy production and environmental protection. This is the focus of this research. The paper examines the potential impact of clean coal technologies on greenhouse gas emissions based on available evidence in the literature. According to the findings, clean coal technologies have the potential to reduce greenhouse gas emissions, but not on a large scale and within the time frame required to address the problem of climate change.

1. Introduction

The role of energy in human activities and economic development cannot be over-emphasized. Energy is used in homes, businesses, agriculture, industries, and for transportation. Individuals and businesses use energy in the form of electricity to power their computers, lights, electronics,
etc. Industries use energy in the form of electricity and fuel to power their machines and production processes. Energy is an indispensable input in every facet of human activities, and is crucial to economic growth, global prosperity, poverty reduction and equity, now and in the future.

Energy consumption has risen significantly over the last few decades. Particularly, global energy consumption increased at an alarming rate between 2000 and 2010. According to the United States Energy Information Administration (EIA), it increased from 400.072 quad Btu in 2000 to 510.551 quad Btu in 2010 as shown in figure 1 below. The increase in energy consumption has been attributed majorly to the demand for energy in emerging and developing economies, particularly the BRICS. There is need for adequate supply of energy to fuel the development activities of these economies.

![Fig 1: Trend of World Energy Consumption, 2000-2010](image)

Source: United States Energy Information Administration (EIA) Database

According to McNeill (2000), power consumption increased by 16-fold in the 20th century. Increase in power consumption was produced by fossil fuel, as it accounts for about 85% of primary power consumption as at 2002 (Hoffert et al, 2002). Coal is currently the most used fossil fuel for electricity generation. This is because it is available in large quantity and also commands lower prices compared to other fossil fuels like oil and gas. Coal accounts for over half of electricity generation in the United States, China, South Africa, Germany, among others. Specifically, coal-fired plants generate about 92% of electricity in Poland and South Africa, 77%
in China and Australia, 70% in India, 65% in Czech Republic, 51% in the US, and 39% globally, in 2002 (IEA/OECD, 2005). Current statistics shows that the share of coal/peat in world electricity generation has increased to 41.3% in 2012 (IEA, 2013). This is in confirmation of Owen (2006) that posits that fossil fuel including coal, is expected to provide about 85% of EU’s energy in the foreseeable future.

The continued use of coal and other fossil fuel as energy sources has however resulted in severe environmental problems, including pollution and climate change through greenhouse gas emissions. Coal burning is a significant contributor to global warming. Confirming this assertion, statistics from the Australia Greenhouse Office shows that energy-related emission, which is dominated by coal, accounts for about 70% of Australia’s greenhouse gas emissions in 2000 (AGO, 2002). Furthermore, IEA (2006) reveals that coal produces 40% of world’s CO₂ emissions from fuel combustion. EIA (2012) also states that the electricity sector, which is largely dependent on coal, accounts for a large share of greenhouse gas emissions increase in the country. The increased use of coal has heightened the present challenge of climate change.

Climate change is presently the greatest threat to the sustainability of progress already made in global poverty reduction. It has far-reaching effects on plants, animals, humans, natural resources and the environment, now and in the future. Though the effects of climate change permeate all countries, developing countries in general and sub-Saharan Africa in particular have been identified to be the most vulnerable due to their dependence on natural resources and their vulnerability to weather, energy and agricultural shocks. Already, climate change is being associated with increasing poverty and inequality, energy crisis, food and water insecurity, infant mortality, natural disasters and conflicts in developing countries (PACJA, 2009). In effect, though scientists are still uncertain about the extent and several forms of the impact of climate change, available evidence shows is expected to have severe impact on human existence (IPCC, 2014).

In recognition of the adverse consequences of climate change, policy makers are already initiating measures to tackle the problem. One of such measures is the reduction in the use of coal and facilitating the use of renewable energy in the global energy mix. Coal for electricity
generation is the single most important cause of CO$_2$ emission (IEA, 2012), and there is urgent need to reduce its use or improve the efficiency of coal-fired power plants. The former is however not feasible given the substantial dependence of some countries on coal. According to the United States Energy Secretary, Dr. Steven Chu, developing countries such as China and India would not give up the use of coal even if the United States and the EU decide to replace coal (Siobhan, 2009). Hoffert et al. (2002) also state that the United States withdrew from the Kyoto Agreement because it perceives the emission target as an economic burden. Collier (2014) asserts that despite Germany’s claim of the largest green party in the world, it is producing more coal today than it has for 20 years. Besides, coal is one of Australia’s most lucrative commodity exports. The excessive dependence on coal, in one way or the other, will make significant reduction in coal consumption not feasible in the short to medium term. This is buttressed by the EIA forecast which shows that coal-fired power plants will account for 38% of electricity in 2030, a very modest decrease from 39% in 2002 (IEA/OECD, 2005). This indicates that coal will continue to be a significant part of the global energy mix in the foreseeable future.

The overwhelming conviction of the important role of coal in the energy mix in the future have prompted the increasing emphasis on and development of clean coal technologies in recent years. This is based on the idea that if there is no possibility of considerable reduction in coal consumption in the nearest future, there is need to make significant modification in the way coal is utilised in order to reduce emissions associated with its use. Hoffert et al. (1998) confirms this assertion by arguing that an effective way to reduce CO$_2$ emissions while maintaining economic growth and equity is through energy technology across the entire supply chain.

Clean coal technologies are seen as improved technologies that can sustain the utilization of coal for electricity generation and other activities while significantly reducing the amount of greenhouse gas emissions. However, the potentials of clean coal technologies to significantly reduce greenhouse gas emissions in accordance with global targets has been a source of contention among politicians, policy makers and scientists; and this is the focus of this paper. This paper reviews existing literature on the potential of clean coal technologies to reduce greenhouse gas emissions and summarises the current arguments relating to clean coal technologies.
2. Clean Coal Technologies and Greenhouse Gas Emissions: Available Evidences

IEA (2012) investigates the technology options required to realise sustainable energy supply and lower emissions. It argues that clean technology would help to reduce dependency on fossil fuels, lessen the amount of carbon emission from electricity generation, cut government spending, improve energy efficiency and reduce emissions emanating from the industrial transport and building sectors. However, it observes that the potential for clean technology to reduce CO₂ emissions is bleak due to the low deployment of the major technologies required to achieve set targets. According to the study, sufficient progress is being made in the deployment of renewable energy technologies such as hydro, biomass, onshore wind and solar photovoltaic (PV) while key clean coal technologies such as carbon capture and storage (CCS) is not making the expected progress, despite its perceived importance in enabling the industrial sector meet emission reduction goals. The study reveals that coal-fired power plants with higher steam temperature are capable of reducing CO₂ emissions from power generation to around 670 grams per kilowatt-hour. It also posits that CCS alone can account for about 20% of cumulative reduction in CO₂ by 2050 but its low deployment rate, huge cost outlays and the lack of large-scale demonstration projects in electricity generation could undermine such potentials.

Torvanger et al. (2004) examine the impact of clean coal technologies on emission and environmental problems. They argue that there is no clear cut evidence that clean coal technologies is totally devoid of environmental problems. According to them, clean coal technologies, particularly carbon capture and storage, are mainly transferring emissions from one waste steam to another, with no certainty of how to manage the end product. They added that there is evidence that carbon capture and storage could leak.

Bhure et al. (2005) provide a comprehensive review of research that has been undertaken with respect to oxy-fuel combustion technology (a type of clean coal technology) and assessments, and presents the comparisons between the technology and other power generation options.
According to the review, the technology recycles flue gas back into the furnace to control temperature and make up the volume of the missing N₂ to ensure there is sufficient gas to maintain the temperature and heat flux profiles in the boiler. The study posits based on the review that there is strong evidence that oxy-fuel technology substantially reduced NOₓ emissions in coal-fired power plants.

Wilkenfield et al. (2007) examine the myths associated with clean coal and other greenhouse gases. According to the report, they argue that clean coal is unreal, and the carbon sequestration system that has been at the centerpiece of the clean coal advocacy is unproven and expensive. They also claim that the development of clean coal technologies and other technologies takes time, and technologies that are not presently available will be behind schedule and cannot contribute significantly to the rapid, extensive and large-scale reductions in greenhouse gas emissions needed to stem global warming. They added that that the techniques and infrastructures required to remove the pollutants in coal, such as liquefaction, gasification and sequestration, are highly energy intensive.

IPCC (2005) argues that carbon capture and storage technologies can capture about 85 - 95% of CO₂ from coal power plants, but it will require additional 10 - 40% coal to produce the same level of energy. This was also corroborated by IEA/OECD (2005), which argues that available clean coal technologies involve significant efficiency losses. However, an earlier study by Wibberley (2001) refutes this claim, stating that new clean coal technologies require less coal to produce the same amount of energy, as they have higher thermal efficiency. According to Wibberley’s study, new coal technologies have about 10 to 20% lower greenhouse gas emissions compared to conventional coal-fired power plants.

IEA/OECD (2005) posits that coal-based technology has the potential to make significant reduction to CO₂ emissions if effective market and regulatory frameworks that encourage investments in these technologies are available. However, IPCC (2005) argues based on literature and industrial experience that clean coal technologies will not deploy in the absence of measures limiting greenhouse gas emissions. Furthermore, Rising Tide Australia (2008) asserts based on previous studies that clean coal technologies will only reduce growth rates of emissions...
until 2050, but not actual emission levels. Meanwhile, urgent and rapid actions are required to stem the pace of climate change.

Ansolobehere et al. (2007) examines the potential impact of clean coal technologies on CO₂ emissions. The study finds that with carbon capture and storage, more coal will be used in 2050 than today, while global CO₂ emissions from all sources of energy will be only slightly higher than today’s level, and less than half what it would have been if there were no carbon capture and storage technologies. The study concludes that there is still no convincing evidence that the technology will be effective. Similarly, Fisher et al. (2006) affirms that the Asia Pacific 6 (AP 6), which consists of the United States, Australia, India, China, Republic of Korea and Japan, has the potential to reduce global emissions in the year 2050 to between 11 and 23% lower than they would otherwise been, subject to the deployment of carbon capture and storage technologies in all new coal power plants in Australia, US and Japan from 2015, and in China, India, and South Korea from 2020.

3. Summary of Arguments on Clean Coal Technologies

One of the issues being raised with respect to clean coal technologies, particularly carbon capture and storage, in the literature is storage capability (OECD/IEA, 2012). There are concerns whether CCS facilities would be able to store carbon indefinitely and safely. There is no concrete evidence yet that storing of carbon underground does not have effect on the ozone layer and the environment. Meanwhile, there are insinuations that carbon stored underground could leak and aggravate environmental challenges for future generations, raising concern about intergenerational equity and liability. Considering also that coal power plants will not exist perpetually, questions have been raised about how CCS sites will be monitored when coal power companies are no longer in existence.

Another concern about clean coal technologies is the perceived unequal distribution of the costs and benefits of its adoption across industries, sectors and countries (Wilkenfield et al., 2007). There are arguments that world-wide adoption of clean coal technologies will have different
impacts on different sectors, countries and at different times. It is believed that the adoption of clean coal technologies may have significant effects on the power sector relative to other sectors and companies. It may also have more effect on countries like China and South Africa than Denmark due to the latter’s low dependence on coal. This may have considerable impact on the competitiveness of these countries in the global market. As a result of the potential impact on competitiveness, some countries may not be willing to adopt clean coal technologies if they perceive the cost is higher than the benefits compared to other countries.

Continued construction of coal-fired plants because of clean coal technologies encourages unsustainable coal mining practices, which are detrimental to nature. The argument is that as more clean coal technologies are developed, power companies will be encouraged to construct more coal-fired power plants. This is because they perceive that the construction of new coal-fired power plants with clean and efficient technologies as environmental-friendly, as it reduces carbon emission from power generation. However, this practice will encourage more exploitation and mining of coal, and undermine global initiatives to reduce coal consumption. Moreover, clean coal technologies do not account for the environmental impacts of coal mining. Coal mining itselfpromotes several environmental problems such as pollution, soil degradation as well as destruction of natural habitats (Fears, 2009).

Feasibility of world-wide adoption of clean coal technologies has also been called to question. Present development of clean coal technologies has focused extensively on developed countries such as US, UK, Denmark, Norway and Germany, while neglecting developing countries. Even in developed countries, the deployment rate of clean coal technologies is slow and the current installed capacity is low (IMT, 2007 and IEA, 2006). This has been largely attributed to the huge financial resources that are required to invest in clean coal technologies. Financial institutions in the United States and Europe are unwilling to invest in newer technologies because of uncertainties about future climate policies and long pay-back periods (IEA/OECD, 2005). This will further slow down the deployment rate of clean coal technologies and reduce its potential to significantly reduce emissions and stem climate change. Moreover, developing countries, which are likely to be major consumers of coal in the future, are not carried along in the process. Thus, when developed countries shift to more environment-friendly energy sources in the future,
developing countries, which would still depend substantially on coal, will continue to increase carbon emissions. The issue of intellectual property rights and international politics associated with technology transfer would also have effect on the deployment of clean coal technologies in some countries, especially those with low level of home-grown innovation and technological development capacity.

There is argument about cost-effective means of removing and sequestering CO$_2$ emissions from coal-fired power plants (IEA/OECD 2005; and Wilkenfield et al., 2007). One of the key questions is: how easy will carbon capture and storage be integrated into large scale projects? This question arises from the huge costs associated with removing and capturing of carbon from power plants. This is also valid based on the position of IEA/OECD (2005) and the assertion of influential environmental activist, Flannery (2007) that clean coal technologies might not be viable for all geographical locations, which is true in the case of Australia where most power plants are situated in locations that are not ideal for carbon capture and storage facilities. Thus, substantial additional cost is required to transport carbon from where it is captured to the storage facilities. Also, there might also be difficulties to effectively and efficiently remove, capture and store CO$_2$ from industries and factories, especially in countries that do not have organised industrial estates and clusters.

Using clean coal technology will result in increase in the price of electricity generated from coal-fired plants relative to other power source such as combined cycle gas turbines. Further imposition of levelised costs such as carbon tax and emission permits, in the form of climate change mitigation measures, will also reduce the competitiveness of coal-generated electricity compared to renewable energy such as wind or solar. For instance, based on the cost estimates in Larson et al. (2012), sub-critical pulverized coal technology without CCS has an estimated installed cost, levelised electricity cost and coal input of 1,598 US$/kW, 62 US$/MWh and 1,496 MW at higher heating value (HHV) respectively compared to the same technology with CCS which has 2,987 US$/kW, 114 US$/MWh and 2,211 MW HHV respectively, both for a plant capacity of 550MW. The increased regulation and costs that is likely to be associated with the use of clean coal technologies may also make investors skeptical about its deployment. This is coupled with the concern over the efficiency of the technologies in terms of electricity output.
Therefore, investing in clean coal technology may not even be a rational decision in terms of relative price in the long term.

Clean coal technology is a distraction from renewable energy. Environmentalists, in the propositions to combat climate change, tend to promote renewable energy as one of the key policy options. However, the increasing emphasis on clean coal technologies is perceived as shifting of policy makers’ attention from renewable energy investments. Environmentalists have argued that the financial resources expended on clean coal technologies would yield better impacts on the environment if they are invested in renewable energy. This argument is supported by the concept of carbon lock-in advocated by Unruh (2000). According to the concept, certain systemic process could interact to undermine the diffusion of carbon-saving technologies.

4. Conclusion and Policy Recommendations

This paper reviews existing literature on the potentials of clean coal technologies to significantly reduce greenhouse gas emission. It also provides a summary of the sources of argument on clean coal technologies in the literature. According to the review, coal will continue to play important role in the global energy scene in the foreseeable future. This is because of its availability on a large scale and its low cost compared to other energy sources. Politicians, private sectors and environmentalists are divided on the role of clean coal technologies in reducing emission. While politicians and the private sector are confident that clean coal technologies will significantly reduce carbon emissions, environmentalists are of the opinion that it will aggravate environmental problems in the future. Of the different types of clean coal technologies, the carbon capture and storage (CCS) has attracted so much attention. Clean coal technologies have the potentials to reduce emissions, but its impacts are severely limited due to a number of factors. Besides, greenhouse gas emissions need to be reduced on a large scale to meet international target than what only clean coal technologies can do. Furthermore, massive deployment of clean coal technologies is not feasible in the short to medium term, where strict actions are required. In addition, the development and deployment of clean coal technologies is currently limited to developed countries. Clean coal technologies may encourage more coal production and
consumption, with attendant environmental consequences. Clean coal technology could also shift
attention and investment from renewable energies which is seen as the most potent measure to
address carbon emission.

Politicians, private sector, international organisations, environmentalists and civil societies must
collaborate on the way forward with respect to technology and environmental protection. It is
also important that clean coal technologies must be developed and deployed alongside energy
efficiency and conservation measures to make significant impact. Increasing emphasis on clean
coil technologies should not crowd-out the importance of renewable energy, cap and trade,
carbon tax, and other climate policies. Market and regulatory frameworks also need to be
developed in order to encourage clean coal technologies. Developing countries should be carried
along in the process of developing policies for clean coal technologies and supported to embrace
them.

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