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ACPC
African Climate Policy Centre

United Nations Economic Commission for Africa
African Climate Policy Centre

Working Paper 12

Fossil Fuels in Africa in the Context of a Carbon Constrained Future

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AfDB	African Development Bank
APF	Africa Partnership Forum
AR4	The Fourth Assessment Report of the IPCC
BP	BP, Inc. Oil Company
CCGT	Combined Cycle Gas Turbines
CCS	Carbon Capture and Storage
CCTs	Clean coal technologies
CDM	Clean Development Mechanism
CHP	Combined Heat and Power
CIA	Central Intelligence Agency
CO_2	Carbon Dioxide
DFID	Department of for International Development, U.K
DRC	Democratic Republic of Congo
DRFN	Desert Research Foundation of Namibia
EAC	East African Community
EIA	U.S. Energy Information Administration
FBC	Fluidised Bed Combustion
FITs	Feed-in-tariffs
GDP	Gross Domestic Product
GHG	Greenhouse gas
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilo Watt Hours
MDGs	Millennium Development Goals
MW	Mega Watts
NEET	Networks of Expertise in Energy Technology
NREL	National Renewable Energy Laboratory, US
OECD	Organisation for Economic Co-operation and Development
OFID	The OPEC Fund for International Development
PCC	Pulverised Coal Combustion
PFBC	Pressurised Fluidised Bed Combustion
PV	Photo Voltaic
R&D	Research and Development
REN21	Renewable Energy Policy Network for the 21st Century
RPS	Renewable Portfolio Standards
SHPs	Small Hydropower Systems
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organisation
WCA	World Coal Association

WEC	World Energy Council
WGA	Western Governor's Association
WHO	The World Health Organisation
WWEA	World Wind Energy Association

ABSTRACT

Africa has considerable reserves of fossil fuels of all kinds: oil, coal and natural gas. Much of this resource is either utilised outside of Africa or some of the resource is not developed at all for use within the continent. Meanwhile, there are concerns that the future of fossil fuel use will need to take place in the context of a low carbon development pathway. It is therefore important to explore the resource and technical challenges and opportunities associated with the expanded utilisation of fossil fuels in Africa. This paper will review existing reserves and geographical distribution of fossil fuels across the continent, review technical options for decarbonising efforts and provide policy recommendations that would enable the use of resources for the continent's development efforts while ensuring minimisation of GHG emissions.

1. INTRODUCTION

Fossil fuels (crude oil, natural gas and coal) are important energy sources that play vital roles in the energy system and economies of African countries. Africa has enormous potentials of fossil fuels accounting for about 9.5%, 8% and 4% of the total proven reserves of crude oil, natural gas and coal in the world, respectively (BP, 2011). These resources account for about 50% of total primary energy supply and one-third of energy consumption (excluding contribution to electricity generation) in Africa (IEA, 2011a). According to the same source, over 80% of electricity generated across the continent is also from fossil fuels. These energy resources are also a major source of revenue for the major oil and gas producing countries in Africa, accounting for about 50 – 80% of government revenues (Zalik and Watts, 2006). For example, oil exports account for about 80% of government revenues in Libya, Nigeria and Angola while natural gas exports account for about 60% of Government revenues in Algeria (CIA, 2011). These figures suggest that a huge amount of fossil fuels produced in Africa is consumed elsewhere.

More strikingly and despite these huge energy resources, the continent is still faced with enormous energy challenges that include low access to modern energy, insufficient energy infrastructure, low efficiency and lack of institutional and technical capacity to use these huge resources. For example, only about 31% of Sub-Saharan African population have access to electricity with about 60% and 14% electrification rates in the urban and rural areas, respectively (IEA, 2011a). In addition, traditional biomass dominates energy consumption in the region, accounting for about 50% of the total energy supply in 2008 (IEA, 2011a). These energy challenges have hampered economic growth thus contributing to both economic and energy poverty in the continent. Despite these challenges, the vast reserves of fossil fuels in the continent provide Africa with great opportunities to improve energy access, accelerate economic growth and reduce poverty.

However, the heavy reliance on fossil fuels to generate energy has contributed to a number of environmental and social problems at the local, regional and global levels including depletion of non-renewable resources, Ozone depletion, acidification and global warming, etc. The contribution of energy generation to the latter is particularly significant due to the emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs) generated during combustion of fossil fuels, which has exacerbated the impacts of climate change. According to the IEA (2010a), the burning of fossil fuels for energy accounted for about 65% of the global GHG emissions in 2008. Clearly, there are concerns with the continuation of this trend.

The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) (2007a) suggests global GHG emissions must be reduced by 50-80% by 2050 (compared to 1990 levels) in order to limit average global temperature increase to 2°C above pre-industrial levels. This implies a carbon constrained future where the use of fossil fuels will be restrained and more attention paid to less polluting energy systems. Although Africa accounts for less than 4% of the global GHG emissions (APF, 2007; World Bank, 2009), it is the most vulnerable region to the impacts of global climate change. The continent is highly vulnerable to increased climate-related 'shocks' such as droughts, storms, flooding and extremes of temperatures. This vulnerability will have enormous implications on key areas/sectors including agriculture and food security, water supply, healthcare, energy and regional security, biodiversity etc. (Boko et al., 2007; Conway, 2009; DFID, 2004; World Bank, 2009). This will be a major threat to the achievement of the Millennium Development Goals (MDGs) and the socio-economic development of the continent. Africa thus has twin challenges. First is using its huge amount of fossil fuel resources to improve energy access and increase economic growth, which is vital to sustainable development in the continent. The second challenge is to simultaneously mitigate the potential contributions from the consumption of these resources to climate change. Thus the future utilisation of fossil fuels in Africa will need to take place in the context of a low carbon development trajectory.

This paper aims to explore the current impacts of fossil fuels in Africa and the challenges and opportunities that exist for fossil fuel technologies in the context of low carbon development. The objective of the paper is to review reserves, production and consumption of fossil fuels as well as associated GHG emissions in Africa and explore the technical and policy options of mainstreaming fossil fuels into the future energy mix in a low carbon pathway. The paper has five main sections. Section 2 provides a brief overview of the current role of fossil fuels in Africa in terms of reserves, supply and consumption and associated GHG emissions. Section 3 explores the fossil fuel opportunities and technical options for Africa in a carbon constrained world and in the transition towards low carbon development pathways. The policy, institutional and financial challenges of these options are discussed in Section 4 while the policy implications and conclusions are provided in Section 5.

2. FOSSIL FUEL PRODUCTION AND USE AND ASSOCIATED GHG EMISSIONS IN AFRICA

With the increasing turmoil in the Middle East, the importance of Africa as a source of energy for the US and Western Europe has grown considerably. Fossil fuels are a major source of revenue for the leading oil and gas producing countries in Africa. For example, crude oil accounts for over 90% of foreign exchange earnings in Nigeria and the hydrocarbon sector accounts for about 35% of Algeria's GDP (CIA, 2011).

2.1. Fossil fuel reserves in Africa

Table 1 shows the reserves of fossil fuels and their distribution in Africa. Over 80% and 90% of the oil and natural gas reserves respectively, are found in Northern and Western Africa. Libya accounts for over 70% of the oil reserves in Northern Africa and Algeria accounts for about 55% of the natural gas reserves in the same region. Nigeria accounts for almost all the oil and natural gas reserves in Western Africa. In addition, three countries – Libya, Nigeria and Angola – account for about 80% of the proven oil reserves in the continent (EIA, 2011). This distribution of energy resources across the continent becomes more uneven considering South Africa accounts for about 95% of the coal reserves in the continent (EIA, 2011).

Table 1 Fossil fuel reserves in Africa

Energy Type	Reserves	Regional distribution
Crude oil	132.1 billion barrels	Northern Africa: 53.2% Western Africa: 28.2% Central Africa: 16.9% Other Africa: 1.7%
Natural gas	14.7 trillion m^3	Northern Africa: 55.8% Western Africa: 36.1% Other Africa: 8.2%
Coal	31,696 billion tonnes	Southern Africa: 95.2% Eastern Africa:1.6% Other Africa: 3.2%

Source: BP (2011)

There is also a more optimistic side to this state of affairs. The proven crude oil reserves in Africa is increasing; the proven reserves increased from 58.7 billion barrels in 1990 to 132.1 billion barrels in 2010 (BP, 2011). The recent increases in crude oil prices now make it economical to explore 'marginal' deposits. Today, exploration is taking place in many regions in Africa while countries such as Ghana, Uganda and Chad have already started drilling activities..

2.2. African fossil fuel production, consumption and export patterns

The trends in African oil production and consumption in comparative perspective are shown in Figure 1. There is generally an upward trend in Africa's share in global production especially since the 1980s. Similarly, Africa's share in global oil consumption has been increasing steadily since the 1970s. A comparison of oil consumption in barrels per day across continents in 1965 shows that it was 531 thousand in Africa compared to 3.25 million in Asia, almost 12 million in Europe and 13 million in North America (BP, 2011). Between 1965 and 1985, Africa's oil consumption tripled to 1.7 million barrels per day and reaching 3.2 million barrels per day in 2010. Oil consumption in North America was nine times that of Africa in 2005 but declined to seven times in 2010, largely owing to the financial crisis which shrunk the economies of countries in North America and Europe. One feature which is characteristic of the African fossil fuel situation is the gap between fossil fuel consumption and production. Africa's share of global consumption in 2010 was only 3.7% compared to a production share of about 12.4% (see Figure 1). Production has remained between 10.4% and 12.3% as a proportion to the total, while the long-term trend in consumption across Africa has remained at less than 4% of the global consumption from 1965 to 2010. Another paradox in this picture is that most African countries are net energy importers in view of the fact that currently exploitable oil reserves are concentrated in a few countries. As a consequence, the continent has 38 net oil-importing countries, demonstrating the high dependence of African economies on fossil fuels, often imported, and highly exposed to volatile world oil prices, jeopardising their balance of payments positions. For most oil-importing countries, the sharp increase in the cost of energy imports, coupled with the increasingly scarce resources of traditional energy due to rapid depletion, have created what can be called a double energy squeeze. The severe impact has eroded some of the gains in economic reforms in recent years and exerted strong pressure on macroeconomic stability and economic growth.

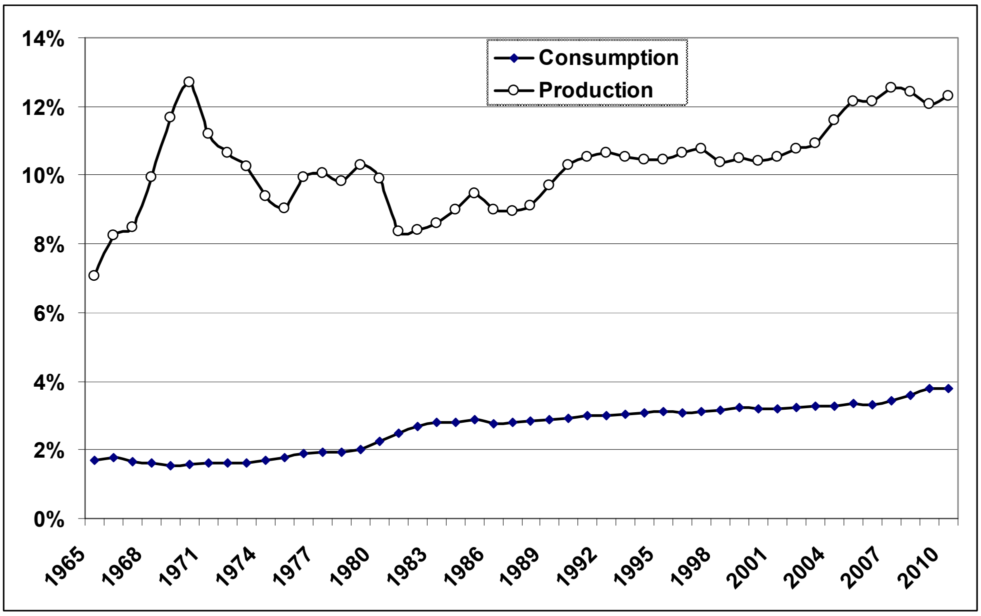

Figure 1 Africa's share in world oil production and consumption 1965-2010

Source: BP (2011)

From the total production of crude oil in Africa, Nigeria, Libya and Angola account for over 75%, and well over 70% of the crude oil produced in the continent is exported (EIA, 2011). For example, about 8 million barrels of the 10.6 million barrels daily production in 2009 was exported (see Figure 2). During the same year, about 915 thousand barrels per day was imported into the continent (South Africa accounted for almost 50% of this import). One explanation for this is the limited refining capacity across the continent, which stands at just over 3 million barrels day (EAC, 2008). Thus a majority of the African countries (including oil producers) are net importers of petroleum products; over 1 million barrels per day of petroleum products was imported into the continent as at 2007 (EIA, 2011).

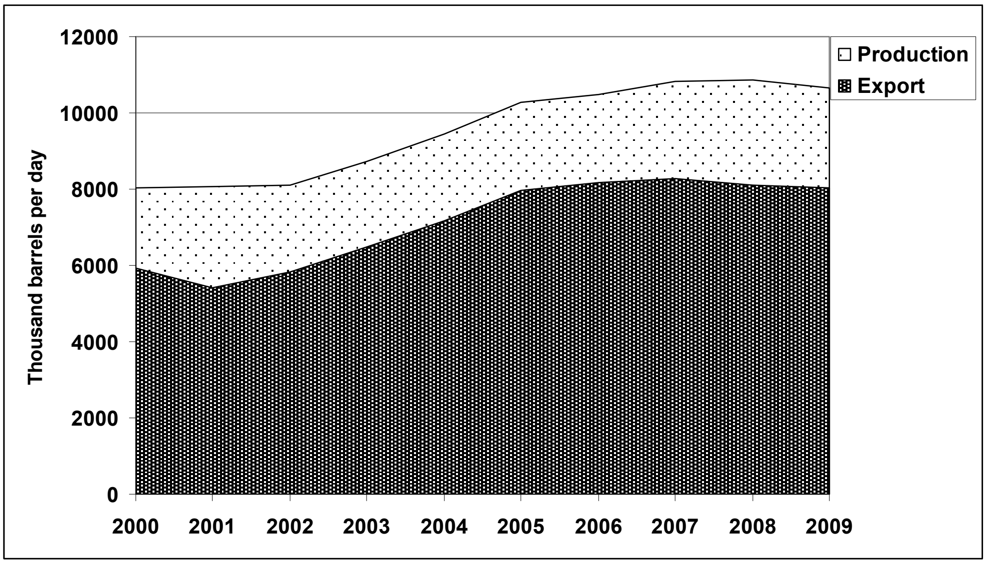

Figure 2 Production and exports of crude oil in Africa 2000 - 2009

Source: EIA (2011)

The production of dry natural gas in the continent increased by over 60% from 2000 – 2009 (see Figure 3). Algeria and Egypt account for 40% and 30%, respectively of the total production of natural gas in the continent and similar to crude oil, over 55% of the dry natural gas produced in the continent is exported (EIA, 2011). According to the IEA (2011a), coal production in Africa reached 262 million tonnes in 2008 (representing about 4% of global production) with only about 23% of this amount being exported, suggesting that this resource is mostly used within the continent. An increasing share of these reserves is most likely to be earmarked for the generation of electricity within Africa as there is high demand for electricity across the continent.

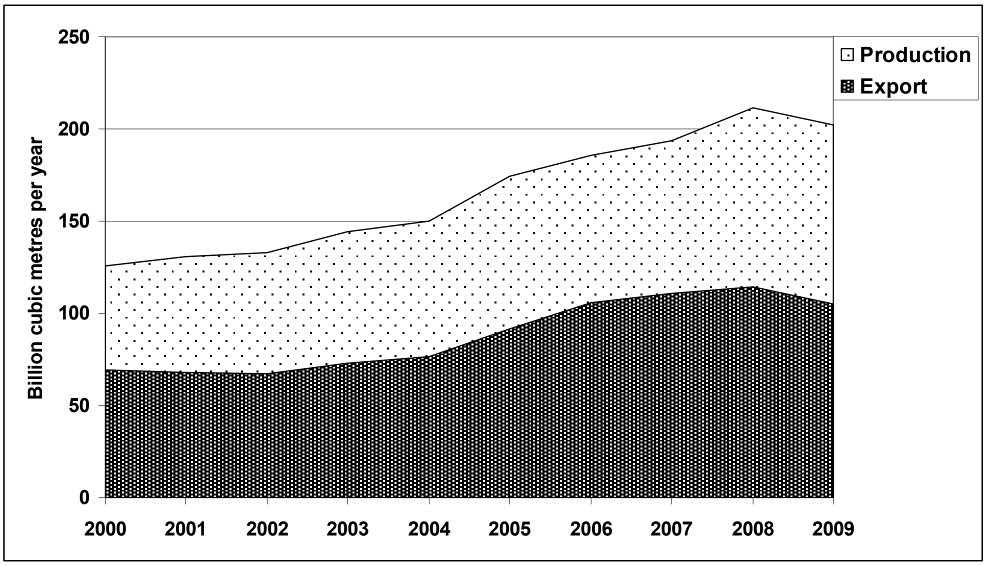

Figure 3 Production and exports of dry natural gas in Africa 2000 - 2009

Source: EIA (2011)

Africa will continue to play a significant role in the world energy market. Oil and gas resources are central to the economic growth of many African countries. Europe and China are the main partners for Africa. It is now evident that China has turned to Africa in order to meet the increasing energy demand for its economic growth. As a result, about one-third of its total oil imports come from Africa (Jiang and Sinton, 2011). With respect to gas, Algeria, Egypt, Equatorial Guinea, Libya, Mozambique and Nigeria are net exporters (AfDB, 2010). The export of refined petroleum products peaked at almost 1.5 million barrels per day in 2001, declining to about 900 thousand barrels per day in 2008 (see Figure 4). These exports are mostly dominated by Northern African countries, with Algeria alone accounting for about 50% of the exports in 2008 (EIA, 2011). However, the volatility of oil/gas prices, social and political conflicts and poor management have significantly reduced the gains from export revenue in most of these countries, thus there is a need for these countries to diversify their revenue bases in order to reduce the dependence on single commodities (AfDB, 2010).

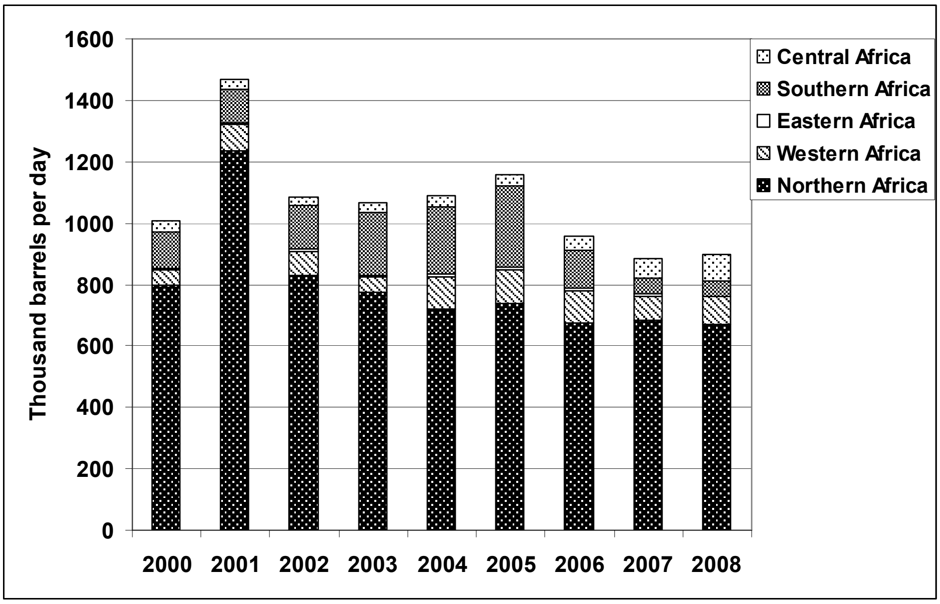

Figure 4 Share of exports of refined petroleum products per region 2000 - 2007
Source: EIA (2011)

The industrial and transport sectors are the biggest consumers of fossil fuels in Africa[1] (see Figure 5). The industrial sector accounts for about 55% of the coal and natural gas consumed while the transport sector accounts for over 60% of the crude oil consumption in the region. In terms of electricity, fossil fuels account for about 82% of the total electricity generation, mostly dominated by coal (41%) and natural gas (28%) (see Figure 5).

[1] This analysis does not include consumption in the electricity sector

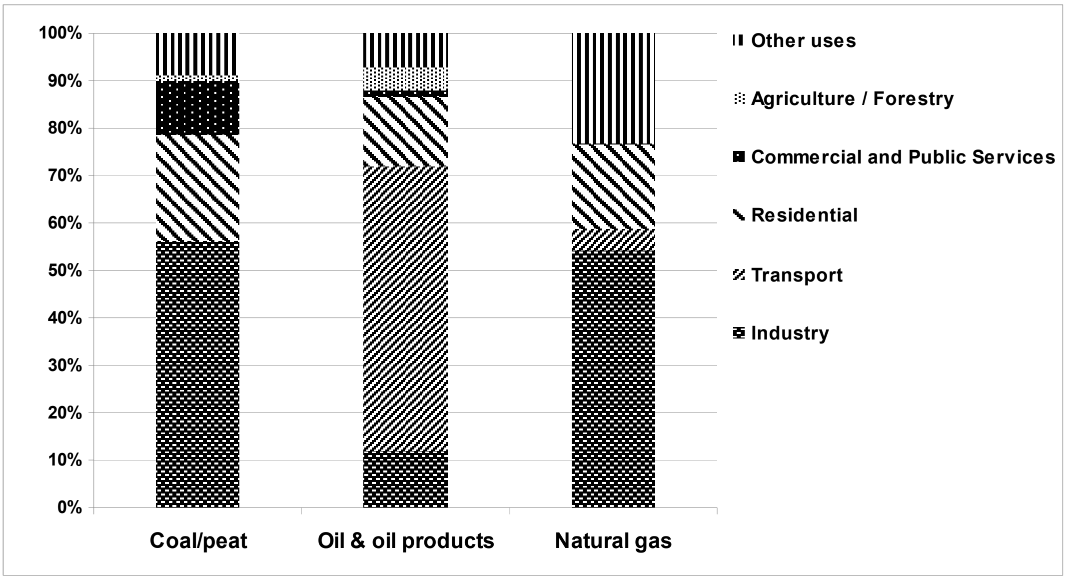

Figure 5 Sectoral consumption of fossil fuels in 2008
Source: IEA (2011a)

2.3. The role of fossil fuels in GHG emissions

Africa emits relatively low amounts of GHG emissions in comparison to other regions and it has very low CO_2 emissions per capita. Africa accounted for about 3.7% of the global CO_2 emissions from the consumption of energy in 2009 (EIA, 2011). The total CO_2 emissions increased by 26% from 2000 – 2009, reaching about 1.12 billion tonnes of CO_2 in 2009 (see Figure 6). Much of this increase is attributed to a combination of higher GDP growth across the continent, largely driven by the construction and industrial sectors. This trend is not unique to Africa. GDP growth and increased energy consumption have often followed parallel trajectories in developments across Europe, North America and more recently in Asia. In terms of the source of CO_2 emissions, consumption of petroleum accounted for the most (40%), followed by coal, natural gas, and gas flaring at 35%, 18.4%, and 6.3%, respectively. A small number of countries in Africa are largely responsible for the African emissions. Six countries – Algeria, Egypt, Libya, Morocco, Nigeria and South Africa accounted for over 70% of the CO_2 emissions from the consumption of petroleum while Algeria and Egypt also accounted for about 71% of the CO_2 emissions from the consumption of natural gas in 2009. South Africa accounted for over 92% of the CO_2 emissions from coal consumption, that same year. Africa also accounted for about 31% of the global CO_2 emissions from gas flaring; Nigeria accounted for about 36% and 11.4% of the CO_2 emissions from gas flaring in Africa and the World, respectively (EIA, 2011).

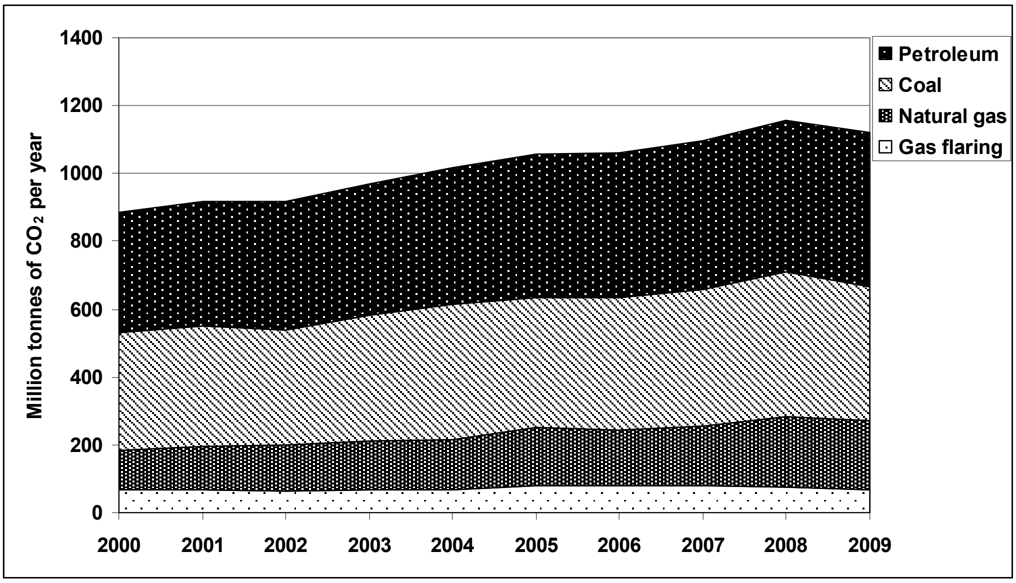

Figure 6 CO_2 emissions from the consumption of fossil fuels in Africa 2000 - 2009
Source: EIA (2011)

3. AFRICA'S OPTIONS IN A CARBON CONSTRAINED WORLD

3.1. Role of renewable energy sources

Renewable energy accounted for about 16% of the global final energy consumption and about 50% of new electricity generation capacity added globally in 2010 (REN21, 2011). Recently, renewable energy is gaining attention in Africa due to a number of reasons: (1) the high volatility and increasing prices of fossil fuels, especially oil, means a shift to other energy sources is necessary for energy security. Moreover, the increasing prices of fossil fuels and costs of grid extension also make the prices of some renewable energy technologies competitive under certain conditions. (2) There is a growing demand for energy in the region and renewable energy systems (especially small-scale) offer cost-effective options to provide off-grid energy supplies to isolated and remote areas due to their availability and modularity. (3) Fossil fuels are also the major cause of anthropogenic GHG emissions and thus renewables are perceived to constitute an important option for mitigating and avoiding the emissions of GHGs. (4) The region is also endowed with significant amount and variety of renewable energy resources including hydro, biomass, solar, wind and geothermal.

The potential for hydropower in Africa is estimated at 1,834 TWh/yr, mostly concentrated in Central (57%) and Eastern (32%) Africa; Democratic Republic of Congo (DRC) alone accounts for about 42% of the hydropower potential in the continent (WEC, 2010). Hydropower already accounts for about 16% of the electricity generation in Africa (IEA, 2011a), while it already supplies over 50% of the electricity consumed in 23 countries in the region (UNIDO, 2009), however, only about 7% of the hydropower potential in Africa is utilised (WEC, 2010). Thus there is an enormous potential and incentive to develop this energy resource in the continent. While large-scale hydropower could be harnessed to provide modern energy for development and urban areas, small-scale hydropower systems (SHPs) could also be used to provide electricity to rural areas.

The potential for biomass resources (woody biomass) is estimated at over 70 billion tonnes (Parikka, 2004), and this resource is available in all regions. Biomass is the most used energy resource in the continent accounting for about 50% of the total primary energy supply in the continent. However, the current consumption of biomass in the continent is unsustainable, with about 654 million people in Africa relying on traditional biomass for cooking; most of them in rural areas (IEA, 2010b). The unsustainable consumption of this resource has also exacerbated environmental and health problems. For example, more than 400,000 people in Africa die each year due to indoor pollution caused by the burning of biomass for cooking; most of the casualties are women and children (WHO, 2009). However, there are huge prospects in deploying modern and more efficient biomass fuels and technologies such as biogas and improved cooking stoves in the household sector. Biogas could also be used for power generation and transport. Bioenergy in the form of bio-ethanol and biodiesel could also serve as substitutes for petroleum products in the transport sector.

Africa also has an enormous potential for solar energy, which is available in all regions. Solar insolation in the continent is estimated at 1800 – 2850 kWh/m^2.a (WEC, 2010). The NREL (2008) also estimates the PV technical potential in the continent at 33 – 8,700 TWh/a and concentrating solar power potential at 7 – 40,500 TWh/a. With current electricity consumption in the continent of about 512 TWh as at 2008 (EIA, 2011), this potential could meet the electricity demand multiple times. Despite the high potential of solar energy in Africa, especially in desert areas like the Sahara and Namibia, so far, only South Africa operates a solar thermal power plant which has a capacity of generating 0.5 MW (UNIDO, 2009). Cost is considered as the major constraint for large-scale development of solar energy projects in Africa. With Wind speeds of about 6 – 7 m/s in Southern Africa (DRFN, 2010) and 5 – 8.5 m/s in Northern Africa (Business Insights, 2010), wind energy could also play a significant role in diversifying the energy sector in the continent. There is already about 1,014 MW if installed wind power capacity in the continent with about 96% of this capacity concentrated in Northern Africa (Egypt, Morocco and Tunisia) (WWEA, 2011). Geothermal energy potential is also estimated at about 14,000 MW (WEC, 2010), with this resource mostly concentrated in Eastern Africa. Currently, about 172 MW is installed in the continent, with about 95% of this installation in Kenya (WEC, 2010).

The enourmous potentials of renewable energy resources in the continent suggest there are prospects for the wide-scale development and dissemination of renewable energy technologies in the continent. Renewable energy systems could be deployed in the form of large-scale or small-scale systems for a variety of applications including electricity, heating, mechanical power etc. Large-scale renewable energy systems could help to diversify energy supply, reduce energy imports and help in mitigating climate change at the local and global levels. Large-scale renewable energy systems are usually grid-connected, requiring huge investments for their deployment and are normally funded through public funds (national budgets). Small-scale renewable energy systems in Africa are usually used in off-grid applications and as stand-alone systems, aimed at increasing modern energy access in areas that are too far or too costly to connect to the grid. Many African countries have a huge potential for SHPs, which require lower costs and increase the participation of the private sector. Stand-alone modular systems such as solar PV and wind pumps could also provide mechanical power needed in isolated communities such as rural areas.

3.2. The role of cleaner (fossil fuel) technologies

A major share of the increased concentration of CO_2 and other GHGs in the atmosphere could be attributed to the unsustainable production and consumption of energy, mainly from fossil fuels. According to the IPCC (2007b), the burning of fossil fuels (coupled with some contribution from cement manufacture) is responsible for over 75% of the increase in the concentration of anthropogenic CO_2 emissions in the atmosphere since pre-industrial times. The burning of fossil fuels in the electricity, transport and industrial sectors are the largest contributors to global CO_2 emissions, accounting for 41%, 23% and 20%, respectively of the total emissions in 2009 (IEA, 2011b). In terms of fuel sources, the IEA (2011b) also estimates about 43% of CO_2 emissions from fuel combustion were produced from coal, with oil and gas accounting for 37% and 20%, respectively in 2009. The global electricity sector relies heavily on coal, the most carbon-intensive fossil fuel source, which accounts for about 42% of the world's electricity (WCA, 2011). The level of dependency on coal for electricity generation is even higher in developing countries and economies in transition such as China (79%), India (69%), Poland (90%), South Africa (93%) and Kazakhtan (70%) (WCA, 2011). This trend of fossil fuel consumption, especially in developing countries is likely to continue in the short- to medium-term for reasons such as resource availability in these countries, low technical capacity and high costs of many clean energy sources, and the imperatives of increasing modern energy access to satisfy demand in these countries. Thus, the use of cleaner fossil fuel technologies in these countries will be critical in reducing GHG emissions. For example, the IEA (2011b) suggests that the widespread deployment of technologies such as carbon capture and storage (CCS) is necessary to curb the CO_2 emissions from the intensified use of coal.

The critical imperatives of improving energy access and poverty alleviation in Africa suggests some expansion of the fossil fuel supply would be necessary, perhaps in the short- to medium-term. But that expansion should be balanced with measures to develop cleaner energy solutions for the future. Therefore, focusing on technologies that improve energy efficiency and energy conservation would be the best strategy for reducing GHG emissions from the combustion of fossil fuels. This is because a shift to new renewable energy technologies is a long process due to many challenging barriers such as lack of information and awareness, high initial costs, lack of technical expertise, institutional problems for formulating and implementing renewable energy policies, etc. Furthermore, it also makes good financial sense to make maximum efficiency gains as the first step, which is likely to reduce the supply base and therefore likely to create an attractive investment environment for renewables. Given that fossil fuels will still dominate modern energy supplies in the short- to medium-term, there is need to give sufficient attention to advanced and cleaner fossil fuel technologies and strategies in order to reduce GHG emissions.

Technologies such as Clean Coal Technologies (CCTs) offer opportunities for GHG (and other pollutants) reduction potentials from the utilisation of coal for heat and electricity generation. The IEA (2008a) identifies four groups of CCTs including coal upgrading, improvements in existing power plant technologies, advanced technologies and near-zero emission technologies. Coal upgrading technologies involve treating coal before combustion to improve certain characteristics of the fuel such as moisture content, which affect the plant efficiency and energy density. Treating of coal before the combustion stage increases the efficiency and also reduces the emissions during the combustion stage. This technology can reduce CO_2 emissions by up to 5% (IEA, 2008a). Improving the efficiency of existing coal-fired power plants is also another strategy to reduce the amount of coal burned, thus reducing the CO_2 emissions. Increasing the efficiency of burning of coal to generate power is one of the less expensive ways of modestly reducing CO_2 emissions although it will require the construction of new equipments (WGA, 2008). This strategy offers CO_2 emissions reduction potential of up to 22% (IEA, 2008a). High-efficiency advanced coal technologies also offer CO_2 reduction opportunities in addition to a reduction in other pollutants such as Sulphur dioxide and Nitrous oxides. These advanced technologies include Integrated Gasification Combined Cycle (IGCC), Pulverised Coal Combustion (PCC) using sub-critical and super-critical steam, Pressurised Fluidised Bed Combustion (PFBC), and Fluidised Bed Combustion (FBC) using bubbling and circulating FBC beds. Near-zero emission technologies such as CCS also offer up to 99% reduction in CO_2 emissions (IEA, 2008a). However, CCS is still in the early stages of technical maturity and not ready for commercial use although there are signs that this technology could make a breakthrough given the sizable R&D investment in CCS technology. CCS normally involves capturing and storing CO_2 emissions deep underground or under the ocean floor and thus there are concerns about leakages and other environmental ramifications. On the other hand, CCS offers an opportunity in the medium-term for CO_2 mitigation.

Other advanced fossil fuel technologies that could be used to reduce CO_2 emissions from electricity generation due to their higher efficiencies compared to conventional turbine technologies include Combined Cycle Gas Turbines (CCGT), co-firing systems (e.g. combining coal with other fuels such as biomass) and Combined Heat and Power (CHP) systems (using coal, oil or gas). In general, the deployment of advanced fossil fuel technologies is limited in developing countries and Africa in particular due to high capital and operating costs. A number of barriers are also hindering the adoption and spread of advanced technologies such as CCS. These include lack of experience and expertise in the technology, lack of incentives and regulations from the government and increased fuel consumption due to CO_2 capture, and increased cost of operations, which will ultimately increase electricity prices (Anastassia et al., 2009).

GHG reduction measures need not be solely concentrated on technologies. Inter-fuel substitution and fuel switching strategies could also be deployed to reduce GHG emissions from fossil fuels consumption and moving to cleaner modern energy sources. Inter-fuel substitution and fuel switching in Africa will be particularly important in the electricity, household, industrial, and transport sectors. For example, Natural gas could serve as a 'cleaner' alternative to coal or oil due to its much lower CO_2 emissions per unit of energy compared to both fuels. Comparing coal and natural gas in electricity generation, coal power plants emit about 1 kg of CO_2 per kWh of electricity while natural gas plants emit only about 40% of this figure (0.4 kg) per kWh (Levine et al., 2010). Thus there is a huge potential deploying natural gas as a 'cleaner' fuel in the continent. Other GHG emissions reduction strategies in sectors with high fossil fuels consumption such as the transport sector are also critical in mitigating the current and future GHG emissions. For example, measures that can reduce energy and GHG emissions in the transport sector include improved traffic management and vehicle maintenance, modal shift and increasing vehicle efficiency, in addition to fuel switching.

4. POLICY, INSTITUTIONAL AND FINANCIAL CHALLENGES

4.1. Policy instruments

A number of policy instruments could be used to address climate change and related issues associated with the production and use of fossil fuels. These include emission taxes, targeted subsidies or their removal as appropriate, product charges, regulation, tradable permits/emissions trading, and information provision.

a. Taxes

Economic incentives such as taxes and subsidies could in principle be used to change behaviour of polluters. More particularly, taxes could be used to discourage emissions of GHGs from fossil fuel use, which are negative externalities. However, the poor regulatory environment in African countries could make imposition of taxes on GHG emissions very difficult. African countries do not also have binding agreements on GHG emissions reduction due to the low emission levels in the continent, thus limiting the scope for imposition of taxes. However, policy instruments such as product charges, e.g. taxes on gasoline or diesel used as transport fuels could be used to control GHG emissions. While such product charges may not be perfect substitutes for taxes on GHG emissions due to the use of fossil fuels, they could be very close to the target depending on the degree of association between fuel use and the extent of emissions. A number of African countries already impose taxes on fossil fuel consumption. However, product charges in these countries are normally applied to raise revenue and not to reduce GHG emissions, though it might help address the latter objective to the extent that consumers are sensitive and/or the taxes are high enough to influence behaviour. Other instruments such as tariffs, import duties and taxes on vehicles/equipments such as vehicles that use fossil fuels could also reduce fossil fuel consumption.

b. Subsidies

Subsidies could also be used as a policy instrument. For example, a company that uses a low-emission technology could be subsidised so that any additional costs due to such activity could be covered by the subsidy, thus encouraging such behaviour. This is generally not an option that could be used widely in the context of African countries because of the limited capacity of African countries to provide subsidies to such activities. This is more so when taking into account the fact that climate change is a global environmental problem mainly caused by developed countries and without assistance (e.g. climate finance), developing countries would not give priority to such actions due to limited capacity. On the other hand, there are significant fossil fuel subsidies which do the opposite of what is required, i.e. to reduce GHG emissions. Fossil fuels are the most heavily subsidised energy sources in the world (UNFCCC, 2007). According to the IEA (2010b), fossil fuel subsidies in the world totalled US$312 billion in 2009 and removing these subsidies could make a big contribution to meeting energy security and environmental goals, including mitigation of GHGs and other emissions. In the case of Africa, Nigeria, South Africa and Egypt are among the twenty largest primary energy consuming non-OECD countries with significant energy subsidies. An example is the case of South Africa where poverty tariffs are imposed on utilities, with the aim of providing free electricity (20 – 50 kWh per month) to poor households (Winkler et al., 2011). Using such tariffs to provide free energy has implications as it amounts to a huge cost to the economy in addition to implications on GHG emissions. For example, removal of an average subsidy of 6.4% of the market price in South Africa would improve annual economic efficiency by 0.1% of GDP while reducing energy consumption and CO_2 emissions by 6.3% and 8.1%, respectively UNFCCC (2007). The challenge here is to reduce and even eliminate such subsidies so that inefficient fossil fuel consumption could be discouraged and, among others, GHG emissions reduced. On the other hand, subsidies are also needed to address issues of limited access to modern energy and equity issues. Though there could be targeting problems, subsidies on fossil fuels such as kerosene used as cooking fuel are used to help the poor. While such policies may not necessarily help the poor (Kebede, 2006), increased consumption due to subsidies would imply increased emissions.

c. Product charges

Product charges as a policy instrument could take two forms. One is putting a limit on the amount of GHG emissions from different sources, which is difficult to monitor especially in the context of African countries. The second is putting restrictions on the type of technology to be used such as the type of vehicle or equipment. Although the intention may not be the reduction of GHG emissions, there are examples of the second form of regulation where older and more polluting technologies such as import of older cars are discouraged.

d. Tradable permits

Tradable permits also provide another policy option where emission permits are granted to different agents, which implies putting limits on emissions, but the agents are allowed to trade in permits so that those who find it more costly to limit emissions could buy permits from those whose cost of reducing emissions is lower. An important advantage of tradable permits over regulation is that the costs of controlling emissions would be lower as abatement will be done by agents with lower costs. While such policy instruments are becoming more common in developed countries, they are not common in developing countries in general and Africa in particular. There have been some useful experiences in Clean Development Mechanisms (CDM), although the proportion of projects implemented in Africa through the CDM has been minimal. At present, discussion and negotiations are underway within the UNFCCC process on how to reform CDM rules and methodologies so that the mechanism can be accessible to African countries.

e. Information provision

Information provision could serve as a policy instrument by mandating the provision of information on GHG emissions from agents/activities thereby influencing the behaviour of agents. This could take various forms such as labelling or public disclosure strategies. Such instruments are applied in some developing countries such as Indonesia and Mexico although the primary purpose is typically not to reduce GHG emissions but to address more local types of pollution problems (Sterner, 2003; Tietenberg and Lewis, 2009).

f. Indirect effects of some instruments

Another important dimension is the effect that policy instruments applied on other energy sources have on fossil fuels consumption. In particular, policy instruments to encourage the use of renewable energy such as feed-in-tariffs (FITs) and Renewable Portfolio Standards (RPS) or mandated quotas could contribute towards the reduction of GHG emissions by reducing the consumption of fossil fuels. Other instruments such as financial and fiscal incentives, e.g. exemption from import duties to encourage the use of renewable energy technologies, could also contribute to reduced consumption of fossil fuels, ,thus reducing GHG emissions.

Some polices also have implications on issues such as efficiency and equity. For example, removal of subsidies or imposition of taxes on fossil fuel use could contribute towards more efficient use of fossil fuels. However, whether or not such policies are equitable could depend on the nature of the subsidies or taxes and/or whether they are progressive or regressive. Recent studies have found that taxes on transport fuels in some African countries are progressive, suggesting that the burden of these taxes would fall more on the richer households (Sterner, 2007; Sterner, forthcoming (2012)). However, this is less so for fossil fuels (e.g. kerosene) used for cooking as the poor depend on it (Mekonnen et al., forthcoming (2012)). This suggests that application of the various policy instruments should consider different dimensions such as equity and efficiency as well as contribution towards emissions reduction.

The various policy instruments discussed have implications in terms of costs in various forms for society at large. This implies the need to support African countries in terms of finance, human and institutional capacity as well as technology transfer to enable them contribute towards reduction in GHG emissions.

4.2. Barriers to technology development and use

Miller and Eil (2011) review the different barriers to the development and deployment of clean energy technologies by classifying them into two categories. These include economic and institutional barriers. Economic barriers include high development and capital costs; limits on access to financing; lack of trained staff; technology risks that are difficult to mitigate in regular financial markets; lack of internalisation of environmental externalities of competing, high-emission energy sources; and policy barriers (such as fossil fuel subsidies) that artificially reduce the competitiveness of new technologies. Energy prices are still below marginal opportunity costs in many developing countries, reflecting the desire of governments to use energy supply to achieve political objectives (UNDP, 2000). Moreover, African countries generally prefer to invest in additional capacity rather than investing in cleaner fossil fuel technologies or in energy efficiency unless there are clear positive net benefits in the short-term for the country concerned. This implies that it is necessary to make climate finance available to encourage these countries to use cleaner fossil fuel technologies and improvements in energy efficiency.

The capital and operating costs are the main barriers for the deployment of advanced fossil fuel technologies in developing countries in general and Sub-Saharan Africa in particular. For example, CCS technology has the potential to substantially reduce global energy-related CO_2 emissions if deployed at a significant scale, in a timely manner and at competitive costs needed to attract investments. However, the high cost of CCS is seen as a serious impediment to its deployment (WEC, 2007).

Institutional barriers include weak institutional capacity to support adoption of new technologies. In addition, problems of monitoring and enforcement, environmental regulations, information shortages, and cultural and social barriers impede the diffusion and commercialisation of technologies. UNDP (2004) also associates institutional barriers to the weak deployment of advanced co-generation and poly-generation systems.

In general, the development and deployment of new technologies is particularly difficult in most developing countries and much more difficult in Sub-Saharan Africa except South Africa. Moreover, in a region where the main focus is the transition to modern fuel sources (reducing use of traditional energy sources), the adoption of cleaner fossil fuel technologies may not be the priority of the governments. Hence additional efforts and incentives would be required to encourage the use of these technologies.

4.3. Investment requirements and availability of finance

In Sub-Saharan Africa, excluding South Africa, lack of finance is the principal barrier to sustainable energy use. While official aid flows to Africa is increasing, there is still a need for additional external financing mechanisms to reduce poverty and improve lives, and this takes precedence over sustainable energy development (UNEP, 2009). Since Africa has huge fossil energy resources, it can conveniently meet its electricity needs solely from fossil fuels. However, the amount of investment capital allocated for electricity generation is very limited.

The World Bank (2006) estimates that developing and transition economies, including Africa, would need an average investment of US$300 billion per year between 2003 and 2030, to meet their energy needs, of which electricity need constitutes about 73% of the total. According to the same source, the yearly investments of US$80 billion in electricity in these countries only cover about 50% of what is needed. In Africa, there is already a financing gap of about US$23 billion per year in the power sector out of a US$41 billion[2] (6.4% of GDP) per year funding requirement for energy in the continent (Duarte et al., 2010). It is obvious that this huge investment gap cannot be covered by only public funds (which include funds from government, bilateral and multilateral donor sources). This is because public investments are increasingly difficult to finance as governments respond to pressures to balance budgets. Private investment capital, both foreign and domestic can be attracted to electricity infrastructure development. This requires the presence of markets for electricity and appropriate policy framework (OFID, 2008). Policy makers in the energy sector must pave the way for investment by the private sector.

Financing of clean fossil fuel technologies such as CCS is even more difficult. Financing is particularly difficult if emission trading credits are below the higher cost of advanced technologies and if long-term mitigation policies and incentives remain uncertain (WEC 2007). Moreover, political risks, absence of the necessary institutional frameworks and effective legal remedies, and prevalence of arbitrary interventions pose powerful barriers to mobilising investments in sustainable energy in Sub-Saharan Africa (UNDP, 2000). In order to move to a low carbon and clean energy pathway, Africa needs to significantly scale up investments in low-emission fossil-fuel technologies (including other technologies such as renewables).

[2]This estimate excludes the cost of clean and sustainable energy

4.4. Research and development

Secure, affordable, and environmentally acceptable energy sources are essential to a nation's security and economic prosperity. New technologies can make the future production and use of fossil fuels more efficient and environmentally cleaner. There is a concerted international effort to make advances in developing and implementing cleaner fossil fuel technologies. However, most of these efforts are in developed countries and are in research and development (R&D) networks.

The IEA Networks of Expertise in Energy Technology (NEET) initiative seeks to expand greater participation of all major energy consumer nations in the IEA energy technology collaborative network. To facilitate this, NEET energy technology workshops in non-IEA countries with fast growing economies enable energy technology experts and policy makers to share know-how and experience on technical issues, but also on institutional and market questions (IEA, 2008b). The best option is for African countries to be part of these networks.

Developing and deploying clean, efficient energy technologies presents challenges for many nations around the world (IEA, 2008b). Africa lacks the R&D capacity to support decision-making on energy. The problem of research and development in the energy sector can be understood by looking at the proportion of the GDP that Africa has on average allocated to R&D. According to the World Bank (2008), Africa devoted just 0.3% of GDP to research and development, which makes it difficult to provide the relevant knowledge and core skills needed for the continent. Lack of adequate funds, skilled professionals and commitment from policy makers are also responsible for the limited R&D in cleaner fossil fuel technologies in Africa.

5. CONCLUSIONS AND POLICY IMPLICATIONS

Fossil fuels are important energy sources that play vital roles in the economies of African countries. Today the bulk of energy needed for many applications in the continent are largely met by fossil fuels. These resources account for about 50% of total primary energy supply and one-third of energy consumption (excluding contribution to electricity generation) in the continent. Over 80% of electricity generated across the continent is also from fossil fuels. These energy resources are also a major source of export earnings for the major oil and gas producing and exporting countries in Africa such as Libya, Nigeria and Angola. Despite having huge energy resources, the continent is still faced with enormous energy challenges that include low access to modern energy, insufficient energy infrastructure, low efficiency and lack of technical capacity to use these huge resources. These energy challenges have hampered economic growth thus contributing to both economic and energy poverty in the continent. Despite these challenges, the vast reserves of fossil fuels in the continent provide Africa with great opportunities to improve energy access, accelerate economic growth and reduce poverty. Africa thus has to depend on its considerable amount of fossil fuel resources to improve energy access and increase economic growth, which is vital to sustainable development in the continent. However, use of fossil fuels could have major local, regional and global environmental impacts, and the environmental challenge is great. Although per capita emissions in Africa is still very low compared with the rest of the world, emissions from all fuel sources have grown in the African region over time. South Africa, Egypt, Algeria, Nigeria, Libya and Morocco are largely responsible for the African emissions from fossil fuels and cement production in Africa. Africa has to deal with mitigating the potential contributions of these resources to climate change. Thus the future utilisation of fossil fuels in Africa will need to take place in the context of a low carbon development trajectory.

Cleaner energy systems mitigate and even neutralise the adverse consequences of the use of fossil fuels and permit their positive qualities to be enjoyed for economic and social development. Africa has many options in a carbon constrained world. Use of renewable energy systems such as biofuels, hydropower, solar, wind, and geothermal provide attractive environmentally-sound technology options for Africa and many countries are moving towards developing these technologies in the medium and long-term. Inter-fuel substitution or shifts to other fuels which can reduce the local and global environmental problems are also important for African countries. Though there are few studies that examine inter-fuel substitution in developing countries in general and Africa in particular, it is believed that fuel substitution is possible at the household and industrial levels. Polices that encourage energy consumers to shift to less polluting fuel sources should be designed and implemented in the continent. This, however, should be based on a detailed examination and understanding of the behaviour of consumers towards the consumption of different types of fuels.

It is also increasingly clear that simply abandoning traditional fossil fuel energy sources is not a viable option. Therefore, the role of cleaner fossil fuel technologies should be given emphasis in developing countries in general and Africa in particular. Though there are a number of these technologies in developed countries and emerging countries such as China, India and South Africa, most of the African countries are faced with many challenges in the use and deployment of state-of-the-art fossil fuel technologies. South Africa is the only African country that is highly dependent on coal and currently trying to deploy clean coal technologies. The use and implementation of such advanced technologies in Africa is limited due to both economic and institutional barriers. The high capital and operating costs are the main barriers for the deployment of advanced fossil fuel technologies in developing countries in general and Sub-Saharan Africa in particular. Moreover lack of finance, lack of expertise and policy barriers such as subsidies also contributes to the problem. Institutional barriers such as problems of monitoring and enforcement, environmental regulations, information shortages, and cultural and social barriers impede the diffusion and commercialisation of such technologies. Moreover, in a region where the main focus is the transition to modern fuel sources, the adoption of cleaner fossil fuel technologies may not be the priority of the governments. There is also a need to cooperate with developed nations in this area as the associated environmental problems are both local and global in nature. Clean energy technology deployment requires concerted public and private commitment/partnership, supported by governments' actions that could facilitate the deployment of clean technologies in their respective countries.

There are various policy instruments that could be used to reduce the GHG emissions from fossil fuels consumption in Africa. These include emission taxes, subsidies, product charges, regulation, tradable permits/emission trading, and information provision. Taxes could be used to discourage emissions of GHGs from fossil fuel use although implementing these taxes could be difficult mainly due to the poor regulatory environment in African countries. Policy instruments such as tariffs, import duties and taxes on equipments that use fossil fuels could also have positive effects on fossil fuels use. Subsidies could also be used as a policy instrument. The challenge here is how to reconcile the removal of subsidy to increase economic efficiency with the cost incurred by the poor as a result of removal or decrease in subsidies on fossil fuels such as kerosene.

Another policy instrument is regulation which could be in the form of putting a limit on the amount of GHG emissions or putting restrictions on the type of technology to be used. The former is difficult to monitor especially in the context of African countries. The latter can be applied easily by restricting, for example, older and more polluting technologies such as import of older cars.

Policy instruments such as tradable permits are becoming increasingly common in developed countries. These instruments could be used in Africa to mitigate GHG emissions. Policies designed to affect other energy sources such as renewables can also reduce consumption of fossil fuels and hence reduce GHG emissions. This may occur if such policies reduce GHG by substituting fossil fuel consumption.

It is argued that Africa lacks the R&D capacity to support decision-making on energy. Sufficient resources (due to lack of sufficient funds) have not been allocated to conduct detailed studies of GHG mitigation measures in the continent as a whole. In addition, lack of skilled professionals and commitment from the government officials are also responsible for the limited R&D in fossil fuel technologies in Africa. Increasing public investment in innovation through support for R&D, as well as large-scale demonstrations is necessary. Moreover, it is advisable for African countries to be part of networks such as the IEA NEET initiative, which would enable Africa to gain expertise and experience on clean and advanced technologies.

Finally, further research on fossil fuels may help Africa reduce GHG emissions and enable the design of appropriate policies and strategies for the deployment of fossil fuel technologies. For example, there is a need to deeply investigate the role of different tax systems in the consumption of fossil fuels in Africa. There is also a need to examine the barriers to the adoption of different fossil fuel technologies in each country as the problems are country-specific. Strategies to move to clean technologies should also be planned based on the outcome of the research on the consumption, production and barriers of adoption of different types of clean technologies.

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