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ORIGINAL ARTICLE

Clean Development Mechanism Potential and Challenges in Sub-Saharan Africa

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Abstract Sub-Saharan Africa lags far behind other regions in terms of the implementation of Clean Development Mechanism (CDM) projects due to several reasons. One of the reasons is a general perception that, since the region contributes very little to global GHG emissions, it also offers few opportunities to reduce these emissions. Using a bottom-up approach, this study investigates the technical potential of reducing GHG emissions from the energy sector in Sub-Saharan Africa through the CDM. The study finds that sub-Saharan Africa could develop 3,227 CDM projects, including 361 programs of activities, which could reduce approximately 9.8 billion tons of GHG emissions during the CDM project cycles. The study also estimates that the realization of this CDM potential could significantly enhance sustainable development in the region as it would attract more than US$200 billion in investment and could generate US$98 billion of CDM revenue at a CER price of US$10/tCO2. Another notable finding of the study is that the realization of this CDM potential could supply clean electricity by doubling the current capacity and thereby providing access of electricity to millions of people in the region. However, realization of this CDM potential is severely constrained by a number of financial, technical, regulatory and institutional barriers.

Keywords GHG mitigation potential · Sub-Saharan Africa · Clean development mechanism

1 Introduction

The Clean Development Mechanism (CDM), introduced in Article 12 of the Kyoto Protocol (KP), might be considered as the main incentive for developing countries (DC) so far to participate in the global effort to combat climate change. This mechanism allows industrialized countries (IC) that are signatories to the KP to partly meet their emission limitations by buying certified emission reductions (CERs) generated from greenhouse gas (GHG) mitigation projects implemented in DCs. The mechanism has been operational since

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February 2005, when the KP entered into force. Since then 1,596 CDM projects have been registered (as of May 1, 2009) (URC 2009). These projects are estimated to reduce 1,594.2 million tons of carbon dioxide equivalent (CO_{2e}) GHGs by the end of first commitment period of the KP (i.e., 2012). Moreover, 3,137 additional projects are in pipeline for registration, which are expected to deliver another 1,337.6 million tons of CO_{2e} by 2012 (URC 2009).

Like other DCs, countries in Sub-Saharan Africa (SSA) region are expected to get opportunities for cleaner and low carbon economic development through the CDM as well as other climate change mitigation funding mechanisms such as World Bank's Climate Investment Funds (CIFs), Forest Carbon Partnership Facility, (FCPF) and the Reducing Emissions through Deforestation and Degradation (REDD). Until now, however, SSA's participation under the CDM has been extremely low. Out of the 1,596 projects already registered under the CDM only 20 are in the SSA (and 15 out of the 20 in South Africa). In terms of CERs to be delivered by 2012, these projects account for 2.25% of the total. Even if all 4,733 CDM projects already registered, requesting registration and submitted for validation are considered, SSA's share merely accounts for 1.6% in terms of the number of projects and 2.5% in terms of emission reduction by 2012. Why is SSA participation in CDM so low? Is this because of a lack of potential CDM projects in the region? No comprehensive answer is yet available to this question. What are the barriers that have prevented implementation of CDM projects in the region? What could be possible strategies to overcome these barriers? This study aims to answer these questions.

Only limited studies are available in the literature exploring GHG mitigation potential in SSA (e.g., URC 1995, 2001a). These studies only address selected countries, and they do not assess CDM potential. Some studies, such as Ajayi (2009), Sebitosi and Pillay (2008), Batidzirai et al. (2009) and URC (2001b), assess the renewable energy potential in selected countries in SSA, but they do not estimate GHG mitigation potential. Most recent climate change related studies in SSA are focused on climate change adaptation instead of climate change mitigation (e.g., Osbahr et al. 2008; Paavola 2008; Stringer et al. 2009; Thomas 2008).[1] Thus, studies covering the wide range of GHG mitigation options in all SSA countries would fill an important gap in climate change mitigation research in SSA region.

Using a bottom-up approach this study investigates potential CDM projects and estimates the GHG mitigation that can be achieved from those projects in 44 countries in the the SSA region. The methodologies developed by the CDM Executive Board (CDMEB) to screen CDM projects were used to identify the potential CDM projects in the study. The projects identified are from energy supply and demand side activities. Supply side activities include, among others, cleaner fossil fuel based power generation (e.g., combined cycle power plants, combined heat and power); electricity generation from renewable sources (e.g., hydro, photovoltaics, biomass, landfill gas); oil and gas upstream activities (e.g., gas flare control, coal bed methane) and efficient production of charcoal. Demand side options include energy efficiency improvement and fuel and technology switching activities in industry, transport and residential sectors (e.g., steam efficiency improvement in industry, compact fluorescent lamps, energy efficient electrical appliances, clinker reduction in cement manufacturing, substitution of diesel with Jatropha based biodiesel, etc.).

[1] However, there exists a number of studies on biological and geological sequestration of carbon dioxide emissions in SSA countries (e.g., Henry et al. 2009; Surridge and Cloete 2009; Williams et al. 2008; Unruh 2008; Roncoli et al. 2007; Perez et al. 2007).

Our study identifies 3,227 potential CDM projects, including 361 programs of activities,[2] with GHG mitigation potential of 740.7 million tons of CO_{2eq} annually in the 44 SSA countries. These projects are estimated to attract US$158 billion of total investment to the region and could generate US$7.5 billion of carbon revenue annually at a modest carbon price of US$10/$tCO_2$. Moreover, these projects could add 149 GW of clean electricity generation capacity, which is more than twice the region's current total electricity generation capacity of 68,675 MW. In addition, the energy efficiency CDM projects could avoid 21.5 GW of capacity addition, 31.3% of current existing capacity in the region. Many of these options comply with the conventional energy sector's strategy to provide consumers with sufficient, cost-effective, and reliable energy supplies. However, the potential has never been estimated before, and investment communities are therefore unfamiliar with it. The exploitation of this potential is contingent on the assistance in overcoming several barriers, such as market failure, lack of infrastructure and institutional capacity, lack of local skilled human resources, lack of awareness and information sharing, and, most importantly, lack of financial resources and foreign investors' perception that investment in SSA is risky. There exists a general perception that the SSA region has few industries, emits fairly small amounts of GHG emissions, and therefore has limited opportunities to reduce these emissions.

The study is organized as follows: Section 2 briefly discusses the overall methodological framework, followed by the estimation of CDM potential in Section 3. Investment flow that the potential CDM project could create is presented in Section 4, and the analysis of clean electricity generation and energy savings potential is presented in Section 5. Section 6 highlights the major challenges that the exploitation of CDM potential would face in the region. Finally, key conclusions are drawn in Section 7.

2 Methodological approach

The study selected 22 technologies or types of CDM projects based on suitability to a specific country or the region as a whole, availability of CDM methodologies for baseline establishment, and potential multiple benefits (e.g., reduction of energy dependency, improvement of local air quality) pertaining to economic development and environmental quality in the region. Table 1 lists the selected GHG mitigation technologies.

The overall approach used in the study to determine the technical potential and investment curve for abatement is illustrated in Fig. 1.

As can be seen from the figure, we used already approved CDM baseline and monitoring methodologies to estimate GHG mitigation from the selected options or potential CDM projects.[3] Table 2 presents the CDM methodologies either used in this study or similar to

[2] A programme of activities is an action that implements any policy/measure or stated goal (i.e. incentive schemes), which leads to GHG reductions or removal. This allows to bundle several similar CDM project activities to implement them under a single program.

[3] As May 29, 2009, about 118 methodologies had been approved, which includes 63 large scale CDM methodologies, along with 14 consolidated methodologies covering a wide range of activities and 41 simplified methodologies designed for small-scale projects. Each of the approved methodologies has unleashed a large number of mitigation activities. An additional 35 methodologies have been proposed and are under consideration. To date, about 1,647 projects have had their descriptions posted freely on the website of the UNFCCC secretariat. Please visit http://cdm.unfccc.int/methodologies/index.html for latest information on CDM project activities and methodologies.

Table 1 GHG mitigation technologies selected for the study

Category	Sub-category	Technology or CDM project type
Energy supply side	Electricity generation from fossil fuels	Open to combined cycle gas fired power plant (CCGT)
		Combined heat and power (CHP) for industry (CHP-Ind)
	Electricity generation from renewable sources	CHP for sugar mills (CHP-Sug)
		Agricultural residue (Residue-Agr)
		Forest residues (Residue-Forest)
		Wood-processing residues (Residue-Wood)
		Typha australis[a] (Typha)
		Jatropha biodiesel (Biodiesel-Elec)
		Hydroelectricity (Hydro)
		Photovoltaics in isolated rural areas (PV)
		Landfill gas (LFG)
	Electricity T&D	Electricity T&D loss reduction (T&D)
	Oil & Gas Upstream	Flared gas recovery (FGR)
		Coal mine methane (CMM)
	Oil Refinery	Waste gases in crude oil refinery (Refinery)
	Charcoal production	Improved charcoal production (Charcoal)
Energy demand side	Industry sector	Improved steam system (Steam)
		Clinker reduction in cement manufacturing (Clinker)
		Non-lighting electricity for industry (EE-Ind)
	Transport sector	Biodiesel from Jatropha (Biodiesel–Tran)
		Shift to Bus Rapid Transit (BRT)
	Household sector	Compact fluorescent lamps (CFL)
		Energy efficient appliances (EE-HH)

[a] a perennial, rhizomatous invasive plant species found in abundance along the Senegal and Niger rivers, where it has spread rapidly in recent years

the methods used in the study to estimate GHG mitigation from the activities considered under the study.

The estimation of technical potential involves a large set of data and assumptions. Detailed descriptions of data and assumptions and the step by step process employed for the estimation of technical potential and investment requirements are available in de Gouvello et al. (2008). A summary of key assumptions is presented in the Appendix, where the basis for estimating numbers of CDM projects under each project category is also indicated. Note however that estimation of CDM potential in the study requires a large volume of data, parameters and technical details in addition to these key assumptions. We recommend readers who are interested to reproduce the results to refer to Gouvello et al. (2008).

The unit investment costs are calculated by dividing the total investment requirement for a project by the volume of GHG mitigation that can be achieved throughout the CDM life of that project. Total investment of a CDM option is estimated by multiplying total capacity by the unit capital cost. In the case of electricity generation projects, for example, investment costs are estimated by multiplying total installed capacity (MW) in each project by unit capital cost (US$/MW). Total investments have not discounted as the study does not develop investment plans, instead it estimates the investment need if all technical potential

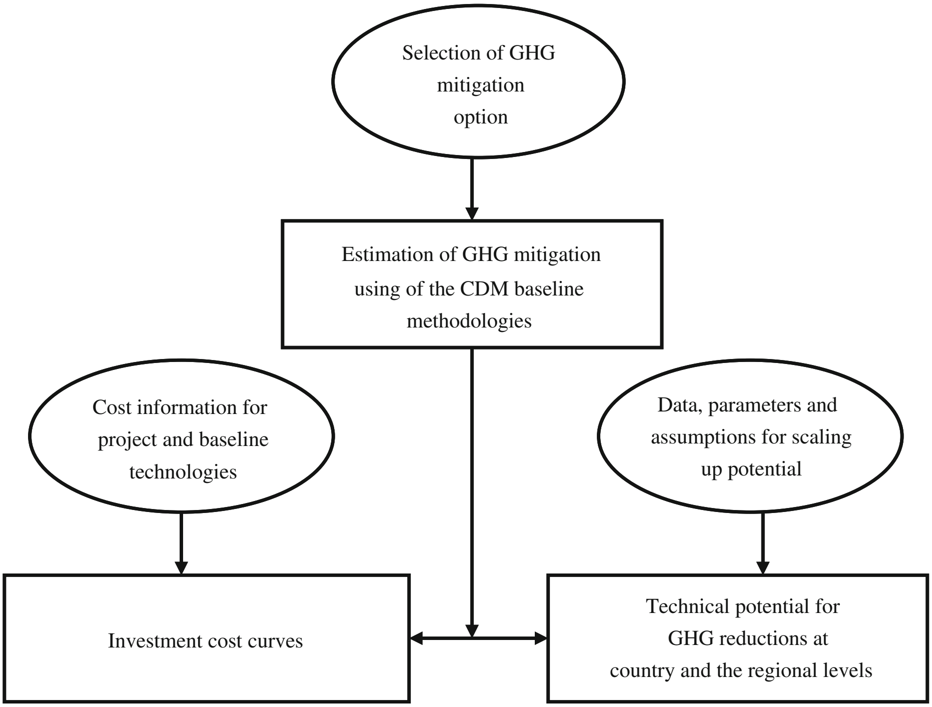


Fig. 1 Overview of the methodological approach

were to be realized immediately. Following current CDM regulations, the CDM project lives are either 10 years or 21 years depending upon the project type. While, biodiesel from jatropha, hydroelectricity and bus rapid transit system are assumed to have 21 years of CDM operation, the rest of the projects are assumed to have 10 years. Even with the longer CDM life period (i.e., 21 years), the unit investment costs of GHG mitigation from a project may be overestimated as the economic life of many project types would be much higher than their CDM life period. While unit investment costs calculated considering the full economic life of a project would be more relevant from societal perspective, unit investment costs calculated based on CDM life (i.e., truncated economic life of the project) would be more relevant for a CDM investor. While it would be highly relevant to analyze GHG abatement costs that capture both incremental capital costs and benefits from energy savings, this is beyond the scope of this study. Such an analysis requires numerous economic comparisons of these low-emission energy alternatives with more conventional ones at the local level. We consider that the abatement cost analysis could be part of a further study. Moreover, although at present, economic analyses are normally used for additionality test, all projects considered in this study are likely to pass the additionally test through other barrier analysis and hence economic analysis might not be needed. In addition, the fact that a large number of similar CDM projects are being implemented in other countries, mainly by the private sector, strongly indicates that such projects can be attractive when taking carbon revenue into account. The study assumes that project hosts (i.e., SSA country parties) receive a net price of US\$10/tCO_2 while estimating carbon revenue from all potential CDM projects and program of activities.

Table 2 CDM methodologies used to estimate GHG mitigation

CDM project type	Most relevant or used CDM methodology
CCGT	Conversion of gas turbine from simple cycle to combined cycle (ACM0007)
CHP-Ind	No CDM methodology (AM0014, AM0048, ACM0006)
CHP-Sug	Replacement of grid electricity as well as on-site diesel based power generation with baggase-fired electricity (ACM0006, ACM002)
Residues (Agr, forest, wood)	Replacement of fossil fuels with agricultural, forest and wood processing residues to produce electricity (ACM006, ACM007, ACM002, AMS-I)
Typha	Replacement of fossil fuels with Typha woody biomass to produce electricity (ACM006, ACM007, ACM002)
Biodiesel-Elec	Replacement of diesel with biodiesel to generate electricity (No CDM methodology available)
Hydro	Hydropower to replace fossil fuel use for power generation (ACM002)
PV	Solar photovoltaic to replace fossil fuel based power generation (AMS-I.A)
LFG	Capture and use of landfill gas to produce electricity thereby reducing methane release as well replacement of grid electricity (ACM001)
T&D	Reduction of fossil fuel use in power generation through reduction of electricity transmission and distribution losses (No CDM methodology available)
FGR	Utilization of flared or vented gas to produce electricity thereby reducing methane emissions (AM0009, AM0037, AMS-III.K)
CMM	Avoidance of methane emissions from coal mines (No CDM methodology available)
Refinery	Utilization of refinery waste gas to replace grid electricity as well as heavy fuel oil for on-site electricity generation (AM0055, ACM0012)
Charcoal	Reduction of methane emissions from charcoal production (AM0041)
Steam	Reduction of fossil fuel consumption through improvement of steam system efficiency in the industry sector (No CDM methodology available)
Clinker	Reduction of clinker to cement ratio in cement manufacturing industry (AM0005)
EE-Ind	Reduction of grid electricity through improvements of energy efficiency in industrial processes and devices (AMS-II.C)
Biodiesel-Tran	AMS-III.O; AMS-III.T; AM0047
BRT	Reductions of fossil fuel consumption through fuel efficient transport system (AM0031)
CFL	Replacement of energy inefficient incandescent lamps with energy efficient compact fluorescent lamps (AM0046)
EE-HH	Use of energy efficient appliances in the households (No CDM methodology available)

3 Potential GHG mitigation under the CDM

This study finds a large, diversified range of CDM opportunities across Sub-Saharan Africa's energy sector. Table 3 presents the estimated number of potential CDM projects, annual GHG mitigation that can be achieved from those projects and CDM proceeds at US\$5/tCO_2 and US\$10/tCO_2 CER prices. As can be seen from the table, more than 3,200 potential CDM projects, including 361 Programs of Activities, each consisting of hundreds of single activities, could be possible in the 44 SSA countries from the 22 technologies considered. If implemented, these projects would reduce about 740 million tCO_2 annually, more than the region's current annual GHG emissions (680 million

Table 3 Estimation of CDM potential in Sub-Saharan Africa

CDM project type	# of projects	Emission reduction				CDM proceeds (Million US$)	
		Annual		CDM life		US$5/t$CO_2$	US$10/t$CO_2$
		MtCO_2	%	MtCO_2	%		
CCGT	204	36.1	4.9	360.8	3.7	1,804.0	3,608.1
CHP-Ind	373	72.9	9.8	729.4	7.5	3,647.0	7,294.0
CHP-Sug	67	2.4	0.3	24.4	0.2	122.1	244.2
Residues-Agr	553	140.8	19.0	1,408.4	14.4	7,042.2	14,084.3
Residues-Forest	321	62.6	8.4	625.8	6.4	3,128.9	6,257.9
Residues-Wood	406	20.3	2.7	203.4	2.1	1,029.9	2,053.9
Typha	40	3.1	0.4	31.0	0.3	155.1	310.3
FGR	55	91.8	12.4	917.6	9.4	4,588.0	9,176.1
LFG	3	0.9	0.1	9.0	0.1	44.8	89.6
Biofuel from jatropha	555	176.8	23.9	3,712.0	37.9	18,560.0	37,120.0
Clinker	46	2.8	0.4	28.4	0.3	142.1	284.1
Refinery	26	4.3	0.6	43.4	0.4	216.9	433.8
T&D	20	1.1	0.2	11.3	0.1	56.6	113.2
Steam	211	36.6	4.9	366.4	3.7	1,831.8	3,663.6
CFL	49	13.3	1.8	132.7	1.4	663.4	1,326.8
EE-HH	30	7.4	1.0	74.4	0.8	372.0	744.0
EE-Ind	20	1.5	0.2	1.4	0.0	6.9	13.9
CMM	18	2.5	0.3	24.7	0.3	123.6	247.2
Charcoal	68	22.5	3.0	224.8	2.3	1,123.8	2,247.5
Methane leakage reduction	13	0.1	0.0	0.7	0.0	3.6	7.2
BRT	63	12.4	1.7	260.2	2.7	1,301.0	2,601.9
Hydro	26	25.2	3.4	528.6	5.4	2,643.1	5,286.3
Fuel switch	60	3.2	0.4	66.2	0.7	330.9	661.8
Total	3,227	740.7	100.0	9,785.0	100.0	48,938	97,870

tCO_2).[4] Moreover, these projects would install more than 170 GW of additional power-generation capacity, more than twice the region's current installed capacity. The additional energy provided, both electrical and thermal, would equal roughly four times the region's current non-conventional energy production.

The distribution of GHG mitigation potential across project types (i.e., GHG mitigation option) is notable. About 65.7% of the annual emission reduction potential would be achieved through supply side options, mainly biomass based electricity generation (e.g., bagasse, agricultural and agro-industrial residues, and forest and wood-industry residues). On the other hand, demand side options have relatively smaller potential, options such as energy efficiency improvements and fuel and technology switching activities in industry, transport and residential sectors, etc., would reduce only 34.3% of the total potential. In

[4] Because the technical potential of clean energy generation is larger than current energy demand, it could meet future demand growth and thus avoid additional GHG emissions under a business-as-usual development scenario.

terms of CDM life time emissions, supply side options account for 52.6%. More than half of the total electricity capacity addition (i.e., 53%) would be contributed mainly by cleaner fossil fuel based technologies. One should also note that clean energy projects that incur only incremental investment on already existing facilities, (e.g., fossil fuel or sugarcane–based cogeneration in industry) could deliver one-third potential additional capacity and one-fifth emission reductions.

Table 4 presents the distribution of potential CDM projects and emission reductions across 44 Sub-Saharan countries considered in the study. South Africa exhibits the highest potential of emission reductions with 23.8% of the total emission reduction potential. This is followed by Nigeria (15.4%), Democratic Republic of Congo (7.1%) and Angola (5.3%).

While unexpectedly large, this potential is not inconsistent with the rapid scaling up of the CDM worldwide, which is roughly doubling each year, (URC 2009). Indeed, the potential can be considered underestimated for two major reasons. First, the number of methodologies approved by the CDM's Executive Board is increasing every two months, suggesting that many more clean-energy activities might be applicable to the region. Second, various other types of projects (e.g., geothermal, concentrated solar power, wind farms, small hydropower plants, waste-to-energy projects¸ building energy efficiency, solar water heaters and improved household stoves) are left out due to the lack of data. In fact, the results are indicative rather than exhaustive.

4 Investment requirement

The study also estimates total investment or capital costs required to implement the CDM projects. Figures 2 and 3 illustrate the magnitude of investment by project type and by country, respectively. Due to a lack of data, investment requirement could not be estimated for some project types, namely, T&D loss reduction, energy efficient appliances in household and industry, gas flaring reduction, improved steam systems, BRT and biodiesel for transport, all together representing 417 CDM projects. A conservative estimate of the total capital cost of the remaining 2,755 clean energy projects is about US$155 billion.[5] If investment required for the options for which detailed data are missing were included, the capital cost estimate could exceed US$200 billion.

Figure 2 illustrates that replacement of electricity generation based on diesel with that based on biodiesel produced from jatropha could require as much as US$54 billion in capital costs. This is followed by power generation from agricultural residue, combined heat and power for industry, and forest residues. Substitution of inefficient lighting systems with efficient compact fluorescent lamps would require approximately US$5 billion.

The total investment requirement of US$155 billion represents 39.4% of the GDP of the 44 countries included in the study in 2006. The flow of these funds to SSA through climate change mitigation funding mechanisms, particularly the CDM, would thus significantly help sustainable development of the region. From an economic perspective, the net costs of CDM projects would be very small because most of these projects are electricity generation projects and most of the cost of such project can be recovered through the sale of electricity. For example, the jatropha biodiesel based electricity generation CDM projects are estimated to produce 218,767 GWh electricity annually. With a relatively low price of electricity of US$30/

[5] This figure does not include investment required for projects representing 36% of added power-generation capacity and 21% of emission reductions due to a lack of data.

Table 4 Distribution of CDM projects and emission reduction by country

Country	Project		Emission reduction	
	No.	% of the total	Million tons CO_{2e}	% of the total
Angola	251	5.2	520.5	5.3
Benin	51	1.0	80.0	0.8
Bissau Guinea	16	0.3	10.4	0.1
Botswana	42	0.9	128.9	1.3
Burkina	30	0.6	82.7	0.8
Burundi	13	0.3	6.5	0.1
Cameroon	70	1.4	167.6	1.7
Cap-Vert	4	0.1	0.7	0.0
Central African Republic	27	0.6	127.4	1.3
Chad	45	0.9	98.9	1.0
Comores	12	0.2	1.1	0.0
Congo Dem	170	3.5	696.8	7.1
Congo Rep	34	0.7	116.5	1.2
E. Guinea	33	0.7	62.5	0.6
Ethiopia	163	3.3	485.5	5.0
Gabon	56	1.1	108.9	1.1
Gambia	8	0.2	0.8	0.0
Ghana	149	3.1	187.4	1.9
Guinea	41	0.8	115.7	1.2
Ivory Coast	251	5.2	233.3	2.4
Kenya	317	6.5	265.9	2.7
Liberia	22	0.4	23.8	0.2
Madagascar	107	2.2	143.9	1.5
Malawi	90	1.8	90.7	0.9
Mali	37	0.8	94.8	1.0
Mauritania	36	0.7	32.3	0.3
Mauritius	26	0.5	12.9	0.1
Mozambique	123	2.5	415.7	4.2
Namibia	37	0.8	223.8	2.3
Niger	24	0.5	54.0	0.6
Nigeria	563	11.6	1,503.9	15.4
Rwanda	13	0.3	7.6	0.1
Senegal	55	1.1	102.9	1.1
Seychelles	5	0.1	5.7	0.1
Sierra Leone	22	0.5	26.9	0.3
Somalia	67	1.4	253.8	2.6
South Africa	834	17.1	2,325.1	23.8
Sudan	389	8.0	118.1	1.2
Swaziland	18	0.4	13.7	0.1
Tanzania	194	4.0	332.3	3.4
Togo	52	1.1	53.1	0.5
Uganda	144	3.0	160.8	1.6

Table 4 (continued)

Country	Project		Emission reduction	
	No.	% of the total	Million tons CO_{2e}	% of the total
Zambia	159	3.3	297.6	3.0
Zimbabwe	70	1.4	160.4	1.6
Sub-Saharan Africa Total	4,871	100	9,785.0	100

MWh, the CDM projects would generate approximately US$57 billion from electricity sale alone at a 10% discount rate over a CDM life of 21 years. This revenue is approximately 6% higher than the required investment of US$53.6 billion. Although we have not presented it in the study, a rough estimation indicates that many of these CDM projects with relatively large emission reduction potentials are likely to produce more revenue than they cost when their carbon reductions are priced at US10/tCO_2. This simple calculation indicates that many of the CDM projects could be attractive to private investors on purely financial ground. However, investors tend to consider many risks, including political risks, and therefore might not be interested in investing in CDM projects in SSA countries unless the various risks they perceive can be minimized. Moreover, CDM projects could face several barriers as discussed in Section 6. Hence, involvement of multi-lateral institutions such as the World Bank and African Development Bank, which have higher risk management capacities, looks imperative to realize the investment demand under the CDM in SSA countries.

It would also be interesting to analyze the investment intensity of the CDM projects identified. Figure 4 presents an investment curve for GHG abatement. As can be seen from the figure, CDM projects for reducing clinker use in cement industry, improving energy efficiency in charcoal production, generating electricity from landfill gas and coal mine methane require relatively small investment per unit of GHG reduction (< US$5/$tCO_2$). However, the emission reduction potential is also relatively small from these options: 262 million tons during their CDM project cycle. On the other hand, CDM projects replacing diesel with biodiesel from jatropha offer the highest volume of GHG mitigation (3,712 million tons) but are estimated to require US$14/$tCO_2$ of investment. CDM projects using agricultural, forest and wood residues to produce electricity are estimated to reduce 2,228 million tons of GHG during their project cycle with investment of US$27-28/$tCO_2$. The investment cost curve reveals, contrary to general perception, that GHG mitigation or CDM projects are not expensive in SSA. Note that the investment per unit of GHG mitigation presented in Fig. 4 is the total investment under the CDM scenario; this is not incremental to the baseline investment. Still, these costs are relatively low. Moreover, most options considered in the study not only reduce GHG emissions but also produce electricity through clean sources. If revenue generated from electricity sales is accounted for, most of these projects would be economically attractive even at a relatively low carbon price (< US$10/$tCO_2$). For example, using a 10% discount rate, we find that electricity revenue alone would be higher than investment at the lowest electricity price of US$30/MWh available in SSA for the CDM projects with larger mitigation potentials (e.g., jatropha, agricultural, wood and forestry residues).[6]

[6] A detailed economic analysis of GHG mitigation options is beyond the scope of this study; it could be an interesting further analysis.

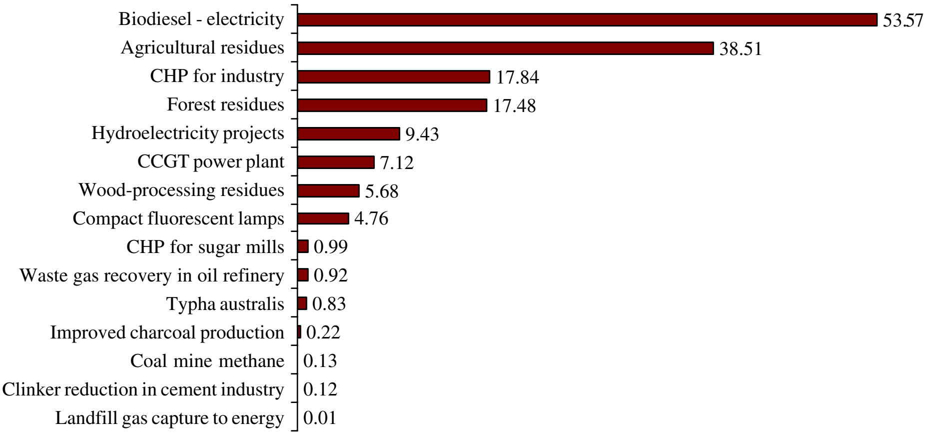


Fig. 2 Investment demand by project type (in billion US$)

5 Electricity generation and saving potential of the CDM project

One of the main objectives of the CDM is to help developing countries to achieve their sustainable development (UNFCCC 1998). Electricity generation from clean or green sources to increase access to modern energy in SSA certainly helps to meet this objective. Considering this objective, the study focused mostly on those projects which have the potential to produce clean electricity while reducing GHG emissions. Table 5 presents electricity generation capacity and annual generation of clean electricity from the potential CDM projects. The table also presents potential savings in electricity consumption and avoidance of capacity addition due to demand and supply side energy efficiency improvements.

As can be seen from the table, the clean electricity CDM projects could produce 1,178 TWh of electricity annually, more than three times as much as the 2006 total generation of 375.5 TWh

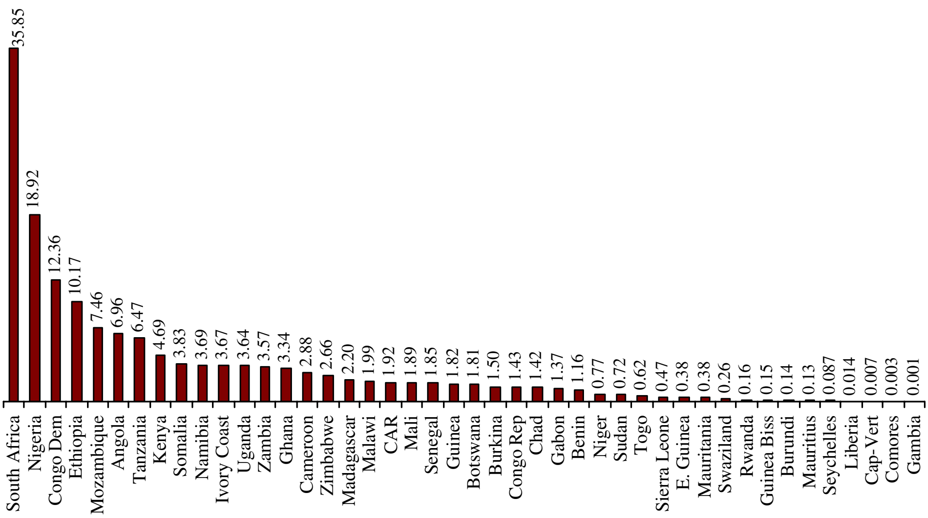
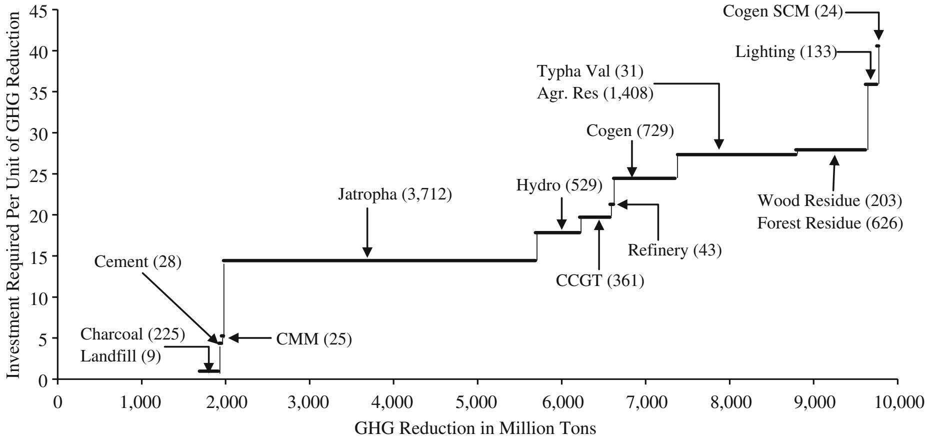


Fig. 3 Investment demand by country (in billion US$)



A total mitigation potential of 1,627 million tons including 918 million tons from reducing gas flaring, 366 million tons from improved steam systems in industry, 260 million tons from bus rapid transit, 74 million tons from energy efficiency in households, 66 million tons from fuel switching in industry and 2 million tons from energy efficient motors and reduction of leakage from gas pipelines are not shown in this figure due to lack of investment data.

Fig. 4 Investment curve for GHG abatement in Sub-Saharan Africa

Table 5 Potential clean electricity generation and savings

CDM Project type	Electricity generation capacity (MW)	Annual generation (GWh)
Clean electricity capacity addition and energy production		
Landfill Gas	10	49
Coal Mine Methane	109	809
CHP – Sugar mill	661	3,489
Typha australis	593	4,675
Waste gas in oil refinery	659	5,777
Wood Residues	4057	31,987
Hydro	6,443	35,961
CCGT Power	5,931	51,912
Forest Residues	12,483	98,415
CHP – Industry	17,844	156,314
Agri. Residues	27,504	216,842
Biodiesel – Electricity	27,748	218,767
Flared Gas Recovery	44,826	353,409
Total Additions	148,868	1,178,406
Electricity savings and capacity avoidance		
Efficient Motors in Industry	740	5,837
Efficient Appliances in Households	1,412	11,131
Compact Fluorescent Lamps	15,248	17,269
T&D Loss Reduction	4,056	31,974
Total Savings	21,456	66,211

in the region. Similarly the energy efficiency CDM projects could save 66 TWh annually, or 17.6% of total generation in 2006. The clean electricity generating CDM projects would add approximately 149 GW of capacity, more than double the 2006 capacity of 68.7 GW. Similarly, the energy efficiency CDM projects could avoid 21 GW of additional capacity, or 31.2% of the total installed capacity in 2006. Thus, the CDM projects considered in the study clearly meet both objectives of the CDM, promoting sustainable development in developing countries and lowering the cost of GHG mitigation in industrialized countries.

6 Challenges to realizing the potential

A large number of technical, regulatory and economic barriers have been preventing the implementation of clean energy projects, even if the CDM provides some incentives for their implementation. Examples of these barriers include the lack of: (i) infrastructure planning and development, (ii) awareness and information sharing, (iii) local capacity for operating clean energy technologies, (iv) research and development, (v) development of level-playing field for clean energy projects, and (vi) other facilitative mechanisms besides CDM.

Lack of infrastructure planning and development is one of the main barriers to the development of CDM projects. For example, biomass-based energy generation faces a dual infrastructure challenge: collection and transport to the energy production facility and construction of transmission lines to deliver power to the market. Lack of awareness and information sharing contributed to the slow start of the CDM process in SSA. Most of the region's small- and medium-sized industries ignore the opportunity provided by energy-efficient options for improved profitability and competitiveness. As a result, the use of older, inefficient and polluting equipment persists. With regard to agro-industry and forest and wood-processing industries, residual biomass (e.g., sugarcane bagasse, groundnut shell, rice husk, and palm fiber) is commonly viewed as a waste-disposal issue or, in certain cases, is burned inefficiently to generate a limited amount of process heat to eliminate an undesirable byproduct. In addition, there exists a lack of knowledge and information regarding the CDM and carbon finance (CF) opportunities and procedures. This presents a key obstacle to CDM project identification.

Lack of local capacity, particularly the skilled human resources required for proper operation and maintenance of equipment, contributed to energy losses and increased emissions. For example, when steam traps in industrial steam systems malfunction, the traps are not immediately repaired or replaced, thereby causing the release of condensate into drainage lines and loss of considerable amounts of energy. In the area of bio-energy, lack of proper operational skills for certain techniques also generates bottlenecks that limit the development of corresponding clean-energy potential. The capacity to adapt clean technologies to local resources is low in SSA as compared to other developing regions. For example, most countries in the region lack the equipment required to obtain the full energy potential from local biomass. R&D activities to adapt efficient, pre-use transformation solutions and combustion equipment to the unique characteristics of diverse biomass residues found in SSA are absent.

Overcoming the barriers mentioned above is the greatest challenge to implementing CDM projects in SSA. Some options with the potential to address the challenges include: (i) focusing of new instruments for low carbon economic growth (e.g., clean energy technology fund of the World Bank) to SSA region, (ii) establishment of SSA region specific carbon finance facilities, (iii) enhanced south-south cooperation and (iv) addressing social, political and cultural needs.

While the CDM is the main vehicle for climate change mitigation investment in developing countries, the CDM alone will not solve the financing problem SSA is currently facing to implement climate change mitigation projects. This is because the carbon revenue could be very small compared to the total investment required in many CDM projects with large infrastructure components, and it will not usually suffice to ensure financial closure. Therefore, additional funding, either for the preparation or the implementation of climate change mitigation projects, is imperative to realizing the CDM potential in SSA. Moreover, in the context of resource constraints and political pressure on public utilities to contain a looming energy crisis, most industrial companies seek quick fixes and less capital-intensive options, which are usually more carbon intensive. For many of the region's smaller poor countries (e.g., Burkina Faso, Burundi, Cape Verde, Chad, and Senegal), this frequently means the multiplication of small diesel or heavy fuel-oil generators (less than 10 MW each) and simple, short-lived repairs of inefficient, outdated generators. In larger countries (e.g., Kenya and Nigeria), it is more likely that power-utility decision makers will implement single-cycle gas turbines, which are faster to build and cheaper to operate compared to combined-cycle systems or large hydropower plants. Breaking this vicious circle, which harms not only these countries' economies but also the global environment, requires new investment financing instruments, earmarked to promote medium-term clean and efficient solutions, in addition to existing instruments to finance shorter-term solutions and carbon funds to internalize global benefits. Thus, compatibility between new funding for clean technology (e.g., the Clean Technology Fund, CTF[7] of the World Bank) and the CDM is critical since many of the region's clean energy projects must overcome both a lack of investment financing and low returns compared to other investment opportunities, and thus may need to remain eligible for CDM and CTF.

Although this study finds huge technical potential of CDM projects in SSA countries, this does not imply a dramatic increase in CDM projects in the region because removal of key barriers to these projects takes time. Moreover, a similar study could identify much higher CDM potential in big countries, such as China, India, Brazil and Indonesia, where investment markets and climate are more favorable than that in the SSA region. Most countries in SSA have less attractive investment climate as compared to the rest of the world. The World Bank's 'Doing Business 2010' report ranks most countries in SSA at the bottom of the list of 183 countries (World Bank 2009a).[8] Hence, new and innovative mechanisms should be introduced to facilitate clean energy investments in the SSA region. One approach could be an establishment of clean investment mechanisms dedicated to this region. The CTF established at the World Bank could be an in important milestone in this direction as it aims to facilitate the flow of both public and private sector investment to climate change mitigation activities in the developing countries. Through the public sector channel, it directly invests in clean energy projects and programs. On the private sector front, it provides incentives necessary to engage the private sector in clean energy projects including a range of concessional financing instruments, such as grants and concessional loans, and risk mitigation instruments, such as guarantees and equity (World Bank 2009b). However, considering the current size of this fund and its mandate and also considering the competition from other regions for the same resources, its contribution to realize the full CDM potentials in the SSA region would be limited.

[7] CTF is an innovative funding mechanism established in 2008 by the World Bank Group in consultation with the regional development banks and developed and developing countries, and other development partners to support climate change mitigation activities in developing countries. The CTF aims to demonstrate how financial and other incentives can be scaled-up to accelerate deployment, diffusion and transfer of low-carbon technologies (World Bank 2009b).

[8] Some SSA countries, such as Rwanda, Botswana and Malawi have been recently regarded as the top reformers to improve their business environment (World Bank 2009a).

Most of the region's CDM projects might be smaller in size than that required by many existing carbon funds. Most investing parties would be interested in investing emission reductions activities in relatively large deals, because working through a large number of relatively small projects not only possesses a huge transaction costs but also turns out to be too burdensome administratively. This issue can be addressed, in part, by bundling together many similar smaller projects under the CDM's new Program of Activities. However, the challenge is to develop regional institutional approaches for bundling together a large number of projects and offering them to a "buyer" as a package. Moreover, bundling of projects activities could trigger additional coordination challenges that may be difficult when similar projects are scattered across countries, some of which may be located in conflict or post-conflict zones. Nevertheless, African countries have already started to present themselves as a unified group in the international climate change negotiations.[9] This spirit could continue to set up regional or sub-regional institutions that coordinate issues like bundling of CDM projects. Existing regional or sub-regional economic organizations, such as The African Union, The Common Market for Eastern and Southern Africa (COMESA), The Southern African Development Community (SADC), The East African Community (EAC), The Economic Community of Central African States (ECCAS), and The Economic Community of West African States (ECOWAS), could be helpful for this purpose.

Another possibility to promote CDM implementation in SSA countries could be enhanced south-south cooperation. A large proportion of registered CDM projects in middle income developing countries such as Brazil, China and India are unilateral projects. The private or public sectors of these countries, which have already acquired good experience with CDM project development, could also be interested in CDM projects in SSA countries. Even the private sectors of the middle income countries within the region, such as South Africa, could invest in clean energy projects in other SSA countries.

One of the specific characteristic of most countries in the SSA region is that CDM projects that help meet social, cultural and political needs would likely be more successful as compared to others. Unemployment among the unskilled population is a key source of crime, political violence and social backwardness. CDM projects that create more jobs for unskilled populations would help address this issue. CDM projects such as agricultural and forest residues for power generation, jatropha based biodiesel for transportation and power generation are likely to create more jobs to unskilled population. For example, harvesting jatropha is very labor intensive. Interestingly, this study finds the largest number of CDM projects and the highest amounts of GHG mitigation in these project categories.

7 Concluding remarks

Using a bottom-up approach, this study estimates greenhouse gas mitigation through potential CDM projects in the sub-Saharan Africa region. The study identifies 3,227 potential CDM projects, including 361 programs of activities, with GHG mitigation potential of 740.7 million tons of CO_{2eq} annually in the 44 SSA countries. These projects are estimated to draw more than US$200 billion of total investment in the region and could generate US$7.5 billion of carbon revenue annually at a modest carbon price of US$10/t$CO_2$. Moreover, these projects could add 149 GW of clean electricity generation capacity, which is two times as high as the region's current total electricity generation capacity. In addition, the energy efficiency CDM

[9] African countries are presenting themselves in the Copenhagen climate conference as a single group thereby strengthening their position during the negotiation.

projects could avoid 21.5 GW of capacity addition, i.e., 31.3% of current existing capacity in the region. Many of these options comply with the conventional energy sector's strategy to provide consumers with sufficient, cost-effective, and reliable energy supplies. However, this potential has never been estimated before, and therefore investment communities are unfamiliar with it. The exploitation of this potential is contingent on the removal of several barriers, such as market failures, lack of infrastructure and institutional capacity, lack of local skilled human resources, lack of awareness and information sharing, and, most importantly, lack of financial resources and foreign investors' perception that investment in SSA is risky. There exists a general perception that the SSA region has few industries and opportunities for GHG mitigation, but this study demonstrates that the potential for clean energy projects in Sub-Saharan Africa is large. In this context, innovative, climate change–related financial instruments offer an unprecedented opportunity to explore this overlooked potential for the socioeconomic benefit of countries across the region. This goal can be achieved via appropriate coordination of new climate-change aid with conventional energy sector–based support provided by development aid agencies. An illustration of such required coordination is the need to fill regulatory gaps in the region's energy sectors, which prevent implementation of clean energy projects. Without appropriate coordination between climate-change and conventional-development aid, economies in Sub-Saharan Africa will be further hindered, or even prevented, from receiving their share of the carbon revenues that already flow to the world's other developing regions.

As discussed above, the financing required to implement some 2,755 potential clean energy projects for which preliminary costing could be done is estimated at about $US155 billion. If the capital cost of projects related to large flared, associated-gas recovery could be calculated, this figure would likely exceed US$200 billion. While this figure may be perceived as large, in the context of global climate change, it represents only a small fraction of recently estimated amounts required for industrialized countries to shift from conventional to cleaner energy over the next several decades.

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Appendix

Key assumptions to estimate GHG mitigation potentials

Technology or CDM Project Type	Key Assumptions
Open to combined cycle gas fired power plant	All open cycle gas turbines (OCGT) commissioned since 1991 are converted to combined cycle (CC) mode, and all planned but not yet operational OCGT plants are replaced with CC plants; economic life of a power plant is 30 years, a power plant can have a single or multiple CDM projects depending on the country situation and size of the plant
Combined heat and power (CHP) for industry	All industrial establishments requiring low and medium temperature heat (e.g., food processing industries) adopt CHP; the emission mitigation threshold of a CDM project is set at 20 and 40 $ktCO_2$/year depending upon the annual GHG mitigation potential through this option in a country

CHP for sugar mills	Existing sugar mills implement an efficient, high pressure baggase fired CHP plant to replace low pressure inefficient stand-alone power and steam plants normally run with diesel or heavy fuel oils; a project site (sugar mill) represents a CDM project
Agricultural residue	Agricultural residues from perennial plantation and annual crops are used to produce electricity which would otherwise have been produced by burning fossil fuels (natural gas for conservative estimates); residue to product ratios vary across countries; avoidance of methane emissions from the decay of residues was ignored for of conservative estimates of GHG mitigation potential; the size of a CDM project is 50 MW.
Forest and wood residues	Forest residues (e.g., branches, stumps, top of trunks) and residues from wood processing industries (e.g., log cores, wood slabs, end pieces and saw dust) are used to produce electricity which would otherwise have been produced by burning fossil fuels (natural gas for conservative estimates); 0.134 tons of forest residues per ton of roundwood harvest; thermal efficiency of residue-fired steam turbine is 33%; the size of a CDM project is 10 MW due to the diffuse nature of forest residues as compared to agriculture residues.
Typha australis	Typha found along Senegal and Niger rivers is used to produce electricity which would otherwise have been produced burning fossil fuels (natural gas for conservative estimates); harvestable quantities available in the Senegal River valley 200,000 tons/year, energy density 17MJ/kg of dry mass; thermal efficiency of residue-fired steam turbine is 33%; the size of a CDM project is 10 MW
Jatropha biodiesel for electricity generation[a]	Degraded lands amounting to 2% of the total land area is available for cultivation of jatropha; diesel is replaced with biodiesel in existing diesel-fired power plants; jatropha yields vary across country depending on soil and climatic conditions; a CDM project (or program of activities) represents an electricity plant with installed capacity 10 MW or lower
Hydroelectricity	Selected hydropower plants in countries endowed with significant hydropower potential (e.g., Guinea, Cote d'Ivoire, Mali, Democratic Republic of Congo, Republic of Congo, Burkina Faso) displace or delays thermal power plants with average emission intensity of 0.8tCO_2/kWh, a CDM project represents a hydropower plant irrespective of its installed capacity
Photovoltaics in isolated rural areas	Electricity generation from PV cells replaces kerosene or diesel fired electricity for lighting in rural and peri-urban areas; 120,000 households are supplied with 75-kW PV kit per households
Landfill gas	Use of landfill gas to produce electricity in cities with population more than 1 million and an average precipitation above 500 mm; recovery efficiency of LFG is 70% and fraction of methane in LFG is 0.5; countries average emission factor varies from 0.69tCO_2 to 0.8tCO_2 per MWh
Electricity T&D loss reduction	Refurbishing and upgrading of existing electricity transmission and distribution systems to reduce T&D loss in the region except Southern African Development Community (SADC) from an existing average value of 27% to 8% and from an average value of 15% to 8% in SADC region; an average 33% thermal efficiency of fossil fuel fired power plants; one CDM project per country
Flared gas recovery	Recovery of associated gas, which would be flared or vented otherwise, from oil fields in 12 oil producing countries; existing levels of flaring and venting in the baseline scenario and recovery rates in the project scenario vary across countries; recovered gas is used for power generation in combined cycle power plants with

	thermal efficiency 59%; One CDM project per electricity plant, 500 MW or small; number of power plants vary across countries with volume of recovered gas
Coal mine methane	Use of methane, which would be vented otherwise, is captured in coal mines and is used for power generation; 5% of methane is used as a mine fuel or flared; power generation technology is gas turbine with 35% thermal efficiency and 85% capacity factor; one CDM project per coal mine
Waste gases in crude oil refinery	Use of waste gas (i.e., incondensable gases rich in hydrogen, methane and light hydrocarbons), which would be flared otherwise, captured from oil refinery is used for on-site power generation in oil refineries; waste gas represents 2% of crude oil feedstock in the refinery; 90% of waste gas is recovered; One CDM project per refinery
Improved charcoal production	Improving charcoal production efficiency from existing level of 18% on average to 35-40% by replacing traditional charcoal kilns with high yield, low emission technologies; a CDM project corresponds minimum of 150 kilns with total annual charcoal production capacity of 9,855 tons
Improved steam system	15% improvement of steam generation and distribution efficiency in industrial establishments through optimization of condensate return systems, retrofitting or replacement of boilers and improving distribution systems; the activity is implemented under POA with annual emission reduction capacity of a POA is 60,000 tCO_2 or lower
Clinker reduction in cement production	Reducing clinker to cement production ratio from 0.95 to 0.75 by increasing the proportions of additives (e.g., limestone, fly ash etc.); ratio of raw materials to cement is 1.54; calcium carbonate ($CaCO_3$) to raw material ratio is 0.78; CO_2 to $CaCO_3$ stochiometric ratio is 0.44; one CDM project per cement factory
Industrial energy efficiency improvement (except for lighting)	Improvement of end-use energy efficiency in processes and devices excluding electric bulbs/lamps in industrial establishments (.e.g., electrical motors, air conditioning etc.); the level of improvements vary across countries depending on average efficiency of existing stock of devices and processes; One CDM project or POA for each country selected
Biodiesel from Jatropha for transportation[a]	Degraded lands amounting to 2% of the total land area is available for cultivation of jatropha; resulting blend contains 20% of biodiesel (B20) which can be used in normal diesel-run vehicles without engine modification; a CDM project (or program of activities) represents biodiesel production facility with a processing capacity of 100,000 tons or less per year
Shift to Bus Rapid Transit	Candidates cities for BRT have population more than 500,000; in countries with no city exceeding threshold population, the largest city is considered; all together 54 cities identified for 71 BRT projects; a BRT project saves up to 20% of diesel and gasoline consumption combined
Compact fluorescent lamps in households	90% households will replace their incandescent lamps with CFL; 2 CFL per lighting point over a 10-year project crediting period; number of households vary across countries and number of lighting points vary along with average floor space; the activity is implemented under POA with annual emission reduction capacity of a POA 100,000 tCO_2 or lower

Energy efficient appliances in households (except lighting)	10% savings in electricity consumption through use of energy efficient appliances excluding electric bulbs/lamps (e.g., refrigerators, air-conditioning units, stoves, electronic devices); the activity is implemented under POA with annual emission reduction capacity of a POA 50,000 tCO_2 or lower in South Africa and 10,000 tCO_2 or lower in the rest of the countries

[a]Total land available for jatropha needed for both electricity generation and transportation CDM projects is 2% of the total land area

Reference

Ajayi OO (2009) Assessment of utilization of wind energy resources in Nigeria. Energy Policy 37(2):750–753

Batidzirai B, Lysen EH, van Egmond S, van Sark WGJHM (2009) Potential for solar water heating in Zimbabwe. Renew Sustain Energy Rev 13(3):567–582

De Gouvello C, Dayo FB, Thioye M (2008) Low carbon energy projects for development in Sub-Saharan Africa: Utilizing the potential, addressing the barriers. The World Bank, Washington

Henry M, Tittonell P, Manlay RJ, Bernoux M, Albrecht A, Vanlauwe B (2009) Biodiversity, carbon stocks and sequestration potential in aboveground biomass in smallholder farming systems of western Kenya. Agric Ecosyst Environ 129(1–3):238–252

Osbahr H, Twyman C, Adger WN, Thomas DSG (2008) Effective livelihood adaptation to climate change disturbance: scale dimensions of practice in Mozambique. Geoforum 39(6):1951–1964

Paavola J (2008) Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. Environ Sci Policy 11(7):642–654

Perez C, Roncoli C, Neely C, Steiner JL (2007) Can carbon sequestration markets benefit low-income producers in semi-arid Africa? Potentials and challenges. Agric Syst 94(1):2–12

Roncoli C, Jost C, Perez C, Moore K, Ballo A, Cissé S, Ouattara K (2007) Carbon sequestration from common property resources: lessons from community-based sustainable pasture management in north-central Mali. Agric Syst 94(1):97–109

Sebitosi AB, Pillay P (2008) Renewable energy and the environment in South Africa: a way forward. Energy Policy 36(9):3312–3316

Stringer LC, Dyer JC, Reed MS, Dougill AJ, Twyman C, Mkwambisi D (2009) Adaptations to climate change, drought and desertification: local insights to enhance policy in southern Africa. Environ Sci Policy (In Press)

Surridge AD, Cloete M (2009) Carbon capture and storage in South Africa. Energy Procedia 1(1):2741–2744

Thomas RJ (2008) Opportunities to reduce the vulnerability of dryland farmers in Central and West Asia and North Africa to climate change. Agric Ecosyst Environ 126(1–2):36–45

Unruh JD (2008) Carbon sequestration in Africa: the land tenure problem. Glob Environ Change 18(4):700–707

UNEP Risoe Centre (URC) (1995) Climate change mitigation in Southern Africa: methodological development, regional implementation aspects, national mitigation analysis and institutional capacity building in Botswana, Tanzania, Zambia and Zimbabwe. Phase 1. Riso National Laboratory, Denmark

UNEP Risoe Centre (URC) (2001a) Economics of greenhouse gas limitations: senegal. Riso National Laboratory, Denmark

UNEP Risoe Centre (URC) (2001b) Implementation of renewable energy technologies—opportunities and barriers: Ghana country study. Riso National Laboratory, Denmark

UNEP Risoe Centre (URC) (2009) CDM/JI Pipeline Analysis and Database, May 1st 2009

United Nations Framework Convention on Climate Change (UNFCCC) (1998) The kyoto protocol. UNFCCC Secretariat, Bonn, Germany

Williams M, Ryan CM, Rees RM, Sambane E, Fernando J, Grace J (2008) Carbon sequestration and biodiversity of re-growing miombo woodlands in Mozambique. For Ecol Manag 254(2):145–155

World Bank (2009a) Doing business database, http://www.doingbusiness.org/documents/DB10_Overview.pdf; retrieved on 25 November 2009

World Bank (2009b) Clean technology fund, http://go.worldbank.org/SG8NYY3DK0; retrieved on 25 November 2009