Low-carbon Energy Projects for Development in Sub-Saharan Africa

Unveiling the Potential, Addressing the Barriers

Executive Summary

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2008
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The Norwegian Trust Fund for Private Sector and Infrastructure (NTF-PSI), established by the Royal Norwegian Ministry of Foreign Affairs and the World Bank Group (WBG) in 2002, is an "umbrella" trust fund for supporting private-sector development and infrastructure within WBG operations. The NTF-PSI funds activities across the World Bank and International Finance Corporation (IFC) that aim to develop WBG and client-country capacity, promote inclusion of cross-cutting issues into World Bank and IFC operations, and foster cooperation among WBG units.

NTF-PSI activities are broadly grouped into four strategic windows: investment climate and governance, infrastructure service delivery to the poor, petroleum governance initiative, and existing global/regional programs or multi-donor trust funds. Proposed themes, activities, and programs are prioritized by the WBG and agreed between the WBG and the Donor during semi-annual discussions. Contribution funds target the poorest countries comprising the bottom three categories of the Development Assistance Committee List of Aid Recipients (least developed, other low-income countries, and lower middle-income countries), with approximately 50 percent of funds allocated for Africa.

Executive Summary

Amid rising oil prices and the adverse effects of global climate change, Sub-Saharan Africa has an unprecedented opportunity: choosing a cleaner development pathway via low-carbon energy alternatives that can reduce greenhouse gas (GHG) emissions and, at the same time, meet current suppressed energy demand and future needs more efficiently and affordably. Indeed, countries across the region stand to benefit from an increasing array of financial instruments—from the Clean Development Mechanism (CDM) and Carbon Finance (CF) products to the newly created Climate Investment Funds (CIFs)—with which to develop clean and efficient energy. These and other innovative instruments can help to channel the additional funds needed for investing in new and existing generation assets to increase energy services via efficiency improvements or by turning net energy consumers into net producers in return for avoidance of future GHG emissions. Using such instruments, global efforts to combat climate change can provide the region's countries energy solutions for sustainable socioeconomic development.

While opportunities for such sustainable solutions are considerable in theory, to date, Sub-Saharan Africa has missed out. In the context of the CDM, for example, the region's current share in the project pipeline is only 1.4 percent—only 53 out of 3,902 projects—or nine times smaller than its global share in GHG emissions.[1] Thus, despite its comparatively small economies, the region's number of CDM projects should be larger.

Financial Instruments: An Overview

The CDM, defined in Article 12 of the Kyoto Protocol, is a process of certifying emission reductions achieved by projects executed in developing countries. Under the CDM, projects that demonstrate that they avoid GHG emissions that otherwise would have occurred can obtain international certificates, termed certified emission reductions (CERs). CERs are calculated using CDM approved methodologies. CF—a way to ascertain the future revenues from the sale of the CERs—serves as a bridge between CDM projects and the financial carbon markets, allowing CDM project developers to reflect the value of the CERs in their business plans. As a result, since November 2001, implementation of the CDM has generated strong financial incentive, unleashing a dynamic, bottom-up response from project developers worldwide. Indeed, the number of validated CDM projects has grown rapidly, more than doubling every year (figure 1).

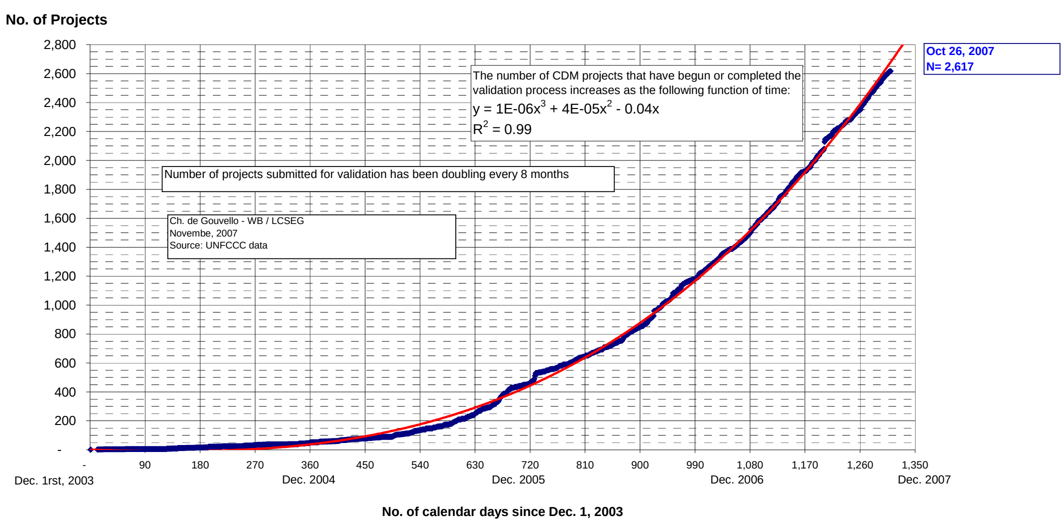
Over the past decade, the Carbon Finance Unit of the World Bank (ENVCF) has played a pioneering role in CF development, beginning with the creation of the world's first carbon fund, known as the Prototype Carbon Fund (PCF) in 1999. Subsequently, the World Bank has been asked to host and manage other carbon funds on behalf of industrialized countries wishing to benefit from World Bank experience to ensure their efficient purchase of CERs needed to comply with emission targets of the Kyoto Protocol. As a result, other funds have been created, including those targeting specific

[1] Including emissions from land use and land-use change.

project segments. By March 2008, the number of carbon funds hosted in the World Bank had increased to 11, and the total funds pledged had reached more than US$2.1 billion. Outside the World Bank, more than 60 carbon funds have been created. Worldwide, CF transactions related to CDM projects are expected to channel more than US$5 billion to developing countries before the end the first commitment period of the Kyoto Protocol in 2012. On September 25, 2007, the World Bank Board of Executive Directors approved the creation of the Carbon Partnership Facility (CPF) to purchase post-2012 emission reductions. The target size of the Facility over the first five years of operation is expected to reach €5 billion.

Besides CF tools, in July 2008, the Board of Directors officially approved the creation of CIFs, international investment instruments designed to provide interim, scaled-up funding for financing investment in projects and programs in developing countries that contribute to the transfer of low-carbon technologies and the testing of innovative approaches to climate change, respectively.

Figure 1: Number of CDM Projects That Have Already Applied for Validation



Implications for the Energy Sector

More than two-thirds of the more than 108 methodologies approved under the CDM to date are related to the energy sector. This emphasis is reflected in the pipeline of projects already submitted for validation, most of which are clean energy projects. As a result, a wide array of technical opportunities is available for reducing emissions associated with the energy sector—both projects focused solely on reducing emissions of the existing infrastructure, referred to as "pure decarbonization," as well as those that also increase or free up supply capacity that can contribute to sustainable economic and social development.

Together with CF tools, CIFs, and other financial instruments aimed at promoting low-emission technologies, the CDM can affect the development of the energy sector in developing countries. For example, it can optimize primary energy demand, make a cleaner technology preferable when additional power-generation capacity is needed, or realize a local renewable-energy potential. In such large countries as Brazil, China, and India, where hundreds of CDM projects are already in the pipeline, the CDM is expected to influence energy planning exercises.

Like other developing regions where CDM projects have been successfully implemented using commercially available technologies, Sub-Saharan Africa is similarly endowed with resources and facilities. For example, the region has many open-cycle power plants to which a second cycle could be added, thereby increasing generation capacity and plant efficiency at zero additional emissions. Efficient cogeneration plants could be added to sugar mills. In addition, refineries, flared gas, landfills, and other concentrated sources of GHG emissions could be used to generate power and heat. Incandescent lamps could be replaced by compact fluorescent lamps, thus saving significant amounts of fossil-fuel energy and, at the same time, reducing household energy bills.

Many such options comply with the conventional energy sector's strategy to provide consumers sufficient, cost-effective, and reliable energy supplies. But without supporting quantitative data, which is currently lacking, a common assumption among those in the climate-change community unfamiliar with the region is that its weak CDM portfolio simply reflects its poverty—that is, its countries have few industries, little emissions, and thus limited emission-reduction opportunities. Without verifiable data that demonstrates the region's technical potential, it is difficult for energy practitioners familiar with the region to convince a broader audience of Sub-Saharan Africa's significant potential for low-carbon energy development, particularly CDM projects, and the uptake of associated financial assistance.

Exploring Potential via the CDM Lens

Past efforts to produce detailed inventories of Sub-Saharan Africa's energy conservation potential proved extremely difficult. Earlier assessments were heavily constrained by an inability to form technical teams large enough to develop the detailed methodological framework required to cover the wide range of technical processes, equipment types, and operational conditions and assess an even greater diversity of emission-reduction potential. To date, few, if any, reports have been published on inventories of GHG emission-reduction opportunities in the region. However, with the recent development of the CDM methodological framework, that situation has changed.

The dynamic, bottom-up CDM process provides an unprecedented opportunity for exploring low-carbon energy opportunities. Each methodology developed under the CDM captures relevant details of the technology and operational parameters that determine emission reductions for one or more processes and describes the types of facilities in which these processes operate. In addition, the CDM validation pipeline database, publicly available on the website of the United Nations Framework Convention on Climate Change (UNFCCC), provides concrete examples of the facilities, processes, and achievable emission reductions. Thus, for any given country, it becomes far easier to count the number of facilities where emission-reduction projects corresponding to approved CDM methodologies can be developed.

Study Approach

Using the CDM lens, this study aimed to explore the potential for low-carbon energy projects for development in Sub-Saharan Africa. To this end, the study team identified technologies that could use the available approved CDM methodologies—many of which have already been applied successfully to projects in other developing regions—to both reduce GHG emissions and support energy development in the region via additional energy supply or more cost-effective use (box 1).

Box 1: Reshaping the CDM Scope from an Energy-sector Perspective

To ease comprehension for energy specialists unfamiliar with CDM terminology, the study team aggregated the methodologies approved by the CDM Executive Board and the corresponding clean energy technologies along the production chains of the most relevant energy subsectors. Generically, these production chains consist of three main stages: generation or production, transmission or transport and distribution, and consumption and use. The aim was not to propose a purely academic typology, but to choose one, among others, to help energy practitioners and decision makers relate the large amount of complex CDM information to the operational categories with which they are familiar.

The proposed structure, adjusted to reflect the feedback of energy practitioners and decision makers in Africa, is as follows:

- **Power**. The main stages of this subsector are generation, transmission and distribution, and consumption.
- **Fuels for industry**. This subsector includes several production chains, among which the two most important are oil and gas and coal. For oil and gas, the main stages are production (upstream industry), refining (downstream industry), transport (generally by pipeline, boat, or surface motorized means), and consumption in the industry, mainly for thermal uses in furnaces and boilers.
- **Fuels for vehicles**. While the conventional upstream part of this production chain is the same as that for the fuels-for-industry subsector, it differs with respect to clean-energy alternatives via the introduction of biofuel production (bio-ethanol and bio-diesel). Consumption occurs in motorized vehicles.
- **Woodfuel for households**. Sometimes referred to as traditional energy, this subsector encompasses the production, transport, and consumption of ligneous woodfuels.

The 22 technologies identified, organized along the production chains of the subsectors most relevant to Sub-Saharan Africa, are as follows:

- **Power**

  Generation from Fossil Fuels
  - Second-cycle additions to open-cycle, gas turbine plants
  - Combined heat and power for industry

Generation from Renewable Energy
- Combined heat and power in sugar mills
- Agricultural residue
- Forest and wood-processing residues
- Typha australis
- Jatropha biofuel
- Hydroelectricity
- Photovoltaics in isolated rural areas
- Landfill gas

Transmission and Distribution
- Grid-loss reduction

Consumption and Use
- Non-lighting electricity for industry
- Switch to compact fluorescent lamps
- Energy-saving household appliances

- **Fuels for industry**

Production
- Flared gas recovery
- Coal mine methane
- Waste gases in crude oil refinery

Thermal Use and Consumption
- Improved steam system
- Reduced clinker use in cement manufacturing

- **Fuels for vehicles**

Production
- Biodiesel from Jatropha

Consumption and Use
- Shift to Bus Rapid Transit (BRT)

- **Woodfuel for households**

Production
- Improved charcoal production

The study team investigated existing databases and visited 12 countries to collect primary data with which to build a bottom up–driven, clean energy projects inventory for the region.[2] Where no detailed data were available at the facility level, the team used a mix of bottom-up and top-down approaches. Based on the current, publicly available information in the UNFCCC CDM pipeline, the team determined the average size and characteristics of the clean energy projects and host facilities. Then, aggregated country-sector data were used to estimate how many facilities, on average, should be present in the respective countries and thus how many projects could be developed. In addition, the team used specific methods to determine the contribution of these projects to the energy sector (in terms of added energy or demand management), expected volume of emission reduction and corresponding carbon revenue (assuming US$10 per tCO_2), and the required investment.

Synthesis of Study Results

This study revealed a large, diversified range of CDM opportunities across Sub-Saharan Africa's energy sector. For the 44 countries and 22 technologies considered, the study team estimated a technical potential of more than 3,200 clean energy projects, including 361 large programs (known as Programs of Activities), each consisting of hundreds or even thousands of single activities. If fully implemented, this estimated technical potential could provide 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 modern-energy production. The achievable avoidance of future GHG emissions would total about 740 million tCO_2 per year, more than the region's current annual GHG emissions (680 million tCO_2).[3]

About 64 percent of the *emission-reduction* potential would be related to biomass (e.g., bagasse, agricultural and agro-industrial residues, and forest and wood-industry residues), while 53 percent of the potential for *added power-generation capacity* would be derived from the improved use of fossil fuels. 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 1 presents the aggregate results for the region, according to each of the technologies studied.

[2] The databases that have been used are presented as an excel file in a separate volume.

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

Table 1: Consolidated Results of Potential Clean-energy Project Opportunities for Sub-Saharan Africa (All)

Technology	No. of projects	Projects' emissions reductions: millions tCO_2/yr	Projects' emissions reductions: % of country total	Reductions over projects' life span (millions tCO_2)[1]	Value of projects' emissions reductions (millions US$): US$5/tCO_2	Value of projects' emissions reductions (millions US$): US$10/tCO_2	Electricity generation: Projects (GWh/yr	Electricity generation: Projects (% country total)	Added power of projects (MW): 90% load factor	Added power of projects (MW): % of total installed	Total investment cost of projects (billions US$)
Second-cycle addition to open-cycle gas turbine	204	36.1	5.3	360.8	1,804.0	3,608.1	51,912	0	5,931	8.6	7.1
Combined heat and power for industry	373	72.9	10.7	729.4	3,647.0	7,294.0	156,314	0	17,844	25.9	17.8
Combined heat and power in sugar mills	67	2.4	0.4	24.4	122.1	244.2	3,489	0	661	1.0	1.0
Agricultural residue	553	140.8	20.7	1,408.4	7,042.2	14,084.3	216,842	1	27,504	40.0	38.5
Forest residue[2]	321	62.6	9.2	625.8	3,128.9	6,257.9	98,415	0	12,483	18.1	17.5
Wood-processing residue[2]	406	20.3	3.0	203.4	1,029.9	2,053.9	31,987	0	4,057	5.9	5.7
Typha australis	40	3.1	0.5	31.0	155.1	310.3	4,675	0	593	0.9	0.8
Jatropha biofuel	555	176.8	26.0	3,712.0	18,560.0	37,120.0	218,767	1	27,748	40.3	53.6
Hydroelectricity	26	25.2	3.7	528.6	2,643.1	5,286.3	35,961	0	6,443	9.4	9.4
Landfill gas	3	0.9	0.1	9.0	44.8	89.6	49	0	10	0.0	0.0
Grid-loss reduction	20	1.1	2.2	11.3	56.6	113.2	31,974	0	4,056	5.9	--
Non-lighting electricity for industry	20	1.5	0.2	1.4	6.9	13.9	5,837	0	740	1.1	--
Switch to compact fluorescent lamps	49	13.3	2.0	132.7	663.4	1,326.8	17,269	0	15,246	22.1	4.8
Energy-saving house-hold appliances	30	7.4	1.1	74.4	372.0	744.0	11,131	0	1,412	2.1	--
Flared gas recovery	55	91.8	13.5	917.6	4,588.0	9,176.1	353,409	1	44,826	65.1	--
Coal mine methane	18	2.5	0.4	24.7	123.6	247.2	809	0	109	0.2	0.1
Waste gases in crude oil refinery	26	4.3	0.6	43.4	216.9	433.8	5,777	0	659	1.0	0.9
Improved steam system	211	36.6	5.4	366.4	1,831.8	3,663.6	--	--	--	0.0	--
Reduced clinker use in cement manufacturing	46	2.8	0.4	28.4	142.1	284.1	--	--	--	0.0	0.1
Shift to Bus Rapid Transit (BRT)	63	12.4	1.8	260.2	1,301.0	2,602.0	--	--	--	0.0	--
Biodiesel from Jatropha	60	3.2	0.5	66.2	330.9	661.8	--	--	--	0.0	--
Improved charcoal production	68	22.5	3.3	224.8	1,123.8	2,247.5	--	--	--	0.0	0.2
Reduced methane leakage in pipelines[3]	13	0.1	0.0	0.7	3.6	7.2	--	--	--	0.0	--
Total	**3,227**[4]	**740.7**	**109.0**	**9,785.0**	**48,937.8**	**97,869.7**	**1,244,618**	**4**	**155,078**	**225.3**	**157.6**

Note: In 2003, the region's total electricity generation was 327,079 GWh per year and total installed power was 68,841 MW.

[1] With regard to projects' life span, a carbon-crediting period of 21 years was used for Jatropha biofuel, hydroelectricity, shift to BRT, and biodiesel from Jatropha; for all other technologies, a 10-year crediting period was assumed.

[2] Results for forest and wood-processing residues are disaggregated in this table.

[3] This technology does not have a corresponding chapter section.

[4] The 3,227 projects include 361 Programs of Activities.

At this stage, it was not possible to include an economic analysis of the cost effectiveness of the project opportunities inventoried in this study. Such an analysis would have required numerous economic comparisons of these low-emission energy alternatives with more conventional ones at the local level, which, in turn, would have required additional data collection. But the ever-increasing number of similar clean energy projects registered in the UNFCCC pipeline being implemented in other countries, mainly by the private sector, strongly indicates that such projects can be attractive when taking carbon revenue into account.

While already unexpectedly large, this potential is not inconsistent with the rapid scaling up of the CDM worldwide, which is roughly doubling each year. 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, for various types of projects, the study team could neither collect exhaustive data nor the potential (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, among others).

In addition, two investment curves—one for GHG abatement and the other for additional generation capacity—were created (figure 2).[4] The study also attempted to assess the financing needed to implement these potential projects. Data were unavailable for projects representing 36 percent of added power-generation capacity and 21 percent of emission reductions.[5] A conservative estimate of the total capital cost of the remaining 2,755 clean energy projects is about US$157 billion. If the capital cost of large flared, associated-gas recovery projects could be calculated, this figure would likely exceed US$200 billion.

[4] These results, along with corresponding tables synthesizing CDM opportunities, are presented by country in a separate volume. The excel file, which contains all of the databases and calculations used to generate the tables and curves presented here, is provided in an annexed CD. Readers can easily revise the key assumptions and parameters when more accurate data become available.

[5] Data were unavailable for the following project categories: efficiency improvements in electricity distribution, steam systems, and BRT; energy-efficiency improvements in household appliances and industrial equipment (motors); methane leakage reduction in pipelines and emission reduction in oil-producing facilities (flaring); and industrial fuel switching.

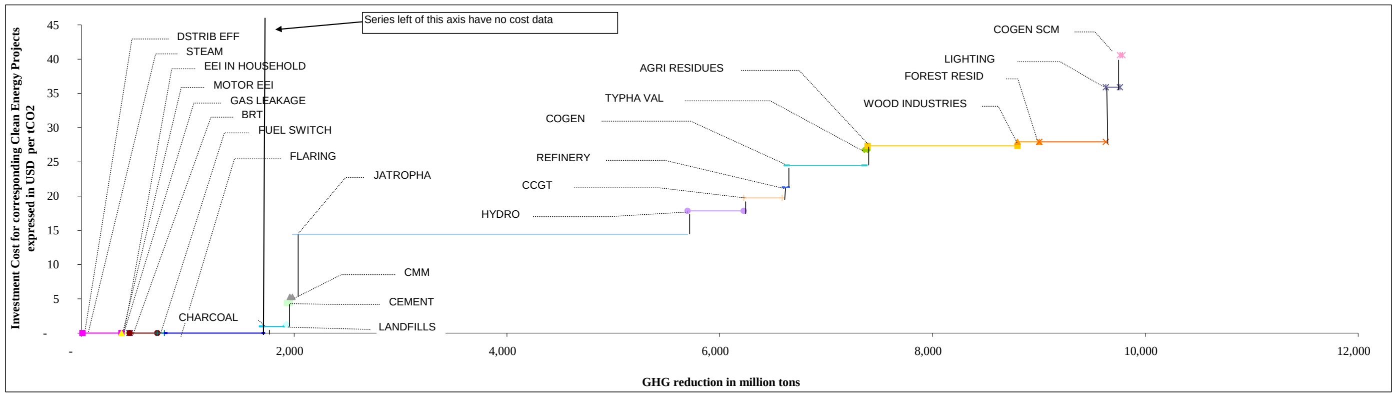
Figure 2: Consolidated Investment Curves for Sub-Saharan Africa (All)

Potential for Emission Reductions

(Ranked by Investment Cost for Corresponding Clean Energy Projects expressed in USD per tCO2)

No cost data was available for the listed categories (DISTRIB EFF IN through FLARING)

Sector	Investment Cost ($/tCO2)	Reduction over project life (10 or 21 years) *
DISTRIB EFF IN	-	11
STEAM	-	366
EEI IN HOUSEH	-	74
MOTOR EEI	-	1
GAS LEAKAGE	-	1
BRT	-	260
FUEL SWITCH	-	66
FLARING	-	918
CHARCOAL	1	225
LANDFILLS	1	9
CEMENT	4	28
CMM	5	25
JATROPHA	14	3,712
HYDRO	18	529
CCGT	20	361
REFINERY	21	43
COGEN	24	729
TYPHA VAL	27	31
AGRI RESIDUES	27	1,408
WOOD INDUST	28	203
FOREST RESID	28	626
LIGHTING	36	133
COGEN SCM	41	24

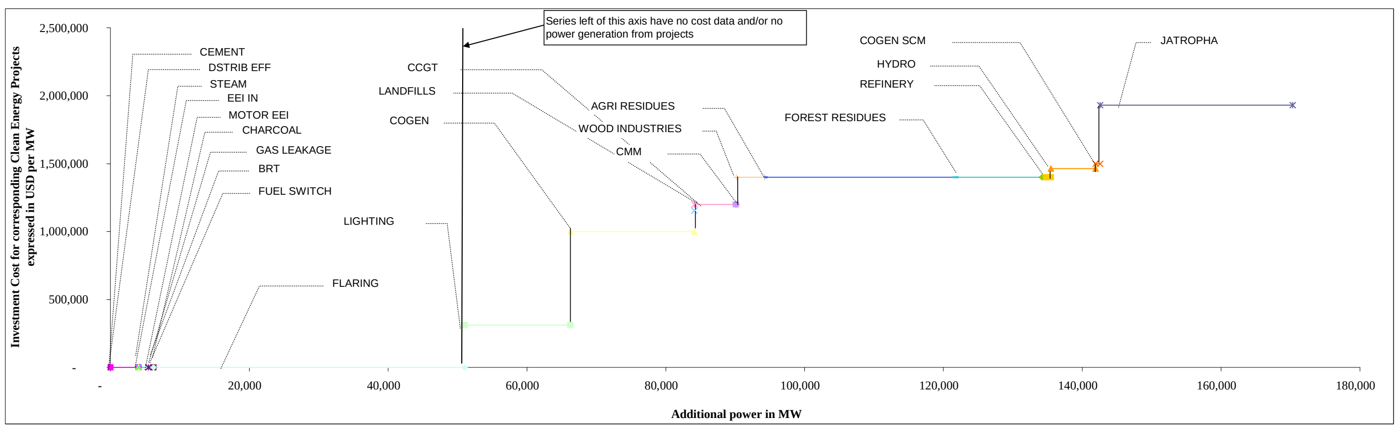


Potential for Additional Generation Capacity

(Ranked by Investment Cost for Corresponding Clean Energy Projects expressed in USD per MW)

No cost data and/or no power generation from projects (CEMENT through FLARING)

Sector	Investment Cost ($/MW)	Additional power due to the project implementation (load factor = 90%) MW
CEMENT	-	-
DISTRIB EFF IN	-	4,056
STEAM	-	-
EEI IN HOUSEH	-	1,412
MOTOR EEI	-	740
CHARCOAL	-	-
GAS LEAKAGE	-	-
BRT	-	-
FUEL SWITCH	-	-
FLARING	-	44,826
LIGHTING	312,500	15,246
COGEN	1,000,000	17,844
LANDFILLS	1,154,813	10
CCGT	1,200,000	5,931
CMM	1,200,000	109
WOOD INDUST	1,400,000	4,057
AGRI RESIDUES	1,400,000	27,504
FOREST RESID	1,400,000	12,483
TYPHA VAL	1,400,000	593
REFINERY	1,400,000	659
HYDRO	1,463,517	6,443
COGEN SCM	1,500,000	661
JATROPHA	1,930,533	27,748



* A carbon crediting period of 10 years was used for all sectors with the exception of Jatropha, BRT, Hydro and Fuel Switch. For these the study assumed a crediting period of 21 years (3 x 7 years). This was done so as to reflect the difference in capital investment useful life accross sectors (up to 30 years for Hydro, etc.)

Note: Clean Energy projects simultaneously deliver power and generate emission reductions. Therefore, investment costs related to emission reductions cannot be isolated from investment costs related to power generation. As a consequence, unitary cost expressed in US$/tCO2 presented here are not marginal emissions abatement costs but investment costs corresponding to the associated clean energy projects divided by the volume of emission reductions generated by these projects during their lifetime as CDM projects activities generating certified emissions reductions (CERs). Lifetime considered for corresponding CDM project activities is the most probable crediting period as defined by the CDM, e.g. one single 10 years crediting period or 7 years renewed three times, depending of the type of project considered.

Unlocking Sub-Saharan Africa's Potential

Based on field visits to 12 countries and many exchanges with potential project developers, energy-sector authorities, and other stakeholders, the study team investigated the barriers that have limited the implementation of clean energy projects in Sub-Saharan Africa relative to other developing regions. The study found that the region faces key institutional, market, and project-level barriers.

Beyond pointing out the obstacles, the study team developed preliminary recommendations for energy-sector authorities and the international donor community—particularly energy-sector operational units (ESOUs)—on how to address these barriers and thus begin to unlock Sub-Saharan Africa's large potential for clean energy projects.

Recommendations for Mitigating Barriers

1) It is essential to fill the regulatory and logistics gaps that bar clean energy projects from access to energy markets.

Without appropriate market access, clean energy projects can realize neither their contribution to energy development nor global environment benefits. To date, regulatory gaps in the region's energy sectors hinder or prevent clean energy projects from selling their energy production. One example is the lack of purchase tariffs in monopolistic, vertically integrated public-power sectors. Filling such gaps is a priority that may require technical support that can apply lessons from international best practices.

2) Market access requires appropriate infrastructure planning and policies to overcome logistics bottlenecks.

In many cases, especially for biomass-based cogeneration and power generation, the primary energy resource is dispersed, creating a dual logistics challenge: collection and transport to the transformation facility and construction of transmission lines to convey the power generated to market. Meeting this challenge requires appropriate planning of clean-energy and infrastructure development and policy and financing mechanisms. In many countries across the region, outside technical assistance is needed to develop planning capacity.

3) Technical information on mature, clean energy technologies must be appropriately disseminated.

In Sub-Saharan Africa, the sustainability of clean energy development is hindered by a lack of technical knowledge, information sharing, and capacity building, including the necessary background data and inventory of potential energy sources. For example, 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.

To engage potential clean-energy project developers who currently run inefficient facilities or waste bio-energy, the first step is to disseminate information to them on existing technologies that would become attractive via carbon revenues (or sometimes without them). One approach might be to jointly organize technology-focused national or multinational information campaigns with equipment and technical-services providers, targeting the technologies that match the available clean-energy potentials of the region and decision makers of corresponding companies.

4) The local skills required to run mature, clean technologies must be developed.

A significant share of the region's GHG emissions results from inappropriate maintenance schemes, themselves caused by lack of a skilled labor force. For example, the region's principal barrier to efficient industrial steam systems is poor maintenance. When steam traps malfunction, the traps are not immediately repaired or replaced; such routine neglect causes the release of condensate into drainage lines and thus the loss of considerable amounts of energy that should have been put into productive use in industrial processes. In the area of bio-energy, lack of mastery of certain techniques (e.g., achieving high enough yields to make production competitive), also generates bottlenecks that limit the development of corresponding clean-energy potential. Countries in the region must be assisted in building national technical capacity rather than relying on traditional turnkey solutions with imported technology, in which case scaling up and efficiency will be limited.

5) Technical assistance and research and development (R&D) are required to enable clean energy technologies to achieve full efficiency and sustainability.

In Sub-Saharan Africa, the capacity to adapt technologies to local resources is low compared to other developing regions. For example, biomass products typically require drying and size reduction before becoming usable fuels. In certain applications, they require carbonization (e.g., for charcoal production). Most countries in the region lack the equipment required to obtain the full energy potential from local biomass. Thus, specific technical assistance and R&D activities are required to adapt efficient, pre-use transformation solutions and combustion equipment to the unique characteristics of diverse biomass residues found in Sub-Saharan Africa. In addition, research and knowledge should be gathered on reducing the time and costs involved in biomass-residue collection, transport, and other infrastructure- and logistics-related activities.

Local research is required not only to realize maximum potential from local clean-energy potential at least cost, but also to ensure sustainable resource use. Because of its numerous potential benefits for the local energy sector (e.g., reduced dependency on high-priced petroleum products) and the economy (e.g., new income-generation activities), biomass residues represent an especially attractive, clean-energy potential. At the same time, environmental and social impacts assessments are critical. In the context of Sub-Saharan Africa subsistence-farming practices, agricultural productivity is especially sensitive to the amount of post-harvest residue on farms. Therefore, it is vital that agricultural research be conducted to strike an optimal balance between fuel and alternative uses.

6) Support is still required to develop local expertise and institutional procedures to facilitate project developers' access to the benefits provided by an increasing range of financial resources earmarked for climate change.

In Sub-Saharan Africa, relevant actors' lack of knowledge and information regarding the CDM and CF opportunities and procedures presents a key obstacle to CDM project identification. In previous capacity-building programs, the focus of seminars and workshops was often too theoretical, and the targeted group too limited, involving mainly professionals from the environment community. Most countries in the region have enough well-trained professionals who could, if properly trained in the CDM and CF, provide key services to help potential project developers prepare clean energy projects (or at a minimum, develop such projects to a point where they could be integrated into carbon fund portfolios and receive assistance to undergo the entire CDM procedure). The same recommendation would likely hold true for accessing the new CIFs.

A critical lesson learned from previous capacity-building efforts is that they should target the right groups: decision makers from industry and local engineering consulting firms. Technical capacity-building activities should involve learning-by-doing strategies involving both local consultants and project developers. In addition to these core groups, each country's relevant institutions should be informed of their potential roles in facilitating CDM development. For example, energy-sector authorities should take appropriate actions to remove specific sectoral barriers that discourage project developers from making investment decisions.

7) Post-Kyoto carbon funds are required to internalize the global benefit of investment decisions and level the playing field for clean energy technologies.

Certain clean energy options, particularly those based on renewable energy, have been unable to compete when the energy market gives zero value to the global environmental benefits provided by these alternatives. The number and wide range of clean energy projects submitted from around the world to the CDM have demonstrated that CF is effective in achieving such internalization. However, most carbon-finance transactions are limited to "the first commitment period" of the Kyoto Protocol, which ends in 2012. Because of uncertainty regarding the post-Kyoto regime, it has become difficult for CDM projects to monetize their post-2012 GHG emission reductions. In the case of Sub-Saharan Africa, where the start of CDM implementation has been delayed, most CDM-eligible clean energy projects are expected to deliver, at best, a small fraction of their emission reductions before 2012.

As a result, instruments that provide financial value to future emission reductions from the region's clean energy projects must be created. New carbon funds that buy post-2012 CERs are an absolute condition for countries in Sub-Saharan Africa to develop their large potential of clean energy projects and thus move along a cleaner development pathway. Featuring such carbon funds to facilitate project access is desirable. Most of the region's CDM projects are smaller than the minimum size required by many existing carbon funds. This issue can be addressed, in part, by bundling together many similar smaller projects under the CDM's new Program of Activities. At the same time, bundling projects triggers additional coordination challenges that may be difficult to address when similar projects are scattered across countries, certain ones of which may be in conflict or post-conflict situations. Therefore, for smaller clean energy projects located in least-developed countries of Sub-Saharan Africa, special windows streamlining access remains a desirable feature for post-2012 carbon funds.

8) However, Carbon Finance alone will not solve the investment financing gap. Earmarked Climate Investment Funds are essential.

For any capital-intensive infrastructure in Sub-Saharan Africa, lack of investment and financing capacity is a chronic barrier, whether involving conventional or clean energy projects. It is important to note that CF alone cannot resolve this issue for clean energy projects. Carbon funds provide neither equity nor investment financing. While signing Emission Reduction Purchase Agreements in hard currency with an entity with a high credit rating may help leverage commercial financing, the carbon-revenue channel does not usually suffice to ensure financial closure. 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 gensets. In larger countries (e.g., Kenya and Nigeria), it is more likely that power-utility decision makers will implement single-cycle, Greenfield facilities, 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 the new CIFs 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 CF.

Since financing and implementing capacity may not be enough to explore the region's large range of clean-energy opportunities, the policy dialogue, generally structured around a country's most relevant strategic objectives, would permit prioritizing the various options identified and strengthening ownership of those projects that best serve the sector policy.

What Donors Can Do

Therefore, a range of objective reasons explains why Sub-Saharan Africa has performed poorly under the CDM and, as a result, has been deprived of its benefits. Overcoming the barriers discussed above presents a challenge, but the required solutions are clear. Interestingly, the Energy Sector Operational Units (ESOUs) of Multilateral Financial Institutions are well prepared to tackle most of the issues. Indeed, ESOUs are endowed with a unique set of organizational features, which, if linked with those of their local counterparts, position them as key contributors to unlocking the region's large potential for CDM-eligible, clean energy projects.

1) Decades of trust building and direct access to key decision makers well position ESOUs to assist sector authorities to fill the awareness gap and remove policy barriers.

An analysis of the major barriers preventing CDM-eligible, clean energy projects from development in Sub-Saharan Africa have revealed the importance of filling regulatory gaps in the region's energy sectors.

Over decades of policy dialogue and financial support, ESOUs have built extensive networking and trust with the region's energy-sector ministries, public utilities, and private-sector decision makers, well placing them to convey key strategic messages and help develop and implement the measures required to unlock these benefits. In countries across the region, ESOUs often present decision makers the only viable option for gaining access to international experience and expertise. Thus, it is important that strategic opportunities related to carbon-based benefits be integrated into the policy dialogue that ESOUs regularly maintain with the region's energy-sector authorities.

2) Clean energy projects in Sub-Saharan Africa require the external technical expertise that ESOUs have a history of providing.

In Sub-Saharan Africa, most potential clean-energy projects require external technical assistance. Unlike carbon funds, which lack the required sector-specific expertise and financial resources for activities other than CF transactions, ESOUs have a history of providing such expertise using in-house staff or outside consultants knowledgeable about international best practices. Examples include support in preparing technical and non-technical loss-reduction projects in public utilities, policy and regulatory frameworks for gas flare–reduction projects, community-based projects to develop sustainable agroforestry for woodfuel and charcoal production, and decentralized rural electrification projects using photovoltaics. Energy investment projects financed by international development agencies typically devote millions of dollars to technical-assistance components. Thus, if the recipient countries are willing, future ESOU projects could easily incorporate technical assistance to address capacity needs for efficient and sustainable implementation of clean energy technologies, especially if additional funds are made available for that purpose. Such technical-assistance activities would serve to enhance the development objectives of these projects.

3) Logistics bottlenecks and sustainability issues require multi-sectoral coordination and support.

International development agencies have a history of coordinating support across sectors (e.g., rural road construction and agricultural development). External support can often create an incentive for administrative divisions to overcome communication barriers.

4) ESOUs are organized to offer the multi-country coordination required by many of the region's larger, clean energy projects.

Because of their small size, many countries in Sub-Saharan Africa require international coordination to facilitate the development of larger, clean energy projects. This is the case for the regional transmission grid system, gas pipelines for regional markets, large hydropower plants, and flared-gas recovery projects. The transaction costs of many smaller-scale, dispersed projects—from improved energy efficiency for industry (e.g., improved motors and steam traps) to smaller hydropower plants and diverse biomass-based energy—could be streamlined via large national or multinational Programs of Activities. ESOUs are already playing such a facilitation role across the region. The Global Gas Flaring Reduction Partnership illustrates how multilateral development agencies can catalyze the working together of larger private and public actors to reduce gas flaring in developing countries. Such capacity positions ESOUs as natural partners for countries preparing to implement such complex projects and programs.

5) Although the private sector in Sub-Saharan Africa is weak, ESOUs are used to promoting private-sector participation.

In other developing regions, CDM-eligible, clean energy projects have been developed mainly by private sponsors, and most Emission Reduction Purchase Agreements have been signed with private companies undertaking the principal investment on their own. The limited flow of private investment across Sub-Saharan Africa explains, in large part, the region's lack of CDM-eligible, clean energy projects. But ESOUs are used to designing projects aimed at attracting and supporting private investments. Typical examples are donor-supported projects that facilitate the participation of Independent Power Producers. In short, ESOUs already have the expertise and experience to catalyze the development of private-based, clean energy projects in the region's energy sector.

6) Clean energy projects in Sub-Saharan Africa require external donor financing, which ESOUs can channel to the project level.

Because of myriad investment barriers, both private- and public-based energy projects are difficult to finance in Sub-Saharan Africa. In most cases, financial closure can only be reached via the financial support provided by international development agencies. The CF market alone cannot provide investment financing. Indeed, ESOUs are the main providers of financing for energy investment projects in the region. Given their accumulated experience and know-how with regard to financing conventional energy projects, ESOUs can be instrumental to channeling resources of the newly created CIFs to finance clean energy projects.

Concluding Remarks

This study has demonstrated 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 the 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 $US158 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.