EMISSIONS REDUCTION PROFILE

Mozambique

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UNEP RISØ CENTRE
ENERGY, CLIMATE AND SUSTAINABLE DEVELOPMENT

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United Nations
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ENERGY, CLIMATE AND SUSTAINABLE DEVELOPMENT

Contents

Brief Profile

Full name: Republic of Mozambique
Population: 23.4 million (UN, 2010)
Capital: Maputo
Area: 812,379 sq km (313,661 sq miles)
Major languages: Portuguese (official), Makua-Lomwe, Swahili, other indigenous languages

Major religion: Christianity, indigenous beliefs, Islam
Life expectancy: 49 years (men), 49 years (women) (UN)
Monetary unit: 1 metical (plural meticais) = 100 centavos

Figure 1. Map of Mozambique[1]

[1] http://upload.wikimedia.org/wikipedia/commons/thumb/1/12/Un-mozambique.png/816px-Un-mozambique.png

Economy, Growth and Emissions

Mozambique is located on the southeast coast of Africa and is bordered by the Indian Ocean in the east, Tanzania to the north, Malawi and Zimbabwe to the west and Swaziland and South Africa in the southwest. It functions as an important coastal gateway for a number of landlocked SADC member states in the interior including Zambia, Malawi, Zimbabwe, Swaziland.

Reflecting the international tensions in the 1970s, Mozambique broke out in a devastating civil war that ended in the early 1990s. In 1994 the first multi-party election was held, resulting in a political shift that introduced a free market structure[2]. With only 18 years to rebuild and develop the nation, this is still considered as on-going and a very difficult task.
Poverty reduction is one of Mozambique's greatest challenges, as nearly 54% live below the poverty line. About 52.2% of the adult population are illiterate, 25% of all children die before they reach the age of 5, and 15% of the adult population are HIV-positive[3]. Out of a population of approximately 23 millions, 60% live in rural areas[4], and 56.9% are living below the poverty line[5]. Although Mozambique is a fairly new state with a vast number of social problems, the country has managed to achieve positive results in terms of non-monetary development, showing constant improvement towards the access to education and health services, and housing standards. Mozambique is also moving in the right direction in terms of economic growth, with a high Gross Domestic Product growth rate average of 7.7% between 1999 and 2009[6]. Most of the population is concentrated in the provinces of Maputo, Gaza, Inhambane, Zambezia and Nampula.
Only 12% of the population has access to electricity. Traditional biomass (fuelwood and charcoal) continues to account for the vast majority of energy consumption in Mozambique. In the bigger cities, mainly charcoal is used for cooking, as is most notably reflected in the data for the provinces of Sofala (Beira City) and Maputo (Maputo City). The average charcoal use of a typical Maputo household was found to be 70 kg per week. In Maputo City, about 25% of the population uses other sources to cook, which includes mainly LPG[7].
The household survey data of 2003 revealed that in most provinces the majority of the population used kerosene for lighting, followed by fuelwood. The other main source for lighting was electricity, which reflected in the electrification pattern of the country, with Maputo City having, by far, the highest electricity consumption.

Natural forests and woodlands are the main source of fuelwood and charcoal. Commercialization of fuelwood constitutes a form of subsistence for many of the rural and urban families. Small and medium-sized enterprises also consume significant amounts of fuelwood and charcoal. Charcoal is produced by inefficient, artisanal methods in Mozambique, and places severe pressure on natural resources, especially around urban centres in the country. The use of biomass for energy purposes is also one of the main

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[2] AMB, 2011.

[3] denstoredanske & TKN 2010 1f, http://www.denstoredanske.dk/Rejser%2c_geografi_og_historie/Afrika/Sydlige_Afrika/Mozambique_(Landeartikel)

[4] Cumbei, Sharme, Lucas 2008:1.

[5] Ministry of Planning and Development 2010: 26; CIA 2011.

[6] Worldbank.org 2011: 1.

[7] Ministry of Energy Statistics 2005, Source: A brief analysis of the energy sector in Mozambique.

causes of deforestation in Mozambique, accounting for 30.6 million hectares of forest consumed by households[8].

Mozambique is rich in modern energy resources, for example, hydropower, natural gas and coal. However, very few RE sources are currently exploited, with the exception of hydropower, contributing approximately 95% of the electricity supply distributed through the national grid. Large amounts of hydropower are also exported to the Southern African Power Pool (SAPP)[9], providing 12.8% of the total export revenue of Mozambique[10].
Hydropower is Mozambique's most important commercial energy resource, with the potential estimated at about 14,000 MW, of which about 2,300 MW has been developed so far -- 2,075 MW at Cahora Bassa Dam over the Zambezi River, and the remaining distributed among a number of sites throughout the country. Mozambique's electricity generating capacity totals some 2,468 MW, with the majority of the capacity being provided by the 2,075 MW Cahora Bassa hydroelectric project operated by Hidroeléctrica de Cahora Bassa (HCB)[11]. Electricity consumption in Mozambique is expected to increase steadily in the future, from approximately 5,336 to 12,263 GWh – more than doubling in 19 years:

Year	Grid Electricity demand projections (GWh/year)		
	Main-grid Demand	Off-grid needs	Total
2011	3348	1988	5336
2012	3544	2025	5569
2013	3814	2063	5877
2014	4090	2103	6193
2015	4317	2146	6463
2016	4611	2190	6801
2017	4850	2236	7086
2018	5175	2284	7459
2019	5421	2334	7755
2020	5758	2387	8145
2021	6089	2441	8530
2022	6451	2498	8949
2023	6807	2558	9365
2024	7168	2620	9788
2025	7524	2684	10208
2026	7886	2751	10637
2027	8241	2821	11062
2028	8573	2893	11466
2029	8904	2968	11872
2030	9216	3047	12263

Figure 2. Grid electricity demand projections for Mozambique[12]

Although Mozambique produces far more energy than it consumes, it will need to exploit new energy sources in the future, in order to provide electricity to larger parts of its own

[8] *IISD, 2010:6, http://www.iisd.org/tkn/pdf/energy_security_mozambique.pdf*

[9] *EDM 2010:16, Sumario Estatistico, Electricitade de Moçambique.*

[10] *INE 2011.*

[11] *http://www.probec.org/displaysection.php?czacc=&zSelectedSectionID=sec1242301147*

[12] Source: Sinnott et.al 2011: 22, Clean Energy Assessment Report - Sustainable energy pathways: Opportunities and challenges for Mozambique, WWF, Maputo Mozambique.

population. This is not due to a limited generation capacity, but largely because of Mozambique's need for financial profit from electricity export revenues and fixed electricity export contracts. This is mainly the reason why the focus of the government has been directed towards expanding generation capacity -- to further benefit from export to the neighbouring countries[13].
The graphs below show the economic growth, and growth in emissions in Mozambique over the past decade.

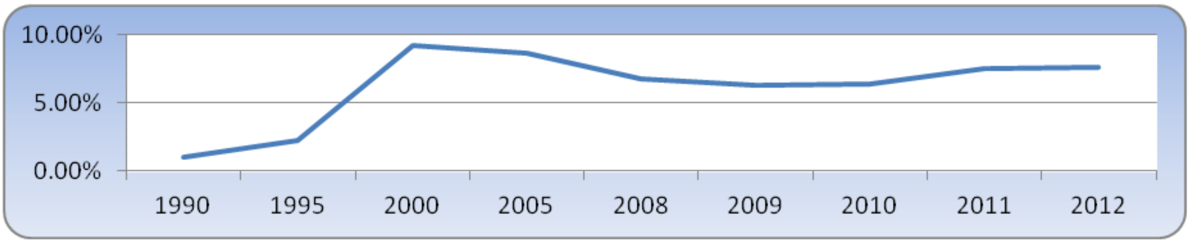

Figure 3. GDP percent change in Mozambique 1990 – 2012

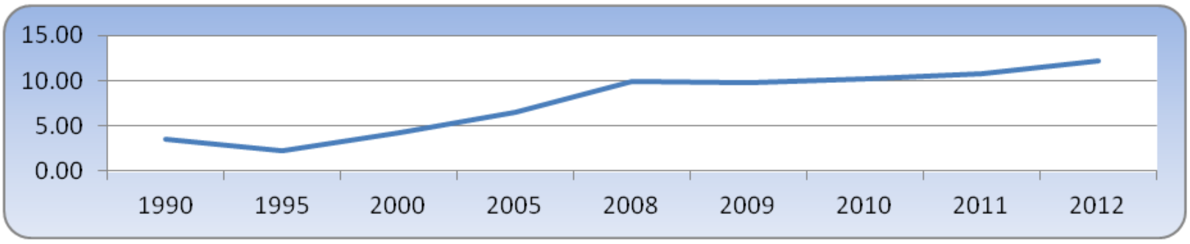

Figure 4. Economic growth since 1990 (GDP USD billions)

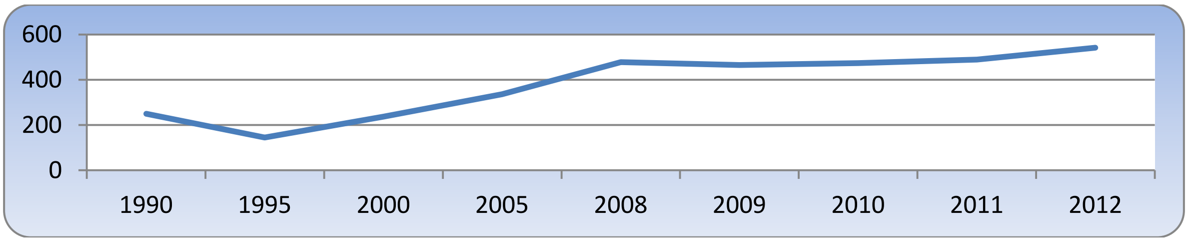

Figure 5. Economic growth since 1990 (GDP per capita)

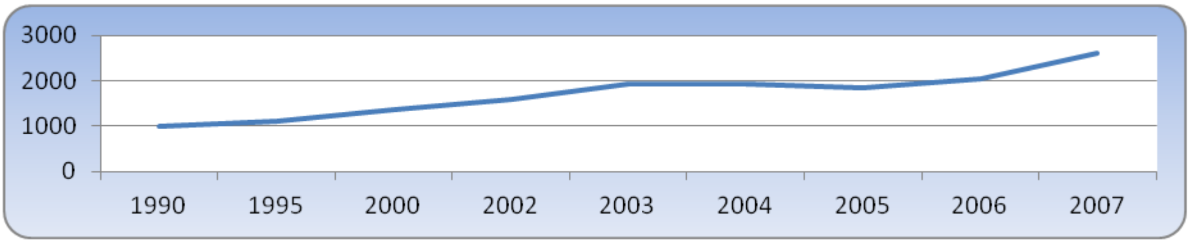

Figure 6. CO_2 emissions since 1990, $ktCO_2$

[13] *Republic of Mozambique 2004: Ch 2. p.2, Electricity Master Plan Study – Volume II – Power Demand Forecast.*

Status of CDM Development and Capacity Building in Mozambique

Currently, two CDM projects from Mozambique are at the validation stage.

Title	Status	Type	tCO_2 reduction/ year	Date of submission
Cimentos do Mozambique – Matola Gas Company Fuel Switch Project	At Validation	Fuel switch	41,876	15-04-2011
Cleanstar Mozambique - Maputo Ethanol Cook stove and Cooking Fuel Project 1	At Validation	Efficient cook stoves	270,275	05-06-2012

In addition, eight Programmes of Activities have included Mozambique as one of the host countries. All of these remain at the validation stage.

Title	Status	Type	tCO_2 reduction/ year	Date of submission
International water purification programme	At Validation	Water purification	12,488	29-07-2011
Southern African Renewable Energy (SARE) Programme	At Validation	Solar, hydro, wind, geothermal , wave, or tidal power	51,444	16-09-2011
CDM Africa Small-Scale Hydro PoA for Southern Africa	At Validation	Hydro	13,200	26-10-2011
PoA for the reduction of emissions from non-renewable fuel from cooking at household level	At Validation	Efficient cook stoves	22,797	13-12-2011
Southern African Solar LED Programme	At Validation	Lighting	10,217	22-01-2012
Promotion of Energy Efficient Cook Stoves within Southern African Development Community (SADC)	At Validation	Efficient cook stoves	44,869	23-03-2012
NuPlanet Small-Scale Hydropower PoA	At Validation	Hydro	18,175	04-04-2012
Improved Cook stoves Program for Malawi and cross-border regions of Mozambique	At Validation	Efficient cook stoves	16,239	01-05-2012

To date, only the latest PoA on improved cook stoves has included a CPA covering Mozambique.

Mozambique was also part of the UNEP project "Capacity Development for the Clean Development Mechanism", with financial support from the Dutch Government. The project was implemented in a number of countries and aimed at building capacity for CDM development.

Overview of CDM Opportunities in Mozambique

Agriculture and Forests

Mozambique possesses considerable potential for development, partly due to its significant quantities of natural resources. The country has historically been a major producer of cash crops. Agriculture is the core of the Mozambican economy, as it accounts for 30% of the GDP, generates 80% of export earnings, and employs 86% of the rural labour force. The country's natural forest areas also provide valuable commercial export wood, and sustain about 11.9 million people relying on fuelwood, charcoal and NTFP.

In recent years, natural resource overexploitation has caused soil degradation, forest depletion and loss of biodiversity. Firewood cutting is also placing serious pressure on Mozambique's 400,000 ha of coastline mangrove forests.[14] The majority of Mozambique's vegetation is classified as tropical savannah, woodland and forests. The main causes for deforestation are land-use conversion for agricultural purposes, wild fires, and fuelwood and charcoal consumption, while The LULUCF sector is the largest source of GHG emissions in the country.

Forest Carbon Options

According to recent FAO estimates, Mozambique's forests cover an area of 39,233,400 ha, which translates into approximately 49.8% of the country's total surface land area.[15] Deforestation has remained relatively low, and between 1990-2010 an average of 217,800 ha or 0.5% was lost per year. In total, this amounted to approximately 10% of Mozambique's forest cover (4,356,000 ha).[16]

Afforestation and reforestation of degraded forest lands, and mangrove restoration, present a potential for climate change mitigation in Mozambique, while generating financial flows from forest carbon activities under the CDM. However, A/R CDM activities have generally remained underdeveloped, compared to other CDM sectors, mainly as a result of the complexity of the A/R CDM procedure, and the limited market demand for A/R CDM credits. Moreover, CERs from these projects are not eligible in the European Emission Trading System, and only tCERs are issued to A/R CDM projects. Nonetheless, Africa holds a significant share in the global CDM forestry sector by hosting 30% of all A/R CDM activities, which represent 8% of CDM activities in Africa[17], altogether reflecting the continent's potential for abatement in the LULUCF sector. While there are currently no A/R CDM activities in Mozambique, the country has potential for generating additional income from forest carbon activities under the CDM.

REDD+ also presents an opportunity for creating financial flows for Mozambique's efforts to mitigate GHG emissions, through forest carbon activities. Currently, Mozambique participates in the World Bank's Forest Carbon Partnership Facility. However, in order for the country to prepare and become 'ready for REDD+', Mozambique will have to clearly define rules on land tenure and carbon rights, and set up institutions for REDD+ governance. Altogether, for REDD+ to become successful, the outcome will have to secure clear, tangible benefits, and access to land for forest dwellers and local communities, while conserving Mozambique's forests and biodiversity.

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[14] http://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/ADF-BD-IF-2006-80-EN-MOZAMBIQUE-PCR-FORESTRY-AND-WILDLIFE-RESOURCES-MANAGEMENT-PROJECT.PDF

[15] http://faostat.fao.org/site/377/DesktopDefault.aspx?PageID=377#ancor

[16] http://rainforests.mongabay.com/deforestation/2000/Mozambique.htm

[17] UNEP Risoe CDM/JI Pipeline Analysis and Database, June 1st 2012.

Calculating the potential emission reductions from REDD+ activities in Mozambique demonstrates that there is mitigation potential if deforestation is avoided completely. Assuming that the baseline is entirely based on historical emissions, avoided emissions are calculated by multiplying the annual deforestation in Mozambique, estimated to be 217,800 ha per year, with 31 tC/ha, which is the approximate amount of tons of carbon stored per ha in the country's forests annually.[18] Based on this data, and the conversion of 1 ton of biomass carbon to the equivalent of 3.67 tCO_2[19], avoiding deforestation, alone, in Mozambique has the potential to contribute nearly 25 million tons in CO_2 emission reductions every year. Reversing the trend and adding reforestation to these estimates would increase this number even more. Afforestation/reforestation initiatives aiming to replant 50% of the loss in forest cover during 2000-2005 (-219,000 ha), would require the regeneration of 109,500 ha of forest land, which could generate more than 12 million tCO_2e reductions annually.

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
REDD+ / Avoided deforestation	24,779,106	Historical baseline
Afforestation/ Reforestation	12,457,815	AR-AM1, AR-AM3, AR-AM4, AR-AM5, AR-AM9, AR-AM10, AR-AMS1, AR-ACM1, AR-ACM2

Fuelwood

Wood-based biomass is the dominant source of energy for sub-Saharan Africa, and fuelwood consumption per capita in Africa is higher than any other continent. In Mozambique, the domestic energy consumption is almost entirely based on fuelwood. However, the demand for wood is a major driver of forest degradation, and subsequently the release of GHG emissions.

Firewood

Biomass consumption (wood-energy and agricultural residues) remains the main source of domestic energy, and energy in small-scale commercial sectors. Reducing the demand for firewood is, therefore, a strategy to reduce drivers of deforestation and an exhaustion of Mozambique's natural resources. Such strategies include improved fuel-efficient cook stoves, and alternative fuels and techniques for cooking and baking, which altogether might have a significant impact on GHG emissions.

Charcoal

Charcoal constitutes the primary urban fuel in most of Africa, and is a major source of income as well as environmental degradation in rural areas. The production, transport, and combustion of charcoal constitute a critical energy, and economic cycle in the economies of many developing nations.

Charcoal production releases methane – especially in the traditional open pits process. There are three phases in the carbonization process: 1) ignition, 2) carbonization, and 3) cooling. CDM projects are implemented in two different processes: 1) improving the kiln design for better temperature control and greater control of carbonization variables, which reduce methane emissions, and 2) capturing the methane released from the charcoaling plant, and combusting it to generate electricity (e.g. in a gas engine).

Since charcoal production involves tree removal from forests, sustainable wood supply is an important concern. Therefore, any introduction of efficient charcoal production technologies should only be approved if facilities have allocated dedicated woodlots for

[18] *ftp://ftp.fao.org/docrep/fao/011/i0350e/i0350e04c.pdf*

[19] *http://aciar.gov.au/files/node/8864/TR68%20part%202.pdf*

sustainable fuelwood plantations. If charcoal is sustainably produced through plantations, and methane emissions are eliminated, charcoal production becomes carbon neutral, since all emitted carbon would subsequently be sequestered in replanted trees.

The annual charcoal production in Mozambique for 2003 was estimated to be 518,550 t.[20] According to a recently registered CDM project, using renewable charcoal from forest plantations, shifting from traditional open kilns to efficient kilns employing methodology AM0041[21], the anticipated methane emissions reduction per ton of produced charcoal is 0.037 tons[22]. This corresponds to 0.777 tons of carbon emissions reduced per ton of produced charcoal, based on the global warming factor of 21. Assuming that project emissions are zero, and that fuelwood is supplied from sustainable plantations, transforming the entire Mozambican charcoal production from a 100% open kiln production in the baseline would potentially result in an emissions reduction of 402,913 tCO_2e/year. Such a project might be viable, but significant uncertainties are associated with this calculation, if not on the actual emissions reduction potential and project emissions, then on the current production methods and the outlook for including the entire charcoal production under one CDM activity.

Technology type	**Emission Reduction Potential per year (tCO_2e)**	**Baseline Methodologies**
Charcoal production	402,913	AMS-I.C., AMS-III.K., ACM00021, AM0041

Waste

Waste management has a great GHG emissions reduction potential. The potential for reductions lies in two different areas of waste handling: proper disposal of organic matter that would otherwise emit methane (CH_4), and waste incineration, that can serve to replace energy (both thermal and electric) that would have been produced from fossil fuels.

Organic matter, for instance in the form of waste, emits large quantities of greenhouse gasses, primarily methane (CH_4), if not disposed of properly. The potential for the reduction of these emissions lies in various sectors.

Waste in the domestic sector, e.g. from small household livestock units, as well as in the industrial sector and municipalities, is most often left unutilized, to decay, or rarely used for the purposes of fertilizer or for burning in open pits. The waste is, therefore, both harmful to the surrounding environment, and often a health hazard. Consequently, a waste management project will be greatly beneficial to local sustainable development.

Waste management projects can be implemented in various sectors in Mozambique. The challenge of mitigating GHG emissions from waste lies in the lack of existing incentives, as the proper handling of waste does not present an opportunity to generate revenue for the stakeholders.

[20] *http://siteresources.worldbank.org/INTCARFINASS/Resources/MainReportLowCarbonEnergyprojectsforDevelopmentofSubSaharanAfrica8.18.08.pdf*

[21] *http://cdm.unfccc.int/filestorage/A/P/Q/APQY8M2DU796JH10G3SKEW5ZR4TBXN/05072010_PDD_Charcole.pdf?t=V298bTZrcmtxfDCc85eDOxwk3EIdOherlYZR*

[22] *http://www.fao.org/docrep/x2740E/x2740e60.pdf*

Agricultural Waste

Agricultural production leaves considerable amounts of agricultural waste, in the form of biomass and animal waste, in particular. Some of it is recycled into the agricultural production as fertilizer, while large amounts remain unutilized – and in many instances pose a disposal problem. Uncontrolled burning in the fields is not only a hazardous disposal solution, it is also a waste of a potential energy source. With efficient collection systems in place, waste from agricultural production can be utilized as fuel for power and heat production. In the sugar industry, significant amounts of bagasse – the waste after extraction of sugar – is an excellent fuel. Rice production may also be industrialized, to the extent that rice husks are available in amounts sufficient for incineration in a boiler, thereby securing a basis for power and heat production. In the forest industry, large concentrations of biomass waste can be utilized for power and heat production, e.g. at sawmills. The forest industry also supplies raw material for briquettes production, where sawdust, charcoal dust, degradable waste paper and dust from agricultural production may constitute a final utilization of waste materials from agriculture related production.

Biomass energy projects can be built in a wide range of sizes and for broad applications. Such projects are also cost-efficient solutions for waste generated by the sugar industry. They can be as large as 100 MW power stations generating both electricity and heat, but are typically 15-30 MW in size. Biomass energy projects are also technically feasible in much smaller sizes, but are rarely commercially viable below 8-10 MW, depending on availability and pricing of biomass residues.

The total emissions from agricultural wastes in 2005 were estimated to be 44.2% of the total national emissions, equalling to approximately 1 million tCO_2e/year.

Bagasse Energy Generation

In 2009, it was estimated that the available waste from sugarcane production, bagasse, was approximately 433,000 tons[23]. This amount of bagasse has an energy potential of about 2,000 GWh. Small biomass power plants could be built at the most suitable locations, and provide heat for the production and export of electricity to the grid. With a heat/power ratio of 60/40, the potential electricity is 800,000 MWh/year. If 50% of the available bagasse could be gathered, and the electricity would be exported to the SAAP, the potential emissions reduction would then be 400,000 MWh * 0.9176 tCO_2/MWh = 367,000 tCO_2/year. This calculation is merely from the replacement of electricity from the grid, and does not include the avoided emissions from the biomass left to decay, as the present storage and disposal practices for biomass waste are uncertain.

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Bagasse	367,000	AM36, ACM6, ACM2, AMS-I.D., AMS-I.C.

Biomass Energy Generation

There are a number of other biomass waste resources that could be utilized for electricity production, thereby avoiding emissions from the SAAP grid. The government of Mozambique has realized the vast potential for utilizing agricultural wastes for energy purposes. There are plans to realize 60 MW of power from at least two locations: Masinjire (50 MW) and Manica (10 MW)[24]. If these power plants produce power 250 days (season days) per year and supply the SAAP grid with electricity, the potential emissions reduction would be 60 MW * 250 days * 24 hours * 0.9176 tCO_2/MWh = 330,000 tCO_2e/year.

[23] *"A Renewable Energy Plan for Mozambique", 2009.*

[24] *"A Renewable Energy Plan for Mozambique", 2009.*

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Other agricultural wastes	330,000	AMS-I.C., AMS-I.E., AMS-III.B., AM36

Biogas

Another unutilized source of waste is domestic waste, in terms of household, human, and bio-waste. It was estimated in a Clean Energy Assessment report from 2011[25] that the theoretical potential for energy production from these sources of waste was about 35% of all cooking needs. A project option could be to implement domestic biogas systems in households still using kerosene for cooking and lighting. The annual consumption of kerosene in Mozambique in 2010 was 35 million litres, assuming that a family on average used 0.5 litres per day - corresponding to almost 200,000 households consuming kerosene. Assuming that 100,000 domestic biogas digesters were installed, the annual emissions reduction potential would be 100,000 * 0.5 litres * 365 days * 2.58 $kgCO_2$/litre = 47,085 tCO_2/year.

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Domestic biogas	47,085	AMS-I.A, AMS-I.C, AMS-I.D., AMS-III.H., AMS-III.D., AMS-III.F., AMS-III.I., AMS-III.R., ACM14, AM25, AM80

Landfill Gas

In all the larger cities of Mozambique, the collection and treatment of municipal solid waste is in very poor condition. As the system lacks proper collection of waste, the waste is most often burned in open pits. Therefore, the waste is primarily stored under aerobic conditions, and does not emit methane. Due to the lack of a proper landfill to collect methane from, such projects are not applicable in Mozambique.

Wastewater

As with the municipal solid waste system, the sewage systems are also in very poor condition[26]. Only 10% of the population is connected to a common sewage system. Currently, the sewage system in Maputo discharges directly into rivers that flow into Maputo Bay. The potential for emission reducing projects is, therefore, very limited because of the present aerobic treatment of the wastewater.

Conventional Power Production

The total installed power production capacity in Mozambique was 2.308 GW in 2009. Hydropower is the source for most of the electricity, accounting for 99.7% of total production. Mozambique is a net exporter of electricity, with more than 73% of the produced power being exported to South Africa. The electrification rates are very low – just 14%, higher in urban areas, and as low as 5% in rural areas. Cahora Bassa dam is the source for most of the country's electricity, 60% of which is used at the Mozal aluminum plant[27]. The power supply is only present part of the time and lacks reliability, which is considered to be a major concern for the successful operation of many industries and businesses.
There have been recent discoveries of offshore gas and coal, which could potentially play a role in future power production and exports. The annual electricity demand is expected to

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25 "*Sustainable energy pathways: opportunities and challenges for Mozambique*".
26 *Information Resource & Hub for the global water community.*

27 *REEGLE, 2012, http://www.reegle.info/countries/mozambique-energy-profile/MZ*

continue to grow at an annual growth rate of 4.7%, with hydropower constituting most of the additional capacity.
A 140 MW gas-fired power plant is also planned by the energy and chemicals group Sasol, with a possible start of operation as early as 2013[28]. Currently, the options for emissions reduction within conventional power production are limited, since most power production comes from emission-free hydroelectric power stations. However, Mozambique's inclusion in the Southern African Power Pool allows for the use of regional grid emission factor, which corresponds to 0.92tons CO_2/MWh. Calculated with 7,000 annual operating hours the emission reductions would be approximately 485,000 tons of CO_2[29] by replacing grid electricity with lower emission gas based power production.

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
New natural gas plant	485,000	AM29

Renewable Energy

Hydro

The water resources in Mozambique are plentiful, due to the many rivers running through the country. It is a large hydropower producer, with hydro accounting for more than 99% of power production. The full potential remains far from being explored, as the current installed capacity is approximately 2,300 MW, while the full potential is estimated at 14,000 MW.
There is also a vast amount of smaller river systems with the potential to enable small-scale hydropower generation in many remote areas (KMPG Draft Report 2008: 32ff). The potential of mini-hydro is estimated to be 1,000 MW, with much of it located in areas that lack access to electricity[30]. A study of 19 river systems showed a potential of 314 GWh from hydropower sites with capacities less than 15 MW. The total mini-hydropower potential in Mozambique must, therefore, be expected to be higher than the suggested 314 GWh. The implementation of mini-hydro plants must be pursued, as the utilization of the power potential can constitute a key energy resource for small communities (Sinnot et al. 2011:32).
In the context of CDMs, producing 314 GWh from mini-hydro could deliver emissions savings of 1,570 tons of CO_2 annually. The national grid emission factor is 0.8794 tCO_2/MWh, but Mozambique is part of SAPP (Southern Africa Power Pool), and using their grid emission factor could yield much higher CER returns. Using the grid emission factor for SAPP (0.9176 tCO_2/MWh[31]), the emissions savings from the small hydro are 288,126 tons of CO_2.
There are also a number of larger scale hydropower projects in the pipeline with a total capacity of about 3,000 MW[32]. With a conservative assumption of 3,500 plant working hours a year, these could deliver emission reductions of 9,634,800 tons of CO_2, calculated using the SAPP grid emission factor.

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[28] *Mozambique Power Report 2012 Q3, Business Monitor International, http://www.marketresearch.com/Business-Monitor-International-v304/Mozambique-Power-Q3-7011559/*

[29] *Calculated using plant efficiency of 40% and IPCC standard values for fuel combustion.*

[30] *Hankins, M., 2009, A Renewable Energy Plan for Mozambique.*

[31] Burian et al, Analysis of Grid Emission Factors for the Electricity Sector in Sub-Saharan Africa, 2012.

[32] *Ministry of Energy, Directorate of Studies and Planning, 2012, Energy Sector Priorities Projects and Investment Opportunities, http://www.speed-program.com/library/resources/documents/USInvestorConference/Speechesandpresentations/EnergysectorProjectsandInvestmentOportunities.pdf*

Solar PV

There are only a few studies available on Mozambique's PV potential, but as the sun shines approximately 2,750 hours annually in the country, the potential for PV electricity production should be clear (Climatetemp.info 2011). Mozambique has great insolation, with an approximate generation potential of 4.5-7 kWh/m2/day in all districts, and an average of 5.2 kWh/m2/day (KPMG 2008: 36, IISD 2010: 13). The efficiency of PV modules varies, based on the chosen technology and price. The following figure illustrates the power output from different PV technologies, and the amount of electricity they could generate, based on Mozambique's solar radiation.

Electricity output from PV modules

Parameters	200 Wp Crystalline Silicon Module	230 Wp Crystalline Silicon Module	340 Wp thin film module	380 Wp thin film module
Efficiency	12,15%	13,97%	5,94%	6,64%
Average Solar Radiation in Mozambique 5,2 kWh/m2/day				
Generated electricity (kWh/m2-day)	0,632	0,726	0,309	0,345

The figure shows the expected electricity output per m2, based on Mozambique's solar radiation and various PV modules' efficiency. Source: (NCPRE 2011, IISD 2010: 13)

As shown in the above figure, the expected electricity output from PV modules/m2 is quite high in Mozambique. Even if the least efficient module type were used as reference, it would provide enough electricity for lighting and low power consuming appliances. Moreover, 1 m2 of the same module would also provide enough electricity to supply one person's electricity consumption, in relation to the global standard goal of 100 kWh per year (0.273 kWh/day) set by AGECC. The price for PV modules has been gradually falling due to technology maturation and diffusion, bringing the prices--excluding sale taxes and installation costs--to an average below 2 USD per watt (lowest crystalline silicon module price 1.28 USD per watt, lowest thin film module price 1.18 USD per watt) in 2011 (solarbuzz 2011).

A study estimates that with a coverage of 5% of urban area (8,580 GWh) and 5% of bare land (7,235 GWh) for PV electricity generation, the annual estimated potential amounts to as much as 15,815 GWh -- enough to meet the estimated total electricity demand, both on- and off-grid, in 2030 (12,263 GWh)[33]. Although the 5% land coverage might be very difficult to realize, practically, it gives a good indication of the tremendous solar PV power potential in the country. Assuming that for urban areas the electricity would be replaced from the grid, the emissions savings (for just urban areas) would equal 7,873,008 tons of CO_2 (calculated using the SAPP grid emission factor). For the remaining 7,235 GWh, the emissions savings would depend on the specifics of whether the solar energy replaces kerosene/diesel use in the rural areas or electricity from the grid.

Solar Thermal

Solar thermal water heating has the potential to deliver great emissions savings. Calculated based on 0.55% use of urban lands for solar thermal water installations, the potential is as high as 944 GWh of energy[34]. If this energy is replaced from the grid, the potential emissions savings could be as high as 866,244 tons of CO_2.

[33] Sinnott et al. 2011, Sustainable energy pathways: opportunities and challenges for Mozambique, Clean Energy Assessment Report, Maputo, March 2011.

[34] Ibid.

Wind

Wind power in Mozambique is still at early stages of development. There is good potential for wind power exploitation along the coastline, where wind speeds are 6-7 m/s[35] in some areas. Investigations into wind speeds across the country are underway, and a more detailed wind atlas is expected to be ready in 2013, therefore, the emissions savings potential is yet to be determined.

Geothermal

A considerable geothermal potential has been identified in Mozambique. At least 38 thermal springs have been identified. The most promising areas for geothermal power development are the northern and central provinces, however several lower temperature springs are found elsewhere in the country[36]. A conservative estimate of the geothermal resources in Tete, Manica and Niassa indicates a potential of at least 25 MW[37]. This corresponds to emissions savings of about 174,344 tons of CO_2 (calculated with 7,600 average working hours, from the UNEP Risoe CDM Pipeline and the SAPP grid emission factor). Further resource assessments are needed to determine the full potential.

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Hydro	9,922,926	ACM2, AMS-I.D., AM26, AMS-I.A., AM5, AM26, AMS-II.B., ACM11, ACM12, AM52
Solar PV	7,873,008	ACM2, AMS-I.A., AMS-I.C., AMS-I.D.
Solar thermal	866,244	AMS-I.C., ACM2
Geothermal	174,344	ACM2, AM72, AMS-I.D., AMS-I.C.

Energy Consumption

Greater efficiency in the consumption of energy is commonly an attractive option for emissions reduction, due to its dual benefit of reducing both emissions and the size of the energy bill. However, despite many years of promotion, it is also the most overlooked option. In CDMs, for instance, demand-side energy efficiency projects only make up 1% of the CER generation. Among the many reasons for this is the fact that most developing countries focus on energy access, rather than energy saving. The 2007 census in Mozambique found 4,629.026 households[38], of which 14% had access to electricity[39] -- up from only 7% in 2005.

Efficient Cook Stoves

To date, only one ethanol cook stoves project in Mozambique has been recorded in the CDMpipeline.org. CleanStar Mozambique[40] is Cleanstar's latest and fastest growing project, which will distribute up to 30,000 ethanol stoves and an ethanol processing facility to fuel

[35] *Renewables Readiness Assessment. Mozambique: Preliminary Findings, 2012, IRENA.*

[36] *"The CDM Project Potential in Sub-Saharan Africa", Wuppertal Institute 2011, http://www.jiko-bmu.de/files/basisinformationen/application/pdf/subsaharan_ldcs_cdm_potentials.pdf*

[37] *Hankins, M., 2009, A Renewable Energy Plan for Mozambique.*

[38] *http://www.clubofmozambique.com/solutions1/faq.php?cat_id=27*

[39] *http://www.macauhub.com.mo/en/2009/06/10/7209/*

[40] *http://www.cleanstarmozambique.com/assets/knowledge-centre/Agroforestry_&_Conservation_Agriculture/Bio-Carbon_Opportunities_in_East_and_Southern_Africa_FAO_2009.pdf*

them. This model also includes cassava farmers in producing the ethanol. Cleanstar has had multiple investments in the 7-figure range from multinational corporations including Novozymes, ICM, and Bank of America.[41]

To calculate the greenhouse gas emissions reduction effect from using ethanol, it is important to consider the full cycle of the fuel. Important aspects to consider are: 1) the feedstock used (e.g. by-product of sugar production or raw materials which could have been used for food production), 2) the distance to transport feedstock to ethanol production site, and the transport mode used, 3) the production process itself, and 4) what is replaced by the ethanol -- e.g. unsustainably harvested wood or charcoal stove.

Cleanstar expects to reduce up to 270,000 tCO_2e through the project[42], which is not a PoA and, therefore, will not be expanded (but could possibly be reproduced). If this reduction potential per cook stove is sustained by the CDM executive board--which effectively would mean that the average Mozambican emits 2 tCO_2e/year from cooking alone, likely 4-6 times more than the average person in a developed country--and the technology catches on in Mozambique, the emissions reduction potential would be immense. The project is mainly targeting charcoal replacement. If charcoal is used in about a third of the households in Mozambique, and 50% of these households shift to ethanol-based stoves, the emission reductions would correspond to almost 7 million tCO_2e. If 25% of the remaining households shift to other efficient cook stoves that traditionally reduce about 2 tCO_2e per cook stove per year, another 1.5 million tCO_2e of reduction potential would be added.

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Efficient stoves	8,500,000	AMS-I.E. AMS-II.G. AMS-I.C.

Lighting

Mozambique's grid emission factor is currently 0.72[43], but stands to increase to 0.92 if a common grid emission factor for the Southern African Power Pool is adopted. Emission reduction from efficiency gains in the usage of the 453.35 kwh/capita in 2009, according to a World Bank report published in 2010[44], will, therefore, have a sizeable reduction potential. The current rapid expansion of grid connectivity in Mozambique[45], under the Endev programme, already has emissions reduction effects through the replacement of, first and foremost, kerosene lighting in households, although this constitutes the replacement of one high emission technology with another relatively high emission grid alternative. However, according to the programme website, newly connected households are also supplied with a CFL light bulb. Assuming that currently connected households are already equipped with CFLs, there is no further reduction potential in existing connections. If this and other programmes continue the expansion of grid connections at the current pace, another 300,000 households will be connected over the next five years -- each potentially reducing an estimated 50 kg of CO_2e per year or 15,000 tCO_2e.

Other reduction options may exist in the hotel industry. The website Tripadvisor.com lists 59 hotels in Mozambique, 19 of which are in Maputo. An A/C of HVAC efficiency programme

[41] *http://www.triplepundit.com/2012/05/mozambique-cleanstar-novozymes-cook-stoves/*

[42] *http://cdm.unfccc.int/filestorage/3/W/K/3WKZRQUV2I1XADFTOYMJ964B75NPC8/Cleanstar%20PDD-%20.pdf?t=eEx8bThxbDBkfDANaawk8K8dr1fUT1z2MfmW*

[53] *see 'Analysis of Grid Emission Factors for the Electricity Sector in Sub-Saharan Africa: The Case of the Southern African Power Pool', UNEP Risoe & GFA, 2011.*

[44] *http://www.tradingeconomics.com/mozambique/electric-power-consumption-kwh-per-capita-wb-data.html*

[45] *http://endev.info/index.php/Mozambique*

for (international) hotels in Mozambique might represent emissions reduction options, though in the CDM very few of these types of activities have been observed.

If, hypothetically, 100 rooms in each of these hotels were running one A/C, and the efficiency of these could be improved by 30% by exchanging them for more efficient versions, the power saved could be estimated to be about 8,000 MWh corresponding to about 6,000 tCO_2e --based on reducing the installed effect by 500 watt per A/C, and running the A/Cs 8 hours per day. Other potential options may exist in replacing electricity-based water heating with solar heating, though this would not be considered an energy efficient measure.

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
CFL distribution (with grid expansion)	15,000	AMS-II.E. AMS-II.J.

Industrial Production Processes

Industrial activities cover several industry sectors and reduction options related to energy efficiency, as well as change of processes and substitution of materials. In developing countries there are many cottage industries, such as small-scale brick production or even household-based production, like textiles, which in most cases are not represented and do not constitute noteworthy emissions reduction options. In many countries, brick kilns are the exception, and may even represent considerable reduction potentials.

No information on the production of bricks in Mozambique has been retrievable. However, if current practices in the neighbouring Malawi were to be used as a basis or indication, Mozambique could be producing an estimated 250 million bricks (relative to population) in earthen kilns, using unsustainably sourced fuelwood in the production. If this were the case, the emissions reduction potential could be estimated to be as high as 1 million tCO_2e in a full conversion to vertical shaft kilns, based on calculations made in CDM project no. 582,[46] 'India - Vertical Shaft Brick Kiln Cluster Project'. In this project, 22.88 GWh corresponding to 7,120 tCO_2e/year is saved annually for the production of 1,844,000 bricks from efficiency gains alone, i.e. without fuel switch. Fuel switch to biomass residues, for example, could add further reduction potentials. However, with no information available further investigations are needed.

In 2010, aluminum accounted for 50% of Mozambique's exports, and natural gas accounted for 6% -- both of which are potential sources of significant GHG emissions. The Mozal aluminum smelter, which used alumina imported from Western Australia as raw material, produced 557,000 metric tons (t) in 2010.[47] A CDM project under validation in China, the Hunan Chuangyuan Primary Aluminium Smelter System Renovation Project, targets the optimization of technical conditions of 240kA and 300kA prebaked aluminum reduction cells. The renovation of this smelting technology will reduce electricity consumption by 550 kWh per ton aluminum, reduce dust and PFCs emissions, and lower noises from the smelters. The project is expected to reduce GHG emissions by an estimated 127,166 tCO2e per year during the crediting period.[48] If similar conditions exist at the plant in Mozambique,

[46] *http://cdm.unfccc.int/filestorage/G/O/A/GOALLSJ8VTL1GTWJOKYB7ESJ7N6N6I/Final-PDD-VSBK--April%2017%202006.pdf?t=SGt8bTk1am92fDBbsrRX5-28LkmiBAavErum*

[47] *http://minerals.usgs.gov/minerals/pubs/country/2010/myb3-2010-mz.pdf*

[48] *http://cdm.unfccc.int/filestorage/P/Y/J/PYJBKZSQR63T981COUDIF5HAG70VLE/PDD_Hunan%20Chuangyuan.pdf?t=eEZ8bTk1cX*

and the emissions from electricity generation are based on the SAPP grid emission factor of 0.92, the emissions reduction potential would be 282,000 tCO_2e/year, although a more detailed investigation is necessary.

There are considerable mining activities in Mozambique, but the energy consumption patterns in the industry are not available. Emissions reduction potentials, therefore, cannot be assessed, though in all probability there would be sizeable reduction options, particularly if the SAPP grid emission factor were employed. Potential methane development from gold mining cannot be assessed either. Furthermore, 60,000 artisanal miners accounted for about 90% of Mozambique's gold production[49] leaving the gold mining industry out of reach for emissions reduction initiatives.

National cement consumption was about 1.1 Mt in 2010, which was attributable to the rehabilitation of public infrastructure, as well as new constructions in the mineral sector, real estate, and seaports. Production by domestic plants was insufficient to meet demand.[50] There seems to be several plans for increasing the production. Cimentos de Mocambique SARL produced cement at its Dondo, Matola, and Nacala plants, which had a total combined capacity of about 1.04 Mt/yr. CIMPOR planned to increase the capacity at Matola to 1 Mt/yr from 500,000 t/yr in 2011; the plants at Nacala and Dondo had capacities of 350,000 t/yr and 190,000 t/yr, respectively. CIMPOR purchased a 51% share in Cimentos de Nacala S.A., which had a plant at Nacala with a capacity of 350,000 t/yr.[51] In June 2010, a consortium of Chinese companies announced plans to build a new cement plant with a capacity of 500,000 t/yr in Magude, in the northern part of Maputo Province.

All in all it is not entirely clear what the current capacity is. Assuming a current capacity of 1.5 million tons/year, emissions reduction from waste heat recovery could amount to about 18,000 tCO_2e/year depending on the current source of energy -- if benchmarked against CDM project no. 4329[52] in the Philippines, where a 1 Mta cement plant expects to generate 11,800 tCO_2e/year of emissions reduction from waste heat recovery.

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Aluminium efficiency	282,000	AM0059
Vertical shaft brick kilns	650,000	AMS-II.D
Cement WHR	18,000	ACM0012

Transport

Mozambique has 3,100 km of railways, and 30,000 km of roadways, 6,000 km of which are paved. The value of oil imports in the country in 2010 was 350 million USD[53]. Mozambique imports all of its petroleum products, with the transport sector being the main consumer of petroleum fuel[54]. The emissions from liquid fuels in 2008 were 1.7 million tCO_2e[55],

JmfDD25jpqsvkJt92nHkzsyeI2

[49] *http://minerals.usgs.gov/minerals/pubs/country/2010/myb3-2010-mz.pdf*

[50] *http://minerals.usgs.gov/minerals/pubs/country/2010/myb3-2010-mz.pdf*

[51] *http://minerals.usgs.gov/minerals/pubs/country/2010/myb3-2010-mz.pdf*

[52] *http://cdm.unfccc.int/filestorage/S/T/A/STAX2E8ZGJ5YLCB0VQPI96D1FUNM34/4329%20PDD.pdf?t=ZkJ8bTkzenlzfDBGPXfmebplRcSkZMwW6Zdz*

[53] *http://www.economywatch.com/economic-statistics/country/Mozambique/*

[54] *https://energypedia.info/index.php/Mozambique_Country_Situation*

corresponding to the consumption of about 600 million litres. Under a government mandate taking effect in 2012, petrol must be blended with 10% ethanol, while 2% biodiesel is added to conventional diesel fuel. The blending targets will reduce emissions to the tune of about 5% or 85,000 tCO_2e through the blending of 33 million litres of biofuel (from about 1,000 km^2 of plantation if based on jatropha).

By 2008, strong activity was reported in jatropha production[56] in Mozambique. From 2006 to 2010 the FACT Foundation, together with ADPP, implemented the pilot project "Jatropha for local development" the in Cabo Delgado Province in northern Mozambique[57]. Another example is Sun Biofuels planting 5,000 hectares of jatropha, with the view to producing 2-3 tons of oil per hectare or about 1.5 million litres of oil per year[58], corresponding to about 4,000 tCO_2e of emissions reduction. Overall, it is thought that more than 100 million USD have been invested in over 30 biofuel projects, which are currently being developed[59]. There is also activity in ethanol production. Mozambique has a substantial supply of molasses, which can be used to make ethanol, due to the large number of sugar plantations at Marromeu, Mafambisse, Xinavane and Maragra[60].

The blending strategy faces a challenge as reportedly 30 tons of jatropha oil produced in Mozambique's central province of Manica was crushed by the British company Sun Biofuels, and sent to Germany, as Lufthansa was seeking 400 million litres of biofuels globally. Redirecting biofuels that are already utilized, albeit outside Mozambique, will not have any emissions reduction effect.

Nevertheless, the general blending strategy is the best possible platform for increasing emissions reduction and reducing dependence on fossil fuels – as opposed to captive usage, as required in the CDM methodologies. Particularly the 2% biodiesel blending target seems far too modest to absorb the production capacity imminently at hand (in which case export is the obvious answer). A 10% target would double the emissions reduction potential to 170,000 tCO_2e and better align supply and demand.

Improving transportation efficiency through collective transport solutions like BRT could only meaningfully target Maputo, with its approximately 1.2 million inhabitants. However, if benchmarked against other BRT projects, like the BRT CDM project no. 5437 in Guadalajara, Mexico – a city with 3.7 million inhabitants, and a significantly higher density of vehicles – Maputo's options are not relevant as emissions reduction initiatives. Guadalajara expects to reduce about 50,000 tCO_2e per year by establishing eight BRT lines. This could translate into an estimate of only 1,500 tCO_2e for a single BRT line in Maputo.

Technology type	**Emission Reduction Potential per year (tCO_2e)**	**Baseline Methodologies**
Biodiesel for transport	170,000	ACM17, AMS-III.C., AMS-III.T.
Bus Rapid Transit	1,500	AM31, ACM16

[55] *http://data.worldbank.org/indicator/EN.ATM.CO2E.LF.KT*

[56] *http://www.jatropha-alliance.org/fileadmin/documents/GEXSI_Global-Jatropha-Study_FULL-REPORT.pdf*

[57] *https://sites.google.com/site/mozambiquejatropha/*

[58] *http://www.biofuelsdigest.com/bdigest/2010/06/02/sun-biofuels-ready-for-first-jatropha-harvest-in-mozambique/*

[59] *http://www.thebioenergysite.com/news/9544/mozambiques-biofuels-projects-could-save-682m*

[60] *http://www.thebioenergysite.com/news/9544/mozambiques-biofuels-projects-could-save-682m*

Summary

Mozambique has an overall abatement potential of 42,564,033 tCO_2e. The total investments needed to achieve these reductions can only be roughly assessed, as a sizeable share of the reductions relate to technologies for which no data currently exists -- in terms of their investment to CER-revenue ratio.

Technology type	Emission Reduction Potential per year (tCO_2e)
REDD+ / Avoided deforestation	24,779,106
Afforestation/ Reforestation	12,457,815
Charcoal production	402,913
Agricultural waste	697,000
Biogas waste	47,085
New natural gas plant	485,000
Hydro	9,922,926
Solar PV	7,873,008
Solar thermal	866,244
Geothermal	174,344
Efficient stoves	8,500,000
CFL distribution (with grid expansion)	15,000
Aluminium efficiency	282,000
Vertical shaft brick kilns	650,000
Cement WHR	18,000
Biodiesel for transport	170,000
Bus Rapid Transit	1,500

These estimates should not be regarded as being precise. Rather, they represent a form of calculation that allows comparison among economies, and their relative attractiveness as destinations for carbon finance.

It should be emphasized that while attempting to be exhaustive, the estimates here do not claim to be all-inclusive. There may be unidentified sources of reductions not included in the technology overview, and not represented by existing methodologies, but in all likelihood these would be minor compared to the potentials identified.

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