EMISSIONS REDUCTION PROFILE

Rwanda

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ENERGY, CLIMATE AND SUSTAINABLE DEVELOPMENT

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Brief Profile

Full name:	Republic of Rwanda	Major religion:	Christianity, indigenous beliefs
Population:	10.2 million (UN, 2010)	Life expectancy.:	50 years (men), 54 years (women) (UN)
Capital:	Kigali		
Area:	26,338 sq km (10,169 sq miles)	Monetary unit:	1 Rwandan franc = 100 centime
Major languages:	English, (official), French (official), Swahili	Main exports	Coffee, tea, hides, tin ore

Figure 1. Map of Rwanda[1]

[1] www.rwanda-direct.com

Economy, Growth and Emissions

Structure of the economy and the current energy situation

Rwanda's economy suffered heavily during the 1994 genocide, with widespread loss of life, failure to maintain the infrastructure, looting, and neglect of important cash crops. This caused a large drop in GDP and destroyed the country's ability to attract private and external investments.

Rwanda is a country of few natural resources, where the economy is based mostly on subsistence agriculture by local farmers using simple tools. An estimated 90% of the working population engages in farming, and in 2006 agriculture comprised an estimated 39.4% of the GDP. Since the mid 1980s, farm sizes and food production have been decreasing, due, in part, to the resettlement of displaced people. Despite Rwanda's fertile ecosystem, food production often does not keep up with population growth, and food imports are required.

Due to the number of inhabitants living below the poverty line, and the subsistence farming, the GHG emissions from the residential sector are mainly from deforestation, as a result of firewood collection, charcoal production in open kilns, and the spare use of fossil fuels in generators and kerosene for lighting and cooking.

Crops grown in the country include coffee, tea, pyrethrum, bananas, beans, sorghum, and potatoes. Coffee and tea are the major cash crops for export, with the high altitudes, steep slopes, and volcanic soils providing favourable conditions. Reliance on agricultural exports makes Rwanda vulnerable to shifts in prices.

Livestock are raised throughout the country, with animal husbandry contributing about 8.8% of the GDP in 2006. Animals raised in Rwanda include cows, goats, sheep, pigs, chicken and rabbits, with geographical variation in the numbers of each. Production systems are mostly traditional, although there are a few intensive dairy farms around Kigali. Shortage of land and water, as well as insufficient and poor quality feed, and regular disease epidemics with insufficient veterinary services are major constraints that restrict output. Fishing takes place on the country's lakes, but stocks are greatly depleted, and live fish are being imported in an attempt to revive the industry. Hence, due to the decentralised agricultural production of both crops and livestock, the GHG emissions from the sector are equally small and dispersed.

The industrial sector is small and uncompetitive. Manufactured products include cement, agricultural products, small-scale beverages including beer, soap, furniture, shoes, plastic goods, textiles, and cigarettes. Rwanda's mining industry is an important contributor, generating 93 million USD in 2008. Mined minerals include cassiterite, wolframite, gold, and coltan, of which the latter is used in the manufacture of electronic and communication devices such as mobile phones[2]. Rwanda's current power installation consists of 4 hydropower plants with a combined installed capacity of 26 MW, a methane-based power plant of 4 MW, and 5 fossil fuelled (heavy fuel oil) plants of combined 47 MW. The weighted grid emission factor is 0.65 tCO_2e/MWh according to information published by the Rwandan Designated National Authority in 2009, based on data from the three previous years.

[2] http://www.articlesbase.com

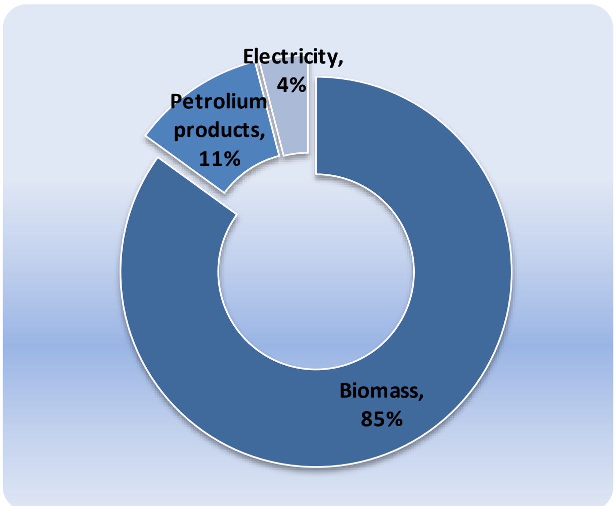
Rwanda's updated 2010 grid emission factor was calculated in June 2011, to be validated by the end of August 2011[3].

The Energy, Water and Sanitation Authority (EWSA) have been the sole integrated electricity supplier in the country. Rwanda imports electricity through cross-border interconnections of about 15.5 MW from the DRC and SINELAC, and about 3 MW from Uganda (MININFRA 2009a). There is about a 50% gap in electricity generation. By 2004, this amounted to about 380 MWh of electricity supplied.

Electricity shortage has necessitated regular load shedding. Frequent power shortages have resulted in individuals, manufacturing entities and firms purchasing their own generators. This has led to an increase in production costs of industry, a subsequent increase in consumer goods, and increased emissions to the environment. Power shortages have led to a 250% increase in power prices – from 48 to 120 Rwf per unit of power. There has also been a shortage of charcoal. Most of the shortages are caused by deforestation, due to exploitation of forests for biomass energy.

In order to meet demands, Electrogaz has purchased a number of diesel-powered generators. By the second quarter of 2006 the cost of paying for the diesel was estimated to be approximately 65,000 USD per day. Although electricity is consumed mainly in urban areas, there are cost implications of these expenditures to the rest of the economy. Kigali, alone, consumes about 60% of the entire generated electricity (UNDP, 2007).

Energy remains very expensive in Rwanda, accounting for 14% of all non-food expenditures, though the proportion is higher for poorer households. Rwanda has one of sub-Saharan's lowest electricity consumption per capita at approximately 20 kWh/year[4]. Therefore, the primary energy sources are dominated by biomass -- with 85% coming mainly from wood used directly as fuel or for charcoal production (Figure 2). Electricity, which accounts for 4% of the primary energy consumption, is mainly derived from hydro and thermal energy sources, which is seen in Figure 2.



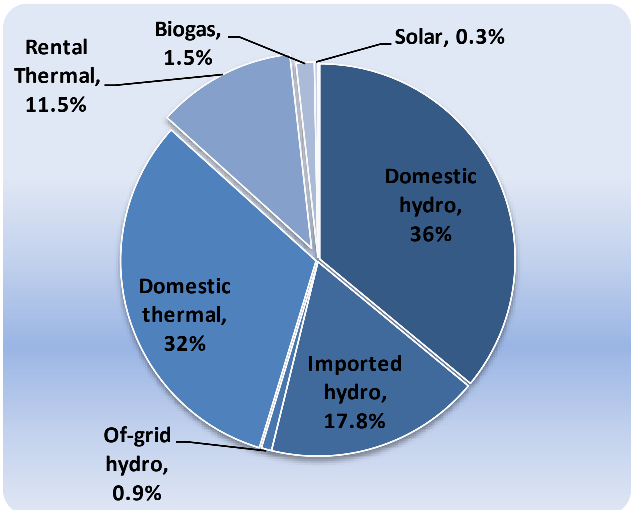


Figure 2. Primary energy sources in 2009, and electricity-generating technologies in percent of electricity generated in Rwanda 2009.

[3] *Expectations are that the new grid emission factor will be lower than the current one of 0.65.*

[4] *"National Energy Policy and Strategy", Ministry of Infrastructure – Republic of Rwanda, Kigali, 2011.*

Despite the relatively high share of non-fossil derived electricity, by 2007 the grid emission factor was 0.65 tCO_2e/MWh[5]. Due to the relatively small generation capacity, and hence a big marginal change in the primary energy mix, when new renewable or low emitting technologies are connected to the grid, the grid emission factor will decrease as the planned hydro, geothermal and methane power projects will be developed and implemented in coming years[6]. Overall, the need for energy is projected to grow in the coming years. The residential sector is expected to increase its demand for electricity and, hence, have a bigger share of the total electricity produced, as seen in Table 1, below. The projected rise in electricity demand calls for a significant development of new electricity producing projects.

Table 1: Electricity demand projections in Rwanda[7]

Energy demand projections 2008-2020	2008	2012	2015	2020
Peak power demand (MW)	55	165	700	1,300
Energy demand after losses (GWh)	225	460	1,500	2,100
Households with electricity	6%	16%	35%	60%
Energy consumed by households	38%	64%	75%	83%

The government has increased investment in the transport infrastructure of Rwanda since the 1994 genocide, with aid from the United States, European Union, Japan, and others. Nevertheless, much needs to be done both for rural roads and energy to support growth, as corroborated by the Ubudehe survey, in which the roads network was identified as a top infrastructure priority. The proportion of roads in good condition has only risen from 4.7% to 6.4%, implying that large sections of the population face immense transportation obstacles to bring produce to markets, and more generally integrate into the national economy. The transport system primarily revolves around the road network, with paved roads between Kigali and most other major cities and towns in the country. Rwanda is linked by road to other countries in East Africa, notably the port of Mombasa via Kampala and Nairobi, which provides Rwanda's most important trade route. The principal form of public transport in the country is shared taxi. Express routes link the major cities, while local service is offered to most villages along the main roads. The country has an international airport at Kigali that serves one domestic and several international destinations. Currently, the country has no railways, although funding has been secured for a feasibility study into extending the Tanzanian Central Line into Rwanda[8].

The GDP in percentage change, in total and per capita from 1990 to 2012, and total GHG emissions from 1990 to 2007 are presented in tables and figures below[9].

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[5] *From the PDD; "Rwanda Electrogaz Compact Fluorescent Lamp (CFL) distribution project", prepared by Alexandra Le Courtois, World Bank, 27 October 2008.*

[6] *"National Energy Policy and Strategy", Ministry of infrastructure – Republic of Rwanda, Kigali 2011.*

[7] *"National Energy Policy and Strategy", Ministry of infrastructure – Republic of Rwanda, Kigali 2011.*

[8] *2007, The Republic of Rwanda, "ECONOMIC DEVELOPMENT AND POVERTY REDUCTION STRATEGY, 2008-2012".*

[9] *Data created from "World Economic Outlook Database, September 2011", IMF: http://www.imf.org/external/pubs/ft/weo/2011/02/weodata/index.aspx*

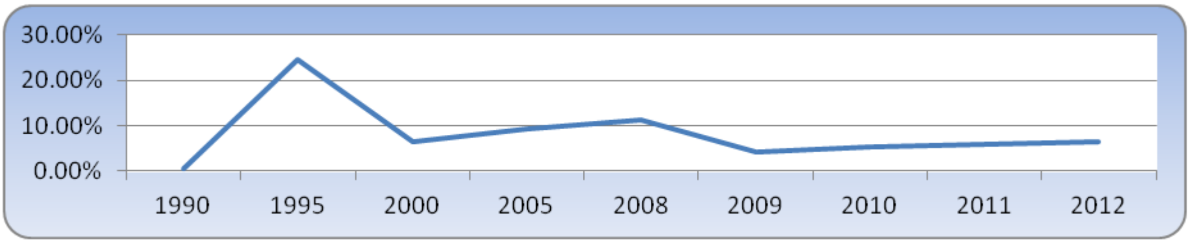

Figure 3. Economic growth since 1990 (GDP percent change)

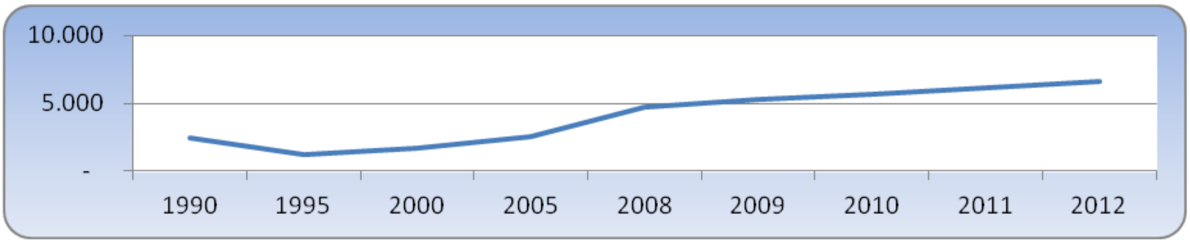

Figure 4. Economic growth since 1990 (GDP USD billions)

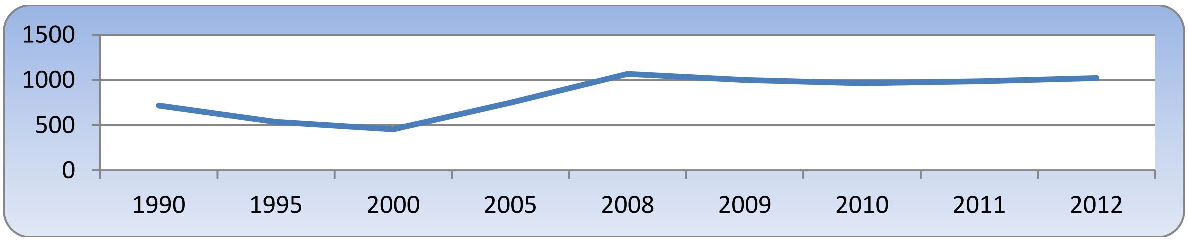

Figure 5. Economic growth since 1990 (GDP per capita USD)

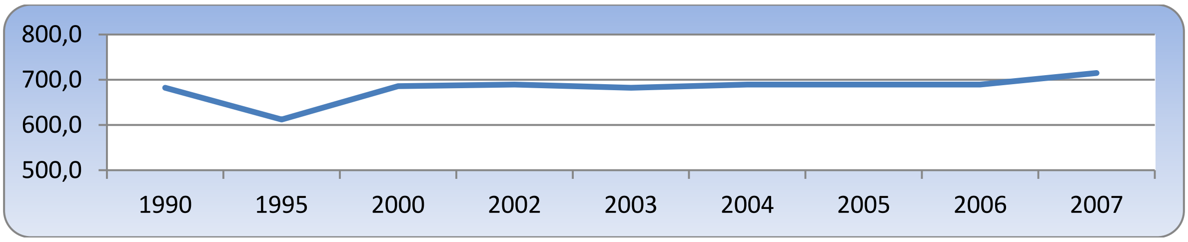

Figure 6. CO_2 emissions per year in $ktCO_2$/year

Status of CDM Development and Capacity Building in Rwanda

Despite Rwanda being a latecomer in the CDM, with the DNA only starting operation in 2009, activity is growing significantly in the country. Currently there are six CDM projects in the CDM pipeline – four stand-alone projects and two PoAs:

Name	Status	Type	tCO_2 reduction/year	Date of submission
Rwanda Electrogaz Compact Fluorescent Lamp (CFL) distribution project	Registered	Energy efficiency households	23.9	01-11-2008
Rwanda Natural Energy Project: Water Treatment Systems for Rural Rwanda (Shyira and Fawe)	Registered	Solar (Solar PV water disinfection)	2.7	12-11-2009
Rwanda Natural Energy Project: Water Treatment Systems for Rural Rwanda (Mugonero Esepan, Rwesero, Nyagasambu)	Registered	Solar (Solar PV water disinfection)	3.2	12-11-2009
Nuru Lighting Project – Rwanda	At validation	Energy efficiency households	64.6	23-Nov-10
Improved Cook Stoves programme for Rwanda (PoA)	At validation	Energy efficiency households	51.8	14-05-2011
Efficient Cook Stoves Programme: Rwanda (PoA)	At validation	Energy efficiency households	56.8	12-10-2011

The Nuru Design Lighting Programme, project 1, was registered in May 2010, while projects 2 and 3 were registered in May 2011. The Nuru project concerns efficient lighting in households, and is expected to generate about 24,000 CERs/year, while the two other registered projects are relatively small, generating about 3,000 CERs/year, each. A number of small hydro projects have been under development as a bundle, supported by the Swedish government. The current state of development of these projects is not clear, but at least one is on the list of on-going projects. A programmatic CDM project entered the CDM Pipeline on 30 May 2011 concerning improved cook stoves, with an estimated emissions reduction of 57,000 tCO_2e/year for the first CPA.

In neighbouring countries like Burundi, DRC, Tanzania, and Uganda there are 31 projects identified through the CDM Pipeline, 4 of which are registered in Uganda, 1 in Tanzania and 2 in DRC; 7 projects have not made it through validation. Projects are mainly small reforestation activities, hydro projects, or biomass and landfill utilization.

Rwanda is the target of bilateral assistance activities through the ACP-MEA project, the aim of which is to build capacity to develop CDM projects as well as specifically develop concrete project activities. Other donors include SIDA for the development of the hydropower projects.

Overview of CDM Opportunities in Rwanda

Agriculture and Forests

Rwanda is currently at net sink for GHG emissions due to the large amounts of CO_2 absorbed by forests, which are estimated to sequester approximately 9,000 Gg of CO_2/yr (2005). However, in order to achieve low-carbon development in Rwanda, deforestation will need to be addressed. Statistics from the forestry department show that forests were estimated to cover 659,000 ha in 1960. This reflects a loss of approximately 36% of forests since 1960, while the rapid rise in population is increasing pressure on forests in terms of encroachment and deforestation. However, the national government has engaged in large-scale tree planting initiatives through its 'Vision 2020', which aims to reach a tree cover of 30% of the national area by 2020[10], and forest areas are now increasing by 2.5% each year.[11]

Forest Carbon Options

According to the latest mapping inventory, the forested area of Rwanda was estimated to be 425,000 ha in 2009, which translates to approximately 17% of the surface area (dry lands – 2,476,000 ha).[12] Of this, the majority consists of planted forest (86%), with the remaining being naturally regenerated forest (13.4%) and 7,000 ha (1.6%) that is classified as primary forest.[13] Humid natural forests constitute the majority of the forest cover in Rwanda (33%), followed by Eucalyptus plantations and degraded natural forests at 26% and 15.7%, respectively. The terrestrial carbon stocks amount to a total of approximately 130 MT, where 67 MT are stored in biomass and the remaining 63 MT in soils.[14]

Forest carbon activities hold significant potential for Rwanda, and the on-going efforts to restore degraded forests present opportunities under the scope of REDD+, and in a NAMA context. Currently, forest carbon projects (A/R) aimed at the voluntary market are planned in the Gishwati forest, Eastern Province, Volcanoes National Park and Nyungwe National Park (Carbon market and forestry in Rwanda). An agreement has also been signed with the Congo Basin Forest Fund, amounting to 4.9 m Euro, with the objective of supporting sustainable Woodland Management and Natural Forest Restoration under REDD+, thereby making Rwanda eligible for carbon market benefits.

Afforestation and reforestation of degraded forest lands are possible under the Clean Development Mechanism. However, despite the potential to mitigate climate change through forest regeneration, A/R CDM activities have remained underdeveloped, compared to other CDM sectors. This is mainly related to the complexity of the A/R CDM procedure and the limited market demand for A/R CDM credits, since CERs from these projects are not eligible in the European Emission Trading System. Furthermore, in order to address issues related to non-permanence, 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[15], altogether reflecting Africa's potential for abatement in the LULUCF sector. While there are currently no A/R CDM

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[10] *http://www.minirena.gov.rw/spip.php?article162*

[11] *FAO 2010. Global Forest Resources Assessment. Main report. FAO Forestry Paper 163. Food and Agriculture Organization of the United Nations, Rome, Italy.*

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

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

[14] *http://www.carbon-biodiversity.net/Content/ShortProfiles/Rwanda%20Profile%20110408_final.pdf*

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

activities in Rwanda, the country holds significant potential for generating financial flows from forest carbon activities under the CDM, as well as under REDD+ and NAMA initiatives.
Calculating the potential emission reductions from Rwanda's initiatives to restore its forest cover, demonstrates that there is mitigation potential if the country increases forest areas from 17% to 30%. Rough calculations estimate that the replantation of 325,000 ha of forest land could potentially contribute to more than 100 million tons in CO_2 emission reductions every year. This is based on an estimation of Rwanda's forests storing 92 tC/ha per year[16], and a conversion factor of 1 ton of biomass carbon to the equivalent of 3.67 tCO_2[17].

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Afforestation/ Reforestation	109,733,000	AR-AM1, AR-AM3, AR-AM4, AR-AM5, AR-AM9, AR-AM10, AR-AMS1, AR-ACM1, AR-ACM2

Issues for consideration

While opportunities exist for forest carbon crediting, there are several issues that need to be in place in order for Rwanda to provide a good investment environment for investors. The potential is strongly linked to having the necessary institutional arrangements in place, the ability to demonstrate additionality, and clarity on land tenure and carbon rights.
A preliminary National Forest Inventory was conducted in 2007 for forests with areas greater than 0.5 ha, and it is recommended to include estimates of carbon biomass for the new forest inventory. It is highly advisable to complete the National Forest Inventory and make it available to the public in order to facilitate the development of carbon forest projects.[18]

Fuelwood

Fuelwood is the dominant source of energy for sub-Saharan Africa, and its consumption per capita is higher in Africa than any other continent. In most African countries, fuelwood remains the main part of primary energy consumption, with the majority being consumed by households. However, the demand for wood is a major driver of forest degradation, and subsequently the release of GHG emissions. Some sources estimate that cooking with traditional biomass fuels contributes to approximately 18% of current GHG emissions, if deforestation and forest degradation are included in the equation[19].

Firewood

Biomass consumption (wood-energy and agricultural residues) remains the main source of domestic energy for 90% of the country's population, and energy in small-scale commercial sectors. Besides reforestation/afforestation activities for increased fuelwood quantity and improved forest management through rehabilitation, reducing the demand for fuelwood is also an important strategy to reduce drivers of deforestation and an exhaustion of Rwanda's natural resources. Such strategies include improved fuel-efficient cook stoves, and alternative-fuels and techniques for cooking and baking. There has been a government initiative to ensure that improved fuel stoves are used in households, and in 2008, 50% of households already had installed improved stoves. By 2020, the government expects that fuelwood will be reduced to 40% of the total energy consumption. Other fuels that may well reduce future demand and use of biomass include peat and biogas, although according to

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

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

[18] *http://www.rema.gov.rw/dna/index.php?option=com_content&view=article&id=71&Itemid=63*

[19] *http://siteresources.worldbank.org/EXTAFRREGTOPENERGY/Resources/717305-1266613906108/BiomassEnergyPaper_WEB_Zoomed75.pdf*

the IPCC, peat cannot be regarded as carbon free. By 2030, biogas is expected to contribute to 50% of the rural household energy sources, thereby replacing the heavy demand for firewood, reducing the use to a remaining 50%.[20]

In 2005 the population comprised of 1,830,000 households, with an estimated energy consumption of 30 kWh per year per person. Wood energy consumption was 4,982,063 tons corresponding to an area of 63,560 ha wood trees, while total demand amounted to 7,822,063 tons, or an area of 99,792 ha. Considering the expected reduction in the consumption of fuelwood by households, it is estimated that 200,000 ha (of mainly Eucalyptus, Pinus and Grevillea) will be sufficient to meet the future demand in 2020.

Charcoal

Charcoal constitutes the primary urban fuel in most of Africa, and is a major source of income and 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 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 Rwanda for 2011 was estimated to be 48,000 t.[21] According to a recently registered CDM project, using renewable charcoal from forest plantations, shifting from traditional open kilns to efficient kilns employing methodology AM0041[22], the anticipated methane emissions reduction per ton of produced charcoal is 0.037 tons[23]. 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 Rwandan charcoal production from a 100% open kiln production in the baseline would potentially result in emissions reduction of 37,296 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.

Type of Technology	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Charcoal production	37,296	AMS-I.C., AMS-III.K., ACM00021, AM0041

[20] *http://static.weadapt.org/knowledge-base/files/757/4e257f0bc8f8eRwanda_national_energy_and_carbon_-_key_messages_2_circ-edits_SL_page_21.pdf*

[21] *http://faostat.fao.org/site/626/DesktopDefault.aspx?PageID=626#ancor*

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

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

Agriculture Sector

Rwanda's economy is based on agriculture, which contributes approximately 34% of the GNP and employs more than 80% of the country's work force. Together with the energy sector, agriculture is the largest GHG emitter, with sources mainly arising from N_2O from soil cultivation, and CH_4 from enteric fermentation. Expansion of crop- and pasturelands is also the main driver of land use change, with agriculture contributing to approximately ¾ of tropical deforestation. Part of the future demand for land will be driven by the expanded production of biofuels, itself driven by subsidies (CCAFS policy brief no. 4).

Due to the importance of the agriculture sector, it has received high priority in the government's planning for development. One of the pillars of the Vision 2020 is to shift from subsistence farming to a productive and market-based agriculture that is fully integrated with environmental protection and sustainable natural resource management. However, an ambition to intensify agricultural production could increase CO_2 emissions through more intensive use of the land for crops, e.g. through increased use of nitrogen-based fertilizers. Furthermore, due to the high population in Rwanda, land area for agriculture is insufficient. This is aggravated by the fact that most farmers practice mainly rain-based agriculture. Soil fertility has been deteriorated due to the demographic pressure on lands, while the use of organic and inorganic inputs remains low. It is essential that intensification considers better nutrient management, low-impact farming measures such as reduced tillage, and ways to improve soil carbon retention without compromising food and livelihood security. Measures also need to be taken to minimise CH_4 emissions from increasing livestock production.[24]

The emerging concept of Climate-Smart Agriculture is currently being highly promoted by the World Bank and FAO as a "win-win-win" solution that can increase crop yield and food security, strengthen climate change resilience, and increase GHG sequestration in soils and plants. Sustainable intensification where yield per unit of land is increased, such as in agroforestry, is one such pathway. Sustainable Agricultural Land Management (SALM) approaches that aim to increase organic matter in the soil should also be explored further for their mitigation potential, and for the possibility of generating external financial flows to Rwanda's agriculture sector.[25]

Briquettes

Briquettes can be made of all kinds of agricultural residues as well as waste from animal production. They can be manufactured using automatic briquetting machines or they can be made as a household "industry" with manual presses, compressing the biomass typically in cylindrical shapes with a press that squeezes out liquids from the waste. The briquettes may be used as fuel in domestic stoves or on larger scales for power production, typically replacing fossil fuels.

A briquetting project is already being implemented and is intended to be scaled-up (see section on solid waste, as the briquettes are produced from collected household waste).

Briquettes are usually produced from the sawdust of wood processing industries. Domestic species are cypress, musave, eucalyptus, pine, and a few other timber relevant species. Only 1%, or 86,000 m^3, of timber is cut to planks in the Rwandan timber industry. A conservative ratio of waste to timber is about 50%, thus resulting in approximately 43,000 m^3 of wood wastes. Additional amounts of cut-offs of imported MDF would be available. Using such wood waste as briquettes could replace other fuelwood, in which case no emissions reduction would occur. Replacement of kerosene would result in significant reductions. Approximately 12 million litres of kerosene is consumed in Rwanda every year, resulting in

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[24] http://unfccc.int/resource/docs/natc/rwanc2.pdf

[25] Wollenberg, E., Campbell, B.M., Holmgren, P., Seymour, F., Sibanda, L. and Braun, J. von. 2011. Actions needed to halt deforestation and promote climate-smart agriculture. CCAFS Policy Brief 4. Copenhagen, Denmark: CCAFS.

about 36 million kg, or 36,000 tons of CO_2/year. The energy content of the kerosene is 35.8 GJ per 1,000 litres, or 429,600 GJ for 12 million litres. Moreover, 40,000 tons of sawdust with an energy content of 15 GJ/ton corresponds to 600,000 GJ, which means that even the small Rwandese timber production may produce enough fuel to replace the entire kerosene consumption for the country, corresponding to 36,000 CERs annually.

Large-scale methodology AM36 may be relevant for such a fuel switch project, but more relevant would likely be AMS-I.C.

Type of Technology	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Biomass briquettes	36,000	AMS-I.C., AMS-III.B., AM36

Biodiesel

Biodiesel may be produced from vegetable oil, animal fat, or from the cleaning of waste cooking oil. Vegetable oil can be extracted from dedicated plantations, e.g. jatropha, or other oil seeds, such as linseed or palm. Some of these crops are equally usable for food production, while others may be grown on arid lands with little other use. Animal fat can come from slaughterhouses or facilities disposing of dead animals. Most diesel engines can accept solutions of diesel and biodiesel, and many may run on pure biodiesel. This pertains to both stationary and mobile engines, i.e. diesel power plants as well as cars, busses, trucks or boats.

In the context of CDM, biodiesel must be used in a captive fleet, i.e. a (large) number of identifiable vehicles like city busses or the trucks of specific companies, to allow the generation of Certified Emission Reductions. Alternatively, and probably more relevant in a Rwandan context, biodiesel may be used in existing diesel power plants, or possibly in plants using heavy fuel oil -- as is the case in Rwanda.

Since 2007, Rwanda seems to be embarking on jatropha biodiesel production projects to reduce energy dependency on wood and oil[26]. The Government of Rwanda, through Rwandan Institute of Scientific and Technological Research (RIST), is encouraging the development and cultivation of moringa, jatropha, or palm oil, requiring participating families to grow at least 100 trees in its plots and/or by the roadsides, so as to avoid jeopardizing the food security of the country. The first factory has begun producing biodiesel and bioethanol. There has been no CDM involvement in the activity. RIST has calculated that by growing biodiesel plants on 225,000 hectares, 8% of the total national land, Rwanda would not need to import diesel. In 2009, Rwanda signed a 250 million USD investment deal with US-based Eco Fuel Global and the UK's Eco Positive, to produce biofuel. Consequently, Rwanda should have the capacity to produce more than 20 million litres of biofuel annually from jatropha curcas. No attempts of registering these projects as CDM activities have been recorded, and the status of the actual implementation of the projects are unclear.

If expansion of these activities would be considered (or in case the first project did not move ahead), three methodologies are relevant, of which so far only one has been applied in a registered project: AMS-III.T. The recently consolidated ACM17 is currently being applied in 9 projects under development, while 1 project follows AMS-III.AK.

There are well-known risks affiliated with biofuel production, both biodiesel and ethanol, as food production may be crowded out if returns on fuel crops are higher. These risks may be addressed through regulation, which already appears to be the case in Rwanda.

The main challenge lies within current applicable methodologies which require biofuels to be utilized for replacement of fossil fuels in "captive fleets" to qualify for CDM registration. This is a significant challenge in Rwanda, where 19 bus companies operate a total of only

[26] *http://biocommodity.com/rwanda-shifting-to-jatropha-biodiesel-production/*

1,633 buses of various makes, models and sizes in various parts of the country. If only Kigali City is considered, there are 622 buses operating of which 90% are small Toyota Hiace vehicles, mostly over 10 years old, and many much older. These will not be able to absorb sufficient amounts of biodiesel to make a viable project. Alternatively, the diesel-fired power plants with a total capacity of 15 MW would produce about 100,000 MWh/year, consuming approximately 35 million litres of diesel, which is sufficient for off-taking the anticipated 20 million litres of biodiesel from the planned project. With a grid emission factor of 0.65, such a replacement would result in about 65,000 CERs/year.

Type of Technology	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Biodiesel	65,000	AMS-III.T, AMS-III.AK, ACM17

Ethanol

Ethanol production from crops containing sugar is mainstream technology that has been employed in countries such as Brazil for decades. Ethanol, or ethyl alcohol, production employs simple technology fermenting the sugar content of crops into a viable fuel, typically for mixing with petrol or less commonly with diesel. Potentially, petrol may be replaced 100%, while diesel may absorb up to 20% ethanol - though normally much less. The most common challenge facing ethanol production is a popular sentiment that it competes with food production from the same crops. Second generation biofuel is cutting edge technology which employs dedicated enzymes to extract the sugar content from agricultural waste, like maize stalks. Here, any competition with food production is eliminated.

There is a significant production of potatoes and cassava in Rwanda, which would be excellent crops for ethanol production. It is unclear, however, whether there is potential for increasing the production of these crops. If there were no potential, utilizing these crops for fuel production would be in direct competition with food production, and thus not a desirable avenue for emissions reduction.

Waste

Waste is generally divided between agricultural waste, liquid waste and solid waste, each of which is discussed in the following sections.
Waste handling systems contribute to sustainable development in many ways. Sustainability of the local environment is greatly improved if the waste is utilized rather than left to cause environmental and health problems. Furthermore, if the waste is replacing fossil fuels or fuelwood from non-renewable forests, it has a significant impact on the local environment, women and children workload, and household economy. CDM projects in this sector create local capacity for these technologies, and could benefit local entrepreneurs and SMEs.
There is no local tradition for waste handling on a bigger scale in Rwanda. Hence, this requires an organised gathering of wastes, which is not normally practised in the country.

Agricultural Waste

Agricultural waste includes some major sources that are predominant in CDM project development – forest residues, rice husk, palm oil, and sugar – in addition to a range of other relevant biomass residues.

The staple crop in Rwanda is bananas, or plantains, while other important crops include sweet potatoes, peas and beans, cassava melons, and sorghum. Crops such as wheat, rice, and peanuts are raised only in small amounts. A list of the 20 most important crops in Rwanda is shown below. Plantains produce very little waste on site; instead waste is generated from its use in households. In fact, the first 6 crops on the list generate very little waste compared to the crop weight, and are, in all probability, not relevant bases for biomass waste utilization. With a crop-waste ratio of 1:1, maize production would generate about 167,000 tons of waste annually, of which a significant share is assumed absorbed for feeding of animals. Even if all maize waste would be available – and as importantly, also collectable – it would suffice as feedstock for an approximately 12 MW power plant, potentially generating about 46,000 CERs annually at Rwanda's grid emission factor of 0.65 tCO_2/MWh. Therefore, 12 MW * 0.65 tCO_2/MWh * 6,000 hours = 46,800 tCO_2/year.

Sorghum, producing waste at the same ratio, could potentially add another 144,000 tons of waste, and these two crops combined could conceivably produce enough available biomass for the establishment of a single power plant. It would, however, require a collection system that covers the entire country, which is unrealistic.

Nevertheless, there may be options in multi-country Programmes of Activity for household-based systems, e.g. in briquetting for cook stoves. Such options are already being pursued by the Uganda Carbon Bureau, and would need further investigation. The bottom line is that the emissions reduction potential will not exceed what could have been achieved through the establishment of a biomass fired power plant. Briquetting, however, could absorb other sources of waste, as described under 'solid waste'.

Rank	Commodity	Production (MT)
1	Plantains	2,604,000
2	Potatoes	1,162,000
3	Cassava	978,541
4	Sweet potatoes	826,000
5	Beans, dry	308,000
6	Pumpkins, squash and gourds	215,000
7	Maize	167,000
8	Sorghum	144,000
9	Cow milk, whole, fresh	118,790
10	Taro (cocoyam)	110,607
11	Rice, paddy	82,000
12	Avocados	79,291
13	Cabbages and other brassicas	70,828
14	Fruit, fresh	65,000
15	Sugarcane	63,000
16	Vegetables, fresh	59,000
17	Tomatoes	41,035
18	Indigenous Cattle Meat	37,137
19	Eggplants (aubergines)	30,059
20	Goat milk, whole, fresh	26,800

The Government of Rwanda planned calls for the establishment of 240 washing stations in the country in 2010, producing some 44,000 tons of fully washed coffee, or about 20,000 tons of refined coffee, which was the production in 2010 (down 17% due to bad weather conditions). Assuming that there is about 20,000 tons of waste from coffee production, in different forms, and that 30% is recycled into the soil in the coffee plantations, the rest is more or less accessible as fuel, with a conversion factor of about 0.4 toe/t. This translates into 5,600 toe potentially replaced, or about 20,000 tCO_2e. Avoided methane emissions are disregarded in this respect, which may represent significantly higher GHG emissions, in many instances 5-6 times greater than CO_2. At 20,000 tCO_2e per year, this option could potentially attract interest, also at lower levels with less than full participation of the Rwandan coffee industry. However, much more thorough investigation of the potential in the sector needs to be performed. With larger coffee producing countries having generated no CDM projects, there may be reasons that are not considered here. Currently only two CDM projects are under development in the coffee industry, one in Brazil and one in Israel, both related to steam generation for manufacture of

soluble coffee (instant coffee). As far as is known, there is no instant coffee production in Rwanda.
The entire country's maize production would generate about 167,000 tons of maize stalks. This could theoretically fuel a 15 MW biomass-based power plant, if it could be collected. It is, however, unrealistic to establish a stable and reliable collection system that covers the entire country, as it would not be viable. Smaller gasification plants might be feasible, particularly if agricultural residues, like stalks, are mixed with liquid wastes (manure), but such options need more thorough investigation, and might not compete with pure household manure gasification systems.

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Maize waste	46,800	AMS-I.C., AMS-I.D., AMS-II.D., AMS-III.E., AMS-III.Z., AMS-III.F., ACM2, ACM6, ACM18, AM36
Maize waste	46,800	AMS-I.C., AMS-I.D., AMS-II.D., AMS-III.E., AMS-III.Z., AMS-III.F., ACM2, ACM6, ACM18, AM36

Liquid Waste

Liquid waste consists of wastewater from sewage plants, waste oil from industry, and manure from husbandry.
Kigali planned to establish a sewage system by 2012, but is still looking for investors. Before plans are finalized, it is worth noting that there appear to be no emissions reduction options here. The larger enterprises in Rwanda produce beer, soft drinks, cigarettes, hoes, wheelbarrows, soap, cement, mattresses, plastic pipe, roofing materials, textiles, and bottled water -- none of which generate waste oil in notable quantities.
The major animals raised in Rwanda are cows (991,697), goats (1,270,973), sheep (371,766), pigs (211,918), chicken (2,482,124), and rabbits (498,401). The three provinces having the largest number of cattle are Umutara, Gitarama, and Kigali.
The table below shows the average stock per household, indicating that there is no intensive livestock farming in Rwanda. Thus, projects based on manure utilization would have to be based on programmatic approaches that accumulate large numbers of household gasification installations. Under the assumption that all cow manure is currently stored anaerobically, the potential emissions reduction from a complete utilization of all manure from Rwandan cows equals 0.06 tCO_2e x 1 million cows, or 60,000 tCO_2e per year[27]. Under the same assumption, pigs would contribute another approximately 10,000 tCO_2e at full utilization. CDM relevance would demand significant penetration rates for such household systems, but this could likely be relevant for programmatic approaches, in cooperation with neighbouring countries.
It should be mentioned, though, that the numbers in the table below might underestimate the current stock of animals. The "GIRA INKA Program" initiated by HE Paul Kagame resulted in the distribution of a significant number of milk cows. It is unlikely, however, that the programme has significantly raised the average number of cows per household in the country. Hence, while the theoretical estimate above would be higher, the actual utilization would likely remain below the 60,000 tCO_2e per year.

Sectors	Poultry	Cattle	Goats	Pigs
Mean	67.8	5.7	2.9	1.8

Table 2. Number of animals per farmer in the urban and peri-urban areas of Kigali in 2002[28]

[27] *http://www.habmigern2003.info/biogas/methane-digester.html. Figures here are converted to African conditions through the IPCC 1996 guidelines demonstrating that African cows on average emit about 20% of the amount of methane emitted by American cows.*

[28] *http://www.acss.ws/Upload/XML/Research/635.pdf*

A number of small-scale methodologies would be relevant in this regard, particularly AMS-III.R., but the main challenge to such projects remains the current treatment/storage of the manure. If current conditions are aerobic treatment, the foundation for these kinds of projects erodes.

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Manure	70,000	AMS-I.A,C,D. AMS-III.H. AMS-III.D., AMS-III.F., AMS-III.I., AMS-III.R., ACM14, AM25, AM80

Solid Waste

Kigali landfill has been in operation for over 20 years and is still used for dumping household waste. With 1 million inhabitants, the city should produce sufficient biodegradable material to establish a landfill gas project, with or without power production. To get a sense of emissions reduction potential, a landfill gas project is currently under development in Abidjan, Cote d'Ivoire, with about 5 million inhabitants. In this case, The Akouedo landfill is the main (but not exclusive) recipient of household waste. This is an equally old landfill, still in use, which means that the methane development and destruction is quite stable, though gradually increasing from about 450,000 to 600,000 tCO_2e/year without any power generation.

A Kigali parallel at a fifth of this size would have the potential to generate about 100,000 increasing to 125,000 CERs/year, although landfills are notoriously difficult to assess, and it would require specific analysis to determine the actual potential in Kigali. Other cities in Rwanda are not immediately interesting for landfill gas development due to their limited size, and potentially less structured waste collection.

Kigali is hosting a recycling project run by ACEN (Association for the Conservation of the Environment), a local cooperative with funding from UNDP, and the Global Environment Facility (GEF). ACEN members are now charging 12,000 families in Kigali between 1 USD and 37 USD to collect their trash, which they bring to a central facility for the waste to be sorted, dried and pressed into fuel briquettes. These fuel-blocks are replacing wood or coal, thereby reducing pollution and deforestation. Approximately 3,000 tons of trash is collected per year, replacing 17,000 cubic meters of fuelwood. ACEN plans to increase production to meet growing demand for the briquettes, which can bring the cost of fuel material down from approximately $25/month to less than $8/month for per household.[29]

Early on, the Conference of Parties decided that avoided deforestation projects are ineligible as CDM project activities, as was otherwise allowed through the AMS-I.C. methodology. To accommodate projects like that of the ACEN, therefore, it was later decided that it could be assumed that such projects replace a future theoretical usage of kerosene or other fossil fuel-based stoves with a significantly higher efficiency than wood. Consequently, the accepted emissions reduction effect (from replacing fossil fuels) is considerably less than would otherwise be the case if fuelwood were used as the baseline. In emission terms, based on AMS-I.C., the replacement of 17,000 cubic meters of fuelwood corresponds to about 18,000 tCO_2e.

[29] *www.triplepundit.com*

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Landfill gas	100,000	AMS-I.C., AMS-I.D., AMS-I.F., AMS-III.D., AMS-III.E., AMS-III.F., AMS-III.G., ACM1, ACM2, AM25, AM53
Waste to briquettes	18,000	AMS-I.C., AMS-I.E., AMS-III.B., AM36

Conventional Power Production

Rwanda has considerable opportunities for energy development – from hydro sources, methane gas, solar, and peat deposits. Untapped resources for power generation amount to about 1,200 MW. Most of these energy sources have not been fully exploited. As a result, wood is still the major source of energy for 94% of the population, and imported petroleum products consume more than 40% of foreign exchange.

The current inadequate and expensive energy supply constitutes a limiting factor to sustainable development. Rwanda's Vision 2020 emphasizes the need for economic growth, private investment, and economic transformation, supported by a reliable and affordable energy supply as a key factor for the development process.

Rwanda's Vision 2020 energy target is to have at least 35% of the population connected to electricity (up from the current 6%) and to reduce the rate of wood use in national energy consumption from the current 94% to 50%.

	MW installed	Commissioned	Fuel
JABANA	7,8	2004	HFO
Jabana II	20.0	2009	HFO
GATSATA	4,77	2004	HFO
Aggreko I Gikondo	10.0	2005	Diesel
Aggreko II Mukungwa	5.0	2006	Diesel

From the table above, it is evident that there are two main points of production, each with two units. The Aggreko plant employs diesel engines and produces limited excess heat for utilization. It would be easier to use the Jabana for waste heat recovery, to about 10 MW of capacity. If sufficient off-take capacity is present, a CDM activity with a CER generation capacity of perhaps 30,000 CERs/y (this estimate is affiliated with significant uncertainties), and the necessary investments could be considerable. Thus, further investigation is needed to determine if this represents a cost efficient emissions reduction response. Another potentially easier implementable solution would be to use hot water to replace electrically-heated consumption water in hotels. Such options might, however, compete with solar water heating options, which are modular and thus more scalable than a waste heat utilization project. These emissions reduction options are not cost efficient, *per se,* therefore, investment barriers can be used to prove additionality.

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Waste heat recovery	30,000	ACM12, AMS-II.B.

Renewable Energy

Renewable energy sources consist of hydro, wind, solar and geothermal sources, while biomass options have already been discussed earlier. Tidal power is obviously not relevant for Rwanda.

Methane

Rwanda disposes of an enormous but unexploited energy source in the reserves of methane gas in Lake Kivu. Lake Kivu, in the west of Rwanda, is unique in the world as its deep waters contain an enormous quantity of dissolved gas. There are 50 billion cubic meters of exploitable methane, the equivalent of 40 million tons of oil (tep), lying at a depth of 250 m. If exploited, this would give Rwanda an almost inexhaustible energy source. The lake is continually recharging with gas, and the rate of recharging is estimated at between 125 and 250 million cubic meters per year.

While in emissions reduction terms there would be no possibility of crediting methane destruction, partly because there are currently few emissions, but mainly because these emissions are not anthropogenic, there is in fact a potential environmental liability in extracting these gas resources as a fossil fuel potentially replacing hydropower resources. Only in the case where methane is used for fuel switch in the existing heavy fuel oil-based power units would there be a potential emissions reduction effect. The emissions reduction could be approximately 25% of the current CO_2 emissions from these plants (about 65,000 tCO_2e/y), or about 15,000 CERs annually. Given the anticipated significant costs of exploitation, this is not likely a contribution that makes it worthwhile pursuing, from an emissions reduction perspective.

Hydro

For most hydro projects, water is supplied to turbines from some type of storage reservoir, usually created by a new or existing dam. The reservoir allows water to be stored and electricity to be generated at more desirable times – for example, during periods of peak electrical demand. Therefore, hydropower with reservoirs is a very good 'balancing capacity' in an electrical supply system. Such balancing capacity, however, is less important in systems with significant deficits in power production, such as in Rwanda. Under such circumstances, "*run-of-river*" projects are equally interesting. These, in addition, are the most environmentally sound hydro systems that do not impact the amount or pattern of the existing water flow. Such run-of-river systems may use a special turbine placed directly in the river to capture the energy of the water flow, but as it follows the natural variability of the river it may generate less power during times of low water flow.

Hydro systems generally have a long project life. Turbines last 20–30 years, while concrete civil works may last up to 100 years. This is often not reflected in economic analyses of hydropower projects, where costs are usually calculated over a shorter period of time. This is important for hydro projects, as their initial capital costs tend to be comparatively high. Hydro systems do not create any pollution, but there are environmental considerations linked to changing water flows, reservoirs, and displacement of people.

Hydropower is the most obvious and, yet, unexploited energy resource in Rwanda. It is estimated that up to 1,000 MW of power may be extracted from the rivers in Rwanda, if a full exploitation were initiated. Currently, a number of smaller projects are underway, being developed as CDM projects initially by the Swedish Government. The combined installed power of these hydro projects is about 50 MW, thus leaving significant scope for further development.

The grid emission factor for the Rwandan grid is 0.65 when replacing electricity with renewable energy such as hydropower. Assuming 5,000 full-load hours of production (which may be optimistic), every installed MW of power would potentially generate 3,500 CERs/year, with a likely range of 2,800-4,200 CERs/year (4-6,000 full-load hours). Fluctuations are particularly outspoken for run-of-river projects due to the lack of storage options.

With the size of the current national power generation capacity, even relatively small increases in hydropower capacity will eventually significantly dilute the grid emission factor, as the share of hydropower on the grid increases. This would be the case unless projects can be established as isolated grids with a plausible reason to believe that it would replace diesel or other fossil fuel-based power production. Such arguing is not possible as a rule, and therefore, from a carbon finance perspective, there would be a limit, likely about 100 MW, where the financial contribution from emissions reduction becomes marginal. Depending on the rate and fluctuation of uptake, an estimate of the total emissions reduction potential would be corresponding to about 200,000 CERs per year. This could possibly grow, depending on transnational grid connections, which recent (2011) methodological adjustments now allow to be included in calculations of emission reductions. However, Rwanda is not part of the Southern African Power Pool, and as such would not immediately be able to benefit from any indirect connections to the emission intensive Southern African grid. Other grids in East Africa are, more or less, hydro dependent.

Wind

As the wind regime in Rwanda is practically located at the equator, it is not relevant for any noteworthy exploitation, and should be disregarded in a CDM context.

Solar

There are many solar options in the country. The sun's energy can be collected directly to create both high temperature steam (greater than 100°C) and low temperature heat (less than 100°C), for use in a variety of heat and power applications.

High temperature solar thermal systems use mirrors and other reflective surfaces to concentrate solar radiation. Parabolic dish systems concentrate solar radiation to a single point to produce temperatures in excess of 1,000°C. Line-focus parabolic concentrators focus solar radiation along a single axis to generate temperatures of about 350°C. Central receiver systems use mirrors to focus solar radiation on a central boiler. The resulting high temperatures can be used to create steam to either drive electric turbine generators, or power chemical processes such as the production of hydrogen. Solar thermal is generally considered a high-tech expensive solution, ideally for larger installations. It is not an immediate first choice for Rwanda, where a number of lower cost solutions are easily implementable.

Among these is, first and foremost, solar water heating. Low temperature solar thermal systems collect solar radiation to heat air and water for space heating in homes, offices and greenhouses, domestic and industrial hot water, pool heating, desalination, solar cooking, and crop drying.

There are significant opportunities in Rwanda for greater use of solar water heaters. Public buildings and hotels could be the immediate large-scale rollout targets, where electric water heaters are currently the preferred source of heating. Determination of actual energy savings is contingent upon the emission factor for displaced electrical heating. In a CDM project in India (CDM project no. 3757), it is estimated that one 2 m^2 solar panel results in emissions reduction of 0.7 tCO_2e. A complete shift in Rwanda to solar water heating for the 5% of the country that is currently grid connected[30] - converted into number of households

[30] *www.rura.gov.rw/docs/RURA/%5BRwanda_power_situation%5D.pdf*

– results in a potential of about 100,000 installations (based on an average of 5 persons per household). This calculation assumes that households that are not grid connected do not heat their water with electricity. This is the rural average, while the urban (and grid connected) average may be smaller, resulting in a marginally higher potential number of installations. This translates into about 70,000 tCO_2e annually. Thus, any viable project, likely a Programme of Activities, should include a minimum of 10% of the grid connected population (to generate 70,000 CERs).

Solar PV

PV is often used for solar powered remote fixed devices that have seen increasing use recently, in locations where significant connection cost makes grid power prohibitively expensive. Such applications include parking meters, emergency telephones, temporary traffic signs, and remote guard posts and signals. In rural areas of developing countries many villages have also begun using PV, e.g. to power water disinfection or LED lighting, which in many cases displaces kerosene lamps. Conversely, solar PV power stations, with typical capacities of 10-60 MW, are not immediately attractive options in most developing countries due to relatively high costs of the technology. It is better suited to off-grid installations, where costs of alternatives are high.

Most micro installations of solar PV are capable of running a lamp or two, a radio and/or a television set; 100-200 W panels with a battery attached are normal. It can be argued that such systems replace diesel generators or kerosene lamps, and thus have a relatively high emissions reduction factor per kWh produced. However, the limited capacity means that a very significant number of panels have to be distributed, in order to achieve a sizeable amount of emissions reduction. Determining from the CDM Pipeline, very few projects have less than 1 MW installed effect. If this is an indicator, at least 5,000 200 W or 10,000 100 W panels must be distributed, to generate an estimated 2,000 tCO_2e per year (assuming 2,000 full load hours of operation -- which is an optimistic assessment). Such activities may be well suited for programmatic approaches bearing in mind that one household may only contribute 0.2-0.4 tCO_2e of emissions reduction per year. Hence, the total CER potential for implementing solar PV in all 2 million households is 400,000 tCO_2/year, with a conservative emissions reduction assumption.

Rwanda's Economic Development and Poverty Reduction Strategy (EDPRS) covers the period 2008-2012, and already includes reliable electricity supply (through on and off-grid systems, such as solar PV) to 100% of health facilities and administrative offices, at least up to sector level, and 50% of all schools. The health facilities are typically equipped with a 4 kW installation, which amounts to 1.5 MW for about 360 health clinics throughout the country. As there are more schools with less power consumption, at a 50% penetration rate, this could potentially amount to approximately the same accumulated capacity, bringing the effect of the initiative, if fully implemented, up to about 3-4 MW installed effect. At 2,000 full load hours, such installations, combined, would generate about 5,000 tCO_2e reductions per year. Investments could easily reach 30 million Euro, or more.

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Methane	15,000	AMS-I.A., AMS-I.C., AMS-I.D, ACM2, AM53, AM69
Hydro	200,000	AMS-I.A. AMS-I.D, AMS-I.F, ACM2
Solar heating	70,000	AMS-I.C., ACM2
Solar PV	400,000	AMS-I.A., AMS-I.D, AMS-I.F, ACM2

Energy Consumption

Emissions reduction related to energy consumption naturally refers to energy efficiency through reduction of consumption. Such reduction options exist through the employment of different technologies like efficient appliances, or through the grid connection of isolated villages, assuming the grid emission intensity is lower than a local grid or individual sources of power production, like diesel generators. However, it also concerns the reduction of fuel consumption, through the employment of efficient cook stoves.

The EDPRS objectives[31] include a massive extension and densification of the national electricity grid, in order to connect at least 16% of the population (or 350,000 connections) to electricity by 2012. To achieve emission reductions from such an initiative it is of course a requirement that the alternative source of supply have higher emission intensity than the grid, which currently has an emission factor of 0.7 tCO_2e per kWh. A 5 kW diesel generator has a low efficiency, typically about 25%, which converts into an emission factor of approximately 1.0 (the smaller the generator the less efficient it is). Emission reductions of 0.3 tCO_2e per replaced MWh of consumption in 350,000 households, assuming a high estimate of 1,000 kWh of consumption per household per year, would correspond to approximately 100,000 tCO_2e reduced by the electrification programme. A fair share of the electrification, however, will probably serve a suppressed demand, though this does not necessarily affect the calculation of the emissions reduction (which does not result in real reductions).

Efficient Cook Stoves

Efficient cook stoves have broad application potential all over Africa, and many programmes have been set in motion, mainly as a result of the launching of the Programmatic CDM approach. Rwanda has been one of the early movers on efficient cook stoves, and estimations are that only few options remain for further penetration of this technology. Two Programmes of Activity (PoAs) have already been developed (by Atmosfair) and were uploaded for public feedback in May 2011, in addition to other earlier private initiatives that have also promoted efficient cook stoves in Rwanda. CO2Balance has also started a PoA that should cover the entire country. Furthermore, a regional cook stoves programme originating in Uganda (Uganda Carbon Bureau) also includes Rwanda. The estimated emissions reduction from the Atmosfair projects is 56,000 tCO_2e for the first CPA covering 8,000 households. This is a high estimate compared to other cook stoves, which – if rolled out to the entire country's 2 million households – would have the potential to reduce about 14 million tCO_2e. But even at a lower estimate of 2-3 tCO_2e of emissions reduction per year per cook stove, the potential of about 5 million tCO_2e is considerable. The only question that remains is to what extent this potential is already being harvested by existing PoAs.

So far the only registered CDM project in Rwanda is an energy efficiency project based on the distribution of efficient light bulbs, CFLs. The project was registered in May 2010 and aims at distributing about 400,000 CFLs for the reduction of 21,000 tCO_2e per year, or 50 kg of CO_2e per lamp per year. With the current level of electrification there may not be much scope for expanding the project, which includes about 4 lamps per grid connected Rwandan household.

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
Electrification	100,000	No specific methods
Efficient cook stoves	5,000,000	AMS-I.C., AMS-I.E., AMS-II.G.

[31] *http://mininfra.gov.rw/index.php?option=com_content&task=view&id=110&Itemid=138*

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.

The industrial sector in Rwanda is small. Apart from the cement industry, the emissions reduction potential in industry is difficult to assess. In mining, there would, in theory, be methane destruction potential -- at least in gold mining. The potential, however, would need to be specifically assessed. Energy efficiency in mining might also be a potential, although expectations on the potential are low.

Currently the CIMERWA cement plant produces about 70,000 tons per annum (tpa) of clinker, equivalent to 100,000 tpa of cement using the wet process of cement manufacture. The plant uses heavy fuel oil from Kenya, leading to high production costs of cement. CIMERWA is modifying its existing plant to replace the use of oil by peat, which is available in abundance in the near vicinity of the plant. After modification, the fuel will comprise 70% peat and 30% oil. The emission intensity of peat is even higher than heavy fuel oil. These emissions could be reduced by implementing energy efficiency technology.

One option is waste heat recovery from the clinker production, but the capacity of the plant is relatively small and appears not to lend itself to more than a maximum of 1 MW. Such dimensions of WHR systems are rarely viable. Another avenue could be the use of pozzelana with a finer particle structure. Rice husk is one of the options, and the current 82,000 tons/year production of rice paddies should produce about 50,000 tons of rice husk – easily sufficing to replace the traditional pozzelana – and with a potential of reducing energy consumption to about half the current level. The average energy use per tons of clinker is about 6 GJ/ton in wet kilns and 4.5 GJ/ton in dry kilns. Therefore, the potential savings could be 150-200,000 GJ, which if produced by peat at 30% efficiency would correspond to 45,000-60,000 tCO_2e/year of emissions reduction.

Alternatives to the peat/oil fuel mix could also be considered, particularly biomass residues. Following the above estimates of energy consumption for the relatively small cement production the remaining 70% of the energy consumption could result in reductions of up to 120,000 tCO_2e in a complete conversion to biomass residues.

Technology type	Emission Reduction Potential per year (tCO_2e)	Baseline Methodologies
EE Cement	52,500	AMS-II.D., AMS-III.B., AMS-III.Q., AMS-III.AS. ACM12, AM24
Fuel switch	120,000	ACM6, AM36

Transportation

It has already been assessed that the potential in transportation, in terms of introducing alternative fuels, is small and practically unattainable. Other options in transportation would be BRT systems, but the potential in Kigali with about 1 million inhabitants is limited, though congestion problems are growing. There are currently no railways in Rwanda, and being a landlocked country there are no harbours or terminals that could present emissions reduction. Hence, transportation is generally not considered a source for potential emissions reduction.

Summary

Rwanda has an overall abatement potential of 116,155,296 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)
Afforestation/ Reforestation	109,733,000
Charcoal production	37,296
Biomass briquettes	36,000
Biodiesel	65,000
Maize waste	46,800
Coffee waste	20,000
Manure	70,000
Landfill gas	100,000
Waste to briquettes	18,000
Waste heat recovery	30,000
Methane	15,000
Hydro	200,000
Solar heating	70,000
Solar PV	400,000
Electrification	100,000
Efficient cook stoves	5,000,000
EE Cement	45,000 – 60,000
Fuel switch	120,000

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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