LOW-CARBON AFRICA: RWANDA

POVERTY

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1. COUNTRY CONTEXT

1.1 Introduction to Rwanda

Rwanda is one of the smallest countries in Africa by land size. It has an area of 26,338 km^2. The country is located in equatorial East Africa and landlocked with four neighbouring countries: the Democratic Republic of Congo (DRC), Burundi, Uganda and Tanzania. Rwanda is often referred to as the 'land of a thousand hills' due to its mountainous terrain. The climate is temperate due to its altitude, which ranges from 950 to 4,500 metres above sea level. The country has a bimodal rainy season with a mean annual rainfall of 1,028 mm. The country's rivers drain into two major drainage basins – the Nile basin in the east and the Congo basin in the west.

Rwanda has a population of around 10 million people and is the most densely populated country in Africa. There is an average of 370 people per square kilometre. With a population growth rate of 2.87 per cent, Rwanda is one of the fastest growing countries in the world. The population is expected to have grown to around 16 million by 2020 [1]. This high growth rate is due to a combination of factors including a high birth rate (5.41), incoming refugees and the returning diaspora. The Rwandan population is young with over 41 per cent under the age of 14. Life expectancy is low at 50.1 years compared to a global average of 68.9 years. The population is largely rural with only 20 per cent living in urban areas. Nearly half (44 per cent) of the urban population live in the capital city, Kigali.

In order to understand fully the present situation in Rwanda it is necessary to have a historical perspective. One of the most influential events in Rwanda's recent history is the 1994 Rwanda Genocide, during which an estimated 800,000 Tutsi, politically moderate Hutus and Twa were killed. This event, which lasted for about 100 days, was the result of a long period of ethic rivalry and conflict including a civil war which lasted from 1990 to 1993. The civil war was temporarily ended by a peace agreement between the government of Rwanda and the Rwandan Patriotic Front (RPF), under mediation of the US, France and the African Union. However, with the outbreak of the genocide in 1994, the Rwandan Patriotic Front restarted their offensive and eventually took control of the country, ending the genocide.

Since 1994 much progress has been made in Rwanda. Following the damage done by civil war and the genocide, there was necessarily a period of reconstruction and reconciliation. After this, the government has proceeded to outline its long and mid-term development goals, the crux of which is to make Rwanda a middle income country by 2020. Rwanda is now generally viewed as being tough on corruption with good governance. Economic growth in the past few years has been strong.

Rwanda is a presidential unitary republic, based upon a multi-party system. The President of Rwanda is the head of state and has broad unilateral powers. The President is elected by popular vote every seven years. The incumbent President is Paul Kagame who took office under transitional government arrangements in 2000 and won elections in 2003 and 2010. The President also appoints the Prime Minister and members of Cabinet. The Rwandan Parliament is made up of two chambers. The lower chamber is the Chamber of Deputies, which has 80 members serving five-year terms. A series of these seats are reserved for women (24), youth and disabled members (three). The remaining 53 seats are elected under a proportional representation system. Following the 2008 elections the Rwandan Parliament gained a female majority – making it the country with the highest percentage (60 per cent) of women in Parliament in the world.

The upper chamber is a 26-seat Senate. The members of the Senate are selected by a variety of bodies and serve for eight-year terms. Again it is mandatory that at least 30 per cent of the Senate be women.

Rwanda has strong leadership and good governance with low corruption levels. In 2010, Transparency International ranked Rwanda as the 66th 'cleanest' out of 178 countries. Public officials, including the President, are required by the constitution to declare their wealth to an Ombudsman and the public.

Rwanda is an LDC – Least Developing Country – with 56 per cent of its population living below the poverty line. It ranks 152nd out of 167 nations with a Human Development Index of 0.385. At present Rwanda's economy is dominated by agriculture which makes up 34 per cent of GDP and employs around 80 per cent of the workforce. Services contribute 46 per cent to GDP. Industry makes up around 14 per cent of GDP with around half of this coming from the construction sector. Almost all of the businesses in Rwanda can be classified as small and medium enterprises. Tourism is a growing industry in Rwanda and has recently become the largest foreign exchange earner. Export revenues are dominated by minerals, tea and coffee.

Rwanda's per capita income is presently US$560. This is up from US$200in 2000. Rwanda has experienced an average GDP growth rate of 8.5 per cent in the past five years. Following a period of reconstruction, the government of Rwanda, through a national consultative process developed Rwanda's Vision 2020. Vision 2020 is a policy document that sets out where Rwanda aims to be in the year 2020. The document states that Rwanda aims to transform the country from a subsistence agriculture economy to a knowledge-based middle income economy with a per capita annual income of US$900. It is also stated that the ambition is to transform Rwanda into a regional services hub [1]. The Economic Development and Poverty Reduction Strategy (EDPRS) policy document was formed to guide this transition in the medium term, for the period 2008-2012.
In order to meet the Vision 2020 targets the government of Rwanda (hereafter GoR) aims to develop a strong private sector which will drive growth and economic diversification. The GoR has taken a number of steps to facilitate this including reforms in justice and business regulations. This has led Rwanda to be named as a top global reformer in the ease of doing business.

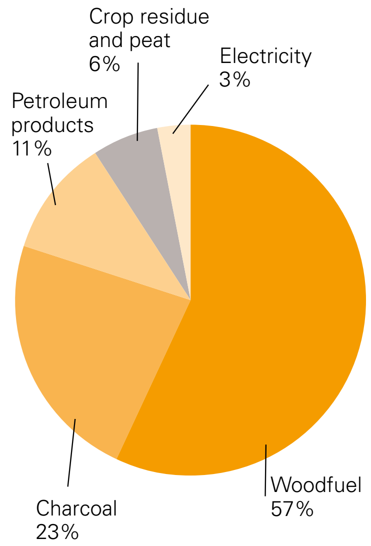
While serious progress has been made towards realising Vision 2020, this programme is severely hindered by limited infrastructure including transport network, electricity grid and water pipelines. It has been suggested that expensive and unreliable electricity supply is one of the factors limiting Rwandan's development [1].

1.2 The Current Energy Situation

1.2.1 Energy balance

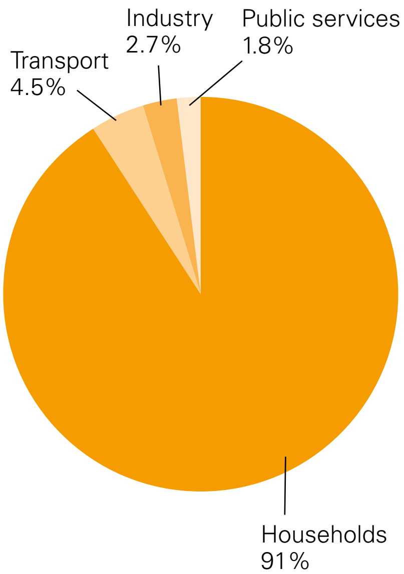
Figure 1 shows the current energy balance in Rwanda. At present, Rwanda's primary energy source is biomass which makes up 86 per cent of energy used. The biomass comes largely from on-farm trees, plantations of eucalyptus trees, agricultural residues and regional charcoal imports. Energy from electricity makes up only 3 per cent of total energy used. Petroleum products make up the rest of Rwanda's primary energy use (11 per cent), the majority of which are used in transportation and electricity production [2].

Figure 1: The energy balance in Rwanda



Source: Adapted from MININFRA 2009[2]

Figure 2: Rwandan energy consumption by sector



Source: Adapted from MININFRA 2009[2]

1.2.2 Energy Access

Up to 90 per cent of Rwandans have no access to electricity. These rely solely on biomass as the main source of energy. Indeed, energy consumed in rural areas where the majority of the population lives, accounts for up to 86 per cent of total energy used in the country. Figure 2 shows the energy consumption by sector. As can be seen, households account for about 91 per cent of energy use. Wood and charcoal energy is used by about 98 per cent of the population for cooking and about 17.7 per cent for light. Of the 20 per cent living in urban areas only about 25 per cent are connected to the national grid. The rest relies, like those in the rural areas, on biomass and liquid fuel for cooking and light. Generally consumption of electricity is very low. At about 44 KwH per capita per year Rwandan electricity consumption per capita is among the lowest in the world. Average per capita annual consumption of electricity in Sub-Saharan Africa and East and Central Africa region (excluding South Africa) is 478 KwH and 152 KwH respectively.

1.2.3 Current and Proposed Capacity

Rwanda has a very low installed electric power generation capacity. At present, the country has around 85 MW installed generation capacity and about 77 MW available capacity. This represents a roughly 100 per cent growth compared to available capacity in 2007 which was 41.25 MW. The breakdown of sources is shown in Table 1. As can be seen from Table 1, electricity is generated largely by hydropower and thermal power plants, each of which makes up a roughly equal share of generation. Historically, nearly all Rwandan electricity was generated through hydropower. The introduction of thermal power plants to increase electricity generation is a relatively new development. These were brought in after unusually low

Table 1: Rwanda's Installed and Available Generation Capacity [3]

Category	Name	Installed Capacity (MW)	Available Capacity (MW)
Domestic Hydro Power	Ntaruka	11.25	10
	Mukungwa	12	12
	Gihira	1.8	0 (rehabilitation)
	Gisenyi	1.2	0 (rehabilitation)
Regional Hydro Power	Rusizi 1 (SNEL)	3.5	3.5
	Rusizi 2 (SINELAC)	12	11
Micro Hydro Power	Nyamyotsi I	0.1	0.1
	Mutobo	0.2	0.2
	Agatobwe	0.2	0.2
	Nyamyotsi II	0.1	0.1
	Murunda(REPRO)	0.1	0.1
In-house Thermal Power	Jabana (Diesel)	7.8	7.8
	Jabana (Heavy Fuel Oil)	20	20
Rental Thermal Power	Aggreko (Gikondo)	10	10
Methane to Power	KP1	4.2	1.8
Solar Power	Kigali Solar	0.25	0.25
Total		**84.7**	**77.05**

river levels in 2004 led to severe electricity shortages and a national energy crisis. Since then the sector has been increasingly dependent upon thermal power plants. Since 2008 electricity has been generated in small amounts from methane extracted from Lake Kivu. This currently makes up around 5 per cent of electricity generated each year [3]. As indicated, Rwanda also imports electricity through cross-border interconnections. This comprises about 3.5 MW from Rusizi I (SNEL) owned by DRC and 12 MW from Rusizi II (SINELAC) co-owned by Rwanda, DRC and Burundi, the so-called CEPG countries. Under the current development plan, the GoR has an ambition to increase generation capacity to up to 1,000 MW by 2017. This represents a massive increase of more than 300 per cent of current generating capacity.

1.2.4 Distribution and Cost

Although the national grid in Rwanda is reasonably extensive, access levels are quite low at around 10.5 per cent of the population. The grid is made up of 383 km of high voltage lines and 4,900 km of medium and low voltage lines, a large amount of these being located in the capital city, Kigali. It was estimated in 2010 that the grid covered around 57 per cent of the country's population within a boundary of 4 km along the MV line [2]. However, despite the extent of the grid, only around 35 per cent of the population within this distance from the grid have the purchasing power to pay the necessary fees for their consumption [4]. The current retail price of electricity is high and for domestic consumers is 112 RwF/KwH (0.21 US$/KwH). Commercial and industrial consumption is rated at 105 RwF/KwH (0.19 US$/KwH). The high price of electricity is due to the high cost of renting thermal plants from a private company (10 MW) and the large cost of importing fuel for government-owned diesel generated power plants (27.8 MW). The price would be even higher if subsidies put in place by the government were removed. At present, subsidies include a waiver on import duties for imported fuel and direct financial support to the Energy, Water and Sanitation Authority (EWSA) (formerly known as Electrogaz) to offset the high price paid for the electricity produced by the rented generators [2].

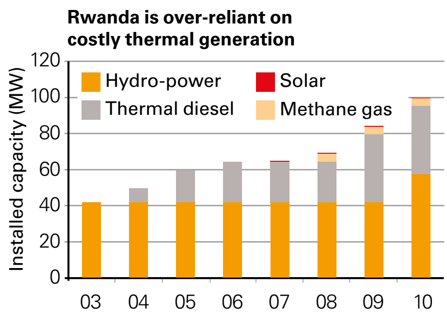
The main users of electricity in Rwanda are the industry and services (both public and private) sectors. Together the two sectors account for over 60 per cent of electricity sales. At the end of 2008, most electricity customers were in Kigali (around 60%) [2]. The national electricity company, EWSA, had around 130,000 customers at the end of 2010 [2]. Demand for electricity in the future is estimated to be around 600 MW by 2017 based upon the planned expansion of the national grid and growth in industry [3]. Of this, around 60 per cent of peak demand is predicted to come from domestic sources whilst 20 per cent will come from cross border mining and industry projects and a further 20 per cent will come from the sub-regional electricity market. Currently, Rwanda's electricity consumption is the second lowest per capita in East and Central Africa at 44 KwH per person per year.

1.2.5 The Power Crisis of 2004

In 2004 Rwanda suffered the worst energy crisis since its independence in 1962. Up until 2004, nearly 100 per cent of Rwandan electrcity came through domestic and regional hydropower plants. Following a long period of drought and low rain fall, two of the country's hyrdoelectric plants Ntaruka and Mukunga, which produced half of Rwanda's power, experienced a severe drop in yield. This happened when there had been increased drawdown at both lakes to cater for increased agricultural activity. At the same time, the system was experiencing demand pressure due to economic growth. Furthermore, Burundi had in early 2004 pulled out of Rusizi II causing restrictions on electricity import acessiblity. Moreover, the drought had resulted in low water levels at lake Kivu and consequent drop in output of the Rusizi plants.

The result of this was severe electricity rationing and long daily power cuts across the country. This had a huge negative impact on businesses, many of which were forced to buy highly expensive diesel generators. It was against this background that the government rapidly rehabilitated the Gatsata diesel generation plant in Kigali and quickly commissoned the building of two new plants. In addition, to provide emergency relief, the government signed a contract for 15 MW of rental diesel plant with AGGREKO, an independent power provider. Since then thermal power has increased from zero to its current level of 37.7 MW – accounting for nearly half of Rwanda's generation capacity (Figure 3). The reliance on thermal generation with transcontinentally imported diesel fuel especially at a time of high oil prices means that Rwanda is paying a great price to sustain its rapildy growing economy. It also means that economic growth is very fragile and threatened by the rising cost of oil.

Figure 3: Rwanda's growing reliance upon thermal power plants[3]



The government recognises the need to deal with the problem of shortages of energy, high prices, low access and over reliance on thermal generation. Several official planning documents state commitment to increased access recognising that energy provision is a fundamental prerequisite to economic growth and poverty alleviation. In doing so the GoR says it is keen to promote 'cost-effective and environmentally appropriate energy' that will ensure the long-term sustainable developmnt of the country. Achieving a sustainable energy mix is well within the reach of the country given the abundance of renewable energy potential and the visionary leadership so far demonstrated by the current government.

1.3 Renewable Energy Potential

Rwanda has considerable renewable domestic energy resources. It should be possible, with the right support and policy tools for Rwanda, to achieve an independent, secure and sustainable energy future by exploiting more of its renewable energy sources. Low carbon energy development is also very much in Rwandan's own self interest given its landlocked position and the absence of known oil reserves. Such a move will additionally help to decouple economic growth from carbon emission while providing wider economic, environmental and social benefits. It is therefore interesting that many of the renewable domestic energy resources in Rwanda are currently being considered for development by the Rwandan government as outlined below.

1.3.1 Hydropower

Rwanda has potential for both decentralised and large-scale energy generation from hydropower. At present hydropower is produced in four domestic plants, two regional plants and five micro-hydro plants. A number of mid-size micro-hydro plants are currently under construction. The Rukarara hydropower project built at the cost of US$23.5m is expected to inject between 2.5 MW to 6 MW into the national electricity grid. The Nyabarongo hydro electric project which will be producing 28 MW is currently under construction and is expected to go online by February 2013. The cost is estimated at around US$80m. Costs for hydropower projects are high in Rwanda; the mountainous terrain often makes construction difficult, the need to employ consultants from overseas as well importing all parts for construction also pushes costs up.

Three sites all located on border rivers have been indentified for large-scale hydropower generation. Feasibility studies for Rusizi III HEP, to produce 145 MW, shared among Rwanda, DRC and Burundi, and for Rusumo, expected to produce 61 MW, shared among Burundi, Tanzania and Rwanda, have been completed. It is expected that both will start generating electricity by 2016 at the latest.

A hydropower atlas was published by the Ministry of Infrastructure in 2007 which assessed the country's potential for micro and pico-hydropower. This study identified 333 sites. However, a number of these sites were of zero potential [5]. Overall it was estimated that the total theoretical hydropower potential for Rwanda, excluding border sites, is around 82.6 MW. Of this amount 61.2 MW is found at sites that have already been equipped with hydropower stations or are in the process of being developed. However, not all of these equipped stations are operational. This leaves the remaining unexploited potential at 21.4 MW [5].

It must be noted that the total potential for hydropower is based purely upon whether it would be technically feasible. This means that it is likely that a number of sites will be ruled out for being economically unfeasible. The remaining potential is therefore likely to be less than the above figure [5]. The study did highlight that there is a potential for much greater use of pico-hydropower. There are at least 172 pico-hydro (<50 kW) sites.

1.3.2 Geothermal

Geothermal energy comes from the internal heat of the earth, a small fraction of that which travels to the surface of the earth can be utilised. This utilisation usually occurs where there are geological conditions that allow this heat to be carried to the surface by a medium such as water in liquid or vapour form [6]. Basically, electricity is generated by using steam or hydrocarbon vapour to turn a turbine-generator set [6].

Geothermal energy offers a renewable low-carbon source of electricity and is unaffected by climate and weather changes. It is also available 24 hours per day, 365 days a year, aside from maintenance shut-downs, and as such is a reliable source of electrical power. Electricity generation systems on average have capacity factors of around 95 per cent.

Rwanda lies on the Eastern Rift valley and as such has geothermal potential. It has been estimated that the resource could lie in the region of 700 MW [7]. However, geothermal exploration and development in Rwanda is still at a very early stage. Surface reconnaissance studies have been carried out in the western region (Gisenyi, Karisimbi and Kinigi) and further detailed surface studies and exploration drilling needs to be carried out in order to confirm the resource potential [7]. GoR has indicated that it proposes to give the development of geothermal energy 'the highest priority' [9] as part of its effort to increase capacity.

1.3.3 Methane Gas

Lake Kivu in Rwanda is one of only three lakes in the world in which gases can accumulate. The other two are located in Cameroon. Lake Kivu is estimated to contains up to 250 billion m^3 of CO2 and 55 billion m^3 of methane gas [2]. The CO2 is generated continuously from volcanic activity and decomposition and fermentation of organic material by anaerobic bacteria. The CO2 is then transformed through organic decomposition into methane. It has been estimated that 700 MW can be continuously produced from methane extracted from the lake for at least 55 years [8]. It has been estimated that around 100 to 150 million m^3 of methane is generated annually in the lake and as such the resource is referred to as being renewable.

The lake borders both Rwanda and the DRC and the resource is split equally between the two countries. It is necessary to extract the gas to minimise the risk of a dangerous concentration of the gas building up, provoking a gas eruption [9]. This has been known to occur at the two other lakes in Cameroon in which CO2 also builds up. There are a number of pilot projects extracting the methane gas from the lake and the electricity produced feeds the national grid. The electricity produced costs only around US$0.06-0.07 per KwH; much cheaper than that produced by diesel generators which costs around US$25 per KwH [10]. A number of concessions have been given out for exploitation of the resource. However, there have been setbacks with the technology used as it is currently not extracting the gases as efficiently as expected [2].

The carbon intensity of electricity produced from methane extracted from Lake Kivu has been roughly estimated to be around 450-500g CO2/KwH [10]. However the carbon intensity will depend upon the technology used and whether the CO2 that is extracted is released into the atmosphere or re-injected back into the Lake. At present the management prescriptions for gas extraction require that the CO2 is re-injected into the Lake below a depth of around 200m. This prevents short-term release of the CO2. It should be noted that although the utilisation of this resource does emit some greenhouse gases, the carbon intensity is much lower than that of diesel generated electricity (-900g CO2/KwH) [10].

1.3.4 Solar

A solar power plant located at Jali Hill in the Gasabo district is currently the largest solar PV plant in Africa. Built with some funding from the German state of Rhineland, at a cost of about 700m Rwandan francs (£700,000; US$1.3 million), the plant feeds the grid with 250KW of energy. This project clearly demonstrates that solar energy is a viable option for Rwanda. The country has a daily average of around 8 hours sunshine and average solar radiation is 4-6 KwH per square metre per day [2]. At present the GoR has an off-grid solar programme through which it plans to install off-grid solar in all public buildings more than 5 km from the national grid. The GoR plans to install solar PV in over 600 institutions [2]. Solar water heating is also being utilised fairly widely in the city of Kigali. The GoR plans to install solar water heating in at least 70,000 houses, hotels, health centres, schools and hospitals by 2012 [2].

1.3.5 Waste to energy

Biogas digesters provide a small-scale off-grid renewable source of energy which can be used by rural households and institutions in cooking and lighting. The government of Rwanda has in place a National Domestic Biogas Programme which was initiated in 2007. The aim of this scheme is to install 15,000 units by 2015 [11]. The potential is limited, largely due to two main reasons: high capital costs despite subsidies and the need for the household installing a biogas digester to have at least two cows to make the system viable [12]. The potential for waste to energy on a larger scale exists and methane produced from landfill sites could be utilised. It has been estimated that this source could provide 30 MW [2].

1.3.6 Wind

Rwanda does not possess good potential for producing energy using wind power. An albeit sparse wind atlas was produced in 2010 from five different locations across the country [13]. Measurements were taken for one year. The results showed that the potential was low with average wind speeds of 2.4 m/s to 4.4 m/s and capacity factors of less than 13 per cent [13]. That said, wind energy has been utilised in a few individual cases; in the Gabiro district a wind turbine is used for pumping water and in Kigali a 1KW turbine has been built by a private owner [14]. The government plans to conduct more assessments, focusing especially at the Eastern province where wind potential appears to be relatively high.

1.3.7 Biomass

As stated, Rwanda relies upon wood fuels for at least 86 per cent of energy consumption. This is a major problem for Rwanda. The size of the country is not big and being mountainous, the geography is not very conducive to the fast growth of plants. Limited biomass resources combined with overexploitation which is intensifying as the population grows means that Rwanda faces the danger of resource scarcity and environmental degradation. In addition, much of the use of biomass in Rwanda is through inefficient methods which consume the resource at a much faster rate than it can be replaced and releases toxic substances into the atmosphere. That said, the government has long recognised that biomass can be a very important source for addressing the energy needs of households, community institutions, and cottage industries in rural areas. To address this challenge, the Ministry of Infrastructure supported by GTZ, Germany, has prepared a Biomass Energy Strategy (BEST), which places emphasis on reducing consumption, increasing efficiency through the use of improved coke stoves, and the substitution of biomass with alternatives such as biogas, carbonized peat and papyrus and other biomass briquettes. Furthermore the government has been very successful in pursuing a set of aggressive tree planting programs to the extent that a significant percentage of wood used in households now come from trees planted by farmers. The government has prepared a long term program for intensifying the dissemination of stoves both in urban and rural areas, which can save 50 per cent of fuel in comparison with traditional stoves. In parallel with this project, a similar program will address training and dissemination of improved charcoal making techniques to reach 25 per cent of mass yield in many districts in Rwanda. The government is also strongly engaged in the promotion of biogas as a substitute energy source to wood and charcoal. Government sources claim that up to 441 biogas installations built by the National Domestic Biogas Program (NDBP) are currently being used in rural households instead of firewood. The official target is to increase this number by at least 15,000 families by the end of 2015. Government is also funding the construction of biogas installations in schools, hospitals and several other community institutions.

1.3.8 Current Plan to Harness Renewable Energy Potential

The government of Rwanda has ambitious plans for the energy sector. The Energy Sector National Policy and Strategy sets out the aim of installing a total of 1010 MW electricity generation capacity by 2017 (up from 85 MW at present). This expansion of electricity generation capacity is planned to come from four main sources: geothermal (310 MW), hydropower (300 MW), methane (300 MW) and peat (100 MW). Planned new capacity is shown in Table 2. A rapid national grid expansion programme will accompany this increase in generation capacity. It is planed that the grid will be extended by 2100 km (700 km of HV and 1400 of MV), increasing the number of connections to 1,200,000 up from 175,000 today [2]. The aim of this extension is to enable 50 per cent of the population access to the national grid by 2017. In addition to this, by 2017 the GoR plan to ensure that all health centres, local administration offices and all schools in the country have access to electricity, either off or on-grid [2].

The increase in access to electricity is intended to give alternatives to traditional sources of energy, hopefully reducing the dependence upon biomass and limiting risks of deforestation. The target is to reduce the use of biomass from 86 per cent of primary energy use today to 65 per cent in 2017. This will also be accompanied by efficiency measures such as improved cook stoves. Alternatives such as biogas will also be introduced.

The energy generation and access plan is estimated to cost around US$5 billion. A great deal of this sum is hoped to come from the private sector and the donor community. The GoR is therefore trying to encourage the development of a sustainable, commercially viable energy private sector [2].

1.4 Barriers to low carbon development and energy access

There are a number of challenges associated with the GoR plan to develop the energy sector. Of these the two most pertinent are technical capacity and finance.

Despite the ambitious plans, Rwanda lacks the technical capacity to implement the projects as envisioned. This is significant because, despite concerted effort, it takes a long time to develop capacity and the time frame for the strategy does not fully accommodate this fact. Government itself recognises that 'there are significant capacity gaps throughout the delivery chain' [3]. The implementing ministries have an urgent need to strengthen project management and strategic planning skills required to deliver projects of the magnitude planned. In addition, due to reliance of the strategy on private sector involvement the government needs to develop the financial and legal expertise necessary to negotiate with the private sector. The Rwandan private sector itself needs to be developed so that its implementation of projects is more effective and the number of technically skilled labourers within the Rwandan workforce needs to increase [3]. The institutional structures of many of the government bodies implementing the strategy are not as efficient and streamlined as would be ideal.

The second critical challenge is finance. A huge amount of money is needed to implement the strategy. As mentioned, it is estimated that it will cost around US$5bn to implement the strategy. This is roughly twice the GDP of the country. Rwanda needs to attract private investment in order to generate this sum of money. An additional financial issue is the general low level of purchasing power in the Rwandan population, particularly in rural areas [3]. Although energy cost is expected to fall in the long run, the high capital investment required for the new builds implies that the cost in the near and middle term may still be far too high for many to afford.

In addition to these two main challenges, a number of the projects

Table 2: Electricity generation capacity at present and planned additional capacity [3]

Source	Installed Capacity (MW)	Planned New Capacity (MW)
Domestic Hydro	26.25	47.5
Regional Hydro	15.5	164.97
Micro-hydro	0.7	50
Domestic Thermal	27.8	20
Rented Thermal	10	-
Solar PV	0.25	8
Methane	4.2	300
Geothermal	-	310
Peat	-	100
Total	**84.7**	**990.47%**

have associated technological or political challenges. For example, the large-scale hydro projects are all jointly implemented with neighbouring countries and the methane extraction and use for energy generation is a completely new technology. The withdrawal of Burundi from Rusizi II in early 2004 with attendant access complications is a clear example of how things could go wrong in a collaborative project and with serious energy security implications. These challenges explain why the ambitious strategy is not on schedule. Unfortunately, this means that it is likely that high carbon (and relatively abundant and cheap) sources of energy could be used to increase generation rapidly. Rwanda has a large peat resource which it can utilise to generate electricity quickly and cheaply. There is also the potential for importing coal. If the barriers to the development of other renewable sources could be overcome a high carbon future could be avoided.

1.5 Current Low Carbon Development Strategy

A national strategy on low carbon and climate resilient development is currently being developed by the Smith School of Enterprise and the Environment at the University of Oxford in conjunction with the government of Rwanda. The project began at the request of HE President Kagame and the Rwandan government in mid-2010. The project is funded by the Climate and Development Knowledge Network (CDKN) and DFID-Rwanda. Prior to initiating this project, Rwanda had either commissioned or undertaken several studies relevant to climate adaptation and low carbon growth. The country had undertaken its greenhouse gas emission inventory and attempted to develop an emissions trajectory based on various development scenarios. Furthermore an economics of climate change report focusing on adaptation and a rapid assessment of national energy and low carbon path project were funded by DfID-Rwanda in 2009. Rwanda has also invested in preparing a first and second national communication on climate change. The purpose of the low carbon development project was therefore to provide a framework for linking the several pieces of work done in Rwanda and generate a robust national strategy that will guide Rwanda in its plan to transform itself to sustainable middle income country.

1.5.1 Project Rationale

Although Rwanda is currently a low carbon economy; the concern is that the continuing economic development of Rwanda (currently ~7 per cent pa) could be easily put at risk by mild economic shocks (e.g. heightened oil prices) or climatic extremes (e.g. drought or flood). Rwanda with its land-locked nature and long transcontinental supply lines is particularly vulnerable to such shocks. Recent events such as prolonged droughts resulting in massive crop failure and population displacement caused by frequent flooding clearly demonstrate how vulnerable Rwanda is to climate change. A key aim of the project is to feed climate change and low carbon strategy considerations into the national economic and development plans of Rwanda. The strategy will hopefully also position Rwanda to receive international aid to achieve its goal of climate resilience and low carbon development.

1.5.2 Methodology

The Rwandan low carbon development project adopts a unique and highly innovative methodology. The project is led by a Steering Committee made up of senior level representatives from key government ministries including Agriculture, Infrastructure, Forestry and Mines, Industry, Finance and Environment and Lands as well as key representatives from the Rwandan Environment Management Authority, the Private Sector Federation, civil society and development partners. The role of the steering committee is to provide high-level strategic policy input and promote coordination across the various sectors and ministries. In addition the project involves consultations with a stakeholder board comprising senior civil servants, academics, the donor community and civil society, the role of which is to enhance diversity of input and buy-in from other relevant actors outside of government. The core project team from Oxford works across all sectors of the Rwandan economy with research associates placed in and interacting closely with a variety of government ministries to formulate in-depth sector relevant strategy. The objective is to ensure that the project on completion will contain relevant, practical and implementable recommendations.

1.5.3 Baseline Scoping and Project Execution

In generating the national strategy report, an initial scoping phase was undertaken which produced a baseline report of all the initiatives taking place in the country as well as the status of a range of sectors within the economy. The coordination of the various climate related projects that are taking place in the country was seen as a critical requirement. In the second phase, each sector was analysed for potential climate and low carbon risks and opportunities, options were identified and a review of global best practice was undertaken. These two phases provided context for the actions recommended in the national strategy. The key recommendations from the sector analysis were developed into programmes of action in the national strategy. A few key areas in which challenges lie overlap between every sector, these being a lack of capacity, difficulty in financing projects, institutional challenges and a lack of data. Each phase in the production of the national strategy involved a large amount of stakeholder engagement so that the results are fully owned by the Rwandan government. On top of this a proposal was produced for a 'climate centre' that would gather and analyse region-wide climate data as well as conduct climate modelling for the region. The need for an increase in data availability for the region was identified to enable more effective national and local planning.

1.5.4 Outputs

It is intended that the project will result in the development and production of a National Strategy on Climate Change and Low Carbon Development for the government of Rwanda. Key insights from the report will be utilised in the revision of the Rwandan government overarching strategy document – Vision 2020 – to reflect the challenges and opportunities presented by a changing climate. It will also form the basis for a revised Economic Development and Poverty Reduction Strategy (EDPRS) which is the medium term national development strategy for the country. It is widely acknowledged within Rwandan ministries that emerging critical challenges such as climate change and low carbon economic strategies have not yet been incorporated in these two important documents guiding national development. The project will enable modern thinking to be incorporated into the GoR future strategy according to the requirements and expectations of the principal responsible ministries. The strategy has a long-term outlook and looks to the year 2050 when recommending actions that Rwanda can take. In addition, a number of 'quick wins' will be outlined that will set Rwanda on a low carbon pathway. A further outcome of the project was to determine the current predictions for the climate of Rwanda in the 21st century and to assess the availability of climatic observational data in the country. The report produced by this study will be launched at UNFCCC-CoP 17 in Durban, South Africa.

1.6 Links between Energy and Climate Resilience and Adaptation

Rwanda is highly vulnerable to the impacts of climate change because its economy is based on rain-fed agriculture. Any changes to rainfall patterns have a big impact on the economy. Rwanda also has a very poor population with the majority being dependent upon subsistence agriculture for their livelihoods. At present around 80 per cent of the population of Rwanda works in agriculture. It is widely understood that vulnerability to climate change can be reduced through economic development, creating jobs outside of climate vulnerable sectors and social protection. By decreasing the dependence of the population on climate sensitive economic activities and by increasing the number of choices as to how to generate a living, there will be greater resilience to the effects of climate change.

Without a doubt, energy plays a big part in removing people from poverty and increasing their choices as well as in encouraging economic growth and investment. Though energy is not itself a Millennium Development Goal, it is intrinsically linked to all of the eight goals. Increasing access to energy, in particular modern forms of energy such as grid electricity, can help eradicate poverty and hunger, reduce child mortality, improve access to education and increase climate resilience. Increasing the generation capacity of Rwanda and ensuring a reliable, low-cost supply is also important for developing industry and businesses and diversifying the economy.

In terms of the energy sector's resilience to climate change, Rwanda's electricity supply is vulnerable due to its reliance on hydropower which contributes around 50 per cent of its electricity. The generation mix should be diversified in order to minimise the impacts of potential future hydrological variability. The majority of people in Rwanda are dependent upon biomass for energy, particularly wood fuel. Climate change may impact upon the rate of vegetation growth in Rwanda through changes in temperature and rainfall which will add to the uncertainty in future supply created by a growing population. Reducing the use of biomass and ensuring greater access to electricity is one way to address this.

1.7 National Potential Benefits of Low Carbon Development

A major concern for policy makers in Africa and developing countries as a whole is that the adoption of low carbon development strategy will slow their economic growth and further limit their ability to lift the majority of their population out of poverty. This concern is not totally misplaced as it is widely recognised that low carbon development options are broadly more expensive and technically involving than business as usual approaches. At the same time it is possible to miss the benefits of pursuing low carbon development by focusing on the challenges or by getting locked into old ways of thinking.

Rwanda has considerable incentives to follow a low carbon development pathway, particularly in terms of moving away from its current dependence on oil-based fuels for electricity generation and transport. Rwanda has no domestic fossil fuel reserves and as such must import all the oil based fuel that it uses. This situation is problematic for several reasons. First, the high level of imports increases Rwanda's trade deficit. Second, fuel importation consumes a large amount of Rwanda's foreign exchange reserve and limits the country's ability to invest in its real economy. Third, the practice results in high electricity costs and leaves Rwanda's economy susceptible to oil price spikes. Finally, dependence on imported oil implies energy insecurity with all the problems and uncertainties that go with it [2]. Given this situation, there is incentive to develop domestic, low carbon resources.

1.7.1 Reducing Economic Vulnerability

Oil is not only an expensive commodity, but one that is uniquely prone to dramatic prices spikes. Rwanda has increased its dependence on imported oil based fuels to the extent that it is reliant on them for nearly half of its electricity supply. In addition, as Rwanda is a land locked country with no railway infrastructure, everything imported is brought in via oil based transport. The dependence on imported diesel and heavy fuel oil has left the country's economy vulnerable to oil price spikes and electricity generation firmly tied to insecure oil sources. This is undesirable given the volatility and increasing price of the commodity. Oil price spikes directly affect GDP, and in oil-dependent countries the effect is high. On average globally, every 10 per cent increase in the oil price results in a global drop in GDP of around 0.2 per cent [15]. In Rwanda this figure is much higher. Oil price spikes can create very high levels of inflation which reduce the country's economic stability.

A further incentive to move away from a fossil fuel based economy is the effect that the high level of imports has upon Rwanda's trade deficit. The current deficit in trade and services is around US$500 million. This level of trade deficit has only been possible due to the continued support of international development partners. Currently, external aid continues to finance about half of Rwanda's total budget. If Rwanda wishes to develop an independent and resilient economy, it would need to reduce its trade deficit and reliance on foreign aid. The current situation where the import of oil based fuel for electricity generation and transport continually saps scarce foreign reserve is not sustainable for long term economic development.

1.7.2 Lowering Electricity Costs

The high price of oil means that electricity generated using the oil based generators is very costly and must be subsidised by the government in order to make it accessible to consumers. The Rwanda government currently labours under this load and cannot afford to bear it long especially in the context of plans for increased access. In 2005 the GoR spent around 8.4 billion RwF (about US$14m) on fuel for electricity generation which produced 55.2 GWh. This is in comparison to 1.5 billion RwF (about US$2.5m) spent on 86 GWh of imported electricity from regional hydropower stations [16]. Given the very low purchasing power of the Rwandan population, high electricity costs are not ideal. In addition, high electricity costs are off-putting for industries wishing to take root in the country. Utilising domestic renewable energy resources would allow cheaper electricity generation which would enable greater electricity access.

1.7.3 Resilient Energy System

In addition to broader vulnerability of the economy to oil prices as discussed, the energy sector is specifically vulnerable to climate change given the dependence on biomass and hydropower. Diversifying the energy mix through the development of a number of low carbon resources is clearly important for increasing the resilience of the sector. This has the advantage of increasing the installed generation capacity which increases energy security through reducing the supply-demand gap. This can also increase access to electricity leading to poverty reduction.

1.7.4 Job Creation

A number of the low carbon energy technologies are labour intensive relative to fossil fuel technologies. This increases the number of employment options available to the Rwandan population. This is a much desired condition if the country is to meet its goal of reducing its dependence upon agriculture.

The development of an energy private sector will also generate a number of new private sector jobs. Developing a low carbon private sector has the added advantage of the availability of international funding for projects which can help overcome initial barriers that many projects would face.

2. CASE STUDIES

The government of Rwanda has long demonstrated awareness of the economic, social and environmental benefits associated with low carbon development. Although hampered by finance and capacity the government continues to strive to plan and implement a number of low carbon projects across the country and in different sectors. This section describes three such projects: a CDM-funded energy efficiency light bulb project; the National Domestic Biogas Programme (NDBP); and the generation of electricity using Lake Kivu methane. The projects were selected as all three are relatively well established, allowing any difficulties in implementation to be identified. In addition, all three projects have different motivations, utilise different methods of implementation, are aimed at different target groups and use differing levels of technology. The projects cover energy efficiency, energy access and energy generation, respectively.

2.1 Compact Fluorescent Lamp (CFL) Distribution Project

One way of reducing emissions in the energy sector is through increased efficiency. This is particularly important for countries such as Rwanda where installed capacity needs to be massively increased in order to meet demand at the least cost possible. Demand management will mean that energy requirements can be met at less expense. Compact Fluorescent Lamps (CFLs) are 75 per cent more energy efficient than incandescent lamps. The CFL distribution project was established in 2007 in order to take advantage of this energy saving.

2.1.1 Project Objective

The objective of the CFL distribution project was four fold: first, it was designed to help reduce grid electricity demand. This in turn would, it was hoped, allow the utility to increase its consumer base and provide access to unelectrified households. Second, the CFLs project was meant to result in lower electricity bills for the end-user most of whom already struggle to pay the high cost of electricity. Third, the program was intended as a means of educating households on the need for energy efficiency and on ways in which this could be achieved. Fourth, the project had the objective to help reduce carbon emission due to the associated reduction in electricity use. It was estimated that over a period of 10 years the project would reduce CO2 emissions by a total of 238,578 tonnes of CO2e [17].

2.1.2 The Project Plan

It was planned that the national public electricity utility Electrogaz (now EWSA) would implement the World Bank and CDM funded CFL distribution project. Two target groups were indentified. Firstly, existing grid-connected customers were to be given the opportunity to exchange their incandescent lamps of a range of 25 to 100 watts for high-quality self-ballasted compact fluorescent lamps of a range up to 20 watts. The distributing organisation was to gather and record data associated with these transfers including when, who and what was transferred. Using Electrogaz as the implementing agency made sense since it was easy to track current customers from pre-existing information on the database. Records indicated that there were 109,000 electricity customers as of December 2008 when the project fully kicked off.

The second target group was new Electrogaz (EWSA) customers. These were meant to receive a number of CFLs with their electricity meter at the time of connection to the grid as part of a start-up package. As part of the national electrification program access to the grid is planned to increase to at least 36 per cent of the population by 2020. During 2009 and 2010 it was estimated that an additional 95,000 new customers who were connected to the grid would receive the CFLs [17].

2.1.3 Project Implementation

The project was implemented through several phases starting from mid 2007. During the pilot phase in August and September 2007, 50,000 CFLs were distributed. Up to 2 CFLs were exchanged for incandescent lamps. They were exchanged free of charge as the project was promoting a new product and consumer response was not known. In the second phase, beginning in September 2008, 150,000 CFLs were distributed throughout the residential sector. During this phase up to 5 CFLs per household were given at a price of 200 RwF (US$0.37) per bulb and in exchange for incandescent lamps. As there was a positive response from consumers in the initial phase the utility was able to begin charging a small amount for the CFLs. 200,000 and 400,000 CFLs were distributed in the third and fourth phases, respectively. These ran from mid 2009 for the third phase and mid 2010 for the fourth. Distribution took place through 21 decentralised outlets run by Electrogaz in Kigali and throughout rural areas of the country [17].

Prior to and during the project, a large communications campaign was conducted to ensure maximum effectiveness of the programme. This included a variety of modes including billboard rentals, posters and stickers, printing, TV and radio spots, newspaper adverts and through stands at the Rwanda International Trade Fair, 2007 and 2008 [17].

2.1.4 Successes and Barriers

A study conducted on a 200-household sample established the lighting baseline and the market penetration of CFLs, the potential for their use, public awareness and daily lighting time. This study found that high quality CFLs were more expensive than incandescent lamps and therefore represent a very small portion of the lighting devices available in the market. Price was therefore a barrier to the take-up of this technology. During the project, CFLs were therefore provided at a subsidised cost. Following the pilot phase of the project a second survey was conducted. This showed an increase in interest of the population in this low energy device [17].

In Rwanda the costs of CFLs are around 5-15 times more expensive than incandescent lamps, one of the reasons for this being that they need to be imported. A high quality CFL can cost as much as US$7 in a Rwandan market [17]. To put this price in context, the per capita GDP in 2008 was US$450, just over US$1 per day. Upfront costs of CFLs clearly constitute a barrier for households. Lower quality CFLs cost around US$2-3 each. However, these have much shorter lifetimes and have so far served to undermine consumer confidence in CFLs [17]. High quality CFLs still require subsidising in order to encourage uptake.

Without CDM funding the project would have resulted in an estimated loss of around US$1.224m to the utility. As such, the CDM generated CER revenues represented the only financial incentive to implement the project. The project was financed by funds made available to Electrogaz by the World Bank. This allowed the utility to purchase 400,000 CFLs. An advance payment made against the potential revenue from the sale of CERs from these CFLs was used to purchase a further set of 400,000 CFLs [17]. It was estimated that the initial phase of the project, when 400,000 CFLs were distributed, saved the equivalent of 46,000 MWh per year. This is equivalent to around 18,000 new electricity customers.

2.2 National Domestic Biogas Programme

Within the energy sector the government of Rwanda aims to provide safe, reliable, efficient, cost-effective and environmentally appropriate energy services on a sustainable basis. Rwanda has one of the highest human population densities in Africa, with most of the population reliant on subsistence farming. As mentioned biomass, particularly wood fuels, constitute the main source of energy generation. With a growing population, this reliance upon wood fuel for energy is bound to create increasing problems of deforestation, unless effective action is taken. For many households it is already becoming increasingly difficult to satisfy their daily domestic energy requirements, especially as the government in a bid to curtail deforestation has placed restriction on the access to contiguous forests. The GoR therefore is implementing policies aimed at diversifying the sources of household energy as well as increasing access to electricity. Among the fuels being promoted as possible substitutes for wood fuel and charcoal are biogas, briquettes from crops and papyrus, peat carbonisation and methane gas resources [2].

2.2.1 The Project

Methane is produced in biogas digesters by the anaerobic decomposition of human and animal waste and plant residues. The methane produced can then be combusted and used for cooking or in biogas lamps. Slurry is produced as a by-product which can then be used as organic compost [11].

A number of factors in Rwanda make biogas digesters a suitable technology. Firstly, a large number of households own one or two cattle which are used for milk, meat, dung production and financial security. Secondly, legislation is in place that prohibits the free roaming of cattle. Almost all cattle are kept in stables overnight and a growing number kept on zero grazing. Thirdly, the climate in Rwanda is favourable to their operation all year round. Prior to the scheme, biogas digesters have been installed at a variety of public institutions such as schools and prisons. It has been estimated that around 6 per cent of all Rwandan families, over 110,000 families, have the potential for the installation and use of biogas digesters. This figure is estimated to increase with the zero grazing legislation becoming increasingly enforced. In addition, the ‘One Cow per One Poor Household’ programme currently being implemented in Rwanda is likely to increase the number of households for which biogas digesters are feasible once the cows reproduce [11].

2.2.2 Project Objectives

There are many benefits to the utilisation of the biogas resource. The scheme addresses the problem of wood fuel scarcity by reducing dependence upon this conventional fuel. It also delivers reductions in greenhouse gas emissions. The methane produced during anaerobic fermentation is collected in the biogas digester and then burnt. This would otherwise have been released directly into the atmosphere. It was estimated by the GoR that the scheme would result in an annual reduction in CO2 emissions of 54,865 tonnes (based on a 90 per cent success rate) [12]. The NDBP addresses social issues as well. The use of a biogas digester for energy reduces the household workload through reducing the amount of time and money spent by the family collecting firewood. As time spent feeding the biogas plant equates to that spent cleaning the stable it does not require additional time. The time can therefore be used for other purposes – it may allow for additional incomes to be generated or schooling for children. The use of biogas improves the health and sanitation conditions, particularly for women and children as it produces a much lower amount of smoke than wood. The development of an active biogas digester industry in Rwanda will also generate employment opportunities. Lastly, the biogas digester technology has the co-benefit of producing slurry that can be used as fertilizer which will increase agricultural production. The quality of the arable land on farms is mostly poor due to the high cultivation intensity. The slurry produced by the biogas digester has been found to be a better quality fertiliser than collected cow dung.

2.2.3 Project Plan and Implementation

In 2007 the GoR initiated the National Domestic Biogas Programme (NDBP) which aimed to develop a sustainable and commercially viable biogas sector in Rwanda. In addition, it aimed to result in the installation of 15,000 units by 2015. The first phase of the NDBP was five years, 2006 being the preparation and piloting phase and 2007-2010 the implementation phase [12].

In Rwanda biogas digester plants are available in sizes of 6 and 8 m^3 which cost around 630,000 and 743,000 RwF, respectively (US$1,155 and US$1,365). The NBDP implemented a subsidy of around 200,000 RwF for each 6 m^3 biogas plant, paid for by the GoR with the support of SNV and GTZ. Under the programme, the recipient of the biogas digester was required to make a down-payment of around 150,000 RwF which ensured that only committed individuals took part in the scheme. This contribution usually came in the form of unskilled labour and provision of materials. The remainder of the cost of the biogas digester was paid for again by the recipient who financed it either through their own means or by taking out loans through credit issued to the farmers. The need for finance to be available meant that donors were requested to provide a revolving fund to cover the farmer's credit needs. Through the Rwanda Micro Finance Forum an arrangement was made to provide loans for biogas digesters to farmers at 18 per cent interest per year with a four year repayment period [12].

In addition to financing, the NDBP involved a number of other activities:

- Promotion campaigns. These involved a variety of stakeholders, including local authorities, cooperatives, NGOs and community-based organisations.
- User training. This included cooking techniques, slurry application and hygiene.
- Construction, operation, maintenance and repair. This was completed by commercial construction companies following the completion of technical training at a Biogas Technical Training Centre set up under the programme.
- Monitoring and evaluation was implemented to ensure that the programme had the desired effects on reducing poverty and livelihood improvement.
- Quality control. It was important that quality be ensured therefore random checks were implemented to certify that construction and after sales services were sufficient.
- Research and development. This was undertaken in order to reduce costs and improve reliability and user friendliness of the technology.

2.2.4 Successes and Difficulties

The success of the programme was dependent upon innovative farmers who were willing to invest in a biogas plant. Financing was one of the major issues restricting the take-up of the technology and therefore the subsidy and microfinance availability were very important aspects of the programme. Until the programme was initiated, banks and microfinance institutes had no experience in providing loans to farmers wishing to purchase a biogas digester as biogas production was not considered an income generating activity. Subsidies and microfinance will need to be available for uptake of the technology to continue to increase.

The lack of data for reliable predictions of demand was one factor that caused difficulties in the implementation of the programme. There is no market intelligence for introducing a new product such as biogas digesters. In addition, there was little data on the presence of companies that could participate in biogas digester training and most of those companies that were registered were located in urban centres.

2.3 Methane to Power

Lake Kivu is estimated to contain 250 billion cubic metres of carbon dioxide and 55 billion cubic metres of methane gas. For electricity production, the quantity of methane that is available is believed to be sufficient to power 700 MW of electricity generation (350 MW for Rwanda) over a period of 55 years [8].

2.3.1 The Project

In order to diversify the electricity supply and eventually to replace oil-based generators the GoR began to use methane extracted from Lake Kivu to generate electricity in 2008. There are a number of advantages to utilising the methane resource in Lake Kivu. Firstly, the accumulation of gases in the Lake can be dangerous and if allowed to build up to sufficient levels could cause the overturning of the Lake layers. When this occurs, the built-up gas escapes and asphyxiates those in surrounding areas. This occurred at Lake Monoun and Lake Nyos in Cameroon in 1984 and 1986, respectively. Together these two events caused the suffocation of more than 1,700 people [8]. The accumulation of gas in Lake Kivu is slower than the Cameroon lakes and so the frequency of gas eruption events is far lower, however eruption of gas could be triggered by severe volcanic activity. Though the probability of such an event is very low, removing gas from the lake reduces the potential consequences of such an event [8]. Secondly, generating electricity from this source will reduce the vulnerability of the energy sector to climatic changes by diversifying the electricity generation mix. Thirdly, generating electricity from this domestic resource will be lower cost than using oil-based generators. Lastly, burning methane to generate electricity is relatively low carbon and as such the projects undertaken there should be viable for CERs.

2.3.2 Project Implementation

The use of Lake Kivu methane began in the 1960s at a very small scale and was largely used to power the local brewery. In recent years serious plans for its utilisation have been developed with the main end-use being for electricity. Two pilot plants have been built on the Lake and began producing electricity in 2008. The first, a government sponsored 4.5 MW methane gas power plant, named Kibuye Power, was built in order to attract and stimulate investment in the resource. The Rwandan Investment Group has also developed another pilot project of 3.6 MW.

Other projects in various stage are being arranged, the most significant being a project run by the American company ContourGlobal which recently received a MIGA to protect from political risk. This projects concerns the construction of 100 MW methane power plant in two phases, first, 25 MW by 2012 and second, a further 75 MW by 2013 [3]. On top of the Contour Global project there have been discussions in regards to the expansion of the Rwandan Investment Group project up to a capacity of 50 MW. The initial Kibuye Power pilot project is likely to be taken over by Israel Africa Energy Ltd and consequently expanded to 50 MW capacity in a series of stages. A joint project between Rwanda and DRC is in the process of being planned. This is to be a 200 MW project with Rwanda's share being 100 MW [2].

The GoR developed a set of management prescriptions for Lake Kivu Development in 2009 [9], to which it is essential that all companies operating there adhere in order to ensure the safety of the operations. These form the basis for the GoR's legislation for licensing and development of the lake.

2.3.3 Successes and Difficulties

Unfortunately, there have been a number of challenges involved in the development of this low carbon energy resource, and the range reflects quite well the different difficulties in Rwanda in developing a low carbon energy system.
The barrier has not simply been finance, though this is a significant issue; there are technical, capacity, institutional and political challenges. As such the development of the resource has not progressed at the rate hoped and the GoR have been unable to phase out oil-based electricity generation by utilising this resource.

A significant issue in developing this low carbon energy resource has been technical difficulties. There have been many technical problems associated with the pilot projects. It should be noted that whilst the installed capacity of the Kibuye Power pilot is 4.5 MW, since 2008 the project has only delivered 1.2 MW to the grid. A major challenge lies in the fact that the technology is completely new and unique. There have been a number of difficulties in proving the technology works effectively and the efficiency of gas extraction from the lake has been much lower than expected. It is for this reason that the GoR decided to transfer the Kibuye Power plant ownership to Israel Africa Energy Ltd who they perceived as being technically strong. Since the technology is new the projects need to be monitored closely in order to optimise the technology. Research and development also must take place. This is difficult due to a lack of technical capacity in Rwanda. In addition, the effect of the technology on the lake's stability needs to be monitored carefully. Risk lies in increasing the size of extraction. It is important that the overall density gradient of the lake is not weakened, the main density gradient, at approximately 260m, must remain strong enough to prevent the movement of dissolved methane upwards from this region.

Delays in the projects have occurred due to changes in the management prescriptions that were developed. These management prescriptions include a set of regulations for gas extraction design and operation, the key objectives being to ensure the safety of the Lake community and to ensure that the projects are environmentally sustainable. They also address generation of socio-economic benefits for the Lake communities. Discussions are still ongoing in developing a legal and regulatory framework for Lake Kivu gas resource management and an institution that will address the methane gas issues is being set up. That these discussions have not yet been concluded slows the development of the projects.

Another factor that makes development of the resource difficult is the fact that it is a shared resource, with the DRC and Rwanda each having claim to half. The regional nature of the project means that both states need to harmonise their views in regards to the main project partnership ownership structure, design and operation.

3. LEAPFROG FUND POTENTIAL

Finance is without a doubt one of the most critical factors hindering Rwanda's move towards a rapid low carbon economic development pathway. There are a large number of low carbon options in Rwanda the exploitation of which would bring significant economic as well as large social and environmental benefits to the country. There is a high level of awareness and commitment on the part of the government which has already initiated a number of measures and policies consistent with low carbon development. However progress has been limited due largely to financial and technical constraints. As such, a fund designed to overcome this barrier would go a long way in helping to accelerate economic growth, poverty reduction and low carbon development in Rwanda. Indeed, making a sufficient leapfrog fund available to a dynamic country like Rwanda could be perhaps the most important contribution the international community can make in helping the country overcome the problem of energy poverty and underdevelopment.

3.1 Project Finance

The prospects and challenges implicated in the development of geothermal energy in Rwanda provide clear illustration of the importance of adequate finance in achieving energy access and low carbon development in developing countries. The development of Rwanda's geothermal resource to generate electricity would provide a continuous and stable source of electricity, at a low cost once capital costs are paid for. As discussed above, initial surface and reconnaissance studies have suggested that Rwanda has very good potential. With a capacity of between 300 and 700 MW this source could easily supply the entire country with electricity and meet its development demand well beyond the year 2020. Furthermore, unlike available hydropower, geothermal energy is not vulnerable to climate variability such as drought and flood to which Rwanda has been badly exposed in recent times. Moreover, given that it is entirely a domestic source, it will not be a drain on the country's foreign exchange reserves or susceptible to the geopolitics of the rather unstable region. Unfortunately, geothermal, and a large number of other low carbon energy options, has a very high up-front capital cost. According to the draft strategic electricity plan for Rwanda, the development of geothermal sources needed to generate 310 MW will cost the country US$935m. To put this in context, the entire budget for Rwanda including both recurrent and domestic spending for the fiscal year 2009/10 was US$1bn. And of this figure, donor support accounted for about 41 per cent of spending. One can immediately see the difficulty faced by the country in overcoming the problem of energy access which is fundamental to economic growth.

Suggestions have of course been made that government should consider mobilising resources from the private sector to invest in its long term energy and broader economic development. To this effect, GoR has revised its business regulation and put in place many investment friendly policies. However, these have yielded only limited results as the private sector is still generally very reluctant to invest in many African countries. With the geothermal resource, the high cost of exploration lies mainly in proving the resource by drilling but this is a risk which the private sector considers too risky to bear.

Therefore, to make progress, the government of Rwanda must begin the initial exploration to prove the resources and generate interest from the private sector. This was precisely the case with the exploitation of methane resource in Lake Kivu where the government needed to invest in the initial pilot plants before the private sector became involved. The challenge however is that the government does not have enough resources to repeat this with the geothermal resource as doing so would require the GoR to divert funds away from basic spending. Hence a fund that could supplement these initial investments would be extremely useful in ensuring that low carbon development takes place in Rwanda.

3.2 Consumer Finance

A major barrier to the uptake of small-scale energy generation technologies such as solar lanterns, solar home systems, biogas and pico hydro in Rwanda is the lack of consumer finance. For these technologies it is the up-front costs that are the major factor slowing uptake. As demonstrated by the National Biogas Digester Programme, consumer finance that is targeted at consumer investment in renewable technologies needs to be available for technology uptake to occur. This consumer finance is at present not available in Rwanda. The microfinance industry in relatively nascent and does not have adequate resources to facilitate uptake to the scale that will make significant difference. A revolving loan that could provide finance for microfinance institutes and encourage scale up would enhance rural uptake of low carbon technologies.

3.3 Private Sector Investment

A number of local and regional entrepreneurs and venture capitalists have shown interest in investing in the energy sector and development of low carbon technologies in Rwanda. Many of these however suffer from the problem of insufficient capital. For example, notable advances have been made in the development of local biogas technology, low cost and carbon neutral houses using banana stalk, as well as in the area of micro hydropower plants. But many of these projects have been stalled because of lack of adequate finance for technology acceleration and development. Hence in addition to high capital cost projects like geothermal and hydropower, it would be extremely useful if finance could be made available to companies and entrepreneurs wishing to invest in constructing renewable energy projects in Rwanda.

At present, loan interest rates for renewable energy are very high which can put off interested investors. The availability of soft loans for renewable energy projects would remove this barrier. A fund with which the government could provide risk guarantees for both microfinance institutes providing loans to consumers and banks loaning to companies developing renewables projects would incentivise both these acts. In addition, funds made available to the government of Rwanda could then be used to implement grant-per-unit-sold or grant-per-unit-financed schemes with renewable energy companies and microfinance institutes, respectively, which would incentivise uptake.

The government of Rwanda is keen to encourage the involvement of the private sector in the development of the energy sector and hopes for much of the funding for various renewables projects to come from there. Of the US$5bn projected to be spent in developing various energy project in Rwanda between now and 2017, the government expects that US$4.1bn will come from the private sector. However, private sector investment is generally governed by cost and the desire for quick returns and as such does not robustly factor in externalities such as carbon emissions or environmental and social benefits. A fund which could be used by the Rwandan government to incentivise green investment would be beneficial in ensuring that private sector investment will help Rwanda down its chosen low carbon and climate resilient development pathway. The government of Rwanda is already taking steps in this direction by removing VAT and import tax on renewable energy technologies such as efficient cook stoves and solar lanterns. In addition, a renewable energy feed-in-tariff (REFIT) is under investigation and two major studies have been conducted on its potential. At present the Belgium government has provisionally agreed to supplement the REFITs.

3.4 Fund Management and International Financing Architecture

At present there is the tendency for funding for climate related projects to be funnelled through a country via numerous projects, often in an incoherent manner. It would benefit recipient countries like Rwanda if funds were channelled in a more strategic manner preferably streamlined with or directed by a national strategy of action. This would prevent overlap of projects and funding and the alignment would ensure that all projects funded worked towards the same goal in a logical manner. The government of Rwanda is in the process of setting up a National Climate and Environment Fund which would be the ideal destination of any funds received from the Green Climate Fund. However to maximise the effectiveness of such a body, there is the need to reduce fragmentation of current funding flows by increasing coherency in the international development and climate change financing architecture.

3.5 Other Factors

Although finance is a major issue, there are a number of other factors that need to be addressed in order to facilitate a transition to a low carbon economy in Rwanda. One major challenge is widespread capacity gaps. Critical capacity is needed in many areas – technical, legal, finance, project management, administration, etc – to translate current laudable aspirations into reality. In terms of technical capacity, it is often found that renewables installations – and this is particularly relevant to the solar PV sector – are not well maintained. As a result, many such projects are either stalled or running at far below full capacity.

Capacity building has long been recognised by both the government and donor partners as a critical need but the prevalent approach in addressing this need is grossly ineffective. In the main, the approach consists of a variety of ad hoc and poorly coordinated programmes run by many different donor agencies. In most cases, these programmes do not incorporate critical hands on training or budget for follow-up. Given the criticality of the capacity challenges in Rwanda, a significant portion of the leapfrog fund would have to be devoted to well thought through training programmes which must provide for hands on experience. It would be desirable that such training programmes are not restricted to government workers but open to the relevant private sector. Finance for research and development could also prove useful, as could transfer of technologies. Training for finance and management personnel would be extremely beneficial.

3.6 Recommendations

There are a few key recommendations that can be drawn from the above discussion.

- Increasing the ability of the Rwandan population to access micro finance is a key recommendation; this will allow a much greater level of uptake of small-scale energy generation technologies. In addition, developing finance lines for private sector actors wishing to set up low carbon energy generation projects should be made available.

- Enabling access to funds that the government can use to implement demonstration projects within areas that have not been developed would be extremely useful, particularly as many low carbon resources within Rwanda have high capital costs.
- Finance that can be made available for capacity development at many levels will enable projects to be implemented effectively. At present lack of capacity is a problem throughout the energy production chain.
- In Rwanda, a low carbon fund may be best channelled through a national fund such as the future Climate and Environment Fund. This would allow the money to be spent in a cohesive manner.

3.7 Summary and Conclusion

From the above discussion it can be concluded that there are significant advantages to developing along a low carbon pathway. A low carbon energy sector in Rwanda is both possible and preferable to its current dependence upon fossil fuels. The government of Rwanda has clearly realised this and is taking steps towards this goal. However, there are a number of barriers: finance, capacity, and technology. A fund designated to overcoming these barriers in a coherent fashion, aligned with the national strategy, would be extremely beneficial.

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