CLEAN ENERGY ASSESSMENT REPORT

Sustainable energy pathways: opportunities and challenges for Mozambique

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Foreword

This report, commissioned by the World Wide Fund for Nature (WWF) Mozambique, presents the findings and recommendations of a rapid assessment of sustainable energy challenges and opportunities prepared through December 2010 to February 2011.

Research conducted for this report consists of literature review and interviews with national Government institutions, international cooperation agencies, private sector, academia, and civil society organisations in Maputo.

The purpose of this report is to stimulate discussion and feedback is welcome. Where gaps and problems are identified the objective is not to criticise but rather to highlight the opportunities for change.

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Executive Summary

This report presents the findings of the Clean Energy Assessment conducted for WWF and centres on sustainable energy pathway opportunities and challenges for Mozambique. It was prepared to provide information for decision makers that can influence the energy sector and its impact on green house gas (GHG) emissions. At an early stage of consultations and research it became abundantly clear that few stakeholders have considered Mozambique's GHG emissions levels or the need to plan for a transition to a low GHG emissions energy development pathway. Though this report was a short two-month study it provides a first look at the major issues.

The content of this report covers renewable energy mapping and quantification of energy potential for solar, wind, biomass, biogas, biofuel jatropha curcas and small hydro, scenarios for energy supply and CO_2eq emissions levels of different energy pathways, sustainable energy stakeholder capacity, policy and institutional issues, and briefly considers some forest and other CO_2 emission off-set carbon market opportunities.

To prepare this report senior Government members, leading private sector players, civil society organisation managers, and academics were consulted on renewable energy potential, stakeholder capacity issues, emissions sources and levels, Government policies, and community energy needs. Many leading scientists and organisations' publications on energy, climate change and GHG emissions were also reviewed. Projections focus on the period 2010 to 2030, aligned with the Government's Energy Generation Master Plan (2009). Preliminary findings were presented to a multi-stakeholder group in Maputo in February 2011 to test assumptions and generate ideas for effective interventions to achieve sustainable energy pathways.

The key findings of this report:

- Total energy consumption for Mozambique in 2010 was approximately 114,000 GWh and is estimated to exceed 244,000 GWh by 2030. Mains-grid electricity consumption is expected to increase from 3,103 GWh in 2010 to 9,216 GWh in 2030.
- Energy consumption in 2010 was dominated by wood-fuels, accounting for an estimated 85 per cent of total energy consumption, followed by hydrocarbons (diesel, petrol, kerosene, Jet A1, LPG, and natural gas) 12 per cent, and finally mains-grid electricity (hydro power) 3 per cent.
- Energy consumption expenditures in 2010 exceeded USD 2 billion. Fuel wood (firewood and charcoal) accounts for approximately 50 per cent of all energy consumption expenditures with a total value of over USD 1.2 billion. In 2010 the informal charcoal industry was worth approximately USD 467 million in consumer expenditures, representing enormous tax revenue losses for the State.
- Fuelwood consumption is estimated to grow from over 32 million m^3 in 2010 to over 61 million m^3 in 2030. Meanwhile no forest resources of any significant scale are managed to sustainably supply wood-fuel. If current trends continue productive forest could be reduced by as much as 26 per cent during the period from 2010 to 2030.
- The main drivers of energy consumption levels are increasing affluence and population growth. In 2010 the population was approximately 22 million and by 2030 is projected to reach 38 million with 60 per cent of the population residing in urban areas and 40 per cent in rural areas.
- A rapid analysis of Mozambique's direct CO_2eq emissions in 2010 shows total emissions exceeded 161 million tCO_2eq with wood fuels accounting for approximately 98 per cent of all emissions, while hydrocarbons account for only 2 per cent.
- Following Scenario 01 'Business as Usual' for energy supply, by 2030 CO_2eq emissions per capita will reach approximately 2.78 tCO_2eq making it extremely difficult to achieve the annual global target of 0.5tCO_2eq per capita by 2050 (Ecofys 2009 pp. 11). Setting course on Scenario 03 'Efficiency and Sustainability' reaching approximately tCO_2eq 1.16 per capita presents the best chances of reducing CO_2eq emissions to 0.5tCO_2eq per capita by 2050.
- In terms of electricity supply only, it is clear that there are many options and ample resources available to meet the projected total mains-grid and off-grid demand up until

2030 of approximately 12,263 GWh. Total renewable energy potential for the energy sources assessed amounts to 160,757 GWh (Solar PV on 5 per cent urban lands plus 5 per cent of bare lands: 15,815 GWh; Solar thermal H_2O heating on 0.55 per cent of urban lands 944 GWh; Wind areas over 6 m/s wind speeds at 10m height: 24,158 GWh; Biofuels with jatropha curcas on 5 per cent of agricultural lands: 5,065 GWh; Biomass based on productive forests' mean annual increment in 2011: 105,887 GWh; Biogas using human and other bio-waste based on population numbers in 2011: 8,574 GWh; Small hydro based on less than 15MW installed capacity: 314 GWh).

- It is conceivable that the potential GHG emissions from uncontrolled fires may substantially surpass emissions from all other sources in Mozambique, while also suppressing precipitation levels.
- In general, knowledge about CO_2eq emissions in Government institutions, and most other sectors, is poor. Questions around CO_2eq emissions and sustainable energy development pathways do not appear to be on the Government radar.
- The total catchment areas of all small hydro installations assessed amounts to 44,160 Km^2. Catchment site visits were not possible but simply for indicative purposes, assuming additionally is proven and leakage is not addressed, applying an annual average deforestation rate of 1.75 per cent would give approximately USD 4.2 million carbon revenues per year for all catchment areas.
- According to fuel-wood consumption estimates for 2010, the potential CO_2 emissions savings from fuel-efficient stoves, based on a 33 per cent efficiency performance level, could reduce up to 52 million tons of direct CO_2 emissions. Carbon emission savings could be worth over USD 318 million in voluntary carbon markets.
- According to fuel-wood consumption estimates for 2010, the potential CO_2 emissions off-set by biogas use – assuming 100 per cent of the population uses the technology – could exceed 47 million tons of direct fuel-wood CO_2 emissions. In financial terms these emission savings could be worth over USD 289 million in voluntary carbon markets.
- Mozambique has approximately 357,000 ha of mangrove forests. Given the enormous carbon sink capacity of mangroves, investment in mangrove restoration and protection would represent a strategic and powerful asset in a GHG emissions mitigation and reduction strategy for Mozambique.

This report presents critical first stage evidence required to inform discussion and debate to drive Mozambique's transition to sustainable energy development pathways. The report findings and recommendations could be carried forward by senior Government leaders, perhaps through the inter-ministerial Committee for Sustainable Development (CONDES).

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Acronyms

^oC	Degrees Celsius
CCGT	Combined cycle gas turbine
CDM	Clean Development Mechanism
CNELEC	National Electricity Council
CONDES	Committee for Sustainable Development
CO_2	Carbon dioxide
CO_2eq	Carbon dioxide equivalent
tCO_2eq	Tons of carbon dioxide equivalent
EDM	Electricidade de Moçambique
ESKOM	South African public energy utility
EUR	Euros
FCPF	Forest Carbon Partnership Facility
FSC	Forest Stewardship Council
FUNAE	National Energy Fund
GHG	Greenhouse gases
GJ	Giga joule
Gt	Gigatons
GW	Gigawatt
GWh	Gigawatt hours
ha	Hectares
IPCC	Intergovernmental Panel on Climate Change
INAM	National Meteorological Institute of Mozambique
INGC	Instituto Nacional para Gestão de Calimidades
Kg	Kilogramme
Km	Kilometre
Km^2	Kilometre squared
kW	Kilowatt
kWh	Kilowatt-hour
kWhe	Kilowatt-hour
LCA	Life Cycle Analysis
m	Metres
m/s	Metres per second
m^2	Metre squared
m^3	Metre cubed
MJ	Mega joule
Mph	Miles per hour
MW	Megawatt
MICOA	Ministry of Environmental Coordination
MINAG	Ministry of Agriculture
MOTRACO	Mozambique Transmission Company SARL
MZN	Mozambican metical (Mozambique's national currency)
NCAR	National Centre for Atmospheric Research
NCEP	National Centre for Environment Prediction
NOx	Nitrous oxide
NREL	National Renewable Energy Laboratory
p.a.	Per annum
PETROMOC	Petroleum of Mozambique
REDD+	Reduced Emissions from Deforestation and Forest Degradation
R-PIN	Readiness Plan Idea Note
R-PP	Readiness Preparation Proposal
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SO_2	Sulphur dioxide
SWERA	Solar and Wind Energy Resource Assessment
UEM	University Eduardo Mondlane
UNEP	United Nations Environment Programme

UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Population Fund
USD	United States Dollars
W	Watt
WWF	World Wide Fund for Nature

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1. Purpose

The overall goal of this assessment report is to outline the major opportunities and challenges for Mozambique to move towards sustainable energy supply during the period 2010 to 2030.

The specific objectives of the assessment are to:

1. Present an overview of the current energy regime;
2. Analyse and summarise the major energy market factors, especially consumption;
3. Map and demonstrate the quantity of renewable energy potential;
4. Review the key policy, institutional and regulatory factors for expansion of renewable energy services;
5. Map energy sector stakeholders and identify capacity building requirements for the expansion of sustainable energy services;
6. Develop scenarios for energy supply – business as usual, and two sustainable energy supply scenarios – taking into account environmental, economic and demand factors;
7. Present options for sustainable energy supply differentiated for rural and urban populations;
8. Review the National green house gas (GHG) Inventory (MICOA 2010$_a$) and position of Mozambique within global CO_2 equivalent (CO_2eq) budgets; and finally
9. Provide an overview of the potential role Reduced Emissions from Forest Degradation and Destruction Plus (REDD+) could play on small hydro catchments to reduce emissions from forested lands and invest in low-carbon paths to sustainable development.

2. Context

2.1 Energy regime

In 2010 it is estimated that 85 per cent of total energy consumption in Mozambique is based on wood-fuels, the balance comes from hydrocarbons, 12 percent, and electricity, 3 percent. Converting all energy consumption into Gigawatt hours (GWh), the total energy consumption was approximately 114,000 GWh. In terms of household level energy consumption wood-fuels are likely to constitute over 95 per cent of energy consumed.

The informal sector dominates the entire wood-fuel supply chain. According to the Ministry of Agriculture (MINAG), National Directorate of Lands and Forests, there are no forest resources of any significant scale that are managed to sustainably supply wood-fuel. In 2010 an estimated 30 million cubic metres (m^3) of wood fuels may have been consumed, resulting in the unsustainable cutting of up to one million hectares (ha) of forest.

At present over 96 per cent of Mozambique's electrical energy is provided by hydro power from Cahora Bassa dam on the Zambeze River (see Table 1). However combined cycle gas turbine (CCGT) installations are planned in Ressano Garcia, and Maputo where existing diesel powered turbines will be reconverted to use local natural gas extracted on-shore in Temane (Inhambane Province), and thermal coal power stations are planned in the Districts of Benga and Moatize, all increasing the role of fossil fuels in the electricity generation mix.

Table 1. Mozambique's electricity generation installations

Energy Source	Capacity (MW)	Per cent of total
Gas turbine	64	2.9
Diesel	9	0.4
Hydro-power	2,138	96.7
Totals	**2,211**	**100.0**

Source: Ministry of Energy (2009$_a$, pp. 2-01).

The Intergovernmental Panel on Climate Change (IPCC) reports that GHG emissions have increased by 70 per cent between 1970 and 2004, with the majority of emissions coming from the energy sector (IPCC 2007, pp. 5). The continuation of current emission levels during the 21st century will seriously affect water resource availability, ocean acidification, human health, ecosystem functioning and human health (IPPC 2007, pp 7).

In the best-case stabilisation scenario outlined by the IPCC (2007, pp. 20) fossil fuel GHG concentrations must not exceed 490 parts per million (ppm), with emissions peaking not later than 2015, which will result in temperature rises of up to 2.4^{o}C and sea level rises of 1.4m.

Given the earth's finite CO_2eq absorptive capacity limits, establishing a CO_2eq emission per capita accounting system and targets for Mozambique is the most coherent way to approach evaluation of energy pathway options. However answering the transnational question of who should limit their emissions, by how much and when is a very complex political and technical exercise, which requires a dedicated study. In the absence of concrete, comprehensive data on Mozambique's national CO_2eq emission sources and sinks a precautionary approach is merited. The global target of reducing CO_2eq emissions to 0.5tCO_2eq per capita by 2050 (Ecofys 2009 pp. 11) provides an objective benchmark. Considering the significant climate change impacts forecast for Mozambique the safest way forward would be to adopt the target of 0.5tCO_2eq per capita emissions by 2050 and apply it vigorously to energy pathway assessments until more data is available. In 2010 Mozambique's estimated wood-fuel CO_2eq emissions contributed over 90 per cent of all energy consumption direct CO_2eq emissions. The per capita CO_2eq emissions in 2010, including direct wood-fuel emissions, were approximately 7.20 tCO_2eq. Factoring in carbon sequestration by productive forests only, per capita CO_2eq emissions in 2010 were -0.89 tCO_2eq but the net effect of sequestration is falling year on year with unsustainable harvesting of fuelwood resources.

Although Mozambique has signed and ratified the Kyoto Protocol, as a non-Annex I Party, it is currently not subject to binding targets for GHG emissions (UNDP 2008). Yet binding emission targets for all parties are unavoidable – all cycles are subject to the same finite CO_2eq absorptive capacities of Earth.

The assumption that Mozambique does not contribute to GHG emissions because electricity supply is provided by hydro power is contestable. The environmental implications of large hydro power aside, Mozambique's overwhelming dependence on unsustainable fuel-wood extraction results in significant GHG emissions to the atmosphere. This fact is not reflected in national accounting of environmental performance, nor is it addressed in any coherent national emission reduction plans.

The approach in Mozambique is focused on adaptation to and mitigation of the impacts of climate change, exemplified by the Strategic Plan for Climate Resilience (SPCR) due to be published in April 2011 and coordinated by the Ministry of Planning and Development (MPD). The SPCR has a range of 'climate resilience' interventions for capacity building of private sector and Government, and pilot investments in cities, agriculture and infrastructure. The SPCR is financed by the World Bank, the International Finance Corporation (IFC), the African Development Bank (AfDB), the International Development Association (IDA), the United Nations Development Programme (UNDP), the United Kingdom's (UK) Department for International Development (DFID) and the Danish International Development Agency (DANIDA); total funds planned exceed United States Dollars (USD) 100 million. The investment of funds in 'climate resilience', though essential, is hard to reconcile with the fact that nothing is being done to address Mozambique's homemade contributions to the root problems driving climate change.

2.2 Access to modern energy services

According to the National Institute for Statistics (INE, 2010) the total population of Mozambique in 2010 was 22.4 million, of which 60 per cent are rural and 40 per cent urban. By 2030 the population is projected to reach 38 million and the rural-urban ratio will be reversed so that 60 per cent of the population resides in urban areas and 40 per cent in rural areas (ANMM 2009, pp 6).

The IEA (2008) reported rural areas electricity access is 6 per cent while urban access is 21 per cent; in total 12 per cent of the population have access to electricity (see Table 2).

The Southern African Power Pool (SAPP) serves a combined population of over 230 million (SAPP 2009, pp. 3). In 2008, the leading SAPP consumer was the Republic of South Africa with a peak demand of 35,995 Mega watts (MW) (SAPP, 2009 pp. 8). In the same year Mozambique's peak demand reached only 416 MW (see Table 3.).

Table 2. Electricity access in the Southern African region

Country	**Electrification rate (per cent) in 2008**			**Pop. without access (millions)**
	Total	**Urban**	**Rural**	
Angola	26	38	11	13
Botswana	45	68	12	1
Lesotho	16	44	6	2
Madagascar	19	53	5	16
Malawi	9	25	5	13
Mauritius	99	100	99	0
Mozambique	*12*	*21*	*6*	*19*
Namibia	34	70	13	1
South Africa	75	88	55	12
Zambia	19	47	3	10
Zimbabwe	42	79	19	8
Averages/ total	36	58	21	95

Source: IEA (2008).

Table 3. SAPP electricity MW capacity and peak demand

No.	**Country**	**Utility**	**Available Capacity as at June 2009**	**Peak Demand in 2008**	**Required Capacity + Reserve of 10 per cent**
1	Angola	ENE	930	668	676
2	Botswana	BPC	90	503	509
3	DRC	SNEL	1,170	1,028	1,040
4	Lesotho	LEC	70	108	109
5	Malawi	ESCOM	267	260	263
6	*Mozambique*	*EDM + HCB*	*2,249*	*416*	*421*
7	Namibia	NamPower	360	430	435
8	South Africa	Eskom	40,483	35,995	36,427
9	Swaziland	SEC	70	200	202
10	Tanzania	TANESCO	680	1,694	1,714
11	Zambia	ZESCO	1,200	1,604	1,623
12	Zimbabwe	ZESA	1,080	1,714	1,735
Totals			**48,649**	**44,620**	**45,155**

Source: SAPP (2009, pp. 8).

3. Methodology

3.1 Overview

The research methodology is exploratory, based on analysis of limited key informant interviews and quantitative analysis of secondary data. A total of 20 semi-structured qualitative interviews were completed with key representatives from Government, Private Sector, and Civil Society Organisations (CSOs). Secondary data from national, regional and international reports provided all data required for analysis.

3.2 Data collection

Secondary data in the form of reports, surveys and other publications were gathered almost entirely through Internet searches from energy related organisation's websites. Some documents such as the Energy Strategy 2009, the Generation Master Plan 2009, the Forest Inventory 2007 and the GHG Inventory were acquired directly from Government counterparts.

Google Earth (2009) was a fundamental geographic information system (GIS) tool, combined with overlay maps from various sources, for the mapping of renewable energy potential and small hydro catchments.

Primary data was collected through purposefully selected key informant interviews. General interview guides were prepared for each interview, but an open ended and qualitative approach was maintained to ensure a broad range of issues could be raised.

3.4 Data analysis

Population growth analysis was central to projecting future energy needs and energy related CO_2eq emissions. The population in year 2011 is based on the INE projections with a growth rate set at 2.8 per cent up until 2030, and the INE projections for population growth up to 2040 (INE 2010, pp. 30). Rural and urban population numbers for 2011 are based on percentages (rural/urban) attributed by INE for each province. The average rural, 40 per cent, and urban, 60 per cent, population breakdown for 2030 per province is based on general projections for Mozambique according to the National Association of Municipalities of Mozambique (ANMM) (2009, pp 6).

Wood-fuel consumption calculations for cooking and heating per capita assume rural populations consume wood and urban populations consume charcoal. Per capita annual wood consumption in rural areas is based on 1.35m^3 air-dried wood, and annual consumption of charcoal in urban areas, in air-dried wood equivalent, is assumed to be 1.7m^3; the United Nations Food and Agriculture Organisation (FAO) estimates wood-fuel consumption in Southern Africa to range between 1 and 1.7m^3 per person per year (FAO, 2000). Calculations of the impact of wood-fuel supply on forest cover only considers productive forest area, classified by Marzoli (2007, pp. 15) as forests suitable for commercial wood harvesting while all other forest cover areas are ruled out for either legal or eco-physiological reasons. The effects of fuel-wood extraction on productive forest cover were assessed in terms of the net impact of removals by integrating the mean annual increment (MAI) per province. In the absence of data on fuel-wood supply chains per demand centre fuel-wood extraction, for wood and charcoal, is assumed to occur within the same province. This is far from accurate, but without more reliable data offers indicative results on fuel-wood extraction impacts on forest cover.

Future access to mains-grid electricity is based on EDM client figures for 2009 (EDM, 2009 pp. 29-30) with 80,000 new connections per year (Cuambe 2009). Average number of persons with access to electricity per connection is based on 3.5 persons per connection.

Growth projections for mains-grid electricity demand use an annual average peak demand growth rate of 6 per cent and a load factor of 70 per cent. Off-grid electricity needs projections assign a 100 kWh target per person per year based on United Nations targets established for access to modern energy services (UN AGECC 2010, pp 6.).

Valuation of different energy consumption is calculated per original unit of energy purchased and then converted into approximate relative values in GWh, based on the conversion of the energy content of the fuels. The values reflect retail prices paid by consumers but are not adjusted to reflect true market values or externalities; distortions exist, especially in the hydrocarbons and electricity markets due to subsidies and illegal exports, and also in the wood-fuel markets due to the exclusion of forest regeneration and management costs, and losses during wood-fuel harvesting and processing especially for charcoal production. The results are not true market values, and are only demonstrated here to facilitate a rapid comparison of energy costs, in indicative financial terms.

Wood fuel values assume a 70 Kg sack of charcoal is sold at USD 17 in Maputo (Antanassov 2009, pp. 17), giving approximate cost (17/70) of USD 0.24 per kg. Approximately 165 Kg of charcoal is produced per cubic metre (m^3) of fuelwood (FAO, 2001). Thus one m^3 of fuel wood for charcoal can be valued at approximately (165*0.24) USD 39.60; as an approximation USD 39.60 is used as a general value per m^3 for all wood-fuels, i.e. firewood and charcoal. Although it is understood in rural areas where firewood is mainly used, as opposed to charcoal, most people collect the wood for themselves and do not make payments a value for this wood is attributed here (USD 39.60 per m3) for illustrative purposes; an accurate figure would require local case by case analysis and opportunity cost calculations. However it is important to consider that the values attributed to fuel-wood in these calculations *do not reflect the true value of sustainable supply* as the industry operates within the informal sector where licenses for cutting and the costs of replanting are not integrated in retail prices paid by consumers. Note, Sitoe and Tcauhque (2007, pp 1.) estimated a m^3 value of approximately USD 44.12 for wood-fuels in Mozambique, which is slightly higher than the unit values used in the calculations for this assessment.

According to the Ministry of Energy (2010) Directorate of Studies and Planning, Energy Statistics for the period 2006 to 2009, at a rate of MZN 32 per USD 1.00, the following average energy costs apply: USD 0.73 per litre of diesel, USD 0.74 per litre of gasoline, USD 0.20 per litre of Jet A1, USD 0.51 per litre of kerosene, USD 1.28 per litre of LPG, and USD 0.08 per kWh of electricity. According to the Matola Gas Company natural gas is valued at USD 0.94 per litre.

All renewable energy generation potential is presented in GWh to facilitate comparison between different energy sources.

Energy generation potential for wind power is calculated for all sites where average wind speeds exceed 6 m/ second (m/s). A hub height of 50 metres (m) is assumed, with average wind speeds of 8.17 m/ second (m/s) at hub height, and an average capacity factor of 36 per cent. Results draw on findings from a wind atlas developed by Pinto (2008) and wind energy potential analysis by Sinnott (2010).

Solar power potential is calculated per province, according findings by Cuamba et al (2006, pp 79) of provincial daily global solar radiation; 5.7 kWh/m^2/per day is the national average (Cuamba et al 2006, pp 82). In order to calculate energy generation potential we assume 5 per cent of urban lands, such as rooftops, and 5 per cent or bare lands, classified by Marzoli (2007, pp. 9) as having less than 4 per cent vegetation cover, are dedicated to solar photovoltaic (PV) installations.

Small hydro is defined as any installation under 15 megawatts (MW) in this assessment. Sites and MW installed capacity were identified based on an works by Norconsult (2009_a, pp. A6-1-3 of 11). Of the 23 small hydro power sites identified, GWh average annual output was only available for 9 sites from another study by Norconsult (2009_b). The average GWh potential from the 9 sites assessed by Norconsult (2009_b), approximately 1.59 GWh, was applied to the remaining 14 sites to estimate approximate energy generation potential – this is not ideal or accurate but no hydrological data was available for 14 of the 23 sites identified.

The calculations for biofuel potential assume 5 per cent of agricultural lands are dedicated to biofuel production, specifically with *Jatropha curcas* only. Given its significant irrigation needs, cane sugar was deemed to be both too complex to assess with any meaningful analysis within the resource constraints of this study, and too environmentally demanding on water resources. Calculation of jatropha production potential assumes a mature plantation on good soils, with higher rainfall and optimal management practices, producing of 5 tons of seed per ha p.a. and 35 per cent oil content extracted per ton of seed harvested (FAO, IFAD, 2010, pp. 40-41).

Biogas potential, from methane (CH_4), is quantified for human waste and bio-waste, from food preparation, as feedstock based on a study by the International Committee of the Red Cross (ICRC, 2010). Calculations assume 5.847 litres total feed stock supply per day per person, including human waste (faeces 0.44 kg and urine 1.65 litres per person per day), bio-waste (from food preparation, 0.22 kg per person per day), waste dilution water (0.242 litres per person per day), and waste flush water (3.3 litres per person per day). In total 62 litres of biogas production per day per person is projected relative to population size for the year 2011. The quantification of biogas in terms of cooking potential assumes 350 litres of biogas are used per hour of stove burning time, for an average household of 4 members, using approximately 2 hours of stove burning time per day.

Emissions of CO_2eq per fuel type are calculated using conversion factors published by the Carbon Trust (2009) as follows: coal (0.313 Kg CO_2eq per kWh), natural gas, including biogas (0.184 Kg CO_2eq per kWh), diesel (2.669 Kg CO_2eq per litre), gasoline (2.331 Kg CO_2eq per litre), liquid petroleum gas (LPG) (1.497 Kg CO_2eq per litre), kerosene (2.532 Kg CO_2eq per litre).

In the case of fuel-wood emissions, carbon stocks per hectare of productive forest per province are taken from the draft baseline scenario annex of the National REDD+ Strategy Version 3 (MICOA, 2010_b). Calculations assume that each Kg of carbon burned and released into the atmosphere combines with 2.667 Kg of oxygen (O_2) to produce 3.667 Kg of CO_2 (Resurgence, 2009).

Where CO_2 emissions are valued it is assumed that each metric ton of CO_2 emission trades at USD 6.10; this value represents an average of prices in 2009 (Bendana 2010). There are many different possible values depending on the choice of carbon markets, specific types of carbon buyers, the type of certification process applied, and general economic performance, amongst other factors. The unit price per ton of CO_2 of USD 6.10 is a conservative valuation that serves at the very least to demonstrate both costs of CO_2 emissions and the potential for carbon market financing as a result of emission reduction measures.

The energy potential from different sources is converted into GWh equivalent, to facilitate comparison, using conversion factors published by the Carbon Trust (2009) as follows: 11.84 kWh per litre of kerosene; 6.98 kWh per litre of LPG; 10.96 kWh per litre of petroleum diesel; 9.61 kWh per litre of petrol. Biodiesel's energy content is 11 per cent lower than petroleum diesel (EIA, 2004); this is taken into account when calculating GWh equivalent of biodiesel, from jatropha. One metric ton of fuel-wood, according to the U.S. Department of Energy, Oak Ridge National Laboratory (ORNL), at 20% moisture, air dry, is equal to approx 15 giga joules (GJ) and one kWh is equal to 3.6 mega joules (MJ). Biogas energy value, assuming approximately 60% methane content, produces 6 kWh per m3 (GTZ, 2010). Solar, wind and hydro power potential are all directly calculated and reported in GWh.

Statistical tests were not possible in any data analysis due to lack of consistency in the methodologies of secondary data. Instead analysis focused on assimilating qualitative findings, and consolidating data from different sources for quantitative analysis. Note that the results of data analysis are not statistically valid.

3.5 Limitations

The terms of reference for this study commissioned by WWF were ambitious considering the short amount of time (2 months) and wide scope of the work (9 major deliverable sections). Study activities were necessarily confined to rapid research and analysis of the topics.

Financial and time resources limitations did not permit collection of primary data. Hence the foundations of this research exercise rest on secondary data from various different sources, each applying different methodologies and statements of varying degrees of uncertainty. At best we can only consider these results as approximations that may help us to understand the major factors affecting the future of energy development pathways and related direct CO_2eq emissions.

The lack of literature on renewable energy resources and their potential in Mozambique limited opportunities to test assumptions and findings as necessary. Research results will have to be used with extra caution and assumptions tested by energy sector actors. None of these results should be used to make executive decisions on installations for renewable energy. In all cases, local, site-specific resource measurement and installation feasibility studies should be undertaken.

The energy pathway scenarios and corresponding per capita tCO2eq emissions estimated in the sections below only account for direct CO_2eq emissions from energy generation, except for fuel-wood emissions which allow for carbon sequestration through the MAI of forests. CO_2eq emissions from other sectors (agriculture, other land-use change, construction, mining, etc.) and phenomena such as wildfires are not included. Hence the CO_2eq emissions impacts from different energy development pathways presented here are only demonstrate part of the national CO_2eq emissions situation.

In order to assess national per capita CO_2eq emissions relative to a target of 0.5 tCO2eq by 2050, a complete life cycle analysis (LCA) of emissions from the energy sector, plus direct emissions and LCA emissions from all other sectors that emit CO_2eq from activities besides energy generation need to be included. The resource limits and scope of this study did not permit a complete assessment of CO_2eq emissions from all sectors.

Uncertainties that could affect many of the projections, conclusions and recommendations contained in this study include the future cost, efficiency and scalability of energy technologies; economic growth variation; social values and consumer preference; consumer purchasing power; Government policies, objectives and incentives; international climate finance mechanisms; international commitments to address energy access; international decisions on climate change remedial action; evolution of CO_2eq accounting methodologies and the attribution of carbon space; amongst many other factors.

Finally, though the geothermal springs were mapped as planned under this study the calculation of geothermal energy potential was not possible because of a lack of data. The most recent national report on geothermal characteristics of Mozambique by Martinelli et al (1995) identified 38 hot springs throughout the country and noted that the most promising sites were in the north and central provinces. However the report by Martinelli et al does not provide the data needed for the calculation of energy potential for each spring, which includes: geothermal area (m^2); rock thickness (m); reservoir temperature (^oC); rock porosity and water saturation steam (fraction); the density of rock (fraction); heat conductivity of rock (kJ/m^{o}C); the density of steam and water (^oC); and energy in the steam and water (kJ).

4. Results

4.1 National energy markets

4.1.1 Population growth

Population growth is the driving market factor, along with income levels, for energy consumption. In 2010 the population of was approximately 22.4 million people, and will reach an estimated 38.9 million people by 2030 (see Table 4.). The rural population in 2010 accounts for 65 per cent of the total population but by 2030 the urban population will reach 61 per cent while the rural population will fall to 39 per cent.

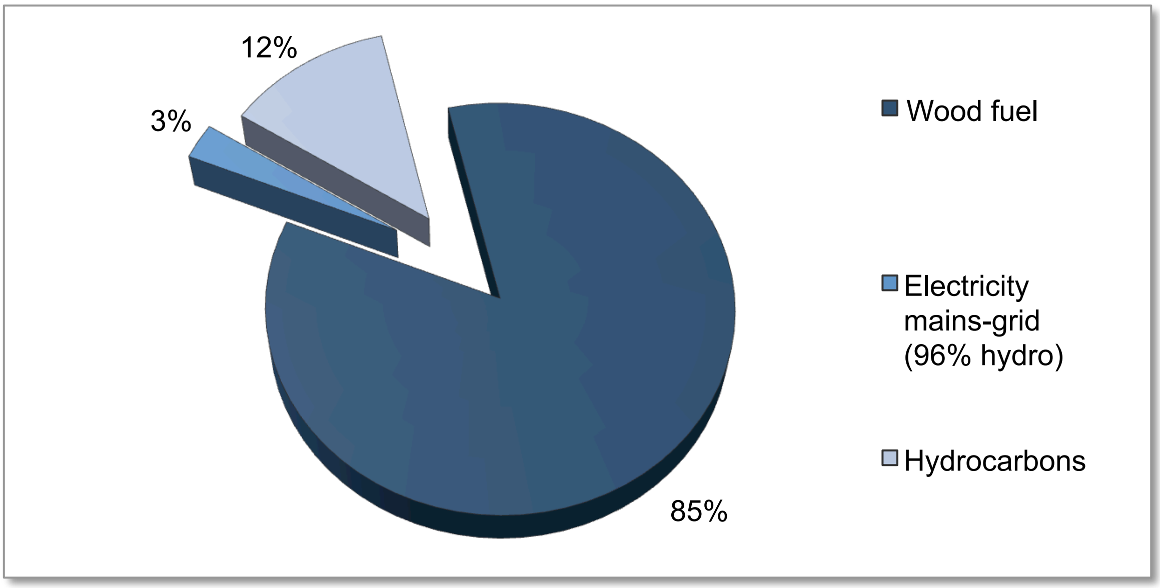
4.1.2 Energy consumption

Energy consumption in 2010 is dominated by wood-fuels, accounting for an estimated 85 per cent of total energy consumption, followed by hydrocarbons (diesel, petrol, kerosene, Jet A1, LPG, and natural gas) and finally mains-grid electricity (based on hydro power) (see Figure 1). National consumption of hydrocarbons may be lower than reported here because some traders, taking advantage of local fuel subsidies, may illegally export a certain amount of the diesel and petrol sold in Mozambique to neighbouring countries. Hence wood-fuels may represent an even greater part of total energy consumption than estimated here.

Table 4. Population growth and rural – urban breakdown from 2010 to 2030

Year	Population				
	Total	Rural		Urban	
		No's	%	No's	%
2010	**22,404,232**	**14,562,751**	**65%**	**7,841,481**	**35%**
2011	23,049,621	14,982,254	65%	8,067,367	35%
2012	23,695,010	14,968,939	63%	8,726,071	37%
2013	24,358,471	15,005,136	62%	9,353,335	38%
2014	25,040,508	15,031,624	60%	10,008,884	40%
2015	**25,741,642**	**15,047,832**	**58%**	**10,693,810**	**42%**
2016	26,462,408	15,053,162	57%	11,409,246	43%
2017	27,203,355	15,046,994	55%	12,156,362	45%
2018	27,965,049	15,028,678	54%	12,936,372	46%
2019	28,748,071	14,997,540	52%	13,750,531	48%
2020	**29,553,017**	**14,952,875**	**51%**	**14,600,142**	**49%**
2021	30,380,501	14,893,952	49%	15,486,550	51%
2022	31,231,155	14,820,005	47%	16,411,150	53%
2023	32,105,628	14,730,241	46%	17,375,387	54%
2024	33,004,585	14,623,831	44%	18,380,755	56%
2025	**33,928,714**	**14,499,913**	**43%**	**19,428,800**	**57%**
2026	34,878,718	14,357,591	41%	20,521,126	59%
2027	35,855,322	14,195,931	40%	21,659,390	60%
2028	36,859,271	14,013,962	38%	22,845,309	62%
2029	37,891,330	13,810,673	36%	24,080,657	64%
2030	**38,952,288**	**15,262,214**	**39%**	**23,690,073**	**61%**

Figure 1. National energy consumption percentages by energy source in 2010



Total energy consumption for Mozambique in 2010 is estimated to be over 114,000 GWh (see Table 5). The projections from 2010 to 2030 assume that the shares of energy by source in 2010 remain constant. Total energy consumption in 2030 is estimated to exceed 244,000 GWh.

Table 5. National energy consumption from all energy sources from 2010 to 2030

Energy consumption (GWh)				
Year	**Wood fuel**	**Electricity mains-grid**	**Hydrocarbons**	**Total**
2010	**97,248**	**3,103**	**13,650**	**114,001**
2011	100,050	3,348	14,579	117,977
2012	103,271	3,544	15,571	122,387
2013	106,595	3,814	16,986	127,395
2014	110,024	4,090	19,018	133,131
2015	**113,561**	**4,317**	**21,427**	**139,305**
2016	117,210	4,611	22,718	144,539
2017	120,974	4,850	24,097	149,922
2018	124,857	5,175	25,570	155,603
2019	128,863	5,421	27,143	161,427
2020	**132,995**	**5,758**	**28,824**	**167,577**
2021	137,258	6,089	30,618	173,966
2022	141,655	6,451	32,535	180,641
2023	146,191	6,807	34,582	187,580
2024	150,870	7,168	36,769	194,807
2025	**155,696**	**7,524**	**39,104**	**202,324**
2026	160,674	7,886	41,599	210,158
2027	165,809	8,241	44,263	218,313
2028	171,105	8,573	47,108	226,786
2029	176,568	8,904	50,147	235,619
2030	**181,908**	**9,216**	**53,393**	**244,518**

Fuelwood consumption is estimated to grow from over 32 million m^3 in 2010 to over 61 million m^3 in 2030 (see Tables 6, 7, 8 and 9). In 2010 Nampula is the province with the highest consumption levels, 6.4 million m^3, followed by Zambezia with 5.9 million m^3. The breakdown of wood versus charcoal use in 2010 is based on INE (2010) percentages of rural (wood consumption) and urban (charcoal consumption) with the highest charcoal consumption levels found in Nampula, Maputo City and Maputo Province.

Table 6. Fuel-wood consumption and population by province 2010

Province	Population	Wood fuel consumption					
		Wood		Charcoal		Per capita consum-ption (m3/ year)	Total consum-ption ('000 m3)
		Pop. %	Quantity ('000 m3)	Pop. %	Quantity ('000 m3)		
C. Delgado	1,714,797	78%	1,796	22%	653	1.43	2,449
Gaza	1,283,983	74%	1,288	26%	561	1.44	1,849
Inhambane	1,362,982	77%	1,417	23%	533	1.43	1,950
Manica	1,625,221	76%	1,657	25%	677	1.44	2,333
Maputo City	1,145,129	-	-	100%	1,947	1.70	1,947
Maputo Prov.	1,404,175	31%	588	69%	1,647	1.59	2,235
Nampula	4,402,969	70%	4,149	30%	2,260	1.46	6,409
Niassa	1,375,533	77%	1,426	23%	543	1.43	1,969
Sofala	1,805,598	63%	1,531	37%	1,142	1.48	2,673
Tete	2,077,844	86%	2,424	14%	480	1.40	2,904
Zambezia	4,206,002	81%	4,599	19%	1,359	1.42	5,958
Totals	**22,404,232**	**65%**	**20,874**	**35%**	**11,801**	**1.46**	**32,675**

Table 7. Fuel-wood consumption and population by province 2020

Province	Population	Wood fuel consumption					
		Wood		Charcoal		Per capita consum-ption (m3/ year)	Total consum-ption ('000 m3)
		Pop. %	Quantity ('000 m3)	Pop. %	Quantity ('000 m3)		
C. Delgado	2,261,957	59%	1,814	41%	1,561	1.49	3,375
Gaza	1,693,679	58%	1,318	42%	1,219	1.50	2,537
Inhambane	1,797,885	59%	1,434	41%	1,250	1.49	2,685
Manica	2,143,800	58%	1,687	42%	1,520	1.50	3,207
Maputo City	1,510,519	-	-	100%	2,568	1.70	2,568
Maputo Prov	1,852,221	31%	775	69%	2,173	1.59	2,948
Nampula	5,807,876	55%	4,336	45%	4,414	1.51	8,749
Niassa	1,814,440	59%	1,445	41%	1,265	1.49	2,710
Sofala	2,381,732	52%	1,660	48%	1,959	1.52	3,619
Tete	2,740,847	64%	2,369	36%	1,676	1.48	4,045
Zambezia	5,548,062	61%	4,583	39%	3,660	1.49	8,243
Totals	**29,553,017**	**51%**	**21,421**	**49%**	**23,265**	**1.52**	**44,686**

Table 8. Fuel-wood consumption and population by province 2030

Province	Population	Wood fuel consumption					
		Wood		Charcoal		Per capita consum-ption (m3/ year)	Total consum-ption ('000 m3)
		Pop. %	Quantity ('000 m3)	Pop. %	Quantity ('000 m3)		
C. Delgado	2,981,368	40%	1,610	60%	3,041	1.56	4,651
Gaza	2,232,349	40%	1,205	60%	2,277	1.56	3,482
Inhambane	2,369,698	40%	1,280	60%	2,417	1.56	3,697
Manica	2,825,630	40%	1,526	60%	2,882	1.56	4,408
Maputo City	1,990,936	0%	-	100%	3,385	1.70	3,385
Maputo Prov	2,441,316	31%	1,022	69%	2,864	1.59	3,885
Nampula	7,655,058	40%	4,134	60%	7,808	1.56	11,942
Niassa	2,391,519	40%	1,291	60%	2,439	1.56	3,731
Sofala	3,139,236	40%	1,695	60%	3,202	1.56	4,897
Tete	3,612,567	40%	1,951	60%	3,685	1.56	5,636
Zambezia	7,312,610	40%	3,949	60%	7,459	1.56	11,408
Totals	**38,952,288**	**36%**	**19,663**	**64%**	**41,459**	**1.57**	**61,121**

Table 9. National fuel-wood consumption from 2010 to 2030

Year	Wood fuel consumption								
	Wood		Charcoal		Per capita consum-ption (m3/ year)	Total consum-ption ('000 m3)	Area cut ('000 ha/ year)	Total consum-ption ('000 metric tons)	Wood fuel consum-ption in GWh ('000)
	Pop. %	Quantity ('000 m3)	Pop. %	Quantity ('000 m3)					
2010	**65%**	**20,874**	**35%**	**11,801**	**1.46**	**32,675**	**984**	23,340	**97**
2011	65%	21,475	35%	12,141	1.46	33,617	1,013	24,012	100
2012	63%	21,532	37%	13,167	1.47	34,699	1,045	24,785	103
2013	62%	21,575	38%	14,241	1.47	35,816	1,078	25,583	107
2014	60%	21,604	40%	15,364	1.48	36,968	1,112	26,406	110
2015	**58%**	**21,617**	**42%**	**16,540**	**1.49**	**38,156**	**1,147**	**27,255**	**114**
2016	57%	21,614	43%	17,769	1.49	39,382	1,183	28,130	117
2017	55%	21,594	45%	19,053	1.50	40,647	1,220	29,034	121
2018	54%	21,556	46%	20,396	1.50	41,952	1,259	29,966	125
2019	52%	21,499	48%	21,800	1.51	43,298	1,298	30,927	129
2020	**51%**	**21,421**	**49%**	**23,265**	**1.52**	**44,686**	**1,339**	**31,919**	**133**
2021	49%	21,323	51%	24,796	1.52	46,119	1,381	32,942	137
2022	47%	21,202	53%	26,394	1.53	47,596	1,425	33,997	142
2023	46%	21,058	54%	28,063	1.53	49,120	1,470	35,086	146
2024	44%	20,889	56%	29,804	1.54	50,692	1,516	36,209	151
2025	**43%**	**20,694**	**57%**	**31,620**	**1.55**	**52,314**	**1,564**	**37,367**	**156**
2026	41%	20,471	59%	33,515	1.55	53,986	1,613	38,562	161
2027	40%	20,221	60%	35,491	1.56	55,712	1,663	39,794	166
2028	38%	19,940	62%	37,552	1.56	57,491	1,716	41,065	171
2029	36%	19,627	64%	39,700	1.57	59,327	1,770	42,376	177
2030	**36%**	**19,663**	**64%**	**41,459**	**1.57**	**61,121**	**1,822**	**43,658**	**182**

A total of 643 million litres of diesel, 251 million litres of petrol and 349 million litres of natural gas were consumed in 2010. National hydrocarbon consumption growth projections suggest that consumption levels will approximately quadruple by 2030 (see Table 11).

Table 10. Hydrocarbon consumption by fuel type 2010 to 2030 in GWh equivalent

Year	National hydrocarbons consumption electricity equivalent (GWh)						
	Diesel	Petrol	Jet A1	Kerosene	LPG	N. Gas	Totals
2010	**7,054**	**2,415**	**947**	**417**	**212**	**2,603**	**13,650**
2011	7,534	2,580	1,012	446	227	2,781	14,579
2012	8,047	2,755	1,081	476	242	2,970	15,571
2013	8,595	2,943	1,154	508	259	3,527	16,986
2014	9,180	3,143	1,233	543	276	4,643	19,018
2015	9,804	3,357	1,317	580	295	6,074	21,427
2016	10,471	3,585	1,406	619	315	6,321	22,718
2017	11,184	3,829	1,502	662	337	6,584	24,097
2018	11,945	4,090	1,604	707	360	6,865	25,570
2019	12,758	4,368	1,713	755	384	7,165	27,143
2020	**13,626**	**4,665**	**1,830**	**806**	**410**	**7,486**	**28,824**
2021	14,553	4,983	1,954	861	438	7,829	30,618
2022	15,544	5,322	2,087	919	468	8,195	32,535
2023	16,601	5,684	2,229	982	500	8,586	34,582
2024	17,731	6,071	2,381	1,049	534	9,003	36,769
2025	18,938	6,484	2,543	1,120	570	9,449	39,104
2026	20,226	6,925	2,716	1,196	609	9,925	41,599
2027	21,603	7,397	2,901	1,278	650	10,434	44,263
2028	23,073	7,900	3,099	1,365	695	10,977	47,108
2029	24,643	8,437	3,309	1,458	742	11,558	50,147
2030	**26,320**	**9,012**	**3,535**	**1,557**	**792**	**12,178**	**53,393**

Table 11. National hydrocarbon consumption by fuel type 2010 to 2030 in litres

Year	Hydrocarbon consumption in litres						
	Diesel ('000)	Gasoline ('000)	Jet A-1 ('000)	Kerosene (lighting) ('000)	LPG (cooking) ('000)	N. Gas ('000)	Totals
2010	**643,639**	**251,331**	**80,013**	**35,243**	**30,430**	**349,435**	**1,390,090**
2011	687,439	268,434	85,458	37,641	32,501	373,231	1,484,704
2012	734,219	286,701	91,273	40,203	34,713	398,648	1,585,757
2013	784,183	306,211	97,484	42,939	37,075	473,415	1,741,307
2014	837,547	327,049	104,118	45,861	39,598	623,211	1,977,383
2015	**894,542**	**349,305**	**111,203**	**48,981**	**42,293**	**815,276**	**2,261,599**
2016	955,416	373,075	118,771	52,315	45,171	848,356	2,393,103
2017	1,020,432	398,463	126,853	55,875	48,244	883,690	2,533,557
2018	1,089,873	425,578	135,485	59,677	51,527	921,429	2,683,570
2019	1,164,039	454,539	144,705	63,738	55,034	961,739	2,843,794
2020	**1,243,252**	**485,470**	**154,552**	**68,075**	**58,779**	**1,004,793**	**3,014,923**
2021	1,327,856	518,507	165,070	72,708	62,779	1,050,780	3,197,700
2022	1,418,217	553,791	176,303	77,656	67,051	1,099,899	3,392,917
2023	1,514,727	591,477	188,300	82,940	71,614	1,152,362	3,601,421
2024	1,617,805	631,727	201,114	88,584	76,487	1,208,398	3,824,116
2025	**1,727,897**	**674,716**	**214,800**	**94,612**	**81,692**	**1,268,250**	**4,061,969**
2026	1,845,481	720,631	229,417	101,051	87,251	1,332,178	4,316,010
2027	1,971,066	769,670	245,029	107,927	93,189	1,400,460	4,587,342
2028	2,105,198	822,047	261,704	115,272	99,530	1,473,392	4,877,142
2029	2,248,457	877,987	279,513	123,116	106,303	1,551,290	5,186,667
2030	**2,401,466**	**937,734**	**298,533**	**131,494**	**113,537**	**1,634,493**	**5,517,258**

The largest mains-grid electricity consumers are medium to high voltage users (1,201 GWh in 2010) and domestic users (1,192 GWh in 2010). Total mains-grid electricity consumption is expected to increase from 3,103 GWh in 2010 to 9,216 GWh in 2030 (see Table 12).

According to the UN Secretary-General's Advisory Group on Energy and Climate Change (AGECC 2010, pp 6.) each person should have access to at least 100 kWh of modern energy services. Taking 100 kWh as a target, total annual off-grid energy needs amount to approximately 1,952 GWh in 2010, reaching 3,047 GWh in 2030 (see Table 12). Assuming there is sufficient consumer purchasing power and willingness to pay the off-grid population constitutes a significant energy market for targeted electricity services.

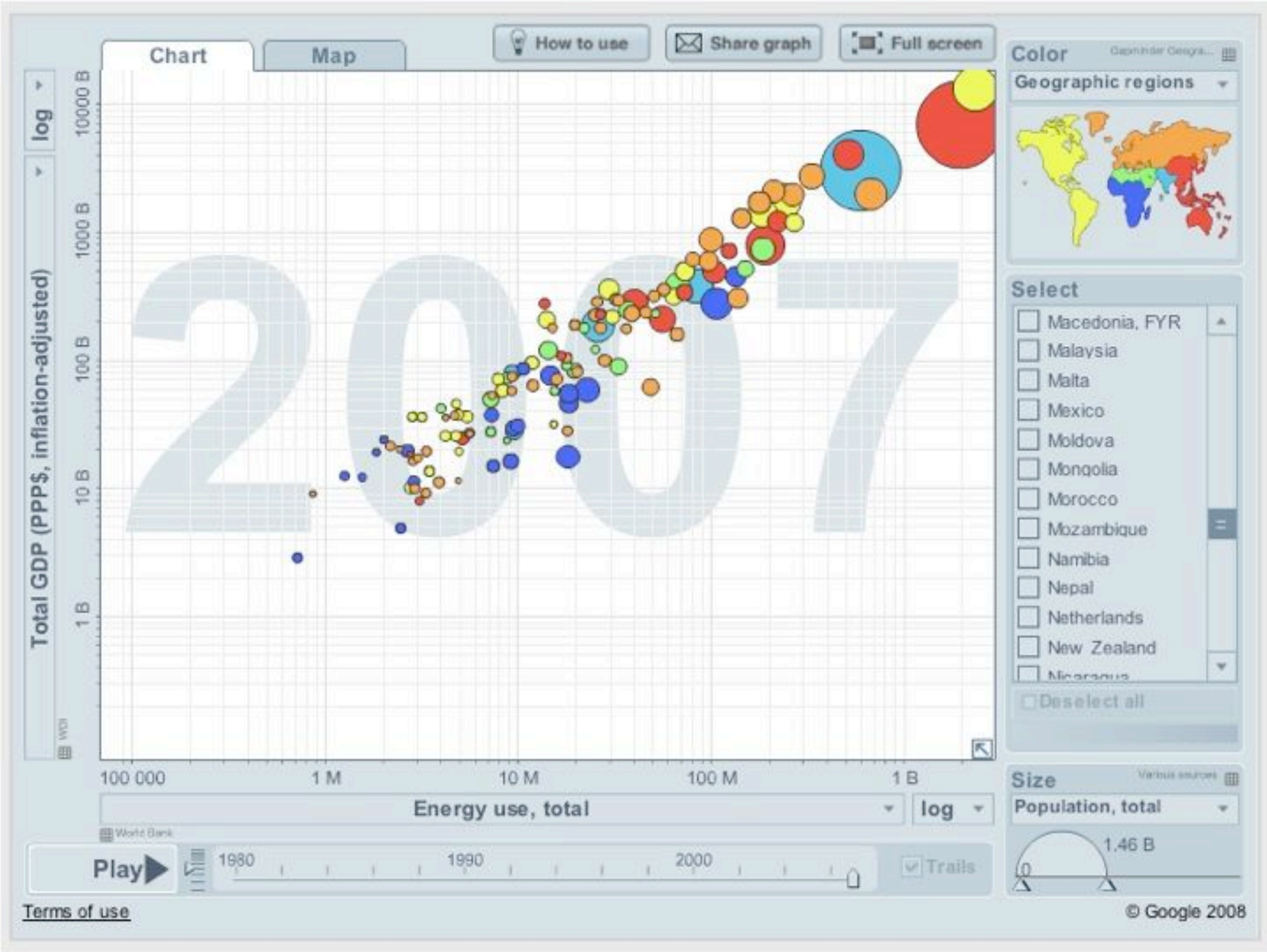
Table 12. Electricity consumption by consumer type from 2010 to 2030

Year	Grid Electricity Demand Projections (GWh/ year)									
	Mains-grid Demand by Consumer Type								Off-Grid Needs	Total Grid & Off-Grid
	Domestic	General Commercial	Agriculture	LV Big Consumers	Med. & High Voltage	Public Lighting	EDM Internal	Total		
2010	**1,192**	**388**	**0.24**	**228**	**1,201**	**78**	**16**	**3,103**	**1,952**	**5,055**
2011	1,286	419	0.26	246	1,296	84	17	3,348	1,988	5,336
2012	1,361	444	0.28	260	1,372	89	18	3,544	2,025	5,569
2013	1,465	478	0.30	280	1,476	96	20	3,814	2,063	5,877
2014	1,571	512	0.32	300	1,583	103	21	4,090	2,103	6,193
2015	**1,658**	**540**	**0.34**	**317**	**1,671**	**108**	**22**	**4,317**	**2,146**	**6,462**
2016	1,771	577	0.36	338	1,785	116	24	4,611	2,190	6,801
2017	1,863	607	0.38	356	1,877	122	25	4,850	2,236	7,086
2018	1,988	648	0.41	380	2,003	130	27	5,175	2,284	7,459
2019	2,082	679	0.43	398	2,098	136	28	5,421	2,334	7,755
2020	**2,212**	**721**	**0.45**	**422**	**2,229**	**144**	**30**	**5,758**	**2,387**	**8,145**
2021	2,339	762	0.48	447	2,357	153	31	6,089	2,441	8,530
2022	2,478	808	0.51	473	2,497	162	33	6,451	2,498	8,949
2023	2,615	852	0.54	499	2,635	171	35	6,807	2,558	9,364
2024	2,754	897	0.56	526	2,775	180	37	7,168	2,620	9,788
2025	**2,890**	**942**	**0.59**	**552**	**2,912**	**189**	**39**	**7,524**	**2,684**	**10,208**
2026	3,029	987	0.62	578	3,052	198	40	7,886	2,751	10,637
2027	3,166	1,032	0.65	604	3,190	207	42	8,241	2,821	11,062
2028	3,293	1,073	0.67	629	3,318	215	44	8,573	2,893	11,466
2029	3,420	1,115	0.70	653	3,446	223	46	8,904	2,968	11,872
2030	**3,540**	**1,154**	**0.72**	**676**	**3,567**	**231**	**47**	**9,216**	**3,047**	**12,263**

4.1.3 Energy use and Gross Domestic Product and Purchasing Power Parity

In addition to rising population numbers, increased levels of Gross Domestic Product (GDP) in purchasing power parity terms (PPP) also drive energy use. Evidence presented by Gapminder (2008) suggests that the higher the GDP PPP of a country, the higher their energy consumption (see Figure 2). Therefore it would be prudent to consider the above energy consumption levels as conservative estimates in the absence of GDP PPP growth factors. The figures presented by Gapminder online (http://www.gapminder.org/data/) for GDP and energy use show a positive correlation between rising PPP and energy consumption levels from 1980 to 2007. As each country's level of GDP PPP rises so too does their energy use.

Figure 2. Energy use and GDP in PPP terms worldwide in 2007



Source: Gapminder 2008.

4.1.4 Access to electricity services

In 2010 it is estimated that 13 per cent of the population, totalling some 2.8 million people have access to electricity, while 87 per cent remain off-grid (see Tables 13, 14, 15 and 16). The provinces of Cabo Delgado and Zambezia have the lowest electricity access rates with 5 per cent each, while the balance of their populations, 95 per cent, remain off-grid i.e. without access to electricity services.

By the year 2030 it is estimated that electricity access in absolute terms will increase by approximately 350 per cent, from 2.8 million people in 2010, to 8.4 million people in 2030. In national population percentage terms, electricity access will rise from 13 per cent in 2010, to 22 per cent by 2030. Despite this significant projected increase in numbers of people with access to electricity some 30.4 million people are still expected to remain off-grid by 2030, representing 78 per cent of the population.

Table 13. Electricity access per province in 2010

Province	Population Access to Electricity 2010				
	On-Grid		Off-Grid		Total Population
	Pop. No's	*%*	*Pop. No's*	*%*	
Cabo Delgado	87,996	5%	1,626,801	95%	1,714,797
Gaza	142,344	11%	1,141,639	89%	1,283,983
Inhambane	231,499	17%	1,131,483	83%	1,362,982
Manica	117,217	7%	1,508,004	93%	1,625,221
Maputo	1,265,336	50%	1,283,967	50%	2,549,303
Nampula	390,603	9%	4,012,365	91%	4,402,969
Niassa	81,832	6%	1,293,701	94%	1,375,533
Sofala	235,370	13%	1,570,228	87%	1,805,598
Tete	124,822	6%	1,953,023	94%	2,077,844
Zambezia	209,497	5%	3,996,506	95%	4,206,002
Totals	**2,886,516**	**13%**	**19,517,716**	**87%**	**22,404,232**

Table 14. Electricity access per province in 2020

Province	Population Access to Electricity 2020				
	On-Grid		Off-Grid		Total Pop. No's
	Pop. No's	*%*	*Pop. No's*	*%*	
Cabo Delgado	173,355	8%	2,088,603	92%	2,261,957
Gaza	280,421	17%	1,413,257	83%	1,693,679
Inhambane	456,060	25%	1,341,825	75%	1,797,885
Manica	230,921	11%	1,912,879	89%	2,143,800
Maputo	2,492,747	74%	869,993	26%	3,362,740
Nampula	769,499	13%	5,038,377	87%	5,807,876
Niassa	161,211	9%	1,653,230	91%	1,814,440
Sofala	463,686	19%	1,918,046	81%	2,381,732
Tete	245,903	9%	2,494,944	91%	2,740,847
Zambezia	412,714	7%	5,135,347	93%	5,548,062
Total	**5,686,516**	**19%**	**23,866,501**	**81%**	**29,553,017**

Table 15. Electricity access per province in 2030

Province	Population Access to Electricity 2030				
	On-Grid		Off-Grid		Total Population
	Pop. No's	*%*	*Pop. No's*	*%*	
Cabo Delgado	258,713	9%	2,722,654	91%	2,981,368
Gaza	418,499	19%	1,813,851	81%	2,232,349
Inhambane	680,621	29%	1,689,077	71%	2,369,698
Manica	344,625	12%	2,481,005	88%	2,825,630
Maputo	3,720,158	84%	712,094	16%	4,432,252
Nampula	1,148,395	15%	6,506,663	85%	7,655,058
Niassa	240,590	10%	2,150,929	90%	2,391,519
Sofala	692,001	22%	2,447,235	78%	3,139,236
Tete	366,983	10%	3,245,584	90%	3,612,567
Zambezia	615,932	8%	6,696,678	92%	7,312,610
Totals	**8,486,516**	**22%**	**30,465,772**	**78%**	**38,952,288**

Table 16. National electricity access from 2010 to 2030

Year	EDM Client Growth		Population Access to Electricity				
			On-Grid		Off-Grid		Total Population
	No. Clients	% diff.	Population	%	Population	%	
2010	**824,719**	**11%**	**2,886,516**	**13%**	**19,517,716**	**87%**	**22,404,232**
2011	904,719	10%	3,166,516	14%	19,883,105	86%	23,049,621
2012	984,719	9%	3,446,516	15%	20,248,494	85%	23,695,010
2013	1,064,719	8%	3,726,516	15%	20,631,955	85%	24,358,471
2014	1,144,719	8%	4,006,516	16%	21,033,992	84%	25,040,508
2015	**1,224,719**	**7%**	**4,286,516**	**17%**	**21,455,126**	**83%**	**25,741,642**
2016	1,304,719	7%	4,566,516	17%	21,895,892	83%	26,462,408
2017	1,384,719	6%	4,846,516	18%	22,356,839	82%	27,203,355
2018	1,464,719	6%	5,126,516	18%	22,838,533	82%	27,965,049
2019	1,544,719	5%	5,406,516	19%	23,341,555	81%	28,748,071
2020	**1,624,719**	**5%**	**5,686,516**	**19%**	**23,866,501**	**81%**	**29,553,017**
2021	1,704,719	5%	5,966,516	20%	24,413,985	80%	30,380,501
2022	1,784,719	5%	6,246,516	20%	24,984,639	80%	31,231,155
2023	1,864,719	4%	6,526,516	20%	25,579,112	80%	32,105,628
2024	1,944,719	4%	6,806,516	21%	26,198,069	79%	33,004,585
2025	**2,024,719**	**4%**	**7,086,516**	**21%**	**26,842,198**	**79%**	**33,928,714**
2026	2,104,719	4%	7,366,516	21%	27,512,202	79%	34,878,718
2027	2,184,719	4%	7,646,516	21%	28,208,806	79%	35,855,322
2028	2,264,719	4%	7,926,516	22%	28,932,755	78%	36,859,271
2029	2,344,719	4%	8,206,516	22%	29,684,814	78%	37,891,330
2030	**2,424,719**	**3%**	**8,486,516**	**22%**	**30,465,772**	**78%**	**38,952,288**

4.1.5 Energy consumption expenditures

The total energy consumption expenditures in 2010, including all fuel-wood use, exceed USD 2.16 billion. Note firewood is often *not* considered to reflect financial transactions because in some areas it thought to be acquired by the rural population without cash exchanges; this may not be the case for areas that are scarce in firewood supplies or where population density is higher. Firewood is often deemed to be an important income source in rural economies. However charcoal generally accepted as a commodity that *is* traded in financial transactions.

Fuel wood (firewood and charcoal) accounts for approximately 50 per cent of all energy consumption expenditures; with a total value exceeding USD 1.2 billion (see Table 17). However, fuel-wood is not integrated in the formal economy and thus represents massive fiscal losses for the State. The expenditures on charcoal, although confined to the informal economy, represent financial transactions of approximately USD 467 million.

The second most important expenditure after fuel-wood is diesel, amounting to USD 470 million.

The true market values of expenditures on hydrocarbons, especially diesel, gasoline and kerosene, are likely to be much higher than reported here because the fuel prices used for calculations are subsidised by the Government.

Table 17. Energy consumption expenditures in 2010

Energy Consumption Expenditures in 2010						
Source	**Units**	**Unit Cost (USD)**	**Quantity Consumed**	**Total Expenditures (USD)**	**Cost per kWh (USD)**	**Energy GWh equivalent**
Diesel	Litre	0.73	643,638,797	$470,459,733	$0.07	7,054
Gasoline	Litre	0.73	251,330,768	$183,000,215	$0.08	2,415
Kerosene	Litre	0.51	35,242,990	$17,874,804	$0.04	417
Jet A1	Litre	0.63	80,012,678	$50,007,924	$0.05	947
LPG	Litre	1.28	30,430,216	$38,922,149	$0.18	212
Electricity	kWh	0.08	3,102,792,000	$248,223,360	$0.08	3,103
Natural gas	Litre	0.94	349,434,851	$327,595,173	$0.13	2,603
Firewood	m^3	39.60	20,874,010	$826,610,795	$0.01	63,211
Charcoal	m^3	39.60	11,801,403	$467,335,574	$0.01	34,037
Totals				**$2,162,694,152**		**114,001**

4.2 Renewable energy mapping and quantification

4.2.1 Renewable energy mapping

Please see Appendices for Google Earth renewable energy mapping of solar, wind, biofuels, geothermal, and small hydro resources. All maps present information on the respective renewable energy zones or sites, and the electricity transport grid, population density, provincial borders and provincial capitals, forest cover, protected areas and main road transport links.

4.2.3 Renewable energy quantification

Biogas

The energy content of biogas resources, essentially methane, could theoretically be developed over time to meet the energy cooking needs of the population. The challenge is to get the right combination of technological efficiency and biogas feedstock, which requires a particular high carbon (C) to nitrogen (N) ratio. Biogas potential was quantified solely on the basis of human excrement, which has a high N to C ratio i.e. not the optimal characteristics as a feedstock, combined with organic bio-waste from daily food preparation.

Total biogas potential in 2010 is estimated at 1.4 million m^3 and could provide as much as 4 million biogas stove burning hours per year (see Table 18). This represents approximately 35 per cent of biogas stove cooking hour requirements to provide a family of four with approximately 2 hours of biogas cooking time per day. Adding other C rich inputs, such as animal dung and municipal organic waste from green areas, could significantly increase the output of biogas from bio-digesters.

Biofuel *jatropha curcas*

The calculation of biofuel *jatropha curcas* (hereafter jatropha) potential is contingent on available land area, the characteristics of the soil and climate, management interventions, genetics of the seed variety, and planting density, amongst many other factors. In order to generate an indicative figure of jatropha potential we have assumed that 5 per cent of agricultural land, according to Marzoli's (2007) classification of land use areas, is dedicated to jatropha production.

Annual potential of jatropha is estimated at 519 thousand litres of jatropha oil, which is equivalent to approximately 462 thousand litres of hydrocarbon diesel (see Table 19). This compares with an annual consumption of diesel in Mozambique of 643 thousand litres in 2010. Assuming diesel demand remains stable at 2010 levels, Mozambique would have to allocate approximately 7 per cent of its agricultural lands to comfortably meet internal needs. At current yield levels, in order to meet growing internal demand for diesel up until 2030, which is projected to reach 2.4 million litres, Mozambique would either have to allocate approximately 27 per cent of all available agricultural lands identified by Marzoli (2007), or open up new agricultural lands probably leading to significant immediate forest loss and related environmental impacts.

Table 18. Biogas cooking energy potential on human excreta and bio-waste

Biogas Cooking Fuel Energy Potential & Needs in 2011						
Province	**Biogas potential / year**				**Biogas cooking needs/ year**	
	Litres of biogas ('000)	**m^3 of biogas**	**GWh**	**Cooking stove burning hours**	**Litres of biogas ('000)**	**Stove burning hours/ family of 4 members**
C. Delgado	109,380	109,380	656	312,514	308,733	882,097
Gaza	81,900	81,900	491	234,000	231,169	660,485
Inhambane	86,939	86,939	522	248,398	245,392	701,123
Manica	103,666	103,666	622	296,190	292,606	836,019
Maputo City	73,043	73,043	438	208,695	206,170	589,058
Maputo P.	89,566	89,567	537	255,905	252,809	722,312
Nampula	280,847	280,848	1,685	802,422	792,715	2,264,902
Niassa	87,739	87,740	526	250,685	247,652	707,579
Sofala	115,171	115,172	691	329,063	325,081	928,806
Tete	132,537	132,537	795	378,678	374,097	1,068,850
Zambezia	268,284	268,284	1,610	766,526	757,253	2,163,582
Totals	**1,429,076**	**1,429,077**	**8,574**	**4,083,076**	**4,033,683**	**11,524,811**

Table 19. Biofuel Jatropha curcas energy potential on 5 per cent of agricultural lands

Jatropha curcas - energy potential on 5% of agricultural lands				
Province	**Area of agricultural lands in 2007 (ha)**	**Potential jatropha/ year**		
		Litres jatropha oil	**Litres diesel equivalent (less 11%)**	**GWh equivalent**
Cabo Delgado	592,000	51,791,250	46,094,213	505
Gaza	416,000	36,417,500	32,411,575	355
Inhambane	496,000	43,435,000	38,657,150	424
Manica	274,000	23,948,750	21,314,388	234
Maputo Prov	250,000	21,892,500	19,484,325	214
Nampula	1,536,000	134,365,000	119,584,850	1,311
Niassa	683,000	59,762,500	53,188,625	583
Sofala	377,000	32,970,000	29,343,300	322
Tete	387,000	33,871,250	30,145,413	330
Zambezia	923,000	80,788,750	71,901,988	788
Totals	**5,934,000**	**519,242,500**	**462,125,825**	**5,065**

Biomass

Mozambique had over 26.9 million hectares in 2007 (Marzoli 2007, pp. 16) with a corresponding volume of over 1 billion m^3. The mean annual increment (MAI) of productive forests in 2011 is estimated to exceed 35.5 million m^3, corresponding to approximately 105 thousand GWh of energy potential (see Table 20).

Trees harvested for fuel-wood are not being replanted, and demand is growing with rising population levels. As a result, in 2014 the forest MAI is surpassed by annual consumption of 36.9 million m^3. Hence 2014 can be viewed as the year in which forest volumes peak, after which forest volumes begin to decline (see Table 21). At this point fuel-wood biomass supplies from productive forest resources enter negative net MAI rates, and without remedial action, begin the trend towards ultimate decimation of forests. Overall area of forest cover is already in decline at the time this study was completed; the reason that total forest volumes only begin decline later, in 2014, is due to the fact that the forests in different provinces have different MAI rates and volumes per ha leading to a delay in the net effect on overall forest volume reductions.

Table 20. Biomass energy potential of estimated MAI of productive forests in 2011

Province	Biomass GWh energy potential of productive forests' MAI						
	Area of forest cover ('000 ha)	Volume per ha (m^3)	Total volume of forests ('000 m^3)	Rate of MAI forest volume (m^3/ ha/ year)	MAI volume of productive forests ('000 m^3/ year)	MAI mass of productive forests (tons/ year)	GWh potential of MAI
C. Delgado	3,321	49	162,417	1.28	4,248	3,034,337	12,643
Gaza	2,263	20	45,266	0.41	937	669,296	2,789
Inhambane	1,282	25	32,169	0.65	828	591,385	2,464
Manica	1,961	42	81,977	1.20	2,346	1,675,395	6,981
Maputo P.	179	15	2,638	0.58	104	74,227	309
Nampula	1,968	41	81,481	1.16	2,275	1,625,120	6,771
Niassa	7,146	30	215,109	1.57	11,241	8,029,586	33,457
Sofala	1,344	48	64,925	1.19	1,597	1,140,644	4,753
Tete	3,367	36	122,206	0.90	3,040	2,171,432	9,048
Zambezia	4,319	58	249,640	2.08	8,962	6,401,419	26,673
Totals	**26,777**	**384**	**1,050,362**	**11**	**35,578**	**25,412,841**	**105,887**

Table 21. Biomass availability of productive forests from 2010 to 2030

Year	Population	Available productive forest resources (fuel wood supply)		Total consumption ('000 m3)	Balance of wood fuel resources (supply less consumption)	
		Area ('000 ha)	Volume ('000 m3)		Area ('000 ha)	Volume ('000 m3)
2010	**22,404,232**	**26,838**	**1,047,808**	**32,675**	**26,777**	**1,050,362**
2011	23,049,621	26,777	1,050,362	33,617	26,694	1,052,323
2012	23,695,010	26,694	1,052,323	34,699	26,587	1,053,545
2013	24,358,471	26,587	1,053,545	35,816	26,453	1,053,982
2014	25,040,508	26,453	1,053,982	36,968	26,292	1,053,588
2015	**25,741,642**	**26,292**	**1,053,588**	**38,156**	**26,101**	**1,052,316**
2016	26,462,408	26,101	1,052,316	39,382	25,880	1,050,116
2017	27,203,355	25,880	1,050,116	40,647	25,627	1,046,934
2018	27,965,049	25,627	1,046,934	41,952	25,339	1,042,716
2019	28,748,071	25,339	1,042,716	43,298	25,017	1,037,407
2020	**29,553,017**	**25,017**	**1,037,407**	**44,686**	**24,656**	**1,030,946**
2021	30,380,501	24,656	1,030,946	46,119	24,256	1,023,273
2022	31,231,155	24,256	1,023,273	47,596	23,816	1,014,323
2023	32,105,628	23,816	1,014,323	49,120	23,332	1,004,031
2024	33,004,585	23,332	1,004,031	50,692	22,802	992,327
2025	**33,928,714**	**22,802**	**992,327**	**52,314**	**22,225**	**979,139**
2026	34,878,718	22,225	979,139	53,986	21,599	964,392
2027	35,855,322	21,599	964,392	55,712	20,920	948,010
2028	36,859,271	20,920	948,010	57,491	20,187	929,911
2029	37,891,330	20,187	929,911	59,327	19,398	910,011
2030	**38,952,288**	**19,398**	**910,011**	**61,121**	**18,551**	**888,324**

Solar

Mozambique has significant solar potential in all provinces of the country. According to Cuamba et al (2006, pp. 79) the highest global solar radiation levels were recorded in Pemba, Cabo Delgado Province, and Maniquenique, Gaza Province, 2,190 kWh/m2 and 2,154 kWh/m2 respectively. The study completed by Cuamba et al (2006) relied on solar radiation data collected from weather stations in only one location per province, rather than averages from multiple locations or mapped models. The results from the Global Environment Facility (GEF) sponsored project, with support from the United Nations Environmental Programme (UNEP) and other partners, for a Solar Wind Energy Resource Assessment (SWERA, 2005) produced solar annual average direct normal maps at a resolution of 40 Km for Africa from the National Renewable Energy Laboratory (NREL). The SWERA (2005) maps indicate that there are zones of global horizontal solar radiation in the interior of Gaza, Inhambane, and Tete, and in the northern parts of Niassa and Cabo Delgado that may rival or even exceed the highest weather station recordings from Pemba.

Solar photovoltaic (PV) energy potential is calculated on the basis of 5 per cent of urban lands availability and 5 per cent of bare lands availability to be covered with solar PV panels. The projected total energy potential for these land areas is estimated to 15,815 GWh, which is sufficient to meet all projected mains-grid and off-grid electricity needs of 12,263 GWh up until 2030 (see Table 22).

Solar thermal water heating potential is calculated on the basis of an allocation of 0.55 per cent of urban lands, and is estimated to generate up to 944 GWh of energy (see Table 23). The domestic mains grid electricity needs are estimated to reach 3,540 GWh by 2030, of which approximately 25 per cent (885 GWh) is required for water heating purposes. Thus it is conceivable that with solar thermal installations covering only 0.55 per cent of urban areas, for example roof tops, water heating needs could be satisfied without resorting to electricity supply. Solar thermal water heating essentially off-sets demand by negating the need for additional electricity generation capacity.

Table 22. Solar PV energy potential on 5 per cent of urban lands, and bare lands

Province	**Solar PV Energy Potential**					
	Solar kWh / m^2/ year	**Area of urban/ built up land-cover ('000 ha)**	**Area of bare land cover ('000 ha)**	**Urban lands solar energy potential** (5% of urban land cover) **(GWh)**	**Bare lands solar energy potential** (5% of bare land cover) **(GWh)**	**Total energy potential (GWh)**
Cabo Delgado	2,190	196	43	2,146	470	2,616
Gaza	2,154	19	13	209	144	353
Inhambane	1,916	59	35	567	338	905
Manica	2,117	8	45	83	474	557
Maputo City	1,935	35	NA	336	NA	336
Maputo Prov.	1,916	5	11	49	101	149
Nampula	1,916	158	275	1,515	2,639	4,153
Niassa	1,898	64	71	605	671	1,275
Sofala	2,081	11	33	109	345	455
Tete	2,008	40	120	398	1,205	1,603
Zambezia	2,008	255	85	2,564	848	3,412
Totals		**850**	**731**	**8,580**	**7,235**	**15,815**

Table 23. Solar thermal H_2O heating potential using 0.55 per cent of urban lands

Province	**Solar Thermal H2O Energy Potential/ Supply**		
	Solar kWh / m^2/ year	**Area of urban/ built up land-cover ('000 ha)**	**Urban lands solar thermal potential** (0.55% of urban land cover) **(GWh)**
Cabo Delgado	2,190	196	236
Gaza	2,154	19	23
Inhambane	1,916	59	62
Manica	2,117	8	9
Maputo City	1,935	35	37
Maputo Prov	1,916	5	5
Nampula	1,916	158	167
Niassa	1,898	64	66
Sofala	2,081	11	12
Tete	2,008	40	44
Zambezia	2,008	255	282
Totals		**850**	**944**

Wind
Under this assessment zones with wind speeds estimated to exceed 6 m/s at a height of 10m were included for assessment of wind energy potential based on a wind atlas assessment by Pinto (2007) and a wind resource energy potential study by Sinnott (2010).

The total maximum average energy potential of all wind zones is estimated to reach 24,158 GWh, which is equivalent to approximately double of all projected mains-grid and off-grid electricity needs of 12,263 GWh up until 2030 (see Table 24).

The highest wind speeds of 8.51 m/s at a hub height of 50m, accounting for wind shear effect and roughness, were mainly found along costal areas in Zambezia, Cabo Delgado, Sofala and Nampula. The biggest area amongst the wind resource zones was identified in Zambezia (see Appendix ‘Wind Resource Maps’, reference: W10a) with 9,710 GWh potential, enough to satisfy mains-grid consumption needs up until 2030. The second most important wind resource zone was identified in Sofala (see Appendix ‘Wind Resource Maps’, reference: W09a) with 3,272 GWh potential.

Only two provinces (excluding Maputo City), namely Tete and Niassa, were identified as wind resource poor i.e. no areas were identified with at least 6 m/s at hub height.

Table 24. Wind energy potential of zones over 6 m/s wind speeds at 10m height

Province	Map ref's of prime wind zones	Wind zone area (Km^2)	No. of turbines	Installed kW power (Gamesa 850kW /turbine)	Wind speed m/s at hub height (50m) – including wind shear effect and roughness	Maximum average annual energy output (GWh)
Cabo Delgado	W14b	2,813	309	262,969	8.51	950
	W15	4,063	447	379,844	8.51	1,372
Gaza	W03	2,188	241	204,531	8.25	673
Inhambane	W04	4,688	516	438,281	8.25	1,442
	W05	1,563	172	146,094	7.86	416
Manica	W06	1,563	172	146,094	7.86	416
	W08	2,500	275	233,750	7.86	665
Maputo City	N/A	-	-	-	-	-
Maputo Prov.	W01	813	89	75,969	7.86	216
	W02	4,375	481	409,063	7.86	1,164
Nampula	W11a	1,875	206	175,313	7.86	499
	W12	1,250	138	116,875	7.86	333
	W13	4,063	447	379,844	8.51	1,372
	W14a	1,250	138	116,875	7.86	333
Niassa	N/A	-	-	-	-	-
Sofala	W07	813	89	75,969	7.86	216
	W09a	9,688	1066	905,781	8.51	3,272
Tete	N/A	-	-	-	-	-
Zambezia	W09b	938	103	87,656	8.51	317
	W10a	28,750	3163	2,688,125	8.51	9,710
	W10b	625	69	58,438	8.51	211
	W11b	2,188	241	204,531	7.86	582
Totals			**8,360**	**7,106,000**		**24,158**

Small hydro

The small hydro resources, defined as sites with a potential installed capacity of up to 15MW, were identified based on two studies by Norconsult (2009_a, and 2009_b). Due to a lack of data the potential of mini hydro (less than 1MW installed capacity), micro (between 300 or 100 kW installed capacity) and pico hydro (less 20 kW installed capacity), as defined by the Southern African Alternative Energy Association (SAAEA, 2010), could not be quantified under this assessment.

The total energy potential of the 19 rivers assessed for small hydro power is estimated to reach approximately 314 GWh (see Table 25). The river with the highest energy potential from small hydro power, Rio Lincungo, is found in Zambezia province with a total potential of approximately 40.3 GWh. The provinces of Cabo Delgado, Gaza, Inhambane and Sofala were reported to have no significant small hydro power resources. Relative to national energy needs up until 2030 small hydro power does not represent a significant solution. However for local demand centres small hydro power could constitute a key energy resource.

Table 25. Small hydro (< 15MW) energy potential

Province	**Ref. Small hydro sites** (< 15 MW)	**Site name**	**Installed capacity (MW)**	**Catchment area (KM2)**	**Energy potential (GWh / year)**
C. Delgado	N/A	N/A	-	-	-
Gaza	N/A	N/A	-	-	-
Inhambane	N/A	N/A	-	-	-
Manica	H04	Lucite	15.0	11,800	23.9
	H05	Massambize	2.0	300	3.2
Maputo City	N/A	N/A	-	-	-
Maputo Prov	H01	Maputo	7.0	700	11.1
	H02	Umbelúzi	2.0	850	3.2
	H03	Sabié	15.0	2,000	23.9
Nampula	H15a	Ligonha A	9.0	3,600	14.3
	H15b	Ligonha B	10.0	6,000	15.9
	H16	Melúli	12.0	7,100	19.1
Niassa	H06	Luángua	1.1	426	4.2
	H07	Luaice	2.3	994	7.1
	H08a	Lucheringo A	1.8	597	7.8
	H08b	Lucheringo B	5.7	673	23.5
	H09a	Luchimua A	0.5	149	1.6
	H09b	Luchimua B	0.5	214	2.4
	H17	Timba	15.0	75	23.9
Sofala	N/A	N/A	-	-	-
Tete	H10	Mese	8.0	700	12.7
	H11	Duángua	10.0	750	15.9
	H12	Máué	15.0	2,050	23.9
	H13	Lifidzi	2.0	1,400	3.2
Zambezia	H14	Muirua	15.0	2,600	23.9
	H18	Molocue	1.9	1,125	9.3
	H19a	Licungo A	1.9	17	8.2
	H19b	Licungo B	7.4	41	32.1
Totals			**143.14**	**44,160**	**314.0**

Renewable energy potential from all sources

The total renewable energy potential from solar PV (on 5 per cent urban lands, plus 5 per cent bare lands), solar thermal water heating (on 0.55 per cent of urban lands), wind (areas over 6 m/s at 10m height), biofuels jatropha curcas (on 5 per cent of agricultural lands available in 2007), biomass (from productive forests' MAI in 2011), biogas (from human excrement, and bio-waste food preparation, based on population numbers in 2011), and small hydro (<15MW small capacity, excluding mini hydro, micro hydro and pico hydro), amounts to approximately 160,757 GWh (see Table 26). This figure is misleading in terms of how these different energy sources could be applied or utilized in their original form i.e. without converting the energy potential into simple GWh terms; nonetheless it provides a very approximate overview of the energy potential from these combined resources.

In terms of electricity supply only, it is clear that there are many options and ample resources available to meet the projected total mains-grid and off-grid demand up until 2030 of approximately 12,263 GWh. Yet the real challenge for Mozambique lies in finding a sustainable solution for cooking and heating requirements currently provided for by unsustainable extraction of forest resources in the form of biomass wood-fuels.

The quantification of renewable energy potential from *all sources* in Mozambique would require further research into geothermal energy, ocean tidal power, ocean wave power, concentrated solar power, micro, mini and pico hydro power, biogas from animal stock, biomass energy from algae[1] and commercial forest plantations, amongst others. Furthermore, to generate more accurate figures on energy potential of all renewable energy resources reviewed in this assessment site specific feasibility studies must be carried out in each case i.e. the figures presented here, based entirely on secondary data, are approximations at best.

Table 26. Renewable energy potential summary

Energy source	Average GWh potential
Solar PV (on 5% urban lands + 5% bare lands)	15,815
Solar thermal H2O heating (on 0.55% of urban lands)	944
Wind (areas over 6 m/s wind speeds at 10m height)	24,158
Biofuels (jatropha curcas on 5% agricultural lands)	5,065
Biomass (productive forests' MAI in 2011)	105,887
Biogas (human and bio-waste, based on pop. in 2011)	8,574
Small hydro (< 15MW installed capacity)	314
Totals	**160,757**

4.3 GHG inventory and CO_2eq emission budget for Mozambique

4.3.1 Mozambique's GHG emission inventory

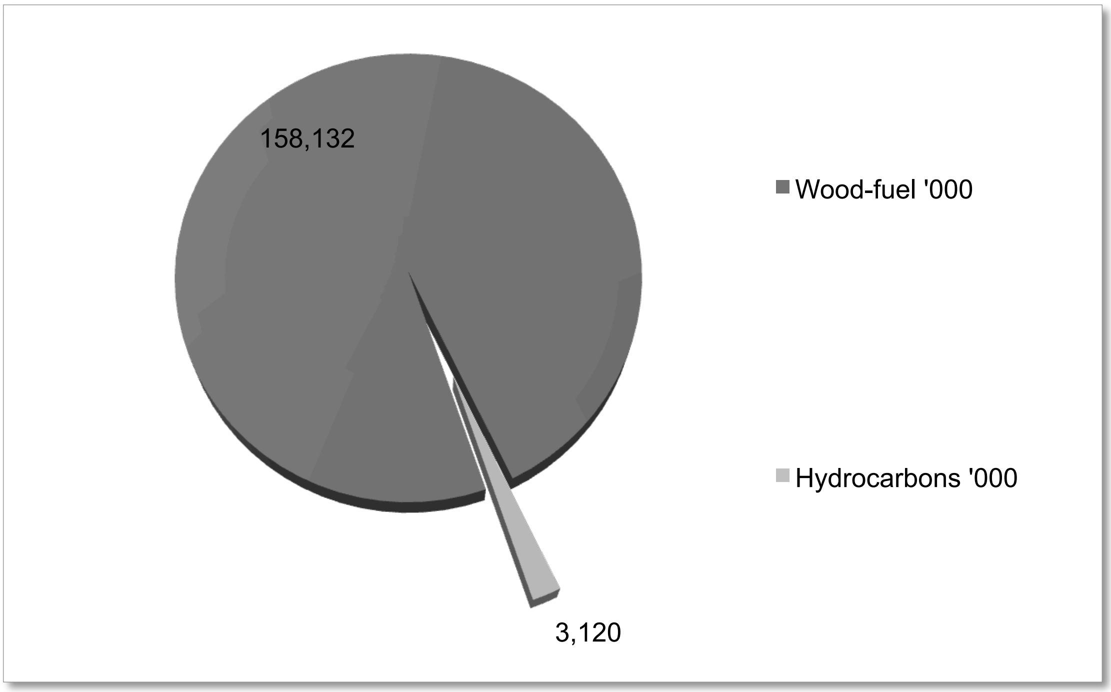
Before assessing possible energy development scenarios for low carbon energy regime pathways we must first understand the limits within which such decisions are made. In Mozambique there are two GHG inventories available for analysis. The first was prepared in 1994 and the second in 2010, both by MICOA. In the latest GHG inventory it is stated that, in general, the data available for analysis is of low quality and thus poor reliability (MICOA, 2010_a pp. 16). Furthermore it is noted that wild fires constitute a very important annual pressure on Mozambique's biomass stocks but due to a lack of data the resulting CO_2eq emissions cannot be reliably quantified (MICOA, 2010_a pp. 19).

[1] Algae are like microscopic factories using photosynthesis to transform CO_2 and sunlight into lipids, or oil, and can generate 30 times more oil per acre than all plants currently used for biodiesel and other biofuels, and algae do not compete with terrestrial food crops (Verrengia 2009 NREL).

The inventory concludes, in terms of CO_2 emissions, that the country emits less than is absorbed on an annual basis (MICOA, 2010_a pp. 29). However the assumption herein is that emissions from biomass combustion (from wood-fuels and wildfires) is balanced by annual sequestration of CO_2 due to vegetation growth. This is an over-simplification. If we accept that population growth is increasing at 2.4% p.a. (INE, 2010) and wood-fuel harvesting is unsustainable, it is prudent to consider alternative scenarios of net CO_2 emissions from biomass combustion.

A rapid analysis of Mozambique's direct CO_2eq emissions in 2010 shows total emissions exceeded 161 million tCO_2eq with wood fuels accounting for approximately 98 per cent of all emissions, while hydrocarbons (diesel, petrol, Jet A1, kerosene, liquid petroleum gas, and natural gas) account for only 2 per cent (see Figure 3).

Figure 3. Direct CO_2eq emissions per energy source in 2010



4.3.2 CO_2eq emissions budgets

Essentially every decision taken regarding natural resources occurs within the finite limits of our global environment. It follows that the determination of sustainable energy pathways for Mozambique depends, in GHG carrying capacity terms, upon how much CO_2eq emissions can be emitted without surpassing those limits.

The discussion of CO_2eq emissions budgets takes place within a historical context of varying levels of emissions from different countries around the world. The difficult question to answer is who must limit their emissions, by how much, and when? Answering this question would eventually provide Mozambique with information on CO_2eq emissions budgets, or emission rights. Unfortunately the complex nature of this question, in technical, political, moral and economic terms, makes it impossible to answer here. Mozambique urgently needs a detailed CO_2eq emissions budget study covering all sectors to be conducted by a specialised team familiar with above factors mentioned along with resources to collect primary data from all sectors and provinces of the country.

Meanwhile in order to frame our energy development pathway scenarios within the context of global CO_2eq emissions limitations, we have referred to the annual per capita emissions target of 0.5 tCO2eq by 2050 estimated by Ecofys (2009, pp. 11). This per capita emission target, from *all sources*, is required in order to prevent global average temperatures exceeding 2^oC and the risk of runaway climate change. The scenarios and corresponding per capita tCO2eq emissions estimated in the sections below only account for direct CO_2eq emissions from energy generation, except for fuel-wood which is based on net emissions accounting for MAI of forests, and do not include emissions from other sectors. Hence the picture presented here is essentially only one part, albeit key, of the national emissions baseline. In order to assess national per capita CO_2eq emissions relative to a target of 0.5 tCO2eq by 2050, a complete life cycle analysis (LCA) of emissions from the energy sector, plus direct emissions and LCA emissions from all other sectors that emit CO_2eq emissions from activities besides energy generation need to be included.

4.4 Energy development pathway scenarios

Introduction

The scenarios presented below demonstrate numerous options for both demand and supply in the development of energy development pathways based on currently available information and best estimates. Much of the focus is on mains-grid electricity supply; this is considered to be the highest priority for the Government.

Rates of technological efficiency improvements, costs, logistical feasibility, consumer preference, consumer purchasing power, international climate related conventions and resource transfers, Government policy and many other factors will affect the rate at which any of these technologies may be introduced and scaled up in Mozambique. Thus the exact point at which different energy interventions, such as the addition of new capacity and efficiency measures, can be introduced is uncertain.

The scenarios present alternatives based on known availability of renewable energy resources in Mozambique and internationally recognised efficiency measures. They serve two purposes, first of all they call attention to the different energy development pathway options available to Mozambique; feasibility studies need to be commissioned to establish exactly how, when and at what cost different interventions could be implemented. Secondly, and most importantly, in the next section the impact of the scenarios are demonstrated in terms of CO_2eq emissions of different pathway decisions.

4.4.1 Scenario 01 Business as usual

Large hydro, coal, gas, biomass co-generation – no energy efficiency or sustainability measures

Scenario 01 assumes all major electricity generation projects considered by the Government proceed as planned (see Table 27), with no introduction of energy efficiency measures or efforts to make fuel-wood supply sustainable. Per energy source type the progression of new capacity added is detailed per year below.

Large hydro

1. Year 2010 large hydro includes currently installed capacity and corresponding domestic supply available from Cahora Bassa, plus Chicamba, Mavuzi and Corumana.
2. Year 2015 rehabilitation of Mavuzi and Chicamba to provide a combined additional 80 GWh approximately (Nicolau 2011).
3. Year 2017 addition of 2,835 GWh from Cahora Bassa North Bank.
4. Year 2020 addition of 9,070 GWh from Mphanda Nkuwa (Nicolau 2011; UTIP May 2003).

Coal

1. The addition of coal thermal generation to the energy regime depends on the markets for coking coal and steel production.
2. Year 2015 addition of 500 MW installed capacity producing 3,066 GWh from Benga.
3. Year 2016 addition of 600 MW installed capacity producing 3,679 GWh from Moatize.

Natural Gas

1. Year 2013 addition of 45 MW installed capacity from Maputo diesel re-conversion of which 100% output GWh available for domestic markets (Nicolau 2011).
2. Year 2014 addition of 165 MW installed capacity from Ressano Garcia B providing 900GWh available for domestic markets (Nicolau 2011).
3. Year 2015 addition of 85 MW installed capacity from Ressano Garcia B providing a total of 2,100 GWh (Nicolau 2011).

Biomass co-generation

1. Year 2015 addition of 280 GWh of co-generation from Portucel industrial forest plantations in Manica and Zambezia (Nicolau 2011).
2. Year 2022 addition of 250 GWh of co-generation from Portucel industrial forest plantations in Manica, Zambezia and Sofala (Nicolau 2011).

4.4.2 Scenario 02 Efficiency

No coal, no new hydro, HCB+20%, Negawatts, and introduction of fuel-efficient stove 33% savings (starting immediately)

In Scenario 02 (see Table 28), it is assumed that there is no coal; no new large hydro; an additional 20 per cent of GWh output is secured from Cahora Bassa; Negawatts[2] are gained from 10 per cent efficiency savings and solar thermal water heating; and fuel efficient stoves are introduced immediately for all households generating a 33 per cent efficiency saving on fuel wood use. Per energy source type, the progression of new capacity added, efficiency measures and sustainability interventions are detailed per year below.

Large hydro

1. Year 2010 large hydro includes currently installed capacity and corresponding domestic supply available from Cahora Bassa, plus Chicamba, Mavuzi and Corumana.
2. Year 2015 rehabilitation of Mavuzi and Chicamba to provide a combined additional 80 GWh approximately (Nicolau 2011).
3. Year 2026 Mozambique's renegotiation of Cahora Bassa power sales contracts provides an additional 20%, or approximately 2,200 GWh available for domestic markets.

Natural Gas

1. Year 2013 addition of 45 MW installed capacity from Maputo diesel re-conversion of which 100% output GWh available for domestic markets (Nicolau 2011).
2. Year 2014 addition of 165 MW installed capacity from Ressano Garcia B providing 900GWh available for domestic markets (Nicolau 2011).
3. Year 2015 addition of 85 MW installed capacity from Ressano Garcia B providing a total of 2100GWh (Nicolau 2011).

Biomass co-generation

1. Year 2015 addition of 280 GWh of co-generation from Portucel industrial forest plantations in Manica and Zambezia (Nicolau 2011).
2. Year 2022 addition of 250 GWh of co-generation from Portucel industrial forest plantations in Manica, Zambezia and Sofala (Nicolau 2011).

Negawatts

1. Year 2012 Government implements electrical energy efficiency savings programme with energy saving light bulbs, and electrical appliances, such as air conditioners with improved efficiency ratings.

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[2] Negawatt power is a theoretical unit of power representing an amount of energy (measured in watts) saved. The energy saved is a direct result of energy conservation or increased efficiency i.e. the efficiency or saving offsets electricity consumption, or results in 'negawatts' gained.

2. All domestic households adopt Year 2012 solar thermal water heating.

Fuel-wood consumption efficiency

1. Year 2010, i.e. immediately, fuel-efficient stoves are adopted by all households, creating a 33 per cent fuel wood efficiency saving.

4.4.3 Scenario 03 Efficiency and Sustainability

No coal, Massingir hydro, diverse renewables (Solar Power, Wind, Tidal), Negwatts, low carbon electric transport (10% by 2020, 15% by 2025), introduction of fuel efficient stove 33% savings (starting immediately), 50% of fuel-wood supplied by sustainable forests (starting in 2025), and biogas meeting 30% of cooking needs (10% of pop. by 2015, 30% by 2020, 50% by 2025, 100% pop. by 2030)

In Scenario 03 (see Table 29), it is assumed that there is no coal; Massingir hydro; Negawatts are gained from 10 per cent efficiency savings and solar thermal water heating; and fuel efficient stoves are introduced immediately for all households generating a 33 per cent efficiency saving on fuel wood use; 50 per cent of fuel wood is supplied by sustainably managed forest resources; and 30 per cent cooking needs are met by biogas. Per energy source type, the progression of new capacity added, efficiency measures and sustainability interventions are detailed per year below.

Large hydro

1. Year 2010 large hydro includes currently installed capacity and corresponding domestic supply available from Cahora Bassa, plus Chicamba, Mavuzi and Corumana.
2. Year 2015 rehabilitation of Mavuzi and Chicamba to provide a combined additional 80 GWh approximately (Nicolau 2011).
3. Year 2025 introduction of Massingir, with an installed capacity of 40 MW, producing approximately 125 GWh. Massingir is recommended here as a low impact intervention because the damn is already built; it only requires adaptation to produce electricity. Though it currently only operates as an agricultural water supply reservoir it was originally envisaged as both a reservoir and a hydro electric installation.

Small hydro

1. Year 2020 addition of Licungo (A+B) hydro station with an installed capacity of approx 9 MW and average power output of 40 GWh per year (Norconsult 2009).

Natural Gas

1. Year 2013 addition of 45 MW installed capacity from Maputo diesel re-conversion of which 100% output GWh available for domestic markets (Nicolau 2011).
2. Year 2014 addition of 165 MW installed capacity from Ressano Garcia B providing 900 GWh available for domestic markets (Nicolau 2011).
3. Year 2015 addition of 85 MW installed capacity from Ressano Garcia B providing a total of 2,100 GWh (Nicolau 2011).

Biomass co-generation

1. Year 2015 addition of 280 GWh of co-generation from Portucel industrial forest plantations in Manica and Zambezia (Nicolau 2011).
2. Year 2022 addition of 250 GWh of co-generation from Portucel industrial forest plantations in Manica, Zambezia and Sofala (Nicolau 2011).

Hydrocarbon fuel switching to low carbon electricity (10% by 2020, 15% by 2025) supplied by:

1. Wind: year 2020 addition of 150 GWh power generating capacity, plus approximately 150GWh power generating capacity each year until 2030.
2. Concentrated Solar Thermal Power: year 2020 addition of 150 GWh power generating capacity, plus approximately 150 GWh power generating capacity each year until 2030.
3. Tidal: year 2020 addition of 150 GWh power generating capacity, plus approximately 150 GWh power generating capacity each year until 2030.

Negawatts

1. Year 2012 Government implements electrical energy efficiency savings programme with energy saving light bulbs, and electrical appliances, such as air conditioners with improved efficiency ratings.
2. All domestic households adopt Year 2012 solar thermal water heating.

Fuel-wood consumption efficiency and supply sustainability, and fuel switching to biogas

1. Year 2010, i.e. immediately, fuel-efficient stoves are adopted by all households, creating a 33 per cent fuel wood efficiency saving.
2. Year 2025 sustainable fuel-wood begins to supply up to 50 per cent of fuel-wood consumption requirements; this leaves approximately 15 years for plantations to be set-up, established and reach maturity to begin sustainable fuel-wood supply by 2025.
3. Biogas meeting 30 per cent of all cooking energy needs is used by 10 per cent of the population by 2015, 30 per cent by 2020, 50 per cent by 2025, and 100 by 2030. Note biogas use off-sets fuel wood consumption by approximately 30 per cent, and emits 90 per cent less CO_2 than fuel-wood combustion for the same amount of cooking time.

Table 27. Energy Scenario 01: Business as Usual

Year	Grid-Electricity Supply, Demand and Balances (GWh)							Fuel-wood demand (GWh)
	Demand	Supply					Energy balance (supply - demand)	
		Large hydro	Coal	Natural Gas	Biomass co-gen	Total Supply		
2010	**3,103**	**3,151**	**-**	**-**	**-**	**3,151**	**48**	**97,248**
2011	3,348	3,151	-	-	-	3,151	(197)	100,050
2012	3,544	3,151	-	-	-	3,151	(393)	103,271
2013	3,814	3,151	-	355	-	3,506	(308)	106,595
2014	4,090	3,151	-	1,255	-	4,406	316	110,024
2015	**4,317**	**3,236**	**3,066**	**2,455**	**280**	**9,037**	**4,720**	**113,561**
2016	4,611	6,071	6,745	2,455	280	15,551	10,940	117,210
2017	4,850	6,071	6,745	2,455	280	15,551	10,701	120,974
2018	5,175	6,071	6,745	2,455	280	15,551	10,376	124,857
2019	5,421	6,071	6,745	2,455	280	15,551	10,131	128,863
2020	**5,758**	**15,141**	**6,745**	**2,455**	**280**	**24,621**	**18,863**	**132,995**
2021	6,089	15,141	6,745	2,455	280	24,621	18,532	137,258
2022	6,451	15,141	6,745	2,455	530	24,871	18,420	141,655
2023	6,807	15,141	6,745	2,455	530	24,871	18,065	146,191
2024	7,168	15,141	6,745	2,455	530	24,871	17,703	150,870
2025	**7,524**	**15,141**	**6,745**	**2,455**	**530**	**24,871**	**17,347**	**155,696**
2026	7,886	15,141	6,745	2,455	530	24,871	16,985	160,674
2027	8,241	15,141	6,745	2,455	530	24,871	16,630	165,809
2028	8,573	15,141	6,745	2,455	530	24,871	16,299	171,105
2029	8,904	15,141	6,745	2,455	530	24,871	15,968	176,568
2030	**9,216**	**15,141**	**6,745**	**2,455**	**530**	**24,871**	**15,655**	**181,908**

Table 28. Energy Scenario 02: Efficiency

Year	Grid-Electricity Supply, Demand and Balances (GWh)								Fuel-wood consumption (GWh)
	Demand	Supply						Energy balance (supply - demand)	
		Large hydro	Natural Gas	Biomass co-gen	Negawatts		Total Supply		
					Energy efficient appliances 10%	Solar thermal H2O heating			
2010	**3,103**	**3,151**	**-**	**-**	**-**	**-**	**3,151**	**48**	**65,156**
2011	3,348	3,151	-	-	-	-	3,151	(197)	67,033
2012	3,544	3,151	-	-	354	340	3,846	302	69,192
2013	3,814	3,151	355	-	381	366	4,253	439	71,419
2014	4,090	3,151	1,255	-	409	393	5,208	1,118	73,716
2015	**4,317**	**3,236**	**2,455**	**280**	**432**	**415**	**6,817**	**2,500**	**76,086**
2016	4,611	3,236	2,455	280	461	443	6,875	2,264	78,531
2017	4,850	3,236	2,455	280	485	466	6,922	2,072	81,053
2018	5,175	3,236	2,455	280	518	497	6,986	1,810	83,654
2019	5,421	3,236	2,455	280	542	521	7,034	1,613	86,338
2020	**5,758**	**3,236**	**2,455**	**280**	**576**	**553**	**7,100**	**1,342**	**89,107**
2021	6,089	3,236	2,455	280	609	585	7,165	1,076	91,963
2022	6,451	3,236	2,455	530	645	619	7,486	1,035	94,909
2023	6,807	3,236	2,455	530	681	654	7,555	749	97,948
2024	7,168	3,236	2,455	530	717	688	7,626	458	101,083
2025	**7,524**	**3,236**	**2,455**	**530**	**752**	**723**	**7,696**	**172**	**104,316**
2026	7,886	5,436	2,455	530	789	757	9,967	2,081	107,651
2027	8,241	5,436	2,455	530	824	791	10,037	1,795	111,092
2028	8,573	5,436	2,455	530	857	823	10,101	1,529	114,640
2029	8,904	5,436	2,455	530	890	855	10,166	1,263	118,300
2030	**9,216**	**5,436**	**2,455**	**530**	**922**	**885**	**10,228**	**1,011**	**121,879**

Table 29. Energy Scenario 03: Efficiency and Sustainability

Year	Grid-Electricity Supply, Demand and Balances (GWh)												Fuel-wood consumption (GWh)
	Demand	Supply										Energy balance (supply - demand)	
		Large hydro	Small hydro	Natural Gas	Bio-mass co-gen	Solar Power	Wind	Tidal	Negawatts		Total Supply		
									Energy efficiency 10%	Solar thermal H2O heating			
2010	**3,103**	**3,151**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3,151**	**48**	**65,156**
2011	3,348	3,151	-	-	-	-	-	-	-	-	3,151	(197)	67,033
2012	3,544	3,151	-	-	-	-	-	-	354	340	3,846	302	69,192
2013	3,814	3,151	-	355	-	-	-	-	381	366	4,253	439	71,419
2014	4,090	3,151	-	1,255	-	-	-	-	409	393	5,208	1,118	73,716
2015	**4,317**	**3,236**	**-**	**2,455**	**280**	**-**	**-**	**-**	**432**	**415**	**6,817**	**2,500**	**73,803**
2016	4,611	3,236	-	2,455	280	-	-	-	461	443	6,875	2,264	76,175
2017	4,850	3,236	-	2,455	280	-	-	-	485	466	6,922	2,072	78,621
2018	5,175	3,236	-	2,455	280	-	-	-	518	497	6,986	1,810	81,145
2019	5,421	3,236	-	2,455	280	-	-	-	542	521	7,034	1,613	83,748
2020	**5,758**	**3,236**	**40**	**2,455**	**280**	**150**	**150**	**150**	**576**	**553**	**7,590**	**3**	**81,087**
2021	6,089	3,236	40	2,455	280	290	290	290	609	585	8,075	32	83,686
2022	6,451	3,236	40	2,455	530	350	350	350	645	619	8,576	38	86,367
2023	6,807	3,236	40	2,455	530	490	490	490	681	654	9,066	31	89,133
2024	7,168	3,236	40	2,455	530	640	640	640	717	688	9,587	38	91,985
2025	**7,524**	**3,361**	**40**	**2,455**	**530**	**1,170**	**1,170**	**1,170**	**752**	**723**	**11,371**	**34**	**88,669**
2026	7,886	3,361	40	2,455	530	1,350	1,350	1,350	789	757	11,982	24	91,504
2027	8,241	3,361	40	2,455	530	1,540	1,540	1,540	824	791	12,622	31	94,428
2028	8,573	3,361	40	2,455	530	1,730	1,730	1,730	857	823	13,257	38	97,444
2029	8,904	3,361	40	2,455	530	1,920	1,920	1,920	890	855	13,892	26	100,555
2030	**9,216**	**3,361**	**40**	**2,455**	**530**	**2,120**	**2,120**	**2,120**	**922**	**885**	**14,553**	**37**	**85,315**

4.4.4 Risks of over dependence on hydro power

In all scenarios large hydro power energy, generated by Cahora Bassa, forms the keystone foundation of mains-grid electricity supply. Yet large hydro power is not guaranteed or 'firm' power in the long term context of growing regional population numbers in the Zambezi basin and the risks of reduced rainfall due to climate change. According to the Stern Review climate change could result in 30 to 50 per cent reductions in water availability in Southern Africa (Stern 2006, pp. 57). In addition Twanda and Mpande (1996) report that population growth in the Zambeze River catchment area, spread over eight southern African countries, will double every 27 years, coupled with rising levels of agricultural activity, which may further reduce levels of water available downstream for hydro-power in Mozambique. Projected reduced levels of precipitation in the Zambeze River catchment area due to climate change, could result in significant decreases in flow volumes (INGC 2009 pp. 35), upon which Cahora Bassa and the planned Mpanda Nkuwa depend. Meanwhile large-scale hydro-power on the Zambeze River, is estimated to cost USD 30 million a year in decreased fish stocks and prawn losses (Lemos Ribeiro 2008, pp. 15).

The risk of lower output from hydro power installations is not confined to the Southern African region. Barnett and Pierce (2008, pp. 21) report a 50 per cent chance by 2021 that the water levels of the Colorado River supplying Lake Mead, which powers the 2,000 MW Hoover Dam will fall below minimum levels for electricity generation. The falling water levels are attributed to increasing temperatures and evapo-transpiration, and decreasing precipitation driven by human-induced climate change (Barnett and Pierce 2008, pp. 3).

Conclusively, Mozambique's long term energy security depends on diversification of energy supply sources. Relying almost exclusively on large hydro power leaves little room for manoeuvre if water flow dynamics change in the region.

4.5 Energy and CO_2eq emissions scenarios

4.5.1 Scenarios for direct energy generation CO_2eq emissions

Scenario 01 Business as Usual

The projected approximate CO_2eq emissions per capita by 2030 for Scenario 01, from the energy sector only, and based on net fuel-wood emissions[3], are approximately tCO_2eq 2.78 (see Figure 4 and Table 30). Setting course on for Scenario 01 would make it a formidable challenge to reduce CO_2eq emissions to 0.5tCO_2eq per capita by 2050, essentially requiring a reduction of emission per capita of approximately 450 per cent between the year 2030 and 2050.

Scenario 02 Efficiency

The projected approximate CO_2eq emissions per capita by 2030 for Scenario 02, from the energy sector only, and based on net fuel-wood emissions, are approximately tCO_2eq 1.93 (see Figure 5 and Table 31). In Scenario 02 reducing CO_2eq emissions to 0.5tCO_2eq per capita by 2050 still appears very challenging, essentially requiring a reduction of emission per capita of over 280 per cent between the year 2030 and 2050.

Scenario 03 Efficiency and Sustainability

The projected approximate CO_2eq emissions per capita by 2030 for Scenario 03, from the energy sector only, and based on net fuel-wood emissions, are approximately tCO_2eq 1.16 (see Figure 6 and Table 32). Reducing CO_2eq emissions to 0.5tCO_2eq per capita by 2050 in Scenario 03 appears to be more feasible, essentially requiring a reduction of emission per capita of approximately 130 per cent between the year 2030 and 2050. Nonetheless making these changes will be no small feat.

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[3] Net fuel-wood emissions here, refer to the balance of direct emissions that remain in the atmosphere after accounting for the CO_2 sequestration effect originating only from the MAI growth of productive forests.

Figure 4. CO_2eq emissions Scenario 01 Business as Usual

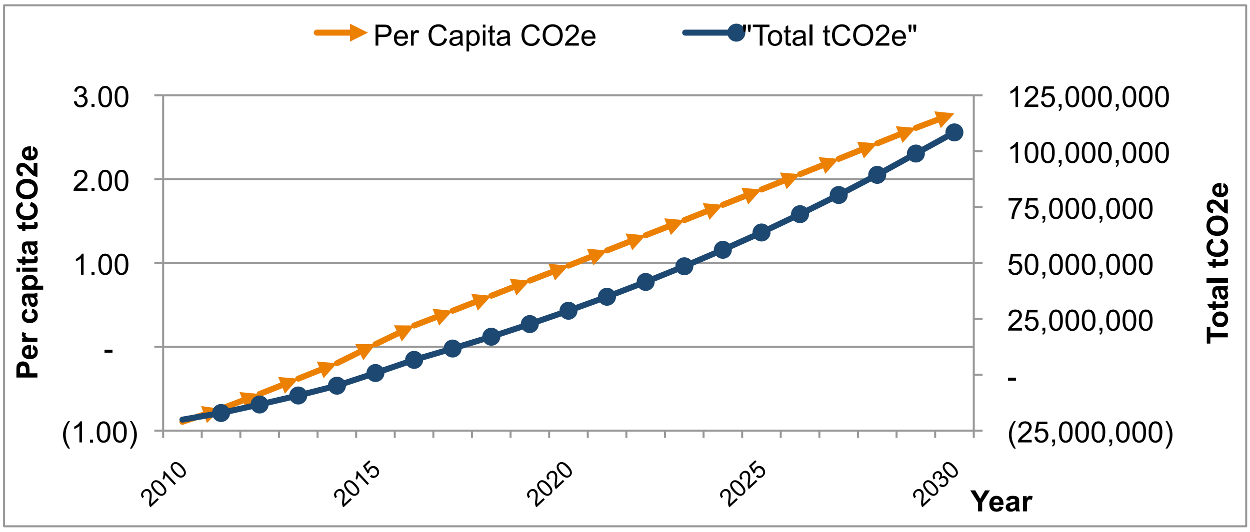


Figure 5. CO_2eq emissions Scenario 02 Efficiency

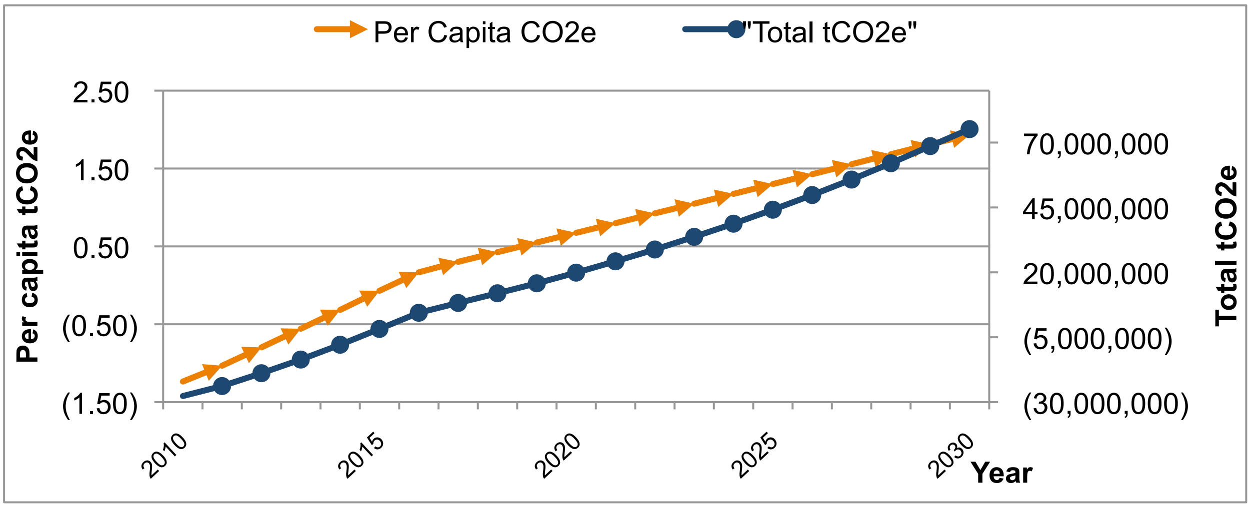


Figure 6. CO_2eq emissions Scenario 03 Efficiency and Sustainability

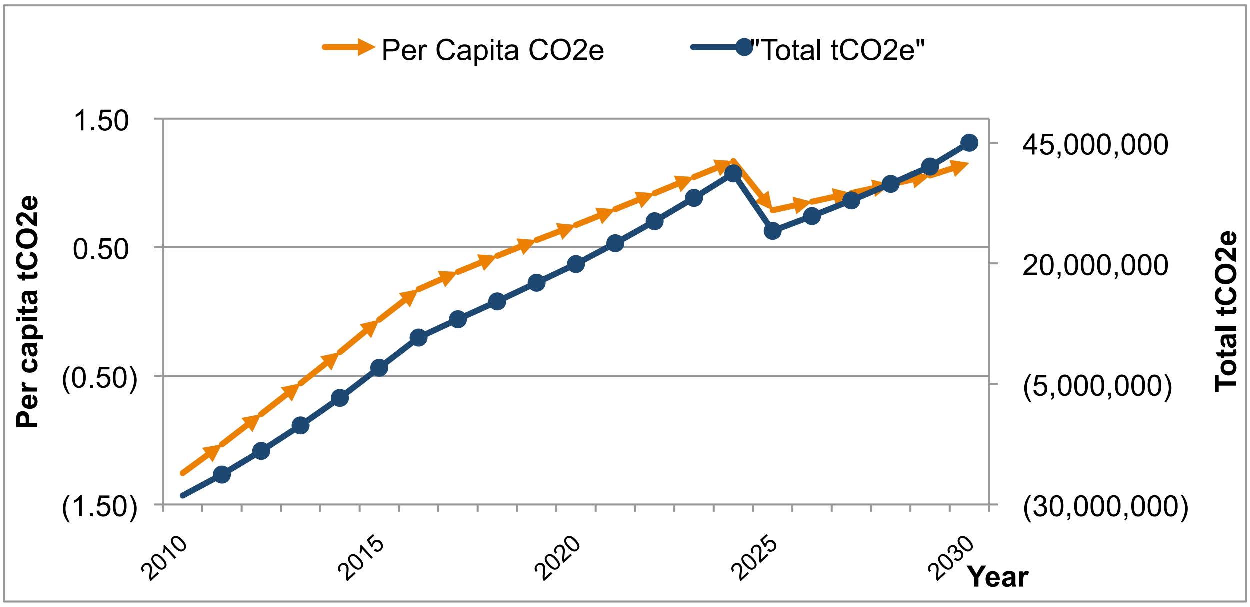


Table 30. CO_2eq emissions Scenario 01 Business as usual

Year	Population	Coal (tCO2)	Wood fuel biomass emissions -- no efficiency savings (tCO2)		Hydro-carbons (tCO2)	Total emissions (tCO2) based on net wood fuel emissions	Cost of net fuel-wood CO2 emission (USD)	Per capita emissions (tCO2) - net wood fuel emissions	Per capita emissions (tCO2) - gross wood fuel emissions
			Gross emissions	Net emissions					
2010	**22,404,232**	**-**	**158,132,457**	**(23,160,888)**	**3,120,136**	**(20,040,752)**	**-$122,248,586**	**(0.89)**	**7.20**
2011	23,049,621	-	162,687,713	(20,399,560)	3,332,486	(17,067,074)	-$170,670,738	(0.74)	7.20
2012	23,695,010	-	167,969,579	(16,880,380)	3,559,289	(13,321,091)	-$133,210,910	(0.56)	7.24
2013	24,358,471	-	173,419,682	(13,141,205)	3,866,806	(9,274,399)	-$92,743,989	(0.38)	7.28
2014	25,040,508	-	179,043,302	(9,172,563)	4,291,130	(4,881,433)	-$48,814,328	(0.19)	7.32
2015	**25,741,642**	**959,658**	**184,845,885**	**(4,964,642)**	**4,788,301**	**783,317**	**$7,833,169**	**0.030**	**7.40**
2016	26,462,408	2,111,248	190,833,042	(507,282)	5,083,440	6,687,405	$66,874,051	0.25	7.48
2017	27,203,355	2,111,248	197,010,561	4,210,035	5,398,665	11,719,948	$117,199,478	0.43	7.52
2018	27,965,049	2,111,248	203,384,407	9,198,198	5,735,344	17,044,789	$170,447,894	0.61	7.55
2019	28,748,071	2,111,248	209,960,733	14,468,473	6,094,937	22,674,657	$226,746,574	0.79	7.59
2020	**29,553,017**	**2,111,248**	**216,745,880**	**20,032,519**	**6,479,003**	**28,622,769**	**$286,227,690**	**0.97**	**7.62**
2021	30,380,501	2,111,248	223,746,385	25,902,394	6,889,207	34,902,849	$349,028,487	1.15	7.66
2022	31,231,155	2,111,248	230,968,991	32,090,570	7,327,329	41,529,147	$415,291,470	1.33	7.70
2023	32,105,628	2,111,248	238,420,645	38,609,942	7,795,269	48,516,459	$485,164,593	1.51	7.73
2024	33,004,585	2,111,248	246,108,511	45,473,841	8,295,056	55,880,145	$558,801,452	1.69	7.77
2025	**33,928,714**	**2,111,248**	**254,039,977**	**52,696,044**	**8,828,858**	**63,636,150**	**$636,361,497**	**1.88**	**7.81**
2026	34,878,718	2,111,248	262,222,656	60,290,787	9,398,989	71,801,023	$718,010,234	2.06	7.85
2027	35,855,322	2,111,248	270,664,397	68,272,776	10,007,921	80,391,945	$803,919,455	2.24	7.89
2028	36,859,271	2,111,248	279,373,293	76,657,201	10,658,297	89,426,746	$894,267,456	2.43	7.93
2029	37,891,330	2,111,248	288,357,687	85,459,745	11,352,936	98,923,928	$989,239,278	2.61	7.97
2030	**38,952,288**	**2,111,248**	**297,117,473**	**94,187,893**	**12,094,850**	**108,393,990**	**$1,083,939,903**	**2.78**	**7.99**

Table 31. CO_2eq emissions Scenario 02 Efficiency

Year	Population	Reduced wood-fuel emissions with fuel efficient stoves 33% efficiency saving (tCO2)		Hydro-carbons (tCO2)	Total emissions (tCO2) based on net wood fuel emissions	Cost of CO2 emission (USD)	Per capita emissions (tCO2) - net wood fuel emissions	Per capita emissions (tCO2) - gross wood fuel emissions
		Gross emissions	Net emissions					
2010	**22,404,232**	**105,948,746**	**(30,803,981)**	**3,120,136**	**(27,683,845)**	**-$276,838,449**	**(1.24)**	**4.87**
2011	23,049,621	109,000,768	(27,131,415)	3,332,486	**(23,798,929)**	-$237,989,287	(1.03)	4.87
2012	23,695,010	112,539,618	(22,450,905)	3,559,289	**(18,891,616)**	-$188,916,162	(0.80)	4.90
2013	24,358,471	116,191,187	(17,477,802)	3,866,806	**(13,610,996)**	-$136,109,964	(0.56)	4.93
2014	25,040,508	119,959,013	(12,199,508)	4,291,130	**(7,908,379)**	-$79,083,786	(0.32)	4.96
2015	**25,741,642**	**123,846,743**	**(6,602,974)**	**4,788,301**	**(1,814,673)**	**-$18,146,730**	**(0.07)**	**5.00**
2016	26,462,408	127,858,138	(674,685)	5,083,440	**4,408,754**	$44,087,543	0.17	5.02
2017	27,203,355	131,997,076	2,820,723	5,398,665	**8,219,389**	$82,193,886	0.30	5.05
2018	27,965,049	136,267,553	6,162,792	5,735,344	**11,898,137**	$118,981,366	0.43	5.08
2019	28,748,071	140,673,691	9,693,877	6,094,937	**15,788,814**	$157,888,137	0.55	5.11
2020	**29,553,017**	**145,219,739**	**13,421,788**	**6,479,003**	**19,900,790**	**$199,007,902**	**0.67**	**5.13**
2021	30,380,501	149,910,078	17,354,604	6,889,207	**24,243,811**	$242,438,111	0.80	5.16
2022	31,231,155	154,749,224	21,500,682	7,327,329	**28,828,011**	$288,280,113	0.92	5.19
2023	32,105,628	159,741,832	25,868,661	7,795,269	**33,663,931**	$336,639,307	1.05	5.22
2024	33,004,585	164,892,703	30,467,474	8,295,056	**38,762,530**	$387,625,300	1.17	5.25
2025	**33,928,714**	**170,206,785**	**35,306,350**	**8,828,858**	**44,135,207**	**$441,352,074**	**1.30**	**5.28**
2026	34,878,718	175,689,179	40,394,827	9,398,989	**49,793,816**	$497,938,161	1.43	5.31
2027	35,855,322	181,345,146	45,742,760	10,007,921	**55,750,682**	$557,506,816	1.55	5.34
2028	36,859,271	187,180,106	51,360,325	10,658,297	**62,018,622**	$620,186,216	1.68	5.37
2029	37,891,330	193,199,650	57,258,029	11,352,936	**68,610,965**	$686,109,645	1.81	5.40
2030	**38,952,288**	**199,068,707**	**63,105,888**	**12,094,850**	**75,200,738**	**$752,007,381**	**1.93**	**5.42**

Table 32. CO2eq emissions Scenario 03 Efficiency and Sustainability

Year	Population	Biogas (tCO2)	Wood fuel biomass emissions with fuel efficient stoves 33% efficiency saving plus sustainable forest management of 50% of productive forests by 2025 (tCO2)		Hydro-carbons (tCO2)	Total emissions (tCO2) based on net wood fuel emissions	Cost of CO2 emissions (USD)	Per capita emissions (tCO2) - net wood fuel emissions	Per capita emissions (tCO2) - gross wood fuel emissions
			Gross emissions	Net emissions					
2010	**22,404,232**	**-**	**105,948,746**	**(30,803,981)**	**2,659,392**	**(28,144,590)**	**-$281,445,897**	**(1.26)**	**4.85**
2011	23,049,621	-	109,000,768	(27,131,415)	3,332,486	(23,798,929)	-$237,989,287	(1.03)	4.87
2012	23,695,010	-	112,539,618	(22,450,905)	3,559,289	(18,891,616)	-$188,916,162	(0.80)	4.90
2013	24,358,471	-	116,191,187	(17,477,802)	3,866,806	(13,610,996)	-$136,109,964	(0.56)	4.93
2014	25,040,508	-	119,959,013	(12,199,508)	4,291,130	(7,908,379)	-$79,083,786	(0.32)	4.96
2015	**25,741,642**	**176,196**	**123,846,743**	**(6,602,974)**	**4,788,301**	**(1,638,477)**	**-$16,384,766**	**(0.06)**	**5.00**
2016	26,462,408	181,130	127,858,138	(674,685)	5,083,440	4,589,884	$45,898,842	0.17	5.03
2017	27,203,355	186,202	131,997,076	2,820,723	5,398,665	8,405,590	$84,055,901	0.31	5.06
2018	27,965,049	191,415	136,267,553	6,162,792	5,735,344	12,089,552	$120,895,518	0.43	5.08
2019	28,748,071	196,775	140,673,691	9,693,877	6,094,937	15,985,589	$159,855,885	0.56	5.11
2020	**29,553,017**	**404,569**	**145,219,739**	**13,421,788**	**6,034,015**	**19,860,372**	**$198,603,720**	**0.67**	**5.13**
2021	30,380,501	415,897	149,910,078	17,354,604	6,413,938	24,184,439	$241,844,393	0.80	5.16
2022	31,231,155	427,542	154,749,224	21,500,682	6,819,719	28,747,942	$287,479,424	0.92	5.19
2023	32,105,628	439,513	159,741,832	25,868,661	7,253,115	33,561,290	$335,612,899	1.05	5.22
2024	33,004,585	451,820	164,892,703	30,467,474	7,716,009	38,635,302	$386,353,018	1.17	5.24
2025	**33,928,714**	1,161,176	**85,103,392**	**17,653,175**	**7,901,180**	**26,715,531**	**$267,155,307**	**0.79**	**2.78**
2026	34,878,718	1,193,689	87,844,590	20,197,414	8,408,182	29,799,285	$297,992,846	0.85	2.79
2027	35,855,322	1,227,113	90,672,573	22,871,380	8,949,690	33,048,182	$330,481,824	0.92	2.81
2028	36,859,271	1,261,472	93,590,053	25,680,162	9,528,052	36,469,686	$364,696,863	0.99	2.83
2029	37,891,330	1,296,793	96,599,825	28,629,014	10,145,778	40,071,585	$400,715,848	1.06	2.85
2030	**38,952,288**	**2,666,206**	**99,534,353**	**31,552,944**	**10,805,544**	**45,024,695**	**$450,246,947**	**1.16**	**2.90**

4.5.2 Life Cycle Analysis CO_2eq emissions

The full impact in terms of CO_2eq emissions can only be accurately assessed with a complete LCA, assessing the emissions from all life cycle stages, known as the *cumulative emissions*. Emissions occur upstream in the extraction, processing and transport of energy fuels, and in the production, transport and installation of energy generation equipment and plants. Direct emissions occur as energy is generated. Finally, downstream emissions occur when energy generation plants and equipment are decommissioned.

In addition to GHG LCA emissions other common impacts that should be assessed include (Weisser 2007, pp 7.):

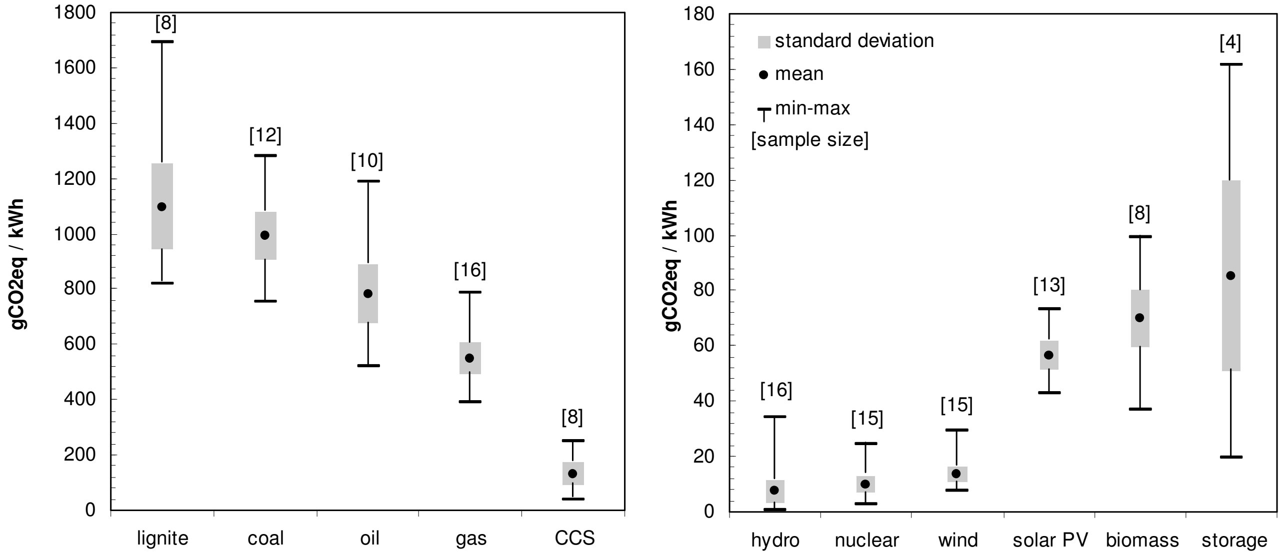
1. Stratospheric ozone depletion;
2. Acidification;
3. Eutrophication;
4. Photochemical smog;
5. Terrestrial toxicity;
6. Aquatic toxicity;
7. Human health;
8. Resource depletion; and
9. Land use.

Weisser (2007) reported the following cumulative emissions in a comparative study of different *presently* operating power plants (see Figure 7):

- Lignite 1100-1700 gCO_2eq/kWhe;
- Coal 950-1250 gCO_2eq/kWhe;
- Oil 500-1200 gCO_2eq/kWhe;
- Gas 440-780 gCO_2eq/kWhe;
- Nuclear 2.8-24 gCO_2eq/kWhe;
- Solar photovoltaic 43-73 gCO_2eq/kWhe;
- Wind (onshore) 8-30 gCO_2eq/kWhe;
- Hydro 1-34 gCO_2eq/kWhe; and
- Biomass 35-99 gCO_2eq/kWhe.

The above findings indicate that amongst the renewable energy options assessed in this study in Mozambique hydro, wind and solar offer the lowest cumulative gCO_2eq/kWhe. If resources allow, further studies on LCA cumulative emissions would provide a much more comprehensive assessment of different energy regime scenarios CO_2eq impact. Indeed Environmental Impact Assessments (EIAs) should take an LCA approach to the evaluation of specific installations. Unless LCAs are conducted decision makers may substantially underestimate the complete CO_2eq impact of different power generation options, especially with regards upstream emissions that may arise outside the legislative boundaries of a national GHG mitigation programme / regulation (Weisser 2007, pp. 19).

Figure 7. LCA cumulative emissions analysis of selected energy sources



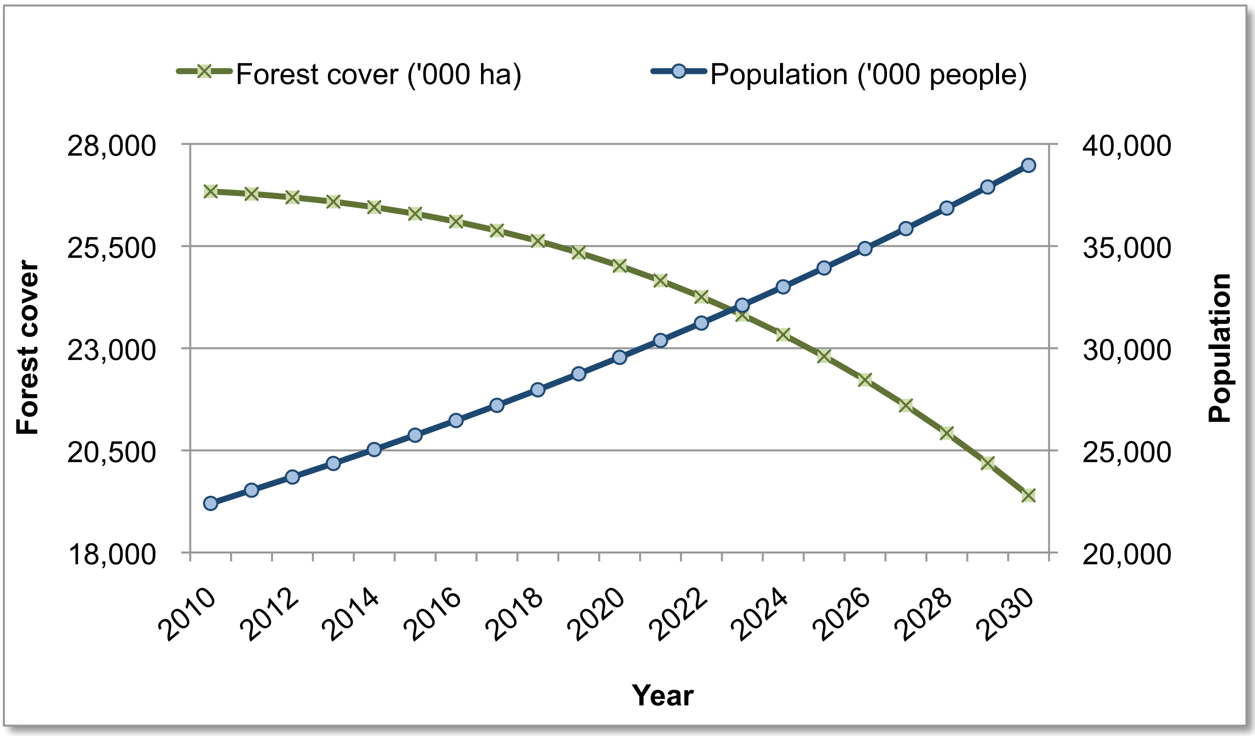
Source: Weisser (2007, pp 12.).

4.5.3 Wood-fuel consumption and forest cover

The forest loss projections are alarming given that Mozambique's forest resources currently act as enormous biodiversity banks, providing essential natural resources for society, and multiple environmental services, including but limited to carbon sequestration and storage, water cycling and climate regulation.

It is estimated that 26 million hectares of productive forest cover existed in 2010. But if current consumption patterns continue and no efforts are made to replant what is cut, productive forest cover may fall to 19 million hectares by 2030 i.e. productive forest cover could be reduced by as much as 26 per cent during the period from 2010 to 2030 (see Figure 8).

Figure 8. Productive forest cover and population from 2010 to 2030



4.5.4 Uncontrolled fires

The total area affected by uncontrolled fires in Mozambique is not known. However Rauno Laitalainen, Chief Technical Adviser for the National Directorate of Lands and Forestry at MINAG, and Professor Genito Maure, Faculty of Sciences, Department Physics, Energy, Environment and Climate Research Group, concur in their estimates that uncontrolled fires affect the majority of rural lands at least once a year. These estimations suggest enormous biomass energy is wasted on an annual basis.

It is conceivable that the potential GHG emissions from uncontrolled fires may substantially surpass emissions from all other sources.

Finally, uncontrolled fires are responsible for the majority of organic compound aerosols in the atmosphere and though their impact on cloud formation is not well understood and the magnitudes of associated indirect radiative effects are poorly determined they are believed to suppress precipitation and increase the albedo effect of clouds (Boers, 2010, pp 37). This is a point of concern for Mozambique given that uncontrolled fires affect large areas of the country every year which could be affecting rainfall patterns and intensity.

4.6 Energy supply for ever greater urban numbers

Mozambique is no exception to the trend of worldwide urbanisation of human populations. The shift from a rural population accounting for 65 per cent of the total in 2010 to an urban population of over 60 per cent in 2030 will have profound impacts on the needs for energy services in urban areas. Effectively, urban areas constitute the heart of the future challenge of sustainable energy supply. At present, poverty relief programmes in Mozambique tend to focus on rural areas and issues. However planning for the growth of urban areas must begin now with sustainable design principles.

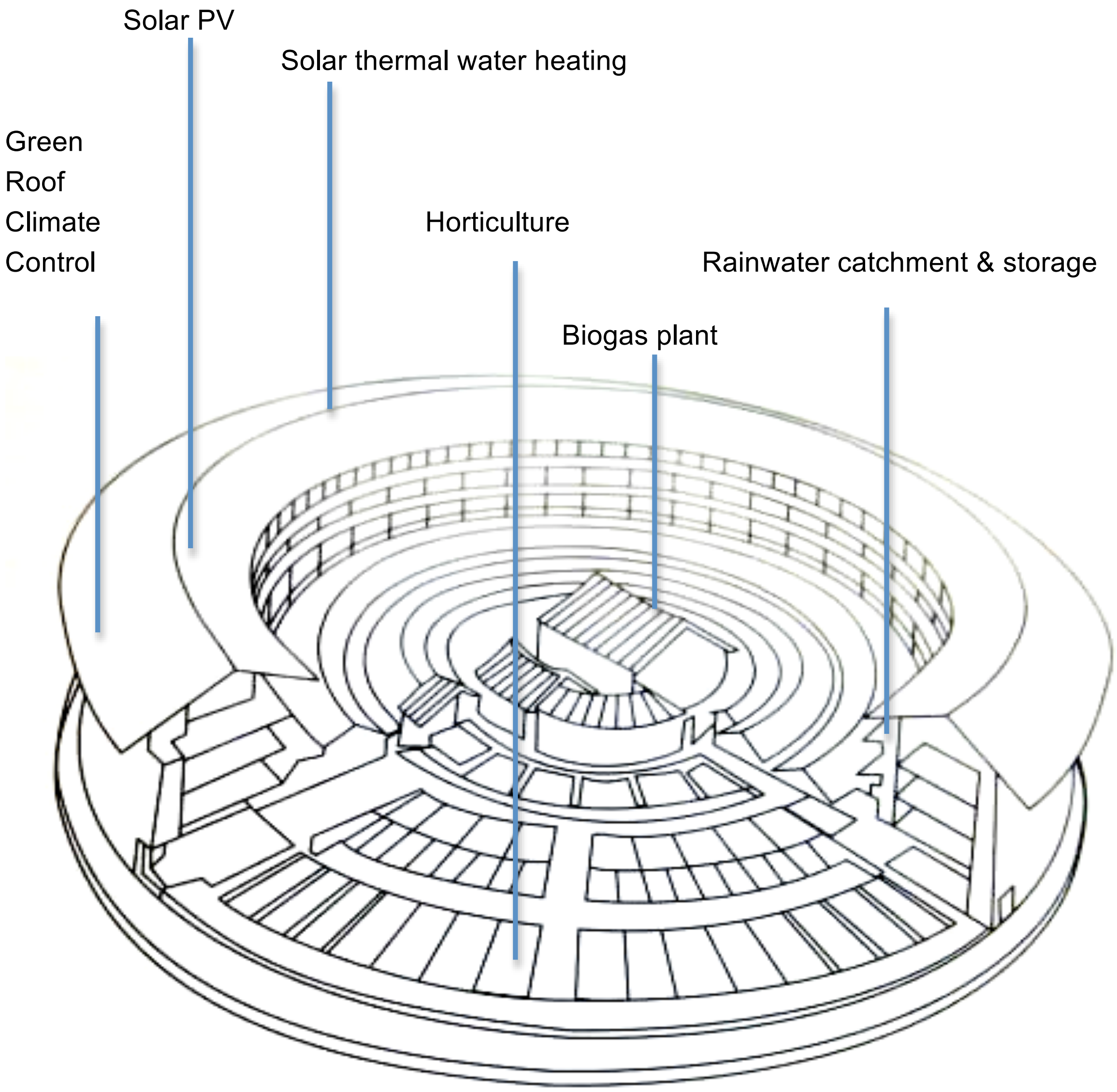
Urban residential areas need to be designed to close the energy loop of resource use such that products and effects typically considered as useless waste or nuisances, such as human excrement and organic kitchen leftovers, grey water, rainwater and solar radiation, are reused in other systems – closing the resource loop much in the same was a natural ecosystems do.

Human excrement, kitchen organic leftovers and other municipal bio-waste could eventually meet more than half of cooking fuel needs for urban areas in the form of biogas. Solar thermal water heating can provide close to 100 per cent of water heating needs. Green roofs could significantly reduce the energy required for cooling buildings. Inner city gardens and roof top gardens could provide seasonal horticultural produce, reducing food related transport emissions and creating inner city agricultural economic opportunities. Appropriately scaled rain-water catchment and grey water recycling systems could provide important sources of washing, cooling and urban irrigation water reducing the need to expend energy processing and pumping water from faraway reservoirs. There are numerous possible interventions, but they must be incentivised, along with suitable urban planning and construction standards.

The success of sustainable urban growth depends on integrated planning and service delivery. But bringing these various areas and levels of public services – water supply, energy, food production, waste management, transport, housing, infrastructure, civil engineering/public works, plus the local municipalities – together requires a streamlined approach, strong leadership and adept coordination.

The traditional concept of round-residential spaces offer a simple model upon which sustainable, off-grid energy and related services could be concentrated to serve urban community needs (see Figure 9).

Figure 9. Sustainable urban energy services with closed loop systems



Source: original image adapted from hakkauk.com

4.7 Policy and regulatory framework

4.7.1 The role of energy in the socio economic development of Mozambique

The Mozambican Government considers energy an important element for the socio-economic development of the country and fundamental to all sectors of society in order to improve the quality of life of all Mozambicans.[4] One of the main challenges in this sector is to increase the access to energy in a sustainable manner contributing to the fight against poverty and the improvement of the well-being of Mozambicans.

The first strategic objective of the Government in the energy area is to expand the access of energy to the lowest possible cost by expanding the geographic coverage of infrastructures and

[4] Government of Mozambique. 2010. Five Year Plan. Pars. 121 and 122.

services that provide energy.[5] When the Government states 'lowest possible cost' it is assumed that environmental costs, so called 'externalities', are not included in these calculations. The main strategy of the Ministry of Energy is to increase the access of modern energy to 23 per cent of the population by 2014.[6]

The low access to energy is not due to lack of power generation capacity. The total power generating capacity including the share from Cahora Bassa is in excess of what is needed in the country right now. In spite of the generation capacity, distribution is insufficient and requires investment in transmission lines, particularly in rural areas. Due to lack of power transmission lines and distribution networks, the availability of hydroelectricity for the time being is largely restricted to urban areas. The CESUL project, which aims to link the Central Northern and the Southern grids extending from Tete to Maputo and further on to SAPP, is a priority action for the Government in the area of electric energy and includes the construction of a 1,400 Km long high-voltage transmission. Estimates suggest that Government investment per annum in transmission and distribution will total USD 55 million over the next 10 years.[7]

The five year plan of the Government in the area of production of electric energy includes several other priority actions like the promotion of the construction of several new power stations namely: the Hydropower Stations of Mphanda Nkuwa (1500 MW), and Cahora Bassa Norte (1245 MW). It also includes the Thermal Station of Moatize (600 MW), Benga (500 MW) and the Thermal Electric Station with Natural Gas of Moamba (600 MW).[8]

4.7.2 The Electricity law and its concession regime

The Electricity Law n. 21/97 regulates the entire electric energy sector. The law describes the legal framework for electrical energy generation, transmission, distribution and sale within the country, as well as its exportation to and from outside Mozambique, and the granting of concessions for such activities. The Law also opens the activities of generation, transmission and distribution of electricity to the private sector. At present the law is under review.[9]

The production of energy requires a concession granted by the public authorities, regulated under Decree 8/2000. The production of energy will be only exempted of concession when the electric energy production is destined for particular use and consumption, and there is no provision of energy to third parties.[10] The attribution of concessions for electric energy production, transport, distribution and commercialization falls under the Council of Ministers, the Minister of Energy and the local authorities, depending the capacity of the installations.

The Council of Ministers has the competence of attribution of concessions for installations equal or superior to 100 MW. For installations between 1 MW and 100 MW the competence for the attribution of concessions fall under the Minister of Energy. However between 1 MW and 10 MW the Minister has the capacity to delegate its competence of concession attribution to the municipal and district level bodies when the electric installations is confined within the area of its jurisdiction and is not interconnected with other electric installations located out of its jurisdiction.

When the installations are under 1 MW the municipal and district authorities will have the competence of attribution of concessions if the 1 MW is destined to provide energy to consumers that are within its jurisdiction area. In this case, the electric installation must be also totally located under its area of jurisdiction.[11]

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[5] Five year plan. Idem. Par. 123.
[6] Relatorio do grupo de Energia para o PARPA 2010.
[7] Belgium Cooperation. 2009. Technical and Financial File. Renewable energy for rural development Mozambique.
[8] Five Year Plan. Idem.
[9] Ministry of Energy/ERAP. 2010. Review of Mozambique Electricity Law. Interim Report. OCtober 11, 2010.
[10] Articulo 10, Lei de Electricidade 21/97 de 1 de Outubro.
[11] Articulo 3, Decreto 8/2000. Regulamento que estabelece as competências e os procedimentos relativas a atribuição de concessões de produção, transporte, distribuição e comercialização de energia eléctrica, bem como a sua importação e Exportação.

The Decree 8/2000 approves the process of attribution of concessions to activities of generation, distribution and commercialization of electric energy, with the assumption that the units are interconnected to the National grid. Therefore there is potential for the construction of installations of generation, distribution and commercialization of electric energy off-grid, for which there is no specific regulation.[12]

The concession procedure establishes a compulsory consultation with CNELEC, the national electricity regulator.

A concession for the use of water may be granted to any natural or legal person, public or private, national or foreign if the applicant is legally authorized to be in Mozambique and the concession does not damage the environment.[13] It is important to note that concessionaires authorized to access to hydro basins for electricity production purposes (such as hydroelectric dams) will be exempted from the payment of fee for water rights.[14]

The execution of the concession agreement requires that the project developer provide an environment license when required by the project. Activities related to the energy sector may have an impact to the environment and therefore require an EIA based on the Decree 45/2004.[15] The EIA decree establishes different categories of economic activities subject to different requirements. Category A for instance is subject to a full Environmental Impact Assessment while Category B is subject to a simplified Environmental Assessment. Within category A are included hydroelectric, thermal, and geothermal plants; industries of briquettes, charcoal and lignite with a production capacity equal or above 150t/day; and energy transmission lines of 110 KV and with more than a 10 km extension.[16] Public participation is compulsory for projects within the Category A and optional for Category B.

4.7.3 Concession of DUATs

The Land Law governs the key aspects of land occupation and use. The right to use land conferred by the State through the Land Law 19/97 is known as the "*Direito de Uso e Aproveitamento de Terra*" or "*DUAT*". [17] A DUAT guarantees legal possession of a tract of land, and where is documented, it provides formal proof of this possession and enables the State to organize its land cadastre.[18] Environmental licensing may be required when there is a need for large-scale use and clearance of land.

The law distinguishes between areas of total protection and areas of partial protection where DUAT rights cannot be allowed. Total protection areas of public domain are those areas aimed at nature conservation and protection and State defence and safety. Partial protection areas include, *inter alia*: the piece of land surrounding dams up to 250m and the land occupied by electricity overhead lines and electricity superficial, subterranean and submarine ducts, with a neighbouring piece of land of 50 meters each side. [19] In the areas of total and partial protection though it is not possible to acquire a DUAT, it is possible to deliver special licenses for the performance of specific activities.[20]

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[12] Draft Estrategias de Energias Novas e Renovaveis. 2010.
[13] Ministry of Energy/ERAP Mozambique. 2010. Review of Mozambique Electricity Law Interim Report. October 11.
[14] Article 34, par. 2 Lei de Electricidade: "São isentos de pagamento de quaisquer taxas sobre a utilizacao de agua, os concessionários a quem for autorizado o acesso aos caudais hídricos para efeitos da producao de hidro electricidade nos termos desta lei.
[15] Decreto 45/2004 de 29 de Setembro que aprova o regulamento sobre o processo de availacao do Impacto Ambiental e revoga o Decreto 76/98 de 29 de Setembro.
[16] Annex I, Decreto 45/2004.
[17] Lei 97/97 de 1 de Outubro. Lei das Terras.
[18] Ministry of Energy/ERAP Mozambique. Ibidem.
[19] Ibidem.
[20] Article 9, Lei das Terras

4.7.4 Power Purchase Agreements

A Power Purchase Agreement (PPA) is a crucial part of a clean energy project, as it allows a developer to accurately estimate the project's revenue stream over a number of years. The negotiation of a PPA is among the most complicated aspects of developing a clean power project and it consists of a contract between an electricity producer (seller) and a purchasing entity for the sale and purchase of electricity generated by a power plant (buyer). The PPA defines the price at which generated power is sold as well as other obligations with respect to purchase of the generated power.

The seller under the PPA is typically an independent power producer (IPP). Energy sales by regulated utilities are normally regulated by local or state government and no PPA is required.

There are different types of PPAs depending on the renewable technology utilized, but the most abundant PPAs so far are solar PPAs and wind PPAs. Geothermal PPAs are also being explored.

In Mozambique there are no renewable PPAs so far, and in general there is no model framework for PPAs in the country. According to the legal services of the Ministry of Energy the only IPP existing in the country right now is Cahora Bassa.

4.7.5 The policy developments on renewable energy in Mozambique

There is no general or specific law on renewable energy in Mozambique but a policy on new and renewable energy was adopted by the Government in 2009, and the Ministry of Energy is formulating a new strategy at present. Renewable energies also constitute a key element in the general policy framework on energy of Mozambique, and are explicitly included in key legal and policy instruments such as the Five Year Plan, the National Strategy for Energy and are also included in the current drafts of the new Poverty Reduction Strategy (PARP).

The National Strategy for Energy

The National Strategy for Energy from June 2009 asserts that renewable energies have to assume a more prominent role in the national energy balance in order to contribute to the reduction of the national economy from fossil fuels and in order to allow a transition to an energy matrix more decentralized.[21] The National Strategy specifically mentions hydroelectric installations under 15 MW, wind energy, geothermal, biomass, biogas and solar. The National Strategy only gives an overview of the different source of renewable energy, which is further developed by a specific policy on new and renewable energies published in October 2009.

The National Policy for the Development of New and Renewable Energies

By Resolution 62/2009 the new Policy for the development of new and renewable energies was adopted[22]. The resolution develops seven types of new and renewable energies: human and animal energy, biomass, hydropower, solar, wind, geothermal, and ocean energies. The policy recognizes that the development of pilot projects and some programmes of off-grid electrification mainly based on solar panel systems have characterized the promotion of new and renewable energies until then. It recognizes that at present more efforts are needed to develop the market for renewable energies, institutional capacity, financial mechanisms coordinated planning and service delivery. The Policy aims to reinforce the local and national energy security and inter alia to create a competitive market for new and renewable energies in Mozambique. One of the challenges that the Policy aims to tackle is to convert the traditional technologies like biomass and animal and human force into modern energy systems, with great efficiency and of better quality.

The policy also commits to produce several strategies and instruments inter alia: a strategy for biomass energy, a strategy for off-grid systems, and specific regulations for biomass energy, wind energy, solar, geothermal, ocean and mini-hydro.

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[21] Resolução 10/2009, 4 junho. Estratégia de energia.
[22] Resolução n. 62/2009 de 14 de Outubro. Politica de desenvolvimento de Energias Novas e Renováveis.

Renewable energies in the Five Year Plan
The Five Year Plan emphasizes the need for renewable energies and emphasizes its use on three particular types: solar, wind and hydro power prioritizing two particular applications, its use in health centres and schools. The Second Strategic Objective of the Five Year Plan asserts that it is necessary to "create capacity of utilization of new and renewable energies in the country, stimulating the development of those technologies for the production and installation of solar energy systems, wind and hydropower and prioritize its installation in health centres and schools". A third strategic objective of the Five Year Plan specifically asserts that there is a need to "boost the use of local resources for the generation of energy, giving prominence to the construction of small and medium scale stations, and co-generation stations and wind parks".

Besides the strategic objectives, the Five Year Plan includes priority actions in four specific renewable energies: wind, solar, mini-hydro and biofuels. On wind two actions are described. First there is a need for the mapping of wind resources using the installation of wind anemometers in various districts of the country and to continue the installation of wind systems for water pumping and installation of "wind pumps" for irrigation. In what concerns solar, it calls for continuing the installation of solar systems in rural areas with priority in school and health centres in all provinces and to electrify some localities in all provinces. Regarding mini-hydro, it calls for continuing the mapping of hydropower resources and the installation of mini-hydro stations in the provinces of Manica (1), Tete (2), Zambezia (1) and Niassa (2). Finally on biofuels it proposes to continue the activities aiming to create a national market for biofuels and to promote the production of biofuels.

Apart from the actions related to those four renewable energies, there is a priority action related to technology development and the private sector where it is said that there is a need to incentivize the private sector in the production of new and renewable energies at the national level through the adoption of policies and strategies favourable to the technology development.

The Draft National Strategy on New and Renewable Energies
The Ministry of Energy is currently preparing a draft strategy for new and renewable energies. The new Strategy is for on-grid and off-grid and establishes a National Plan for Renewable Energy that contains short-term and medium targets that do not specify concrete dates. For instance under the area of intensification of access to energy services of quality from renewable energy the indicator aims to provide a level of access to electricity for domestic lightening on-grid or off-grid of 100 per cent. The level of access to refrigeration equipment being individual or community based should be of 25 per cent.

The Strategy introduces the innovative concept of Community Sustainable Energy Plans (Planos Comunitarios energeticos sustentaveis – PCES), which consists of planning of development and the expansion of energy infrastructure from a local perspective, instead of a national perspective. The PCES will constitute the basis of planning for energy development off-grid. In the context of the PCES the communities under orientation from the technicians of the Provincial Directorate of the Ministry of Energy and Mineral Resources (DIPREME) will make an inventory of their necessities and energetic potential of the respective localities. Clearly this would be contingent on technical guidance being available to those local communities.

The draft strategy also aims to reduce the use of wood biomass for cooking by 10 per cent in the whole country in the short-medium term, and mentions that a separate strategy will be created to deal with wood fuel.

4.7.6 Tariff regimes
It has been very common around the world to introduce special tariff regimes in order to promote the sustainability of the use of renewable energies and a favourable investment climate for those energies.

Feed in tariff
Feed in tariffs (FITs) are key tools for the development of various sources of renewable energies. FITs have been introduced in more than 40 countries around the world with different models. One

common characteristic that all FITs have is the overarching principle that energy generators receive a fixed rate of return for their generation or export for a set period of time. It is very common that the payment for renewable energy is greater than the standard market power prices.[23]

Challenges of implementing FITs in the developing world include financial sustainability of the tariffs and ensuring payments for the renewable energy to the IPP.

A new concept called Global Energy Transfer Feed in Tariffs (GET FIT) aims to support renewable energy scale up and energy access in the developing world through the creation of new international public-private partnerships, by combining a fund of public money directed for renewable energy incentives with risk mitigation strategies and coordinated technical assistance to address project development and financing barriers. This approach aims to catalyze the supply of, and the demand for private sector financing of renewable energy projects in both middle and low-income countries.[24]

The expansion of FITs is a key part of that programme. It is estimated that FITs have driven 75 per cent of newly installed PV capacity and 45 per cent of wind capacity worldwide. Around 25 developing countries have adopted feed-in tariff policies, with varying designs and models. However many of them lack the financial strength, grid infrastructure, and/or regulatory frameworks for full implementation. GET FIT would partner with those countries to deploy policies like advanced FIT designs that target on-grid, commercialized renewable resources at the right prices focused on technologies adapted to local conditions; and PPAs as a pre-FIT regulatory mechanism in countries that face grid integration constraints. In any of those cases the GET FIT Program would contribute public sector funds to share the above-market costs of renewable electricity with partner countries, whereas utilities would commit to purchasing electricity from generators at market price.

At present there are several ongoing or proposed bilateral national partnerships focusing on climate change and renewable energy technology deployment in developing countries that currently have feed-in tariff policies. South Africa is exploring FIT partnerships opportunities with Germany, while Kenya has announced plans to work with Japan. According to the Deutsche Bank report those bilateral partnerships could provide a means for deploying the GET FIT concept in an institutionalized way.[25]

Tariff for off-grid systems
The draft strategy for the development of new and renewable energies also introduce the idea of a tariff for off-grid systems based on the production costs and aligned to the national tariff framework in order to avoid socio-economic inequalities.

4.7.7 Biofuels Strategy
Among the five renewable energies studied in this report, small-hydro, solar, geothermal, wind and biofuels, none has its own stand-alone legislation, policy or strategy with the exception of biofuels.

In 2009 the Government approved a specific policy and strategy for biofuels.[26] This instrument focuses in the promotion of ethanol and biodiesel produced from agriculture raw materials for the production of liquid fuels to be used mainly in the transport sector. Although biomass and other fuels made from municipal and agriculture waste could be classified as biofuels, they are not addressed in the Strategy.

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[23] Good Energy. 2009. Feed-in Tariffs for the UK: an analysis of feed-in tariff models and an evaluation of their suitability for the UK electricity market.
[24] Deutsche Bank Climate Change Advisors. 2010. GET FIT Program: Global Energy transfer Feed-in Tariffs for Developing countries.
[25] Idem.
[26] Resolucao 22/2009 of 21 of May.

Some of the main challenges of this industry is the attribution of DUATs without conflicts with the communities; achieving the balance between the production of biofuels and food; the rational use of water; and the management of secondary impacts such as the displacement of agricultural activities for food production which lead to new clearing of forested lands. There are crops selected for the production of biofuels in Mozambique: sugar-cane and mapira doce for ethanol, and for biodiesel *jatropha curcas* and coconut.

A plan of action is outlined in the strategy that identifies specific activities to be carried for several institutions and respective budgets. In what concerns the institutional framework it foresees the creation of a National Biofuel Commission, a National Programme for the Development of Biofuels (PNDB) and a Programme of Biofuels Purchase (PCB).

The policy and strategy for biofuels has a timeframe divided in three phases:

- Pilot phase: the PCB will start purchasing biofuels to the national producers (2009-2015);
- Operational phase: consolidation of the biofuel sector, reaching higher level of mixes from 2015 onwards; and
- Expansion phase: From 2011 onwards developing the distribution of separate or parallel networks of distribution for fuels with higher levels of ethanol (E75 and E100) and pure biodiesel (B100).

4.7.8 Policy and regulatory framework analysis and improvement opportunities

Biomass strategy and implementation plan

In Mozambique the energy policy dialogue principally centres on electricity access and generation. Yet wood-fuels provide the biggest portion of domestic energy needs. The ability to pay and consumer preference for wood-fuels are unlikely to change quickly. Cooking energy provided by woody biomass should be given much higher priority in the energy debate.

The GTZ managed biomass cooking fuels programme, Probec, was a positive initiative. In the last 12 months management of Probec was transferred to FUNAE for the next phase of implementation. FUNAE is an implementing agency, not a policy developer. Hence it is not clear how Probec will continue to evolve and improve going forward.

The Ministry of Energy policy focus rests on politically sensitive efforts to increase electricity access. There is no wood-fuel strategy. The level of financing and political attention given to this biomass is simply insufficient. This disconnect leaves the wood-fuel sector in the obscure, informal economy of unsustainable extraction.

The central role of wood-fuels at present and in the near future needs to be properly reflected in policy documents and regulatory systems. The Ministry of Energy, FUNAE and MINAG should urgently jointly design and implement a wood-fuel sustainable supply and efficiency strategy.

Bringing wood-fuel into the formal economy for sustainable supply

Wood-fuel extraction activities largely operate in the informal sector. There is no immediate plan to bring wood-fuel extraction into the formal economy yet the potential tax revenues from the sector could be very attractive.

As long as wood-fuel remains outside of the formal economy it will be difficult to introduce sustainable supply measures and almost impossible for private sector companies to enter the market with competitively priced wood-fuel products and alternatives. However the industry must be urgently brought under sustainable management practices.

It is vital that the wood-fuel industry players are not marginalised in any attempt to formalise the industry. Many thousands of jobs and rural livelihoods may depend on the wood-fuel economy. The process for bringing the wood-fuel business under effective public sector regulation should worked out in round-table meetings with key industry actors, Government and civil society groups.

Energy efficiency demand side management
Energy efficiency does not feature strongly in the energy policy debate, yet it presents a tenable opportunity to improve demand management and reduce overall energy requirements.

Efficiency measures need to be incentivised and accessible to different types of energy consumers. Simple affordable measures such as replacing incandescent light bulbs with compact fluorescent light (CFLs) bulbs would reduce lighting energy requirements, typically consuming only 20-30 percent of the energy required for an incandescent light.

A national policy and corresponding regulations could be implemented to make energy efficient products such as CFLs mandatory. The Ministry of Energy, together with the Ministry of Finance, could collaborate to prepare and execute an energy efficiency plan with fiscal incentives such as reduced import duties on energy efficient products.

Stimulating energy sector investment
If an investor is considering setting up energy supply services in Mozambique there is no model PPA available to facilitate feasibility research exercises. Furthermore there is no FIT established for any particular energy type.

The lack of PPA models and clear FITs both represent gaps in the policy and regulatory framework, which may increase the cost of research for potential investors. The preparation and dissemination of a model PPA and FITs may assist stimulate investment in the energy sector in Mozambique. The Ministry of Energy and CENLEC could jointly prepare a model PPA, while the Ministry of Energy, CENLEC and the Ministry of Finance could develop FITs.

LCA for comparison of energy generation CO_2eq emissions impacts
Although the energy generation options in the Ministry of Energy 'Generation Master Plan for the Mozambican Power Sector' (2009_a) considers environmental impact, it does not assess CO_2eq emissions over the life cycle of projects. This is a serious gap in the energy planning policy framework. When evaluating energy generation options upstream and downstream CO_2eq emissions must be included to get an accurate assessment of potential total emissions, not only direct impacts. LCA tools allow cumulative CO_2eq emissions to be comprehensively assessed from fuel prospecting through to the decommissioning of energy generation installations.

MICOA and the Ministry of Energy may consider integrating LCAs as a requirement on all energy generation planning and Environmental Impact Assessments (EIAs) to maintain a robust method for comparison of energy generation options' respective cumulative CO_2eq emissions impacts. Without LCA tools national GHG emission accounting will not reflect the true impact of CO_2eq emissions.

National low CO_2eq emissions development policy
The Government's 5 Year Plan reflects the national development policy for all sectors. It is not conditioned by the global CO_2eq emissions limits all countries face. This is unfortunately the status quo worldwide. Few countries, if any, have comprehensively structured their development and management plans to fit within the global CO_2eq emissions constraints. The complex political and environmental issues that animate the global CO_2eq emissions rights, allowances and reductions debate should not distract decision makers from the fact that the discussion takes place within ever clearer emission boundaries. The more CO_2eq emissions entering the atmosphere the more extreme the potential effects on global environmental systems. Mozambique has the responsibility, like all countries, to understand its own CO_2eq emissions dynamics and set course for a sustainable energy regime development pathway. This should not be limited to the energy sector but rather embrace all CO_2eq emissions sources and sinks.

The inter-ministerial Committee on Sustainable Development (CONDES) may convene its members to define the targets and thresholds of for CO_2eq emissions controls, reductions and mitigation.

National CO_2eq emissions accounting and reductions policy
National policy documents do not address how to account or the need to account for CO_2eq emissions. A robust, obligatory emissions accounting framework must be established. Otherwise this gap will lead to uncoordinated efforts to understand CO_2eq emissions, if at all.

The Ministry for Planning and Development (MPD), MICOA, the Ministry of Energy and the Ministry of Finance may come together to define a suitable emission accounting policy and emission reduction incentives. CONDES could also be a suitable forum for this task.

Sustainable urban design
Urban areas are the future population centres for humanity. This is the widely understood end result of the rapid urbanisation and migration from rural areas being experienced around the world. Mozambique has an opportunity to ensure that these future cities are designed to sustainably provide energy and other related services. A policy debate specifically targeting solutions to urban area energy needs be launched in earnest. Different urban areas may be suited to various solutions depending on population density, available energy resources, and ability to pay amongst other factors.

MPD, the Ministry of Energy, the Ministry of Public Works, MICOA and relevant Municipal Authorities should be convened to zone and plan population expansion areas with a view to delivering sustainable, local, accessible energy services. The urban expansion policy dialogue should be driven by principles such as sustainable design, closing the resource loop, and local renewable energy services. CONDES could also be a suitable forum for this task.

Low CO_2eq emissions transport policy
Sustainable low CO_2eq emissions transport is not properly sanctioned in energy policy documents. The most recent Government policy document regarding energy sources for transport is the Biofuels Strategy (2009). The motivation behind the development of this instrument is to reduce dependence on imported fossil fuels for the transport sector. However important energy security is it should not overshadow the need to move towards, as soon as possible, low CO_2eq emissions transport.

The abundance of cheap off-peak electricity from Cahora Bassa is an obvious place to start exploring options to take advantage of available low CO_2eq emissions energy for urban transport. Clearly this would require large investments in public transport infrastructure that must be duly studied for feasibility in the short, medium and long term.

The Ministry of Transport, MPD, the Ministry of Energy, the Ministry of Public Works, MICOA and relevant Municipal Authorities should be convened to assess how and where public urban transport systems can begin to shift towards affordable, low CO_2eq emissions transport systems.

Investing in knowledge
Policy to promote knowledge gathering and dissemination is lacking, along with data collection infrastructure and systems. Many predictions about possible impacts of increasing GHG concentrations have been made for Mozambique, most notably in the INGC (2009) 'Study on the impact of climate change on disaster risk in Mozambique'. But in Mozambique basic and reliable data on temperatures, wind speeds, solar radiation, rainfall, sea-levels, hydrological dynamics, land use and forest cover, amongst other important variables, are very hard to come by. This leaves the country handicapped, unable to read the situation for itself and plan accordingly. Investing in knowledge should be a top Government policy priority.

4.8 Stakeholders, institutional setting and capacity building

4.8.1 Government institutions
The main energy sector institutional actors in Mozambique are the Ministry of Energy, EDM, FUNAE and CNELEC. The Ministry of Energy is responsible for national energy planning and policy formulation and for overseeing the operation and development of the energy sector. At

present the Ministry of Energy has a total of 156 staff, of which only 30 per cent are university graduates. While the Ministry of Energy has experienced a remarkable development in the last few years, it remains seriously understaffed with respect to its level of responsibilities and volume of work, requiring significant institutional strengthening and capacity development.

EDM was transformed into a public company in 1995 with the responsibility for the public supply of electricity including generation, transmission, distribution and sale throughout the Republic of Mozambique. EDM currently operates two isolated power systems, the Central Northern system and the Southern system. Total installed generating capacity is nominally 233 MW but the available capacity is 157 MW, comprising 82 MW of hydro and 75 MW of thermal power generation. In addition, there is a 2,075 MW hydroelectric power station at Cahora Bassa, which is owned by a limited-liability corporation *Hidroeléctrica* de Cahora Bassa (HCB) and which sells electric power to South Africa, Zimbabwe and also EDM.

FUNAE was established in 1997 as a public institution to promote rural electrification and rural access to modern energy services, in a sustainable manner, and as a contributor to economic and social development in the country. Since its establishment FUNAE has been able to implement numerous successful projects using solar, wind and biomass energy resources and technologies to electrify and/or bring access to modern energy services (water pumping, milling, communications, etc.) to schools, clinics and rural communities. FUNAE has two decentralized offices in Tete and Nampula.

CNELEC was established as an independent advisory regulatory body for the electricity sector in early 2008. In a July 2006 directive issued by the Minister of Energy, CNELEC was instructed to give its highest priority to an evaluation of EDM under its Performance Contract with the Government of Mozambique. This is a very important task because the financial sustainability of EDM has been questioned in recent years.

The existing regulatory framework does not provide CNELEC with an adequate definition of its legal mandate, and its advisory and oversight functions are too limited, with considerable lack of powers on monitoring, compliance and enforcement tasks. It is expected that a revision of the Electricity law will improve the current situation together with other key elements and institutional aspects related to EDM and the Ministry of Energy.

Besides the above four institutions directly related to energy issues there are two other institutions that can play an important role in the energy sector: those are MINAG, particularly for wood-fuels, and MICOA.

MICOA is entrusted with the responsibility of "promoting sustainable development through the practical leadership and execution of the country's environmental policy[27]". For that effect the Ministry is structured in five major areas of activities: (i) inter-sector coordination; (ii) research, planning and environmental management; (iii) environmental impact assessment; (iv) environment education and promotion; and (v) inspection and supervision. The Ministry is relatively new compared to other traditional ministries and it has been struggling to attract and retain highly qualified staff. MICOA faces several challenges in fulfilling its mandate due to weaknesses in its human resource capacity. These weaknesses are related to insufficient knowledge and skills, low number of staff, low level of incentives and poor motivation and a bureaucratic and hierarchical system.[28]

The Organic Statute of MINAG was approved by the Ministerial Diploma n. 202/2005 of 29th of August and three national directorates are highlighted: the national Directorate of Agricultural

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[27] Cabinet Diploma n. 133/2000, of September 27.

[28] Government of Mozambique and Danish Ministry of Foreign Affairs. 2010. DANIDA Environment Sector Programme Support ESPS II 2011-2015.

Services, the National Directorate of Land and Forest and the National Directorate of Agriculture Extension.[29] The National Directorate of Land and Forest has nine units. The Department of Forests for instance is in charge of some energy related issues. According to Article 21 of the Rule of Procedures, the Department of Forests is "responsible for ensuring the rational and sustainable use of the local forest and development of plantations for purposes such as conservation, energy and socio-economic".[30]

4.8.2 Civil Society Organizations

Civil society plays an important role in the efforts to promote renewable energies in Mozambique. Advocacy for the implementation of new and renewable energies is a key task for the years to come at the local, regional and national level and civil society organizations based at the different levels in the country can help promote the use of cleaner forms of energies.

Religious and development based CSOs, often with significant presence at the district and local level, can be vital for advocacy campaigns for the energy sector issues, such as deforestation and uncontrolled fires. There is a need for increasing awareness campaigns particularly at the community level against uncontrolled fires, as it is one of the major sources and waste forms of energy existing in the country.

4.8.3 Energy Donors Working Group

At present Sweden co-chairs the Energy Sector Working Group (ESWG), established in 2004 and consists of representatives from key Energy Development Partners and representatives from Mozambican energy institutions. The Development Partners also regularly meet in the Energy Donor Working Group (EDWG), which is chaired also by Sweden with the objective to better coordinate the efforts of the partners of the energy sector with the Mozambican Government.

Since 2001 Sweden has contributed with approximately USD 168 to the Energy Sector, mainly to support electrification projects of EDM in the provinces of Sofala, Manica, Tete, Niassa, and Inhambane. Sweden has also provided technical assistance to EDM. In June 2010 an agreement between Sweden and Mozambique on the rehabilitation of the hydropower stations in Mavuzi and Chicamba was signed with an estimated value of USD 53 million.

Besides Sweden, the most active members of the Energy Donor Working Group include the World Bank, the African Development Bank, the European Commission, Belgium, Norway, Germany and France. The group is well coordinated and activities are strategically divided amongst different institutions, some supporting EDM, while others support FUNAE and the Ministry of Energy.

The total value of all ongoing projects in the energy sector in Mozambique is estimated to approximately USD 620 million and made available to Mozambique through either grants or soft loans. In addition, Mozambique has requested further financial assistance from the partners which is under preparation. The projects are to be implemented by Mozambique during the short to medium term and amounts today to approximately 530 million USD.[31]

The German Agency for Technical Co-operation (GTZ) led ProBEC (Programme for Basic Energy and Conservation), a regional programme implemented in the SADC region, and concluded in 2010. ProBEC established various projects for basic energy conservation, especially biomass fuel consumption efficiency, in 10 member states in SADC. [32] In Mozambique the government has decided to appoint the FUNAE to take over ProBEC activities in the country post-2010.

GTZ is continuing its work programme on renewable energy with a particular focus on the province on Manica where they plan to install 20 micro-hydro installations in two years, and 100,000 efficient cook-stoves in 2-3 years.

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[29] IUCN. 2009. Analysis of the legal and institutional framework on climate change in Mozambique.
[30] Idem.
[31] Speech of Swedish Ambassador Torvald Akesson at the Annual Meeting of Energy Partners in 2010.
[32] Probec. www.probec.org

In July 2010 the Belgium Technical Cooperation signed a €218 million project on renewable energy between with FUNAE. The project is co-managed by both institutions in order to promote rural electrification and rural access to modern energy services for a period of five years from 2010-2015.[33] The Programme will be based in hydro, solar and wind resources in remote rural areas where no grid connection is foreseen within the next five years. The program will finance via grants, electrification systems for community infrastructures such as schools, health centres and public lighting. While renewable energy installations for private use will be supported via subsidies and soft loans through micro-finance systems.

4.8.5 Stakeholder analysis and capacity building opportunities

There are numerous different capacity building issues, including technical skills/knowledge gaps, coordination problems, financial resources for information gathering on critical issues such as CO_2eq emissions, and public awareness about the impacts of detrimental activities like uncontrolled fires. Below, per sector, some of the most prominent and urgent capacity building measures are considered and briefly outlined.

Government

In general, knowledge about CO_2eq emissions in Government institutions, and most other sectors, is poor. At a multi-sector workshop held in February 2011 to share preliminary results and generate ideas for interventions all participants recognised the need to share the study findings as soon as possible, especially with Government. Some participants at the workshop suggested that the CO_2eq emission impacts of different energy development pathways are simply not on the Government radar. The summary of this report for policy makers should be disseminated to Government through CONDES.

The next key area of intervention to build the capacity of the Government to move towards sustainable energy development pathways relates to CO_2eq emissions appraisal tools and accounting systems, essentially CO_2eq emissions knowledge for action. The first step on this path requires a professional and comprehensive CO_2eq baseline for all sectors. With adequate technical support this could be lead by MPD, supported by MICOA, the Ministry of Energy and MINAG. Once a baseline is in place a leading Government institution must be appointed or created, perhaps as an independent unit in MPD or the Ministry of Finance, responsible for gathering, compiling, analysing and auditing CO_2eq emissions data from all sectors and sources. Special tools for LCA of CO_2eq emissions for different energy generation master plan options and specific projects should be developed and disseminated for use by key government institutions such as MPD, MICOA and the Ministry of Energy. These measures are key for the sustainable management of CO_2eq emissions and an opportunity exists to seek funding to kick-start the process at the Durban Climate Change Summit in November/December 2011: MPD and the Ministry of Energy should consider preparing a Low CO_2eq Emissions Economy Action Plan for presentation at the Climate Change Summit to build technology and resource transfer partnerships.

The Ministry of Energy must strengthen energy data collection and analysis systems to identify per energy source (biomass, hydrocarbons, hydropower, solar, etc.) how much is used, for what purpose, when and by which users. This type of information is currently not readily available or collected in a structured manner with a robust methodology. Solid, up-to-date energy data collection and analysis systems would improve the Ministry of Energy's and other institutions' capacity to weigh up and plan energy alternatives much more effectively.

The fundamental role of biomass in Mozambique's energy regime might lead observers to assume it has a prominent role in the Ministry of Energy, FUNAE and MINAG. This is not the case. Though departments and staff are working on biomass Government actions in this area are not visible.

The Ministry of Energy, FUNAE and MINAG need an effective command of biomass interventions

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[33] Belgium Technical Cooperation. 2009. Idem.

for both sustainable supply side management and consumption efficiency. A single strong Government institution must be appointed to lead on biomass. This unit must have sufficient staff and resources to establish progressive relationships with the wood-fuel informal sector to bring them into the formal economy, foment and direct the development of sustainable biomass plantations are established, and improve harvesting and processing techniques to increase efficiency while also promoting fuel efficient stoves for end-users.

Finally, education is the most valuable long term investment for energy regime sustainability. The Government is in a unique position to influence attitudes, values and behaviour of its citizens. Starting with the public education system, Government should design and implement an environmental course as part of the primary school and secondary school mandatory curriculum, teaching the basic concepts of finite natural resource availability, ecosystem services and the environmental impacts of different key services such as energy supply.

Changing attitudes and values can take considerable time but a common understanding of basic environmental dynamics could prove to be a stellar asset in the process of building sustainable energy practices in Mozambique.

CSOs

CSOs should also receive the results of this study to raise awareness about the impacts of different energy development pathways. The majority of CSOs, like Government and the Private Sector, are not aware of the CO_2eq emissions situation in Mozambique or the implications of different energy development pathways.

A capacity building intervention targeting key CSOs working on environment and natural resource use should be considered to equip them with CO_2eq emissions LCA tools and skills. This would enable them to effectively participate in strategy energy generation and services planning stages and also at project level on EIAs. Providing CSOs with LCA tools and skills would also introduce a common and coherent method for appraisal of energy alternatives.

Lastly CSOs are well positioned to reach communities with energy efficiency advocacy material through their own community based staff, faith-based leaders (Muslim, Christian, Hindu, etc), and local traditional leaders (chiefs, community leaders, curandeiras, etc.). Key community education and awareness issues to be communicated, in local languages, include sustainable fuel-wood supply, fuel-wood efficiency stove technology and the prevention of uncontrolled fires. Community radio programmes, and TV (dramas and documentaries), are important media channels that could be exploited by CSOs for this purpose.

Private Sector

The Private Sector should also receive the results of this study to raise awareness about the impacts of different energy development pathways, and to explore profitable interventions that could be exploited to deliver low CO_2eq emissions energy services.

Providing International Standard Organisation (ISO) 14000 series trainings, especially with regards to energy performance audits, specifically for energy consulting firms and installation companies could introduce a strong standard for sustainable and efficient energy systems. The establishment of ISO type benchmarks for energy sector goods and services is an important step towards higher (sustainable) performance among private sector players.

CO_2eq emissions can be off-set and mitigated through different interventions, one of the most prominent among them is carbon sequestration. Local private sector groups have had limited success in accessing the carbon markets. A series of intensive workshops for ecosystem services, energy, forestry, and investment companies, lead by international carbon experts, on how to design carbon based business models and gain access to international carbon markets may stimulate the emergence of a local carbon off-setting industry. This would be beneficial for the local economy and increase Mozambique's contribution to slowing the impact of CO_2 emissions on climate systems.

Another important issue that could be addressed through private sector capacity building is sustainable urban design. Local architecture, engineering and construction companies should be provided with short module trainings on sustainable urban planning, housing, public transport, renewable energy services and energy efficiency.

There are opportunities for the banks in Mozambique to make a greater contribution to energy service sustainability through reduced lending rates for credit. Procredit, operating in south east Europe, has established a credit line with reduced lending rates for businesses that seek credit for the implementation of energy efficiency investments, amongst other environmentally sustainable investment categories. Providing reduced credit rates for Mozambican businesses investing in fuel-efficient stoves, renewable energy systems, CFLs, etc. could be financed by international climate change funds and stimulate a shift towards sustainable energy services.

Currently there is not dedicated forum for businesses involved in the energy sector to interact. A Clean Tech Forum with an annual meeting bringing in foreign clean tech investors, producers and researchers to meet and share business opportunities with local private sector players could open up the national energy market for more diverse products and services. This type of forum would also provide a dynamic platform for private sector and public sector dialogue on sustainable energy issues and could be supported by a publicly accessible website with available renewable energy maps, clean tech investment opportunities, B2B contact information, energy efficiency solutions, and carbon market opportunities.

Informal charcoal and firewood sector
The number of players and influence of the different business entities involved in the fuel-wood (both charcoal and firewood) sector is difficult to decipher because of its informal status. However it is clear that at a local level fuel-wood extraction and processing is a vital livelihood strategy providing income for many households. Though it operates in the informal sector the fuel-wood industry is a strong economic force, with charcoal alone estimated to generate over USD 470 million per year in retail sales. It is possible that the industry is aware of the dwindling natural forest resources upon which their business models depend because charcoal harvesting and production is taking place in locations further and further away from urban centres with every passing year. The increased distances add growing transport costs to the final product sold in urban markets.

The fuel-wood sector should be presented with the results of this study to inform them of the extent and implications of Mozambique's forest resources' rapid decline, demonstrating the expiry date stamped on their current mode of operation. Partnerships for plantations of fast growing native species such as bamboo and should be established on a pilot basis with industry members that are willing to become the future winners in the fuel-wood sector. Where possible plantations should be set-up closer to urban centres to reduce transport costs and compete with those that are not willing or able to make the transition to from unsustainable extraction to sustainable production. Plantations should be designed using best practices, such as those established by the Forest Stewardship Council (FSC) and efficient charcoal production techniques should be introduced.

Academic Institutions
University Eduardo Mondlane (UEM) is the main academic institution involved in environmental research in Mozambique and should certainly be provided with the results of this study for comment. Many research activities are taking place in UEM on uncontrolled fires, renewable energy, climate systems, and CO_2 emissions.

Academic institutions should be encouraged and supported where necessary to develop technical courses designed for undergraduates to provide them with practical skills for: renewable energy systems design, installation and maintenance; and assessment and mapping of renewable energy resources (wind speeds, river flows for pico/micro/mini hydro, tidal speeds, solar radiation, etc.).

Another essential role of Mozambique's academic institutions, in addition to top class education services, is research. Research funds invested to explore the feasibility of local production of fuel-efficient stoves, solar thermal water heating, and biogas installations could assist introduced these relatively accessible technologies which are particularly suited to the energy needs of

Mozambique. More demanding and newer areas of research such as the energy potential, impacts and feasibility of algae production, and the energy potential, impacts and feasibility of tidal power could also be explored.

4.9 REDD+ potential and other carbon market opportunities

4.9.1 Clean Development Mechanism

The draft strategy for new and renewable energy considers that all projects of new and renewable energies can take advantage of the Clean Development Mechanism (CDM). It also foresees the creation of agencies in Mozambique that help elaborate candidate projects to the CDM.

CDM allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one ton of CO_2. CERs can be sold and traded by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol.

Africa has 54 CDM projects registered, out of total of 2,754 worldwide. Over 2,000 CDM projects are located in the Asia Pacific Area and 500 in the Latin America and the Caribbean. A total of 18 of all the African projects are located in South Africa. Mozambique has is in the process of completing a CDM project for fuel switching from diesel to natural gas for cement production in Matola.

Table 33. CDM Projects in Africa

Country	No. Projects
Cameroun	1
Cote D'Ivoire	1
Egypt	7
Ethiopia	1
Kenya	3
Liberia	1
Madagascar	1
Mali	1
Mauritania	1
Morocco	5
Nigeria	5
Rwanda	1
Senegal	2
South Africa	18
Tunisia	2
Uganda	3
Zambia	1
Total	**54**

CDM also covers small scale renewable energy projects like for example a hydroelectric dam inferior to 15 MW. In South Africa, the Bethlehem project consists in developing 7 MW hydro power station linked national grid which will off-set coal use[34]. Bethlehem Hydro will be the one of the first new IPPs to be constructed in South Africa for the sole purpose of selling power commercially and not for internal use. To date no other new IPP could compete with the low cost of power produced by ESKOM. The carbon revenue is an essential component of the project's income in order to meet its debt payment requirements.

In Mozambique there is significant potential for small scale hydro and hence in theory, there should

[34] Bethlehem Hydroelectric project. Project Design Document Version 7 rev. 4. 7 October 2009.

be possibilities to develop CDM projects of that type. However there is a substantial difference between Mozambique and South Africa and this is the factor grid, which is an important element in the methodologies calculations of the CDM projects. For instance almost 90 per cent of South Africa's electricity is generated in coal-fired power stations, and one of the parameters that will be used is the emission factor for the South African grid. The emissions derived from the South African grid are high as they are coal derived, however the Mozambican grid which is almost in its totality derived from hydropower is very clean, so the reduction of emissions from new hydropower schemes will be much lower than in South Africa and therefore less Carbon credits will be allowed. This can make a similar project like the Bethlehem hydropower station unviable in the Mozambican context. Any project in Mozambique for CDM on renewable energies that intends to provide electric energy to the grid will face the challenge of the grid factor.

4.9.2 REDD+ status in Mozambique

REDD+ policy

Deforestation and forest degradation, through agricultural expansion, conversion to pastureland, infrastructure development, destructive logging, fires etc., account for nearly 20 per cent of global GHG. Reducing Emissions from Deforestation and Forest Degradation (REDD) is based on a simple concept: countries that are willing[35] and able to reduce emissions from deforestation should be financially compensated for doing so.

REDD aims to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon pathways to sustainable development. "REDD+" goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.[36] The total pledges in May 2010 for the initial public finance of REDD+ stood at USD 4 billion.

Mozambique and the Forest Carbon Partnership Facility

Mozambique has been one of the countries in the world elected to benefit from the support of the World Bank in order to prepare the legal and institutional framework needed for the implementation of REDD+. The Forest Carbon Partnership Facility (FCPF) created in 2008 has focused to provide beneficiaries of the Partnership to be ready for implementing REDD+ projects. Thirty-seven REDD countries (14 in Africa, 15 in Latin America and the Caribbean, and eight in Asia and the Pacific) have been selected in the partnership. MICOA submitted a Readiness Plan Idea Note (R-PIN) in March 2008,[37] and is at present preparing a Readiness Preparation Proposals (R-PPs). So far only thirteen of these countries (Argentina, Costa Rica, the Democratic Republic of Congo, Ghana, Guyana, Indonesia, Kenya, Lao PDR, Mexico, Nepal, Panama, the Republic of Congo and Tanzania) have submitted R-PPs. The World Bank is analysing these R-PPs with a view to entering into readiness grant agreements of up to USD 3.6 million to assist these countries conduct the preparatory work.[38]

Mozambique and the draft REDD+ Strategy

Mozambique is in the process of completing a REDD+ Strategy, which was presented to the development partners in the beginning of February 2011.[39]

The draft strategy has four objectives:

1. To create favourable conditions for the progressive reduction of the levels of deforestation to zero for the period that follows the strategy;
2. To reduce the rate of deforestation to the historical levels registered between 1972-1990 until 2025;

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[35] The Global Canopy Programme. 2008. The little REDD Book.
[36] Interim REDD+ Parntership Document adopted at OCFC on the 27th of May 2010.
[37] Mozambique Readiness Plan Idea Note, March 2008. FCPF.
[38] The Forest Carbon Partnership Facility http://wwww.forestcarbonparthership.org
[39] MICOA. 2010. Estrategia nacional de reducao de emissoes por desmatamento e degradacao.

3. To reduce the rate of forest degradation; and
4. To increase the capacity of the terrestrial ecosystems natural or artificial to sequester 30 million tonnes of carbon until 2025.

At the institutional level the creation of a Technical Unit for REDD is proposed, with administrative and financial autonomy to manage REDD+ funds. The Unit will be under the responsibility of MICOA in coordination with the Secretariat of CONDES, in consultation with MINAG.

4.9.3 REDD+ opportunities

REDD+ on small hydro catchments

The total catchment areas of all small hydro installations assessed amounts to 44,160 Km^2. However local up to date information on the different catchments' extent of forest cover, forest types, C stocks (above and below ground), deforestation rates, and rates of MAI, plus an understanding of leakage dynamics are necessary to calculate the potential REDD+ carbon credit revenues. Catchment site visits essential for this task were beyond the resources of this study making it impossible to generate meaningful REDD+ carbon credit revenues estimates at this stage. Nonetheless the maximum theoretical carbon stocks, not carbon credit revenues, have been assessed and quantified in financial terms (see Table 34) amounting to over USD 244 million – simply for indicative purposes, assuming additionally is proven and leakage is not addressed, applying an annual average deforestation rate of 1.75 per cent would give approximately USD 4.2 million carbon revenues per year.

Table 34. REDD+ carbon credit potential on small hydro catchments

Province	Average forest C stocks (tons/ ha)	Catchment area (KM2)	Maximum theoretical forest carbon values (USD)
Cabo Delgado	68.6	-	-
Gaza	28.1	-	-
Inhambane	35.2	-	-
Manica	58.7	12,100	70,978,636
Maputo City	0.0	-	-
Maputo Prov.	20.6	3,550	7,323,382
Nampula	58.1	16,700	97,024,812
Niassa	42.2	3,128	13,212,933
Sofala	67.8	-	-
Tete	50.9	4,900	24,961,386
Zambezia	81.1	3,782	30,680,419
Totals		**44,160**	**244,181,570**

Carbon markets opportunities and fuel-efficient stoves

Expansion of fuel-efficient stove technology is perhaps the most important immediate, low cost and feasible intervention for Mozambique to reduce fuel-wood consumption emissions. In addition to the reduced impact of lowered CO_2 emissions and protection of forests and related ecosystem services resources, there are also potentially lucrative business opportunities in carbon markets arising from the CO_2 emissions savings.

Carbon credits could be leveraged to reduce the local costs of fuel-efficient stoves, making them more accessible to consumers with lower ability to pay. According to fuel-wood consumption estimates for 2010, the potential CO_2 emissions savings from fuel-efficient stoves, based on a 33 per cent efficiency performance level, could reduce up to 52 million tons of direct CO_2 emissions. Carbon emission savings could be worth over USD 318 million in voluntary carbon markets (see Table 35).

Table 35. Fuel-efficient stove avoided forest loss and carbon market potential

Forest cutting-loss avoided/ year		CO2 emission avoided/ year		Capital cost for stove purchases (USD/ year)
Total savings ('000 m3)	Total area ('000 ha)	Quantity of avoided direct emissions ('000 tCO2)	Value of direct emissions avoided (USD)	
10,783	**296**	**52,184**	**318,320,636**	**24,893,591**
11,094	305	53,687	327,490,366	25,610,690
11,451	315	55,430	338,122,762	26,327,789
11,819	325	57,228	349,093,819	27,064,967
12,199	335	59,084	360,414,168	27,822,787
12,592	**346**	**60,999**	**372,094,766**	**28,601,825**
12,996	357	62,975	384,146,913	29,402,676
13,414	369	65,013	396,582,259	30,225,951
13,844	380	67,117	409,412,812	31,072,277
14,288	393	69,287	422,650,956	31,942,301
14,747	**405**	**71,526**	**436,309,456**	**32,836,685**
15,219	418	73,836	450,401,474	33,756,113
15,707	432	76,220	464,940,578	34,701,284
16,210	445	78,679	479,940,757	35,672,920
16,728	460	81,216	495,416,433	36,671,761
17,264	**474**	**83,833**	**511,382,474**	**37,698,571**
17,816	489	86,533	527,854,206	38,754,131
18,385	505	89,319	544,847,431	39,839,246
18,972	521	92,193	562,378,439	40,954,745
19,578	538	95,158	580,464,023	42,101,478
20,170	**554**	**98,049**	**598,097,472**	**43,280,319**

Carbon markets opportunities with biogas

Similar to fuel-efficient stoves, biogas-use, off-setting wood-fuel consumption, could reduce fuel-wood combustion emissions, saving forest resources, and create significant opportunities in carbon markets.

Carbon credits could be leveraged to reduce the local costs of biogas units, making them more accessible to consumers. According to 2010 fuel-wood consumption estimates, the potential CO_2 emissions off-set by biogas use – assuming 100 per cent of the population uses the technology – could exceed 47 million tons of direct fuel-wood CO_2 emissions. In financial terms these savings could be worth over USD 289 million in voluntary carbon markets (see Table 36).

Table 36. Biogas avoided CO_2 emissions and carbon market potential

Year	Total wood fuel CO_2 off-set by with 100% pop. using biogas ('000 tCO_2)	Wood fuel CO_2e off-set by biogas ('000 tCO_2)				Value of CO_2 emission off-set by 100% pop. using biogas (USD)
		10% pop using biogas	30% pop using biogas	50% pop using biogas	100% pop using biogas	
2010	**47,440**	**4,744**	**14,232**	**23,720**	**47,440**	**289,382,396**
2011	48,806	4,881	14,642	24,403	48,806	297,718,515
2012	50,391	5,039	15,117	25,195	50,391	307,384,329
2013	52,026	5,203	15,608	26,013	52,026	317,358,018
2014	53,713	5,371	16,114	26,856	53,713	327,649,243
2015	**55,454**	**5,545**	**16,636**	**27,727**	**55,454**	**338,267,969**
2016	57,250	5,725	17,175	28,625	57,250	349,224,467
2017	59,103	5,910	17,731	29,552	59,103	360,529,326
2018	61,015	6,102	18,305	30,508	61,015	372,193,465
2019	62,988	6,299	18,896	31,494	62,988	384,228,141
2020	**65,024**	**6,502**	**19,507**	**32,512**	**65,024**	**396,644,960**
2021	67,124	6,712	20,137	33,562	67,124	409,455,885
2022	69,291	6,929	20,787	34,645	69,291	422,673,253
2023	71,526	7,153	21,458	35,763	71,526	436,309,779
2024	73,833	7,383	22,150	36,916	73,833	450,378,576
2025	**76,212**	**7,621**	**22,864**	**38,106**	**76,212**	**464,893,158**
2026	78,667	7,867	23,600	39,333	78,667	479,867,460
2027	81,199	8,120	24,360	40,600	81,199	495,315,846
2028	83,812	8,381	25,144	41,906	83,812	511,253,126
2029	86,507	8,651	25,952	43,254	86,507	527,694,567
2030	**89,135**	**8,914**	**26,741**	**44,568**	**89,135**	**543,724,975**

REDD+ mangroves, seagrass and salt marshes

Though the REDD+ opportunities and challenges for mangroves, seagrass and salt marshes were not covered under the terms of this study it is worth briefly mentioning them here in the context of carbon sequestration.

Mangroves, seagrass and salt marshes cover less than 0.5 per cent of the ocean bed and comprise only 0.05 per cent of plant biomass on land, but store a comparable amount of carbon per year making them some of the most intense carbon sinks on the planet (Nellemann et al 2009, pp. 6).

Mozambique has approximately 357,000 ha of mangroves concentrated in the provinces of Cabo Delgado 32,100 ha, Inhambane 29,300 ha, Maputo 5,400 ha, Nampula 75,000 ha, Sofala 93,200 ha and Zambezia with the greatest area of 121,900 ha (Marzoli 2007, pp. 9). Over the period 1972 to 2004 total coverage of mangroves was reduced by 51,000 ha (Marzoli 2007, pp 57.). Although mangroves are legally protected in Mozambique they are often harvested for firewood and local housing construction poles. Given the enormous carbon sink capacity of mangroves investment in mangrove restoration and protection should feature as a central component of Mozambique’s GHG net emissions reduction strategy and actions.

5. Conclusions

This rapid study has revealed the first layers of the opportunities and challenges for Mozambique's transition to sustainable energy pathways. Biomass is clearly the number one energy issue in Mozambique, providing essential cooking fuel for the vast majority of the population. But coupled with uncontrolled fires, the unsustainable extraction of fuel-wood resources contributes the lion's share of direct GHG energy related emissions. Any effort to introduce sustainability in Mozambique's energy regime must address sustainable biomass supply and efficient consumption, and where possible substitute fuel-wood with lower impact alternatives such as biogas. Fuel-efficient stoves offer one of the cheapest and most rapidly scalable interventions to reduce massive forest loss and CO_2 emissions. Stimulating local fuel efficient stove production and distribution networks, and markets, should become a top priority, along with formalising the fuel-wood industry to introduce sustainable supply.

Formulating a low CO_2eq emissions energy development pathway plan in isolation from the other sectors that contribute to GHG emissions such as agriculture, construction and mining, is futile. All GHG emission sectors and sources must be bound by an agreed national emissions budget. In this respect without a comprehensive and expertly compiled national GHG emission baseline, supported by annual monitoring report updates, Mozambique is driving blind. The best reference at this stage is the global per capita emissions target prepared by Ecofys (2009, pp. 11) of 0.5 tCO_2eq emissions to be achieved by 2050. In the absence of a sound emissions baseline and annual monitoring reports the most prudent approach is to design energy development plans aiming for the annual per capita 0.5 tCO_2eq emissions by 2050.

Of the three energy pathways developed and analysed in this study only Scenario 03 'Efficiency and Sustainability' presents a reasonable chance of reducing CO_2eq emissions to 0.5t CO_2eq per capita by 2050. Still, Scenario 03 would require emissions reductions of 130 per cent between the year 2030 and 2050 – a challenge that should not be underestimated. Following either Scenario 02 'Efficiency' or Scenario 01 'Business as Usual' locks Mozambique into an emissions trajectory that would be extremely difficult to change to meet the global target by 2050 and likely commit the country to net GHG emissions (as opposed to reductions through sequestration), contributing to the climate change impacts that will be suffered by its own citizens. Quickly Mozambique must adopt a pathway similar to Scenario 03: adhering to sustainable energy supply, increasing Negawatts and efficient energy appliances and practices, and keeping within a reasonable emissions range to achieve the 2050 target.

Migration to and growth of urban areas will make them the foci of future energy challenges. The high concentration of bio-waste generated in urban areas should make it feasible to gradually substitute fuel-wood with biogas for cooking. Rural areas are likely to continue using fuel-wood for cooking, here fuel-efficient stoves and local wood lots for sustainable supply are vital.

Wind, solar thermal water heating and biogas appear to be the most viable and least environmentally damaging options to deliver renewable energy services at scale. Energy efficiency measures and solar thermal water heating offer the lowest cost solutions to meet growing energy needs in the short term. Further research into biogas and tidal power is merited.

Knowledge and leadership for a low CO_2eq emissions sustainable energy pathway must be strengthened and decision-making streamlined. CONDES is a logical place to start the streamlining process and MPD may be one of the better-positioned Government institutions to take the overall lead. Unless leadership is strengthened, the virulent short-term political and economic objectives that converge on energy services decisions will postpone the critical question of sustainability and the eventual cost of change and climate change impacts will be passed on under ever more demanding circumstances to future generations.

6. Summary recommendations

1. *Develop Government CO_2eq knowledge and accounting skills starting with an expert baseline study on GHG emissions from all sectors and sources; establish emission reduction targets; and finally ensure annual monitoring is done to guide corrective action as a formal part of Government annual reporting frameworks.*

2. *Draft a Low CO_2eq Economy Action Plan to be presented at the 2011 Climate Change Summit in Durban to secure partnerships and funding to kick-start the transition a sustainable energy development pathway.*

3. *Rapidly promote investment in Scenario 03 'Efficiency and Sustainability' of energy generation components, sustainability and efficiency interventions, or a similar combination, to achieve the CO_2eq emissions target of 0.5t CO_2eq per capita by 2050.*

4. *Urgently build fuel-wood supply sustainability (by moving the fuel-wood industry into the formal economy, rapidly introducing FSC certified fuel-wood plantations, and creating efficiency of charcoal production and processing), and stimulate fuel-wood consumption efficiency (by promoting a local fuel-efficient stove production and distribution network and markets) to reduce deforestation rates and cut back CO_2eq emissions levels.*

5. *Launch a national programme of energy efficiency starting with the replacement of incandescent bulbs with subsidised CFLs with a deadline declared barring further imports of incandescents.*

6. *Incentivise local production and distribution networks and markets for solar thermal water and biogas technology to off-set energy demand growth with low to zero CO_2eq emissions impact.*

7. *Promote carbon sequestration and in particular build the capacity of private sector to launch carbon sequestration ventures linked to fuel efficient stoves and hydro power catchments, and also specifically targeting mangrove forests.*

8. *Invest vigorously in sustainable urban design capacity with Government and Private Sector to ensure sustainable urban expansion guided by the principles of closed loop systems, renewable energy, and decentralised energy supply.*

9. *Promote investment in knowledge (data collection systems on climate variables, research on renewable energy resources and technology, land use and forest cover, etc.) and information sharing to enable all stakeholders to plan more effectively going forward.*

10. *Promote one Government agency, possibly MPD, to lead on all sustainable energy pathway and related GHG emissions decisions to strengthen and streamline decision-making, and accountability.*

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Appendices

Appendix A Key informant interview list

1. Antonio Saide (Director, Directorate of New and Renewable Energy) and Joao Lima (Head of Deparment, Department of Alternative Energy, Directorate of New and Renewable Energy), and Ilidio Bombo (Legal), Ministry of Energy;
2. Miquelina Menezes (President of the Administrative Council), and Miguel Diogo (Head of Division of Renewable Energy), FUNAE;
3. Rauno Laitalainen (Chief Technical Advisor), National Directorate of Lands and Forests, MINAG;
4. Thelma Manjate (), MICOA;
5. Osvaldo Pereira (Resident Consultant) and Iacumba Ali Aiuba (Senior Economist), National Council of Electricity (CENLEC);
6. Oystein Botellin (First Secretary) and Thor Oftedal (First Secretary), Embassy of Norway;
7. Chance Briggs (Programme Director) and Gary Bayer (Team Leader, Agriculture and NRM), World Vision;
8. Alda Salomao (General Director), Centro Terra Viva;
9. Dirk Van Eijk (Project Coordinator) and Crispen Zana (Project Engineer), GTZ;
10. Antonio Malelane (Project Manager) and Charles Chadimba (M&E Officer), PROBEC/GTZ;
11. Stephane Derweduwen (Director), AVIAM;
12. Genito Maure (Professor in the Faculty of Sciences, Department Physics, Energy, Environment and Climate Research Group), UEM;
13. Reto Thoenen (Energy Specialist), World Bank;
14. Sigrun Pahr Skudem (Environment Project Manager), Procredit;
15. Kwasi Abegly (Project Manager), Arco Norte Programme (USAID)/Nathan Associates;
16. Jose Coelho (General Director), Metalurgica de Chimoio;
17. Boris Antanassov (Director), GreenLight Ltd;
18. David Nadaud (Consultant), Ministry of Energy;
19. Peter Coughlin (Director), Ceramica Termica; and
20. Peter Bechtel (New Product Development), Jeremias Manusa (Clean Energy Project Coordinator) and Ana Ribeiro (Biofuels Officer), WWF Mozambique.

Appendix B Full list of recommendations by Clean Energy Project output

Output 1:
Information on key energy sector development issues collected, analysed and disseminated.

Recommendations and comments:

1. Disseminate Clean Energy Assessment Report to Government, Private Sector, CSOs, and Academia.
2. Investment of funds in 'climate resilience', though essential, is hard to reconcile with the fact that nothing is being done to address Mozambique's homemade contributions to the root problems (GHG emissions) driving climate change.
3. Population growth coupled with rising affluence is the driving force of energy demand and GHG emissions. By 2030 the population is projected to reach 38 million and the rural-urban ratio will be reversed so that 60 per cent of the population resides in urban areas and 40 per cent in rural areas. Population growth may seem like an unusual issue to address on a Clean Energy Project but the elephant standing in the room cannot be ignored.

Output 2:
Environmental screening of small-hydropower sites carried out in geographical priority areas.

Recommendations and comments:

1. In the Clean Energy Assessment Report 19 rivers with small hydro power potential and their catchment areas were identified and mapped – these should be now be assessed with individual feasibility studies.
2. Small hydro may provide local solutions to energy needs (generating a maximum of 314 GWh per year) but do not offer a significant solution to national energy needs.
3. Further assessment of pico and micro hydro potential should be carried out where resources permit – this type of activity could be integrated in curricular activities of university undergraduates.

Output 3:
Assessments of design options for selected larger hydropower sites carried out.

Recommendations and comments: No assessments or study activities were required under the Clean Energy Assessment for large hydro power. However it is important to note that projected reduced levels of precipitation in the Zambeze River catchment area due to climate change, could result in significant decreases in flow volumes (INGC 2009 pp. 35), upon which Cahora Bassa and the planned Mpanda Nkuwa depend. Mozambique's long-term energy security depends on diversification of energy supply sources. Relying almost exclusively on large hydro power leaves little room for manoeuvre if water flow dynamics change in the region.

Output 4:
Opportunities for linking hydropower projects to upstream catchment management and potentially new forest-carbon management regimes explored and pilots initiated, including mechanisms for payment for ecosystem services.

Recommendations and comments:

1. In the Clean Energy Assessment Report 19 rivers with small hydro power potential and their catchment areas were identified and mapped – these should be now be assessed with individual feasibility studies analysing (both the hydro power potential and) the REDD+ potential on their respective catchments.
2. Catchment site visits essential to generate meaningful REDD+ carbon credit revenues estimates were not feasible in this study. However for indicative purposes, assuming additionally is proven and leakage is not addressed, applying an annual average deforestation rate of 1.75 per cent would give approximately USD 4.2 million carbon revenues per year i.e. it appears at a superficial level that significant revenues may be within reach, and where they are, the revenues may subsidise the electricity production costs of particular hydro power installations making them viable where they would otherwise be unfeasible as stand alone projects.

Output 5:
Non-hydro clean energy output promotion: Solar; Wind; Geothermal; Biomass.

Recommendations and comments:

1. Biogas: Energy potential from biogas (based on human bio-waste – from food preparation and excrement – only) in 2010 is estimated at 1.4 million m3 providing up to 4 million biogas stove burning hours per year. This represents approximately 35 per cent of biogas stove cooking hour requirements to provide a family of four with approximately 2 hours of biogas cooking time per day. Biogas should be aggressively promoted in all major urban areas, and also in rural areas where suitable conditions (concentrations of livestock) exist, as a fundamental element of clean energy services for cooking purposes.
2. Biofuel jatropha curcas: With current yield levels, in order to meet demand for diesel up until 2030, projected to reach 2.4 million litres, Mozambique would either have to allocate approximately 27 per cent of all available agricultural lands identified by Marzoli (2007), or open up new agricultural lands probably leading to significant immediate forest loss and related environmental impacts. At this point biofuels remain a contentious and unproven solution for sustainable, low impact, energy services.
3. Biomass: The mean annual increment (MAI) of productive forests in 2011 is estimated to exceed 35.5 million m3, corresponding to approximately 105 thousand GWh of energy potential. However if current consumption patterns continue and no efforts are made to replant what is cut productive forest cover could be reduced by as much as 26 per cent during the period from 2010 to 2030. Energy produced from biomass co-generation using plantation forestry waste is projected to produce 530GWh of energy by 2022 on Portucel's plantations. This type of biomass use is reasonable as the forestry waste would have decayed and entered the atmosphere as emissions at some stage. Where plantations are developed for timber production biomass co-generation appears to be worth exploring and promoting if feasibility and EIA results demonstrate reasonable efficiency and environmental performance levels.
4. Solar thermal water heating: Solar thermal water heating potential is calculated on the basis of an allocation of 0.55 per cent of urban lands, and is estimated to

generate up to 944 GWh of energy. The domestic mains grid electricity needs are estimated to reach 3,540 GWh by 2030, of which approximately 25 per cent (885 GWh) is required for water heating purposes. Thus it is conceivable that with solar thermal installations covering only 0.55 per cent of urban areas, for example roof tops, water heating needs could be satisfied without resorting to electricity supply. Solar thermal water heating, characterised by low cost and low environmental impact credentials, should be aggressively promoted in Mozambique to off-set growth in energy demand.

5. Solar PV: Solar photovoltaic (PV) energy potential is calculated on the basis of 5 per cent of urban lands availability and 5 per cent of bare lands availability to be covered with solar PV panels. The projected total energy potential for these land areas is estimated to 15,815 GWh, which is sufficient to meet all projected mains-grid and off-grid electricity needs of 12,263 GWh up until 2030. At present solar PV makes most sense to pursue for off-grid energy solutions but as production prices fall it will become increasingly competitive with conventional mains-grid supply fuels (coal, hydro, natural gas). Solar power should be promoted in Mozambique as a key component of the sustainable energy supply regime.
6. Wind: The total maximum average energy potential of all wind zones is estimated to reach 24,158 GWh, which is equivalent to approximately double of all projected mains-grid and off-grid electricity needs of 12,263 GWh up until 2030. In terms of energy production costs wind is one of the cheapest renewables available. Wind power should be promoted in Mozambique as a key component of the sustainable energy supply regime.
7. Small hydro: The total energy potential of the 19 rivers assessed for small hydro power is estimated to reach approximately 314 GWh. However small hydro potential is restricted to the Provinces of Manica, Maputo, Nampula, Niassa, Tete and Zambezia. Relative to national energy needs up until 2030 small hydro power does not represent a significant solution. However for local demand centres small hydro power should be pursued as an important decentralised energy resource.

<u>Output 6:</u>

Assessment carried out of carbon footprint of various energy development paths, and awareness increased on potential linkages between national energy development paths and a global climate treaty.

Recommendations and comments:

1. Scenario 01 'Business as Usual': Setting course on for Scenario 01, tCO2eq 2.78 CO2eq emissions per capita by 2030, would make it a formidable challenge to reduce CO2eq emissions to 0.5tCO2eq per capita by 2050, essentially requiring a reduction of emission per capita of approximately 450 per cent between the year 2030 and 2050. Mozambique must reconsider its current trajectory – leaders should not push on the task of dealing with Mozambique's own contributions to GHG emissions for future generations, this will lead to more violent climate change impacts and an almost impossible emissions reductions task.
2. Scenario 02 'Efficiency': The projected tCO2eq 1.93 emissions per capita by 2030 for Scenario 02 present a less alarming situation than Scenario 01 but still reducing CO2eq emissions to 0.5tCO2eq per capita by 2050 still appears very challenging, essentially requiring a reduction of emission per capita of over 280 per cent between the year 2030 and 2050. Scenario 02 gives cause for hope but falls short of achieving a sustainable energy pathway.
3. Scenario 03 'Efficiency and Sustainability': The projected tCO2eq 1.16 emissions per capita by 2030 for Scenario 03 requires a reduction in emissions of 130 per

cent between the year 2030 and 2050 to reach the target of 0.5tCO2eq per capita. Investing in the energy generation components, sustainability and efficiency interventions in Scenario 03 would give Mozambique the best chance of aligning itself with global commitments to reduce GHG emissions to avoid the worst possible impacts of climate change. The various interventions and investments outlined in Scenario 03 (No coal, Massingir hydro, diverse renewables – Solar Power, Wind, Tidal – Negwatts, low carbon electric transport, fuel efficient stove technology, sustainable fuel-wood plantations, and biogas) should be vigorously pursued along with feasible alternatives and promoted through the highest executive branches of Government.

4. Uncontrolled fires in Mozambique are thought to affect the majority of rural lands at least once a year. Consequently enormous biomass energy is wasted on an annual basis and more importantly uncontrolled fires may substantially surpass GHG emissions from all other sources. Urgent action is required to bring uncontrolled fires under sustainable management.
5. Given the enormous carbon sink capacity of Mozambique's mangroves (357,000 ha) investment in mangrove restoration and protection should feature as a central component of Mozambique's GHG emissions reduction strategy and actions.

Output 7:
Capacity built on key energy sector development issues.

Recommendations and comments

A. Policy and regulatory framework interventions:

1. Biomass strategy and implementation plan: The central role of wood-fuels at present and in the near future needs to be properly reflected in policy documents and regulatory systems. The Ministry of Energy, FUNAE and MINAG should urgently jointly design and implement a wood-fuel sustainable supply and efficiency strategy.
2. Bringing wood-fuel into the formal economy for sustainable supply: The fuelwood industry must be urgently brought under sustainable management practices. It is vital that the wood-fuel industry players are not marginalised in any attempt to formalise the industry. Many thousands of jobs and rural livelihoods may depend on the wood-fuel economy. The process for brining the wood-fuel business under effective public sector regulation should worked out in round-table meetings with key industry actors, Government and civil society groups.
3. Energy efficiency demand side management: Efficiency measures need to be incentivised and accessible to different types of energy consumers. Simple affordable measures such as replacing incandescent light bulbs with compact fluorescent light (CFLs) bulbs would reduce lighting energy requirements, typically consuming only 20-30 percent of the energy required for an incandescent light. A national policy and corresponding regulations could be implemented to make energy efficient products such as CFLs mandatory. The Ministry of Energy, together with the Ministry of Finance, could collaborate to prepare and execute an energy efficiency plan with fiscal incentives such as reduced import duties on energy efficient products.
4. Stimulating energy sector investment: The preparation and dissemination of a model PPA and FITs may assist stimulate investment in the energy sector in Mozambique. The Ministry of Energy and CENLEC could jointly prepare a model PPA, while the Ministry of Energy, CENLEC and the Ministry of Finance could develop FITs.

5. LCA for comparison of energy generation CO2eq emissions impacts: MICOA and the Ministry of Energy should integrate LCAs as a requirement on all energy generation planning and Environmental Impact Assessments (EIAs) to maintain a robust method for comparison of energy generation options' respective cumulative CO2eq emissions impacts. Without LCA tools national GHG emission accounting will not reflect the true impact of CO2eq emissions.
6. National low CO2eq emissions development policy: Mozambique has the responsibility, like all countries, to understand its own CO2eq emissions dynamics and set course for a sustainable energy regime development pathway. This should not be limited to the energy sector but rather embrace all CO2eq emissions sources and sinks. The inter-ministerial Committee on Sustainable Development (CONDES) should convene its members to define the targets and thresholds of for CO2eq emissions controls, reductions and mitigation.
7. National CO2eq emissions accounting and reductions policy: A robust, obligatory emissions accounting framework must be established. MPD, MICOA, the Ministry of Energy and the Ministry of Finance may come together to define a suitable emission accounting policy and emission reduction incentives. CONDES could also be a suitable forum for this task.
8. Sustainable urban design: Given the future importance of urban areas as the principle population centres a policy debate specifically targeting solutions to urban area energy needs be launched in earnest. MPD, the Ministry of Energy, the Ministry of Public Works, MICOA and relevant Municipal Authorities should be convened to zone and plan population expansion areas with a view to delivering sustainable, local, accessible energy services. The urban expansion policy dialogue should be driven by principles such as sustainable design, closing the resource loop, and local renewable energy services. CONDES could also be a suitable forum for this task.
9. Low CO2eq emissions transport policy: The abundance of cheap off-peak electricity from Cahora Bassa is an obvious place to start exploring options to take advantage of available low CO2eq emissions energy for urban transport. The Ministry of Transport, MPD, the Ministry of Energy, the Ministry of Public Works, MICOA and relevant Municipal Authorities should be convened to assess how and where public urban transport systems can begin to shift towards affordable, low CO2eq emissions transport systems.
10. Investing in knowledge: In Mozambique basic and reliable data on temperatures, wind speeds, solar radiation, rainfall, sea-levels, hydrological dynamics, land use and forest cover, amongst other important variables, are very hard to come by. This leaves the country handicapped, unable to read the situation for itself and plan accordingly. Investing in knowledge should be a top Government policy priority.

B. Stakeholder capacity building:

1. Government:
    a. The summary of this report for policy makers should be disseminated to Government through CONDES.
    b. Develop Government CO2eq emissions appraisal tools and accounting systems, essentially CO2eq emissions knowledge for action. The first step on this path requires a professional and comprehensive CO2eq baseline for all sectors. With adequate technical support this could be lead by MPD, supported by MICOA, the Ministry of Energy and MINAG.
    c. Once a baseline is in place a leading Government institution must be appointed or created, perhaps as an independent unit in MPD or the Ministry of Finance, responsible for gathering, compiling, analysing and auditing

CO2eq emissions data from all sectors and sources.

   d. Special tools for LCA of CO2eq emissions for different energy generation master plan options and specific projects should be developed and disseminated for use by key government institutions such as MPD, MICOA and the Ministry of Energy.
   e. An opportunity exists to seek funding to kick-start the development of sustainable management of CO2eq emissions capacity at the Durban Climate Change Summit in November/December 2011: MPD and the Ministry of Energy should consider preparing a Low CO2eq Emissions Economy Action Plan for presentation at the Climate Change Summit to build technology and resource transfer partnerships.
   f. The Ministry of Energy needs to strengthen energy data collection and analysis systems to identify per energy source (biomass, hydrocarbons, hydropower, solar, etc.) how much is used, for what purpose, when and by which users.
   g. A single strong Government institution must be appointed to lead on biomass. This unit must have sufficient staff and resources to establish progressive relationships with the wood-fuel informal sector to bring them into the formal economy, foment and direct the development of sustainable biomass plantations are established, and improve harvesting and processing techniques to increase efficiency while also promoting fuel efficient stoves for end-users.
   h. The Government is in a unique position to influence attitudes, values and behaviour of its citizens. Starting with the public education system, Government should design and implement an environmental course as part of the primary school and secondary school mandatory curriculum, teaching the basic concepts of finite natural resource availability, ecosystem services and the environmental impacts of different key services such as energy supply.

2. CSOs:
   a. CSOs should also receive the results of this study to raise awareness about the impacts of different energy development pathways.
   b. A capacity building intervention targeting key CSOs working on environment and natural resource use should be considered to equip them with CO2eq emissions LCA tools and skills. This would enable them to effectively participate in strategy energy generation and services planning stages and also at project level on EIAs. Providing CSOs with LCA tools and skills would also introduce a common and coherent method for appraisal of energy alternatives.
   c. CSOs are well positioned to reach communities with energy efficiency advocacy material through their own community based staff, faith-based leaders (Muslim, Christian, Hindu, etc), and local traditional leaders (chiefs, community leaders, curandeiras, etc.). Key community education and awareness issues to be communicated, in local languages, include sustainable fuel-wood supply, fuel-wood efficiency stove technology and the prevention of uncontrolled fires. Community radio programmes, and TV (dramas and documentaries), are important media channels that could be exploited by CSOs for this purpose.

3. Private Sector:
   a. The Private Sector should also receive the results of this study to raise awareness about the impacts of different energy development pathways, and

to explore profitable interventions that could be exploited to deliver low CO2eq emissions energy services.

b. Providing International Standard Organisation (ISO) 14000 series trainings, especially with regards to energy performance audits, specifically for energy consulting firms and installation companies could introduce a strong standard for sustainable and efficient energy systems. The establishment of ISO type benchmarks for energy sector goods and services is an important step towards higher (sustainable) performance among private sector players.
c. Workshops for ecosystem services, energy, forestry, and investment companies, lead by international carbon experts, on how to design carbon based business models and gain access to international carbon markets may stimulate the emergence of a local carbon off-setting industry. This would be beneficial for the local economy and increase Mozambique's contribution to slowing the impact of CO2 emissions on climate systems.
d. Another important issue that could be addressed through private sector capacity building is sustainable urban design. Local architecture, engineering and construction companies should be provided with short module trainings on sustainable urban planning, housing, public transport, renewable energy services and energy efficiency.
e. The banks in Mozambique could make a greater contribution to energy service sustainability through reduced lending rates for credit. Providing reduced credit rates for Mozambican businesses investing in fuel-efficient stoves, renewable energy systems, CFLs, etc. could be financed by international climate change funds and stimulate a shift towards sustainable energy services.
f. A Clean Tech Forum with an annual meeting bringing in foreign clean tech investors, producers and researchers to meet and share business opportunities with local private sector players could open up the national energy market for more diverse products and services. This type of forum would also provide a dynamic platform for private sector and public sector dialogue on sustainable energy issues and could be supported by a publicly accessible website with available renewable energy maps, clean tech investment opportunities, B2B contact information, energy efficiency solutions, and carbon market opportunities.

4. Informal Fuel-wood Sector:
    a. The fuel-wood sector should be presented with the results of this study to inform them of the extent and implications of Mozambique's forest resources' rapid decline, demonstrating the expiry date stamped on their current mode of operation.
    b. Partnerships for plantations of fast growing native species such as bamboo and should be established on a pilot basis with industry members that are willing to become the future winners in the fuel-wood sector. Where possible plantations should be set-up closer to urban centres to reduce transport costs and compete with those that are not willing or able to make the transition to from unsustainable extraction to sustainable production. Plantations should be designed using best practices, such as those established by the Forest Stewardship Council (FSC) and efficient charcoal production techniques should be introduced.

5. Academic Institutions:
    a. UEM should be provided with the results of this study for comment.

b. Academic institutions should be encouraged and supported where necessary to develop technical courses designed for undergraduates to provide them with practical skills for: renewable energy systems design, installation and maintenance; and assessment and mapping of renewable energy resources (wind speeds, river flows for pico/micro/mini hydro, tidal speeds, solar radiation, etc.).
c. Research funds should be invested with academic institutions to explore the feasibility of local production of fuel-efficient stoves, solar thermal water heating, and biogas installations could assist introduced these relatively accessible technologies which are particularly suited to the energy needs of Mozambique. More demanding and newer areas of research such as the energy potential, impacts and feasibility of algae production, and the energy potential, impacts and feasibility of tidal power could also be explored.

Output 8:
Options for strategically targeting processes influencing charcoal / wood use at national level identified, developed and communicated at national policy level.

Recommendations and comments:
1. The fuel-wood industry must be urgently convened to explore and implement transition from the informal sector into the formal sector.
2. Sustainable supply (Forest Stewardship Council certified plantations) should be urgently promoted in coordination with the current players in the fuel-wood industry.
3. Efficient charcoal production techniques should be disseminated for all charcoal producers in the supply chains.
4. Fuel efficient stove technology must be rapidly introduced to improve fuel-wood consumption efficiency.

Appendix C Renewable Energy Maps

Because of the large size of these files they have been attached separately.